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An Evergreen Agriculture for Food Security and Environmental Resilience

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KEYNOTE ADDRESS

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It gives me great pleasure to deliver the Keynote Address in the in the National Seminar on "Agroforestry: An Evergreen agriculture for Food Security and Environmental resilience" at Navsari being organized by ASPEE College of Horticulture and Forestry, Navsari Agriculture University, Navsari (Gujarat).

I am very happy to note that this Conference is touching upon very important thematic areas of today's needs, *viz.*, agroforestry models under different agro-ecological regions, agroforestry management for food and livelihood opportunities, agroforestry for mitigating global warming and genetic resource conservation, social forestry a way towards greening India, clonal propagation, tree breeding and biotechnological interventions for increasing farm productivity and sustainable natural resource management in agroforestry.

Evergreen agriculture is a form of intensive farming that integrates trees with annual crops, maintaining a green cover on the land throughout the year. Conservation Agriculture with Trees (CAWT) is a form of evergreen agriculture that is premised on strengthening CA principles with agroforestry. Agriculture acquires much larger importance in our policy of INCLUSIVE GROWTH. The transformation from a food importing nation to a food-exporting nation has not been easy. It has been brought about by technology interventions, huge investment in infrastructure, policy changes encouraging higher productivity and most importantly, the unrelenting hard work of millions of Indian farmers.

Land-use options that increase resilience and reduce vulnerability of contemporary societies are fundamental to livelihoods improvement and adaptation to climate change. Agroforestry as a wide-spread land-use adaptation may potentially support livelihoods improvement through simultaneous production of food, fodder and firewood as well as mitigation and adaptation to climate change.

Livelihoods improvement is not just about the positive change towards better quality of life and human well-being but it takes into account the local and global change which determines livelihoods. The adverse impact of climate change may be more severely felt by poor people who are more vulnerable than rich. Appropriate policy responses combining the agro-ecosystems as key assets can strengthen adaptation and help build the resilience of communities and households to local and global change. There is, thus, a need for intensified management and governance efforts to generate products and services in agro-ecosystems. Tree growing in combination to agriculture as well as numerous other vegetation management regimes in cultural landscape including in farms, watersheds and regional landscape can be integrated to take advantage of services provided by adjacent natural, semi-natural or restored ecosystems. Increasing the livelihood security and reducing the vulnerability call for societal adaptation. Such adaptations are possible when combined with

traditional resource management systems. Agroforestry as a local adaptation, therefore, is a promising area of interest for scientists, policy-makers and practitioners.

Land management actions that enhance the uptake of CO_2 or reduce its emissions have the potential to remove a significant amount of CO_2 from the atmosphere if the trees are harvested, accompanied by regeneration of the area, and sequestered carbon is locked through non-destructive (non-CO_2 emitting) use of such wood. Agroforestry for carbon sequestration is attractive because: (i) it sequesters carbon in vegetation and in soils depending on the pre-conversion soil, (ii) the more intensive use of the land for agricultural production reduces the need for slash-and-burn or shifting cultivation, (iii) the wood products produced under agroforestry serve as substitute for similar products unsustainably harvested from the natural forest, (iv) to the extent that agroforestry increases the income of farmers, it reduces the incentive for further extraction from the natural forest for income augmentation, and finally, (v) agroforestry practices may have dual mitigation benefits as fodder species with high nutritive value can help to intensify diets of methane-producing ruminants while they can also sequester carbon.

A winning strategy for conservation and human welfare can be achieved by protecting the largest possible area of natural ecosystems while growing food on the smallest possible area to reconcile food production with conservation. Yet, this combination is not always feasible. Therefore, a trade-off strategy for addressing multiple functions is required. Accordingly, agro-forests need to be strengthened by innovations in technology, domestication, governance and market regimes. Future research is required to eliminate many of the uncertainties that remain, and also carefully test the main functions attributed to agroforestry against alternative land-use options in order to know unequivocally to what extent agroforestry served these purposes. Agroforestry has the potential to become a model of sustainable agriculture, provided we come to a better understanding of it. The combination of trees and crops creates an ecosystem that helps preserve biodiversity.

Agroforestry systems can be useful in maintaining production during both wetter and drier years. During the drought deep root systems of trees are able to explore a larger soil volume for water and nutrients, which will help during droughts. Furthermore, increased soil porosity, reduced runoff and increased soil cover lead to increased water infiltration and retention in the soil profile which can reduce moisture stress during low rainfall years. Tree-based systems have higher evapotranspiration rates and can thus maintain aerated soil conditions by pumping excess water out of the soil profile more rapidly than other production systems.

The tree-based production systems often produce crops of higher value than row crops. Thus, diversifying the production system to include a significant tree component may buffer against income risks associated with climatic variability, in synergy with climate change mitigation and support to help vulnerable populations adapt to the negative consequences of climate change. Adaptation to climate change is now inevitable. Research on agroforestry as an adaptation to climate change and as a buffer against climate variability is still evolving. Main pathway through which agroforestry may qualify as an adaptation to climate change is through diversifying production systems and increasing the sustainability of smallholder farming systems. The role of agroforestry in reducing the vulnerability of agro-ecosystems - and the people that

depend on them to climate change and climate variability needs to be understood more clearly.

I would like to thank the Organizers, ASPEE College of Horticulture and Forestry, Navsari Agriculture University, Navsari (Gujarat) for giving me this opportunity to address issues related agroforestry, Food Security and Environmental resilience.

Agroforestry – Balancing food security with environmental resilience

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ABSTRACT

"Agroforestry is a collective name for land-use systems and technologies in which woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately combined on the same management unit with herbaceous crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economic interactions among the different components". In its early days, agroforestry may have been viewed as the domain of the 'landcare enthusiast'. Today, integrating trees and shrubs into productive farming systems is seen as a core principle of sustainable agriculture from green to evergreen basis. Agroforestry for natural resource management provides the foundation for an understanding of agroforestry practice in both high and low rainfall zones across India. It is warranted that appropriate extension methods are required for popularizing agroforestry practice to balance food security with environmental resilience.

INTRODUCTION

Agroforestry is now receiving attention, long overdue, as a resource efficient, environmentally positive, and profitable method of farming. Incorporating trees in farming and range management can provide many benefits. Continuous production from these systems and the flexibility of having several options for management, make agroforestry systems of immediate and potential value for farmers in the rainfed areas of India. Culturally, agroforestry means many things to different people. For instance, the farmers of north east India attach social values to agroforestry practices. The primitive '*taungya*' cultivation is one of its kind. It is often applied to the integration of trees, typically one species grown for timber, with pasture; but it may also include more complex systems that include trees with a variety of crops, both annual and perennial species, and animals.

The definition developed by **Lundgren and Raintree (1982)** is one of the simplest and most comprehensive, "Agroforestry is a collective name for land-use systems and techniques where trees are deliberately used on the same land management unit as agricultural crops and or/animals, either in the same form of spatial arrangement or temporal sequence. In agro-forestry systems there are both ecological and economic (*and cultural*) interactions between the different components."

ADVANTAGES OF AGROFORESTRY

The advantages of agroforestry systems include the potential for increased resource use efficiency both above and below ground, with roots reaching 10-80 meter depths on some trees and canopies reaching 5-70 meter high. Trees can draw upon

resources, groundwater, nutrients, etc., that are unavailable to annual plants. Trees are often immune from all but the most severe droughts and can provide emergency fodder for animals when nothing else is available. Adding complexity with trees can also provide many other benefits, including reduction in pest problems, micro-site modification to allow plants with diverse climatic requirements to be grown in a small area, and the production of a diverse variety of products for subsistence and sale, including: firewood, biofuel, timber, food, fodder, building material, material for tools, fiber, medicine, etc. Trees can also provide a number of other benefits, including soil improvement, erosion control, shade, windbreak, groundwater management, erosion control, , habitat for wildlife, and perhaps, selenium harvesting. This wide range of products and purposes combine with the increased resource base to help minimize risk for the farmer. By spreading out cultural and management requirements over the year these systems can also reduce peak workloads and ensure a more stable economy. These benefits and advantages have become increasingly well known and appreciated in recent years, although J. R. Smith first described them almost sixty years ago (**Smith, 1929**).

AGROFORESTRY IN RECENT PAST

Especially during the last 3-5 centuries spectacular improvements have been made in tree plantation. The most important agroforestry practice is known from the Kangeyam tract of Tamil Nadu, where *Acacia leucophloea* + *Cenchrus setigerus* in silvi-pasture system was perfected. Similarly, in ravines of Yamuna and Chambal, trees, shrubs and bamboos with grasses were planted for rearing milk-producing Jamunapari breed of goats and sheep. Scattered trees in association with bajra, jowar and chillies were grown in the semi-arid area of Tamil Nadu. Tree plantation continued as demarcation and control against wind erosion throughout the country. Plantation of khejri (*Prosopis cineraria*) trees for various uses on on-farm was a common practice in Rajasthan.

In coastal areas, *Casuarina equisetifolia* and other trees were grown in association with crops on farm lands for cash and to generate small timber. Live hedges were common as an agroforestry practice in which *Lawsonia inermis*, *Agave sisalana* and *Euphorbia* species were common. In paddy-growing areas *Pongamia glabra* and *Sesbania grandiflora* were grown, lopped annually and their leaves applied to fields as green manure. Application of green manure to paddy field was common in Madhya Pradesh and Uttar Pradesh. In the Western Ghats, *Terminalia* leaves were harvested, spread on land, burnt and then paddy, ragi and millets were sown multistorey homesteads or home-gardens were in existence in Kerala, Karnataka, Tamil Nadu, Tripura, Assam and other North Eastern states as an important agroforestry practice. This practice is still followed in these states. In the north-eastern India, there has been a consistent change in the *modus operandi* of the agroforestry practice (**Box 1**), from the age old *taungya* to varying shifting agricultural practice including homegardens.

Box 1. From shifting to permanent cultivation

Integral taungya

In the classification of swidden systems, a distinction is made between "integral" and "partial" swidden. Partial swidden reflects "predominantly only the economic interests of its participants (as in some kinds of cash crop, resettlement, and squatter agriculture)", whereas integral systems "stem from a more traditional, year-round, community wide, largely self-contained and ritually sanctioned way of life" (**Conklin, 1957**). By analogy with integral shifting cultivation, the proposed concept of "integral *taungya*" is meant to invoke the idea of a land-use practice that offers a more complete and culturally integrated approach to rural development: not merely the temporary use of a piece of land and a poverty-level wage, but a chance to participate equitably in a diversified and sustainable agroforestry economy.

Enriched fallows

There are two variants of this approach: *economically enriched fallows*, which increase the economic utility of the fallow vegetation by enrichment with trees valued for cash or subsistence purposes; and *biologically enriched fallows*, which enhance and accelerate the vegetative regeneration of soil fertility and control of weeds. These become attractive to farmers somewhere around stages 1-2 and 2-3 respectively in the intensification sequence. Long fallow forest shifting cultivators are not likely to be interested in techniques concerning soil fertility and weed control since these are not yet much of a problem, although they may well respond to opportunities for economic benefits from improved fallows.

From the viewpoint of the shifting cultivator, the forest phase of the *taungya* cycle is equivalent to the fallow phase of the swidden cycle. To marry the two types of production successfully the phase lengths must match. Hence, the entry point of primary feasibility for integral *taungya* would seem to be in stage 1, when fallow lengths are of the same order of magnitude as the growing period for commercial forest trees. However, it could possibly be introduced at stage 2, providing that short-rotation (less than ten years) forest species are selected, or that agricultural practice can be intensified to accommodate the reduction in available fallow land that would accompany the planting of longer-duration forest trees.

If fruit-trees are planted instead of conventional forest trees, very long "fallow" durations may be required to sustain shifting cultivation, since farmers will be reluctant to cut down the fruit-trees in the years of their heaviest bearing (which may extend from ten to 100 years for some trees). Indeed, the planting of fruit- or other trees - economically valuable, long-lasting and continuously productive - may be the shortest route to permanent removal of the land from the fallow cycle. This is not necessarily a bad thing if the resulting land-use mix, including biologically enriched short fallow or other means of meeting the production requirement of preferred field crops, is significantly more rewarding than the continuation of conventional swidden practice.

BALANCING FOOD SECURITY WITH ENVIRONMENTAL RESILIENCE

Agroforestry has the potential to significantly improve the livelihoods, economic viability, and agricultural production of small farmers in traditionally marginalized areas. In addition, agroforestry can be used as a tool for changing attitudes towards natural resource management (NRM). In order to understand how extension can better accommodate natural resource management through the successful introduction of agroforestry and tree planting, extension agents, both public and private, must strive to understand the socio-economics of agroforestry and of the communities within which they work. While agroforestry has traditionally been successful in humid and semi-humid areas, it is most needed in dry-land areas, which are characterized by acute climactic challenges and extremely low levels of agricultural production beyond technical and biotic constraints. While limits to the adoption of agroforestry are many, the ability of extension agents to recognize socio-economic characteristics of farmers is essential in learning how to target potential innovators who can then generate change within their communities. More emphasis on the development of participatory programs, more efficient targeting, and intensified focus on the traditional communication channels will increase the adoptability of agroforestry in dry-land communities. In turn, an implicit understanding that the attitudes of farmers towards natural resource management are based on agroforestry successes and failures will help extension to increase the environmental reclamation of degraded landscapes, especially those in dry, rain-fed agro-ecosystems. Dry-land agricultural areas in India face specific problems that must be overcome for both improved agricultural production and environmental conservation. Agroforestry can help overcome limited water availability, fuel shortages, degraded soils, and a lack of biodiversity. When trees are used that is adapted to water-limited areas, such as *Gliricidia*, communities can realize both agricultural and environmental benefits.

In general, agroforestry produces a multitude of benefits, including increased income from selling surplus goods, improved environments and enhanced biodiversity, increased access to education through income generation, shelter from harvesting trees for building materials, improved health when medicinal plants are incorporated, a greater diversity of food sources, and an increase in the energy of an agricultural system because manure can be used for fuel instead of food. Specifically in rain fed agro-ecosystems, like those found in dry-land agricultural areas of southern India, successful agroforestry projects can increase the organic matter in soil, improve the physical properties, increase crop yields, increase the availability of nitrogen in the soil, increase the water-holding capacity of soil, and reduce soil erosion. In addition, there is a reduction in pollution because of a decrease in chemical fertilizers. Most environmentally significant, the biodiversity of an agricultural area is enhanced.

Agroforestry's scientific benefits, however, have been well documented within the humid and semi-humid agricultural regions, and the challenge for extension agents is to successfully spread these benefits in dry-land areas where, traditionally, farmers have been marginalized due to resource limitations (such as soil-fertility and water availability). Most importantly such extension and education must be localized and participatory in nature. In order for training and education to be localized, extension agents must understand the important role of socio-economic factors as well as the technical aspects of agroforestry, and therefore they must begin to focus more on the social and communication constraints of the specific villages and communities within

which they work. Indeed the foundation of success is the "participation of the people for whom the forestry programme is intended". This participation of local residents will help transform the extension programs from the current "top down" structure, pioneered in "transfer of technology" methodology, to "bottom up" participant defined priorities and goals. In this way, participants are much more responsive to the education and training offered by extension agents. In fact, the potential participatory nature of agroforestry programs in rural communities can be a useful vector for knowledge generation that incorporates local information and global science. Villagers and communities, depending on a number of variables, are continually gathering knowledge from various sources, and extension agents should do less to emphasize the strict dichotomy of global science and indigenous knowledge as it can be harmful to the adoption rates of tree management and agroforestry. Ultimately, it is mostly advocated that synergy instead of variety of knowledge sources to advocate certain practices. Communities within dry-land regions of India have already developed knowledge concerning tree management; however, these knowledge systems are "open", thereby allowing an exchange of information which can be more conducive to innovation than enhancing a "closed system" through strict juxtaposition of local knowledge with global sustainable agro-ecosystem in dry-land agricultural areas, and they cannot be realized without appropriate extension and education. For small landholders' personal communication with neighbors and extension agents are the two modes of communication and knowledge sharing that are most strongly linked to potential adoption and tree planting. Understanding the constraints will enable extension agents to enhance capacity building of farmers, which will, in turn, help demonstrate the low economic risk of agroforestry as well as harness the environmental benefits and improvements in agricultural yields. Thus the importance of successful agroforestry extends beyond satisfying agricultural production and economic goals, it is also critical in establishing an understanding of why natural resource management and environmental conservation are important in the sustained productivity of ecosystems. The future of natural resource management depends on the attitudes of farmers which are distinctly shaped by the information they receive from communication channels guided by extension services. One of these, nutrient management in soil fertility, is of overwhelming importance for cropping systems. Further examination of nutrient management in Indian dry-land agriculture is needed to understand the future of agricultural productivity, and the overwhelming importance of agroforestry in degraded landscapes. Such novel approaches aimed at better understanding local conditions and farmer capacities and attitudes toward adopting improved land management are also a useful tool for analyzing nutrient management issues in much of India's degraded dry-land agricultural soils. It is often felt that agro-ecological constraints to enhanced food production often are exacerbated by poor land management practices among resource poor farmers living in these areas. Thus, new soil and cropping systems management must be adapted to local conditions in order to ensure sustained agricultural production without depleting the existing natural resource base.

ACC.NO. R-5258
DT. 15-2-12

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Agroforestry management for food and livelihood opportunities

Summary of Presentation by

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Growing human and livestock population coupled with urbanization in India have exerted intense pressure on arable land and forest in the country. The increasing demand for food, fodder, fuel and basic livelihood needs can be met either by increasing the farm area or by increasing the productivity of unit piece of land. As regard, increasing the farm area is concerned we have almost reached the frontiers, therefore, enhancing the productivity of agricultural field by mixing the crop growth with trees, as agroforestry seems to be better option. Agroforestry is considered to be one of the reasonable alternatives, that has got the potential to contain land degradation and recover site productivity through interactions among trees, soil, crops, and livestock, and thus restore environment and enhance the productivity. Though, traditional agroforestry models are well recognized in India since ancient times, the inclusion of scientific technology and proper management plan for better understanding of fundamental dynamics between social and economic values of rural community in modern agroforestry practices is essential.

In order to design strategy for poverty alleviation and adaptation to local and global change, land-use options that increase livelihood security and reduce vulnerability are to be preferred. Such adaptations are possible when combined with traditional resource management systems. The indigenous agroforestry systems are practically feasible, whereas enhancing the productivity of these systems is yet another milestone to be set. Steeper decline in per capita land availability and shrinking farm size are challenges that the country are facing for food security and livelihood opportunity. With smaller land holding the food security and livelihoods opportunities would depend on the performance of small and marginal farmers. Agroforestry has proved to be sustainable model for the marginal farmers by growing trees and fodder crops and including fodder trees with vegetables in marginal lands of many parts of country. Moreover, in the hot arid and semi-arid areas tree species such as Prosopis, Albizia, Zizyphus and Acacia provide many times more returns per unit of land than agriculture alone. The Poplar and Eucalyptus based agroforestry models have been found more profitable than pure agriculture in Punjab, Haryana and Western Uttar Pradesh. The well managed home gardens in Kerala, a classical example of multilayered agroforestry systems, utilize the complete space and time in a unit piece of land and maximize the productivity and provide the diverse produce, thereby generating extra income to the farmers. In Himalayan region, the Grewia based agroforestry system is a boon for the farmers, where it provides the fodder during lean period and also supplement the requirement of fuel, fiber and fruits. The various agroforestry models practiced by the farmers in agrisilviculture fashion provide the fuel

and fodder and thereby reduce the biotic pressure on existing natural forests. In addition, the Boundary plantation (trees on boundary + crops), Block plantation (trees + crops), Alley cropping (shrubs + crops), Agrihorticulture (fruit trees + crops), Agrihortisilviculture (trees + fruit trees + crops), Agrisilvipasture (trees + crops + pasture / animals), Silvipasture (trees + pasture/ animals), Shelter belts (trees + crops) and Wind breaks (trees +crops) are also quite rewarding for the farm community.

The need for adopting agroforestry has been emphasised with proper tree crop combinations for different agro-climatic regions of the country and sound management practices. The agroforestry system aims to manage in such a way that the production of preferred commodities as well as productivity of the land piece may remain tied in increasing trend. Even though the terminology of agroforestry is relatively new, it is an old set of practices and therefore accepted by the farming community. However, there is need to include the improved or new environment friendly technologies and management options that can be well accepted by the local communities. Local factors are always important in good management planning. It is therefore necessary to include the local factors in analyzing the existing land-use system and resource allocation at the community and household levels. Marketing of produces is a big constraint before the rural community; thereby proper market linkage for agroforestry commodities through cooperatives and other feasible means is a viable option. The sound knowledge of component interaction (tree-crop) is important as it is a complex task. Proper silviculture management for better and compatible growth of the tree that helps in various stages of agroforestry practices is important so is the agronomical operation in case of agricultural crop. Agroforestry with sound management practices can help in achieving food security, livelihood opportunity and environmental protection.

Agroforestry scenario of Gujarat-past, present and future perspectives

H. S. Singh

ABSTRACT

Social Forestry, especially agro-forestry during the last four decades in Gujarat State has tremendous impact on the tree cover and wood production in the non-forest areas. The two tree countings in 2003 and 2009 in the non forest areas in state indicate that about half a dozen fast growing exotic species, introduced few decades ago, have changed composition of trees and the landscape in rural Gujarat. The present trend of plantations in farm lands favour timber producing fast growing species. Due to non availability of other categories of lands, the future of social foretry depends on advancement of agro-forestry. Since Anand and Kheda model of agro-forestry has proved beyond doubt that such practices lay sound ecological and economic foundation for sustainable development of the rural area, this model needs replication in other irrigated areas, particularily Narmada Cammond Areas. As clonal plantations of the two species-Eucalyptus sp. and Populus sp. have already changed the face of ago-forestry in some areas of the country, similar technological advancement is necessary in several other such agro-forestry species, especially about a dozen tree species planted by the farmers in the state. Gujarat Forest Department has already taken initiatives by establishing clonal and tissue culture plant production centres to supply quality seedlings to bring qualitative and qualitative changes in the agro-forestry but development and establishment of institutions to work on agro-forestry research and technological advancement is a call of the day.

• Introduction

Tree cover outside forest (TOF), foundation for sustainable development of the rural India, is a backbone of economy and a main source of rural energy. The contribution of TOF, especially agro-forestry to the national economy and ecology is substantial, but it has not been adequately recognised in the planning process. As per an estimate of the Forest Survey of India, Dehradun, the growing stock of the TOF is 1,599.6 million cubic meters in India[1,2]. This figure speaks about the tree wealth in agro-forestry plantations, quantity of wood production and ecological & environmental benefits. Recently, the value of this resource has also been recognized as a main source of Carbon sink, maintenance of soil health and earth environment.

Improving tree productivity in agro-forestry plantations is a key issue to make tree crop as an economically viable option. Development of high yielding agricultural crop varieties resulted into manifold increase in agricultural productivity in five to six decades but similar advancement is lacking in indigenous tree species which are preferred in agro-forestry. The forestry sector has only two major technological advancements in its credit and both of them are in two fast growing exotic species-*Eucalyptus* sp. and *Populus* sp. There are indigenous fast growing species like semal-*Bombex ceiba*, sewan-*Gmelina arborea* etc but high yielding clones of these species are yet to be identified and developed. The high yielding clones of *Eucalyptus* sp. and poplar has major impact on national economy, rural income and employment. Similar

clone-development of species like teak, sissoo, khair, neem, babool, ardusa, sevan, semal etc may turn agro-forestry an economically viable option.

Progress of Social Forestry in Gujarat

In Gujarat, forest cover is relatively low but tree cover in the non forest area is the second amongst the Indian states. Due to the fact that further allocation of land from agricultural and other land uses towards forestry purpose being almost impossible, there was only one alternative for increasing the tree cover and augmenting the supply of forest produce, and that was of organizing and motivating people, and with their help, planting tree in the low productivity wastelands and farmlands. Accordingly, the government of Gujarat adopted a new approach more than four decades ago, and in 1969-70, Social Forestry was born as a People's Programme for planting trees outside the forest lands. Social forestry divisions, first in country, were established in the State. This programme was implemented from 1969-70 to 1979-80, setting an example, which was later followed by other States as well. With this initiative, the State becomes pioneer in social forestry in the world.

The results of initiative of the Social Forestry implemented under the state plan were encouraging and were appreciated by the international community. The World Bank expressed readiness to fund Social Forestry activities in the State. Thus, the First Phase of the Social Forestry Project commenced from 1980, and the Second Phase from 1995-86 to 1992-93. Subsequently, Social Forestry became a part of the Integrated Forestry Development Project (IFDP) in 1996-97. Since the first project in 1980, the State Government has implemented three social forestry projects financed by the World Bank and the Japanese Overseas Bank. The fourth project-the Second Phase of the IFDP financed by the OECF (Overseas Economic Co-operation Fund), Japan is already under implementation. These projects as well as plantations under the State Plans have made a significant contribution in improving tree cover, which is apparent in the reports of the Forest Survey of India (FSI), Dehradun and also in the reports of tree countings in the State[2,3,4].

Social forestry in Gujarat had different models of plantations and its supporting activities. Strip plantations (plantation along road, railway and canal sides), raising village woodland or village forest on community lands, afforesting and rehabilitating wastelands, afforesting degraded farm lands, farm forestry, urban forestry, environmental plantation, raising social security plantation, raising cultural forest, pond plantation and supplying seedlings to people under *Van Mahotsav* were main activities of plantations. Farmer-*shibirs* or activities related to transfer of technology, supplying fuelwood saving devices, promoting decentralized nurseries (*kishan*, school and institutional nurseries) were supporting activities. The Forest Department has started celebrating *Van Mahotsav* by creating Cultural Forest to strengthen link between people and tree. Recently, the Department has focused on production of high quality seedlings to encourage agro-forestry and also to improve tree productivity.

Under the Social Forestry Programmes, till the year 2010, plantation was done in 234, 200 ha of public lands. Farm land plantation at the cost of the Government was started in 1970s in a small scale which was scaled up in late 1980s. During the last two decades, agro-forestry was a focused programme. Till the year 2010, a total of 238,750 ha area of private lands have been planted by the Government. Besides this, a total of 4810.1 million seedlings, including herbal plants and ornamental shrubs have been

distributed among farmers, individuals and institutions during the last four and half decades.

Status of TOF

Although tree cover outside forest was poor in Gujarat in 1970s, it is difficult to assess its extent of coverage. Reports of the FSI, Dehradun indicate that tree cover has improved consistently in Gujarat[1,2]. Status of trees in the non forest areas, including agro-forestry plantations was monitored through tree counting in 2003 and again in 2009. In 2003, tree counting above 10 cm Girth at Breast Height (GBH) was done in the non-forest areas of 833 sample villages in 24 districts, out of total 25 districts (now 26 districts) in Gujarat. The tree counting was divided in three groups and they were-(i) trees in orchards, (ii) trees in the departmental plantation-village woodlots, strip plantations etc, and (iii) farm/agro-forestry, scattered trees, including human habitations. This exercise was again repeated in 2009 in 835 villages, covering all districts and *talukas*. Based on tree population in sample villages, the total tree population was projected for different districts[3,4].

The main findings of tree countings in the state are as follows[3,4].

- Total number of trees in the non forest areas (NFAs) in 2003 was 251.03 million which increased to 268.69 million in 2009. Thus, tree population has increased by 17.66 million at the annual rate of 2.93 million trees.
- Of total trees growing in the NFAs, about 71.3% was in private lands-farmland and orchards (agro-forestry), human habitation and miscellaneous lands, and 28.7% in the departmental plantations.
- Tree density in the NFAs has increased from 14.1 trees/ha in 2003 to 16.1 trees/ha in 2009.
- Anand district has maximum tree density. There are seven districts which have tree density over 30 trees/ha and they are Anand (68.4 trees/ha), Tapi (64.0 trees/ha), Gandhinagar (58.2 trees/ha), Mahesana (51.8 trees/ha), Valsad (35.6 trees/ha), Surat (35.0 trees/ha) and Kheda (31.0 trees/ha). These districts are in high rainfall areas or have substantial areas under irrigation.
- Surendranagar district has lowest tree density-only 2.9 trees/ha. There are six districts in the semi-arid and arid regions which have tree density less than 10 trees/ha and they are Surendranagar, Kachchh, Jamnagar, Amreli, Ahmedabad and Rajkot.
- Although tree population of *Prosopis chilensis* has declined after its cutting for charcoal preparation during the last six years, its number is still highest-393.8 million. Neem is state tree and its population (297.8 million) is highest among large to medium size trees.
- Although a total of over 405 tree species have been recorded in the forest and non-forest areas in Gujarat, only about few dozen are preferred for growing by the people in their lands. Ten most dominant tree species have 76.7 % of total tree population in the NFAs, and the rest of over 150 tree species cover only 23.3 % of total trees.
- Five exotic species-*Prosopis chilensis*, *Eucalyptus sp.*, *A. tortalis*, *Casuarina equisetifolia* and *Leucanea leucocephala*, which were absent or rarely seen five decades ago, are now dominant species, constituting about 31.7 % of total trees in the non-forest areas of the State. If other three exotic species namely

Pithecellobium dulce, Ailanthus excelsa and *Acacia auriculiformis* are added, the eight exotic species alone constitute over 36.7 % of the tree population in the non-forest areas of the state. In other words, these exotic species have changed landscape of the state and also improved wood production.

- The TOF in Gujarat State, primarily agro-forestry produces about 3.17 million cubic meter of small, medium and large timber[5]. Thus, social forestry generates huge employment and makes a significant contribution to the economy of the State.
- A total of 35 tree species used in saw mills or domestic timber for different purposes have a total of 166.80 million trees[5]. These species produce substantial quantity of timber in the state.

Tree cover in the non forest area (NFA) was 8,390 sq. km. in 2009 which is the second largest after Maharashtra[2]. Also, average tree density in the NFA of Gujarat is the second highest after Kerala among the Indian states and Union Territories. Although a major part of Gujarat is in semi-arid and arid region, the tree density is relatively high. The growing stock in the NFAs of Gujarat is 122.83 million cubic meter against only 48.28 million cubic meter in the forest areas in the state[2]. This indicates about the importance of tree resource availability outside the forest lands. Also, Carbon store in trees outside forest is much more than the Carbon store in the forest cover in the state.

As per the FSI Report (2005)[1], 40 tree species in India constitute 71.3 % of total trees of the TOF whereas the rest of the species shared remaining population. In the TOFs, mango-*Magnifera indica* has the maximum contribution both in number (7.11 %) and volume (10.36 %)[1,2]. This is followed by coconut/palm-*Cocos nucifera*, neem-*Azadirachta indica*, jamun-*Syzygium cuminii* and mahuda-*Madhuca latifolia* in term of volume. In term of number, khair-*Acacia catechu* (7.49 %), neem-*Azadirachta indica* (4.05 %), coconut/palm-*Cocos nucifera* (4.99 %), *Pinus roxburghii* (3.83), babool-*Acacia arabica* (3.59 %) and khijada-*Prosopis cineraria* (2.58 %) are major species after *Magnifera indica*.

In Gujarat, ten most dominant tree species in the non forest areas are-*Prosopis chilensis, Azadirachta indica, Acacia nilotica, Eucalyptus sp., Tectona grandis, Mangifera indica, A. tortalis, Casuarina equisetifolia, Prosopis cineraria* and these species constitute 76.7 % of total tree population in the NFA, and the rest of over 150 tree species cover only 23.3 % of total trees[3,4].

Agroforestry

Tree cover in the farmlands is high in the high rainfall area or in the lands having canal irrigation. Agro-forestry practices have advanced in over a half dozen districts-Anand, Kheda, Mahesana, Gandhinagar, Navsari, Valsad and Surat. Neem, deshi babool and ardusa are the three main trees species in the agro-forestry plantations in north Gujarat. With supply of good quality seedlings, ardusa has become a lead species due to its increasing demand in packing and plywood industries. In central Gujarat, *Eucalyptus* sp is main species in commercial plantation of agroforestry. Along with *Eucalyptus*, Deshi baval, neem, and ardusa are other species preferred by farmers in this region. Plantation of sharu and Bengali babool has an increasing trend in the high rainfall areas of south Gujarat, although teak, khair and bamboo are also preferred

by the farmers. Saurashtra and Kachchh have relatively less agro-forestry plantations due to nature of climate and condition of land. Sharu, neem, sitafal are preferred by the farmers in this region.

Except in south Gujarat, neem and deshi babool are dominant species in all regions of Gujarat. At present, nine species-neem-*Azadirachta indica*, deshi babool-*Acacia nilotica*, Nilgiri-*Eucalyptus* sp., *Casuarina* sp, ardus-*Ailenthus* sp., Teak-*Tectona grandis*, subabool- *Leucanea leucocephola*, Bengali babool- *Acacia auriculiformis* and bamboo are economic species in agro-forestry plantations. Recently, the Forest Department started supplying clonal seedlings of Nilgiri and sharu, and tissue culture plants of teak to promote and also to increase yield of agro-forestry plantations. These species constitute about 54.9 % of total trees on private lands. Semal- *Bombex ceiba* and sevan-*Gmelina arborea* are other potential species for agro-forestry. Among fruit species, mango-*Mangifera indica*, sargavo-*Moringa oleifera*, sitafal-*Annona squamosa*, amla-*Embilca officinalis, Bordi-Zizyphus sp.*, jamun-*Syzygium cimini* and Nariyali-*Cocos nucefera*, chikoo-*Acrus sapota*, and jamfal-*Psidium guajav* are aimportant tree species raised by farmers.

Forest Department supports a model of farm forestry to encourage small and marginal farmers to take up plantation on their lands, especiallty degraded lands. During the last decade, on an average, about 9,500 ha of the farm lands are planted every year at the cost of the Government. In addition to this, about 80 million seedlings were supplied every year to people and institutions unde Van Mahotsav programme and about half of these seedlings were planted by the farmers on their lands.

Anand district-A modal district in tree farming

Anand, a non forest district in central Gujarat has canal irrigation. After commencement of canal irrigation, the district has turned one of the greenest districts in India with highest density of trees in the non forest areas. In this district, the land and water are used in such a fashion that productivity of the land stands optimum for all three sectors-agriculture, animal husbandry and agro-forestry. Anand tops in agricultural, milk and wood production in the country[6]. Amul dairy at Anand is known across the globe. Also, the district is nationally known for cash crop production, especially tobacco cultivation. As per the recent tree counting, about 20.12 million trees grow with highest density of 68.4 trees per hectare which is four times the average tree density in the state. A good number of trees are cut annually to produce substantial wood, beyond the local need. Earning income from tree plantation has become one of the main economic activities for farmers in the district. Anand is also famous for NTFP as huge quantity of Amla is exported to other states in India. Orchards of Amla in Anand district employ a good number of people in the season. Tree density is improving fast after commencement of Narmada canal in Nadiad, and in a few years, tree cover in Nadiad may be in line of Anand. Extent of tree cover in Mahesana and Gandhinagar in semi-arid zone is also high and these districts are now wood surplus districts. Timber trade and export of wood to other states are very interesting in Anand district. In fact, this district is a model district in sense of true rural development, including agro-forestry. A large scale timber based industries in Nadiad and Anand is integrated with timber production in the area.

Road map for improving agro-forestry

Social Forestry, especially agro-forestry in Gujarat has been one of the most successful greening programmes in the world. At present, it needs new initiatives, innovation and technological advancement to increase productivity of farm land plantations. Gujarat Forest Department re-examined agro-forestry activities in the State and has decided to provide new momentum by supplying quality seedlings.

Success of agro-forestry, a key area of social forestry, depends on economic return from the lands. To increase plantation yield, it has been planned to supply high quality-clonal or tissue culture seedlings to farmers. Over a dozen clonal plant production centres for *Eucalyptus* sp and *Casuarina* sp. have been established in 2011 in different districts. A tissue culture lab at Gandhinagar has started producing tissue culture plants of teak. A good quantity of clonal and tissue culture plants has been supplied to farmers in 2011 and it has been planned to scale up supply to about 12 million plants in 2012. North Gujarat already produce quality seedlings of ardusa using seeds from Plus Trees. Quality seedlings for other species will be raised by using good quality seeds from seed orchards, seed collection areas and from plus trees. Development of viable model of agro-forestry practices, including inter cropping acceptable to people may improve tree plantation in farm lands. Existing research plantations-clonal multiplication plantations, clonal trial plaantations, clonal seed orchards, seed production stands etc of different species in different parts of the state provide a great opportunity for high quality seed production and also for development of good lones of the species.

The analysis of tree counting data indicates that the tree density is very high in irrigated districts. With expansion of irrigation under Narmada canal systems, tree cover is expected to improve in the command area. The Forest Department has planned to pay attention in these areas for taking up different types of plantation, including supply of quality seedlings to farmers. Replication of Anand and Kheda model in the Narmada command area is a focussed programme of the Government.

It is expected that improving tree cover in the non forest area in the State may accelerate in near future, taking tree population from about 269 million to about 350 million in the next two five years plan. Gujarat has been a leader in forest and wildlife conservation. Conservation of Asiatic lion and Indian wild ass has been globally acclaimed. Restoration and conservation of mangroves in Gujarat is one of the best conservation stories in the world. Improvement of tree cover in the non forest areas of the State is another such successful conservation story, setting an example to convert wood deficit state to wood surplus state. Development of agro-forstry provides another opportunities to the state to become global leader in imoroving tree cover, initiating a new approach to address global warming and also to evolve a model of rural development in the line of the dream of Mahatma Gandhi for **"Gramya Swaraj"**.

The main future strategies to advance agro-forestry in Gujarat needs following strategies.

- Developing clones of nine agro-forestry species as discussed above and supply of their quality seedlings to farmers for increasing productivity.
- Collection of good quality seeds of neem and deshi babool-the two traditional agro-forestry species for raising quality seedlings and also establishing their seed production stand.

- Scaling up high quality seedling production of teak, bamboo, Bengali babool, and sharu for their supply to farmer in south Gujarat, and also to develop superior clones of these species.
- Supporting teak and bamboo plantations under farm forestry schemes in Dangs, Navasari and Valsad districts in such a manner that agro-forestry in these districts tuns a main economic activities of the farmers.
- Scaling up clonal seedling production of *Eucalyptus* sp in central Gujarat and also of sharu in south Gujarat to meet the demand of high quality seedlings.
- Scaling up the quantitaive and qualitative seedling production of ardusa for the farmers of central and north Gujarat.
- Integrating cultivation of herbal plants with agro-forestry systems to enhance economic return to the farmers.
- Developing new agro-forestry practices by integration tree plantation with agricultural and NTFP crops.
- Developing clones of semal and sevan for central and part of south Gujarat and also to encourage farmers to plant these fast growing economic species as both of them have potential for agro-forestry plantations.
- Raising trial of fast growing agro-forestry exotic species like Mahogani to assess scope of its plantations in Gujarat.
- Developing suitable agro-forestry practices along with cultivation of NTFP for Saurashtra and Kachchh region.

Economic and environmental contribution of TOF

In Gujarat, about 268.7 million trees outside forest area, mainly in private lands with growing stock of 122.83 million cubic meter produce about 4.43 million cubic of timber[2,4]. On other hand, the Gujarat Forest Department has estimated that the TOF produces about 3.17 million cubic meter of small and large timber and about 15.0 million tones of fuel wood[3,5,8]. These figures provide some idea about the quantity of timber, firewood, fodder, NTFP, bio-fertilizers that might be used by the people every year. With increasing environmental problem like climate change, tree plantation and wood consumption are expected to increase at fast rate in near future. Agro-forestry provides an opportunity to improve rural economy and also environment. Economic contribution of TOF in the GDP of the state in form of timber was about Rs 40,523 million in 2009 and this figure might become very high when fuel wood from TOF is accounted in this figure[7]. With increasing tree cover in agricultural land, growing stock is expected to increase, resulting into increased production of timber, poles, fuel wood, NTFP and also the Carbon store in the TOF.

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Table-1: Social Forestry Plantations in Gujarat

Period	Category of plantation				Total
	Strip plantation	Village forest	Farm forestry/ Private land	Other lands	
1969-70 to 1979-80	19,333	17,576	176	0	37,085
1980-81 to 1984-85	37,590	38,208	2,521	461	78,780
1985-86 to 1992-93	21,010	37,945	44,164	2,524	105,643
1993-94 to 1995-96	3,294	13,895	26,651	2,570	46,410
1996-97 to 2001-02	12,644	13,567	59,894	8,136	94,241
2002-03 to 2003-04	1,955	2,689	34,285	2,553	41,482
2004-05 to 2010-11	6,648	7,843	71,045	12,048	97,584
Total	**102,474**	**131,723**	**238,736**	**28,292**	**501,225**

Table-2: Tree population of the main species in the non-forest areas

Tree species	No. of trees (million)	% of total trees	Tree species	No of trees (Million)	% of total trees
1. *Prosopis chilensis*	39.38	14.7	11. Bordi- *Ziziphus* sp.	4.75	1.8
2. Neem-*Azadirachta indica*	29.78	11.1	12. Goras-amli *Pithecellobium dulce*	4.38	1.6
3. Deshi baval-*A.nilotica*	23.99	8.9	13. Subool- *Leucanea leucocephala*	3.62	1.3
4. *Eucalyptus* sp.	21.73	8.1	14. Jamun-*Syzygium cuminii*	3.38	1.3
• Mango-*Mangifera indica*	10.79	4.0	15. Kanji-*Holoptelia integrifolia*	3.19	1.2
• Teak-*Techtona grandis*	9.73	3.6	16. Sargavo-*Moringa oleofera*	3.18	1.2
• Israel baval-*A. tortalis*	8.75	3.3	17. Khair-*A. catechu*	3.34	1.2
• *Casuarina equisetifolia*	8.66	3.2	18. Bengali baval-Casia	2.98	1.1
• Khijado- *Prosopis cineraria*	8.26	3.1	19. Khakharo-*Butea monosperma*	2.46	0.9
• Arudosa-*Ailenthus excelsa*	5.49	2.0	20. Karanj-*Pongamia pinnata*	2.45	0.9
Total	**166.56**	**62.0**	**Total**	**33.73**	**12.5**
			Grand total	**199.29**	**74.5**

Agroforestry science for achieving an evergreen agriculture

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EXTENDED ABSTRACT

Agroforestry and Evergreen Agriculture have very similar goals and objectives. They both tend to address a particular challenge faced by agriculture today; the challenge of how to increase the productivity from depleted natural resources--- soil, water and biodiversity and do so in the face of climate change. Albeit younger than other sciences in agriculture, agroforestry research has a scientific framework and produces sound concepts, methods and practices for developing sustainable tree based farming systems. Evergreen Agriculture on the other hand is emerging as an affordable and accessible science based solution for better land care and increasing small holder's livelihoods. It combines the best options of conservation agriculture and agroforestry to increase farm productivity, while conserving their natural resource base and the environment. In summary, agroforestry research produces scientific basis for developing sustainable tree farming systems, the evergreen agriculture combines the available best practice options for such an endeavour and puts that in practice.

Traditional agroforestry farming systems have been sustainably providing the life support over centuries. It is a way of life throughout much of the South Asia and is recognized as an optimal multifunctional land use system that provides a variety of important benefits, a. o. sustainable livelihoods, sound economy and environmental safety. They contribute greatly to the food and nutritional security of the house hold and thereby ensure their health. These systems also offer greater opportunities for the landless, women and resource poor populations than most of the other on-farm and off-farm employment prospects. Such an array of advantages is also the objectives and expected benefits to be derived from practicing the evergreen agriculture.

Both these systems are ecology specific, and natural resource domain bound, and therefore have enormous prospects for synergy, complementation and drawing benefits from each other. Their application can be throughout in all the ecological conditions and socio-economic settings. However, in order to fully realize the evergreen agriculture objectives, agroforestry science scope has to be broadened to accommodate in it the practice of agroforestry as a specialized form of agriculture. Specialized in the sense wherein multi-strata farming is used as the basis for designing the commodity production systems (not only for economic gains, but also for the nutritional, health and environmental benefits), and commensurate to it the natural resources management alternatives.

The agroforestry / evergreen agriculture efforts need to focus on the design and application of "high-value low volume systems", and making the post harvest, value

addition, packaging and marketing their integral part. Another important consideration is the recognition of the fact that the tree component of any farming system also provides environmental services, and therefore, may be one of the ways to mitigate the climate change effects. Agroforestry systems are probably the only means for getting the desired tree cover, especially in places that have limited area under forests. Agroforestry efforts thus, can positively contribute to livelihoods, food security and environment.

Such efforts at the national can be implemented through four channels: a) overcoming natural resource degradation in intensive irrigated systems, b) arresting land degradation in smallholder farms in sub humid and semi arid areas, c) searching for alternatives to slash and burn in tropical humid areas, and d) providing shelter belt in the coastal areas. The result would be a nationwide Evergreen Agriculture. The details of such an implementation mechanism are in the paper.

Genetic Engineering towards an Evergreen Agriculture, Food Security and Environmental Resilience -A tour De Force in Biotechnology

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ABSTRACT

The presentation "Genetic Engineering towards an Evergreen Agriculture, Food Security and Environmental Resilience-A Tour De Force in Biotechnology envisages the journey of Biology into the exciting field of Biotechnology as a product of Classical Biology, Geology, Physics, Chemistry, Information Technology and Biophysics wherein it has transformed itself to answer the subtle mysteries of life operating at the molecular level and in turn are maneuverable. The theme picks up the thread from the great works from renaissance period which initially led to the progress of traditional biology into what at present is called the Modern Biology where all fields have merged into a single state and is concerned with its application in agriculture, medicine/health or environment. A unique compilation of this lecture and its partial appraisal is on the relevance of the descent of all branches of biology into one common pool (Biotechnology) and shows how the different scientific missions have accomplished their relevance to society through their welfare potential. The audience will have a chance to see the classical milestones in the field of Biotechnology which has revolutionized the dogmas of the modern world and is at the doorstep to serve everyone with their inexplicable powers. The presentation will definitely be a rare acoustics and visual experience to the minds and souls of the audience. It will reveal the gradual progress of classical Life Sciences vis-à-vis Biotechnology through the works of innumerable Noble Laureates who have worked even on the molecules of consciousness. The revelation will be that how man since immemorial has been creating weird crop species for millennia. First he simply selected the ones he liked and planted them again, and then he used chemical mutagenesis to speed up mutations and arrive at the ones that weren't likely to appear anytime soon. Then he discovered that radiations mutagenesis was even more effective. In the last two decades he invented genetic engineering (GE) to transform the physiological and immunological profiles of plants and animals which allowed him to pick trait and splice it in rather than discovering that trait he was looking for in amongst the rubble of mutated seedlings. All have this in common: they are biological solutions, based on understanding of the living organisms they seek to control and of the whole fabric of life to which all the organisms belong. Specialists representing various areas of the vast field of biotechnology are contributing – entomologists, pathologists, geneticists, physiologists, biochemists, ecologists – all pouring their knowledge and their creative inspirations into the formation of a new science of biotic world which may provide a better life in terms of food, feed and welfare feeling to all of us.

INTRODUCTION:

It is more than 200 years since Thomas Malthus offered his famously pessimistic prediction that the rise in human populations would outrun the growth in food supplies. But despite devastating regional famines, prognostications of mass starvation have not been fulfilled, even though the population has risen around six-fold since Malthus's time. Nonetheless, projections for the coming decades are deeply disquieting. We are already unduly dependent on farming techniques that have harmful environmental impacts. To meet the needs of a growing population with changing consumption patterns, productivity must be enhanced, but it must be done so sustainably. This paper report describes how the prudent application of recent and prospective biological advances can contribute to the 'sustainable intensification' of agriculture. It argues that a multi-pronged approach is needed. Improvements in farming practices and crop management are essential, but modern genetics must be utilised too.

Food security is an urgent challenge. It is a global problem that is set to worsen with current trends of population, consumption, and climate change and resource scarcity. The last 50 years have seen remarkable growth in global agricultural production, but the impact on the environment has been unsustainable. The benefits of this green revolution have also been distributed unevenly as the growth in Asia and America has not been matched in Africa. Science can potentially continue to provide dramatic improvements to crop production, but it must do so sustainably. Science and technology must therefore be understood in their broader social, economic and environmental contexts. The sustainable intensification of crop production requires a clear definition of agricultural sustainability. Improvements to food crop production should aim to reduce rather than exacerbate global inequalities if they are to contribute to economic development. In the present food crops scenario about two million more farmers have planted biotech crops in 2009, to total 12 million farmers globally enjoying the advantages from the improved technology. Notably, 9 out of 10, or 11 million of the benefiting farmers, were resource-poor farmers ..... In fact, the number of developing countries (12) planting biotech crops surpassed the number of industrialized countries (11), and the growth rate in the developing world was three times that of industrialized nations (21 percent compared to 6 percent)

The fact is that there is not a shred of any evidence of risk to human health from GM crops. Every academy of science, representing the views of the world's leading experts – the Indian, Chinese, Mexican, Brazilian, French and American academies as well as the Royal Society, which has published four separate reports on the issue – has confirmed this. Independent inquiries have found that the risk from GM crops is no greater than that from conventionally grown crops that do not have to undergo such testing. In 2001, the research directorate of the EU commission released a summary of 81 scientific studies financed by the EU itself – not by private industry – conducted over a 15-year period, to determine whether GM products were unsafe or insufficiently tested: none found evidence of harm to humans or to the environment.

In the light of these supervening developments in scientific world, the next five years are likely to see the ushering in a number of transgenic food crops in Indian markets especially the one belonging to the group of herbicide tolerant crops and to answer the fundamentals intricacies to the consumers as well as to the other under informed about

the nuance of the GM food crops , efforts have to be directed to illuminate all the stake holders to know about the facts of these crops as well as knowing about the contemporary global developments in their research and marketing.

CONCLUSIONS AND RECOMMENDATIONS:

The whole presentations would make the following recommendations with salient conclusions.

- Consumers need to be informed of the pros and cons of various agricultural biotechnology packages with regard to genetically modified food crops and how holistic approaches have been adopted, over a period of time, to keep a check on the dangers of using unsuitable germplasm, and further care has been taken to avoid the loss of local germplasm while concomitantly maintaining their *in situ* local diversity. Other checks and balances have been undertaken to avoid patenting local germplasm and innovations and that the policies on intellectual property rights have been ensured to avoid any unfair competition. To establish their environmental safety, *at all costs*, field trials have been done intensively, under local conditions,. To prevent the monopoly buying of local seed companies and exploitation of local consumers and companies by non serious commercial agencies the precautions have been completely taken at all levels.

- Since many of the [GE] detractors justify their anti-biotech tirades by reasoning that farmers will have to buy seed and have turned "farmer-saved seed" into a holy mantra. Almost all those well experienced in agriculture know that there is nothing worse for farming than farmer-saved seed. Yields steadily decrease because of the loss of vigor, an increase in disease, and an often massive contamination with weed seeds. Only the very best growers are chosen to grow certified seed, and even they are heavily monitored by the seed companies, who are further regulated by governmental authorities. The growers need to enlightened about this fact rigorously and all ill founded myths about the same must be dispelled

- Since we want to see more farmland transitioned to modern practices and at the same time we want to use the most powerful technologies available to create an environmentally friendly, sustainable, and high-yielding farm we must remember that the way in which the introduction of genes from novel species, through breeding revolutionized farmers' management of pests, so can the introduction of genes through GE can revolutionize control of diseases, herbicide tolerance, insects, and nematodes for which there is presently no organic solution. GE can also greatly increase our understanding of what is going on in plants at a molecular level.
- One of the major drivers of GE agriculture is climate change. How a farm can switch from being a climate problem to a climate solution. Some of that transformation will come from better practices that enrich soil and preserve wild land, some from engineered "ecology in the seed" through genetic engineering. Consider nitrous oxide, a greenhouse gas three hundred times worse than carbon dioxide that fumes up from soil drenched with chemical fertilizer. If the use of

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nitrogen fertilizer went down by a third, says a report in *New Scientist* that "would reduce greenhouse emissions by more than grounding every single aircraft in the world." So will new varieties of rice and other crops now being engineered for far more deficient uptake of nitrogen from fertilizer, so less is needed, saving the famer money while reducing atmosphere and water pollution.

Consider also the gases that come out of us and our livestock and pets exhaling, burping, and farting; Scientist like Lovelock says that this accounts for 23 percent of all greenhouse-gas emissions. Australia is on the case. One project there is engineering lower-lignin grass that would reduce the methane emitted from cows by 20 percent. Another is trying to transfer the digestive bugs from methane-free kangaroo guts to cow guts for hoped-for 15 percent methane reduction. (One anticipates a climate-friendly pro-biotic yogurt for humans called Roo.)

- Every GE-capable foundation, corporation, and government department working on drought-tolerant, herbicide tolerant and salt-tolerant crops, especially for climatically fragile and unpredictable Indian subcontinent must be encouraged and the entire academic and the infrastructure support may be extended to them after completely verifying their antecedents and scientific accumenship. Since such crops are so crucial for adapting to climate change and they are sure to come, and the sooner the better. But ecologists are rightly worried about these crops going feral – weed and invasive – in the dry or salty terrain they're designed to thrive in, because there is less native plant competition in such harsh land. This is a case where serious ecological research must be done during the field trials, to figure out how best to contain the newly talented crops.
- If environmentalists and others dubious about genetic engineering had taken this approach from the start in the 1980s, cleaving close to researchers out in the fields, they would have quickly discovered that GE foods are safe to eat, GE crops can be ecologically beneficial, and corporations are significant but not necessarily controlling players in the technology. Environmentalists would have helped lead the doubly green agricultural revolution in the developing world instead of delaying it. Two decades of time, money, people, and credibility wasted on anti-GE activism would have been saved for solving real rather than imaginary environmental problems, and genetic technology would have arrived in the world Green from the ground up.

We would like to add that it is the time for all of us to have a panoptic view that in India we are at 30-40 per cent productivity levels and any technology that can push up the yields, say to 70 per cent, would have a tremendous impact in transforming our agricultural sustainability. After having worked in life sciences for the last four decades, I am convinced that only a continued adoption of Biotechnology can make us leader in agriculture productivity.

As apparent from the presentation, our farmers have created a revolution. After cotton production was reducing towards in 1990s, they successfully doubled its production since 2001 and have increased its productivity by over 75 %. The farmers from cotton growing states have led the way, and after doubling its production they are

ready to do more. They credit this revolution to their hard work in the fields, and use of hybrid cotton seeds with Bt technologies which the key Ministries, and Genetic Engineering Approval Committee made available only in the last decade. For cotton farmers, after bollworm insects, which cotton seeds with Bt technologies have helped manage, weeds are the next big challenge as these compete with the crop for nutrition and lower their productivity.

With the successful implementation of our nation's employment schemes, farmers are facing still big challenges - shortage of agricultural labor when needed for sowing, weeding and harvesting; high rural labor costs; unpredictable climate increases weed growth and difficulty to remove weeds by hand, bullock or tractor. Today, farmers do not have an easy and effective solution to remove weeds. Another technology to manage weeds is approved and used by farmers in cotton, maize, soya bean, and other crops, in scientifically awakened countries for over the last 12 years and a is called herbicide tolerant technology('Bollgard II Roundup Ready Flex technology'). This technology allows farmers to plant the new Bollgard II Roundup Ready Flex seeds and then spray a special Roundup® herbicide and through this, the weeds get managed. We understand that this technology has been evaluated in India for the last four years and farmers are very anxious to use it in their own fields at the earliest. Despite being potentially promising it is indeed a pity that several aspects of debate in this country on genetically modified (GM) crops and foods have adopted the adversarial approach rather than a consensual one. When will the time come when we will have the confidence that our scientific personnel are our guardians with the arsenal of the knowledge and expertise, can sift the grain through the chaff and can point out what is relevant to excellence for our country. The need of hour is to accept the GM technology further. We have to assess what is relevant to our land and lab, have faith in our scientific community and have an innate confidence that nobody can rob us.

Clonal Multiplication and Plantation of Eucalyptus hybrids FRI-5 & 14 for higher productive gains in Agroforestry models

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INTRODUCTION

Integration of trees with agriculture crops has been attempted since time immemorial. In recent years efforts have been made to grow fast growing trees with agriculture crops so as to get the best returns of their associations. Now a day's agroforestry has become a science of designing and developing integrated self sustainable land management system besides it is an option for carbon mitigation also. Presently people are interested in opting for agroforestry system especially for industrial species like Eucalyptus, Popular, Casuarina, Tectona, *Melia dubia*, Gmelina and more recently Bamboos etc. Emphasis has greatly increased for fast growing clonal materials which can go suitably with the crops. In this direction eucalyptus and popular are the first choice for agroforestry system in northern India.

Eucalypts are credited with high growth rate and multiple uses and are planted extensively. *Eucalyptus* produces some of the heaviest, hardest and most durable wood, thus making this genus the most valuable source of hardwood in the world. To meet the increasing demand for timber in the future, fast growing *Eucalyptus* plantations are preferred. *Eucalyptus* hybrids have been a widely planted species in India owing to its adaptability in different eco-climatic zones. Hybridization is a known process by which the desirable traits of the two parents may be combined in F_1 offspring. It also offers a means to capture the benefits of hybrid vigour (heterosis), which is often manifested in certain specific parental species combinations in hybrids. Promising F_1 hybrids of Eucalyptus produced at Forest Research Institute plantation have displayed a very high degree of vigour (positive hetrosis) both in height, diameter and wood quality. Development of hybrids, their clonal multiplication and post juvenile character studies still remains a serious problem due to various reasons. Forest Research Institute, Dehradun, has 13 mature F1 hybrids out of these different interspecific hybrids developed, two hybrids were selected for the present study i.e. FRI-5 and FRI-14. Both these Eucalyptus hybrids FRI-5 and FRI-14 selected for present study has shown superior character over their parental combination. They have also displayed a very high degree of hybrid vigour and proved 3-5 times superior in growth parameters than the parent combinations. However, when F2 population raised through seeds a lot of segregation was observed which had reduced the average yield per unit area per unit time. These hybrids produced higher biomass than the parental progenies and the Mysore Gum (Venkatesh and Sharma, 1977a,b).

Production of clonal materials of eucalyptus FRI-5 & 14 hybrids were made possible by developing Tissue culture technology. Present paper describes production of clonal material of fast growing eucalyptus FRI hybrids and their successful field plantations under different climatic conditions.

MATERIALS AND METHODS

Nodal shoots segments containing axillary buds were harvested from the two natural F1 hybrid of Eucalyptus, that is FRI-5 (*E. camaldulensis* Dehn x *E. tereticornis* Sm) and FRI-14 (*E. torelliana* F. V. Muell x *E. citriodora* Hook). The explants were harvested from newly developed fresh shoots early in the morning and proved to be the best time for explant collection. It was found that the explants collected during months of January to February and August to September were the best for *in vitro* studies as they showed least phenolic exudation and gave 65 - 70% bud break response as compared to other months.

RESULTS OF *IN VITRO* STUDIES

Collection and sterilization of Explant

The nodal shoot segments containing axillary buds were collected from 30-32 years old mature trees of *Eucalyptus* hybrids FRI-5 and FRI-14 growing at New Forest experimental field of Forest Research Institute, Dehradun. Axillary bud/nodal segments measuring 2-3 cm were cut. Explant treated with bavistin (1%) and antibiotics (Streptomycin and Chloramphenicol) for 3-5 minutes followed by surface sterilization with (0.15%) $HgCl_2$ (12 min for FRI-5 and 10 min for FRI-14) was found to be very effective in controlling 78 - 80% contamination with good survival rate of 65 - 75%.

Axillary Shoot Proliferation

Initiation of axillary buds started within 3-5 weeks from the date of inoculation of the nodal segments without an intervening callus phase. MS medium (1962) was found to be very effective for axillary bud induction and shoot initiation for both the hybrids. Nodal segments of FRI-5 when cultured on MS medium supplemented with 1.0 mg/l BAP, gave 80% bud break. In FRI-14, 70% bud break response was obtained on MS+1.5 mg/l BAP + 0.5 mg/l NAA .

In vitro Shoot multiplication

The proliferated axillary shoots were excised and transferred onto the fresh MS medium supplemented with different concentrations of BAP alone and in combination with NAA. Out of different media combinations tested, optimal *in vitro* shoot multiplication occurred on MS+ 1.0 mg/l BAP + 0.1 mg/l IBA in FRI-5 hybrid and MS + 1.0 mg/l BAP in case of FRI-14 (Table 1 & 2). *In vitro* shoots multiplied in 5 weeks in both the hybrids. A regular sub-culturing with 16 hr light (illuminated by 40 watt fluorescent tubes,1200 lux) and 8 hours in dark cycle gave healthy shoot cultures. The cultures were regularly transferred into fresh medium in every 5 weeks to check the browning of cultures. Cultures were incubated at 25 ± 2°C.

Regeneration of roots

In vitro shoots measuring 2.5 to 3.0 cm were inoculated onto half strength MS medium supplemented with IBA (0.1-2.0 mg/l) alone and in the combination with NAA (0.1-2.0 mg/l) for rooting. Nearly 80% rooting was achieved in FRI-5 on ½ MS supplemented with IBA (1.0 mg/l) and 70-80% rooting was achieved in FRI-14 on ½ MS supplemented with IBA (0.5 mg/l) (Table 3 & 4).

Acclimatization, hardening and field transfer

Micropropagated plantlets were hardened *in vitro* in liquid ¼ MS medium having 2% sucrose. Paper bridge or absorbent cotton was placed in the liquid medium for supporting root system of *in vitro* raised plantlets. Plantlets were maintained in culture room for 2 weeks. Later these plants were shifted to mist chamber in polythene bags containing a mixture of soil, sand and manure (1:1:1) and covered with perforated polythene bags. Again after two weeks these plants were transferred into bigger polythene bags and placed in the net house. After four weeks of open shade acclimatization the plant were finally transferred to the field. 85 - 95% success in field survival rate was observed in both the hybrids when field planted in 5x5 spacing and watered twice in every 15days.

FIELD TRIALS

In the present study tissue culture raised cloned plants were planted at three sites of different climatic conditions of Uttarakhand. An average height of 7.5-9.5 m were observed with an average diameter of 6.5-8.5 cm and a survival rate of 90-92% at the sites of Dehradun, while at Pantnagar and Haldwani fields a survival rate of 86-90%was recorded after three years of plantation. Total height and collar diameter taken on breast height (~137.0 cm) were recorded after three years and variation was observed in height and collar diameter at different plantation sites (Table 5).

The growth performance and survival percentage of both Eucalyptus hybrids FRI-5 and FRI-14 showed their suitability in particular environmental conditions. The analysis of survival percentage showed that the hybrids as well as the localities also when compared do not differ significantly. It indicates that localities or hybrids have no effect on survivability of plants.

Eucalyptus is well adopted in agroforestry system, however with the supply of clonally superior eucalyptus hybrid planting stock for agroforestry will increase the economic gains to the farmers. In the present study effective and commercially viable micropropagation techniques were successfully developed for mass multiplication of two superior Eucalyptus hybrids FRI-5 and FRI-14. Preliminary investigation after three years of field plantation at different eco-climatic sites having varied environmental conditions showed that Eucalyptus hybrids FRI-5 and FRI-14 are promising in terms of height, diameter, clear bole length and self- pruning capability. However, suitability of hybrids in a particular eco-climatic zone can be determined by making continuous observations over a period of about 8-10 years (Rawat *et.al.*1984). Present finding is based on a period of three years.

Summary

Eucalyptus hybrids are an important forest tree species under the social and commercial forestry programme with a view to get more yield per unit area. The wide spread application of *in vitro* propagation on its cost-competitiveness and is profitable only when there is an associated advantages over conventional propagation methods. The field testing of these hybrids revealed their suitability in a particular climatic zone. Also these results had shown their performance with respect to the total bio- mass production. The hybrid if found suitable even after 7-8 years (rotation cycle) with improved timber and oil production will be of immense value for commercial growers of Eucalyptus.

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Table 1. Effect of cytokinin (BAP) in MS medium on *in vitro* shoot multiplication of FRI-14 (data recorded after 5 weeks)

BAP(mg/l)	Mean shoot number	Mean shoot length (cm)	Multiplication rate
Control	22.33 ± 1.12	1.07 ± 0.02	5.58 ± 0.28
0.5	33.50 ± 1.26	2.01 ± 0.12	8.38 ± 0.31
1.0	51.33 ± 2.35	3.03 ± 0.16	11.83 ± 0.16
1.5	40.80 ± 1.40	2.63 ± 0.05	6.80 ± 0.15
2.0	30.17 ± 0.91	1.97 ± 0.06	5.20 ± 0.12
2.5	20.50 ± 0.62	1.46 ± 0.05	3.53 ± 0.18
Significance	***	***	***
CD at 5%	4.00	0.26	0.42

***Significance at 0.1%; ± values represent the standard error.

Table 2. Effect of hormonal interaction cytokinin and auxin (BAP + IBA) in MS medium on *in vitro* shoot multiplication of FRI-5 (data recorded after 5 weeks)

BAP + IBA (mg/l)	Mean shoot number	Mean shoot length (cm)	Multiplication rate
Control	10.33 ± 0.42	0.50 ± 0.03	2.07 ± 0.08
1.0 + 0.1	57.17 ± 1.38	1.51 ± 0.04	11.43 ± 0.28
1.0 + 0.5	45.83 ± 0.75	1.33 ± 0.08	9.17 ± 0.15
1.0 + 1.0	37.17 ± 0.83	0.61 ± 0.06	7.43 ± 0.17
1.0 + 1.5	24.33 ± 1.20	0.44 ± 0.01	4.87 ± 0.24
1.0 + 2.0	23.80 ± 0.96	1.12 ± 0.07	4.70 ± 0.19
Significance	***	***	***
CD at 5%	2.81	0.16	0.56

Table 3. Effect of IBA on rooting of *in vitro* shoot on half strength MS medium of FRI-5 (data recorded after 5 weeks).

IBA (mg/l)	Rooting (%)	Mean root number	Mean root length (cm)
Control	12.5 ± 0.29	0.50 ± 0.22	0.35 ± 0.16
0.1	20.83 ± 0.48	8.67 ± 0.56	0.73 ± 0.05
0.5	66.66 ± 0.38	17.17 ± 0.48	1.02 ± 0.03
1.0	87.50 ± 0.29	20.17 ± 0.60	2.34 ± 0.04
1.5	70.83 ± 0.48	18.83 ± 0.70	1.47 ± 0.05
2.0	54.16 ± 0.09	11.33 ± 0.67	1.30 ± 0.03
Significance	***	***	***
CD at 5%	1.11	1.62	0.22

Table 4. Effect of IBA on rooting of *in vitro* shoot on half strength MS medium of FRI-14 (Data recorded after 5 weeks)

IBA (mg/l)	Rooting (%)	Mean root number	Mean root length (cm)
Control	12.5 ± 0.29	0.50 ± 0.22	0.35 ± 0.16
0.1	45.83 ± 0.68	8.67 ± 0.56	0.73 ± 0.05
0.5	91.66 ± 0.86	17.17 ± 0.48	1.02 ± 0.03
1.0	79.16 ± 0.24	20.17 ± 0.60	2.34 ± 0.04
1.5	62.50 ± 0.46	18.83 ± 0.70	1.47 ± 0.05
2.0	41.66 ± 0.54	11.33 ± 0.67	1.30 ± 0.03
Significance	***	***	***
CD at 5%	1.11	1.62	0.22

***Significance at 0.1%; ± values represent the standard error.

Table 5. Field performance after three years of tissue cultured clones of *Eucalyptus* hybrids (FRI-5 and FRI-14) under different varied climatic conditions of Uttarakhand State

Plantation sites	Avg. height (cm)			Avg. collar dia. (cm)			Avg. clear bole length			Volume (m3)		
	FRI-5	FRI-14	Control	FRI-5	FRI-14	Control	FRI-5	FRI-14	Control	FRI-5	FRI-14	Control
Dehradun	695.71	765.96	546.35	6.93	7.89	4.00	174.0	283.5	133.4	0.011	0.016	0.003
Pant Nagar	705.76	579.02	493.62	7.04	7.16	3.86	213.2	183.4	123.8	0.011	0.009	0.002
Haldwani	704.19	594.02	511.67	7.35	7.33	4.05	216.6	194.5	129.5	0.011	0.009	0.003
Significance	**	**	**	***	***	***	NS	NS	NS			
CD at 1%	129.04			0.617			-			-		

*** Significance at 0.1%; ** Significance at 1.0 %; * Significance at 5.0%; NS- non significant. Note: Average of 50 plants.

Tree improvement for enhancing productivity and carbon sink services of Agroforestry Systems

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ABSTRACT

Green India Mission (GIM) puts the "greening" in the context of climate change adaptation and mitigation mainly meant to enhance ecosystem services like carbon sequestration and storage in forests and other ecosystems. Among three fold objectives of the GIM, one objective is to increase the Green House Gases (GHGs) removals by India's forests to 6.35% of India's annual total GHG emissions by the year 2020 (an increase of 1.5% over what it would be in the absence of the Mission). . Out of nine sub-missions, which will be implemented under GIM, one sub-mission is Agro-forestry and social forestry (increasing biomass and creating carbon sink) in 1.5 m ha. Under agro-forestry, 0.80 m ha would involve improved agro-forestry practices on the existing lands under agro-forestry, and that 0.70 would involve additional lands under agro-forestry. The Mission will support a program of nurseries for raising quality seedlings to meet the demands of farmers. GIM would also support putting in place a system for certification of seed and genetically improved clonal planting stock or registration of clones and nurseries in India. In this context, this paper reviews and discusses on efforts being made at Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore in conducting tree improvement programmes on industrially important tree species with the objectives of a) productivity enhancement, b) ideotyping for agroforestry systems and c) enhancing carbon sink services of agroforestry systems. The paper also discusses on IFGTB initiatives on domestication and genetic improvement of indigenous species like Teak, Neem, Artocarpus, Terminalias, Ailanthus, etc. A brief mention has also been made in this paper on National Programmes like FGRM Network and Collaborative Industrial Agroforestry, relating to tree improvement.

Keywords: Tree Improvement, Agroforestry systems, Productivity, Ideotypes, Carbon sink services

INTRODUCTION

Promoting agroforestry is a major opportunity to deal with problems related to land-use and CO_2-induced global warming (Albrecht and Kandji, 2003). According to recent projections, the area of the world under agroforestry will increase substantially in the near future. Undoubtedly, this will have a great impact on the flux and long-term storage of carbon in the terrestrial biosphere (Dixon, 1995). Several studies have shown that the inclusion of trees in the agricultural landscapes often improves the productivity

of systems while providing opportunities to create carbon sinks (Winjum *et al.*, 1992; Dixon *et al.*, 1993; Krankina and Dixon, 1994; Dixon, 1995). The amount of carbon sequestered largely depends on the structure and function agroforestry systems - which are, to a great extent, determined by environmental and socio-economic factors. Other factors influencing carbon storage in agroforestry systems include tree species and system management. The significance of agroforestry with regards to carbon sequestration and other CO_2 mitigating effects is being widely recognized. There are sound reasons to believe that agroforestry can contribute significantly to carbon sequestration. It is important that research attention is focused on this aspect of agroforestry systems (Nair and Nair, 2002).

As per IPCC assessment on potential of various options (Table-1), tropical afforestation and tropical agroforestry has a major role to play in mitigation of global emission of CO_2.

Table-1: Potential of various land management activities to mitigate global emissions of CO_2 by increasing carbon sink potential

Tropical afforestation:	15%
Tropical agroforestry:	6%
Tropical regeneration:	18%
Slowing deforestation:	14%
Temperate afforestation:	13%
Temperate agroforestry:	1%
Agricultural management:	33%

In the processes of creating sinks in the biosphere, forest plantations could play a major role. With reference to important plantation species in India, *Eucalyptus* spp., *Tectona grandis* and *Acacia* spp. are the main species having larger area under the plantations compared to other species. Another fast growing, N-fixing tree species gaining importance and presently having great market potential is Casuarinas. Other commercially viable tree species getting popularized and on which some tree improvement initiatives have been done are: a) Neem, b) Pungam, c) Bamboos, d) *Dalbergia sissoo*, e) *Ailanthus excelsa*, f) *Anthocephalus cadamba*, g) *Gmelina arborea*, h) *Thespesia populnea*, i) *Tamarindus indica*, j) Calophyllum inophyllum, and k) *Melia dubia*.

TREE IMPROVEMENT FOR PRODUCTIVITY ENHANCEMENT

A conservative estimate on possible enhancement over current level of productivity for important tree species indicated that two to three fold increases in productivity is achievable with tree improvement.

A study conducted at IFGTB, Coimbatore to assess the carbon sequestration potential of important tree species namely *Eucalyptus tereticornis* and *E. camaldulensis*, Casuarinas (*Casuarina equietifolia* and *C.junghuhniana*) Acacias (*Acacia auriculiformis* and *A. mangium*) and teak under different ages, site conditions and management systems revealed that total dry matter production was 52.0 MT ha^{-1} for clonal origin and 32.4 MT ha^{-1} for seedling origin at the age of 4 years, of which, stem contribution was 31.0 and 15.5 MT ha^{-1} respectively for clonal and seedling origin

plantations. In *Acacia mangium* raised under wide-row alley cropping agroforestry system, total dry matter production was 26.8 MT ha^{-1} for clonal origin and 14.5 MT ha^{-1} for seedling origin at the age of 3 years. Of which, stem contribution was 9.4 and 4.4 MT ha^{-1} respectively for clonal and seedling origin plantations (Buveneswaran, 2011). This study clearly indicates that there is greater scope for enhancing productivity through tree improvement for all the tree species of agroforestry systems.

Further, in Casuarina, Buvaneswaran *et al* (2010) reported that girth varied within an even aged plantation, the difference between the smallest and biggest trees being to an extent of 3 to 4 times. Similar observations of wide variations in growth attributes in *C. equisetifolia* have been reported by Kushalapa (1987) and Sugur (1989). Such huge variation within an even-aged plantation brings down productivity. However, there is lot of scope to further enhance productivity and in turn the carbon sequestration potential of these plantations, owing to the fact that at present most of the *C. equisetifolia* plantations are being raised from unimproved local seed source which showed greater within plantation variation in terms of growth (the co-efficient of variation (CV) in terms of girth varied from 16.3 to 43.3 %) and in turn carbon sequestering potential. In future, the option of clonal plantation in this species is to be promoted to maximize carbon sequestration potential in these plantations, as reported in China in Hainan province, a single clone-Bao 9-comprised over 95% of *C. equisetifolia* plantation during the year 2000 (Zhong *et al.*, 2010). IFGTB aims to increase the productivity of Casuarina through tree improvement using second generation breeding population from current yield potential of 100 MT ha^{-1} in 4 years in irrigated lands and in 6 years under rainfed condition to 130 MT ha^{-1} through seedlings and to 200 MT ha^{-1} through clonal route.

IDEOTYPE BREEDING FOR AGROFORESTRY SYSTEMS

Agroforestry systems aim to integrate agriculture and forestry crops to generate economically productive, ecologically diverse and socially acceptable sustainable land-use systems. In such integration of agriculture and forestry crop, the most important desirable traits are narrow canopy, less branches, acute branch angle, self-pruning ability and deep root production rather than lateral root production. These traits help to minimize tree-crop competitive interactions for light, water and nutrients.

A study conducted at IFGTB, Coimbatore on dry matter productivity of different biomass components in Eucalyptus plantations raised by TAFCORN revealed that Clone C-274 produced less foliage and branches and on the other hand Clone C-285 produced greater foliage and branch biomass, as given in Table below.

Table 2: Intra-specific variation in dry matter allocation (MT ha^{-1}) in Eucalyptus plantation in Tamil Nadu

Clone No.	Age (Years)	Spacing	Leaf	Branch	Bark	Bole
C 285	3	3x1.5	7.8	6.8	5.0	56.9
C 274	3	3x1.5	3.6	4.6	4.6	52.4
Seed origin	3	3x1.5	5.4	2.8	7.7	30.7

This clearly indicates that there exist greater scope for selecting an ideotype for agroforestry systems for having lesser foliage and branch biomass without much compromise on stem wood productivity.

IFGTB developed *Acacia auriculiformis, A. mangium* and their hybrid based agroforestry systems. However, the major issue was heavy branchiness of these phyllodenous Acacias particularly under wide-row intercropping agroforestry system. To address this issues, IFGTB is carrying out tree improvement programme for selecting phenotypes of these two species and their hybrids for straight stem form with less branchiness as well as having self-pruning ability. In *Acacia auriculiformis*, provenances from Papua New Guinea had these desired traits of straight stem form and less branchiness suitable for wide-row agroforestry system. Candidate Plus Trees (CPTs) have been selected and multiplied for field evaluation. Similarly, such ideotype selection for wide-row alley cropping system is being carried out in *Casuarina equisetifolia* as well in IFGTB. This is due to fact that intercropping is currently done for only in the first year under Casuarina. If suitable phenotypes are selected for alley cropping system, the intercropping may be done up to the harvest of tree components that is three to four years.

Contrary to this selection of trees for wide-row alley cropping system, suitable ideotype for 'Windbreak and Shelterbelt' agroforestry systems need to have more branches and foliage biomass. The branch angle also needs to be near right angle. Nicodemus *et al.*, (2001) reported that certain phenotypes of *Casuarina equisetifolia* and *C. junghuhniana* have shown certain branching characteristics which are ideally sought for in windbreaks. IFGTB recently initiated efforts to select phenotypes of Casuarina which are suitable for developing a windbreak agroforestry system. The selected phenotypes will be useful to address the recurrent problem of crop damages particularly in plantain growing belt of the Coimbatore district, which is caused by strong gusty winds during monsoon period. 21 phenotypes were selected by adopting 'Point grading method', while giving greater score for higher productivity, trees having more branches were given additional weighted scores. Theses phenotypes along with one productive clone released by IFGTB and seedlings were planted in Clone Bank of IFGTB. After a period of six months, all these 24 phenotypes were evaluated for branch characteristics and height growth parameter. The results are presented in Table 3. Interestingly, the top three clones in terms of height growth *viz.* **IFGTB-WBC 8, IFGTB-WBC 17** and **IFGTB-WBC 18** recorded greater number of branches, branch length as well as wider branch angle. These clones are under field tests.

Table 3: Branch characteristics and height growth of different phenotypes selected for windbreak agroforestry systems

Clone No.	Number of branches up to 2 m height	Branch Length (cm)	Branch Angles (Degree)	Height growth (cm)
IFGTB-WBC 1	27	31.95	61.20	181.3
IFGTB-WBC 2	20	36.79	57.98	174.0
IFGTB-WBC 3	9	16.80	51.63	61.7
IFGTB-WBC 4	33	27.3	58.08	129.0
IFGTB-WBC 5	40	39.17	64.31	239.0
IFGTB-WBC 6	39	52.69	69.81	223.3
IFGTB-WBC 7	48	42.75	65.00	254.3
IFGTB-WBC 8	**54**	**61.66**	**61.72**	**293.7**
IFGTB-WBC 9	47	38.63	59.37	242.7
IFGTB-WBC 10	49	35.91	59.61	204.7
IFGTB-WBC 11	36	41.99	59.28	175.0
IFGTB-WBC 12	39	37.79	55.18	163.7
IFGTB-WBC 13	37	31.37	48.78	151.3
IFGTB-WBC 14	43	40.15	50.71	188.0
IFGTB-WBC 15	37	38.37	65.72	178.7
IFGTB-WBC 16	27	35.86	56.06	172.7
IFGTB-WBC 17	**42**	**57.00**	**78.13**	**314.3**
IFGTB-WBC 18	**43**	**64.87**	**67.12**	**269.7**
IFGTB-WBC 19	11	24.80	45.96	88.3
IFGTB-WBC 20	23	37.51	47.26	195.3
IFGTB-WBC 21	28	44.50	70.96	206.0
CE-Seedlings	30	37.63	66.11	170.7
CJ-Seedlings	24	29.87	59.82	156.7
IFGTB-CE 3	16	31.99	60.81	126.7

TREE IMPROVEMENT FOR ENHANCING CARBON SINK SERVICES

A conservative estimate on possible enhancement over current level of productivity for important tree species indicated that there exits two to three folds increase in productivity is feasibly achievable with tree improvement activities (Table-4). With average improved productivity of 10 t of C / ha/year under available 40 million ha of lands for forestry option, enhanced sequestration level can be 400 million t of C per year from afforestation programme alone. Further, introduction of the improved planting stocks in the existing plantation during replanting after harvest also has greater scope for enhancement of carbon sequestration potential of production forestry to the extent of twice or thrice the current level (Surya Prakash *et al.*, 2006).

Table-4: Carbon sequestration potential of current level and possible enhancement with tree improvement for important tree species

SPECIES	(t of C /ha /year)	
	Current potential	With TIP
Eucalyptus spp.	4 - 5	15 - 20
Tectona grandis	3 - 5	10 - 15
Casuarina equisetifolia	10 - 12	20 – 25

Buvaneswaran (2011) estimated that carbon sequestration in plantations of *C. equisetifolia* on an annual basis, amounted to 9.12 MT C ha^{-1} $year^{-1}$ at harvest age and this greater amount of carbon sequestration registers *C. equisetifolia* as a potential species to act as carbon sink. By considering the extent of plantation of *C. equisetifolia* in Tamil Nadu as 1.37 million ha (DES, 2008), it can be estimated that the plantation of *C. equisetifolia* sequester 1.15 million MT C $year^{-1}$ in Tamil Nadu alone. However, there is lot of scope to further enhance carbon sequestration potential of these plantations, owing to the fact that at present most of the *C. equisetifolia* plantations are being raised from unimproved local seed source which showed greater within plantation variation in terms of growth (the co-efficient of variation (CV) in terms of girth varied from 16.3 to 43.3 %) and in turn carbon sequestering potential. In future, the option of clonal plantation in this species is to be promoted to maximize carbon sequestration potential in these plantations.

With regard to management inputs to enhance carbon sequestration potential of *C. equisetifolia*, it can be suggested that i) use of productive clones (or) at the least use of improved seed source, ii) a little wider spacing than the existing 1 x 1m spacing, iii) continuing pruning of branches upto 2 years, iv) optimum irrigation and fertilization and v) increased sand proportion in soil for better nodulation and greater root expansion, all of which lead to maximizing carbon sequestration potential of plantations of *C. equisetifolia*.

If we consider the extent of eucalyptus plantation as 6.0 million ha in the country, annual carbon sequestration potential in the biomass alone would be 40.8 million MT C $year^{-1}$, when the plantations are raised entirely with productive site specific clones. However, deploying site specific clone is more important than

promoting clonal forestry itself to enhance productivity and in turn carbon sequestration potential of these plantations. Clonal forestry in teak, *Acacia mangium* and *A. auriculiformis* also need to be promoted to enhance carbon sequestration potential of plantations of these species up to 3 to 5 folds.

TREE IMPROVEMENT FOR INDIGENOUS TREE SPECIES

IFGTB had done the pioneering work in teak improvement in India by establishing Seed Production Areas, identifying Plus Trees and organizing seed collection from identified sources under Indo-Danish Project on Seed Procurement and Tree Improvement (IDPSPTI). International provenance trials of teak was also coordinated under this project. IFGTB continued the efforts of IDPSPTI. One of the Clonal Seed Orchards of teak established in 1978 at Walayar is being maintained. IFGTB has developed Clonal propagation technology for multiplication of superior teak trees through juvenile coppice shoots. A total of 75 superior trees of teak were selected with a selection intensity of 0.3 to 0.5%, in different parts of Kerala out of which 13 trees showed substantially superior height and girth. IFGTB aims to promote clonal forestry in teak to enhance productivity.

With regard to Genetic Improvement of Neem, IFGTB selected high fruit yielding trees all over Tamil Nadu, multiplied vegetatively through branch cuttings and assembled in the clone bank. The clone bank is used for multiplication of clones for establishing clonal seed orchards. The clones in the clone bank showed early flowering and fruiting (first or second year after planting) thus reducing the vegetative phase of the tree. Generally neem tree through seed origin takes about 10 years for fruiting. Further, a international provenance trial of neem was established under the International Neem Network. The 18 provenances represented in the trial are from India, Thailand, Laos, Myanmar, Nepal and Tanzania.

IFGTB conducted variation studies in natural populations of *Artocarpus heterophyllus*, *A. hirsuta* and *A. lakoocha* in Tamil Nadu and Kerala as well as in the cultivated populations. Superior phenotypes were selected and a progeny trial of selected trees in different populations of *A. integrifolia* was raised in Kolli hills. A Seed Production Area (10 ha) of *A. hirsuta* was established at Palode (Kerala). This SPA serves as a good ex situ conservation stand as the species is an endemic and threatened species in Western Ghats.

Terminalia chebula and *T. bellirica* are another important indigenous tree species of pharmaceutical and trade value. IFGTB has undertaken a project to conserve and utilize available germplasm in Tamil Nadu. In this effort, 85 superior trees of *T. chebula* and 17 superior trees of *T. bellirica* have been selected in various places in Tamil Nadu based on fruit yield. Fruit samples collected from identified trees were screened for medicinally important biochemical compounds like total phenols, tannins, gallotannin, free gallic acid and ellagitannins to investigate the relationship between geographic location and the biochemical content.

As an another initiative to Genetic Improvement on indigenous tree species, *Ailanthus excelsa* seeds have been collected from individual superior trees from different parts of the country and established as germplasm banks at BIOTRIM, Tirupati (Andhra Pradesh) and Salem (Tamil Nadu). The germplasm bank will serve as a base population for genetic improvement of the species.

In Tamarind, breeding programme has been initiated for promoting red and sweet tamarind as well as silvicultural strategies have been standardized to cultivate high yielding clones of tamarind in farmland and to get successful fruit yield from tamarind plantations.

Research initiatives have also been made to domesticate some native tree taxa such as *Melia dubia, Ailanthus malabarica, Thespesia populnea, Pongamia pinnata, Anthocephalus cadambae, Callophyllum inophyllum, Macaranga peltata* for various end users.

IFGTB also has a strategy to slowly replace the planting stock in farm forestry from seed material grown in local nurseries, (which have problems of uneven quality, high mortality, etc) to genetically proven seed and planting material from clonal techniques and through hybridisation. Advanced biotechnological inputs, parallel pest and disease control measures will also be drawn in for the improvement programmes.

NATIONAL PROGRAMMES AND COLLABORATIVE EFFORTS OF IFGTB

IFGTB recently working on some national programmes like FGRM Network, All India Coordinated Programmes as well as few collaborative efforts which will in turn support to promote tree cultivation in private lands and outside forest areas.

FGRM NETWORK FOR SUPPORTING TREE IMPROVEMENT PROGRAMME

Forest Genetic Resources (FGR) are valuable to the country as they are the important elements warranting ecological and economic security. The diminishing rate of these resources is alarming due to biotic and anthropogenic factors, coupled with climate change problems and therefore demands conservation both *in-situ* and *ex-situ*. In this scenario, during to XI five year plan period, as a prelude to the establishment of National Bureau of Forest Genetic Resources the Ministry of Environment and Forests, identified the Indian Council of Forestry Research and Education (ICFRE) as the nodal centre for establishing the Forest Genetic Resource Management Network (FGRMN) with its two regional stations, one in the south at the Institute of Forest Genetics Tree Breeding, Coimbatore and the other in the north at Forest Research Institute, Dehra Dun. The FGRMN will act as a nodal agency at national level for collection, characterization, conservation, documentation and exchange of information on FGR. The FGRMN activities have been initiated, identified the collaborating stakeholders and species to be taken up for conservation in a phased manner (Krishna Kumar *et al.*, 2011). However, for the effective and continued progress of the FGRMN it is necessary to widen its reach by networking on national and international scale and accommodating a large number of stakeholders on the lines of National Bureau of Plant Genetic Resources, New Delhi (NBPGR). This demands the establishment of a bureau, the **National Bureau of Forest Genetic Resources** as a central organization under ICFRE (Ministry of Environment and Forests), stationed at Coimbatore.

In this context, IFGTB aims to have a programme on germplasm collection and assemblage, with a view to improve the breeding programmes of various tree species, aimed at improved forest productivity and thus greater carbon sequestration. This would be the first step in the forest genetic resource conservation in respect of 30 different species *viz., Tectona grandis, Gmelina arborea, Melia dubia, Casuarina*

equisetifolia, Eucalyptus camaldulensis, Ailanthus excelsa, Eucalyptus tereticornis, Neolamarckia cadamba, Pterocarpus santalinus, Acacia mangium, Acacia auriculiformis, Casuarina junghuhniana, Calophyllum inophyllum, Sapindus emarginatus, Azhdirachta indica, Tamarindus indica, Dalbergia latifolia, Dalbergia sissoo, Artocarpus heterophyllus, Santalum album, Pongamia pinnata, Aegle marmelos, Pterocarpus marsupium, Ailanthus triphysa, Terminalia chebula, Albizia lebbeck, Leucaena leucocephala, Thespesia populnea, Bombax ceiba and Bamboos (Anandalakshmi and Krishnakumar, 2011).

The assemblages of these prioritized species would serve as national germplasm collections in respect of those species. IFGTB will network with various partners for different species and add on more species for Tree Improvement during the 12th and 13th V year plan periods.

INDUSTRIAL AGROFORESTRY TO CAPTURE THE GAINS FROM TREE IMPROVEMENT

The gap in the raw material supply to industries is estimated at 93 million m^3 in 2020. This gap can be met to some extent by technology based plantations managed through industry- farmer linkage (Pandey and Rangaraju, 2008). About 50% of the plantations raised since 1980 are in agroforestry systems, and the area under the industrial agroforestry plantations is also on the rise steadily, mainly due to the interventions of a few paper and pulp companies. There is an opportunity to utilize this industries-farmer link to boost the productivity of the plantation forestry sector, by technological interventions. The technological interventions can be provided by involving the forestry research institutes and forging a tripartite relationship of industries-farmers-research institutes. Technological intervention like adoption of clonal technology in plantations of eucalypts and poplar have shown higher productivity ranging from 20 to 60 m^3/ha/yr compared to 3-7 m^3/ha/yr from the seedling raised plantations (FAO, 2009). Successful models of such arrangements exist, as in the National Agricultural Innovation Project (NAIP) funded by the World Bank, wherein in the project "A value chain in industrial agroforestry in Tamil Nadu", IFGTB is a partner. Similarly, IFGTB wish to take up a project in the near future, to establish sources of genetically improved planting stock in the form of seeds as well as clones, both with the farmers and the industries.

To conclude, the present review indicates that there is greater scope for enhancing productivity and in turn carbon sequestering potential by two to three folds through tree improvement for all the tree species of agroforestry systems and this is owing to the fact that at present most of the agroforestry plantations are being raised from unimproved local seed source which showed greater within plantation variation in terms of growth. Further, it is also observed that there exists greater scope for selecting an ideotype for agroforestry systems for having lesser foliage and branch biomass without much compromise on stem wood productivity. If suitable phenotypes are selected for wide-row alley cropping system, the intercropping may be done up to the harvest of tree components, particularly in the short rotation tree species like Casuarina, Eucalyptus and phyllodinous Acacias. Contrary to this selection of trees for wide-row alley cropping system, suitable ideotype for 'Windbreak and Shelterbelt' agroforestry systems need to have more branches and foliage biomass. Greater efforts are to be

ploughed in for ideotype breeding for agroforestry systems in our country. National programmes like FGRM Network, All India Coordinated Programmes as well as few collaborative efforts need to be promoted which will in turn support to promote tree cultivation in private lands and outside forest areas. In the coming years, State Forest Departments, Research Institutions, Universities will have to work together in a coordinated manner to enhance productivity of tree species outside the forest areas by identifying appropriate tree species. Adequate fund support to such coordinated efforts need to be provided. Thereby, tree cultivation will become a more profitable business besides ameliorating the environment by sequestering more carbon.

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Development of Agroforestry Models for Forest Fringe Communities

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INTRODUCTION

Forests mantain bio-diversity, preserve genetic resources, sequester carbon and provide many other environmental services. Being life support system, they play a crucial role for the food and water security for people dependent on them. The ever increasing anthropogenic pressure on forests, particularly in tropical countries, has led to depletion of the vegetation, land degradation, distortion of hydrological cycles and consequent decrease in productivity of natural ecosystems resulting in enhancement of poverty and misery. Problem becomes more acute in forest fringe areas where there is neither enough land available for cultivation nor industries to provide employment in remote areas. People still practice primitive subsistence agriculture that has low productivity and to meet ever increasing food grain requirements, and thus the are compelled to opt for unhealthy cultivation practices i.e. shifting cultivation or encroachment to new forest areas that causes degradation of forests by over exploitation of resources.

In the past, attempts made in the restoration of fringe forests and non-forestlands to enhance their synergies in an integrated and sequential manner did not have hollistic approach and thus failed to solve this problem. In the absence of operational planning and convergence, degradation of forests continued which severely affected the sustainability of crops in forest fringe areas and natural vegetation.

Farming is the predominant occupation in India and many types of farming practices have evolved over the years. A lot of these farming practices involve the use of trees either simultaneously or sequentially with agricultural crops and are therefore, agroforestry by definition. However, agroforestry is not commonly practised by the farmers in the forest fringe areas, preventing them from exploring the full potential of this land use system.

Programmes with participatory approach like JFM to manage livelihood development alongwith ecological security has been seen as an important innovation that benefits forest-fringed communities who otherwise have no right or limited rights over forest usufructs or access to them. Many different sustainable management systems have been put forward as viable solutions to minimize pressure on forests. Through its combined economic, environmental and social functions, agroforestry models can make a significant contribution to sustainable development of the fringe villages.

THE FRINGE COMMUNITIES: STATUS, ISSUES AND CONFLICTS

The rural papulation in India is vitally dependent on products and services from local ecosystems, both for subsistence farming and for supplementary harvest of various ecosystem products and services. Therefore, we face the dual challenge of conserving biodiversity on the one hand and enhancing the livelihood security of those

who rely on biodiversity on the other. In reference to the eco-development, the forest fringe villages around the Protected Areas (PAs) are known to be the most critical and contested areas for management.

Protected areas as refered here are the locations which receive protection because of their recognised natural, ecological and/or cultural values. These areas have a varied limitations/restrictions on exploitation of their resources. As per the International Union for Conservation of Nature (IUCN) in its categorization guidelines for protected areas, "it is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values".

In India about 350 million people in around 2,00,000 villages are living in forest fringes areas. A state can effectively protect forests only by soliciting people's participation in forest Management. On the other hand, village communities that are forest users can take the responsibility for protecting and managing their forests along with the forest department. The current forest and tree cover of the country is estimated to have 78.34 million hectares accounting for 23.84% of the geographic area of the country (FSI, 2009). Out of this, the forest cover is about 69.09 million hectare, which constitutes 21.02% of the geographic area of the country. Despite of an increase in the recorded forest area the accelerated pace of population growth has resulted in declining trend in the per capita availability of forest area since the 1950s. The per capita availability of forest land declined from 0.124 hectares per capita in1961 to 0.074 hectares in 2001. Growth of population is expected to be greater than desired for improvements of forest cover as well as quality.

The indirect dependencies of fringe communities on the protected areas mainly aim to generate an additional income so that they can meet their day to day expenses for better standard of living. These may include the illicit felling of trees for supply of wood charcoal, collection of NTFPs and medicinal herbs for commercial purposes, poaching for sale/use of animal products etc. Such activities voilet the rules and regulations of the protected areas. Thus, the indirect dependancies have always been a cause of conflicts between the forest department and communities in the fringe areas.

AGROFORESTRY AND ECO-DEVELOPMENT

Need of community participation in public forest lands management has been increasingly acknowledged by the planners, policy makers, foresters, social scientists, and NGO around the world. An emerging consensus that local inhabitants should play a greater role in management decision-making, has also strengthen the concept of community participation. India has significant population of native people who claim forests lands and consider forests to be their ancestral domain.

Ecodevelopment integrates environmental and forestry activities with social welfare of local communities around protected areas in India. These include the provision of drinking-water and irrigation facilities, soil and moisture conservation, fencing, village road-work, health care camps and employment generation for local communities in the vicinity of PAs. These activities have been recognised as an indirect link to the conservation aspects and also identified much helpful as entry point activities to win over the trust of the villagers.

Ecodevelopment also is an attempt to reduce forest dependence and to compensate local communities - in cash and kind as well as through alternative off-

farm income-generating opportunities - for the lost access to resources in PAs. The approach acknowledges that people living near PAs may have to bear enormous opportunity costs while deriving few tangible benefits from conservation. In fact, many fragmented attempted were made to reduce the dependency of the fringe communities, but, none of the alternative opportunities tested so far has generated sufficient benefits to dissuade forest-dependent people from going to the forests.

In view of above, agroforestry has been considered as one of the viable alternate solution and a dynamic natural management system which diversifies and sustains small landowners to increase socio-economic and environmental benefits. The major function of agroforestry is associated with sustainability for the farmer, stability of resources, production and income and minimization of risk. National Agricultural Policy (2000) has also recognized agroforestry as a prime requisite for maintaining ecological balance, efficient nutrient cycling, nitrogen fixation, organic matter addition and augmentation of biomass production in agricultural system.

GUIDELINES FOR DESIGNING AGROFORESTRY MODELS

Designing an agroforestry model has always been a complex while combining different components considering their mutual suitability (internal interactions) as well as adaptability to the local environment without any risk factor (external interactions) in view of the site specific conditions and issues. The criteria for selection of the different component and their arrangement in a model becomes more vital when the agroforestry model is designed for the forest fringe communities nearby protected areas. The process of setting a criteria also involves multi facet preferences to address the issues of farmers as well as wildlife and plant diversity. The preferences of different components particularly trees and crops needs to be recorded correctly in real terms to meet the long term ecological and livelihood security for both the protected and production areas respectively.

Process of Agroforestry Development for fringe communities

In view of addressing both the conservation as well as production priorities together, the criteria may be broadly classified as follows:

The species or the alternate species to minimize the pressure on the protected area.

Species – a). suitable to climate b). community preferred c). minimizing man – animal conflict d). favourable for other components. e). economically beneficial.

Identification of problems related with farming in forest fringe:

- Crop damage incidences due to wild animals.
- Land availability.
- Lack of awareness on cultivation, management & value addition.
- Lack of infrastructural facilities.
- Marketing of products from remote location.

Exploring dependencies on the Protected Areas:

Direct dependency (using products for self consumption):

The direct dependency may be reduced by -

- Promoting the suitable species or the alternate species in outside forest areas to fulfill the basic needs for which the communities depend on nearby forest areas/protected areas to minimize the pressure on protected areas. (Basic needs may include – food, fuel, fodder, construction materials and other products)
- Providing possible alternative to uses of forest based products.

Indirect dependency (using products for income generation):

The indirect dependency may be reduced through -

- Agroforestry – an eco-friendly alternatives for additional income generation

Criteria for designing an agroforestry model:

- Should involve farmer's friendly techniques.
- Species must not be susceptible to be damaged by wild animals.
- Techniques and planting materials must be compatible in local conditions and available resources.
- Easy to transport.
- Easy in storage.
- Valuable and demanding in local market.
- Should give instant and regular income.

Examples from the fields

The experiences from the RFRI - Demo Village program and agroforestry models under practice are worth sharing as an existing examples from the fields. To establish Demo trials for development of agroforestry in the forest fringe, the Meleng Grant village cluster adjacent to the Gibbon Wild Life Sanctuary in Jorhat Distt., was selected as the project site. The village comprising of three hamlets viz. Bhogpur, Madhupur and Govindpur has a variety of target groups among 222 households.

Demonstration of the agroforestry models through On-farm participatory research at Meleng Grant has been a great opportunity to have a significant impact on the biodiversity conservation and combating the fragmentation of nearby forest cover with follwing aims and objectives -

- To provide sustainable livelihood alternatives through viable agroforestry models in the fringe villages around the Protected Area (Gibbon WL Sanctuary).
- To benefit both science and society through On-farm Participatory Research.
- To create an opportunity for instant and effective extension of promising packages of practices developed On-farm
- To generate awareness among different stakeholders for biodiversity conservation.

As a first face for agroforestry planning, PRA exercises were conducted in regard to explore information on their preferences in reference to problems with wild animals. The exercises on *village time line* and *resource time trend,* reveal that 30 years ago, sugarcane and other crops traditionally grown by the villagers were very often damaged by wild elephants. Severe crop loss led the farmers towards change in their preferences of cropping pattern and land use. Presently, the villagers prefer those new crops only which do not attract the wild elephants and monkeys. Considering the complaints of crop damage by wild elephants, king chilli and patchouli (*Pogostemon cablin*) were identified as alternate potential crops for additional income by introducing in the interspaces under Mangium and other tree gardens. Among these crops, Patchouli, the medicinal and aromatic plant, does not attract the animals' even goats because of its unpalatable leaves while the highly valuable King Chilli itself is very effectively used for keeping away the monkeys and even elephants from the croplands in some localities of Assam.

The King Chili, known as 'Bhut jolokia', is an interspecific hybrid grown in the states of Assam, Nagaland and Manipur. In 2007, Guinness World Records certified the King Chili as the hottest chili in the world.

And thus, the following agroforestry models were established in Demo Village

Mangium - King chilli AF Model

It was a fact that the farmers had experienced difficulties in growing King Chili in the past due its instant mortality caused by insect pests and other unfavourable climatic conditions. Realizing the huge income and high demand in local as well as national and international markets, it was planned to promote the crop under tree gardens with suitable agroforestry management techniques. In this connection, the newly raised mangium plantation was identified as the upper storey component for the agroforestry field trial. The existing tree gardens of Arecanut were also considered for introducing King Chili to utilize the interspaces for additional income. The plants were also grown in open condition to compare the performance under the two conditions. An On-farm participatory Research was initiated to introduce King chili as an intercrop with an aim to utilize the interspaces under *Acacia mangium.* The survival of hottest chili was observed to be 16 times better in comparison to the monoculture (survival % increased from 5% in monoculture to 80% under agroforestry after six months). The Preliminary data projects an income @ Rs. 6,00,000/ per acre at the end of the rotation period (based on current rate Rs.125.00 per kg, fresh weight).

The huge value and demand of the King Chili in national and International market has encouraged the farmers to cultivate in large scale the farmers were helpless to save the plants from the insect pest attacks and diseases in previous year. This year they have witnessed the positive biophysical interaction in terms of the 16 times better survival percentage under mangium plantation. Potential of this agro forestry practice has assured for its wide scope of extension. In view of the increasing market potential in national and international trade, the model has been identified as a viable one to addressing livelihood issues by generating additional income from the use of interspaces which was otherwise not being utilized.

Arecanut - patchouli AF Model:

Being a conducive environment under the tamul (Arecanut) gardens in Assam, the model has a huge potential for its dissemination. In view of the increasing market potential in national and international trade, the model has been identified as a viable one to address livelihood issues by generating additional income by using the interspaces which are otherwise not being utilized The observations reveals that the farmers get 29 % more income under the agroforestry as compared to its monoculture that is also with a minimum capital input in terms of fertilizer, irrigation required under tree garden.

The agroforestry practice has increased the interest of the farmers to utilize the interspaces under Tamul garden for an additional income. The patchouli has also got preference among the other plants in the fringe village sensitive to the wild animal problems.

Mangium – patchouli AF Model

An agroforestry trial on patchouli by intercropping with three months old plantation of *Acacia mangium* was established for standardization of the practice. The performance of patchouli was observed to be 30% better in comparison to the monoculture. The farmers could earn an additional income from patchouli @ Rs. 35,000/- per acre.

The speedy growth of *Acacia mangium* plants witnessed by the farmers in their homestead block plantations itself has attracted and motivated the neighbour farmers to raise more block plantation in the RFRI Demo Village. The performance of patchouli grown under mangium has also assured the farmers for sure to get additional income. The model has been identified as a viable one to address livelihood issues by generating additional income from the use of interspaces which is otherwise not being utilized. The agro-forestry techniques introduced as a new practice in the locality. In view of the instant income generation characteristic of the practice, the farmers are self motivated to plant more seedlings of mangium. Farmers from neighbouring villages are also demanding the plant materials from RFRI Nursery.

Arecanut – King Chilli AF Model

King Chilli was tried under monoculture but the farmers were unable to get the plants survived. The new intercropping system of cultivating bhoot jalukia under Areca nut plantations could be an extensive addition to the source of revenue generation for the rural cultivators of the local people. In view of the above, an On-farm Participatory Research was initiated to introduce King chili as an intercrop with Areca nut. The survival of hottest chili was observed to be 18 times better in comparison to the monoculture. The farmers could earn an income of Rs. 25,000 from a small area of 5m x 7m (Rs. 715/- per sq m, @ Rs. 200/- per plant)

The farmers owning existing Tamul Gardens are the prominent beneficiaries of this agroforestry practice. The entrepreneurs engaged in export of King Chili to meet the demand in International market are also the beneficiaries of this agroforestry technique.

The huge value and demand of the King Chili in national and international market has encouraged the farmers to cultivate in large scale the farmers were helpless to save the plants from the insect pest attacks and diseases in previous year. This year they have witnessed the positive biophysical interaction in terms of the 16 times better survival percentage under mangium plantation. Potential of this agroforestry practice has assured for its wide scope of extension. In view of the increasing market potential of the King Chili in national and international trade, the model has been identified as a viable one to address livelihood issues by generating additional income from the use of interspaces which was otherwise not being utilized.

The economics of the one of the most promising AF model is given below -

Table – 1: ECONOMICS OF AGROFORSTRY MODEL

Name of the Agroforestry Model: King chili- mangium - silvipastoral model

INPUT/OUTPUT ANALYSIS										
Year	Expenses/ha				Benefits/ha				Net Benefit/ha	Present Value @15%
	Tree	Crop (King Chilli - 7 months)	Cows - (40 Nos./ha)	Total	Tree	Crop (King Chilli - 7 months)	Cows (includes Milk and Cow dung - 5 months)	Total		
Year 1	23000	85000	0	108000	0	750000	0	750000	642000	558260.8696
Year 2	2000	75000	15000	92000	0	1125000	95000	1220000	1128000	852930.0567
Year 3	1000	75000	30000	106000	0	1125000	190000	1315000	1209000	794937.125
Year 4	1000	75000	30000	106000	0	1125000	190000	1315000	1209000	691249.6739
Year 5	1000	75000	30000	106000	0	1125000	190000	1315000	1209000	601086.673
Year 6	1000	75000	30000	106000	0	1125000	190000	1315000	1209000	522684.0635
Year 7	1000	75000	30000	106000	0	1125000	190000	1315000	1209000	454507.8813
Year 8	200000	75000	30000	305000	2500000	1125000	190000	3815000	3510000	1147425.226
				1035000				12360009	11325000	5623981.599

Assumptions

(Based on our existing Demo Model owned by the farmers in Assam)

Tree ***A. Mangium***

No. of trees per ha : 1100 (3mx3m)
Survival : 90 %
Income per tree in the 8th year : Rs. 2500
Expenses per tree : Rs. 200
Crop **: King Chilli (for 7 months every year)**
Yield per ha : 6000 plants x 1.5 kg 9000 kg
Survival : 60 %
Sale price per kg : Rs. 125 per kg
Expenses per ha : 25000 per year
Animal **(Cows) : for five months every year**
No. of cows – 40 : As per the carrying capacity
BC Ratio
Analysis Net Present Value at 15% Discount Factor

Participatory evaluation of AF Models

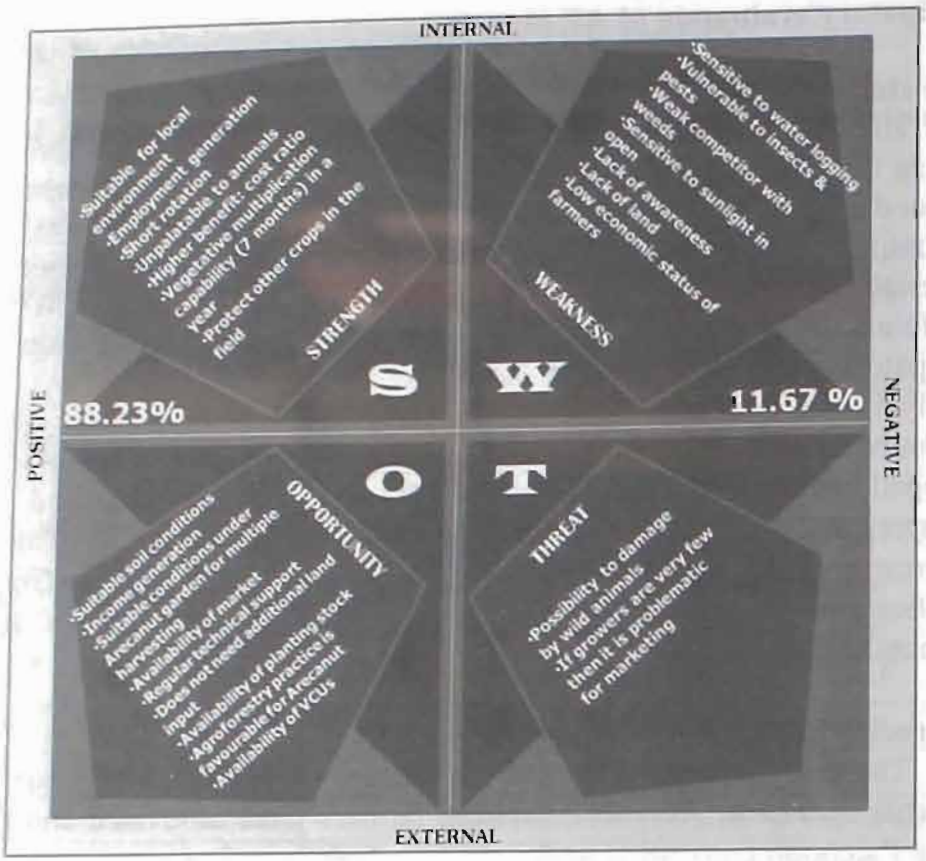
A case study –

The idea behind developing any agroforestry model after a series of trials is to optimize the land use, enhance productivity and improve management for sustainable livelihood of farming communities. However prior to their extension to the user groups; input-output, cost-benefits and other qualitative traits need to be quantified precisely so as to establish their adoptability and sustainability. In this regard, SWOT analysis has been found to be an effective decision making tool for agroforestry extension. A participatory method to analyze such models based on their SWOT followed by quantifying the qualitative data is the Analytic Hierarchy Process (AHP). AHP has been found to be aneffective decision making tool for agroforestry extension. The tool developed under field conditions has proved to be consistent and reliable by the developers and stakeholders as well. In view of that finding, the Patchouli-Arecanut agroforestry model was subjected to a SWOT analysis in *Meleng Grant* followed by quantification of qualitative traits through AHP to establish its adoptability and sustainability.

The process of participatory evaluation

The study was carried out in the villages Govindpur, Madhupur and Bhogpur of the Jorhat district in Assam. Inhabiting farmers were motivated and technical know-how on Patchouli cultivation under existing Arecanut plantations was extended through training programmes for establishing the demo-plots with farmers' participation. Farmers were supplied with planting material and were provided with the necessary technical support after receiving their assurance for land preparation and execution of various field activities at their level as per the prescribed schedule. In view of the great number of willing farmers, and the large area to be covered requiring much planting stock, two nurseries were established on the sites with participation of the local farmers. On-farm demonstration plots of Patchouli-Arecanut model were established in the three villages along with a display of *Activity Appraisal Sheets* prepared with the participation of the farmers. An *Activity Calendar* was also developed with input-output details and financial implications.

In the first phase, brainstorming sessions were organized to identify different attributes under the four aspects of SWOT explaining its purpose and refreshing details of Patchouli-Areanut agroforestry model to the participating farmers (see Fig. 1). Some new facts and experiences were also shared betweenthe farmers and the research team. After a detailed discussion on the pros and cons, the SWOT attributes as expressed by the participating farmers were listed under each of the four aspects on a white board to be visible to everybody. The atmosphere in this participatory approach was further improved by encouraging the farmersto express their views and to add a new attribute at any moment. The final the lists were confirmed after screening followed by combining the attributes having similar sense.



In the second phase of SWOT analysis, set of six combinations were made within the four aspects for their paired comparison. The attributes under the two aspects in a pair were read out loudly so that every participant can make a sense of their qualitative weights/influences. A diagrammatic scale graduated '0 to 10' either side from the centre, was drawn in between the two aspects. Farmers were given sufficient time to put their weight based on their assumptions or realizations of amount of influence of one aspect over another. The score assigned on 10-point scale against the aspects of their choice were circled keeping in view their influence on adoption of the agroforestry model. Forms were collected and the variables were processed for general average as 'mean value' for each and every pair. The mode values were arranged in a Reciprocal Matrix. The Reciprocal Matrix was converted into 'Normalized Matrix' to obtain the principal Eigen Vector i.e. sustainability vector for the particular AF model. The Principal Eigen Vectors of the two positive aspects viz. Strength and Opportunity were compared with negative aspects viz. Weakness and Threat to have an idea about the level of sustainability.

SWOT Analysis – as Decision Making Tool

During SWOT analysis, sore assigned on 10-point scale by the participating farmers against the all six paired combinations of the four aspects of SWOT are presented in Table -2. A diagrammatic scale graduated '0 to 10' either side from the centre, was drawn in between the two aspects.

Table-2: Analytic Hierarchie Process for SWOT of Patchouli-Arecanut Agroforestry Model

Farmer Code	S – W Scale	S – O Scale	S – T Scale	O – W Scale	W – T Scale	O – T Scale
PatchAF/001	8	2	7	8	2	9
PatchAF/002	7	2	7	8	1	8
PatchAF/003	7	1	6	9	2	9
PatchAF/...	---	---	---	---	---	---
PatchAF/025	6	3	7	7	1	6
Total	183	62	196	204	52	200
Mean Value	7.32	2.48	7.84	8.16	2.08	8.00
Reciprocal values	0.14	0.40	0.13	0.12	0.48	0.13

The mean values arranged in a Reciprocal Matrix were converted into 'Normalized Matrix' to obtain the principal Eigen Vector i.e. sustainability vector for the agroforestry model (Table-3).

Table 3: Traingular, Reciprocal and Normalized Matrix of SWOT Scores

TRAINGULAR MATRIX				
Criteria	**S**	**W**	**O**	**T**
S	1.00	7.32	0.40	7.84
W		1.00	0.12	2.08
O			1.00	8.00
T				1.00
Sum	3.74	16.96	1.65	18.92

RECIPROCAL MATRIX				
Criteria	**S**	**W**	**O**	**T**
S	1.00	7.32	0.40	7.84
W	0.14	1.00	0.12	2.08
O	2.48	8.16	1.00	8.00
T	0.13	0.48	0.13	1.00
Sum	3.74	16.96	1.65	18.92

NORMALIZED MATRIX					Sum	Adoptability Vector
S	0.266	0.432	0.243	0.414	1.354	33.86%
W	0.036	0.059	0.074	0.110	0.280	6.99%
O	0.664	0.481	0.607	0.423	2.175	54.38%
T	0.034	0.028	0.076	0.053	0.191	4.77%
Sum	1.000	1.000	1.000	1.000	4.000	100.0%

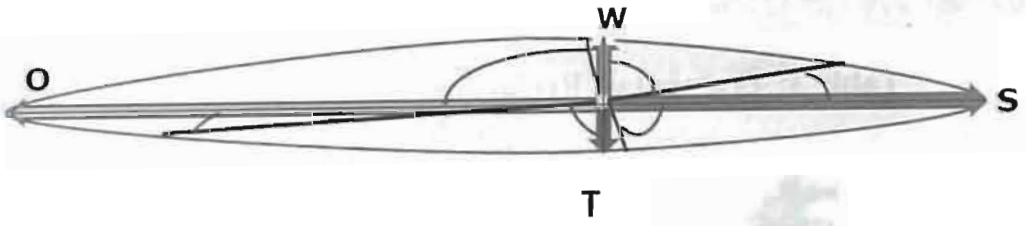
$\lambda max = 3.74(0.3393) + 16.96(0.0699) + 1.85(0.5430) + 18.92(0.0477) = 4.25592$

CI = (λmax –n) / (n – 1), where 'n' is the size of the comparison matrix.

CR = CI/RI, where RI (Random Consistency Index) is 0.9 for size 4 matrix (Saaty, 1980).

Lambda max	4.25592	where n = 4
Consistency index (CI)	8.53%	
Consistency ratio (CR)	9.48%	If < 10%, the subjective evaluation by the farmers is consistent

SWOT Profile of Arecanut – Patchouli AF Model



The above profile shows the score of Opportunities available for the practice is higher side followed by that of Strength in terms of suitability to the site-specific conditions as well as the local socio-cultural aspects, whereas the negative factors have insignificant effect over sustainability of the agroforestry model.

CONCLUSION

The case study conclude that the well researched Arecanut – Patchouli agroforestry model can be extended as a promising model in the forest fringe areas in India. The results of the analysis and participatory exercise have established the model as highly adoptable and sustainable for forest fringe challenged with the man-animal conflict..

Prospective impacts of Eco-development through Agroforestry

As witnessed from the RFRI – Demo Village Program, the agroforestry models have shown direct and indirect impact on the dependancies of the villagers over the Protected Areas. The official records belonging to the forest department reveal that the incedences of illicit felling of trees and poaching have reduced to 40 percent. The impact of awareness generation due to the countinuous visits and meetings has also to be accounted as a contribution towards the above reduction. The impact so far and the

expectations of the managers of the Protected area from the RFRI – Demo Village Program is attached as Annexures.

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Feedback from the forest officials of the Sanctuary collected recently gives a preliminary idea of the impact of Community Based Approaches:

- 50% reduction observed in forest related offences.
- Incidences of both illicit felling and poaching reduced by 40%.
- Unlike earlier, extending cooperation in WL protection
- Man - Elephant conflict still a challenge that is being worked upon.

However, trend shows improvement in social relationship with officials

After effects of Hollongapar Gibbon Wildlife Sanctuary after establishment of Madhupur-Gobindpur Demo Village, by the Rain Forest Research institute, Jorhat an organization of Govt. of India.

Sl. No.	Before establishment of the Demo Village	After establishment of the Demo Village
1	• Effects on Resource depending	
	1.1 The villagers used to collect firewood from the sanctuary to a great extent and naturally grown seedlings could not get establish in the bordering forest areas of the sanctuary in the northern boundary.	1.1 Collection of firewood has reduced considerably and naturally grown seedlings are coming-up profusely towards establishment of a regular forest.
	1.2 There were as many 39 households of the village involved in manufacturing charcoal by collecting woods from the sanctuary illegally.	1.2 Presently no villager has engaged in manufacturing charcoal due to the reason of having alternate source of income as provided in the Demo village.
2	• Environmental effects	
	2.1 The loss of timber, fuel wood, MFP etc. made degradation to the forest land to the extent of about 300 ha. of the sanctuary	2.1 Due to the reduction of dependency on the forest land the natural eco-restoration process has started and degradation of the forest land has checked.
	2.2. The eco class of the said 300 ha. of the forest land under the category of Eco Class I was turned open	2.2 The eco-class of the forest land is in the process of up-gradation and within 15-20 years it will regain the dense forest under the category of Eco Class-I.
3	• Effects on Wildlife Management	
	3.1 The sanctuary is the unique habitat for 7 primate species which are mostly arboreal in nature. Their distribution in the degraded areas were almost nil due to canopy gaps. This caused hinderness towards management of the endangered arboreal denizens of the sanctuary.	3.1 The reduction of resource dependency of the locals on the sanctuary and creation of the environment for the natural process of eco-restoration shall overcome the hinderness within 15-20 years.

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2.5.12

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Enhancing the Productivity of Poplar (*Populus deltoides* Bartr. Ex. Marsh) and wheat (*Triticum aestvium* L) in an Agrisilviculture system

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ABSTRACT:

Agroforestry is now being seen as an alternative paradigm for rural development worldwide that is centered on species-rich, low-input agricultural techniques including a diverse array of new indigenous tree crops, rather than on high-input monocultures with only a small set of staple food crops. This alternative paradigm addresses many of the global challenges highlighted by the UN millennium development goals and environmental conservation. These challenges are associated with deforestation, land degradation, unsustainable cropping practices, loss of biodiversity, increased risks of climate change and rising poverty, hunger and malnutrition. Almost all agroforestry systems are being practiced in the India, but in North West India the most common system being practiced is 'Agrisilviculture'. Poplar is one of the most popular amongst the species introduced recently. There are reports that poplar tree grows better under agroforestry conditions. There are also reports that poplar tree growth is effected by arable crop intercropping. However, information on the growth performance of poplar in pure form and under agroforestry systems as well as economic viability is still very limited. The crop growth of wheat and performance of its various genotypes under poplar is still very limited. The present paper will review the work done on the Agrisilviculture system having Poplar as tree and wheat as crop component and will suggest future strategies for research to enhance the Productivity of Poplar (*Populus deltoides* Bartr. Ex. Marsh) and wheat (*Triticum aestvium* L).

INTRODUCTION:

A major role for agroforestry is now emerging in the domain of environmental services such as biodiversity conservation, watershed protection, and carbon sequestration and mitigating climate change effects. The emerging challenges and opportunities call for a paradigm shift in the innovation driven agroforestry research to connect inventions as per the needs of its stakeholders. In the current scenario in which global warming and associated impacts have been established, the fundamental requirement far ensuring and improving livelihoods, is to identify the land-use options that increase resilience, adapt to environmental change and reduce vulnerability of existing production systems. Agroforestry integrates perennial woody plants, annual crops and animals together and provides livelihoods support through simultaneous production of food, fodder, firewood and timber. It also enhances the resilience of agriculture to climate change through micro-climate moderation and natural resources conservation in the short run as well as through carbon sequestration in the long run. Thus, the present challenges of food, nutrition, energy and environment security can be met through different agroforestry systems developed far various agro-climatic zones.

GROWTH OF POPLAR

GENOTYPES AND ENVIRONMENT:

Owing to their specific photo-periodic requirements exotic poplars have only a limited distribution in India. They have performed exceedingly well and have shown good growth in the areas lying north of approximately 28^0north latitude in the States of Jammu and Kashmir, Punjab, Haryana, Uttar Pradesh and Himachal Pradesh. Considering the importance of exotic poplar clones for their fast growth and ability to provide substantial production of wood on a short rotation, a major programme of introduction to select suitable species and their hybrids/clones/cultivates for varying agro climatic conditions in India was initiated at the Forest Research Institute (FRI), Dehradun as early as 1950. Various clones for different state of India have been recommended for J&K.(Jamwal 1979, Dutt and Jamwal1994), Himachal Pradesh (Khurana and Khosla 1978 Singh and Negi (1996), Punjab (Dhanda (1982), Sidhu (1996), Haryana (Singh(1982) , Dalal and Trigotra (1983), Toky *et al.*, (1996), Khanna *et al.*, (1996), in U.P including Uttrakhand (Karnatak *et al.*, (1994),Burfal *et al.*, 2001)

In India about 90 percent of the poplar plantations in India are based on clones G-48, D-121, S7C15 and G-3. This affects the genetic material and its inheritance of desired characters in subsequent generation. The yield of clone G-3, which once used to be the most popular clone, is declining due to attack by leaf blight disease.

GROWTH OF INTERCROPPED POPLAR:

Growing agriculture crops with Poplar is highly beneficial to the tree crop. Poplar growth enhances up to 40%, because of regular irrigation, weeding, hoeing and fertilizer application provided during cultivation of crops (Jha and Gupta 1991, FAO 1980).

TREE STAND MANAGEMENT:

SPACING

The classical silvicultural tradeoff, however, is maximizing individual tree growth or total system productivity, or compromising one for other. The nature of compromise will depend on the objective of Management. The management objective often is to optimize the combined production of trees and crop. In case of small farmer, in Poplar + Wheat agrisilviculture system optimum spacing of tree component is maintain to achieve minimum reduction in grain yield of wheat with optimum production of tree component. Mishra *et al.*, (2010) reported that total biomass varied from 48.5 to 62.2 m^2 ha-1 in 6-year old clones planted at 4 × 4 m spacing; it followed the order 65/27 > D121 > G48 > G3 > S7C1. Stem wood accounted for 60.4-68.9% of total biomass, followed by coarse roots (12.2-18.9%), branches (12.3-15%), leaves (3.02-6.9%) and fine roots (1.5-2.7%). Khan and Chaudhary 2007 reported that crown development has a linear relationship with tree spacing and increases with the increase in spacing. Wood production was higher under closer spacing of 3.7× 6.1m with a tree density of 455 trees/ha. While it was lower under wider spacing 3.7 × 12.1m. It was observed that wood volume contribution per tree was 31.4% more in lower density of 230 trees/ha. (3.7 × 12.1m.) as compared to higher density of 455 trees/ha. (3.7×6.1m) while the difference was only 9.6% under 305 trees/ha. Density (3.7 x 9.1m.),

indicating competition amongst trees for below ground resources (water and nutrients) at closer spacing. Misra *et al.*, (1996) reported that poplar clone D-61 grown with mixed cropping system under Tarai conditions of U.P. resulted in higher tree Height, DBH, MAI in 5 X 5 m and 5 x 3.75 m. Spacing in comparison to other treatments viz. 5 x 2.5 m, 5 x 1.25 m, 5x 1 m, 10 x 3.75 m (paired rows), 10 x 2.5 m (paired rows), 10 x 1 m.

INSECT PEST MANAGEMENT

Coyle *et al.*, (2002) *Chrysomela scripta* defoliator resulted in a 50 to73% loss of above-ground volume. Defoliation also resulted in increased lateral branching and forked terminals on unprotected trees. Natural resistance /susceptibility in Poplar clone against *Cloesta cupreata* (a defoliator) in northern India by Singh and Pandey 2002 and reported that 7 American clones were among the first 12 clones at the resistant end. American clone S7C4 seems to be more resistant to this insect. Development of control measures of insects can help to reduce damage. Spray of Carbaryl (0.3%) gives good protection against defoliaters in Punjab (Sangha, 1997).

NUTRIENTS MANAGEMENT:

Input of nutrients in agri-silviculture system takes place by precipitation (Imbach *et al.*, 1989 and Nelson *et al.*, 1982) fertilizers, litter fall and nutrient fixation. The contribution of N, P, K Ca and Mg through rainfall has been reported to be 10,1,4,6 and 2 kg/ha/year, respectively in 7 year poplars (Nelson, 1987). Vegetation cover may modify the properties of incident precipitation (Switzer *et al.*, 1988). Ralhan *et al.*, (1997) reported that maximum nutrient return (39.67 N, 8.19 P, 20.06 K and 24.88 Ca kg/ha was found under four year old plantation. Total leaf litter fall amounting to 3432.8, 3063.2, 4158.8 and 3530.8 kg/ha under 2, 3, 4 and 5 tear old plantation respectively. Across the plantations the release of NPK and Ca was higher under 5 year old plantation. Requirement and removal of nutrients by poplar and wheat have been reported by Nelson *et al.*,(1987).

EFFECT OF SOIL PROPERTIES:

Singh and Kukal (2005) concluded that the poplar growth on compacted soil (Sandy-Loam) was effected negatively due to its effect on moisture storage, total porosity and surface aggregation. The best growth of poplars was observed on soil with bulk density (1.5 g cm^3).

CROP PRODUCTIVITY:

WHEAT CROP

Studies on the performance of wheat in poplar revealed that as the plantation age increased wheat grain yield decreased gradually. Shade tolerance of the variety involved is yet another determinant of productivity of wheat under Poplar. Tolerant varieties are likely to maintain high productivity under increasing levels of canopy closure with age. Under four and six year old plantation, wheat yield was higher. This may be due to the fact that after third year, the poplar plants were subjected to heavy pruning allowing more infiltration of sunlight through canopy as well as the requirements of poplar after pruning might have reduced due to reduced biomass. Mishra *et al.*, ., 2010 reported reduction of grain and straw yield of wheat in different

clone's plantations was in order: S7C1 < G3 < D121< 65/27 < G48.. Grain yield of wheat was highest (3.66 t ha^{-1}) in sole crop and decreased by 15-30.3% under different clones at 4x4 m spacing. The straw yield also showed similar trend. The studies on the performance of wheat varieties in six year old poplar plantation (Singh *et al.*, 1993) reported that wheat variety HD-2329 produced maximum yield of 4.25 t ha^{-1} and it was significantly better than PBW-222 (3.79 t ha^{-1}). Wheat varieties PBW-34 produced the lowest grain yield of 2.02 t/ha and it recorded the maximum reduction in grain yield of 57 per cent as compared to open cultivation.

Pannu (1996) reported that wheat grown under poplar (clone G-48) spaced at 4.8×4.8m planted in February 1990. Highest grain yield in PBW 226 (2.02 t ha^{-1}) over different dates of sowing, although its grain yield was at par with WH-542, HD-2285, HD 2329, PBW-154 and PBW-299. Maximum grain yield (2.78 t ha^{-1}) was recorded when crop was sown on Nov. 3. Thereafter grain yield were considerably reduced by 23.71, 50.29 and 74.65% on November18, and Dec.3, respectively. Singh *et al.*, ., 2006 reported that the there were non significant effects on diameter and height growth of poplar up to one year age where was wheat crop was sown and irrigated after 50, 100 and 150 CPE interval. However effects were significant on wheat yield Maximum grain yield of wheat under poplar was produced with irrigation after 50mm CPE.

Kaur *et al.*, (2010) reported the 25% additional seed rate (125 kg/ha) over recommended to sole wheat significantly increased (6%) the grain yield of wheat under poplar(Clone G-48) plantation spacing of 5 x 4 m, at the age of 2, 3 and 4 years in 2004, 2005 and 2006, respectively. Among different fertilizer levels, grain yield of wheat was significantly higher (3.93 t/ha) at 50% additional N than recommended to sole wheat with recommended P i.e. at 187.5 kg N and 27 kg P/ha. N and P uptake by wheat was higher in sole wheat than under poplar. Additional application of seed and nutrients over the recommended levels significantly increased their uptake. Singh *et al.*, (1993) observed that increasing seed rate of wheat from 100 to 150 kg/ha increased grain and straw yields significantly which ultimately would have lead to higher uptake of nutrients at higher seed rate.

Similar trend was noticed with total uptake by grain and straw. Yadav *et al.*, (2005) reported lower removal of N and P by wheat grain and straw was observed under different tree species when compared with wheat in open conditions. Higher uptake of N, P and K by wheat in open condition than under 6 year old poplar has been observed by in Punjab.

ALLELOPATHY IN POPLAR & WHEAT AGRISILVICULTURE

Allelopathy is the inhibition effect of one biological system (in this case Poplar) on the growth of its under story (wheat crop). This is executed by release of allelo chemicals which are secondary metabolites (Rice 1984). Allelo Chemicals in poplar are reported to be maximum in leaves followed by buds, bank and stem (Kohli *et al.*, 1997, Narwal 1994). Tripathi *et al.*, 1996 reported reduction in germination in wheat and seedling growth. Tiwari 1993 reported leachates of leaf and root mainly contains glycoside (salicin, salicortin and tremnloidin) and Polyphenoles. Along poplar boundary plantation inhibitory affection wheat seed germination and seedling growth occurred upto 4m distance from Poplar tree line. (Chauhan *et al.*, 1995). The yield of wheat crop can be improved in 4 m strip running along boundary by managing this strip by giving extra irrigation and fertilizer and using higher seed rate.

CARBON SEQUESTRATION IN POPLAR PLANTATIONS:

Agroforestry for carbon sequestration is attractive (Mukundi and Sathye 2004). because : (i) it sequesters carbon in vegetation and in soils depending on the pre-conversion soil C, (ii) the more intensive use of the land for agricultural production reduces the need for slash-and-burn or shifting cultivation, (iii) the wood products produced under agro forestry serve as substitute for similar products unsustainably harvested from the natural forest, (iv) to the extent that agroforestry increases the income of farmers, it reduces the incentive for further extraction from the natural forest for income augmentation, and finally, (v) agroforestry practices may have dual mitigation benefits as fodder species with high nutritive value can help to intensify diets of methane-producing ruminants while they can also sequester carbon (Thornton and Herreren 2010). Rizvi *et al.*, 2011 reported that contribution of poplar plantations to carbon storage was found to be 27–32 t ha^{-1} in boundary system, whereas it was 66–83 t ha^{-1} in agrisilviculture system at a rotation period of 7 years. Poplar-based boundary and agrisilviculture systems account for 99–304 t ha^{-1} CO_2 assimilation at the rotation period of 7 years in the two districts. One advantage of these systems is that sequestration does not have to end at wood harvest. C storage can continue well beyond if tree stem or branches are converted into furniture, poles, hardboards, ply boards, etc. Agro forestry trees also improve land cover in agricultural fields, in addition to providing C input (root biomass, litter and pruning) to the soil. Thus, these plantations make important contribution towards carbon stock vis-à-vis atmospheric CO^2 assimilation, i.e. tapping of GHGs responsible for global warming. Elevated [CO^2] accelerated depletion of soil nutrients P, Ca, and K, and total soil carbon declined throughout the experiment. Enhancement of above and belowground biomass production by elevated [CO^2] accelerated carbon cycling through the coppiced system and did not sequester additional carbon in the soil (Gregbarron-gafford *et al.*, 2005).

Future strategies for research to enhance the productivity of poplar and wheat in agrisilvicultural system.

1. Characterization of *Populus deltoides* clones on the basis of Abaxial Stomatal density, for allelochemicals and on the basis of water use efficiency in different soils.
2. Development of New Clones through Hybridization and Creating variability in existing Clones through mutation breeding.
3. Standardizing Spacing for Maximum Biomass Production (Bio Energy) and Optimum Production for Timber .
4. Selection of naturally resisting clones against defoliators and other insects and development of control measures for insect pest in pure and agroforestry plantations.
5. Studies on nutrient budgeting, application of Manures, Fertilizers and irrigation etc. to increase the production levels of both grain and timber production.
6. Portion of the nutrients from one pool to another pool in Agrisilviculture system needs to be investigated.
7. Requirement of nutrients for poplar and wheat needs to investigate for different soil types.

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Importance of Biodiversity in relation to Homegarden Agroforestry of Tropics

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ABSTRACT

Homegarden agroforestry is one of the most prevalent types of landuse systems in the tropics. A homegarden represents the cultivated land close to the area that serves as a permanent or temporary residence. Since majority of the homegardens are less than a hectare in size, farmers opt for intensive cropping to optimise the yield. Though at a glance the arrangement of crops seems haphazard, a closer scrutiny would reveal that each ensemble occupies a specific niche. In tradition homegardens of Kerala State, the plant canopy area to land area ratio ranged from 210 to 888% indicating the optimum utilization of solar energy. In comparison with the evergreen and semi-evergreen forests located in a given region, floristic diversity in homegardens may be low. However, when sub-species and varieties of a given crop species are considered separately, species diversity values in the homegardens are often comparable to that in the natural forests. It is also revealed that homegardens are playing an insignificant role in conserving wild species diversity outside the protected areas but they represent a `genetic backstop', preserving species and varieties that are not economic in field production. In addition, homegarden agroforestry as an institution is often instrumental to link heterogeneous communities in the village ecosystem. However, during the last few decades, both number and size of homegardens are declining. The homegarden concept is also changing from mixed farming to cultivation of single or few commercially important species. An analysis of the impact of homegarden transformation on species diversity indicated that the plant diversity index values ranged from 1.02 to 2.97 with significantly ($P < 0.05$) greater value in mixed-species homegardens than in single-species dominant homegardens. About 65 - 83 % of total number of naturally growing species in mixed-species homegardens and 20 - 30 % in single species dominant homegardens are managed. The ratio between actual the potential use of species in each homegarden was calculated. The value for naturally growing species was significantly more ($P < 0.05$) in mixed-species homegardens than in single-species dominant homegardens. In this context, the knowledge base on the properties and potential uses of naturally growing species in homegardens needs to be strengthened for sustainable conservation and utilisation of biodiversity in tropical homegardens. In the present socio-economic context, within the existing framework of homesteads, management of homegardens into economically viable enterprise while still retaining features of biodiversity, ecological benefits, socio-cultural acceptance is needed. In the present paper, some of the government policies, institutional mechanisms, research inputs which are needed for promoting ecologically and socio-economically sustainable homestead farming systems are identified.

INTRODUCTION

Agroforestry is a collective name for landuse systems and practices where woody perennials are deliberately used on the same land management system as agricultural crops and/or animals, in a spatial or temporal sequence, there being both ecological and economic interaction between the components. In almost all tropical and subtropical ecozones agroforestry is represented by the homestead farming, essentially the mixed cropping of annual and perennial crops around the farmer's dwelling houses. For instance in Kerala, homestead farming covers about 88% of the total landholding and about 41% of the total cultivable area of the Kerala (KLUB, 1989), while it covers about 14% of the total area of the Sri Lanka (Senanayake et al., 2009). Depending on the nature, type of components, most homegardens in the tropics can be classified as agrosilvopastoral system consisting of herbaceous crops, woody perennials and animals. Some homegardens represent agrisilvicultural system consisting only of the first two components.

The average size of a homegarden in tropical and subtropical regions is much less a hectare (Fernandes and Nair, 1986; Nair and Sreedharan, 1986; Babu et *al.*, 1992; Kumar *et al.*, 1994; Sankar and Chandrashekara, 1997), indicating the subsistence of the practice. It may be mentioned here that very often such small sized landuse systems with monocropping are not viable, particularly in the rural ecosystems (Jose and Shanmugaratnam, 1993). Existence and the predominance of homegarden agroforestry since time immemorial in several tropical countries is the evidence to show that this system of landuse is an ecological and socio-economic adaptive system. Multi-tiered and multi-species structure is essentially the major feature identified for its socio-economic adaptability and stability, biological balance and resilience, and sustained productivity at a low-level equilibrium. Thus in this paper, an attempt has been to explain the linkages between homestead biodiversity and ecological and socio-economic strengths of the system, and also assess the potential of the system for ecodevelopment and rehabilitation of degraded forests.

SPECIES COMPOSITION AND DIVERSITY

The homegardens are glorious examples of species diversity in cultivated and managed plant communities (Kumar and Nair, 2004). Asahira and Yazawa (1981) reported a total of 200 kinds of useful plants including vegetables, especially various root vegetables, herbs, spices, fruit trees, fiber crops cultivated in a tropical Asian homegarden, approximately 0.25 acres in size. Over 170 species were recorded (Appendix 1) from an inventory made in randomly selected 228 homegardens in Kerala (Sankar and Chandrashekara, 2002). Inventory of plants in the live fences alone of 60 homegardens enabled to register 68 species (Chandrashekara *et al.*, 1997). Jose (1991) listed 179 species from 80 homegardens in a village in Kerala. These include 71 tree species, 6 perennial herbaceous crops, 23 annual crop species, 18 medicinal plant and 61 ornamental plants. During a survey conducted in a homestead of about 1ha in size in the Central agroclimatic zone of Kerala, 124 plant species were encountered of which 60 were tree species (Chandrashekara, 1995). All these observations indicate that the

homegardeners are perpetual 'experimentors' and constantly trying and testing new species (Ninez, 1987).

Tropical homegardens are important sites of high plant diversity and may act as reservoirs of crop germplasm (Coomes and Ban, 2004). However, the diversity index for homegardens of Kerala ranged from 0.251 to 0.739 suggesting that its floristic diversity is moderate to low compared to a value over 0.90 for the species-rich evergreen forests (KAU, 1994). However, sub-species and varieties of a given crop species are considered separately while measuring the species diversity, values in the homegardens often comparable to that in the evergreen and semi-evergreen forests located in the given agroclimatic zone (Chandrashekara,1995). The density-based Shannon-index of diversity may vary in response to the size of the homegardens with more value in large homegardens (1.119) followed by small (1.047) and medium (1.008) homegardens. This may be attributed to the fact that while the limited space forces people to accommodate many different species in relatively small plots, the large space provides the people to try to grow more number of species with an intention to optimize the crop yield and also obtain diverse variety of crops from large plots. Jose (1991) reported that small homegardens in a village in Southern Kerala compared to larger ones have high tree crop density. However, Sankar and Chandrashekara (2002) reported that the tree density and basal area in small homegardens may be lesser than those recorded in large size homegardens. They also concluded that homegarden crop diversity and density are determined by a wide range of putative factors, often as a product of ecological conditions, economic context, and specific need, taste, knowledge, ethnicity, culture and experience of the owner.

In general, in a homegarden, both cultivated and naturally growing plants can be seen; most of the naturally growing plants are not managed by the homegardeners. Very often, a given naturally growing species that is managed in one homegarden may not be managed in the other homegarden. Several factors are considered before managing or not managing a given naturally growing species. For instance, generally species which are sparsely distributed with poor density and biomass are not managed. On the other hand, farmers manage those species which adversely affect the growth and yield of major crops in the garden. Data collected on the management of naturally growing species in homegardens of Kerala (Chandrashekara and Baiju, 2010) has revealed that about 65% - 83% of total number of such species in mixed species homegardens and only 20%-30% in single species dominant homegardens are managed. In addition, about 44% to 77% of total number of naturally growing species is put under some uses.

According to Saikia *et al.* (2012) homegardens also serve to conserve rare and threatened species and varieties. However, inventory of floristic diversity in homegardens in Kerala revealed that generally homegardens are playing negligible role in conserving wild species diversity. On the other hand, homegardens are the informal experimental stations for transfer, trial and adaptation of domesticated species. Similarly, these homegardens represent a 'genetic backstop', preserving species and varieties that are not economic in field production and are planted in small scale for reasons of taste preference, tradition, or availability of planting materials. It may be worth to mention here that of the approximately 300 major vegetables favoured today

world over, 200 are produced in the homegardens, while only 20 are used in the field cultivation (Ninez, 1987). Such an analysis may also be extended specifically to other tropical homegardens in order to appreciate the importance of homegarden agroforestry in conserving and utilizing biodiversity.

STRUCTURE OF HOMEGARDENS

At first sight, homegardens seem to lack structure as trees, shrubs and herbaceous plants grow in a complex mixture without any clear pattern (Brierley, 1976). However, a closer look at the vegetation shows that plants do seem to be organized in different patterns or layers. Thus, he multi-species homegardens are also multi-layered one. For instance, five canopy strata have been identified in the homegardens of Kerala. The first layer lies within 2 m high from the ground and is constituted by vegetables, tuber crops, grasses and other herbaceous plants. The second and third layers (within 2m to 10m high from the ground) are almost continuous and overlapping each other. Some of the common constituents of these layers in Kerala homegardens are banana, nutmeg, papaya, mango, cocoa, young coconut palms and saplings of trees. The upper most canopy layer is formed by coconut palms, areca nut palms, teak, jack fruit tree, mahogany, and other tall trees at about 10m to 25m height. However the choice species is determined by the agroclimatic and farmers' socio-economic conditions. Analysis of area occupied by canopy cover of different constituents indicated that in tradition homegardens, which are not less than 40-45 yeear old, the crown to land ratio ranged from 210 to 888% (Sankar and Chandrashekara, 2002).

ROLE OF WOMEN IN HOMEGARDEN MANAGEMENT

Women play an important role in introducing many crops, particularly in the nearest surroundings of homegardens. However, in general men have an upper hand over women in decision making in terms of introduction of cash crops and perennial trees. The role of women in homegarden management depends on factors like their occupation, size of the homegardens, opportunities for off-farm jobs and socio-economic condition of the family. For instance, Sankar and Chandrashekara (2002) recorded that in about 60% of total number of small homegardens (<0.4 ha) women contribute significantly for the management of the system. They also reported that only in 22% and 12% respectively of total number of medium sized homegardens (0.41-0.12ha) and large homegardens (>1.2ha) the role of women in garden management is significant. In general, women contribute more labour to homestead farms than men. It is estimated that about 94% of the total female labour days was constituted by family labour (Jose, 1991). This 94% of the female labour (family labour) forms 41% of the total labour employed in the homestead farm in a year. Since this is unpaid labour, it is not given due value, and is not included in any statistics and thus become invisible. The emerging agricultural scenario and the trends in Kerala' cropping pattern - the drastic transition from subsistence to cash crop monocultures - would increasingly marginalize women. Women's work would become more burdensome and less socially valued (Dunkelman and Davidson, 1988). The marginalization process would be accelerated where there is a desperate and pervasive need for cash to meet family needs. If those

needs can only be supplied by the market, unpaid traditional roles would no longer evoke respect, thereby undercutting the authority of women (Huston, 1985).

CONTRIBUTION OF HOMEGARDEN BIODIVERSITY FOR THE ECONOMY

The homegardens seldom meet the entire basic-staple-food needs of the family. However, they are complementary to other crop lands. Thus homegardens are a component of the larger farming system of the household. Indeed, if the homegarden is the only land available to the household, food crops such as cassava will dominate the species composition of the garden (Kumar and Nair, 2004). It is estimated that about 50% of the total number of homegardens contribute less than 25% of the total income of the household (Sankar and Chandrashekara, 2002). On the other hand, about 32% and 20% of total number of homegardens studied contributed about 25% - 50% and > 50% of the household income respectively. However, the contribution of homegardens for the state economy of wood and bamboo is significant. For instance, according to Krishnankutty (1990) homesteads provide 74% to 84% of wood requirements in Kerala. Similarly the traditional homegardens constitute a principal source of bio-fuels for the rural households. For example 51% of the fuel-wood collected in various geographical regions are derived from homegardens (Shanavas and Kumar, 2003). Analysis of supply and demand of bamboo in Kerala State indicated that during the year 1993-94 the estimated demand for bamboo was 1,69,000 metric tons. Of the total supply of bamboo in State, homegardens contributed 63% and forests the remaining 37% (Krishnankutty, 1998). Homegardens of Kerala are also recognized as repositories of non-timber products such as medicinal and aromatic plants, ornamentals, gums, resins, chemical extractives and green leaf manure. It may also be mentioned here that very often yield of a crop in a given homegarden may be more than the requirement for home consumption, and the excess quantity may not be enough to sell in the market. In such a situation, farmers exchange their crops among themselves or offer to those who do not have such items. In some parts of Kerala, it was also recorded that homegardeners who are having bamboo clumps in their gardens cut branches of bamboo during the months of December and January and use the thorny branches to fence their crop lands. They also offer the bamboo branches to their relatives and friends for the same purpose. In addition, several crops of homegardens in Kerala are often instrumental to link heterogeneous communities in the village ecosystem. For instance, the bamboo weaving communities obtain suitable bamboo poles from the homegardens and weave items such as bamboo mats, baskets, fish nets etc. While some of these items are offered to those supplied the raw materials, rest will be sold by the weavers. Thus homestead bamboo, like many other crops is one element in a complex system of rural relationships where human beings are the main actors.

TRADITIONAL KNOWLEDGE AND PRACTICES FOR SUSTAINABLE MANAGEMENT OF CROP DIVERSITY

It is a known fact that many traditional communities in the tropical and subtropical countries have several traditional knowledge and practices to conserve natural ecosystems and associated biodiversity (Chandrashekara and Sankar, 1998;

Ramakrishnan *et al.*, 2000). Similarly, many farming communities have of such traditional knowledge and practices for managing crop diversity and using the bioresources sustainably. Homestead farming is not an exception to this. For instance, cultivation of bamboo as a crop component in homesteads of Kerala has the strong traditional ecological base. Certain traditional practices of homestead bamboo cultivation and their benefits to farmers (Chandrashekara, 1996) are listed below also explain the management of crop species diversity in the system.

Table 1. Traditional practices of homestead bamboo cultivation and their benefits to farmers (based on Chandrashekara, 1996)

Practice	Benefits
1. Cultivation of bamboo in a corner of homestead	Freedom of movement for gardener within the garden: more space available from other crops
2. Trenching around the bamboo clump	Restriction of horizontal spread of bamboo roots thereby reducing competition with other crops
3. Mounding of soil around clump	Stimulation of production of new culms
4. Detopping of culms	Reduction of shading to other crops; formation of longer axillary branches useful for fencing
5. Intercropping with shade tolerant, short duration crops	Less impact of bamboo on the yield of intercrops; crops can be harvested before the season of bamboo branch cutting so that risks of damage caused to the crops during the bamboo branch cutting process. These crops are also suitable for cultivation on raised beds, so reducing root competition with bamboo

Thus the traditional homegardens represent a typical example for agroforestry systems. This farming system no doubt is rich with inherent ecological, social, economic and cultural strengths. In this context, farming practices associated with homegardens could also be adopted in the joint efforts of the forest department and local communities leading to eco-development, ecosystem rehabilitation and ecosystem recovery. This is because, tree planting and associated activities alone as the rehabilitation efforts in degraded forests near tribal settlements could not solve the problems of tribals in the long run. On the other hand, once the multi-species, multi-crop and multi-tier systems like that of homestead farming are adopted, there is every chance to ensure food security of the local tribal community, uplift of their economic and social status and also improvement of ecosystem health. Similarly, homegardens can be regarded as the model in developing integrated social forestry. By utilizing the farmers' skills in managing and sustainable use of plant diversity, and by using ecologically, socially and culturally accepted species for planting, it is possible to make the social forestry programme more successful even in the difficult areas.

CONCLUSIONS

From the above discussions it is clear that the traditional homegardens are helping in conserving crop diversity, reducing the pressure on local natural forests by being a source of food, timber, fuel wood, fodder, medicinal plants etc. As already indicated crops derived from homegardens is one element in a complex system of rural relationships where human beings are the main actors. However, during the last few years, throughout the tropics, a shift in the multiple cropping patterns of homegardens towards mono-cropping has been observed. With radical changes in time preferences, there is a growing disinterest among farmers to deal with long gestation tree crops. There is a risk due to market instability and unresolved diseases like coconut wilt, quick wilt of pepper, phytophtora of arecanut etc. Vagaries of the monsoonal rain also have long-term ill-effects. In this context, ilt is also reasonable to expect the government's positive actions such as launching of agroforestry extension activities, education and training for farmers on agroforestry, and supply of quality plant propagules and technical know-how, for attaining farmers to diverse varieties of crops in their homesteads. It may also be pointed out here that our primary and secondary and even higher institutions of learning do not have curricula on homegarden agroforestry systems. Lack of solid research data to highlight the importance of crop combinations in homestead farming is another constraint in revitalisng traditional homegarden agroforestry practices. Auto-ecological and syn-ecological properties of plant components, particularly trees, plant-plant interactions, economics of homestead farming, resources management and utilization and other aspects are yet to be studied systematically. This is possible only when the stress is given for conducting research on homegardens at the same order of magnitude as that being given to control pests and diseases in cash crops and to breeding new varieties of rice.

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Appendix 1. List of plant species recorded in the homegardens of Kerala, India

Species	Family	Species	Family
Acacia auriculiformis	Fabaceae	*Eugenia malaccensis*	Myrtaceae
Acalypha hispida	Euphorbiaceae	*Euoodia lunu-ankenda*	Rutaceae
Achras sapota	Sapotaceae	*Euphorbia pulcherrima*	Euphorbiaceae
Adenanthera pavonina	Mimosaceae	*Ficus asperrima*	Moraceae
Aegle marmelos	Rutaceae	*Ficus elastica*	Moraceae
Ailanthus excelsa	Simarubaceae	*Flacourtia indica*	Flacourtiaceae
Albizzia lebbeck	Caesalpiniaceae	*Gardenia jasminoides*	Rubiaceae
Allamanda cathartica	Apocynaceae	*Glyricidia maculata*	Fabaceae
Alocasia sp.	Araceae	*Gomphrena globosa*	Amaranthaceae
Alstonia scholaris	Apocynaceae	*Hedychium coronarium*	Zingiberaceae
Alternanthera sessilis	Amarantaceae	*Hevea braziliensis*	Euphorbiaceae
Amaranthus sp.	Amarantaceae	*Hibiscus esculentus*	Malvaceae
Amorphophallus companulatus	Araceae	*Hibiscus mutabilis*	Malvaceae
Anacardium occidentale	Anacardiaceae	*Hibiscus rosa-sinensis*	Malvaceae
Ananas comosus	Bromeliaceae	*Hydranchea sp.*	Saxifragaceae
Annona reticulata	Anonaceae	*Impatiens balsamina*	Balsaminaceae
Anthocephalus chinensis	Rubiaceae	*Impatiens sultanii*	Balsaminaceae

Aporusa lindleyana	Euphorbiaceae	*Ipomoea batatas*	Convolvulaceae
Areca catechu	Arecaceae	*Ixora sp.*	Rubiaceae
Aristolochia indica	Aristlochiaceae	*Jasminum grandiflorum*	Oleaceae
Artocarpus heterophyllus	Moraceae	*Jasminum sambac*	Oleaceae
Artocarpus hirsutus	Moraceae	*Jatropha curcas*	Euphorbiaceae
Artocarpus incisa	Moraceae	*Lagenaria ciceraria*	Cucurbitaceae
Asclepias curassavica	Asclepiadaceae	*Lannea coromandelica*	Anacardiaceae
Asparagus recemosus	Liliaceae	*Lantana camara*	Verbenaceae
Aster sp.	Asteraceae	*Lawsonia alba*	Lythraceae
Averrohoa bilimbi	Oxalidaceae	*Leucaena leucocephala*	Mimosaceae
Azadirachta indica	Meliaceae	*Mirabilis jalapa*	Nyctaginaceae
Bauhinia retusa	Ceasalpiniaceae	*Momordica charantia*	Cucurbitaceae
Begonia sp.	Begoniaceae	*Morinda tinctoria*	Rubiaceae
Benincasa hispida	Cucurbitaceae	*Moringa oleifera*	Moringaceae
Bombax malabarica	Bombacaceae	*Morus alba*	Moraceae
Borassus flabellifer	Arecaeae	*Murraya konigiii*	Rutaceae
Bougainvillaea spectabilis	Nyctaginaceae	*Musa sp.*	Musaceae
Butea frondosa	Papilionaceae	*Mussaenda sp.*	Rubiaceae
Caesalpinia pulcherrima	Caesalpiniaceae	*Myristica fragrans*	Myristicaceae
Caladium sp.	Araceae	*Nerium odorum*	Apocynaceae
Calotropis gigantea	Asclepiadaceae	*Nyctanthes arbor-tristis*	Oleaceae
Cananga odorata	Anonaceae	*Nympaea stellata*	Nymphaeaceae
Canna indica	Cannaceae	*Ocimum sanctum*	Lamiaceae
Capsicum annum	Solanaceae	*Oroxylon indicum*	Bignoniaceae
Carallia brachaiata	Rhizophoraceae	*Pandanus sp.*	Pandanaceae
Careya arborea	Lecythidaceae	*Pedilanthus tithymaloides*	Euphorbiaceae
Carica papaya	Caricaceae	*Peristeria elata*	Orchidaceae
Caryota urens	Arecaceae	*Persea macrantha*	Lauraceae
Cassia fistula	Caesalpiniaceae	*Phyllanthus acidus*	Euphorbiaceae
Casuarina equisetifolia	Casuarinaceae	*Phyllanthus niruri*	Euphorbiaceae
Catharanthus roseus	Apocynaceae	*Piper betle*	Piperaceae
Celosia cristata	Amarantaceae	*Piper nigrum*	Piperaceae
Chrysanthemum	Asteraceae	*Plumeria alba*	Apocynaceae

coronarium			
Cinnamomum zeylanicum	Lauraceae	*Polyalthia longifolia*	Anonaceae
Citrus aurantium	Rutaceae	*Pongamia pinnata*	Fabaceae
Citrus grandis	Rutaceae	*Portulaca oleracea*	Portulacaceae
Citrus limon	Rutaceae	*Prichardia pacifica*	Arecaceae
Citrus madraspatna	Rutaceae	*Psidium guajava*	Myrtaceae
Coccinia indica	Cucurbitaceae	*Pterocarpus marsupium*	Papilionaceae
Cocos nucifera	Arecaceae	*Ricinus communis*	Euphorbiaceae
Codeum variegata	Euphorbiaceae	*Rosa indica*	Rosaceae
Coffea arabica	Rubiaceae	*Sacharum officinarum*	Poaceae
Coleus amboinicus	Lamiaceae	*Salvia farinacea*	Lamiaceae
Coleus aromaticus	Lamiaceae	*Sanseviera roxburghiana*	Liliaceae
Colocasia esculenta	Araceae	*Saraca indica*	Ceasalpiniaceae
Cordyline terminalis	Liliaceae	*Schumanianthus virgatus*	Marantaceae
Corypha umbraculifera	Arecaeae	*Sida rhombifolia*	Malvaceae
Crossandra undulaefolia	Acanthaceae	*Solanum indicum*	Solanaceae
Cucumis sativus	Cucurbitaceae	*Solanum mamosum*	Solanaceae
Cucurbita moschata	Cucurbitaceae	*Solanum melongena*	Solanaceae
Curcuma amada	Zingiberaceae	*Solanum torvum*	Solanaceae
Curcuma longa	Zingiberaceae	*Spondias mangifera*	Anacardiaceae
Cyclea peltata	Menispermaceae	*Swietenia mahogoni*	Meliaceae
Dahlia sp.	Asteraceae	*Syzygium aromaticum*	Myrtaceae
Dalbergia latifolia	Fabaceae	*Syzygium cumini*	Myrtaceae
Delonix regia	Caesalpiniaceae	*Tabernaemontana coronaria*	Apocynaceae
Desmodium gangeticum	Fabaceae	*Tagetus erecta*	Asteraceae
Diffenbechia sp.	Araceae	*Tamarindus indicas*	Caesalpiniaceae
Dillenia pentagyna	Dilleniaceae	*Tecoma stans*	Bignoniaceae
Dioscorea alata	Dioscoreaceae	*Tectona grandis*	Verbinaceae
Dracaena sp.	Liliaceae	*Terminalia catappa*	Combretaceae
Dracena sp.	Liliaceae	*Terminalia cremulata*	Combretaceae
Ecbolium linneanum	Acanthaceae	*Terminalia paniculata*	Combretaceae
Eclipta alba	Asteraceae	*Theobroma cacao*	Sterculiaceae

Eichhornia crassipes	Pontederiaceae	*Trichosanthus anguina*	Cucurbitaceae
Emblica officinalis	Euphorbiaceae	*Turnera* sp.	Turneraceae
Erythrina indica	Fabaceae	*Vanda roxburghii*	Orchidaceae
Euenia jambos	Myrtaceae	*Vernonia sp.*	Asteraceae
Zingiber officinale	Zingiberaceae	*Vigna ungiculata*	Papilionaceae
Zinnia elegans	Asteraceae	*Vitex negundo*	Verbenaceae

Economic, Nutritional and therapeutic significance and, technology of value added products from economically important underutilized fruits grown in remote, high altitude and forest areas

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ABSTRACT

India is blessed with rich genetic bio-diversity of non-conventional, under-utilised fruits and vegetables which grow in conformity with region-specific agro-climatic conditions. Many of these minor fruits, growing in remote, high altitude and forest areas, have excellent phyto-nutrient composition and are significantly rich in health promoting nutraceuticals. A large number of these minor fruit crops are traditionally used by tribal inhabitants, living in these inaccessible terrains, for their therapeutic and nutritional properties. In spite of their economically significant quality attributes, many of them have remained beyond the scope of domestication, human selection and organised farming. Value addition to minor and under-utilized fruit crops have received less priority in comparison with more established table varieties. With proper post-harvest management and value addition, some of these minor fruits do have the potential of securing the livelihoods of these tribals and poor farmers. Value added products from under-exploited horticultural crops have immense scope in providing food security, nutrition, health and economic sustainability to local tribes in these areas. Defence Food Research Laboratory (DFRL), Mysore has worked on many of these minor fruits, rich in nutraceutical components with the aim of developing suitable value added products from them, using appropriate processing technology, such as RTS health beverages, purees, nectars, spreads, minimally processed products, HT-stabilised products, restructured gelled analogues, etc. The minor fruits and plant extracts which have drawn DFRL's attention include Indain Noni (*Morinda citrifolia*), Gethi (*Dioscorea rumeunensis*), Palmyra fruit (*Borassus flabellifer* Linn.), Heitup (*Meyna spinosa*),seabucthorn (*Hypophae rhamnoides*) and plant extracts of Aloe vera (*Aloe barbedensis* Miller). Processed products developed from these minor fruits can be described as 'Functional food', as aside from variety and nutrition to human diets, they also provide a wide array of biologically active, non-nutritive functional ingredients, referred to as 'Phytochemicals', that impart health benefits beyond basic nutrition in being anti-diabetic, anti-inflammatory, anti-cancer, immuno-modulatory, gastro-protective, anti-microbial, etc. Such products have immense scope, both in domestic and overseas trade, in occupying the growing health-segment space of the 'Wellness' industry.

INTRODUCTION

India is a treasure trove of rich Bio-genetic diversity in terms of its flora and fauna. And, this stems from the country's diversity in ecology and agro-climatic zones. India as a whole has a rich heritage of many indigenous minor and under utilized fruits. Though a great deal is known about the virtues of minor, under-utilized fruits in India, their commercial cultivation has remained a far cry and very few have succeeded in acquiring the organised farming space. Horticultural crops, especially the minor fruits, play a vital role in crop diversification and eco-protection. Many of the minor fruits have special significance to human beings in serving as protective foods. Underutilized fruits are characterized by local importance in terms of their nutritional worth and a niche agro-climatic production system tolerating harsh and adverse ecological conditions. Unfortunately, the germplasm collection of minor and under-utilized fruit crops has received less priority compared to field fruit crops growing in farmer's orchards and peri-urban areas. The unorganised cultivation of many of these economically significant minor fruits ranges from humid tropics to the temperate mountains. Areas such as Ladakh, Northern Himalayan Mountains, the North-Eastern states and the deciduous forests of Western Ghats in India are endowed with and home to many phyto-nutrient rich and commercially unexploited. Underutilized or underexploited horticultural crops have immense potential in securing the livelihood of local tribal farmers besides contributing to food security, nutrition, health, ecosystem sustainability (by thwarting or halting adverse climatic changes and providing cultural identity). Usually, the tribal people's lifestyle and livelihood are intertwined with the flora in the vicinity of their abode. As inmates of nature, these tribals meet most of their needs including that of nutrition from vegetation in their surroundings. Ethnocentrically, tribals have used these minor fruits through ages to fulfil their need for therapeutic cure and as folk medicine. The therapeutic and medicinal properties of many of these minor fruits find mention in ancient Indian medical texts such as *Charak Samhita* and *Sushruth Samhita*. Apart from nutritional and medicinal value, many of these minor fruits are also known for their typical characteristic flavour and often attractive colour. However, in spite of these excellent attributes, conscious phase of domestication and human selection have somehow eluded them. Many have important novel, bio-active functional compounds, known as 'nutraceuticals', embedded in their matrix. These nutraceutical components or phyto-nutrients are known to impart health benefits beyond the call of basic nutrition. Value added products developed from some of these therapeutic- rich fruits and plant extracts are the subject matter of special attention in this paper. Fruits and plant extracts which are covered in this discourse include Indian Noni (*Morinda citrifolia)* fruit, Palmyra fruit (*Borassus flabellifer* Linn.), seabuckthorn (*Hypophae rhamnoids*), Heitup (*Meyna spinosa*), Gethi (*Dioscorea kumeuenesis*) and the phyto-nutrient rich gel from Aloe vera (*Aloe barbedensis* Miller). All these minor fruits including Aloe gel extract have immense scope in both domestic and international trade and, in occupying the growing health segment space of the 'wellness' industry. Lack of process amenability and sometimes their less than acceptable sensory attributes have restricted and impeded their usage from commercial standpoint in spite of their health fortifying richness in various polyphenolic nutraceutical components with well established anti-oxygenic properties. At times, it becomes imperative to use these minor fruits in conjunction with other

flavour-rich more conventional table varieties of fruits to develop value added products from them in order to overcome and circumvent their weakness in processability and sensory traits. Development of consumer acceptable value added products from such underutilized fruits does pose some challenges to any food technologist.

NONI AND VALUE ADDED PRODUCTS

The ripe Noni fruit is valued for its richness in many poly-phenolic, anti-oxygenic and novel nutraceutical components with anti-ageing and immune-enhancing properties. The Noni fruit is especially rich in proxeronine - a biological precursor for xeronine which is a polyphenolic alkaloid compound and reckoned as the basic building block of our immune system. Many clinical studies have established that sustained consumption of noni-derived products has the ability to fortify body's immunity and even help in the amelioration of immune compromised states such as HIV. However, Noni fruit on ripeness exudes a typical rancid butyric smell which many consumers sometimes find offensive and unacceptable. This typical butyric smell of Noni has hindered its ready usage in the development of value added products from this fruit (Alok Shah *et al.*,2011). Apart from the exceptional alkaloid compound xeronine and its biological precursor proxeronine, noni fruit and the juice derived from it are known to be rich in other phyto-nutrients like some antioxidants, anthraquinones, flavonoids, saponins and scopoletin (Nandhasri *et al.*,2005). The beneficial health effects of noni or noni juice are best derived when it is ingested on empty stomach as pepsin and other acids destroy the proenzyme 'proxeronine' that converts proxeronine into xeronine. Xeronine is best activated in the body when noni fruit or noni juice is taken without any intake of coffee, tobacco or alcohol as the latter are known to trigger release of bile acids in the body that can potentially destroy xeronine. Many vital proteins, that act as hormones, anti-bodies and enzymes, require xeronine for their functionality.

Owing to rather unpleasant taste and unacceptable odour, green or white noni fruit is seldom used for table consumption. Though mature fruit is edible, it is not very palatable. Traditionally, the usage of ripe noni fruit has been known to be limited among aboriginal societies in times of distress and famine. Polynesians provided noni fruit to American soldiers during World War II to sustain their combat strength in the battle field. In conjunction with other flavour and phyto-nutrient rich table fruits and plant saps like Alphanso mango, Giant Kew pineapple, strawberry, seabuckthorn, kiwi, raspberry, papaya, lemon, ginger extract and aloe gel. Many value added products have been developed from ripe noni fruit pulp like RTS noni – derived beverages in tetra packs and metallised thermo- stable pouches, noni puree, noni powder, fresh squeezed noni fruit juice, noni capsules, fermented noni fruit juice, etc. with suitable 21st – century food technology intervention protocols to suitably temper and moderate the otherwise unacceptable ripe noni odour (Alok Shah and Das Gupa, 2008).

VALUE ADDED PRODUCTS FROM PALMYRA

Palmyra palms or fruits though are rich in many nutritious components in terms of minerals, sugar, carotenoids, dietary fibre, etc., the presence of bitter saponins in Palmyra fruit pulp often comes in the way of their utilization. Naringinase-catalyzed enzymatic hydrolysis has been found to reduce bitterness in Palmyra fruit pulp and

increase its scope for value addition (Alok Shah *et al.*, 2011). Several value added products from ripe palyra fruit pulp have been developed at DFRL like Restructured palmyra fruit, palmyra fruit bar, RTS beverage, palmyra fruit spread, etc. Raw palmyra fruit kernel has also been utilised for the development of sweetened minimally processed palmyra fruit chunks and hurdle technology (HT) stabilized palmyra kernel slices (Vibhakara *et al.*, 2008). Hydrocolloid texturization of the palmyra fruit pulp was carried out with sodium alginate and bivalent calcium ions to develop restructured products from the palmyra fruit.

PROCESSED PRODUCTS FROM SEABUCKTHORN

Seabuckthorn is a Himalayan thorny shrub that grows at 8000 ft above sea level. It is yet another under-utilized neglected fruit with high nutritional and medicinal value. Seabuckthorn grows in abundance in the Ladakh region and the upper reaches of Himachal Pradesh where it is identified as a 'wonder fruit' because of its richness in vitamin A, E and K, a variety of essential fatty acids, organic acids and amino acids besides vitamin C (Vibhakara *et al.*, 2008). Because of its luxuriant growth in the high altitude areas of Ladakh, it is also popularly known as "Leh berry", with Leh being the capital of Ladakh district in J&K. High acidity of Leh berry fruits necessitates an optimal adjustment of the brix-acid ratio in order to improve the sensory characteristics of the products derived from these therapeutic rich minor fruits. The recent interest in Leh berry fruits is only about a decade old or so. The berries of seabuckthorn have potential of being processed into phyto-nutrient rich RTS beverages with other minor fruits, besides nectars and health tonics. These yellow berries have attracted considerable attention because of their therapeutic value and great economic potential. Suitable jams and jellies have also been prepared from seabuckthorn pulp by blending apple and pumpkin pulps at DFRL.

ALOE GEL PRODUCTS

The interest in value added products from Aloe vera also stems from its therapeutic and economic importance. Many enterprising farmers have taken to organised farming of Aloe vera in some part of their farming land to further supplement their agricultural income. Aloe gel, the plant extract or sap from Aloe vera is valued for its health restorative and protective properties. Aloe vera (*Aloe barbedensis* Miller) is a perennial succulent Xerophyte which is known to develop water storage tissue in its leaves to survive in dry areas of low or erratic rainfall such as desert regions. The innermost part of the Aloe leaf is a clear, soft, moist and slippery tissue that consists of large thin-walled parenchyma cells in which water is held as viscous mucilage and contains not only cell wall carbohydrates such as cellulose and hemi-cellulose but also storage carbohydrates like acetylated mannans. Aloe gel contains phenolic anthraquinones, carbohydrate polymers and various other inorganic and organic compounds. Many of the health benefits of aloe are attributed to the polysaccharides contained in the gel of the leaves which are medicinally implicated in wound healing, antifungal activity, hypoglycaemic or anti-diabetic effects, anti-inflammatory, anti-cancer, immuno-modulatory and gastro-protective properties. Care is taken in Aloe vera processing to avoid contamination of much valued internal fillet (gel) with yellow

sap contained in the basal part of the leaf since this yellow sap is known to contain bitter-toxic 'aloin' in its constitution (Alok Shah *et al.*, 2011). Many value added products can be derived from Aloe gel in conjunction with fruit juices and pulps from other flavour rich table varieties to answer the cry for niche 'wellness' products in the growing health segment market.

DEHYDRATED PRODUCTS FROM GETHI AND HEITUP

Gethi (*Dioscorea kumunensis*) and Heitup (*Meyna spinose*) are minor fruits grown in high altitude areas of Uttaranchal and North Eastern regions respectively. Both Gethi and Heitup are relatively hard fruits with good content of fibres. Gethi and Heitup are not known much for their nutritional richness in known major and minor nutrients and are mostly valued for their fibre and phyto-nutrient composition. DFRL has developed many dehydrated value added products from both Gethi and Heitup like variously convection dried Gethi chunks and fruit pieces and osmo-dehydrated Heitup fruit particulates. Cross flow cabinet drying, HTST convection drying in conjunction with fluidised bed heating and freeze - thaw dehydration were the techniques used for developing various dehydrated value added products from Gethi. Osmo-dehydratd Heitup fruit particulates were found to have very good sensory acceptance among subject hedonic panelists. Such value added products from these underutilised Gethi and Heitup fruits have immense scope in supplementing the agricultural income of high altitude farmers.

Health consciousness is increasingly finding its sway in well heeled and well endowed human societies the world over. The cry for newer value added health products from nutraceutical-rich, less exploited minor fruits and plant extracts, such as RTS beverages, purees, nectars, health tonics, fruit spreads, minimally processed products, hurdle technology products, restructured analogues, etc., have immense scope in securing the livelihood of local farmers and tribals growing them. As the scientific knowledge about their nutritional and therapeutic richness spreads wide across, the commercial significance of these minor fruits is only going to grow both nationally and internationally. And, this is bound to give a further fillip to their commercial organised cultivation and utilization.

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Eco-Restoration planning of land of Sodmal village of Dang district of Gujarat through Development of Agriculture and Agroforestry System

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ABSTRACT

The Dang district, commonly known as Cherapunji of Gujarat state, falls under South Gujarat heavy rainfall agro-climatic zone having average annual rainfall of about 2300 mm. Tribal farmers of Dang are quite unaware about appropriate utilization of land so as to improve their livelihood with simultaneous eco-restoration of their land for safe environment and ecological stability. So, a study was conducted under National Agricultural Innovation Project-III in operational village Sodmal situated at latitude and longitude of $20^0$51'40"N & $73^0$37'10"E encompassing hilly undulating terrain of Dang district of Gujarat with an objective for eco-restoration planning of land through development of agriculture and agro-forestry land use system. The village comes under hyperthermic temperature regime with a total geographical area of 193.4 ha, where as lands under cultivation, forest and pasture are 98.6, 84.4 and 10.3 ha, respectively at varying physiographical situation. Forests are mainly of deciduous (moist/dry) nature interspersed with scrub forest. Apart from Teak, Bamboo, Australian babul as the major forest species, other forest species *viz.*, saru, baval, gulmahor, raintree, spethodia, karanj, arjun sadad, subabul, jack fruit, mango, cashew, sapota, tamarind, aonla, ber are also found in scattered form in the forest zone of the village. Preliminary survey of the entire village as well as analysis of soil characteristics in relation to various crop production related constraints like, soil texture, soil depth, soil erosion, percent of coarse fragments, slope, moisture holding capacity, drainage, etc, were carried out to classify the land of the village under different land capability class and unit. The result revealed that the slope (%) of major soils ranges from 3 to 10 percent which comes down between 0 and 3 percent nearby to residential areas, while the same at hill top and at mid piedmont areas varies from 10 to 25 percent. It was observed that with increase in slope percent, soil erosion increased, which varies from sheet erosion (E1) to big gully erosion (E4) however, major soils come under Rill erosion (E2). Depth of major soil ranges between 0.22 to 0.45 m. However, depth < 0.075 m and > 0.90 m were also encountered. Generally, soils situated at lower elevation were of higher depth. The land of the entire village (including forest) were categorised under IIes to IIesw, IIIs, Ves, IIIes, VIes and VIIes sub-classes which were further classified to different capability units. Very gently sloping flat (< 2%) land and very gently sloping flat hill top (2 to 3%) were found marginally suitable (S3) for rainfed rice, finger millet and vari and moderately suitable (S2) particularly during *kharif* rainy season, for sorghum, pigeon pea and ground nut, vegetables like, cabbage, tomato, french bean, peas and cow pea and horticultural crops like, mango, custard apple, guava and cashew nut. Soil conservation measures like field bunding, soil-stone bunding for higher moisture conservation and reduction of soil erosion. Very gentle sloping (4 to 5%) land coming under IIIs sub-class were placed under marginally suitable (S3) for all the above field

crops whereby proper land conservation measures like field bunding, soil-stone or ston bunding is a must during *kharif* and moderately suitable (S2) for all horticultural plant as above with half-moon bunding around the plants to conserve more moisture Undulating moderately sloping terrace (9 to 10%) land coming under Ves sub-class wa considered non suitable (N1) for all arable crops and marginally suitable (S3) for al horticultural plants as above with development of half-moon bunding around the plant and soil-stone or stone bunding (7 to 10 m apart). Moderately to strongly sloping (14 t 16%) and strongly sloping (19 to 20%) land coming under VIes and VIIes sub-classe were non suitable (N1) for arable crops and should be grouped for development o Agroforestry, forest and pasture with incorporation of Teak, Subabul, Nilgiri, Khair Kalam, Karanj, Saru etc. after appropriate stone bunding across the slope to minimiz erosion and land slide and also for income generation and ecological stabilization a well.

Keywords: Eco-restoration, Planning, Sodmal village, Land capability, Agriculture Agroforestry system

INTRODUCTION

The Dang district, commonly known as Cherapunji of Gujarat state, falls unde South Gujarat heavy rainfall agro-climatic zone having average annual rainfall of abou 2300 mm. Even though the area receive good rainfall, owing to undulating topography and hilly terrain, major portions of rain water goes downstream and out of the zone a runoff water. Thus, on one hand during monsoon there is problem of management o excess of rain water and on the other hand after the ceasation of monsoon right fron December onwards there is acute scarcity of water for successful Agriculture Moreover, absence of storage mechanism and the decreased forest cover causing larg scale erosion of nutrient-rich top soil which flows with runoff water and gettin completely washed away. The traditional slash and cultivation practices also contribut to the erosion since there is little tree canopy to break the intensity of the heavy rainfall The surface soil contains large amount of gravels and rocks fragments. The major cro production related constraints are poor soil texture, shallow depth of soil, sloppy land low moisture retentive capacity, medium to poor soil fertility status and unawareness o modern technological know-how by the tribal farmers. Because of these decreased soi conditions and poor knowledge of the farmers, average yields of crop are poor and as result, socio-economic condition of the farmers is also poor. Thus, there is an enormou scope for proper planning of land in regard to eco-restoration through various lan conservation treatments along with development of agricultural field crop, horticultura and forest plant in accordance with the site suitability so as to improve overall yiel and ecological stability, Keeping the above points in view, a study was taken up a Sodmal village of Dang district for Eco-Restoration Planning of land through variou land conservation treatments along with Development of Agriculture and Agro-forestr System

MATERIALS and Methods

An Overview of Study Area:

Sodmal situated at latitude and longitude of 20°51'40"N & 73°37'10"I encompassing hilly undulating terrain of Dang district of Gujarat. The village come

under hyperthermic temperature regime with a total geographical area of 193.4 ha, where as lands under cultivation, forest and pasture are 98.6, 84.4 and 10.3 ha, respectively spreading at varying physiographical situation. Forests are mainly of deciduous (moist/dry) nature interspersed with scrub forest. Apart from Teak, Bamboo, Australian babul as the major forest species, other forest species *viz.*, saru, baval, gulmahor, raintree, spethodia, karanj, arjun sadad, subabul, jack fruit, mango, cashew, sapota, tamarind, aonla, ber are also found in scattered form in the forest zone of the village. More than 98% of the village population is tribal. The soils are residual type derived from the trappean basalts. These are stony in surface and severely eroded. Soils of the valley plains are somewhat deeper, they are medium in texture (gravelly silty clay), low in water holding capacity and non-calcareous with slightly acidic reaction, mixed in clay minerals, well drained and highly permeable. The major crops of the area are paddy, minor millets, tuber crops and pulses (black gram and *Dolichos*, etc.). The soils of the village developed at varying elevation and physiographic position can be considered as the catena soils where landscape is represented by 5 to 6 distinct geomorphic units namely hill top (cap)/flat hill top, escarpment, upper pedimont, mid pedimont, lower pedimont, and nearly flat land/valley soils.

Field Survey:

After collection of preliminary information on the topography, geology, climate and vegetation/crops, a field survey was undertaken through traversing with village cadastral map (1:3960) and also with a base map (1:16666) provided by BISAG, Gandhinagar. A traversing was done through out the village finalizing some road map to cover up the soils at varying physiographic position and elevation for fixing up soil legend like, surface texture range of soil, depth range, slope and erosion classes etc. Inclinometer/ Abney level was used to determine the slopes while, depth of soil was estimated by using different types of augurs. Further, altimeter was utilized in order to know the elevation of land during traversing. The field data recorded on surface texture range of soil depth, depth range, slope and erosion classes *etc* were digitized on the base map of the soil with the help of scientists of BISAG, Gandhinagar. Depending upon the physiographic position, slope, depth of soil, etc eco-restoration planning of land of the village was made with possible involvement of various land conservation treatments (stone bunding, soil+stone bunding, field bunding (by soil), and making outlet through wire waste, gully plugging, machinery foundation outlet (MFO) including Hydraulic Pump set for drawing water, etc) for reducing soil erosion as well as improving soil moisture and also through development of agricultural field crop, horticultural and forest plant in accordance with the site suitability so as to improve overall yield and ecological stability.Considering the limitations and potentials of the soils, land capability classification was evaluated up to capability unit level as per the procedure given by Klingebiel and Montgomery (1966). The severity of limitations were indicated by 1, 2, 3 and placed as land capability units (Dent and Young, 1981). General suitability of soils for growing different crops in the village currently in practices was evaluated based on the field and laboratory data (not reported in this study) of soils taking into consideration all plant growth related constraints using criteria given by FAO (1976).

RESULTS AND DISCUSSIONS:

The land use pattern of Sodmal village is described in table 1. The data related to distribution of soil with varying depth (cm), state and type of erosion and slope (%) of land at Sodmal village is indicated in table 2 which revealed that the area with soil depth d1 (<7.5 cm), d2 (7.5-22.5 cm), d3 (22.5-45 cm) and d4 (45-90 cm) under cultivated + degraded forest cover is 2.21, 108.07, 5.38 and 2.25 ha, respectively and those in forest land is 1.82, 53.06, 8.25 and 1.95 ha respectively. The maximum area (108.07 ha) under cultivated +degraded forest land was recorded with d2 (7.5-22.5 cm) ,while in forest land d2 (7.5-22.5 cm) was observed only in 1.82 ha. Soil depth d1 (<7.5 cm) was found to spread only in 2.21 ha under cultivated + degraded forest and 1.82 ha under forest land (table 2).

The area under soil erosion e1 (sheet erosion), e2 (Rill erosion), e3 (Small erosion) and e4 (Gully erosion) in cultivated + degraded forest cover is 9.06, 100.21, 8.20 and 0.44 ha, respectively and those in forest land 45.55, 13.01, 4.25 and 2.27 ha, respectively. Rill erosion (e2) was predominant (100.21 ha) under cultivated + degraded forest land while in forest land sheet erosion (e1) was found to cover major areas (45.55 ha). Thus it is clearly indicated that forest cover has pronounce effect on reducing the erosion extent (table 2).

The degree of soil slope under the categories of A= <1%, B=1-3%, C=3-5%, D=5-10%, E=10-15%, F=15-25%, G=25-35%, H=>35% in cultivated + degraded forest was observed 3.10, 5.75, 24.17, 63.20, 12.64, 5.62 and 3.43 ha, respectively and those in forest land was 0.10, 0.10, 1.30, 3.85, 19.52, 35.79 and 4.41 ha, respectively. However, the area covered under minimum slope (A <1%) was maximum (63.20 ha) in cultivated+degraded forest cover area which indicated their good suitability for field crop as well as horticultural crops having less constraints. The area coming under the slope of E, F, G are not suitable for field crops because of higher slope coupled with higher coarse/rocks fragments and shallow soil depth.

The land of the entire village was categorized under land capability classification as per the procedure given by Klingebiel and Montgomery (1966). It was observed that soils situated at lower elevation were of higher depth. The land of the entire village (including forest) belong to IIes to IIesw, IIIs, Ves, IIIes, VIes and VIIes sub-classes which were further classified to different capability units (table 3) for smaller and more homogenous group of soil that have similar use potential and management requirements.

The eco-restoration planning through different probable land conservation treatments *i.e.* SB (Stone Bunding), SSB (Soil + Stone Bunding), FB (Field Bunding by soil), WW (making outlet through wire waste), GP (Gully plugging), MFO (Masonry Foundation Outlet) including HP (Hydraulic Pump set for drawing water) was done for the Sodmal village (survey no. wise) based on soil slope, erosion and soil depth data and are presented in table: 3. The table revealed that even though the slope comes under the category A (<1%) the treatment slightly differ from place to place i.e. (1) FB, WW, field crops (2) FB, MFO, field crops, horticultural crops at border; (3) SSB, FB, MFO, field crops; (4) SSB, SB, MFO, field crops (5) SSB, FB, field crops, (6) SSB, MFO, field crops, field crops + horticultural crops. Similarly, the land comes under the category B (1-3%) slope differs slightly for land conservation as well as development of agriculture and agro forestry i.e. (1) FB, WW, field crops (2) FB, MFO, GS, field crops + horticulture plants at border (3) FB, field crops (3) SSB, FB, MFO, field crops

(4) SSB, WW, Field crops (5) SSB, MFO, well, field crops and horticulture crops at border. Likewise under C (3-5%) slope following treatments are planned (1) FB, MFO, WW; 2) FB, field crops and horticulture crops; 3) SSB, FB, MFO, field crops and horticulture crops; 4) SSB, FB, field crops and horticulture crops; 5) SSB, field crops and horticulture crops; 6) SSB, MFO, field crops and horticulture crops; 7) SSB, GP, field crops and horticulture crops and SSB, FB, WW, field crops and horticulture crops. Under D (5-10%) slope the treatments like, (1) FB, MFO, WW; (2) FB, Horticultural crops; (3) FB, MFO, GP, Horticultural crops; (4) SSB, FB, MFO, Horticultural crops; (5) SSB, SB, MFO, Horticultural crops; (6) SSB, FB, Horticultural crops; (7) SSB, Horticultural crops; (8) SSB, MFO, Horticultural crops; (9) SSB, MFO; (10) SSB, SB; (11) SSB, SB, FB, Horticultural crops; (12) SSB, FB, MFO, small check dam, Horticultural crops; (13) SSB, SB, Horticultural crops; (14) SSB, FB, MFO, Well, HP, Horticultural crops. The land coming under slope E, F, G i.e. with slope >10% are not at all suitable for aerable crop but suitable for development and/or intensification of forest spp. planting either in sole or in appropriate group form along with land conservation treatments under E (1) FB, Horticultural, Forest sp; (2) SSB, FB, Forest; (3) SSB, Forest; (4) SSB, MFO, Forest; (5) SSB, FB and (6) SSB, Well, Forest, under F treatments like, (1) SSB, FB, MFO, Forest spp.; (2) SSB, FB, Forest spp.; (3) SSB, SB, WW, Forest spp and under G Slope treatments (1) SSB, FB, MFO, Forest spp.; (2) SSB, FB, Forest spp.;(3) SSB, Forest spp. and SSB, FB, WW, Forest spp. (table 3)

For the entire village, for eco restoration of land the different types of land treatments along with their quantum/volume/length are presented in table 4. 1220 mt length of stone bunding, 19855 mt soil+stone bunding, 16800 mt Field Bunding (by soil), 14 no. outlet through wire waste, 4 no. Gully Plugging, 91 no. Masonry Foundation Outlet, 1 no. Hydraulic Pump set for drawing water are required to be developed as per planning for eco-restoration of land of the village. Based on the field and laboratory data (not reported in this study) of soils taking into consideration all plant growth related constraints using criteria given by FAO (1976), general suitability of soils for growing different field crops and/or horticultural crops and/or forest spp prevailing in the village was evaluated. Result revealed that very gently sloping flat (< 2%) land and very gently sloping flat hill top (2 to 3%) were found marginally suitable (S3) for field crop like rice, finger millet and vari and moderately suitable (S2) particularly during *kharif* rainy season, for sorghum, pigeon pea and ground nut, vegetables like, cabbage, tomato, french bean, peas and cow pea and horticultural crops like, mango, custard apple, guava and cashew nut along with the land conservation treatments referred under table 4.

Very gentle sloping (3 to 5%) land coming under IIIs sub-class were placed under marginally suitable (S3) for all the above field crops whereby proper land conservation measures as referred under table 4 is a must during *kharif* and moderately suitable (S2) for all horticultural plants as above with half-moon bunding around the plants to conserve more moisture. Undulating moderately sloping land (5 to 10%) coming under Ves sub-class was considered non suitable (N1) for all arable crops and marginally suitable (S3) for all horticultural plants with land conservation measures (7-10 mt apart) as referred in table 4. Here development of half-moon bunding around the horticultural plants would give additional benefits for moisture conservation. Moderately to strongly sloping (10 to 16%) suitable for horticultural plants as mentioned above along with land conservation measures referred in table 4. Strongly

sloping (16 to 20% and above) land coming under VIes and VIIes sub-classes were non suitable (N1) for arable crops at all and should be grouped for development of agroforestry and/or forest and pasture with incorporation of Teak, Subabul, Nilgiri, Khair, Kalam, Karanj, Saru etc. after appropriate land conservation measures as referred under table 4 across the slope to minimize erosion and land slide and also for future income generation and environmental stabilization as well.

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Table 1: Land use pattern of Sodmal Village

Details	Area (ha)
Total Geographical Area	193.4
Land under cultivation	98.6
Land under forest (including degraded + shrub)	84.4
Land under pasture	10.3

Table 2: Distribution of soil under varying depth (cm), erosion and slope (%) at Sodmal village

Soil depth (cm)	Area (ha)		Soil Erosion	Area (ha)		Soil Slope (%)	Area (ha)	
	Cultivated + degraded forest	Forest land		Cultivated + degraded forest	Forest land		Cultivated + degraded forest	Forest land
d1	2.21	1.82	e1	9.06	45.55	A	3.10	0.10
d2	108.07	53.06	e2	100.21	13.01	B	5.75	0.10
d3	5.38	8.25	e3	8.20	4.25	C	24.17	1.30
d4	2.25	1.95	e4	0.44	2.27	D	63.20	3.85
						E	12.64	19.52
						F	5.62	35.79
						G	3.43	4.41

*Cultivated area = 98.60 ha, Main forest area= 65.08 ha, Degraded forest/shrub area = 19.32 ha

d1	:	<7.5 cm	e1	:	Sheet erosion
d2	:	7.5-22.5 cm	e2	:	Rill erosion
d3	:	22.5-45.0 cm	e3	:	Small gully
d4	:	45-90 cm	e4	:	Big gully

A= <1%, B=1-3%, C=3-5%, D=5-10%, E=10-15%, F=15-25%, G=25-35%, H=>35%

Table 3: Land capability class, sub-class and units of Sodmal village

Land capability class	Land capability sub-class	Capability units
II	IIes and IIesw	IIes1s2, IIe2s3, IIe1s2w1, IIe2s3w1
III	IIIs	IIIs2, IIIs3
	IIIes	IIIe1s2, IIIe1s3, IIIe2s2, IIIe2s3
V	Ves	Ve1s2, Ve2s2, Ve3s2, Ve3s3
VI	VIes	VIe2s2, VIe2s3, VIe3s3

Subscirpts 'e', 'w', 's' and 'c' denote main limitations of the hazard of erosion, wetness or accumulation of water, limitations due to soil viz., shallowness, droughtness or stoniness or gravelliness of the soil and the chief limitation in the climate (too cold or too dry), respectively. Severity of limitations were indicated by 1, 2, 3.

Table 4: Eco-Restoration planning of land of Sodmal village of Dang district

Sr No.	Probable Treatments	Area (ha.)	Slope	Survey No.
1.	FB, WW, field crop	3.26	A and B	100,8,74/2
2.	FB, MFO, GS, field crop &Horticultural Plants	0.50	B	6
3.	FB, MFO, WW, field crop &Horticultural Plants	0.36	C, D	3,19/2
4.	FB, Horticultural Plants, Forest sp. Major (E)	15.96	B,C,D,E,	103,47,85,93,92/1,92/3,84,75,22,62,61,74,60,45,103,80,96
5.	FB, MFO, field crops, Horticulture Plants at border	0.57	A	98,98/4
6.	FB, MFO, GP,	0.32	D	102
7.	SSB, FB,MFO, horticulture crops major (D)	30.84	A,B,C,D,F,G	63,101,64,49,101,28,65,10,74,90,77,41,55,78,70,92,60,3,98/2
8.	SSB, SB,MFO, Horticultural crops major (D)	1.73	D	11

9.	SSB, FB, field crops (A, C) Horticultural Plants (D) Forest spp. (E, F, G) major	19.11	A,C,D,E,G,F	65,64,1,81,34,15,9,98,46,70,72,88,43/1,98
10.	SSB, WW, Field crops	0.30	B	91
11.	SSB, , Field crop, Horticulture crops at border (C, D) Forest (E, G) major	7.89	C,D,E,G	47,67,5,52,30,81,46
12.	SSB, MFO, Field crop (A), field+ Horticulture crops (C, D) Forest spp.(E)	11.50	A,C,D,E	89,82,73,33,103,4,101,91,99
13.	SSB, MFO, Horticulture crops	0.55	D	87,76,76
14.	SSB, MFO, GP, Horticulture crops (D) Forest spp. (E)	2.87	E,D	38,48,90
15.	SSB, GP, field+ Horticulture crops	1.34	C	36
16.	SSB, FB, MFO, GP, Horticulture crops	1.99	D	86
17.	SSB, SB, Horticulture crops	1.05	D	70,
18.	SSB, MFO, Well, Field crops, Horticulture crops at border	0.29	B	95
19.	SSB, SB, FB, Horticulture crops	0.30	D	98
20.	SSB, FB, MFO, Small Check-Dam, Horticulture crops	2.20	D	19
21.	SSB, FB, Forest spp.	1.05	E	54
22.	SSB, Well, Forest spp.	3.00	E	38
23.	SSB, FB, WW, field+ Horticulture crops (C), Forest spp. (G)	1.00	C,G	22,68
24.	SSB, SB, WW, Forest spp.	1.12	F	59
25.	SSB, SB, Horticulture crops	2.57	D	25
26.	SSB, FB, MFO, Well, HP, Horticulture crops	1.60	D	48

Table: 4 Details of treatments required for entire village for eco-restoration of land

Treatments details			Length or No. required
SB	:	Stone Bunding	1220 mt
SSB	:	Soil + Stone Bunding	19855 mt
FB	:	Field Bunding (by soil)	16800 mt
WW	:	Making outlet through wire waste	14 No.
GP	:	Gully Pluging	4 No.
MFO	:	Machinery Foundation Outlet	91 No.
HP	:	Hydraulic Pump set for drawing water	1 No.

Assessment of Agroforestry based two –tier-cropping system in Ambala district of Haryana

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ABSTRACT

In North-Western Indo-Gangetic plains (IGP), Poplar based horti-Agro-Forestry models have been adopted by the farmers. The farmers grow poplar due to its fast growing habit, short duration, compatibility with the different crops, eco-friendly and multi-purpose uses in different industries. Poplar is a deciduous tree and very suitable for horti- agro-forestry system. It has no shading effect on various crops rather adds to soil fertility through its leaf litter. Wheat, oat, sorghum, maize, sugarcane, berseem, turmeric, ginger and potato can easily be grown as inter crops. The results obtained during the course of rotation of six years study (from December 2000 to December 2006) revealed that yield of all the inter sown crops decreased appreciably after two to three years of poplar plantation but this yield loss often compensated by the sale of poplar wood at the end of the rotation.

The results of this six year study at KVK farm revealed that in case of poplar plantation the maximum girth size (29.73 inch) was obtained with T_1 (Poplar + Sugarcane) followed by T_2 (Poplar + Turmeric) where the girth size was 28.66 inch, and the minimum girth size (25.06 inch) was with T_5 (Poplar alone). Similarly the maximum timber wood (115.37 t/ha) was also obtained with T_1 followed by T_2 (100.46 t/ha) and the minimum timber wood (54.68 t/ha) was obtained with T_4 (Poplar + Rainfed Wheat/Lentil). Economic analysis showed that the highest net income (Rs.64,355 /ha/annum) was obtained with T_1 followed by T_2 (Rs.59,543 /ha/annum) and the lowest net income (Rs.18,719 /ha /annum) was obtained with T_4 followed by T_5 (Rs. 20188/- ha / annum), where as on the basis of cost of cultivation, the average net return from paddy-wheat rotation which is generally followed in this region was about Rs. 22970 /ha/annum during that period. Hence, the poplar based two-tier cropping system is more economical than the monocropping of agricultural crops and to be a very good alternative to paddy-wheat rotation in Indo-Gangetic plains.

Keywords:- Girth size, Timber wood, Net return

INTRODUCTION

In Indo-Gangetic plains of India comprising mostly North-Western states viz. Punjab, Haryana, Uttar Pradesh, Uttrakhand, lower part of Himachal Pradesh and Jammu and Kashmir, commercial cultivation of poplar (*Poplar deltoides* Bartr.) trees has been adopted by a number of farmers. In this region, sugarcane, turmeric, wheat, oilseeds (toria, mustard, gobhi sarson) or pulses (lentil, summer moong, gram and urd)

are conventionally grown by most of the farmers as a sole crop. However, because of minimum support price and better marketing facilities, the adoption of paddy-wheat cropping sequence is increasing rapidly and causing a lot of pressure on areas covered under these crops as well as on the forest plantation. Therefore, to save the forest and also to maximize the net returns from minimum piece of agricultural land by putting the land in best possible use, the time has come that we should extend the forests to agricultural land by demonstrating the appropriate Horti-Agro-Forestry based cropping models (Deb Roy 1990., Thind 2006).

All tree species cannot be grown in such a model called Horti-Agro-Forestry, comprising horti-agricultural crops plus forest tree species. The tree species selected for this purpose should fulfill some requirements viz. grow fast, grow straight, shed leaves during winter, have thin crown, have deep taproot system and not harbour the insect-pests and birds harmful for agricultural crops. Poplar is such a species, which fulfills many of these requirements.

The farmers grow poplar due to its fast growing habit, short duration, ease of regeneration, good market demand, compatibility with different crops, eco-friendly and multi-purpose uses in different industries. Poplar is a deciduous tree and much suitable even for horti-agro-forestry based multi-storey cropping system. Poplar plantations intercropped with agricultural crops have better growth than those without intercrops and growth of trees is variable under different intercrops. During initial stage, it has least effect on various crops rather adds to soil fertility through its leaf litter. Wheat, oat, sorghum, maize, sugarcane, berseem, turmeric, ginger or potato can easily be grown as an intercrop. However, at early age poplar cause less adverse effects on under forestry crops but at later stages reduces the crop stand due to more production of leaf litter. Kohli et al. (1997) also reported that allelopathic effect of poplar trees played a vital role in growth suppression of associated crops or under forestry vegetation.

Thus to make the poplar based two-tier-cropping system more remunerative in different regions, there is a need to select few most suitable intercrops having good demand in nearby market and also boost up the growth of poplar trees. Keeping this is view; a study was initiated to assess the performance of poplar plantation intercropped with different crops and to select the most remunerative intercrop for cultivation under poplar plantation during the six years of cropping period.

MATERIAL AND METHODS

The study was conducted at the demonstration farm of Krishi Vigyan Kendra, Ambala (vill.Tepla), Haryana for the six years cropping period of poplar plantation from December 2000 to December 2006. The farm is situated at $30^0 18' 20''$ N , $26^0 55' 46''$ and 265m above mean sea level. Annual rainfall during six years cropping period varied considerably and the maximum rainfall (1100 mm) was received in 2006-07, whereas, minimum rainfall (275 mm) was recorded in 2005-06.

The experimental soil (0-15cm depth) was sandy loam in texture, normal in pH level (7.8), normal in EC (0.21 ds/m) , low in organic carbon(0.34%) , low in available N (206 kg/ha) , medium in available P (P_2O_5 35 Kg /ha), medium in available K (K_2O 225 kg/ha) and rich in micronutrient (Zn 1.4 ppm , Fe 32.04 ppm and Mn 21.60 ppm) . Experiments were carried out by cultivating different crops in combination with popular block plantation (plot size 8x40m) for 6 successive years. For poplar plantation

(G-48 clone), plant to plant spacing of 4m was kept in both directions (i.e. east-west & north-south) to faciliate the movement of tractor in both directions for easy inter-culture operations and to maintain a sufficient tree population (600 trees/ha) for good returns and the poplar saplings were planted in the month of February 2001.

During first year of poplar plantation, all the recommended cultural practices, even gap-filling of dead saplings were carried out uniformly in all the plots as followed in sole poplar crop. In the next five years, the application of fertilizer doses at the increasing rate of 50 gm NPK in 2:1:1 ratio per year per tree and the pruning operations were adopted uniformly in all the plots. Thick and vertical branches competing with leader shoot or main stem were pruned during the leafless period in second, third and fourth years of planting.

The growth parameters viz. girth size, clear bole length and weight of timber wood of 10 selected trees, having good commercial value in each plot, were measured in December, 2006 and average values were calculated. Observations about number of survived trees up to harvesting stage in each plot were also recorded and converted into the survival percentage of poplar trees under different agro-forestry systems.

Girth at breast height (GBH) was measured by measuring tape at the height of near about 1.37 m from ground level just before the uprooting of the tree. The clear bole length, having commercial value (i.e. girth size>10 inch) was also measured with measuring tape just after the uprooting of tree. For collecting data on production of timber wood by poplar plantations, the timber wood logs obtained from 10 selected trees in each plot were weighed according to their girth sizes as well as commercial values in local market and the total timber wood production in each plot was calculated. Similarly, on the basis of commercial values of different girth size logs, the gross income from poplar plantation under different agro-forestry systems was calculated.

In this study five poplar based crop combinations (inter-crops) were assessed. In first combination (poplar + sugarcane), sugarcane crop (cv.CoS-767) was inter sown first time in February 2001 just after the transplanting of poplar saplings and subsequently two ratoon crops were also taken during the next two cropping seasons. During the fourth year (2004-05), sugarcane crop (cv. CoS-8436) was again planted after the preparatory tillage in the month of February and in the next cropping season (2005-06) ratoon crop was also obtained. So, during this course of six years rotation, five sugarcane crops were grown successfully by adopting general recommended practices as followed in sole sugarcane crop at KVK farm. In second combination (poplar + turmeric), first time the turmeric crop (cv. Rajapuri) was seeded in March, 2001 and in the next five years four more crops were grown. So, during the six years cropping period of poplar, total five turmeric crops were grown successfully by adopting general recommendations as followed in sole turmeric crop. In third combination (poplar + wheat/oilseed crops), first time wheat crop (cv. PBW-299) was sown in late November, 2000 before the plantation of poplar saplings and in the next year the same cultivar was grown . But in the year 2002-03, oilseed crop (toria cv.T-9) was followed by the late sown wheat crop (cv. PBW-373). During the next two rabi-cropping seasons, wheat (cv.PBW-373) and gobhi sarson (cv.GSL-2) crops were grown in 2004-05 & 2005-06, respectively. All these six crops were grown by adopting general recommended package of practices as followed in sole crops.

In fourth combination (poplar + rainfed wheat/lentil), first time rainfed wheat cultivar (PBW-396) was sown in late November,2000 and in the next two successive

years the same cultivar was grown with early November sowing. But in the next three Rabi-cropping seasons (year 2003-04, 2004-05 & 2005-06), instead of wheat, lentil crop (cv.Sapna) was grown with poplar plantation. However, in this combination, 2-3 irrigations were applied to wheat at critical stages of the crop, but no irrigation was applied to lentil crop.

In fifth combination (poplar alone), however, no crop was grown under Poplar plantation but most of the recommended cultural practices were carried out as usually followed in monoculture plantation of poplar trees. All necessary plant protection measures were also adopted uniformly for controlling disease and pest incidence in poplar as well as other inter sown crops during this period.

The net returns in respect of inter sown crops under poplar plantations were worked out on the basis of year wise input cost, labor cost, inter-culture operation cost, irrigation cost, harvesting cost and output prices in local market. Similarly, net returns from poplar plantations were calculated on the basis of cost of cultivation (year-wise) and market value of harvested timber wood.

RESULTS AND DISCUSSION

Poplar Growth Performance

The commercially important poplar growth parameters viz. girth size (GBH), Clear bole length (girth size > 10 inch), production of good quality timber trees (Nos./ha), survival percentage of timber trees up to harvesting stage and production of timber wood (t/ha) were significantly influenced by the cultivation of annual or seasonal crops during the six years of cropping period (Table-1).

The maximum girth size (29.73 inch), largest clear bole length (31.44 ft.) and highest production of quality timber wood (115.37 t/ha) were obtained with sugarcane cultivation (T_1) followed by turmeric cultivation (T_2) where girth size 28.66 inch, clear bole length 28.11 ft. and production of timber wood 110.46 t/ha were recorded. The minimum girth size (25.06 inch) was recorded with control (T_5), whereas, shortest clear bole (25.44 ft.) and the lowest production of timber wood (54.68 t/ha) was recorded with rainfed wheat/lentil cultivation. Data (Table 1) revealed that significantly more girth size, longer clear bole and higher timber wood production in poplar plantation were recorded with T_1 & T_2 as compared T_3, T_4 &T_5 (control). This can be attributed to the timely application of inter-culture operations, fertilization and irrigation in inter sown crop, which also coincided with the active growth period of poplar trees. Gill et al. (2008) also reported more girth size and higher plant height of poplar trees when inter-cropped with turmeric as compared to wheat crop.

Other growth parameters viz. production of good quality timber trees (no. /ha) as well as survival percentage of timber trees up to the harvesting stage were also significantly influenced by the cultivation of inter sown crops. However, these two parameters were also observed significantly higher in poplar sole crop (T_5) as compared to intercropped with wheat/oilseed crop (T_4) and rainfed wheat/lentil crop (T_5) and this can be attributed to the water stress conditions in these plots during the months of March, April and May which coincided with the flush of new leaves in poplar plantation.

Table 1: Commercially important Poplar growth parameters influenced by intercropping of Various Crops

Sr. No.	Treatment	Girth Size (inch)	Clear Bole Length (ft.)	Production of quality Timber Trees(Nos./ha)	Survival % age of Trees upto Harvesting stage	Production of Timber Wood (t/ha)
T_1	Poplar + Sugarcane	29.73	31.44	557	77.97 (92.86)*	115.37
T_2	Poplar + Turmeric	28.66	28.11	542	74.41 (90.33)	100.46
T_3	Poplar + Wheat/Oilseed Crops	25.60	26.55	486	64.26 (81.06)	71.21
T_4	Poplar + Rainfed Wheat/Lentil	25.33	25.44	445	59.28 (74.16)	54.68
T_5	Poplar alone (control)	25.06	25.88	548	76.01 (91.35)	67.07
	SEm±	0.22	0.15	14.64	5.76	2.23
	CD (P=0.05)	0.51	0.34	33.77	13.29	5.15

* Original values are given in parenthesis

Economics

The viability of any horti-agro-forestry system depends upon the economic feasibility and the best treatment or cropping system not fetching appropriate economic return as compared to paddy-wheat cropping sequence in this region may not be acceptable to the farmers. By keeping in view, the economic yield of poplar as well as inter-sown crops was converted into monetary terms. From the present study, it is apparent (Table 2) that inter cropping of poplar plantation with sugarcane (T_1) and turmeric (T_2) crops during the six years of cropping period was found highly economical and resulted in 2-3 times more net returns as compared to poplar sole crop (T_5) as well as intercropped with wheat/oilseeds/pulses (T_3 and T_4) on the *rabi* cropping seasons of this period. Further more, the highest net returns from poplar plantation was obtained with T_1 (poplar + sugarcane), whereas, the highest net return from other crops was obtained with T_2 (poplar + turmeric) during the course of six years cropping period. This may be attributed to more adverse effects of increased canopy size of trees on sugarcane as compared to turmeric when grown as intercrops during the second half cropping period of poplar plantation. Interestingly, the averages net return obtained with T_4 (poplar +rainfed wheat/lentil) was lower than T_5 (control). This might be due to comparative higher mortality in these plots resulted in production of less number of timber trees.

To find out the economic feasibility of these horti-agro-forestry based two-tier cropping systems, the average net return/ha/annum was also compared even with paddy-wheat cropping sequence as commonly followed in this region. During this period, the average net return from paddy-wheat cropping sequence was obtained Rs. 22970/ha/annum at KVK farm.

TABLE 2: Economics of two tier-cropping systems based on poplar plantation and intercropped with various crops for six years

Sr. No.	Treatment	Gross return from poplar (Rs./ha)	Cost of cultivation of poplar (Rs./ha)	Net return from poplar (Rs./ha)	Net return from other crops (Rs./ha)	Total net return in six years (Rs./ha)	Average net return /ha/annum
T_1	Poplar + Sugarcane	376464	24600	351864	34264	386128	64355
T_2	Poplar + Turmeric	278760	24600	254160	103100	357260	59543
T_3	Poplar + Wheat/Oilseed Crops	203184	24600	200784	16781	217565	36261
T_4	Poplar + Rainfed Wheat/Lentil	118800	24600	94200	18116	112316	18719
T_5	Poplar alone(control)	145728	24600	121128	Nil	121128	20188
T_0	Paddy + Wheat cropping sequence*	--	--	--	--	137820	22970

* Average net return from Paddy-wheat cropping sequence at KVK farm is depicted just to compare the economic feasibility of two-tier-cropping systems.

Note :- Gross returns from poplar block plantations were calculated on the basis of local market price of timber wood for that financial year (2005-06) :

Over-size (>24" girth size) : Rs.3800/ t
Under size(18-24" girth size) : Rs.2600/t
SOKHTA (10-18"girth size) : Rs.1900/t

Conclusively, it has been established from the study that poplar, sugarcane and turmeric based two-tier cropping system is highly remunerative and more economical than the mono cropping of poplar as well as other horti-agricultural crops and to be a very good alternative to paddy-wheat rotation in Indo-Gangetic-Plains (IGP).

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Effect of Different Pruning Intensities on Wood Production and Yield of Late Sown Wheat Varieties under *D. sissoo* based Agrisilviculture system of Agroforestry

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ABSTRACT

Field experiment was conducted during rabi season of 2010-2011 under AICRP on Agroforestry, Depatment of Forestry, JNKVV Jabalpur (M.P.). *Dalbargia sissoo* was planted in 5 x 5 m spacing in the year 1988. The treatment combination involved in main plot were four pruning treatments (viz. no pruning, 25% pruning, 50% pruning and 75% pruning) and one open (without tree) in main plot and three late sown wheat varieties (viz. M.P.-3020; GW 273 and GW 366) in sub plot. The experiment was laid out in strip plot design with four replications. The soil of the experimental area was medium black. Clay sandy loam with pH 6.0 (acidic), high in organic matter (0.81), medium in available nitrogen (288.1 kg ha^{-1}), high in available phosphorus (20.38 kg ha^{-1}) and low in available potash (170 kg ha^{-1}). In inter cropping with D. sissoo three late sown wheat varieties were sown in 20 cm row spacing fertilized with recommended dose of fertilizer i.e. 100:60:40 N:P:K kg ha^{-1}.The result revealed that crop under Open condition recorded significantly higher plant height (77.26 cm), number of effective tiller/MRL (50.53), length of ear head (9.04 cm), number of grains/ear head (41.46) and 1000 grains weight as compared to no pruning which recorded significantly lowest plant height (72.2 cm), number of tillers/MRL(39.86), length of ear head (8.22 cm), number of grains/ear head and 1000 grain weight (27.68 grm). Grain yield open condition (without tree) recorded significantly higher grain yield (1892 kg ha^{-1}) at par with 75% pruning (1700 kg ha^{-1}), 50% pruning (1658 kg ha^{-1}) and 25% pruning (1633 kg ha^{-1}) but significantly superior to no pruning (Rs. 1209 ha^{-1}). The percent reduction in grain yield under no pruning 25% pruning, 50% pruning and 75% pruning over open condition was 36.1, 13.7, 10.9 and 10.1 respectively. Grain yield of wheat was significantly influenced by different varieties. Wheat variety GW-273 recorded significantly higher grain yield (1778 kg ha^{-1}) closely followed by MP-3020 (1617 kg ha^{-1}) and superior to variety GW-266 which recorded significantly lowest grain yield of 1483 kg ha^{-1}. Variety MP-3020 was at par with GW-273. The percent reduction in grain yield in GW-366 and MP-3020 over GW-273 was 16.7 and 9.0 percent respectively. Agrisilviculture system gave significantly higher monetary return (Rs. 29003 ha^{-1}) than growing of crop alone (Rs. 14317 ha^{-1}) or tree alone (Rs. 14531). Managed agroforestry system, wheat+ D. sissoo in 25% pruning gave higher monetary returns (Rs. 33,580 ha^{-1}) at par with 50% and no pruning but significantly superior to 75% pruning (Rs.23332 ha-1) crop alone and tree alone. Among varieties GW-273 recorded high monetary return (Rs.27,927 ha^{-1}) at-par with MP 3020(Rs 26,870 ha-1) but significantly superior to GW-366 (Rs. 23,400 ha^{-1})

Keyword:- Agroforestry, Agrisilviculture system, *Dalbergia sissoo*, Monitory return, Pruning

INTRODUCTION

It is the general apprehension of the farmers that trees in association with crops in agroforestry will compete strongly with crops for light, nutrient and moisture (Dhyani *et al.* 1990). This competition between trees and crops increased with increasing age of trees due to increase in canopy (due to shade). Reduction in yield due to tree shade may reduce by manipulation in tree canopy. There are number of Silvicultural operations which can reduce tree canopy, facilitate entry of sunlight, pruning of tree, maximize the production of the desired products through minimizing competition, for growth resources among the tree crop component. Pruning increases the flexibility of agroforestry system, and enables farmers to balance their individuals needs for tree crop products. Prunings provide woody biomass for fire, wood, leaf biomass and fodder. In pruning, the removal of some part of the tree or the crown will obviously reduce the competition ability of tree because crown management will facilitate more light to underneath crops and reduce demand of moisture and nutrients. There are a number of wheat varieties which perform good in open field but their performance with the trees is not known. Hence it is very necessary to find out the suitable paddy varieties which can be preferred better in Agrisilviculture system too. Keeping above facts in mind the present study is proposed.

Material and Methods

Site description

The field experiment was conducted at Dusty acre area, under AICRP on Agroforestry project, Department of Forestry Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.). Jabalpur is situated at 23'3'' North Latitude and 79.5^0 East longitude with an attitude of 411.78 meters above the mean sea level. It comes under the agro-climate region classified as Kymore Plateau and Satpura Hills and is broadly known as Rice-Wheat crop zone of Madhya Pradesh. The climate of the region is semi and with hot dry summer and cold dry winter. The mean annual rainfall of Jabalpur is 1250 to 1400 mm, received from mid-June to September with occasional rains during the winter. May and June are the hottest month where as December and January is the coldest. The total rainfall of 1629.5 mm with 51 rainy days was received during the year (2010-2011) of the experimentation. Out of which 1531.9 mm (94.05%) rainfall was recorded in 4 months (June 10 to Sept. 11). Though there was normal rainfall but the distribution of rainfall was abnormal. The average maximum (41.5 °C) and minimum temperature (6.0°C) were recorded in May 10 and Jan 2011, respectively. The highest mean value of relative humidity (91%) was recorded in Nov. 2010 whereas lowest mean value (10%) was in April 2010. The maximum wind velocity (8.0 km/hrs) was observed in the month of June 10 and minimum (3.0 km/hrs) in the month of January 2011.

Experimental details

Field experiment was conducted during rabi season of 2010-2011 under AICRP on Agroforestry, Department of Forestry, JNKVV Jabalpur (M.P.). *Dalbargia sissoo* was planted in 5 x 5 m spacing in the year 1988. The treatment combination involved in main plot were four pruning treatments (viz. no pruning, 25% pruning, 50% pruning

and 75% pruning) and one open (without tree) in main plot and three late sown wheat varieties (viz. M.P.-3020; GW 273 and GW 366) in sub plot. The experiment was laid out in strip plot design with four replications. The soil of the experimental area was medium black. Clay sandy loam with pH 6.0 (acidic), high in organic matter (0.81), medium in available nitrogen (288.1 kg ha^{-1}), high in available phosphorus (20.38 kg ha^{-1}) and low in available potash (170 kg ha^{-1}). In inter cropping with *D. sissoo*, three late sown wheat varieties were sown in 20 cm row spacing fertilized with recommended dose of fertilizer i.e. 100:60:40 N:P:K kg ha^{-1}.

The source of nitrogen phosphorus and potash were urea, single super phosphate and murate of potash. Nitrogen was given in two times ie. half amount at the time of sowing as basal and remaining half one month after sowing as top dressing. The growth observations viz. plant height, numbers of effective tiller per meter, length of ear head, number of grains per year-head, thousand grain weight and grain yield were recorded at the time of harvesting. Before sowing of crop, pruning operation in tree were done as per treatment, and tree growth characters viz tree height, diameter at breast height, canopy spread in both N-S and E-W direction, pruned biomass. Cylindrical volume, stand biomass and economics were workout. All the parameters of crop and tree were analysed statistically using analysis of variance for strip plot design. The significance was tested for all the parameters at 0.05% level.

Table- 1: Effect of different pruning intensities and late sown wheat varieties on yield attributes and yields of crop under Agrisilviculture system

Treatment	Plat height (cms)	No of effective tillers/MRL	Length of ear head (cm)	No of grains/ earhead	1000 grain height (gms)	Grain yield (kg/ha^{-1})	% reduction in yield
Pruning intensities							
P_0 = No pruning	72.2	39.86	8.22	34.8	27.68	1209	36.09
P_{25} = 25% pruning	73.5	41.6	8.44	36.88	28.15	1633	13.6
P_{50} = 50% pruning	75.73	43.33	8.62	38.06	29.41	1685	10.9
P_{75} = 75% pruning	76.2	46.46	8.78	39.4	30.72	1700	11
Open condition	77.26	50.53	9.04	41.46	31.73	1892	-
SEM ±	1.02	2.21	0.17	0.55	0.35	108	
CD at 0.05%	3.08	6.67	0.51	1.66	1.05	326	
Wheat varieties							
V_1 = MP-3020	76.12	44.96	9.3	39.32	24.14	1617	
V_2 = GW-273	75.08	44.32	9.26	41.44	24.36	1778	
V_3 = GW-366	73.76	43.8	7.3	33.6	40.07	1483	
SEM ±	0.94	1.22	0.15	0.41	0.15	87.4	
CD at 0.05%	NS	NS	0.42	1.17	0.42	249	

Result

Pruning intensities

Yield attributing characters

All the yield attributing character of wheat crop viz; plant height, number of tiller/MRL, length of ear head, number of grains/ear head and 1000 grains weight were

significantly effected by different pruning intensities. Open condition recorded significantly higher plant height (77.26 cm), number of effective tiller/MRL (50.53), length of ear head (9.04 cm), number of grains/ear head (41.46) and 1000 grains weight as compared to no pruning which recorded significantly lowest plant height (72.2 cm), number of tillers/MRL(39.86), length of ear head (8.22 cm), number of grains/ear head and 1000 grain weight (27.68 grm).Among different pruning intensities, 75% pruning recorded significantly taller plant (76.2 cm) at par with other pruning treatments but significantly superior to no pruning. Similar trend was found in number of effective tillers/MRL.In length of earhead, 75% pruning recorded significantly longest ear head (8.75cm) closely fallowed by 50% (8.62) and 25% (8.44 cm) but significantly superior to no pruning (8.22 cm). Among different pruning intensities, significantly higher number of grains/ear head was recorded in 75% pruning (39.4) at par with 50% (38.06) and 25% pruning (36.86) but significantly superior to no pruning (34.8). 75% pruning recorded significantly higher test weight (30.72 gm) closely fallowed by 50% pruning (29.4) but significantly superior to 25% and no pruning (27.68) which were at par.

Grain yield

Grain yield of wheat was significantly effected by different pruning intensities open condition recorded significantly higher grain yield (1892 kg ha^{-1}) at par with 75% pruning (1700 kg ha^{-1}), 50% pruning (1658 kg ha^{-1}) and 25% pruning (1633 kg ha^{-1}) but significantly superior to no pruning (Rs. 1209 ha^{-1}). The percent reduction in grain yield under no pruning 25% pruning, 50% pruning and 75% pruning over open condition was 36.1, 13.7, 10.9 and 10.1 respectively.

Wheat Varieties

Yield attributing characters

Different wheat varieties sown under late sown condition, showed no significantly effect of plant height and number of tillers/MRL. Varieties revealed significantly effect on length of earhead. Variety MP-3020 recorded significantly longer ear length (9.3m) closely fallowed by GW-273 but significantly superior to GW-266 (7.3 cm). Significantly higher number of grains/ear head was recorded in variety GW-273 and was significantly superior to MP-3020 (39.32 cm). Variety GW-366 recorded the lowest number of grains per head (34.8 cm). Wheat variety GW-366 recorded significantly higher test weight (40.07) and was significantly superior to variety GW-273 (24.36grm) and MP-3020 (24.14 gm) which were at par.

Grain Yield

Grain yield of wheat was significantly influenced by different varieties. Wheat variety GW-273 recorded significantly higher grain yield (1778 kg ha^{-1}) closely followed by MP-3020 (1617 kg ha^{-1}) and superior to variety GW-366 which recorded significantly lowest grain yield of 1483 kg ha^{-1}. Variety MP-3020 was at par with GW-273. The percent reduction in grain yield in GW-266 and MP-3020 over GW-273 was 16.7 and 9.0 percent respectively.

Morphological growth characters of tree

Pruning intensity

Tree height of D. Sissoo was not significantly influenced by different pruning intensities; however pruning intensity showed significant effect on dbh, canopy spread, pruned biomass (kg ha^{-1}), cylindrical volume (m^3 ha^{-1}), Stand biomass (kg ha^{-1}) As the pruning intensity increased, dbh, canopy spread (N-S) & (E-W) direction, , cylindrical volume, and stand biomass increased significantly. Hence, 25% pruning recorded significantly higher dbh (19.91 cm), cylindrical volume (124.12 m^3 ha^{-1}) and tree stand biomass (95571 kg ha^{-1}) where as 75 % pruning recorded the lowest dbh (14.21 cm) canopy spread in both (N-S) & (E-W) direction, cylindrical volume (60 m^3 ha^{-1}) and stand biomass (46861 kg ha^{-1}).

Varieties

Tree when grown with different varieties (Agrisilviculture system) and without crop ie. tree alone showed no significant difference in height, dbh, canopy spread in both (N-S) & (E-W) recorded significantly lowest cylindrical volume (79-5 m^3 ha^{-1}) and stand biomass (61240 kg ha^{-1}) as compared tree grown with different varieties. Under tree but canopy spread in N-S (5.82m), E-W (6.23m)

Net Profit (Rs. ha^{-1})

Table-2 : Net Profit of different wheat varieties grown without *D. sissoo* with *D. sissoo* (Agrisilviculture system) in different pruning intensities and in open condition

Varieties / Pruning intensities/s	MP-3020	GW-273	GW-366	Mean		Tree alone (no crop)
No pruning	28595	29876	29934	29468		12078
25% pruning	33687	36195	30859	33580		19721
50% pruning	31278	32850	24767	29632	29003	15205
75% pruning	26184	24374	19440	23332		11123
Open- crop alone	14610	16340	12001	14317		
Mean	26870	27927	23400			14531

Treatment	SEM	CD at 0.05%
Pruning intensities	1994	6001
Varieties	1599	4477

Agrisilviculture system gave significantly higher monetary return (Rs. 29003 ha^{-1}) than growing of crop alone (Rs. 14317 ha^{-1}) or tree alone (Rs. 14531). Managed agroforestry system, wheat+ D. sissoo in 25% pruning gave higher monetary returns (Rs. 33,580 ha^{-1}) at par with 50% and no pruning but significantly superior to 75% pruning (Rs.23332 ha-1) crop alone and tree alone. Among varieties GW-273 recorded

high monetary return (Rs.27,927 ha^{-1}) at-par with MP 3020(Rs 26,870 ha-1) but significantly superior to GW-366 (Rs. 23,400 ha^{-1})

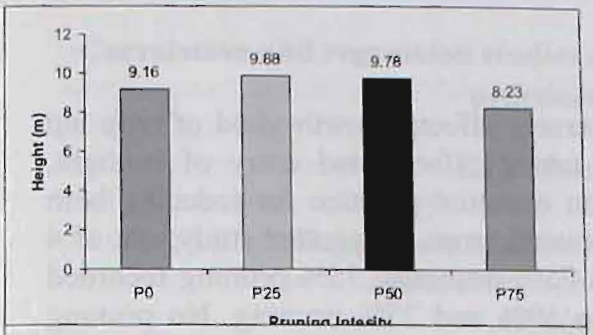
Morphological growth characters and biomass production of *D. sissoo* as influenced by pruning intensities and wheat varieties under Agri-silviculture system.

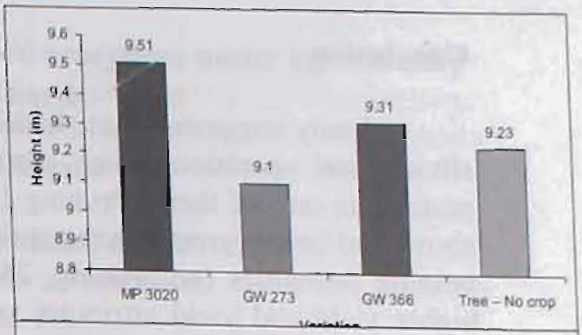
Treatment	Height m	DBH cm	Canopy spread (m)		Pruned biomass kg ha^{-1}	Cylindrical volume (m^3 ha^{-1})	Stand biomass kg ha^{-1}
			N-S	E-W			
Pruning intensity							
P_0 – No pruning	9.16	19.81	7.59	7.29	-	116.43	89716
P_{25} – 25% pruning	9.88	19.91	5.82	6.23	189	124.12	95571
P_{50} –50% pruning	9.78	17.53	5.38	5.65	675	97.31	74861
P_{75} –75% pruning	8.23	14.21	3.39	4.09	825	60.65	46861
SEM	0.83	0.8	0.38	0.35	48	3.16	5884
CD at 0.05%	NS	2.46	1.21	1.09	165	9.78	18302
Late sown wheat variety							
V_1 – MP 3020	9.51	19.40	5.71	6.72	734	115.06	90829
V_2 – GW 273	9.10	18.33	5.43	5.85	720	99.12	76314
V_3–GW 366	9.31	18.26	5.44	5.33	786	101.18	77950
Tree – No crop	9.23	15.41	5.57	5.41	761	79.5	61240
SEM	0.47	1.33	0.45	0.34	60	5.34	4111
CD at 0.05%	NS	NS	NS	NS	NS	17.06	13137

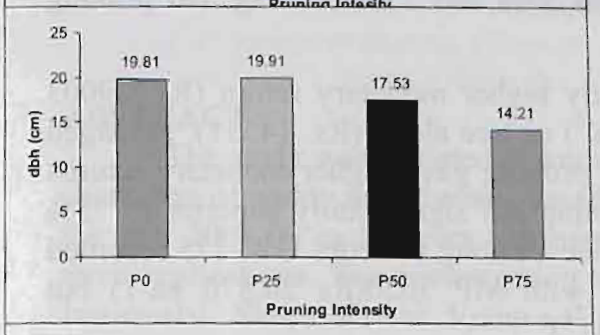
Discussion:

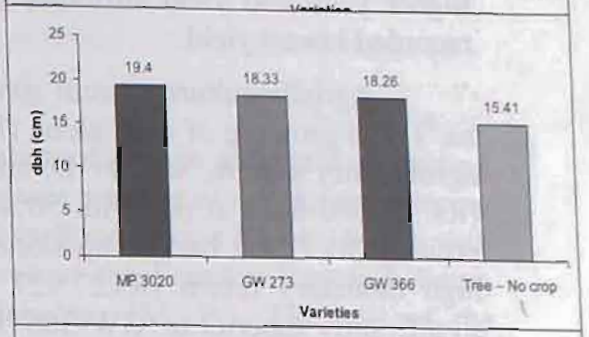
Crop grown open condition (without tree) recorded significantly higher yield attributing characters viz plant height, number of effective tiller/MRL, Length of earhead number of grains per earhead, 1000 grain weight and grain yield as compared to grown with tree under different pruning intensities. In open condition more light was found and it helps in photosynthesis, multiplication of cells as a result it gives higher value of yield attributes which contributes more yield. Ram Newaj et al. (2001) observed that grain yield ahs a positive correlation with number of panicle/m^2, length of panicle, number of grians/panicle and test height. Solar radiation appeared to be the most important factor for growth and yield of inter crops (Suresh and Rao, 1999; Tomar et al. 2000 and Reynold et al, 2007. Among pruning 75% pruning recorded higher yield as compared to other pruning treatments. The probable reason might be due to more availability of in 75% pruning as compared other pruning & no pruning. Cylindrical volume in ultimate product of height & dbh of tree. 25% pruning recorded higher dbh (19-91 cm) and height (9.88m) result significantly more cylindrical volume was recorded. In study managed agroforestry system (pruning) gave higher return (Rs. 29003 ha^{-1}) as compare to crop alone (Rs. 14317 ha^{-1}) and tree alone (Rs. 14531 ha^{-1}) . The probable reason of higher return in managed agroforestry system is that sufficient return obtained from both tree and crop component where as in tree alone or crop alone, return obtained from only one component either from tree or crop. Suggest that agroforestry is more profitable than only agriculture or Forestry (Chandra, 1986 and Patel, 1988).

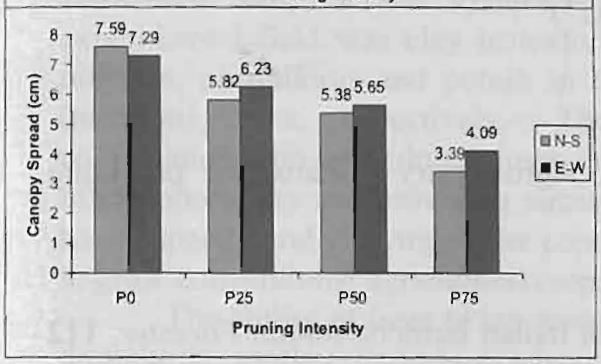
Morphological growth characters and biomass production of D.Sissoo as influenced by pruning intensities and wheat varieties under Agrisilviculture system

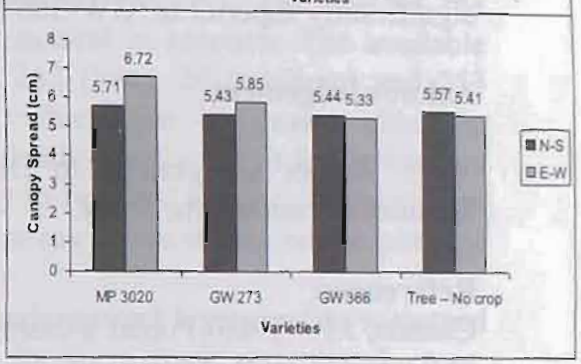


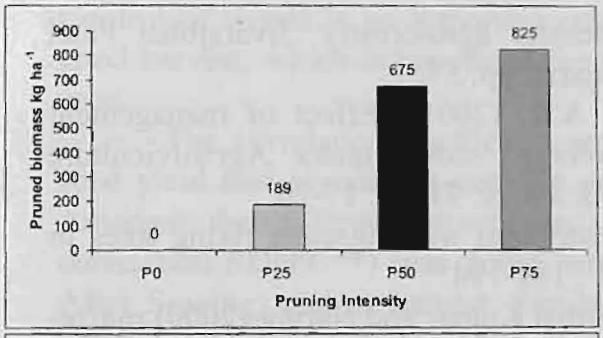


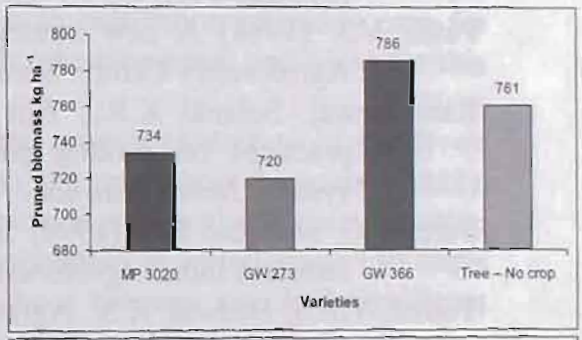


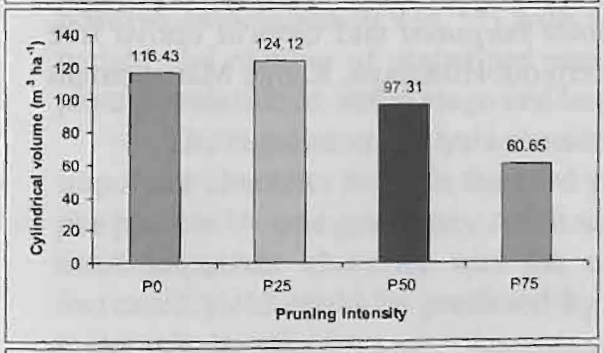


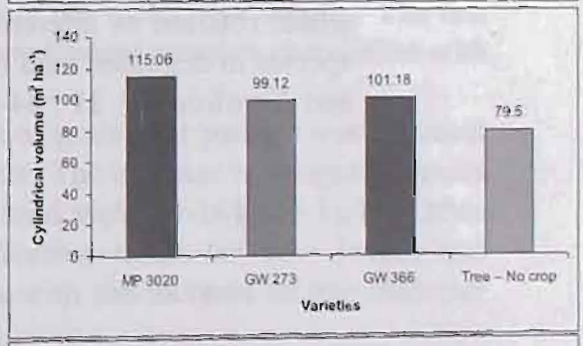


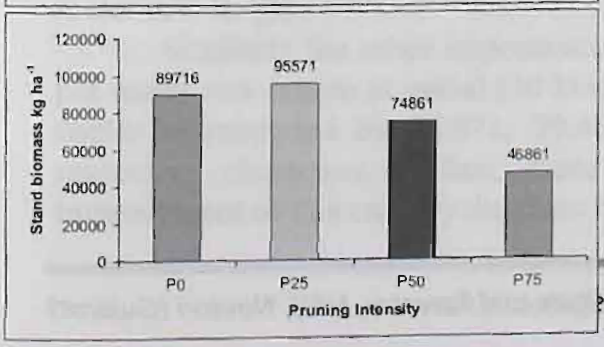


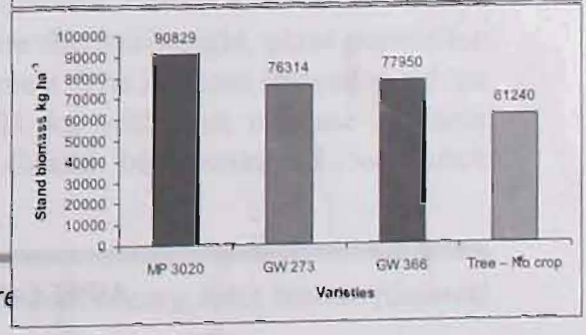












Conclusion

Study suggested that shade of trees adversely affects growth yield of crop but silvicultural operation which can reduce tree canopy, facilitated entry of sunlight, pruning is one of them. Pruning has became an essential practice for reducing both above and below ground competition with associated crops. In present study, out of 4 pruning intensities (no pruning, 25%, 50% and 75% pruning), 75% pruning recorded higher yield and yield attributes on compare to 50% and 25% pruning. No pruning recorded lowest yield.

Agrisilviculture system gave significantly higher monetary return (Rs. 29003 ha^{-1}) than growing of crop alone (Rs. 14317 ha^{-1}) or tree alone (Rs. 14531). Managed agroforestry system, wheat+ D. sissoo in 25% pruning gave higher monetary returns (Rs. 33,580 ha^{-1}) at par with 50% and no pruning but significantly superior to 75% pruning (Rs.23332 ha-1) crop alone and tree alone. Among varieties GW-273 recorded high monetary return (Rs.27,927 ha^{-1}) at-par with MP 3020(Rs 26,870 ha-1) but significantly superior to GW-366 (Rs. 23,400 ha^{-1})

Acknowledgement

Author are grateful to Director, NRC, Agroforestry , Jhansi for providing facilities to conduct the study.

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Correlation and regression studies of paddy-weed ecosystem under agroforestry practices in guava ochards

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ABSTRACT

The study was initiated to know the association of growth and yield attributing characters of paddy under guava based agri-horticulture practice of agroforestry during the year 2008-09 in 15 years old guava plantation in Randomized Block Design with three replications. The investigation was carried out at the Forestry Research Farm, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M. P.). The soil of the experimental field was clay in texture and almost neutral in reaction. The available nitrogen, phosphorus and potash in the soil were 262 (low), 24 (medium) and 253 (medium) kg/ha, respectively. The fruit trees which can be grown either in combination with agricultural crops or on separate lands usually not fit for agriculture offer opportunity and providing nutritional security to farmers' family. Further, trees have capacity and growing under conditions and in areas where it may not be possible to grow conventional agricultural crops.

The ability of trees to tap water from deep underground layers and to withstand drought is another important advantage enjoyed by them over agricultural crops. Control of weeds is an important cultural operation In cultivation of paddy crop for good harvest, which is beneficial for proper growth, development and yield for this crop.

The correlation coefficient amongst different growth characters of paddy on seed yield had significant positive correlation with the crop-shoot biomass (0.811). Amongst the different growth and yield characters significantly highest positive correlation (0.999 **) was noted between plant population at initial stage (30 Days After Sowing) and at harvest. Similarly the crop-shoot biomass also had significant positive association (0.934 **) with number of tillers per meter row length. The test weight and number of grains per panicle also had significant positive correlation with plant population at initial stage and harvest.

The regression analysis revealed that weight of grains per panicle was the most important character towards the seed yield per hectare. The increase in weight of grains per panicle by one gram may result an increase in seed yield by 161.115 kg/ha. Other most important character was the number of effective tillers/ m row length and increased yield could be predicted by 98.423 kg/ha with the increase of one tiller per meter row length.

Similarly the other important characters were the test weight, plant population per meter row length at initial (30 DAS) and at harvest. The increase in seed yield /ha could be predicted by 78.871, 39.461 and 38.301 kg with unit increase in these respective characters. Thus, these characters should be considered for future improvement of this crop by the plant breeder.

From the above going findings it may be concluded that amongst the different crop growth and sink parameter, weight of grains/panicle was the most important character and had the significant positive effect on seed yield followed by number of effective tillers per meter row length. The plant type may be tailored to produce more weight of the grains per panicle and bear more number of effective tillers per plant through genetic engineering or by suitable breeding programmes under shaded conditions of guava plantation.

Key words: Paddy, Correlation, Regression

INTRODUCTION

Guava is an important fruit in the tropical and sub-tropical region of the country. Despite its adaptability to varied agro climatic conditions. Monoculture being risk prove, suitable crop combinations in the inter space of guava orchards can generate extra income, improve productivity per unit area as a result of efficient utilization of natural resources and inputs which ameliorate and improve ecological situation. This leads to the thinking of a diversified cropping system between the inter space of guava orchards.

The agri-horticultre system helps in conservation of vegetation, soil and nutrients conservation and provides fruits and food grains on a sustainable basis.

Uplands rice fields favor growth of semi aquatic weeds. Some of the rice fields get infested with obnoxious weeds such as *Echinochloa* and *Cyperus* species. These weeds pose serous threats in upland rice fields. Rice is reported to be the most sensitive crop to weed competition ranging from 43.5 to 55.5 % (Choudhary; et al. 1995).

Farmers generally keep the rice crop unwedded due to scarcity of laborers. Heavy rains do not permit timely weeding which is very essential to get higher production (King, 1974). The knowledge on behavior of emergence of kharif weeds in paddy crop under guava orchards is almost lacking which is very essential for developing effective and cheapest control measure. The information on the extent of reduction in yield of paddy crop due to different weed species associated in paddy weed ecosystem are not available. The extent of reduction in kharif crop due to weeds is also reported by Jain and Tiwari (1993) and Agrawal et al., (1995). Hence, with the views present study was undertaken.

MATERIALS AND METHODS

The field experiment was conducted at the Forestry Research Farm, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M. P.) during the rainy season of 2008-09 in 15 years old guava orchards planted at a distance of 5 m X 5 m. The soil of the experimental field was clay in texture and almost neutral in reaction, the available nitrogen, phosphorus and potash in the soil were 262 (low), 24 (medium) and 253 (medium) kg/ha, respectively. The crop was irrigated as and when there was moisture stress by using dairy waste water during the crop growth period. Jabalpur is situated at 23 0 3" North latitude and 79.5 0 5" East Longitude with an altitude of 411.78 meters above the mean sea level. It comes under the agro climatic region classified as Kymore Plateau and Satpura Hills and is broadly known as Rice-Wheat crop zone of Madhya Pradesh. The climate of the region is sub-tropical with the hot dry summer and cold dry winter. The mean annual rainfall of Jabalpur is 1250 to 1400 mm mostly received

between mid of June to September with occasional rains during the winter. The mean monthly temperature goes down to the limit of 4 C during winter while the maximum temperature reaches as high as 45 C during summer. Paddy variety **Kranti** was grown under different weed control treatments. The treatment combinations were comprised viz., fenoxaprop –p- ethyl (75,100,125 g ai /ha), fenoxaprop –p- ethyl + 2,4-D (100+500 g ai /ha), 2,4-D (500 g ai /ha), Hand Weeding (twice 20 & 40 DAS), Butachlor + Hand Weeding (200 g ai /ha + 20 DAS) and weedy check. The herbicides were used as post-emergence.

The yield attributing characters, crop shoot biomass and yield of paddy crop were recorded at harvest. With the advances in computer programming, multivariate techniques increasingly being used in the analysis of biological data. It is necessary to have the linear relationship amongst the different growth and sink characters and quantified information on how the growth characters affect the yield.

The correlation coefficient (r) was calculated as suggested by Snedecor and Cochran (1967) with the following formula.

$$\text{Correlation coefficient-r} = \frac{\sum XY - (\sum x).(\sum y)}{\sqrt{\quad\quad\quad

CONCLUSION

From the above going findings it may be concluded that amongst the different crop growth parameters, weight of grains per panicle was the most important character and had the significant positive effect on seed yield followed by number of effective tillers/ plant. Thus, the plant type may be tailored to produce more weight of grains and bear more number of tillers/ plant under the shaded conditions of guava plantation.

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Table 1: Correlation matrix indicating interrelationship of seed yield with growth and Sink parameters

S. No.	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Y
X_1	0.999**	0.502	0.779 *	0.680	0.608	0.799*	0.552	0.800*	0.625	0.428
X_2	-	0.505	0.976*	0.667	0.612	0.784*	0.529	0.795*	0.638	0.451
X_3	-	-	0.381	0.109	0.963	0.472	0.780*	0.763	0.174	0.051
X_4	-	-	-	0.625	0.451	0.438	0.161	0.752*	0.934**	0.649
X_5	-	-	-	-	0.170	0.579	0.311	0.686	0.644	0.665
X_6	-	-	-	-	-	0.575	0.727	0.641	0.194	0.072
X_7	-	-	-	-	-	-	0.724	0.529	0.341	0.446
X_8	-	-	-	-	-	-	-	0.654	0.071	0.190
X_9	-	-	-	-	-	-	-	-	0.675	0.498
X_{10}	-	-	-	-	-	-	-	-	-	0.811*

* Significant at 0.05 level of significance ** Significant at 0.01 level of significance

X1 = Plant population/m Row length (30 DAS)

X2 = Plant population/m Row length (at harvest)

X5 = No. of effective tillers/ m row length

X6 = Length of panicle at harvest

X9 = Test weight

X10 = Crop-shoot biomass (kg/ha)

X3 = Plant height at harvest X7 = No. of grains/panicle Y = Seed yield (Kg / ha)

X4 = No. of tillers/m Row length X8 = Weight of grains/panicle

Table 2. Regression analysis of different growth and sink parameters with seed yield (kg/ ha)

Sr. No.	Variable	^ Y= a + b x	Mean ± SE (Independent Variable)	R^2
1	X1	271.428 + 39.461 X1	34.34 + 1.08	0.183
2	X2	326.915 + 38.301 X2	33.93 + 1.08	0.172
3	X3	1427.051 + 3.314 X3	60.17 + 1.54	0.003
4	X4	65.547 + 15.551 X4	100.37 + 4.11	0.421
5	X5	- 5159.384 + 98.423 X5	68.94 + 0.67	0.442
6	X6	1092.125 + 28.875 X6	18.51 + 0.25	0.005
7	X7	653.077 + 7.276 X7	133.78 + 6.08	0.199
8	X8	1263.082 + 161.115 X8	2.13 + 0.12	0.036
9	X9	- 54.687 + 78.871 X9	21.32 + 0.63	0.248
10	X10	- 400.405 + 0.792 X10	2559.98 + 101.80	0.658

X_1 = Plant population/m Row length (30 DAS) X_5 = No. of effective tillers/ m row length X_9 = Test weight

X_2 = Plant population/m Row length (at harvest) X_6 = Length of panicle at harvest X_{10} = Crop-shoot biomass (kg/ha)

X_3 = Plant height at harvest X_7 = No. of grains/panicle Y = Seed yield (Kg / ha)

X_4 = No. of tillers/m Row length X_8 = Weight of grains/panicle

Evaluation of different tree species in Silviculture system of Agroforestry

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ABSTRACT

Agroforestry is a specialized land use system in which perennial trees are intentonaly grown with crop on the same land management unit, which ultimately leads to favourable ecological and economic interaction. In silviculture system of Agroforestry field experiment was conducted in shallow soil to assess the growth performance of seven different trees species under Rahuri location in Western Maharashtra. The experiment was planted during August, 1996 in a randomized block design (RBD) with three replications. The performance of different tree species *viz,. Tectona grandis, Azadirachta indica, Hardwicki binata, Acacia nilotica, Melia azadirach, Zizipus mauritiana* and *Eucalyptus* was assessed for tree height, collar diameter, diameter at breast height, bole height, and bole volume of fixed samples on twelve years plantation. Among seven treatment Eucalyptus was found promising and showed superior results followed by *Acacia nilotica* var. *cupressiformis*. The differences among tree species in respect of all the growth attributes were statistically significant. Eucalyptus recorded significantly highest plant height (11.76m) and bole height (7.12m) respectively. While, Ramkathi babul (*Acacia nilotica* var. *Cupriciformis*) recorded significantly highest collar diameter (21.74cm) and DBH (18.80cm) followed by Anjan over rest of the tree species. The pooled results indicated that Eucalyptus recorded significantly highest plant height (9.88m) and bole height (6.22m) whereas significantly highest collar diameter (16.19cm) and DBH (13.99 cm) were observed in Ramkathi babul. Among the various treatments highest gross monitory returns (Rs.2,32,522/-) net monitory returns (Rs.2,15,278/-) and B:C ratio (Rs.12.48/-) was recorded by Eucalyptus followed by Ramkathi babul (Rs. 8.10).

INTRODUCTION

Agroforestry is often heralded as a promising land use option with considerable potential for commercial timber production (Kumar, 2005). Coincidentally, timber species abound on farmland or as a boundry planted trees (Kumar et al, 1994). The prime concern in Agroforestry studies has been optimization of various tree species for maximizing tree growth subject to the condition of minimum reduction in crop yield over sole crop (Hegde, 1990). In Agroforestry system, trees are intentionally used within agriculture system which can be advantageous over conventional agriculture and forest production method through increased productivity, economic benefit, social outcome and ecological goods and services provided. Hence, present investigation was undertaken to evaluate the performance of different timber producing tree species in silviculture system of Agroforestry in shallow soil for suggesting best tree species for shallow soil and the effect of various tree species on growth attributes under rahuri condition in western Maharashtra.

MATERIAL AND METHODS

The present investigation was undertaken at AICRP on Agroforestry, MPKV, Rahuri located at an elevation of 500 m above mean sea level. It is situated between 19° 47' N latitude and 74°81' E longitude and having sub tropical semiarid climatic condition with mean annual rain fall 500-700 mm. Most of the rainfall is received during monsoon season (August-October). Mean maximum temperature ranges from 41°C (May) to 22°C (February) and mean minimum temperature varies from 28°C to 7°C (February) the experiment was planted during July, 1996. The soil of experimental area is shallow and light with a general fertility level of low organic carbon, nitrogen, phosphorus and high potassium.

Experiment was laid in a randomized block design with three replications. And trees were planted at 3 x 3 m spacing in each replication. One year old seedlings of *Tectona grandis*, *Azadirachta indica*, *Hardwicki binata*, *Acacia nilotica*, *Melia azadirach*, *Zizipus mauritiana* and *Eucalyptus* were planted in pits of 0.60 x 0.60 x 0.60 m, filled with top soil and decomposed FYM. Trees were pruned 50 % of total height in July-August every year starting from third year onwards. The data on tree growth attributes *viz.*, tree height, collar girth at breast height (GBH), bole height, and bole volume of fixed sample trees was recorded at the end of 12th year. Data obtained for various characters is analyzed as per procedure given by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Observations on the various growth attributes recorded under various treatments at the age of 12 years are presented in Table 1.The differences among tree species in respect of all the growth attributes were statistically significant. Significantly superior plant height, collar girth, girth at breast height and bole volume was obtained in Eucalyptus. Rai et. al., also reported maximum bole biomass in eucalyptus in growth and biomass production study of multipurpose tree species. Significant differential response in plant height and DBH was also observed in various tree species. The tree speeies Eucalyptus recorded significantly highest plant height (11.76m) and bole height (7.12m) respectively. While, *Acacia nilotica* var. *Cupriciformis* (Ramkathi babul) recorded significantly highest collar diameter (21.74cm) and DBH (18.80cm) followed by *Hardwika binata* (Anjan) over rest of the tree species as compared with *Tectona grandis*, *Azadirachta indica*, *E. camandulensis* , *Melia azadirach* and *Zizipus muaritiana* (Ber) tree species. The beneficial effects of trenching , felling or both in Agroforestry associations have been demonstrated in Eucalyptus by Singh and Dayal (1974), Dadhwal *et al* (1984), Verinumbe and Okali (1985) and Shakaranarayan (1986) and Kasole *et. al.*(1999).

The pooled results indicated that Eucalyptus recorded significantly highest plant height (9.88m) and bole height (6.22m) whereas significantly highest collar diameter (16.19cm) and DBH (13.99 cm) were observed in *Acacia nilotica* var. *Cupriciformis* (Ramkathi babul).Growth performance of *Acacia nilotica* has been also reported by Giri Rao *et. al* (2003)

Among the various treatments highest gross monitory returns (Rs.2,32,522/-) as well as net monitory returns (Rs.2,15,278/-) and B:C ratio (Rs.12.48/-) was recorded by *Eucalyptus* followed by *Acacia nilotica* var. *Cupriciformis* (Ramkathi babul) (Rs. 8.10). Growth performance of Acacia nilotica has been also reported by Giri Rao *et al* (2003).

On the basis of pooled result it is to recommend that plantation of Eucalyptus in shallow soil of scarcity zone of Western Maharashtra is recommended for obtaining higher timber yield and net monitory returns at the age of twelve years.

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Table 1 : Growth observations of different tree species

Sr. No.	Treatments	2010-2011			
		Plant ht. (m)	Coll. dia. (cm)	DBH (cm)	Bole ht. (m)
1	Neem (*Azadirachta indica*)	6.69	15.09	11.80	2.35
2	Eucalyptus (*E.camaldulensis*)	**11.76**	18.36	14.59	**7.12**
3	Bakan (*Melia azadirach*)	6.54	14.25	12.59	3.08
4	Teak (*Tectona grandis*)	6.26	14.01	10.12	3.33
5	Anjan (*Hardwickia binnata*)	8.77	20.65	16.93	4.86
6	R. Babul (*Acacia nilotica*)	11.36	**21.74**	**18.80**	4.24
7	Ber (*Ziziphus mauritiana*)	3.15	8.66	6.40	1.34
	G. mean	6.80	14.09	11.40	3.26
	SE ±	0.50	0.98	1.17	0.31
	CD at 5%	1.52	2.97	3.56	0.94
	C.V.%	12.79	12.04	17.81	16.45

Table 2 : Growth observations of different tree species

Sr. No.	Treatments	Pooled mean (12 years)				Bole vol./tree (m^3)	Bole vol./ha. (m^3)	Timber (t/ha)
		Plant ht. (m)	Coll. dia. (cm)	DBH (cm)	Bole ht. (m)			
1	Neem	5.51	12.68	10.05	2.32	0.034	37.75	22.213
2	Eucalyptus	**9.88**	14.99	11.84	**6.22**	**0.273**	**304.01**	**178.863**
3	Bakan	5.45	11.94	9.87	3.01	0.052	57.72	33.823
4	Teak	4.88	11.09	7.65	3.15	0.039	42.83	25.197
5	Anjan	6.46	13.97	11.54	4.57	0.134	149.50	87.960
6	R. Babul	8.47	**16.19**	**13.99**	3.89	0.137	153.11	90.077
7	Ber	2.41	7.08	2.08	1.00	0.006	6.72	3.953
	G. mean	6.15	12.56	9.57	3.45	0.096	107.38	63.15
	SE ±	0.39	0.77	0.71	0.16	0.020	22.06	12.96
	CD at 5%	1.12	2.16	2.00	0.46	0.061	68.01	36.96
	C.V.%	7.17	6.72	8.20	9.42	35.57	35.59	35.56

Table 3 : Gross monitory returns, cost of cultivation, net monitory returns and B:C ratio of different treatments

Sr. No.	Treatments	Gross monitory returns (Rs.)	Cost of cultivation (Rs.)	Net monitory returns (Rs.)	B:C ratio (Rs.)
1	*Azardiracta indica* (Neem)	39984.00	17799.00	22185.00	1.25
2	*Eucalyptus camandulensis*	**232522.00**	17244.00	**215278.00**	**12.48**
3	*Melia azadirach* (Bakan)	60881.00	17799.00	43082.00	2.42
4	*Tectona grandis* (Teak)	100786.00	19466.00	81320.00	4.17
5	*Hardwickia binnata* (Anjan)	158328	17799.00	140529.00	7.89
6	*Acacia nilotica* (R. Babul)	162138.00	17799.00	144339.00	8.10
7	*Ziziphus mauritiana* (Ber)	40444.00	18355.00	22089.00	1.19
	G. mean	113617.90	--	95581.00	5.36
	SE ±	20163.85		20163.62	1.14
	CD at 5%	62149.16		62148.46	3.52
	C.V.%	30.74		36.54	36.90

* The price of timber for Eucalyptus@ Rs.1300/mt, Teak @ Rs.4000/mt and Rs.1800/mt for other timber.

INCOME FROM VARIOUS POPLAR BASED AGROFORESTRY MODELS: HARYANA EXPERIENCE

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ABSTRACT

Poplar *(Poplus deltoides)* - a short rotation woody tree was introduced in Yamunanagar district of Haryana State in 1978 for growing as an agroforestry crop. Because of its ability to grow and mature quickly, it fitted very well into the commercial agroforestry system of Haryana. At present it is grown in northern part of the State mainly in seven districts. During three decades of its cultivation under various agroforestry patterns, it has become the part and parcel of farming system of Haryana. Cooperation extended by the Government of Haryana through non-imposition of any restrictions on its harvesting, transport and sale, has encouraged farmers to take up Poplar Based Agroforestry (PBAF) in a big way. Yamunanagar town of Haryana is the big hub for post-harvest Poplar activity in terms of wood sale, use and value addition mainly in the form of veneer and plywood manufacture, and so to say that Poplar has now become a full fledged industry in itself in the state. It has brought prosperity to the state, has improved the environment by sequestering carbon at faster rate, and has helped in saving the natural forests, wildlife and their biodiversity. It has contributed a lot in making Haryana a timber surplus state. Poplar growers in Haryana have turned their fields into laboratory and are experimenting with various models of its farming combining with horticulture, olericulture, poultry, fish farming and agriculture depending upon the choice of crop they want to grow. They have now come out with various models of its farming and are adopting the ones that give them the highest economic returns. Some of the finally refined PBAF models in practice at present in the state are: Poplar+ Wheat+ Sorghum, Poplar+ Sugarcane+ Wheat + Sorghum, Poplar+ Wheat+ Turmeric+ Sorghum and Poplar+ Sugarcane+ Turmeric. The net benefits from these PBAF models have been computed separately under Haryana conditions.

Keywords: Poplar, PBAF, Haryana, Yamunanagar

INTRODUCTION:

Poplar was introduced in Yamunanagar district of Haryana in 1978 with the active support of WIMCO as a viable alternative to *Eucalyptus* as latter was facing lot of criticism. However, very soon it was realised that Poplar and *Eucalyptus* are not competitors, rather they are complementary to each other as for as the quick wood production and quick returns are concerned. Poplar has found a separate niche and although it did not succeed in forests yet it adapted very well to companionship with the agricultural crops. It did not compete with *Eucalyptus* because it has different

requirements and has limited zone. During more than three decades of Poplar introduction in Haryana, Poplar has witnessed many ups and downs. There was a time in late nineties when poplar prices in the market had crashed to bottom low. The wood fetched price just ninety rupees a quintal almost equal to fodder prices Barseem *(Trifolium alexandrinum)* prevalent at that time. But very soon it revived and today Poplar wood is being sold in the market @ 1000 rupees per quintal. Yamunanagar town of Haryana has emerged as Asia's biggest timber market mainly due to Poplar wood.

At present there are 679 poplar wood based industries in Haryana, out of which 570 are in Yamunanagar alone. There is value addition to the wood in the form of mainly plywood, plyboard and fruit packing cases and more than three dozen uses of its wood have come up. Poplar wood worth one crore and value added goods worth three crores are traded every day in Yamunanagar Timber Market generating huge employment in on farm and of farm activities.

Initially clone numbers G-3, G-48, IC, and ST121 were introduced in the state in early eighties. They stayed on till early nineties. But in early nineties G-3 was wiped out due to its proneness to the pests and new clones UDAI, S7C15, S7C8, L-34 and ST121 were introduced. The clones belonging to "S" were not liked by the farmers and industries due to colour of the wood and they were wiped out. L-34 did not adapt well under Haryana conditions. The twenty first century witnessed the introduction of few more clones in the form of clones namely UDAI, WSL-22, WSL-32, W-39. G-48 has recently become little controversial as it is being blamed for the serious problem of pests. However, inspite of all odds G-48 is staying, though it is likely to be replaced by clone no. 108 introduced in Haryana recently by WIMCO.

Witnessed by the farmers themselves, Poplar has become the undisputed player of agroforestry in Haryana in its zone and over the years lot of permutations and combinations of Poplar Based Agroforestry (PBAF) have emerged. It responds to the inputs applied and agricultural operations done for growing agriculture crop. Crops like turmeric loves to grow under poplar shade as it provides much needed shade and shelter to turmeric. It is planted on boundaries of the field in rows or in the fields as block plantation. So much so that multitier or multiple cropping pattern combining Poplar with horticulture crop, food crop, fodder crop, and medicinal plants has emerged. So, it is planted with wheat, sugarcane, on boundary mixed with other tree species, on the boundary of the fish and poultry farms to provide shade particularly to poultry birds during the period of hot winds. It is plated with crops like Okra (*Abelmoschus esculentus*), Mentha, chillies, Cherry, Bajra and Maize (grown as fodder crop), oats, sunflower and strawberry. So profitable is Poplar business that the farmers grow poplar nursery under Poplar. As regards preference to the crops, most preferred is wheat, followed by sugarcane, barseem maize, Jowar and Bajra grown as fodder crop. Wheat and sugarcane are the preferred crops till first three years. Sunflower can be grown only upto first two years. Oats as Rabi crop can be grown throughout. However, as the trees attain a rotation age, the combination of Poplar with turmeric is most profitable as Poplar acts as nurse crop for turmeric.

Veneer making is the main use of Poplar. Most of the industries using Poplar wood for ply making use wood which has girth more than 90 cms. Poplar attains this girth in about 6 to 7 years. Therefore, rotation age for Poplar has been fixed at 6 to 7 years. No documented information for the returns from various Poplar Based

Agroforestry (PBAF) systems under Haryana conditions is available. Hence, this study was conducted in the year 2011 in Yamunanagar and Kurukshetra districts.

OBJECTIVES OF THE STUDY:

1. To study various Poplar Based Agroforestry models prevalent in Haryana
2. To compute income from various Poplar Based Agroforestry models prevalent in Haryana
3. To suggest the best model of PBAF under Haryana conditions

MATERIALS AND METHODS:

The study on the aforesaid objectives was conducted on farmers fields in Yamunanagar and Kurukshetra district of Haryana in the year 2011. For each model five farmers were selected. A minimum distance of five kilometres was ensured between two samples. As regards the area, a minimum area of one acre was considered for the purpose of study. The discussions were held with the owners and other farmers adopting PBAF. The rates for the sale of Poplar wood were collected from Yamunanagar Timber Market. The prices for grains and sugarcane were collected from grain market and Sugar Mill respectively. Calculations were done based on the present market rates using 7% discounting factor. Accordingly the results were computed. For suggesting best model for PBAF in Haryana the discounted figures for net benefits obtained from different models were compared and accordingly ranking was done.

RESULT AND DISCUSSION:

The results of the above study can be discussed under the following heads:

1. Poplar based agroforestry models prevalent in Haryana
2. Cost- Benefit analysis of practical and widely adopted models
3. Comparison of returns obtained from different models and final recommendation

As regards Poplar based agroforestry models prevalent in Haryana, the description of various PBAF models found during the course of study is given as under:

- **Poplar + Wheat + Sunflower+ Sorghum:** In this model wheat is sown during first week of November and thereafter poplar is planted during first week of February. Upon harvest of wheat during March, sunflower is sown. It is followed by sowing of sorghum in July. This pattern is followed for two years and thereafter growing of sunflower is discontinued as it is not able to grow due to the shade effect of poplar Plants. Third year onwards wheat during Rabi and sorghum during Kharif season are grown. This model was popular with the farmers but later on this model nearly vanished from the fields as farmers did not get desired seed yield from sunflower due to less growing period available to it. At present only very few farmers are continuing with this model. As this model was not found practical, cost benefit analysis was not done.

- **Poplar + Barseem + Sorghum:** This model is followed by the farmers to meet their household

requirement of fodder during the Rabi and Kharif seasons. It is practiced on small scale and hence the cost benefit analysis was not done.

- **Poplar + Mustard + Sorghum:** This model is followed by the farmers to meet their household

requirement of mustard oil and fodder. It is practiced on small scale and hence the cost benefit analysis was not done.

- **Poplar in homesteads:** This model was found in homesteads of poor and landless labourers

who grow less than ten poplar trees as the source of some income. These poor people grow garlic, onion, fenugreek and fennel etc. under poplar. As this model is practiced on very small piece of land, no cost benefit analysis was done.

- **Poplar as shelter/ ornamental tree:** This model is practiced in fish and poultry farming with

the purpose of providing relief particularly to poultry birds from the heat during summers, create aesthetic value and also to have additional income by the optimum use of land. As this model is practiced by the aforesaid farmers who are not many in number, the cost benefit analysis was not done.

- **Poplar + Banana:** This model was introduced just recently but has failed due to non

compatibility.

- **Poplar in multitier (Agri- Silvi- Horticulture) system:** In this system Poplar, fruit and

agriculture crops are grown as top, middle and ground storey respectively. As regards fruit crop, it can be Kinnow, Litchi, Pear, Guava and Mango. Agriculture crop can be Barseem and Wheat during Rabi and Sorghum or Maize during Kharif season as fodder crop. Turmeric is introduced during third year and thereafter no agriculture crop can be grown. This model although looks very impressive, yet it has lot of shortcomings. The main fault lies with the fruit crop. It occupies very large space and does not allow agriculture crop to grow on the ground due to shade effect. Turmeric though can grow but very less space is available for its cultivation. Other crops like Wheat and Sorghum fail to grow during the later stages of fruit crop and poplar. Even fruit crops too do not perform well due to the shade effect of poplar trees. Growing poplar is discontinued after harvest and the horticulture is continued. Even at that stage agriculture crops do not yield desired results. Hence, this model is not being encouraged as it is not a long term sustaining agroforestry model. Moreover, it is not practical and even the overall returns as per the farmers, are not high compared to other models. Hence, no cost calculations were done.

- **Poplar+ Wheat+ Sorghum:** In this model wheat is sown during November and poplar is

planted during first week of February. Wheat is harvested during first week of April and then there is no crop under poplar upto last week of June. This is active period

of growth and Poplar plants need irrigation atleast at fortnightly interval and application of fertilizers once in a month. Sorghum is grown during rainy season as fodder crop. This is practical model and is followed by large number of farmers in Haryana. The cost benefit analysis for this model has been given in Model-1.

- **Poplar+ Sugarcane+ Wheat + Sorghum:** In this model poplar and sugarcane are planted

simultaneously in first week of February. No other crop can be grown during first year as sugarcane remains in the field for about a year. Thereafter, ratooning is practiced in sugarcane during second year. The ratoon crop matures early in November and late Wheat varieties are sown by the end of November. Thereafter, Sorghum and Wheat are grown regularly during Kharif and Rabi seasons respectively upto the harvest of poplar trees. Poplar plants are maintained in the same way as discussed in Model-1. This is practical model and is followed by large number of farmers in Haryana. The cost benefit analysis for this model has been given in model-2.

- **Poplar+ Wheat+ Turmeric+ Sorghum:** In this model Wheat and Sorghum are grown for two

years in Kharif and Rabi seasons respectively and thereafter turmeric is introduced and is grown upto the harvest of poplar trees. Poplar plants are maintained in the same way as discussed in Model-1. This is also practical model and is followed by large number of farmers in Haryana. The cost benefit analysis for this model has been given in model-3.

- **Poplar+ Sugarcane+ Turmeric:** In this model, only sugarcane is grown during first two years

and thereafter turmeric is grown upto the harvest of poplar trees. Poplar plants are maintained in the same way as discussed in Model-1. This is also practical model and is followed by large number of farmers in Haryana. The cost benefit analysis for this model has been given in model-4.

For Cost- Benefit analysis of practical and widely adopted models, the calculations were first done for undiscounted figures. Thereafter, the Net Present Value (NPV) was calculated at 7% Discounting Factor. The cost benefit analysis for four widely adopted and practical models is given as under:

Model: Poplar+ Wheat+ Sorghum (Model-1)

Condition: Irrigated

Year	Costs Per Ha. (In Rupees)				Benefits Per Acre (In Rupees)				Net Benefits Per Acre (Rs.)
	Poplar	Sorghum	Wheat	Total	Poplar	Sorghum	Wheat	Total	
1	5000	3000	10000	18000	0	10000	22000	32000	14000
2	2336	2804	9346	14486	0	9346	20561	29907	15421
3	1922	2620	8734	13276	0	8734	19216	27950	14674
4	1796	2449	8163	12408	0	8163	17959	26122	13714
5	1678	2289	7629	11596	0	7629	16784	24413	12817
6	1569	2139	7130	10837	0	7130	15686	22816	11978
7	1466	1999	6663	10128	433122	6663	14660	454445	444317
Total	15767	17300	57665	90732	433122	57665	126864	617652	526920
Net Present Value at 7 % Discounted Factor					Annual Income at NPV= Rs. 1,50550/-				1053840

Poplar

- Spacing of Poplar: 4mX4m
- No. Of trees per acre: 250 + 100 trees on boundary at 3mx3m spacing
- Expenditure: Y1= Rs. 5000/- (Cost of plants, planting and maintenance)
- Y2 & onwards= Cost of five irrigations from April to June plus cost of application of fertilizers and pesticides
- Rotation of Poplar- 7 years
- Total Number of trees available at harvest: 300
- Income per tree: About 2170 rupees

Crops:

- Wheat is grown in all seven years from November to April.
- Sorghum is grown from July to September.
- Cost and benefits for crops have been calculated at presents rates of inputs, yield and grain/fodder rates in the market.

Model-2
Model: Poplar+ Sugarcane+ Wheat + Sorghum
Condition: Irrigated

Year	Costs Per Acre (In Rupees)				Benefits Per Acre. (In Rupees)				Net Benefits Per Acre (Rs.)
	Poplar	Sugarcane /Sorghum	Wheat	Total	Poplar	Sugarcane /Sorghum	Wheat	Total	
1	5000	33000	0	38000	0	90000	0	90000	52000
2	2336	11215	9346	22897	0	40499	20561	61060	38163
3	1922	2620	8734	13276	0	8734	19216	27950	14674
4	1796	2449	8163	12408	0	8163	17959	26122	13714
5	1678	2289	7629	11596	0	7629	16784	24413	12817
6	1569	2139	7130	10837	0	7130	15686	22816	11978
7	1466	1999	6663	10128	433122	6663	14660	454445	444317
Total	15767	55711	47665	119143	433122	168819	104864	706805	587662
Net Present Value at 7 % Discounted Factor				Per year income at NPV= Rs. 167903/-					1175324

Poplar: Conditions same as for model-1

Crops:

- Sugarcane is planted alongwith poplar in February in first year.
- During second year ratooning of sugarcane is done.
- Wheat is grown from second year onward from November to April as ratoon crop of sugarcane is harvested in October/November.
- Sorghum is grown from July to September after two years as sugarcane does not grow thereafter.
- Cost and benefits for crops have been calculated at presents rates of inputs, yield and grain/fodder rates in the market.

Model-3
Model: Poplar+ Wheat+ Turmeric+ Sorghum
Condition: Irrigated

Year	Costs Per Acre (In Rupees)				Benefits Per Acre (In Rupees)				Net Benefits Per Acre (Rs.)
	Poplar	Sorghum /Turmeric	Wheat	Total	Poplar	Sorghum /Turmeric	Wheat	Total	
1	5000	3000	10000	18000	0	10000	22000	32000	14000
2	2336	2804	9346	14486	0	9346	20561	29907	15421
3	1922	30570	0	32492	0	109180	0	109180	76688
4	1796	28570	0	30366	0	102037	0	102037	71671
5	1678	26701	0	28380	0	95362	0	95362	66982
6	1569	24955	0	26523	0	89123	0	89123	62600
7	1466	23322	0	24788	433122	83293	0	516415	491627
Total	15767	139922	19346	175035	433122	498341	42561	974024	798989
Net Present Value at 7 % Discounted Factor				Per year income at NPV= Rs.228280/-					1597978

Poplar: Conditions same as for model-1

Crops:

- Wheat is grown during first two years from November to April.
- Sorghum is grown from July to September for two years.
- Turmeric is introduced after two years and is grown upto the harvest of poplar.
- Cost and benefits for crops have been calculated at presents rates of inputs, yield and grain/fodder rates in the market.

Model-4
Poplar+ Sugarcane+ Turmeric
Condition: Irrigated

Year	Costs Per Acre. (In Rupees)				Benefits Per Ha. (In Rupees)				Net Benefits Per Acre. (Rs.)
	Poplar	Turmeric	Sugarcane	Total	Poplar	Turmeric	Sugarcane	Total	
1	5000	0	33000	38000	0	0	90000	90000	52000
2	2336	0	11215	13551	0	0	37383	37383	23832
3	1922	30570	0	32492	0	109180	0	109180	76688
4	1796	28570	0	30366	0	102037	0	102037	71671
5	1678	26701	0	28380	0	95362	0	95362	66982
6	1569	24955	0	26523	0	89123	0	89123	62600
7	1466	23322	0	24788	433122	83293	0	516415	491627
Total	**15767**	**134119**	**44215**	**194100**	**433122**	**478995**	**127383**	**1039501**	**1690801**
Net Present Value at 7 % Discounted Factor				Annual Income at NPV= Rs. 2,71320/-					1899259

Poplar: Conditions same as for model-1

Crops:

- For first two years sugarcane is grown.
- After two years turmeric is grown upto the harvest of Poplar.
- Cost and benefits for crops have been calculated at presents rates of inputs, yield and grain/fodder rates in the market.

As regards suggesting the best model of PBAF under Haryana conditions, the summary of net benefits for different practical models is given in the Table-1 below:

Table-1
Comparison of all four models of PBAF

Model No.	PBAF	Income per acre per year at NPV (Rs.)	Ranking	Best Model
1	Poplar+ Wheat+ Sorghum	1,50550	4th	-
2	Poplar+ Sugarcane+ Wheat + Sorghum	167903	3rd	-
3	Poplar+ Wheat+ Turmeric+ Sorghum	2,28290	2nd	-
4	Poplar+ Sugarcane+ Turmeric	2,71320	1st	Poplar+ Sugarcane+ Turmeric

It is evident from the table-1 that model- 4 and model-1 give the highest the lowest returns respectively and Model-2 and Model-3 found second and third place in ranking the practical models. Poplar+ Sugarcane+ Turmeric combination has been the best as for the highest returns are concerned, and hence should be adopted.

CONCLUSIONS:

Though the zone for growing poplar in Haryana is limited yet it is very important pillar of successful agroforestry in Haryana. Multitier system of PBAF combining poplar with fruit and agriculture crop is not successful. A combination of poplar, sugarcane and turmeric is the best combination. Infact poplar acts as nurse crop for turmeric and it flourishes well under poplar than growing in open. This is the best PBAF model for Haryana conditions and should be adopted on large scale for maximising the returns.

ACKNOWLEDGEMENTS:

The author is thankful to Dr. Sanjeev K Chauhan Associate Professor Forestry, Department of Forestry and Natural Resources & Punjab Agricultural University Ludhiana 141 004 India & Coordinator IUFRO Short Rotation Forestry for guiding me on conducting the study. Thanks are also due to Dr. T.P. Singh, IFS, Haryana and Harikant Sharma, Range Forest Officer, Research Range, Pinjore for helping in giving final shape to the data.

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Plantation of Harar in Morni Hills: A good source of an additional income

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ABSTRACT:

Harar (*Terminalia chebula*, family Combretaceae) is found throughout India and sub-Himalayan tract ascending upto an altitude of 1500 m. A survey was conducted in Morni hills in Panchkula district of Haryana state during 2009-10. It was observed that in Morni hills there were 3000 plants of Harar ranging from 10-200 years old on the fields of 200 farmers which were planted by forest department or some were naturally grown. And 1200 grafted plants of Harar in the field of 20 farmers ranging from 2-8 years old. The farmers earn more yield and money from the grafted plants as compared to the naturally grown plants of Harar. The grafted plants start bearing fruit in three years as compared to 10 years taken by the plants of seedling origin grown naturally or planted by forest department.

Keywords: Harar, Altitude, Morni

INTRODUCTION:

Harar (*Terminalia chebula*, family Combretaceae) species is found naturally in forest as well as farmers fields and is rarely under cultivation. It is distributed throughout the greater part of India except arid zone. A moderate sized tree, spreading branches; bark dark-brown, often longitudinally cracked; leaves ovate or elliptic with the pairs of large glands at the top of the petiole; flowers yellowish white, terminal spikes; fruit ellipsoidal, 5-ribbed on drying; seeds hard, pale yellow. Flowers occur during April-June and fruit ripens during November-March. The fruit is extensively used for treatment of diarrhoea, dysentery, heartburn, flatulence, dyspepsia and liver as well as spleen disorders. It is of the main constituents of trifla which is a known panacea for stomach disorders. In addition to medicinal properties, harar fruit is used in tanning and dyeing industries. The tree is lopped for fodder in some areas during lean period and provides good quality durable timber. The species is frost hardy and can grow under varied environmental condition.

MATERIALS AND METHODS:

Morni Hills is a hill station in the Panchkula district of the northern state of Haryana, and is situated at a height of 1220 meters above sea level. The Morni Hills are offshoots of the Shivalik mountain range of the mighty Himalayan range on the north. Morni Hills is known for a large variety of flora and fauna. The hilltops are covered by pine trees and slopes are covered by jamun, shisham, jacaranda, ritha, harar, neem, mango, pipal and sal trees. A progressive farmer, Sh. Tikka Singh (+919416668168) is a key/lead farmer for the area who started the cultivation of harar plantation under the guidance of Krishi Vigyan Kendra's scientists and horticulture department. The grafted

plants were taken from regional horticultural research station, Jachh, Nurpur (HP). These plants were planted at the farmer field in morni area. In Morni hills in Panchkula district of Haryana state there were 3000 plants of Harar ranging from 10-200 years old on the fields of 200 farmers which were planted by forest department and some were naturally grown. And 1200 grafted plants of Harar in the field of 20 farmers ranging from 2-8 years old. The performance was observed by the fruit bearing stage and yield per plant.

RESULTS AND DISCUSSIONS:

The farmers earn more yield and money from the grafted plants as compared to the naturally grown plants of Harar. The grafted plants start bearing fruit in two years (Table3.) as compared to 10 years taken by the plants of seedling origin (Table2.) grown naturally or planted by forest department. The grafted plants start bearing fruit in three years as compared to 8 years taken by plants of seedling origin (Thakur *et al.*, 2011).

Table1. Total plants of harar in Morni hill in Haryana

Plant type of harar	No. of plants	No. of farmers
Seedling origin	3000	200
Grafted	1200	20

Table2. Yield performance of harar grown by seedling origin

Fruit bearing stage (Years)	Yield (kg./plant)	Total income (@Rs. 20/kg.)
10	5	100
20	100	2000
30	200	4000
50-100	250	5000
100-200	250	5000

Table3. Yield performance of harar in Morni hill in Haryana

Fruit bearing stage (Years)	Yield (kg./plant)	Total income (@Rs. 20/kg.)
2	1	20
4	5	100
8	50	1000

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Hortipasture systems for mitigating problem of food, fodder and resource conservation under fragile ecosystem

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Vast area of the country (157 million ha) is under various extent of land degradation, where cultivation of arable crops is economically not viable. Climate change in the last decades, with increase in average temperature and erratic rainfall, has made agriculture in arid and semi-arid regions more challenging. Livestock rearing, which provides major livelihood alternative in these areas, is facing threat for sustenance due to degradation of grazing resources. In the present situation, hortipastoral systems can play a vital role to mitigate the shortage of dry and green fodder for the fast growing livestock population as well as to provide nutritious food for human being in an economically sustainable manner. The studies deals with fruit trees based hortipastoral land use system, which has found more suitable alternative for class IV to V lands. Among the fruit trees, Ber (*Zizyphus mauriana*) and Aonla (*Emblica officinalis*) are preferred due to their hardiness and profitability under harsh edaphic and climatic conditions and limited external inputs. The results revealed that fruit plants can be planted successfully with agricultural crops under various hortipastoral systems, soil fertility was improved. Soil organic carbon content was increased by 39.72 % more over initial status. Bulk density, soil pH were reduced and availability of nutrients (N, P and K) were increased significantly. In general, the fertility status of soil in terms of organic carbon, available nitrogen, phosphorus and potash were improved due to intercropping of grass and legume under aonla based hortipasture system. Besides, soil pH was decreased slightly as compared to initial soil content. Further, integrated nutrients supply to pasture species was found to be significant owing to changes in the physiochemical properties of soil under hortipasture system after 10 years of study carry out at the same site. The highest net return of ₹ 30987/ha and benefit cost ratio1: 2.2 was observed under cowpea and *Cechrus* sown underneath of aonla plants in hortipasture system.

Hortipastoral system is one which involves integration of fruit trees with pasture. This is one of the best economic alternatives for dryland to ensure supply of protective food (fruits) for human being and fodder for animal. This also helps in bridging the wide gap between the supply and demand of fruit as well as fodder. Agriculture in India is extensively rainfed where 70% of the cropped land depends on rain water for their survival. Dryland agriculture supports more than 60 % of the total cattle heads in India. Farmers in these areas are small, marginal and resource poor. Animal husbandry based economy is most common in these areas. The fruit plants which are most common to grow in horti-pasture system viz. Aonla (*Emblica officinalis* Gaerton), Bael (*Aegle marmeols* corr.), Custard apple (*Annona squamosa* L.), Karonda

(*Carrisa carandas* L.), Ber (*Zizyphus mauritiana* L.), Mulberry (*Morus* spp.), Date palm (*Phoenix dactyiifera* L.), Pomegranate (*Punica granatum* L.), Guava (*Psidium guajava* L.), Jamun (*Syzygium cumini*), Piyar / Chironji (*Buchanania lanzan*), Lasoda/ Gonda(*Cordia myxa* Roxb) etc. can grow successfully in rainfed lands. These fruit trees are hardy, deep rooted and can tolerate aberration in monsoon like early or late onset, intermittent dry spell, early withdrawal etc. These trees also yield at least something in drought year when seasonal crops totally fail. Therefore, hortipastoral system may be one of the best alternative systems for rainfed/ dry land areas.

Keywords: Aonla, Arid, Ber, Degraded land, *Dicanthium annulatum*, Hortipastoral system, Semi arid, *Zizyphus rotundifolia*

Restoring ecological balance

Hortipastoral system restores ecological balance by greening rainfed/dryland areas through mixture of fruit trees and pasture (grass and legumes) for the persistence and productivity under shaded or low radiation situation. This system also prevents further land degradation, improves the carrying capacity of native grassland and conserves the soil and water etc.

Selection of fruit trees

The fruit tree species should be chosen according to their complementary or less competitive nature with under story-grown crops for limiting resources such as moisture, nutrients, space and light. The fruit tree species like Ber, Aonla,Tamarind, Wood apple, Lahsoda, Date palm, Jamun and Bael are highly suitable for dryland areas and their package of practices are given in Table1.

Table1.Suitable hardy fruit plants along with general cultural operations in them

Particular	Ber	Custard apple	Bael	Aonla	Guava	Pomegranate
Varieties	Gola, Seb, Umran, Mundia, Banarasi, Kadada, Sanaur, Kaithli, Elachi	Balangar, Atemoya, Red, Seeta phal, Mammoth, Island gem, AtmoyaxBalanagar, Red Seetaphal, Pond apple, Chance seedling	Mizapuri, Kaghji, Gonda, Basti, Selection N.A.6,	Banarasi, Krishna, Kanchan, Chakkaiya, Hathi Jhul, Red fleshed, NA-7, Francis	Lucknow 49, Allahabad , Safeda, Chittidar, Safed Jam, Kohir Safed	Ganesh, Muskat, Dholaka, Papershall, Kandari
Propagation	'T' and ring budding	Seed , 'T' budding	Seed, patch budding	Seed, 'T,'patch budding	Inarching, Sttol, Layering	Cutting, air and ground layering
Planting time	July-August	July- August	July-August	July-September	July- August	July- August
Spacing (metre)	6x6	6x6	8x8	8x8	6x6	4x4
Number of plants /ha	256	256	156	156	256	625
No. of years required for optimum production	5	5	7-8	5-7	5	4
Average yield (kg/ tree)	30-40	20-30	300-500 fruit/tree	60-80	50-60	15-20
Approximate profit (₹ /ha)	25,000	20,000	20, 000	35,000	30,000	15,000

Management of fruit trees in hortipastoral system

The success of a hortipastoral model depends largely on efficient management to give optimum performance. Major factors for success of fruit crops in hortipastoral models are related to establishment of young plants, their proper training and pruning, optimum nutrition, protection from adverse agro climatic conditions, diseases and insect/pests. Protection from water stress, intense radiation and damage by pests, diseases and animals, increases success rate in establishment of the young plants. Planting of fruit saplings is done in pits, which are filled with manurial mixture and insecticide to protect from termite. Depending on location, plantation can be done in contour, terraces, trenches, and gullies or at lower ends of micro catchments for effective accumulation of runoff to provide moisture condition in the root system. Shading may be required to protect from intense radiation. In north India protection from cold during winter is important. The hardy nature of some of the fruit trees and their adaptation to shallow soils can be exploited by combining with suitable pasture species as intercrops for drylands. Special care, particularly protection from biotic factors and watering at the seedling establishment stage of these plants, should be taken. It may increase the survivability of these trees to 100 % and at the same time enhance the growth rate as compared to under no watering during the period of initial two years. Jalsakati @ 20 g /plant has been found to reduce the moisture depletion and promote plant growth. Hence, Jalsakati can be a practical and economic solution for moisture conservation for high value plants.

Agri-horticultural systems

Among various land use systems, agri-horti system is the most important in terms of economic returns as well as farmers' preference. Among the various agroforestry systems evaluated, agri-horticulture was found to be most profitable is giving C: B ratio of 1:5.5 followed by silvipasture and agri silviculture. In sub mountain region of Dehradun, peach based agri-horti system recorded higher returns over sole tree. In semi arid regions of central and southern India, many agri horticultural systems have been evaluated and found more profitable than arable crops and fruit trees grown alone. The combinations of fruit trees+ grasses + legumes were found to achieve maximum productivity and more returns from a piece of land besides improving the dietary quality of marginal farmers. This system would also strive to preserve the natural ecosystem for long-term benefits of land use. At CRIDA, Hyderabad, the hortipastoral system with *Cechrus* / Stylo in rainfed condition with guava and custard apple, *Cechrus* yielded 7 t/ha of dry forage during the first year while stylo recorded 5.6 t/ha of dry fodder during the second year of plantation. In Ber based agri-horti system Pearl millet + pigeonpea (Solapur), Pigeonpea + blackgram (Rewa), Castor(Dantiwada) and Clusterbean (Hyderabad) showed promising results in rainfed environment. Ber on an average gave 40 kg fruits/tree along with the 100 kg of horsegram and 450 kg of cowpea cultivated in interspaces. The integrated farming system models with Agri-horti-silvi-duckery-fishery system studies in North-east India showed that multi-enterprise model comprising cereal crops, pulses, oil seeds, horticultural crops (such as mango and pineapple), vegetables and livestock components (duckery, piggery), and fishery with harvesting structures in one hectare of

land gave 5 times more profit than traditional mono rice crop cultivation which gave maximum production of 1t/ha of rice (₹ 5000-6000/ha/year).

Hortipastoral system

Hortipastoral system is one of the agroforestry systems, which involves integration of fruit trees with pasture. This system acts as one of the best economic alternative for dry land and ensures supply of protective food (fruits) for human being and fodder for animals. This also helps in bridging the wide gap between supply and demand of fruit and fodder. Emphasis on the inclusion of multi purpose tree species in pasture system to maintain a viable input-output ratio of energy has been increasing for the last 10-12 years. Trees like ber (*Zizyphus* spp.) and aonla *(Emblica officinalis)* in agri horticultural system were tested for their performance and productivity in combination of grain and fodder crops, respectively. The fruit plants which are most commonly grown in hortipasture system like Aonla (*Emblica officinalis* Gaerton), Bael (*Aegle marmeols* Corr.), Custard apple(*Annona squamosa* L.), Karonda (*Carrisa carandas* L.), Ber (*Zizyphus mauritiana* L.), Mulberry (*Morus* spp.), Date palm (*Phoenix dactyiifera* L.), Pomegranate (*Punica granatum* L.), Guava (*Psidium guajava* L.), Jamun (*Syzygium cumini* Skeels), Piyar / Chironji (*Buchanania Lanzan*), Lasoda /Gonda (*Cordia mixa* Roxb.) etc. can grow successfully in rainfed lands. These trees are hardy, deep rooted and can tolerate aberration in monsoon like early or late onset, intermittent dry spell, early withdrawal etc. These trees also yield at least something in drought year when seasonal crops totally fail. Cultivation of food/ fodder crops is always at risk in arid and semi -arid areas due to unpredictable, measure and erratic distribution of rainfall. Fruit crops, which are permanent establishment, not only reduce the climatic risk but also give remunerative return. Fruit trees planted along with perennial grasses, act as a good soil and water conservation measure particularly on sloppy, degraded and erosion prone lands due to close and packed anchoring of soil,. Prominent fruit tree of the dry areas are Aonla (*Emblica officinalis*) and Ber (*Zizyphus mauritania*), which can be planted in the configuration of 8x 8 m^2 for aonla and 6x 6 m^2 (for ber) in Agri horti pasture system. Perennial grasses *viz.* Anjan (*Cenchrus* ciliaris), Dhaman (*Cenchrus setigerus*) and Sewan (*Lasiurus sindicus*) can be taken in Agri Horti pasture system in dry areas. Such system fulfills the fodder need of farmers along with cash return in the form of fruit (Meena *et al.* 2008). Horti pastoral system with a combination of fruit trees and pasture or legume is ideal land use option for degraded lands. Spacing between trees also affects the productivity. Importance of spacing between trees is evident from the results of research on Guava based hortipastoral system at CRIDA, Hyderabad, where yield reduction of stylo was less under widely spaced trees (8x5 m) as compared to that in case of closer spacing (5x5m), indicating the necessity of wider spacing of fruit trees. In case of wider spacing, buffel grass out yielded with stylo and took less time for establishment when grown with stylo. *Prosopis cineraria* and *Zizyphus nummularia* are another important top feed species. Even in drought years when the crops fail, the top feed of this species comes to the rescue of farmer's animals. In recent past, intensive use of tractor has wiped out the deep rooted bushes from farmer's field. The results of more than eight years' studies (Sharma and Vashishta, 1985) in sandy rangelands at Samdri (western Rajasthan) have shown that plantation of two jujube species, *viz. Zizyphus rotundifolia* and *Z. nummularia* each with three densities i.e. 280, 140 and 70 plants/ ha, with *Cenchrus ciliaris* as pasture grass gave forage yield varying from 624 kg to 844 kg /ha in

different treatments. Different population densities of Jujube in the pasture was found to have no significant effect on the yield of pasture, indicating that even 280 trees /ha can safely be planted. *Z. numularia* started top feed and brush wood production after 4 years. Sharma and Diwakar (1987) worked out the economics of hortipastoral system and found the return to be remunerative even with higher discount rate of interest (20 %) and increased investment cost (25 %). In a continuous grazing system, Custard apple is an ideal option, as livestock does not browse it. Fruit trees like Ber can be grown very well in combination with pasture, as its foliage is very nutritious and palatable. The Ber produces good amount of foliage during lean period of April-May. Whereas in waterlogged and alkaline soils anola is the best suited.

Ber based horti pasture system

Ber *(Zizyphus rotundifolia)* is an important fruit tree of the arid regions. It grows naturally at the farmers' fields and does not compete with the crops. However, budded ber (*Z. mauritiana*) has also been found suitable to grow well under arid conditions when planted either with water harvesting system or with supplemental irrigation. Three year old plantation of ber at a density of 400 plants/ ha in association with greengram performed well with seasonal rainfall of 210 mm only. Intercropped greengram yielded only 160 kg/ha as against 620 kg /ha from pure crop. The fruit yield from the intercropped system was increased in terms of net profit to ₹ 2886 /ha. This shows that this system is generally recommended for areas where rainfall greater than 250-300 mm. In many areas, aonla (*Emblica officinalis*) and pomegranate can be planted under this system. Ber (*Zizyphus mauritiana*) can be adopted for hortipastoral or agri-horti- systems. *Cenchrus*, bajra, moong under rainfed condition and Lucerne and berseem under irrigated conditions can be successfully grown with ensured fertilizer application. In cereal and grasses 40 kg N and 40 kg P_2O_5 and in legumes 25 kg N/ha and 40 kg P_2O_5 /ha should be applied for higher biomass and fruit yield from each plant.

Aonla based hortipastoral system

Aonla is a rich source of vitamin C and have processing value. It is one of the most suitable fruit tree for semi-arid and arid regions of the country. It is planted at a distance of 8 to 10 metres. The inter space of fruit trees can be effectively utilized for growing many intercrops for sustainable productivity. Aonla is a drought hardy fruit tree. Karad grass (*Dicanthium annulatum*) can be grown in the interspace during establishment phase of the aonla. Aonla exhibited steady growth in terms of height and collar diameter during the establishment of first three years (Table 2). The average fruit production after 6th year of planting was 7.5 t /ha (Kumar *et al.* 2002).

Table 2. Forage production under aonla based cropping system

Year	Hortipasture		Pure pasture
	Fruit yield (t/ha)	Pasture production (t DM/ha)	(t DM/ha)
1	-	1.60	1.20
2	-	3.25	2.95
3	-	4.01	3.65
4	-	5.69	5.05
5	2.64	5.63	5.33
6	7.50	4.97	4.61

Supply of leafy fodder and fuel wood

Hortipastoral system can supply fodder to farmers by both ways. Some of the fruit trees, apart from fruit yield they also supplied valuable leaf. These leaves are nutritive fodder for cattle for example ber leaves contain 16 %, lahsoda/ gonad 12.5-15.2 %, sahtoot 15-22 % crude protein and are sold at high prices especially during drought years. In the same way bael, aonla, piyar/ chironji, pomegranate etc. provides palatable fodder to animals. Pasture crops grown in combination and underbeneath fruit trees supply fodder to animals. In case of energy crisis, fruit trees also provide fuel wood from pruning.

Supply of protective food (fruits)

The fruit is good source of protective food, rich in nutrients, particularly vitamins and minerals in human diet. According to dietary standard, an Indian must consume 85 g fruit/ day but availability is only 46g /day which is one of the lowest in the world. To bridge this gap of demand and supply, production will have to be raised through growing hardy fruits in rainfed / dry lands. Since good irrigated lands are already being used for raising high yielding cereals, cash crops, vegetable crops and for industries and housing, the only hope for future lies with semi-arid areas which occupy 70 % of the total cultivated lands.

Soil fertility buildup

The organic carbon content was increased significantly due to intercropping of crops in hortipasture system. However, it was the maximum when legume proportion higher than cereal (0.30%) and minimum (0.27%) where cereal proportion higher than legume (1:2). But pH and EC of the soil were decreased with 2:1 row ratio (7.77 and 0.176) followed by 1:1row ratio (7.86 and 0.228). Besides electrical conductivity was the highest with 1:2 row ratio (0.240). The available N, P and K were increased significantly with different intercropping row ratios. While the maximum was increased in available N, P and K observed with 2:1 row ratio as compared to initial soil content (Meena *et al.*2011). The increase in available nutrients were extended up to 9.17 -15.42 % higher in N, 21.18 -34.35 % in P and 45.26 - 70.64 % in K, respectively. Dwivedi and Kumar (1998) also concluded that productivity of legume based cropping sequences increases due to effective and economic utilization of residual and cumulative carry-over nutrients and moisture. Thus, it is clear indicated that inclusion

of legumes in intercropping system improves the soil fertility status after harvest of the crops as reported by Singh and Singh (2005). Kumar and Shukla (2011) reported that nutritional build up of soil in association with tree was better in all the respect viz. organic carbon, available nitrogen, phosphorus and potash as compared to sole pasture crop. However, the maximum available carbon (20.3%), N (13.5%), P (4.09%), and K (58.45%) was noticed in combination of aonla + *S.hamata*, *S.hamata* is a leguminous pasture species having nitrogen fixing ability through nitrogen fixation.

Economic stability

Arid and semi- arid lands make up over 40 % of the earth's surface on which over one billion people depend for their livelihoods. Besides, these lands are home to the world's poorest and most marginalized people. These areas have the lowest development indicators and the highest incidence of poverty. Continuously declining ratio of livestock to human population, droughts, conflicts and household food insecurity are common features. Many development analysts have argued in the past that pastoral production is not economically rational while nomadic livestock management systems are environmentally destructive, yet that is the main livelihood strategy in these areas. Private farmers cultivate 40 % of irrigated land for horticulture and export oriented crops. Income generating activities are more developed in the semi arid districts. To sustain fruit trees in the dry land horticulture or horti-pastoral systems, it needs generation of adequate income and gainful employment from marginal and degraded lands. Hortipastoral system involves integration of fruit trees with pasture, enabling lopping of trees and grazing understorey so as to ensure supply of quality fodder round the year. Ber based hortipasture system showed that pruning intensities and understorey pasture combinations influenced the benefit: cost ratio of 10 year –old ber plantation (Kumar and Ram, 2009).The maximum B: C ratio over four years of experimentation was recorded when trees were pruned medium (1:3.99) followed by light (1:3.69) and severely pruned trees (1:2.65). Among understorey pasture combinations, Guinea grass with stylo gave maximum B: C ratio (1:1.99) followed by Guinea grass + Dhaman grass+ stylo (1:1.66), Dinanath +stylo (1:1.19) and natural vegetation (1:1.10).This system involves integration of hardy fruit trees with pasture.

Cost of reseeding varies from ₹ 3500-4000/ ha with a return of ₹ 1000 to 2000 /ha in first year but higher returns in subsequent years with little inputs make the reseeding practice cost effective (Table3).

Table 3. Benefit: cost ratio of pasture in arid zone of Rajasthan

Establishment year	Cost (₹ / ha)	Returns (₹ /ha)	B:C ratio
1 year	5050	1250	1:0.25
2 year	2000	2600	1:1.3
3 year	2000	5250	1:2.63
4 year	2000	6250	1:3.13
5 year	2000	6250	1:3.13

Over a period of five years, benefit: cost ratio increases to as high as 1:3.31 (Gajja, 2000). It was found that the pasture production with aonla tree was beneficial as compared to pure pasture. Aonla with natural vegetation and nitrogen application to pasture resulted in increased production and net profit. (Newaj *et al.* 2006) also reported that at the age of 13 years, the B: C ratio from aonla +blackgram was 1:3.28 and pure crop of blackgram was 1:1.23 and pure aonla was 1:1.97. The high value fruit component provides incentive to the farmers and at the same time provides fodder through tree leaves and understorey pasture. Farmers of these regions can get sustained and stable income by growing of fruit trees which also reduce large-scale migration from rural areas to already congested cities and towns

Future prospects

- The main emphasis should be given on local plant species for the development of grass and pasturelands through hortipastoral system.
- Effective utilization of land resources should be made by growing drought hardy top feed fruit species with grasses as per the suitability of the region.
- Identification of suitable fruit plant species for different agro ecological zones keeping in view their leaf fodder palatability and availability during scarcity period.
- Introduction of new plant species from iso-climatic region of the country may also be given due emphasis.
- Integrated approaches should be adopted to achieve higher crop yield through hortipasture cropping systems in arid region.

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Essentiality of Agro-forestry Based Farming Systems in Dang District of Gujarat for Livelihood Security of Tribal Farmers and Environmental Resilience – An Experience with six villages

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ABSTRACT

Study on the sustainability of livelihood of tribal farmers including some activities on environment resilience are being carried out under National Agricultural Project-III in six operational villages of Dang District namely, Sarvar, Sodmal, Kalamkhet, Chikhalda, Motidabdar and Daguniya situated at hilly undulating Terrain of Dangs district of Gujarat. The average annual rainfall of the villages is about 2500 mm .The total geographical area, area under cultivation , forest and pasture land of Sarvar village are 460, 332, 120.5 and 7.5 ha respectively , while those values for Sodmal village are 193.4, 98.6, 84.4 and 10.3 ha respectively, for Kalamkhet are 212.1, 114.1, 90.5 and7.5 respectively, for Chikhalda are 105.6, 34.9, 45.5 and 26.0 ha respectively, for Motidabdar are 738.7, 309.5, 357.6 and 2.9 ha respectively, and for Daguniya values are 871.5, 255.8, 557.6 and 21.3 ha respectively. The villages consist of foothills between the flat alluvial plains and the high mountains of sahyadries. >98% population is tribal in these villages. Villages are treasure of forest resources with exceptionally rich flora and fauna which are considered its strength, while its weakness is its remoteness, backwardness, technological gap, education and demography of the area resulting in poor crop yield (mainly mono-crop) and poor socio-economic status. There is very little scope for horizontal expansion of land. Thus, to improve the livelihood of increasing population of tribal farmers, emphasis must be given on agro-forestry based farming systems with natural resources management keeping in pace with environment. The study revealed that soil texture, soil depth, soil erosion, percent of coarse/ rock fragments, land slope, moisture holding capacity and drainage are major crop production related constraints. While slope (%) of these villages varies from < 2% to 25 percent, erosion of surface soil varies from sheet erosion (E1) to big gully erosion (E4) and depth of major soil ranges between < 0.075 m and > 0.90 m. Major soils are suffering from Rill erosion (E2). Soils of lower elevation were of higher depth and comparatively more productive. Land and moisture conservation through making field bunding, soil+ stone bunding and stone bunding , rain water harvesting and arresting through check- dam and repairing of water tank, constructing small farm pond and irrigation through sprinkler proved to be beneficial .So far as land capability

class villages (including forest) come under the category of IIes to IIesw, IIIs, Ves, IIIes, VIes and VIIes sub-classes. Very gently sloping flat (< 2%) land and very gently sloping flat hill top (2 to 3%) are found marginally suitable (S3) for rainfed rice, finger millet and vari and moderately suitable (S2) particularly during *kharif* rainy season, for sorghum, pigeon pea and ground nut, vegetables like, cabbage, tomato, french bean, peas and cow pea and horticultural crops like, mango, custard apple, guava and cashew nut. Here, activities on scientific dairy, goatery, poultry and fisheries simultaneously with raising agricultural and horticultural crop were found remunerative and could fetch additional income to the tribal farmers towards livelihood security. Though all the above field crops are marginally suitable (S3) in very gentle sloping (3 to 5%, IIIs sub-class) land ,proper land and water conservation measures like, field bunding, soil-stone or stone bunding during *kharif* proved to be much beneficial in terms higher crop yield and environmental stabilization. However ,all horticultural plants as above were found to be moderately suitable (S2) here and raising field crops like, pigeon –pea and ground nut during kharif in conjunction with soil conservation measures not only remunerative but also helpful for environmental stabilization as well. Undulating moderately sloping terrace (5 to 10%, Ves sub-class) was found non- suitable (N1) for all arable crops and marginally suitable (S3) for all horticultural plants with development of conservation measures for good yield and stability of land .Activity on the development of Agro forestry, forest and pasture should be intensified in moderately (10 to 15%) to strongly sloping (15 to 20%, VIes and VIIes sub-classes)land under joint forest management programme with incorporation of Teak, Subabul, Nilgiri, Khair, Kalam, Karanj, Saru etc. and appropriate conservation measures for generation of additional income of tribal farmers with simultaneous environmental resilience.

Keywords: Agroforestry, Farming System, Livelihood, Tribal Farmers, Environmental Resilience

INTRODUCTION

Forests remain the primary source of fodder, fuel wood, timber and non-wood forest products to the forest dwellers and village communities living in and around forest areas. Out of 0.6 million villages in India, around 0.2 million villages with a population of about 350 million are dependent for sustenance directly or indirectly on the forests. The Dang district of Gujarat state comprised of 311 villages and falls under South Gujarat heavy rainfall agro-climatic zone having average annual rainfall of about 2500 mm. Villages of this districts are situated at undulating terrain. About 33% area is covered by forest in this district. Forest resources with exceptionally rich flora and fauna are considered strength of this district, while its weakness remains in remoteness, backwardness, technological gap, education and demography of area resulting in poor crop yield and poor socio-economic status of tribal farmers. Due to lack of knowledge of scientific animal husbandry, goatery, income from such activities as a means of

livelihood support is low. High undulating terrain coupled with inadequate storage facility of rainwater, old/damaged dams and reservoirs and decreased forest cover not only causing huge loss of rainwater as runoff from the zone but also causing large scale erosion of nutrient-rich top soil with runoff water and getting completely washed away from the zone. Major farming community belongs to marginal & small farmers and there is continuous decline in the per capita availability of land day by day because of fragmentation and subdivision of land and increase in population. The income from seasonal field crops alone from small and marginal farm is hardly sufficient now to sustain the farmers' family. Tribal women population have very important role in the agriculture -cum- forest-based economics in this district. To ensure women's productive and effective participation in the development, intensive and sustained training on an on-going basis would be required for them in opening the windows of livelihood opportunities. To meet the ever growing need of increasing population there is very little scope for horizontal expansion of land for cultivation because of decline in the per capita availability of land .The only alternative is to use and manage land and water resources judiciously for sustainability and shift toward vertical expansion and diversification of farm enterprises which have less demand on space and time particularly for small and marginal farmers with very limited resources in rainfed area of Dang district. The only option left is vertical expansion of natural resources over the available land area where two or more component may overlap each other. Thus in order to improve / secure livelihood of tribal farmers in Dang district socio-specific agro-forestry based farming system(s)in interaction with animals enterprises (like, dairy, api-culture, fishery, poultry etc.) which includes natural resources management on should be practiced keeping in pace with environmental stability so as to ensure better utilization of available resources and employment to the farm-family during off season. A study was under taken in the above line since 2008 under National Agricultural Project-III in six operational villages of Dang District namely, Sarvar, Sodmal, Kalamkhet, Chikhalda, Motidabdar and Daguniya situated at hilly undulating Terrain of Dangs district of Gujarat.

MATERIALS AND METHODS:

OVERVIEW OF SITES

Research activities with an objective to improve the overall livelihood of tribal domiciles, are being carried out since April, 2008 under National Agricultural Project-III in six operational villages of Dang District namely, Sarvar, Sodmal, Kalamkhet, Chikhalda, Motidabdar and Daguniya situated at hilly undulating Terrain of Dangs district of Gujarat keeping in pace with environmental resilience. Sarvar, Sodmal , Kalamkhet, Chikhalda, Motidabdar and Daguniya villages situated at latitude and longitude of 20o 50' 55" N & 73o 36'55"E, 20o 51'40"N & 73o 37'10"E , 20o 51'55"N & 73o 36'39"E, 20o 41'7"N & 73o 35'50"E , 20o 42'33"N & 73o 35'58"E

and 20o 38'31"N & 73o 36'6"E respectively. The total geographical area, area under cultivation, forest and pasture land of Sarvar village is 460, 332, 120.5 and 7.5 ha, respectively while those values for Sodmal are 193.4, 98.6, 84.4 and 10.3 ha, respectively, for Kalamkhet are 212.1, 114.1, 90.5 and 7.5 respectively, for Chikhalda are 105.6, 34.9, 45.5 and 26.0 ha, respectively, for Moti Dabdar are 738.7, 309.5, 357.6 and 2.9 ha, respectively and for Daguniya values are 871.5, 255.8, 557.6 and 21.3 ha respectively. Sarvar, Sodamal and Kalamkhet villages come under Sarvar cluster, while Moti Dabdar, Daguniya and Chikhalda villages come under Chikhalda cluster. The average annual rainfall of these villages is about 2500 mm and come under hyperthermic temperature regime with an ustic moisture regime. More than 98% population of these villages is tribal with communities belonging to Bhil, Warli, Kokni, and Gamit tribes. The natural vegetation consists of deciduous forests interspersed with scrub forest which includes Teak (Tectona grandis), Bamboo (Dendrocalamus strictus), and Australian babul (Acacia auriculiformis) and Catch tree/ Khair (Acacia catechu) etc. Other forest species viz., saru, baval, gulmahor, raintree, spethodia, karanj, arjun sadad, subabul, jack fruit, mango, cashew, sapota, tamarind, aonla, ber are also found in scattered form in the forest zone of these villages. The land use consists of Paddy and minor millets as the major crops followed by Blackgram, Groundnut, Vari, Tur, Niger, etc. during kharif and Groundnut, Gram and Vegetables are grown during rabi season. Soil texture, soil depth, soil erosion, coarse / rock fragments, land slope, moisture holding capacity and drainage are major crop production related constraints. Average crop production is low to medium and as a result farmers are socio-economically poor.

So far as heavy rainfall is concerned, on one hand there is problem of management of excess rainfall during monsoon and on the other hand, after the cessation of monsoon right from December-January onwards, villages suffer from acute scarcity of water to meet the demand of tribal farmers for their livelihood and for successful use in agriculture. High undulating terrain coupled with inadequate storage facility of rainwater, old/damaged dams and reservoirs and decreased forest cover not only causing huge loss of rainwater as runoff from the zone but also causing large scale erosion of nutrient-rich top soil with runoff water and getting completely washed away from the zone. In areas nearby to rivers or nalas or farmers having well or bore water facility go for rabi crops.

Geologically, villages come under trappean basalts with litho-units Basalt which is hard in nature. Villages have fair climatic conditions with well defined seasons exhibiting summer, rainy and winter. Soils of these villages are hilly undulating highly dissected piedmont plateau and escarpment slope are shallow with excessive relief. The soils are residual type derived from the trappean basalts. Soils of the valley plains are somewhat deeper; they are medium in texture (gravelly silty clay). In general, soils are stony/ gravelly in surface and severely eroded, non-calcareous with low in water holding capacity and slightly acidic in reaction, mixed in clay minerals, well drained and moderately high to highly permeable. Major soils have developed with a lithic contact

at higher physiographic position except in nearly flat land and in valleys. The soils of the village developed at varying elevation and physiographic position can be considered as the catena soils where landscape is represented by 5 to 6 distinct geomorphic units namely hill top (cap)/flat hill top, escarpment, upper pedimont, mid pedimont, lower pedimont, and nearly flat land/valley soils. As land physiography and crop -related soil constraints vary widely in all the six villages from upper hill top/ hill plateau to nearly flat to flat land, suitability of soils to different crops would obviously differ at different physiographic position. Tribal farmers are quite unaware of modern / scientific know-how of land use and are utilizing land somewhat arbitrarily and non-judiciously for different crops for their livelihood.

The reason for essentiality of agro-forestry based farming systems including natural resource management

In fact agro-forestry based farming systems would play very effective role in the utilization of the natural resources in a most effective manner for sustainable crop production and socio-economic upliftment with livelihood & health security and employment & income generation. The major farming community of these villages belongs to marginal & small farmers, where there is continuous decline in the per capita availability of land day by day because of fragmentation and subdivision of land and increase in population. The income from seasonal field crops alone from small and marginal farm is hardly sufficient now to sustain the farmers' family because of undulating land, shallow soil depth, high amount of gravels / rock fragments in soil, low moisture holding capacity of soils and above all ,poor awareness of modern agro-technology and allied subjects. Moreover, tribal women population have very important role in the agriculture -cum- forest-based economics in this district. To ensure women's productive and effective participation in the development, intensive and sustained training on an on-going basis would be required for them in opening the windows of livelihood opportunities. Thus, to meet the ever growing need of increasing population there is very little scope for horizontal expansion of land for cultivation because of decline in the per capita availability of land. The only alternative is to use and manage land and water resources judiciously for sustainability and shift toward vertical expansion and diversification of farm enterprises which have less demand on space and time particularly for small and marginal farmers with very limited resources in rainfed area of Dang district. The only option left is vertical expansion of natural resources over the available land area where two or more component may overlap each other.

FIELD SURVEY AND SOIL /LAND SUITABILITY:

After collection of preliminary information on the topography, geology, climate and vegetation/crops, a field survey was undertaken in all the six villages through traversing with village cadastral map (1:3960) and also with a base map (1:16666) provided by BISAG, Gandhinagar. In all the villages some road map was finalized

through traversing to cover up the soils at varying physiographic position and elevation for fixing up soil legend like, surface texture range of soil, depth range, slope and erosion classes etc. Inclinometer/ Abney level was used to determine the slopes while, depth of soil was estimated by using different types of augurs. Further, altimeter was utilized in order to know the elevation of land during traversing. The field data recorded on surface texture range of soil depth, depth range, slope and erosion classes etc were digitized on the base map of the soil with the help of scientists of BISAG, Gandhinagar. Considering the limitations and potentials of the soils, land capability classification was evaluated up to capability unit level as per the procedure given by Klingebiel and Montgomery (1966). The severity of limitations were indicated by 1, 2, 3 and placed as land capability units (Dent and Young, 1981). General suitability of soils for growing different field crops and horticultural plants in the village was evaluated based on the field and laboratory data (not reported in this study) of soils taking into consideration all plant growth related constraints using criteria given by FAO (1976).

ACTIVITIES ON PROMOTION OF IMPROVED/ HIGH YIELDING VARIETIES FOR HIGHER PROFITABILITY

Seed replacement activities were done in all the six villages with improved / high yielding varieties of seed for increasing profitability of tribal farmers. Some new crop was also introduced. Crops like, were taken under crop diversification activities. 12 low-cost greenhouses were constructed involving 12 farmers. All these activities were taken up as a part of livelihood improvement.

CROP DIVERSIFICATION AS PART OF LIVELIHOOD IMPROVEMENT

Crops like, soybean, sorghum, ground nut, okra, water melon, elephant foot, ginger & turmeric were sown under crop diversification activity during 2008-09 in Chikhalda village, 2009-10 in Chikhalda, Sarvar, Daguniya and Sodmal village and during 2010-11 in Chikhalda, Sarvar, Daguniya and Sodmal village as a part of livelihood improvement of tribal farmers.

SEED PRODUCTION

Seed production activity was taken up during 2010-11 in Chikhalda, Moti Dabdar and Sarvar village in a area of 2.5 ha with Ground nut crop (Var. TAG 37) involving 25 tribal farmers.

LOW COST POLY/ GREEN HOUSE FOR INCOME GENERATION AND AS PART OF LIVELIHOOD IMPROVEMENT

Total 12 no. of low coast green house were constructed and various vegetables (chilli, Tamato, coriander etc.) and horticultural crops seedlings were raised as source for income generation.

SCIENTIFIC ANIMAL HUSBANDRY

The activity was taken up in collaboration with BAIF for increasing milk production of Buffalo, Goat etc. through related works including healthcare camps, trainings, and supply of nutrient rich animal feed. Poultry activity was also promoted (BAIF being the main partner) as a source of income generation.

WATERSHED INTERVENTION

Activities like, conservation of soil and soil moisture through construction of field bunds(soil), Soil +stone bunds, Stone bunds etc. across slopes in Moti dabdar village (as per planning stated above), rain water harvesting through digging out of small farm ponds (at Sarvar villge), increasing the capacity of old water storage tank(Chikhalda), creation of surface irrigation facility by installation of pipeline through gravity flow (Chikhalda& Moti Dabdar) ,repairing of old damaged check- dams (Motidabdar, Chikhalda, Sarvar, Sodmal), arresting rainwater at nala through development of temporary check-dam(Sarvar, Sodmal, Kalamkhet, Motidabdar, Chikhalda and Daguniya)

VERMICOMPOST/ COMPOST PREPARATION AS A PART OF LIVELIHOOD IMPROVEMENT

Tribal farmers were involved in all the six villages for the preparation of vermicompost/ compost from waste/ natural resources as a part of livelihood improvement.

MICRO IRRIGATION SYSTEM

Micro irrigation system (sprinkler) were installed in collaboration GGRC on 25 no. of farmers plot at moti dabdar village, 2 no. of farmers plot at chikhalda village with a total area of 27 ha in order to increase crop yield, area under irrigation and higher income, while Drip irrigation set was installed on 5 farmers plot (BAIF) with a total area of 2.90 ha at Chikhalda village to ensure higher crop yield and water use efficiency and thereby higher income.

EMPLOYMENT THROUGH VARIOUS PROJECT ACTIVITIES

The farmers were given the opportunity for earning their livelihood through various activities of the project.

VOCATIONAL TRAINING

Tribal farmers and farm women, farmers' sons and daughters were imparted various vocational trainings as a part of skill improvement and for earnings.

EXPOSURE VISIT & TRAINING

Tribal farmers and farm women, farmers' sons and daughters imparted various vocational trainings and also exposed to various research stations, farms of successful farmers for skill and knowledge improvement.

ACTIVITIES ON DAIRY POULTRY ETC.

Activities on dairy and poultry in collaboration with BAIF and organization of animal healthcare camps in collaboration with Vanbandhu Veterinary collage, NAU, Navsari , supplying nutrient rich feed for animals were done as a part of Agroforestry based farming systems.

SKILL IMPROVEMENT THROUGH TRAINING AND EXPOSURE VISIT

Trainings on package of practices of major crops with their suitability under different land physiographic position, scientific animal husbandry, including goatery were taken up for improving skill of tribal farmers and farm women.

Thus, to improve the overall livelihood of increasing population of tribal farmers of this district, emphasis must be given on natural resource management, Scientific animal husbandry coupled with agro-forestry based farming systems keeping in pace with environment. The only option left is vertical expansion of natural resources over the available land area where two or more component may overlap each other.

RESULTS AND DISCUSSIONS:

Land capability classification and land suitability for various crops

The study revealed that soil texture, soil depth, soil erosion, percent of coarse/ rock fragments, land slope, moisture holding capacity and drainage are major crop production related constraints. Slope (%) of these villages varies from < 2% to 25 percent, erosion of surface soil varies from sheet erosion (E1) to big gully erosion (E4) and depth of major soil ranges between < 0.075 m and > 0.90 m. Major soils are suffering from Rill erosion (E2). Soils of lower elevation were of higher depth and comparatively more productive. Tribal farmers, because of their unawareness, are not judiciously utilizing the land for different crops based on their suitability so as to get higher income and also to sustain ecological stability. The land of these villages (including forest) belong to IIes to IIesw, IIIs, Ves, IIIes, VIes and VIIes sub-classes which were further classified to different capability units (**Table 1**) for smaller and more homogenous group of soil that have similar use potential and management requirements.

So, based on field data laboratory data (not reported here) of soils taking into consideration all plant growth related constraints using criteria given by FAO (1976), general suitability of soils for growing different field crops and/or horticultural crops

and/or forest sp. Prevailing in the village was evaluated in order to utilize land properly/ judiciously for higher income and environmental stability.

Result revealed that very gently sloping flat (< 2%) land and very gently sloping flat hill top (2 to 3%) were found marginally suitable (S3) for field crop like rice, finger millet and vari and moderately suitable (S2) particularly during kharif rainy season, for sorghum, pigeon pea and ground nut, vegetables like, cabbage, tomato, french bean, peas and cow pea and horticultural crops like, mango, custard apple, guava and cashew nut along with the land conservation treatments.

Very gentle sloping (3 to 5%) land coming under IIIs sub-class were placed under marginally suitable (S3) for all the above field crops whereby proper land conservation measures is a must during kharif and moderately suitable (S2) for all horticultural plants as above with half-moon bunding around the plants to conserve more moisture.

Undulating moderately sloping land (5 to 10%) coming under Ves sub-class was considered non suitable (N1) for all arable crops and marginally suitable (S3) for all horticultural plants with land conservation measures (7-10 mt apart) as referred in table 4. Here development of half-moon bunding around the horticultural plants would give additional benefits for moisture conservation.

Moderately to strongly sloping (10 to 16%) were found suitable for horticultural plants along with land conservation measures. Strongly sloping (16 to 20% and above) land coming under VIes and VIIes sub-classes were non suitable (N1) for arable crops at all and should be grouped solely for development of agroforestry and/or forest and pasture with incorporation of Teak, Subabul, Nilgiri, Khair, Kalam, Karanj, Saru etc. after appropriate land conservation measures across the slope to minimize erosion and land slide and also for future income generation and environmental stabilization as well.

Promotion of High Yielding/ improved Varieties for higher profitability

Promotion of high Yielding/ improved Varieties for higher profitability of tribal farmers is presented in Table 2. Nine prevailing crops with improved varieties were taken up under study in six approved villages (Figure 1A & B). The highest percent increase in crop productivity and net income per ha were recorded under groundnut (var.GG-2/J-11) in two clusters followed by Paddy, chick pea, Niger, Wheat, Black gram, Nagli, Pigeon pea, Vari in respect of percent increase in yield due to intervention. Though the tribal farmers prefer to sow paddy (depicted 2nd highest in percent increase in crop productivity) and nagli as their staple food in large areas, the results clearly revealed that they should grow groundnut in certain areas along with paddy and nagli during *kharif* and chick pea (under conserve moisture and under irrigation facility) in large area during *rabi* for higher productivity as well as profitability. Sloppy land with high percent of gravels/stone fragments medium to shallow depth and low to medium moisture holding capacity of these soils are the major crop production related constraints.

Crop Diversification as part of livelihood improvement

The results on crop diversification activity as a part of livelihood improvement are presented in figure 2A & B, while the income under this activity is presented in Table 3 crops like, soybean, sorghum, ground nut, okra, water melon, elephant foot, ginger & turmeric were sown under crop diversification activity. The highest net income was obtained under garlic (var. Lal Gojra) followed by okra (var. Hy-152) and groundnut (var. TAG-37) respectively. To generate more income tribal farmers should go for crop diversification with okra and groundnut in maximum possible area during *kharif* and if possible with garlic in certain areas if affordable by them because of its high input cost.

Seed Production

Under seed production activity (Table 4) with groundnut (var. TAG -37), the percent increase in yield over normal crop is presented in figure 3 This activity gave additional income of Rs.23730/- per ha as compare to local crop (maize and Nagli).

Low cost Poly/ Green house

Low cost green house (LCGH) activity (Table 5) has proved to be a successful venture for higher crop profitability [Rs 9500-17000/unit (50 sq. mt.)/annum] through raising seedlings of various vegetable crops like methi, amaranthus, chilli, tomato, brinjal, coriander, cabbage, etc depending upon the type of crop and management. This activity can improve the income of tribal farmers in a large if they can afford the initial expenditure on establishment of LCGH.

Scientific Animal husbandry

Activities on scientific animal husbandry (health care camps, AI, nutrient-rich-feed) were performed which increased avg. milk yield/animal/year from 400.25 to 608.90 lit. (139.55%) in buffaloes, from 250.23 to 308.51 lit. (35%) in goat (figure 4A & B). During the period of last three years total population of cow, goat and buffaloes increased 62.02, 57.69 and 203.59%, respectively over baseline. Higher total milk yield and higher population fetched higher income to the tribal farmers towards improving livelihood. Thus, scientific animal husbandry proved to be an essential component of livelihood which can go simultaneously with agriculture in these tribal villages.

Activity on poultry (figure 5) with selected farmers had shown its huge scope for promotion as there was an average income increase/ farmer/annum was Rs.1913/- with an increase in egg production of 33.33%. Similarly, goatry activity had also shown huge prospects, as there was an increase in avg. income/farmer/annum was Rs. 2238/- with an increase in milk production of 42.85%.

Activities on fishery

Activity carried out 2009-10 on fishery in both the clusters proved highly beneficial. Small fishes worth Rs.2400/- was purchased from office of the fisheries, Valsad and

after making a group of 12 farmers in each clusters fishes were distributed in two groups. Fishes were allowed to grow up for about four and half months in stagnated rain water in both the cluster. The major fishes were recovered at grown up stage and farmers could harvest about 360 kg of fishes (worth Rs.21,600/-, Rs.60/- per kg) for their own consumption as well as for selling in nearby market.

Watershed intervention

Land leveling activity (Table 6) was carried out in 32.5 ha involving 175 farmers of Chikhalda and Sarvar cluster. The result reveled that increase in average crop productivity was to the tune of 18.5% due to this activity.

Soil conservation activities (Stone bunding, soil + stone bunding, field (earth) bunding etc.) out of sloppy land of 847.27 ha suitable for this activity, were carried out in 528 (65.31%) ha of land (Table 7) to check soil erosion, enhance soil moisture storage, higher crop production and possible alteration of cropping pattern. The results indicated an increase in crop productivity to the tune of 19-20%. Through this crucial activity soil moisture storage was found to increase to about 17-22% with reduction in erosion to about 55-60% and thereby made certain areas possible for other / high value crop cultivation (Table 7).

Water harvesting structures

Rain water harvesting and arresting activities through development /construction work of small farm pond, temporary check dam (TCD), Jalkund, repairing of check dams and water storing tank, open well digging, being most essential components of arresting rain water for hilly, sloppy and highly rainfall areas of this terrain, were covered up for the benefit of 138 farmers in Chikhalda and 34 farmers in Sarvar cluster (Table 8). The result reveled that owing to these activities access of soil moisture and water to crop increased which resulted in increased area under crop cultivation in 15 ha and 16 ha respectively at Chikhalda and Sarvar cluster with and average increase in crop production by around 210 kg/ha.

Vermicompost/ Compost

Vermicomposting and composting activity not only proved to be a very good natural resource management venture for these villages but also contributed to the improvement of livelihood of tribal people through generation of income of Rs. 4183/unit /annum (Table 9).

Micro Irrigation System

MIS Activity in the approved villages particularly in Chikhalda cluster proved to be highly pay off intervention in terms of increase in avg. area (7.65 ha) and avg. net income of Rs.4586/- per ha. This activity is of immense importance for these tribal villages in respect to water saving, higher water use efficiency and higher crop production (Table 10).

Surface irrigation

The effect of surface irrigation on increase in crop yield and income are presented in Table 11. The surface irrigation facility increased the average crop yield to the tune of 26% were as the percent increase in income compare to that under conserve moisture was between 23 and 25%.

Employment through various project activities

About 10,000 man-days were created for the tribal farmers and women in carrying out different activities of the project like, Renovation of check dams, repairing of motor foundation structure, digging of farm ponds, making of various types of field bunding, installation of irrigation pipe line, works during camps, shibir, demonstration, etc. up to March- 2011 and the remuneration received by farmers through employment helped in improving their livelihood.

Vocational training

Under vocational Training 46 tribal girls were trained on sewing works and 20 sewing machines were provided from the project at nominal charge basis for their earnings. Training on "Repair and maintenance & field operation" and "Basic wood work" were given separately to ten tribal boys at Bilimora, ITI campus. Another training on "landscaping and gardening" were imparted to 10 tribal boys for six months at NAU, main campus, Navsari as a part of skill development and for income generation.

Exposure visit

1725 numbers of farmers/farm women were benefited through exposure-cum-learning visit organized at different centers of NAU, including KVK, Waghai and other places up to March - 2011, of which 157 numbers of farmers/farm women were especially exposed to Krushi Mela, held at NAU campus, Navsari for three days during 2009 & 2010.

On and off campus training

857 numbers of farmers were educated on package of practices and technologies on different aspects related to Agriculture, Horticulture and Animal Husbandry through on campus training while, 1228 number of farmers were involved in off campus training.

Essentiality of agro-forestry based farming systems

Agro-forestry based farming systems in integration with other income generating components like, dairy fisheries, goatery, poultry, etc. generally play very effective role in the utilization of the natural resources in a most effective manner for sustainable crop production and socio-economic upliftment with livelihood & health security and employment & income generation. The results obtained and discussed above indicated that all the activities on natural resource management of the six districts have increased

the income the tribal farmers of the six districts contributing to certain extent towards livelihood security of tribal farmers with simultaneous stabilization of environment. Because of undulating land and crop production related many constraints field crops alone unable to improved the livelihood to the desired level. It was observed that in the land coming less than 5% slope somehow be allowed for field crops with soil conservation measures, but between 5% to 10% slope have been found not suitable for field crop alone where horticulture plant like Mango, Cashew nut would be better option along with land conservation measures for higher income generation and environmental stability. As animal husbandry activities (Dairy, goatery and poultry) and fisheries had shown a good income generating activities in these villages, all these income generating components should be practiced along with field crop and horticultural crop as per the land suitability in an integrated manner for livelihood security and environmental resilience of these villages of Dang districts.

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Table 1: Land capability class, sub-class and units of six villages

Land capability class	Land capability sub-class	Capability units
II	IIes and IIesw	IIes1s2, IIe2s3, IIe1s2w1, IIe2s3w1
III	IIIs	IIIs2, IIIs3
	IIIes	IIIe1s2, IIIe1s3, IIIe2s2, IIIe2s3
V	Ves	Ve1s2, Ve2s2, Ve3s2, Ve3s3
VI	VIes	VIe2s2, VIe2s3, VIe3s3

Subscirpts 'e', 'w', 's' and 'c' denote main limitations of the hazard of erosion, wetness or accumulation of water, limitations due to soil viz., shallowness, droughtness or stoniness or gravelliness of the soil and the chief limitation in the climate (too cold or too dry), respectively. Severities of limitations were indicated by 1, 2, 3.

Table 2 : Promotion of High Yielding/ improved Varieties for higher profitability

Sr. No	Name of the crops and varieties	Name of the cluster	Area of the crop in the cluster (ha)	Total No of farmers cultivating the crop in the cluster	No of Farmers covered (also in %)	Area covered ha (also in %)	Total Input cost (Rs/ha)	Baseline Av. Yield (kg/ha)	Ave. Yield after intervention (kg/ha)	% Increase in Yield
1	Paddy (GR-7/IR-28)	Chikhalda	118.11	310	499 (160.96)	198.98 (168.47)	2520	1200	1683	40.25
		Sarvar	243	320	663 (207.18)	278 (114.40)	2520	1200	1650	37.50
2	Nagli (GN-4 / GN-5)	Chikhalda	97.61	230	129 (56.08)	26.58 (0.27)	1804	596	660	10.74
		Sarvar	84	266	259 (97.36)	17.5 (20.83)	1804	596	620	4.03
3	Vari (GV-2)	Chikhalda	10.27	140	63 (45)	5.72 (55.69)	817	600	580	-3.33
		Sarvar	20	135	57 (42.22)	9.99 (49.95)	817	600	580	-3.33
4	Blackgram (GG-1)	Chikhalda	57.06	250	225 (90)	11.3 (19.80)	1475	600	644	7.33
		Sarvar	56	290	245 (84.48)	10.8 (19.28)	1475	600	644	7.33
5	Pigeonpea (Vaishali/ C-11)	Chikhalda	47.07	40	98 (245)	15 (31.86)	1945	350	362	3.43
		Sarvar	19	75	339 (452)	18.42 (96.94)	1945	350	362	3.43

6	Chickpea (GG2/ Vijay)	Chikhalda	8.4	140	380 (271.42)	49 (583.33)	2210	950	1200	26.31
		Sarvar	5.75	75	388 (517.33)	72 (1252.17)	2450	820	1080	31.70
7	Niger (NRS-96-1 & Guj-N-1)	Chikhalda	28	56	79 (141.07)	39 (139.28)	1107	1000	1250	25.00
		Sarvar	32	60	144 (240.00)	2.5 (7.81)	1107	1000	1250	25.00
8	G'nut (GG2 / J 11)	Chikhalda	2.6	38	80 (210.52)	14.8 (569.23)	5800	1250	1825	46.00
		Sarvar	1.0	6	14 (233.33)	3 (300)	5800	1250	1780	42.40
9	Wheat (Lok- 1)	Chikhalda	1	12	42 (350.00)	11.5 (1150)	1330	1364	1525	11.80
		Sarvar	0.4	3	10 (333.33)	4.1 (1025)	1330	1277	1490	16.67

Table 3: Income under crop diversification in operational villages under NAIP-III

Sr No	Year	Village	No. of farmers	Crop with variety	Area covered (ha)	Gross income (Rs.)	Cost of cultivation (Rs.)	Net income (Rs.)	Income/ha from traditional crop variety (Rs.)	Additional income as compared to local crop (eg. maize, nagli, vari etc) Rs.	Additional income/ha as compared to local crop (eg. maize, nagli, vari etc) Rs.
1	2008-09	Chikhalda	7	Vegetables & Groundnut	2.8	72738	40738	32000	10700	21300	7607
2	2009-10	Chikhalda	13	Vegetables & Groundnut	5.1	171502.5	96563	74940	23080	51860	10169
3	2009-10	Sarvar	37	G'nut, Vegetable, Sorghum, Soybean	15.3	597322.5	291532.5	305790	80218	225572	14743
4	2009-10	Daguniya	31	Soybean, Groundnut, Vegetable	10.8	389631	205291	184340	60950	123390	11425
5	2009-10	Sodmal	27	G'nut, Vegetable, Sorghum	5.4	188986	103913	85033	31300	53733	9951
										Average additional income/ ha (2009-10)	11572
6	2010-11	Chikhalda	19	Vegetables & Groundnut	6.25	214700.5	118651	96050	29620	66430	10629
7	2010-11	Sarvar	54	G'nut, Vegetable, Sorghum, Soybean	24.6	958617	470167	488450	124645	363805	14789
8	2010-11	Daguniya	61	Garlic, Groundnut, Vegetable, Sorghum, Soybean	26.05	942817.3	495317.625	447500	136510	310990	11938
9	2010-11	Sodmal	42	G'nut, Vegetable, Sorghum	14	524303.7	268983.75	255320	69277	186043	13289
										Average additional income/ ha (2010-11)	12661
										3 year's Average additional income/ha/village	10613

Table 4: Seed production activity for good quality seed and income generation

Sr No	Year	Village	No. of farmers	Crop with variety	Area covered (ha)	Gross income (Rs.)	Cost of cultivation (Rs.)	Net income (Rs.)	Income from general seed crop (Rs.)	Seed stage	Additional income as compared to local crop (eg. maize, nagli etc.)
1	2	3	4	5	6	7	8	9	10	11	12
1	2010-11	Chikhalada	6	groundnut var. TAG 37	0.6	30540	7200	23340	8971	TF	14340
2	2010-11	MotiDabdar	9	groundnut var. TAG 37	0.9	44870	10800	34070	13395	TF	20570
3	2010-11	Sarvar	10	groundnut var. TAG 37	1	51415	12000	39415	14357	TF	24415
				Total	**2.5**	**126825**	**30000**	**96825**	**36723**		**59325**

Table 5: Low cost Poly/ Green house activity for income generation

Sr. No.	Cluster	Village	Cumulative No.of Poly/Green house	Area covered under poly house (sqm)	Activity	Cost of input per poly/green house (Rs)*	Av. Income generated per poly/green house (Rs)
1	Chikhalda	Chikhalda	1	50	Raising of seedlings of various vegetables and horticultural crops like Amranthus, Chilli, Tomato, Palak, Methi, coriander and Subabul seedlings also	6500	9500
		Moti dadar	3	150		6500	8500
		Daguniya	2	100		6500	17000
2	sarvar	Sarvar	4	200		6500	16500
		Sodmal	1	50		6500	13200
		Kalamkhet	1	50		6500	14500
		Total	12			--	--

*Out of 12 green house, the yield are presented from 6 green houses which are operational since 2009-10

Table 6: Effect of Land leveling activity on increase in average crop productivity and cultivated area in two clusters

Type of Work	Cluster	Total area suitable for watershed intervention (ha)	Total No. of farmers	Area covered, ha (also in percentage)	Avg. cost/ha	Increased in avg. Crop productivity (%)	Area increase under cultivation due to intervention (ha)
Land leveling	Chikhalda	30	168	30 (100%)	2000	18.1	30
	Sarvar	5	7	2.5 (50%)	2000	18.9	2.5
	Total	**35**	**175**	**32.5 (92.86%)**	**2000**	**18.5**	**32.5**

Table 7 : Effect of land conservation measures (farm bunding, Soil + Stone bunding and Stone bunding) on average crop productivity in two clusters

Type of Work	Cluster & village	Total area suitable for watershed intervention (ha)	Total No. of farmers covered	Area covered (ha)	Avg. cost/ha (Rs.)	Increase in avg. Crop productivity (%)	Area increased under cultivation due to intervention (ha)
Farm Bunding, + soil stone bunding and Stone bunding	Chikhalda	444.16	237	293 (66%)	11500	18.8 to 20	14.00
	Sarvar	403.11	343	235 (58%)	11500	19.2 to 20	13.74
	Total	**847.27**	**591**	**528 (65.31%)**	**11500**	**19 to 20**	**27.14**

Table 8: Effect of rain water harvesting and arresting (TCD, Small farm ponds, Jalkund, Water tank repairing, Open well, Chek dam repairing etc.) on average crop production in Chikhalda and Sarvar cluster

Sr No.	Cluster	Various activities	No. of farmers covered	Crop area under cultivation before intervention (ha)	Crop area under cultivation after intervention (ha)	Area under benefit (ha)	Increase in avg. Crop production (kg/ha)
1	Chikhalda	A : 4 no. C : 8 no. D : 1 no. E : 1 no. F : 10 no. G : 1 no.	138	600.21	615.21	15.00	218
2	Sarvar	A : 16 no. B : 15 no. C : 3 no.	34	544.73	560.73	16.00	202

Note: A = No. of temporary check dam (TCD) constructed (cost Rs 3000/unit), B= No. of small farm ponds (cost Rs 12000/unit) dugout, C= No. of Jalkund develolped (cost Rs 15000/unit), D = No. of water tank repaired and its capacity increased (cost Rs 16500/unit), E= No. of open well digging (cost Rs 120000/unit), F = Renovation of check dam (cost Rs 45000/unit), G = Motor foundation structure repaired (cost Rs 25000/unit), Avg cost/ structure : Rs.23,806/- (for Chikhalda cluster), Rs.8,029/- (for Sarvar cluster)

Table 9: Income generation through preparation of Vermicompost

Sr. No.	Cluster & village	No. of units established	Total quantity produced (kg)	Income generated (Rs)	Income generated per Unit/Year (Rs.)
1	Chikhalda	12	16100	50700	4225
2	Sarvar	14	17950	58050	4146
	Total	**26**	**34050**	**108750**	**4183**

Table 10: Effect of micro irrigation (Sprinkler and Drip) on various crops for increasing income

Sr. No.	Village	No. of farmers	Potential area for MIS (ha)	Area covered under MIS (ha)	Crop	Previous irrigated area (ha)	Area Increased after MIS	Total area brought under irrigation incl. MIS(ha)	Total income prior to adoption of MIS (Rs.)	Total income after adoption of MIS (Rs.)	Total net increase in income after MIS (Rs.)	net increase in income/ ha after MIS (Rs.)
1.	Moti Dabdar	25	27	25 (Sprinkler)	Chickpea, Groundnut & Paddy (Partial)	27	6.50	33.50 (Sprinkler)	386890	495803	108913	4357 (Sprinkler)
2.	Chikhalda	2	2.30	2 (Sprinkler)	Chickpea, Groundnut, water melon & Paddy	2.30	0.60	2.90 (Sprinkler)	33650	43376	9726	4863 (Sprinkler)
3.	Chikhalda	5	2.90	2 (Drip)	Mango, Cashew & Bringal	2.90	0.55	3.45 (Drip)	28775	43119	14344	7172 (Drip)
Total			32.20	29.00		32.20	7.65	73.35	836205.00	1078101	132983	4586

Table 11: Effect of surface irrigation on increase in crop yield and income

Sr. No.	Name of village	No. of farmers	Name of crops	Total cultivated area under irrigation (ha)	Increase in average crop yield	Percentage increase in income over conserve moisture
1.	Chikhalda	30	Wheat, Gram, & Vegetable crop	27	26%	23 – 25 %

*Surface irrigation facility created through gravitational flow of water from water reserves at elevated point during 2009-10 through installation of PVC pipeline in 27ha (Rs.-7400/ha)

Figure 1A

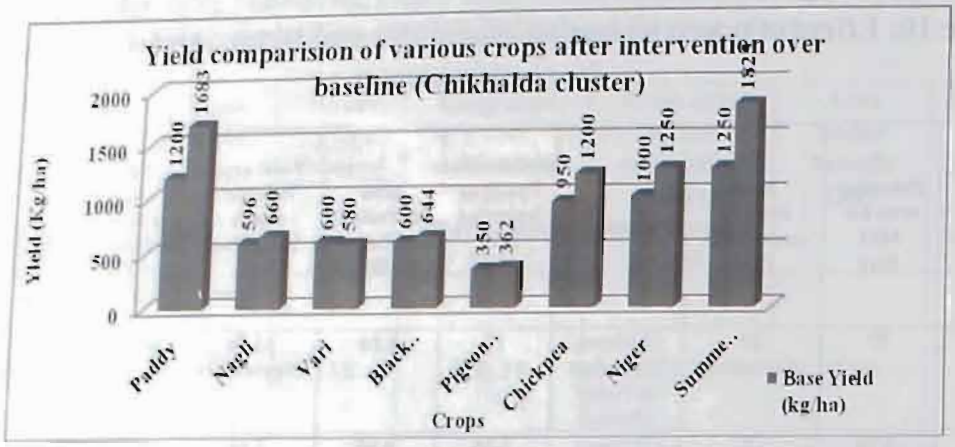


Figure 1B

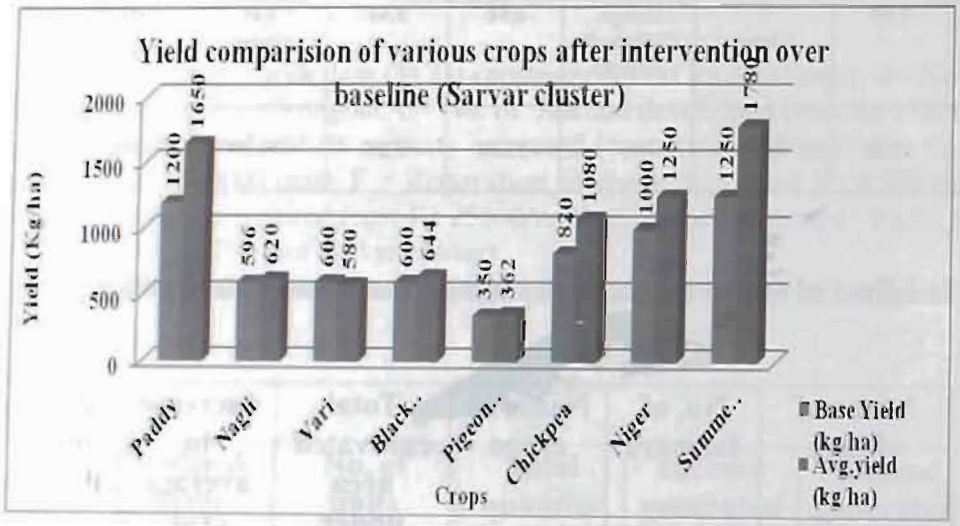


Figure 2A

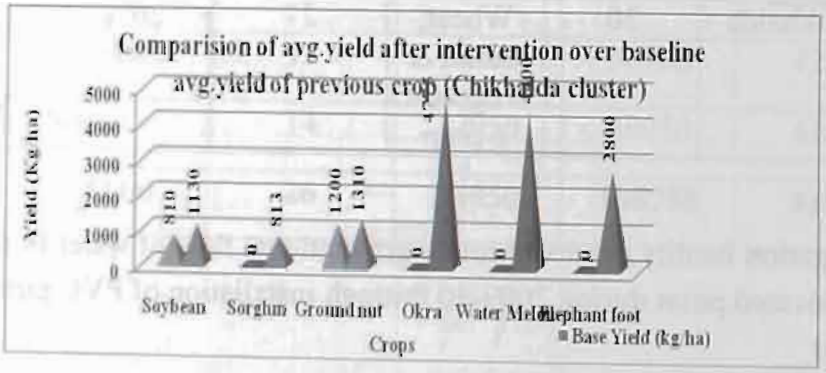


Figure 2B

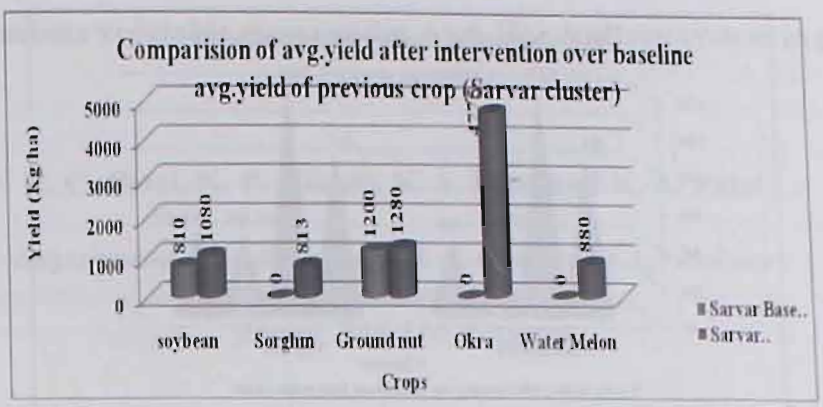


Figure 3

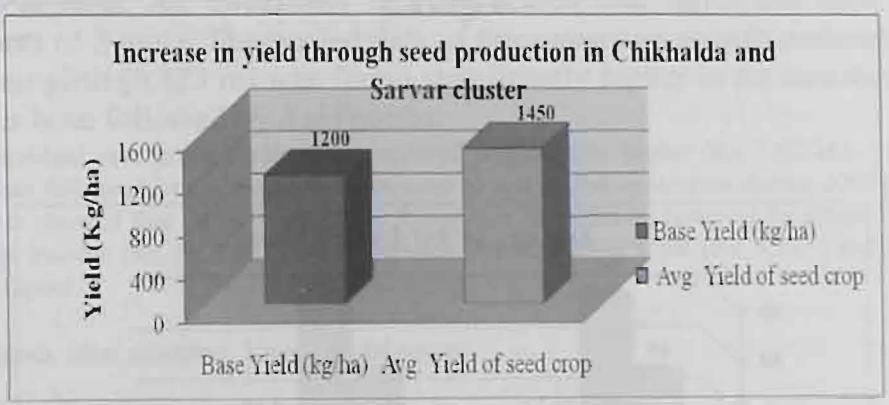


Figure 4A

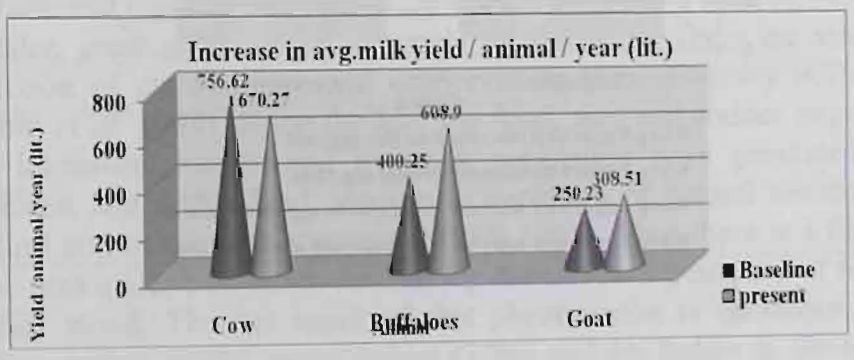


Figure 4B

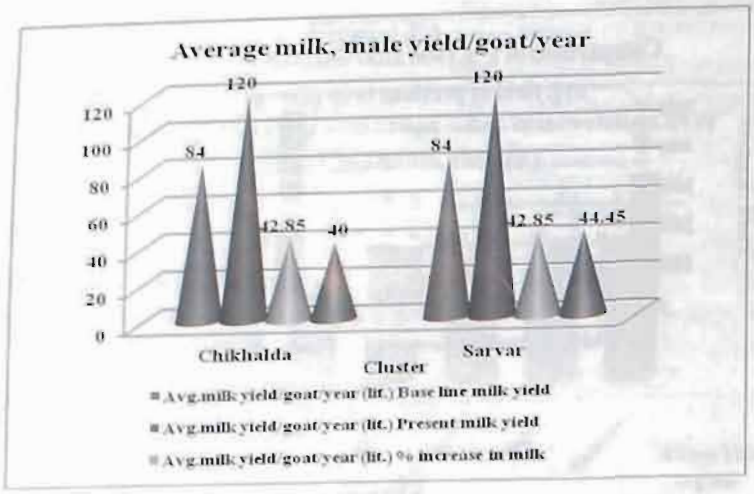
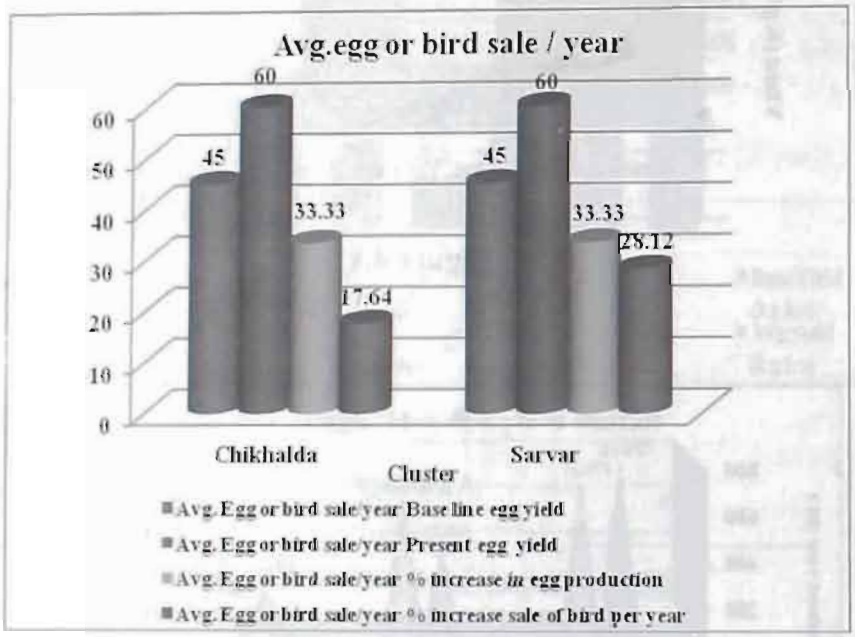

Average milk, male yield/goat/year
120
100
80
60
40
20
0
84
120
42.85
40
84
120
42.85
44.45
Chikhalda
Sarvar
Cluster
Avg.milk yield/goat/year (lit.) Base line milk yield
Avg.milk yield/goat/year (lit.) Present milk yield
Avg.milk yield/goat/year (lit.) % increase in milk

Figure 5


Avg.egg or bird sale / year
60
50
40
30
20
10
0
45
60
33.33
17.64
45
60
33.33
28.12
Chikhalda
Sarvar
Cluster
Avg. Egg or bird sale/year Base line egg yield
Avg. Egg or bird sale/year Present egg yield
Avg. Egg or bird sale/year % increase in egg production
Avg. Egg or bird sale/year % increase sale of bird per year

Influence of various vegetable crops under Agri-Horticulture system in generation of extra income

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ABSTRACT :

A field experiment was conducted to see the effect of various vegetable intercropping on growth and yield of sapota during the years 1998-1999 to 2000-2001 at Horticulture Research Farm, B. A. College of Agriculture, Anand Agricultural University, Anand. The experiment was laid out in Randomized Block Design (RBD) with four treatments. All treatments were replicated four times and each treatment having 2 plants of Sapota. The pooled data of three years on growth parameters shows that only plant girth (0.323 m) was found significantly higher in the treatment T_3- i.e., *Kharif* cluster bean followed by *Rabi* potato.

In individual year gross income was received significantly higher (Rs. 1,02,383/-) in treatment T_4- (Cluster bean followed by Cabbage) as compared to rest of the treatments during 2000-2001. Three year pooled data showed that gross income was found non- significant, however treatment T_4 had given maximum gross income (Rs. 80,906/-), net realization (Rs. 62,375/-), CBR (Rs. 4.39/-) and Net CBR 1 : 3.39 in young sapota.

Keywords: Sapota, Inter cropping, Vegetables, Income

INTRODUCTION

Farming is the main source of livelihoods for the people in rural Asian population. Trees on farmlands or in forests form an integral part of farming system. Both farmlands and forests are important for sustaining human habitations by providing food for nutrition and timber for construction and firewood as a form of energy besides providing fodder, grass and bedding materials for livestock. Trees are also important for the protection of environment and conservation of biodiversity (Gilmour et al. 1991a; Grimble *et al.* 1994). None the less the food, fuel and fodder requirements of continuously increasing human and livestock population have generated enormous pressure on forest and arable land, leading to depletion of natural resources thereby affecting natural and human environment (MPFS 1991). Thus there is a limited scope to increase the area under cultivation for making the increasing demand of food, fodder, timber and fuel wood. The net result of this phenomenon is enormous scarcity of firewood (77%), timber (55%), green fodder (77%) and dry fodder to the tune of 51% (Roy 1999).

Agroforestry is the only viable alternative, which is capable of meeting the present challenges of shortages. It is an integrated land use approach, including cultivation of woody perennials in association with annual crops and holds immense potential to ensure stability and sustainability in production and to provide ecological and economic security as compared to conventional system of mono-cropping. (Toky *et al.* 1989; Gilmour *et al.* 1991a; Gilmour *et al.* 1991b; Thapa *et al.* 1995; Sharma et al. 1995; Singh *et al.* 1997).

MATERIALS AND METHODS

An experiment was carried out at the Horticulture Research Farm, Department of Horticulture, BACA, AAU, Anand, during years 1998-99, 1999-2000 and 2000-01. The experiment was laid out in Randomized Block Design (RBD) with four treatments. All treatments were replicated four times and each treatment having two plants of sapota. Details of treatments are mentioned below. T_1: *Kharif* Okra followed by *Rabi* potato, T_2: *Kharif* okra followed by *Rabi* cabbage, T_3: *Kharif* cluster bean followed by *Rabi* potato and T_4: *Kharif* cluster bean followed by *Rabi* cabbage.

RESULTS AND DISCUSSION

In pooled data of three years on growth parameters shows non-significant results with respect to plant height and plant spread. While in stem girth was significantly maximum (0.323 m) as compared to rest of the treatments.

In individual year treatment T_4- (cluster bean followed by cabbage) gave significantly maximum gross income of Rs. 102383/- in year 2000-01. (Table-2). While in three years pooled data it showed non-significant difference.

Three years pooled data also shows that gross income was found non-significant, however treatment T_4 had given maximum gross income (Rs. 80797). Gross cost of cultivation was found minimum (Rs. 17807) in treatment T_2 followed by T_4 (Rs. 18422). Maximum net realization, Cost benefit ratio and Net CBR were associated with treatment T_4 (62375, 4.39 and 1 : 3.39, respectively). The present study supports the fact that there is an increase in the levels of farm income when the agroforestry system is adapted as supported by other workers in this field (Jain et al. 1999). Similar results were reported by Majumdar (1991) and Kareemulla *et al.* (2002), who reported higher gross and net returns from agri-silviculture system over sole crop system. Reddy and Korwar (1985) and Pathak (1991) also used benefit –cost ratio for evaluating the comparative economics of crops and silvopastoral systems under dry land conditions. The results of this study provided circumstantial evidence in favour of adopting agro-forestry over sole plantation.

Table- 1 : Effect of different intercropping treatments on growth parameters in sapota cv. Kalipatti (Pooled mean of three years)

Treatments	Plant height (m)	Plant spread (m^2)	Stem girth (m)
T_1	2.73	8.79	0.248
T_2	2.50	8.64	0.286
T_3	2.79	9.84	0.323
T_4	2.73	8.34	0.235
S.Em. ±	0.165	1.001	0.021
C.D. at 5%	NS	NS	0.07
C.V.%	20.59	39.89	24.72

Table- 2 : Effect of different intercropping treatments on gross Income in sapota cv. Kalipatti

Treatments	Gross income (Kharif + Rabi)			
	1998-99	1999-2000	2000-01	Pooled
T_1	63957	63962	60957	62958
T_2	82851	36897	70334	63271
T_3	66454	69969	81845	72756
T_4	87906	52103	102383	80797
S.Em. ±	6796	3405	3470	8678
C.D. at 5%	NS	10893	11100	NS
C.V.%	18.07	12.12	08.80	13.79

Table- 3 : Effect of different intercropping treatments on CBR in sapota cv. Kalipatti

Treatments	Gross income per ha (Pooled) (Rs.)	Gross cost of cultivation (Rs.)	Net realization (Rs.)	Cost benefit ratio	Net CBR
T_1	62958	31567	31391	1.99	1 : 0.99
T_2	63271	17807	45464	3.55	1 : 2.55
T_3	72756	32151	40605	2.26	1 : 1.26
T_4	80797	18422	62375	4.39	1 : 3.39
S.Em. ±	8678	-	-	-	-
C.D. at 5%	NS	-	-	-	-
C.V.%	13.79	-	-	-	-

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Economics of Drumstick (*Moringa oelifera Linn.*) based Agri-horticulture system: Implications for enhanced returns and environmental security in Central Gujarat

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ABSTRACT

The Drumstick and drumstick based cropping system have not only been found to be more remunerative than other crops but also this agri-horti system provides environmental services in terms of soil carbon built up and nutrient saving in the soil. This holds promise for agro-ecosystem of central Gujarat, which has predominant tobacco mono cropping system that is averse to soil conservation. Besides saving in irrigation water, the cropping systems enhances returns over variable cost by 46%, saving in soil nutrients valued at ` 621 $ha^{-1}$ and sustained soil carbon built up valued at ` 27720 ha^{-1}. This environmental service provided by drumstick based agri horti system is an economic benefit to society against the traditional tobacco crop in the region, with implications for resource conservation and environmental security. This not only suggests the scope of an alternative cropping system to tobacco mono cropping system for tobacco growing farmers but also make it legitimate effort in view of the national action framework to find alternative crop after signing the Framework Convention on Tobacco Control of World Health Organization.

Keywords : Economics, Returns over variable cost, Resource Conservation, Environmental security

INTRODUCTION

Decision to include agro-forestry/ agri-horticulture in crop programmes world over is necessitated by various dynamic and sustainability factors such as soil health, soil degradation and nutrient loss prevention (Reddy *et al.* 2009). Indian agriculture is pre-occupied with second generation problem debate including lowering of water-table, nutrient imbalance, soil degradation, salinity, environmental pollution and decline in farm profit. Shifting from mono cropping system to tree based system holds lot of promise in alleviating these problems apart from fulfilling other objectives (Gill

and Ahlawat, 2006). In fact, crop diversification now forms an effective strategy for many of the major ailments of developing country such as India for food security, poverty alleviation, employment generation, sustainable agricultural development and environmental improvement (Hegde *et al.*, 2003).

Tobacco is main crop of central Gujarat. The system of long fallow during intensive period of rainfall and before taking of tobacco is a prominent practice in the region. This system contributes to severe soil erosion as splash and excess runoff from bare soil results in loss of soil organic matter and nutrients (Singh, 2006). The annual rainfall pattern of the region further suggests further delaying tobacco transplantation beyond 218th Julian day which could further put a pressure on soil health (Patel *et al,* 2010). To reduce soil erosion, increase cropping intensity and crop productivity, *kharif* legumes are essential for developing any diversified cropping system for the region. A substitute perennial horticultural crop, which does not require frequent primary and secondary tillage operations like field preparation and interculture for optimum production can be tried for enhanced returns and resource conservation in this part of the Gujarat state. In this context, introduction of drumstick (*Moringa oelifera Linn.)* plant along with kharif legume in the existing cropping system is a better and promising option as compared to cropping systems like pearl millet – fallow, peal millet – wheat, paddy – wheat, maize –wheat and sorghum (fodder)–wheat in terms of resource conservation. The glory of green revolution is under stress as the cereal-cereal cropping systems have also led to several new challenges like decline in factor productivity, degradation of lands and water resources, diminishing biodiversity, depletion of ground water table, increase in environmental pollution and resultant climatic changes (Sharma *et al.*, 2003). Moreover, continuously growing of same crops on same land with unbalanced N driven fertilizer practice has not only resulted into mining of macro nutrients but has also led to the multi micronutrients deficiencies.

While resource conservation particularly in the marginal lands susceptible to degradation could also be a significant factor for shifting to resource conserving cropping system considering the water footprint of crops, efforts to study this aspect have been few (Reddy *et al,* 2009). In this perspective, water saving in rainfed areas could be a strong reason for crop diversification. Crops like tobacco with total water footprint of 2925 m^3t^{-1} does not stand a chance against vegetables with a water footprint of 322 m^3t^{-1} (Mekonnen *et al,* 2011).

There is, therefore, a need for of mono cropping system like tobacco to a potential cropping system such as drumstick based agri horticulture so that the system is comparatively more beneficial in terms of profitability, employment generation, lesser water use, balanced cropping system, improved soil health and ecosystem, takes care of resource sustainability. The change suggested should essentially be technologically feasible and economically viable. The cost and net returns (Rehman *et al.*, 2007), and labor intensiveness (De Graaff *et al.*, 2008) are some of the factors affecting the decision of farmers for diversification and adoption of such technologies. Farmers, nevertheless, are willing to adopt any new technology if the technology is compatible with their local conditions (Wejnert, 2002; De Graaff *et al.*, 2008).

Keeping these in view, an attempt was made to identify an alternative cropping system with potential of not only high production but also resource conservation in central Gujarat. Further, Gujarat govt. is planning to release Narmada water for limited irrigation for the crops of low water requirement in the ravine zone IV, under which about 1,36,709 ha of gullied lands are covered in Anand Baroda, Kheda and Panchmahals districts. Development and management of such fragile lands with sustainable production system is a big challenge. Therefore, the present research on crop diversification with introduction of drumstick and spice crops of cumin and fennel in the cropping system for productivity and sustainability in central Gujarat was taken up at the research farm of Central Soil & Water Conservation Research & Training Institute, Research Centre, Vasad. Drumstick is very good vegetable and medicinal crop perennial in nature, grown by raising nursery and transplanting 25 days seedlings. It starts flowering and fruiting after 4-5 months of transplanting.

MATERIALS AND METHODS

An experiment was conducted for four years (2003 -2007) at Research farm of Central Soil & Water Conservation Research Institute, Research Centre, Vasad under irrigated conditions. Six treatments (i) tobacco (control), (ii) pure drumstick (block plantation) (iii) pure Aonla (block plantation), (iv) Drumstick + green gram – cumin (first two years) and green gram - fennel (subsequent years), (v) Aonla + green gram-cumin (first two years) & green gram – fennel (subsequent years), (vi) green gram-cumin (first two years) and green gram- fennel (subsequent years) were studied in completely randomized block design with five replications with plot size of 21m x 80m. The experimental soil was sandy loam and alluvial in nature, very deep, well drained with 0.36% organic carbon, 42 kg ha^{-1} available phosphorus, 230 kg ha^{-1} available potassium and having pH 7.8 and EC 0.18 dSm^{-1}. In first year, after imposing lay out plan, crops were sown according to the treatments.

Drumstick (*Moringa oelifera Linn.)* CV –Multiplex and grafted Aonla (*Emblica officinalis Gaertn.*) CV-NA-7 seedlings were transplanted in the standard size pits dug at 3m x 4m and 7 m x 8m distance, respectively as block plantation and as alley cropping system in green gram–cumin /fennel cropping as agroforestry systems. After Kharif green gram (*Phaseolus radiatus L.*) CV, K-852, Rabi cumin (*Cuminum cyminum Linn.*) CV, G-1 was taken during first two years and fennel (*Foeniculum vulgare Mill.*) CV, G F-1 during two years of second rotation as agroforestry system with drumstick and Aonla. The cropping system of green gram – cumin (Ist rotation) and greengram - fennel (2^{nd} rotation) was followed as cumin did not succeed.

Plantation crops were raised on pits of 75cm x 75cm x 75cm size, dug at 4m X 4m spacing Transplanting of seedlings was done in the month of July after good soaking rains and saturation of soil profile. 100 gm ammonium sulphate + 200 gm single super phosphate + 100 gm potassium sulphate was applied annually per tree during mid of July every year, after first year of planting. Drumstick was pruned every year up to the height of 1.75 m in the middle of June and had little shade effect especially on *Kharif* crop of green gram. Fennel (*Foeniculum vulgare Mill.*) cultivar G F-1 was grown as an alley cropping system in between two rows of drumstick. Twenty to twenty-five days old seedlings were transplanted at row spacing of 70 to 75 cm apart. 20 kg Nitrogen + 30 kg P_2O_5 + 20 kg K_2O as a basal dose and 20 kg Nitrogen were applied as top dressing in two splits. Four irrigations each of 40 to 45 mm depth are

required. Two weedings and soil working are done at 20 and 40 days after sowing/transplanting. All the pure and alley cropping system was raised in a plot size of 20m X 16m.

For comparison Bidi tobacco (Nicotiana tabacum L.) CV, A-119 was grown as prevailing major crop of the region. Recommended rate of fertilizer *i.e.* 180 kg ha^{-1} N was applied in tobacco crop.

Green pods of Drumstick, grain yield of green gram, cumin, fennel and cured leaf yield of tobacco and weight of drumstick pruned materials were periodically recorded. The organic carbon was estimated using Walkley and Black wet digestion method (Jackson, 1967) to know the organic matter build up in the soil after completion of each cropping system (P_2O_5 and K_2O). Drumstick crown was pruned and dry weight of stem and branches were recorded. Standard package of practices was followed for tobacco, green gram, cumin, fennel, Drumstick and Aonla cultivation under irrigated condition.

The input – output data on Drumstick, Aonla and crops were analyzed based on the prevailing market price of the year 2011 to work out the economics of the pure crops and agroforestry systems.

RESULTS AND DISCUSSION

I Crop production and plant growth parameters

Green gram –Cumin cropping system in rotation I

The data recorded in rotation I with cumin is presented in Table 1. It is revealed that green gram yield from drumstick + green gram - cumin cropping system was higher than the treatment Aonla + green – cumin. It could be ascribed to build up of higher soil organic matter content (Table 1) and higher biological nitrogen fixation and phosphorous solubilization because drumstick is a legume crop. The drumstick, with deep rooting system, does not compete with crop. During that period the soil moisture is not a limiting factor for growth and development. Cumin crop, however, was badly affected by bacterial blight and failed during both the years. This was, therefore, replaced with fennel crop in the subsequent year.

Green gram –Fennel cropping system in rotation II

In second crop rotation with fennel crop, similar type of yield trend was observed. More grain yield in green gram was recorded from Drumstick +green gram-fennel cropping system than that of pure crop of green gram – fennel. Because aonla cannot be pruned like drumstick and it provided shed to the green gram and the grain yield was adversely affected. The fennel crop was successfully grown during first and second years of second crop rotation and high yields were recorded from pure green gram – fennel and drumstick+green gram - fennel cropping systems. During *rabi* season the shed and root effect might be limiting factor for the marginal reduction in the yield of fennel crop.

Plant growth parameters

The growth parameters of horticulture crops, aonla and drumstick is presented in Figure 1 reveals that while the collar diameter and canopy of aonla in pure plantation has shown increasing trend, the same in drumstick has achieved a plateau. This has implication for shade effect of horticulture plant on companion crop. In fact, drumstick plant does not interfere with companion crop for shade effect. Similarly, the number of branches are comparatively much higher in drumstick plant as compared to aonla. This has an added advantage of fuel and fodder production.

II Returns from crop production

Net returns over fixed cost realized under different cropping systems revealed that green gram –cumin realized a return of Rs 14545 ha^{-1} where as drumstick + green gram-cumin and aonla + green – cumin gave returns of Rs 29378 ha^{-1} and Rs. 1705 ha^{-}, respectively. Pure drumstick plantation is most profitable system with a net return of Rs. 53953 ha^{-1}, followed by drumstick + green gram – fennel with a net return of Rs. 52928 ha^{-1}. The green gram - fennel cropping system yielded a net return of Rs. 33453 ha^{-1}. On the other hand tobacco gave a net return of Rs. 36231 ha^{-1}. Only drumstick and drumstick + green gram – fennel fared better than tobacco in terms of profitability (Figure 2).

III Saving in Irrigation Water

Drumstick is a rain fed horticultural crops and does not require additional irrigation water for normal growth and development. It thrives well under middle Gujarat region without irrigation. Growing of Drumstick as alternate crop for tobacco in the region may save 100 % irrigation water and may be used for growing of other irrigated crops. In this way area under irrigation can be increased. Further, green gram a cover crop grown in *kharif* being rain fed reduces the risk of soil erosion. Fennel crop (100 days) requires four irrigation of 45 mm each, where as tobacco (180 days) required eight irrigation of 75 mm for maturity (600mm). Growing of green gram- fennel saves about 70 per cent water which may be made available for other crops in the region.

IV Resource sustainability and its valuation

It was revealed that against the traditional cropping system of tobacco a soil carbon built up of 0.18% and nutrient saving of 18 kg ha^{-1} P_2O_5 and 31 kg ha^{-1} K_2O was observed in drumstick against tobacco (Table 2). This not only saves soil nutrients valued at ` 621 $ha^{-1}$ but also sustains soil carbon valued at ` 27720 ha^{-1}. This environmental service provided by drumstick based agri horti system is an economic benefit to society which is not provided by the traditional tobacco crop in the region.

DISCUSSION

The World Health Organization Framework Convention on Tobacco Control (WHO FCTC) negotiated under the auspices of the World Health Organization was developed in response to the globalization of the tobacco epidemic. Article 1 of the FCTC requires that the parties to the convention, among other measures, reduce the production of tobacco in their countries. The FCTC, therefore, requires that alternative crops to tobacco be researched upon so that the farmers who depend on tobacco for

their livelihood, can have alternative sources of income. India ratified the convention on 5 February, 2004 and hence, is bound by the convention. The framework for national action envisages finding an alternative crop to tobacco. Tobacco in India, as in many other countries, yields higher net returns per unit of land than most other cash crops, and substantially more than food crops (FAO, 2003). Yet, following the increasing health concern about tobacco consumption, the central Ministry of Agriculture has not launched any development scheme for the crop since the completion of the Seventh Five-Year Plan (1985–90). Under, this circumstance, research work is needed on a wider scale to find alternative cropping systems for tobacco growing farmers. On farm research suggests profitability of such alternative systems. However, efforts are needed to replicate these attempts at farmers' field level before firm recommendations can be made about them. It is apprehended that should tobacco farmers diversifies into other crops, they are likely to suffer economic hardship. The research efforts at research farm, Vasad nullify this and suggest scope of an alternative cropping system based on drumstick.

CONCLUSION

The Drumstick and drumstick based cropping systems, have not only been found to be more remunerative than tobacco but also this agri-horti system provides environmental services in terms of soil carbon built up and nutrient saving in the soil. This holds promise for agro-ecosystem of central Gujarat, which has predominant tobacco mono cropping system that is averse to resource conservation. This not only suggests the scope of an alternative cropping system to tobacco mono cropping system for tobacco growing farmers but also make it legitimate effort in view of the national action framework to find alternative crop after signing the Framework Convention on Tobacco Control of World Health Organization.

ACKNOWLEDGEMENTs

The authors thank the Director of the institute for providing required facilities and encouragement to do the research work at the Research Farm of the centre at Vasad. The funds provided by the institute to lay the experiment at the farm made it possible. The technical support provided by the staff of the centre is duly acknowledged.

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Table-1: Yield of crops (kg ha^{-1}) under different cropping systems with cumin and fennel (rotations I & II)

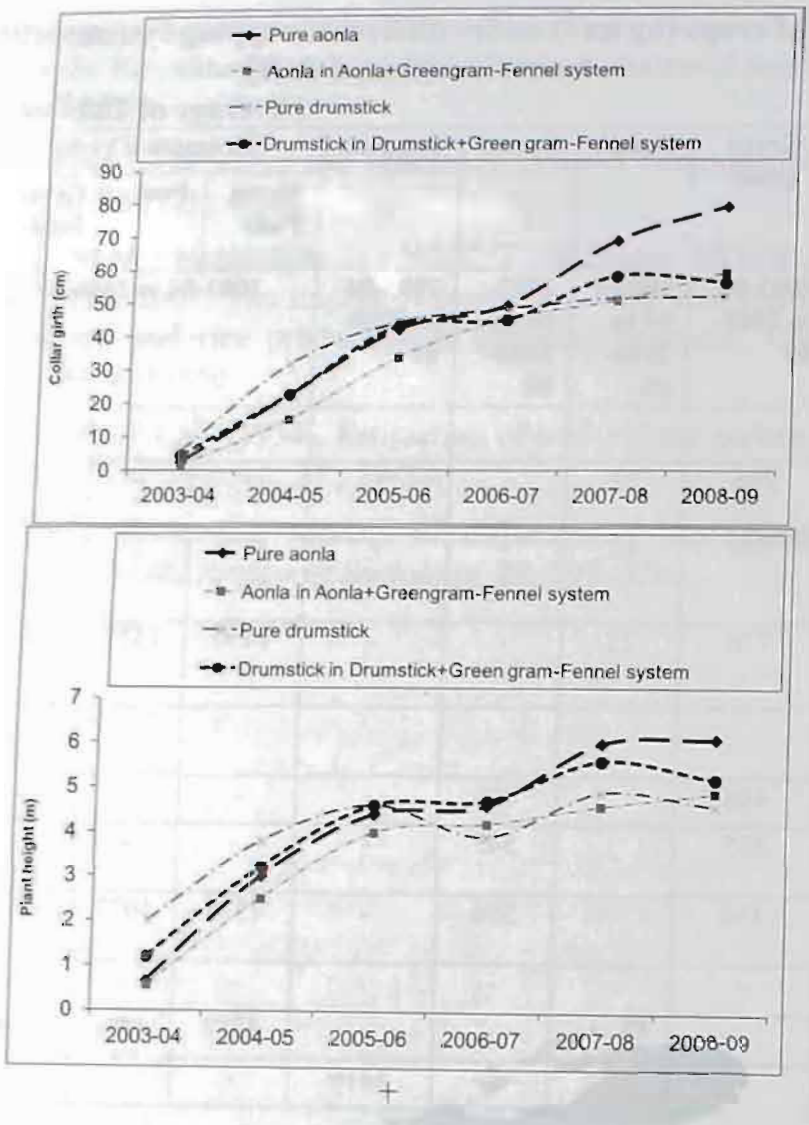
(Average of 2003-04 and 2008-09)

Treatment	Green gram	Cumin	Fennel	Tobacco	Drumstick Yield			Aonla Yield		
					Green Pods	Fuel	Green fodder	Green Pods	Fuel	Green fodder
Period of study	2003-04 to 2008-09	2003-04 to 2004-05	2005-06 to 2008-09	2003-04 to 2008-09	2003-04 to 2008-09			2003-04 to 2008-10		
Rotation I (With cumin)										
1. Green gram-Cumin	706	52	-	-	-	-	-	-	-	-
2. Aonla +Green gram – cumin	776	12	-	-	-	-	-	*	*	*
3. Drumstick +Green gram –Cumin	776	22	-	-	1450	1339	4499	-	-	-
Rotation II (With fennel)										
1.Greengram-Fennel	408		606	-	-	-	-	-	-	-
2.Aonla +Green gram – Fennel	355		545	-	-	-	-	335	626	-
3.Drumstick +Green gram –Fennel	430		596	-	1578	1077	2287	-	-	-
4. Aonla	-		-	-	-	-	-	1064	1119	-
5. Drumstick	-		-	-	5272	4491	7640	-	-	-
6. Tobacco	-		-	1476	-	-	-	-	-	-

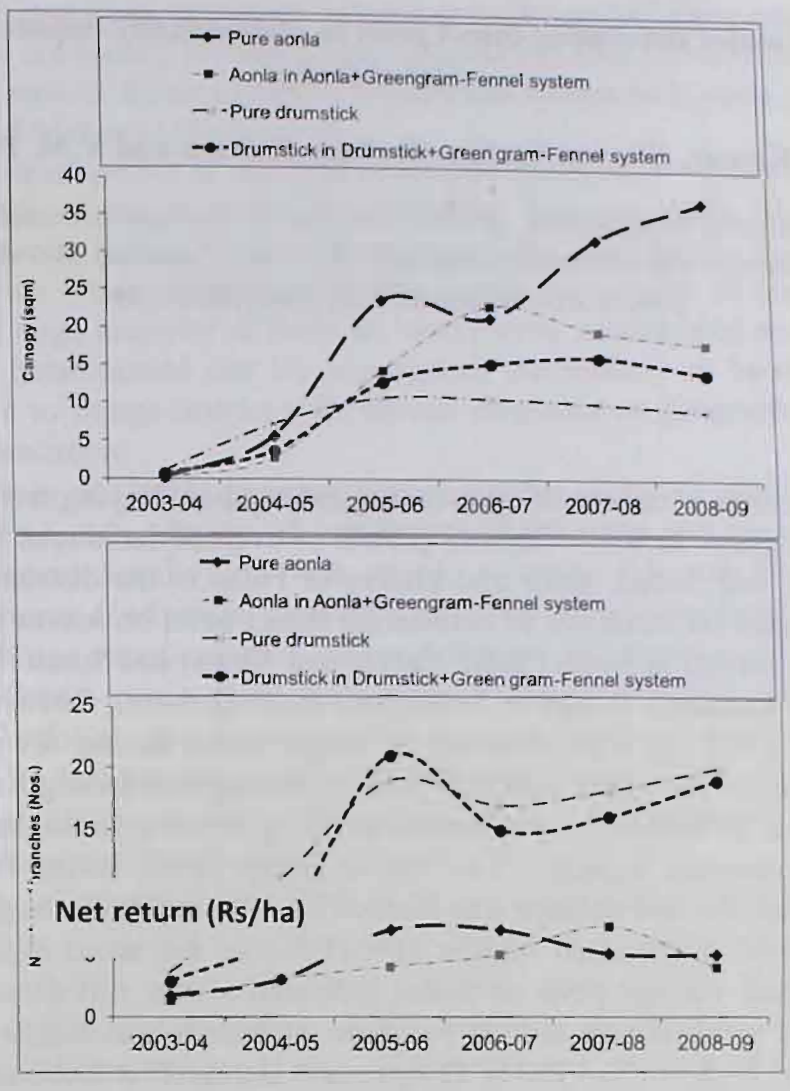
* Plants did not bear fruit, fruiting started during 2006-07

Table 2: Soil Organic Carbon (%), P_2O_5 and K_2O content under different treatments after four cropping cycles (2003-07)

Treatment	Organic Carbon (%)	P_2O_5 (kg/ha)	K_2O (kg/ha)
1.Green gram-Cumin/Fennel	0.40	74	234
2. Aonla	0. 32	49	277
3. Aonla +Green gram –Cumin/Fennel	0.39	68	259
4.Pure Drum stick	0.59	80	285
5.Drum stick + Green gram-Cumin/Fennel	0.49	83	283
6. Tobacco	0.41	62	254



(a) Collar diameter (cm)
(b) Plant height (m)



(c) Plant canopy (m^2)

(d) Number of branches (Nos.)

Figure 1: Plant growth parameters of Aonla and Drumstick

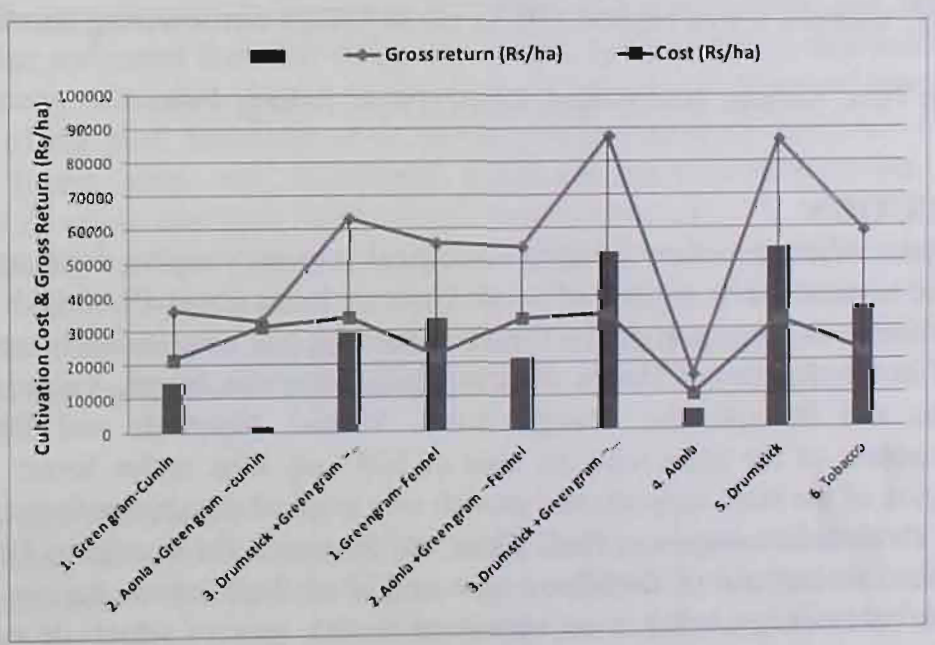


Figure 2: Cultivation cost and gross returns from different cropping systems

Incidence of major defoliating insect pests in economically important forest tree species of Dangs

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ABSTRACT

Gujarat offers a variety of agro-ecological regions varying from arid Kutch to tropical South Gujarat. In south Gujarat, growth of tropical deciduous forest is typified by teak, sisham, hed, sadad, khair and khakra or Palas in the district of Dangs. The roving survey based on incidence of defoliating insect-pests on leaves (newly emerged and mature) was carried in North (Subir, Sarvar and Ahwa) and South (Chichinagavtha, Shamgahan and Galcund) Dangs at fortnightly interval during 2010-11. Lowest leaf damage in teak (3.33 %) was observed in Dangs north during second fortnight of December, whereas it remained highest (73.33 %) during first fortnight of September at the same location. In Sisham, it was lowest (5.00 %) in first fortnight June in Dangs north, while it remained highest (73.67 %) in Dangs south during first fortnight of September. In Hed, the leaf damage was lowest (1.67 %) in first fortnight of January in Dangs north, while it remained highest (60.00 %) in the same region during first fortnight of August. Foliage pests on Sadad indicated lowest leaf damage (3.33 %) in Dangs north and south during second fortnight of March and January, respectively, while it remained highest (76.33%) in Dangs north during first fortnight of August. In Khair, lowest leaf damage (1.67%) was noticed during first fortnight of June in Dangs south, while it remained highest (36.67%) during first fortnight of August in Dangs North. In Kesuda or Khakhro or Palas, lowest leaf damage (1.33%) was observed in Dangs north and south during second fortnight of May and first fortnight of April, respectively, whereas it was highest (70.33 %) in Dangs north during second fortnight of August.

Keywords: Teak, Sisham, Hed, Sadad, Khair, Palas, Foliage Pests

INTRODUCTION

Gujarat offers a variety of agro-ecological regions ranging from arid areas of Kutch to the tropical forest regions of South Gujarat. It has about 19.66 lakh hectares of land under forest. A large part of the forest cover which is economically exploitable is distributed in the districts of Dangs, Panchmahals, Bharuch, Surat, Valsad, Junagadh, Sabarkantha and Banaskantha. Dangs, Surat, Valsad, Narmada and Bharuch, the southern districts of the state have an area of 5041 sq. kms under forest. The South Gujarat region of the state supports the growth of a tropical deciduous forest typified by teak, Hed, *Terminalia tomentosa*, Hed, Khair, etc for which the district of Dangs is well known. These forests are of decidious type and shed their leaves during March and April. Teak (*Tectona grandis*) is an important timber species which drops its leaves only in the cold weather in localities which are relatively dry or cold, but is almost evergreen in the moistest parts of its distribution.

The other important tree crops belonging to Group "A" from commercial point of view in Dangs are mainly Sisham (*Dalbergia sissoo*), Hed (*Adina cordifolia*), Sadad (*Terminalia tomentosa*), Khair (*Acacia catechu*) and Khakra or Kesuda or Palas (*Butea monosperma*) and Mahuva (*Madhuca* sp.).

All these tree species at one time or another are hosts of variety of insect-pests. Amongst them, defoliator, leaf skeletonizer, stem borers in Teak, Sisham and Hed cause huge economic losses. Some of them have been identified on the basis of some preliminary survey work carried out by the Forest department of the Gujarat state, however by and large majority of them are unexplored, unidentified and no systematic study has ever been carried out by any agency particularly in South Gujarat with special reference to Dangs district with special emphasis on geographical distribution and seasonal abundance.

Arguedas *et al* (2004) reported twenty species of insect (48%), 18 species of pathogens (43.9%), two species of vertebrates (4.9%) and one species of mistletoe (2.4%) (Lorathaceae Family) on teak wood, whereas, Ali and Chaturvedi (1996) recorded bark borer (*Indarbela quadrinotata*), teak defoliator/skeletonizer (*Hyblaea puera* and *Eutectona macahaeralis*), sissoo defoliator (*Plecoptera reflexa*), Karanj leaf miner (*Lithocolletis virgulata*) on teak wood (Tectona grandis), sisham (*Dalbergia sissoo* and *D. latifolia*), and *Gmelina arborea*. It is estimated that they cause annual losses of about Rs 100 per square mile of workable forests in India (total bout Rs 12.5 million) (Mathur, 1977). Similarly, Chey Vun Khen (2000) assessed the losses to the tune of 44 % in terms of wood volume growth.

Majority of these forest insect-pests are highly host specific, however teak defoliator (*Hyblaea puera*) has also been recorded on Fountain tree (*Spathodea campanulata*) (Amin and Upadhaya, 1976) and cotton (Chakravarthy and Puttarangappa, 2003). Roychoudhury (1999) similarly recorded incidence of *H. puera* on 15 trees sp. of Bignoniaceae, 13 sp. of Verbenaceae and one each of Juglandaceae and Oleaceae. Observations revealed that all these host plants serve as food for *H. puera* during population outbreak.

The outbreaks of the teak defoliator *H. puera* are generally observed with early seasonal rainfall which confirms positive correlation between defoliator incidence and rainfall (Bhowmick and Vaishyampayan, 1986) and (Loganathan and David, 1999). They further indicated that that delay in rainfall led to delay in defoliator incidence. Wind velocity was also found to have some degree of positive correlation with incidence of the pest. Meshram *et al.* (1990) studied seasonal incidence of 10 insect-pests of forest trees *viz*; defoliator (*Hyblaea puera*), skeletonizer (*Eutectona machaeralis*), white root grub (*Holotrichia serrata*) on teak.

Looking to the regular occurrence of insect-pests of varied group and the economic losses they cause on valuable tree species *viz:* Teak wood, Sisham, Hed, Palas, Sadad and Khair, investigation based on occurrence and distribution of these pests in Dangs tropical forest ecosystem has been carried out so as to know the status of these pests.

Materials and Methods

Roving surveys were carried out on teak, sisham, hed, sadad, khair and kesuda **or** palas or khakhro trees in two distinct forest regions *viz:* Dangs North (Subir, Sarvar and Ahwa) and Dangs South (Chichinagavtha, Shamgahan and Galcund) representing

areas of higher and lower elevations at fortnightly interval from April 2010 to March 2011.

For recording observations, five trees of each species were selected randomly. On each tree, four twigs representing each direction were considered for assessing damage of defoliating insect-pests. On each twig, total number of damaged leaves out of the total leaves was counted which were later categorized as per cent damage, thus abundance of insect-pests was assessed.

Results and discussion

Surveillance of incidence of important insect-pests of selected tree species *viz;* teak, shisham, hed, sadad, khair and kesuda were carried out in Dangs district at fortnightly interval. Amongst the insect-pests, incidence of foliage pests (defoliator and skeletonizer) was observed in varying intensities at six selected locations.

In teak, incidence of foliage pests (defoliator, *Hyblaea puera* and skeletonizer, *Eutectona machaeralis*) was lowest (3.33 % leaf damage) in Dangs north during second fortnight of December, whereas it remained highest (73.33 %) during first fortnight of September at the same location. Overall, Dangs north had higher incidence (29.53 %) than south (25.14 %), though it did not differ significantly. July - October was the peak damaging period (Table 1).

In sisham, leaf damage by foliage pest (defoliator, *Plecoptera reflexa*) was lowest (5.00 %) during first fortnight of June in Dangs north, while it was highest (73.67 %) in Dangs south during first fortnight of September. Overall, there was no significant difference in both the regions. July to November was the main active period of the pest (Table 1).

In hed, damage by foliage pest was lowest (1.67 % leaf damage) during first fortnight of January in Dangs north, while it remained highest (60.00) in the same region during first fortnight of August. Average incidences in both the regions were 15.72 and 11.76 per cent, respectively; however, it was significantly not different. July to November was active period of the pest (Table 1).

Susceptibility of Sadad towards foliage pests was lowest (3.33 % leaf damage) in Dangs north and south during second fortnight of March and January, respectively, while it remained highest (76.33 %) in Dangs north during first fortnight of August. The average incidence in both the regions was 24.53 and 20.53 per cent, respectively, though they did not differ significantly. Major activity of these pests was noticed from June to November (Table 1).

Foliage insect-pest on Khair showed lowest (1.67 % leaf damage) incidence during first fortnight of June in Dangs south. On the other hand, it remained highest (36.67 %) during first fortnight of August in Dangs North. Average leaf damage was 12.32 and 18.60 per cent in respective regions, though, they remained significantly at par. Major activity period of the pest was August - September (Table 1).

In Kesuda or Palas, incidence of foliage pests was lowest (1.33 % leaf damage) in Dangs north and south during second fortnight of May and first fortnight of April in Dangs south, while it was highest (70.33) in Dangs north during second fortnight of August. Average incidence in respective regions was 29.49 and 24.49 per cent, respectively, which was at par with each other. Major activity period of the pest was during July - December (Table 1).

Arguedas *et al* (2004) reported twenty species of insect (48%) on teak wood whereas, Ali and Chaturvedi (1996) recorded teak defoliator/skeletonizer (*Hyblaea puera* and *Eutectona macahaeralis*), sissoo defoliator (*Plecoptera reflexa*) on teak wood (*Tectona grandis*), sisham (*Dalbergia sissoo* and *D. latifolia*).

Majority of these forest insect-pests are highly host specific, however teak defoliator (*Hyblaea puera*) has also been recorded primarily on teak wood (Amin and Upadhaya, 1976). Roychoudhury (1999) recorded incidence of *H. puera* on 15 trees sp. of Bignoniaceae, 13 sp. of Verbenaceae and one each of Juglandaceae and Oleaceae. Observations revealed that all these host plants serve as food for *H. puera* during population outbreak.

The outbreaks of the teak defoliator *H. puera* are generally observed with early seasonal rainfall which confirms positive correlation between defoliator incidence and rainfall (Bhowmick and Vaishyampayan, 1986) and (Loganathan and David, 1999). They further indicated that that delay in rainfall led to delay in defoliator incidence. Wind velocity was also found to have some degree of positive correlation with incidence of the pest. Meshram *et al.* (1990) studied the seasonal incidence of 10 insect-pests of forest trees *viz*; defoliator (*Hyblaea puera*), skeletonizer (*Eutectona machaeralis*) on teak.

In most of the above reports, incidence of defoliating insect-pests of teak, sisham have been reported. Bhowmick and Vaishyampayan (1986) and Loganathan and David (1999) have indicated higher activity of *H. puera* during the period of early rainfall. In the present investigation, incidence of foliage pests (defoliator and skeletonizer) was high during first fortnight of September which witnessed withdrawal of monsoon and period of high humidity, so, results of the present investigation are in close agreement with the above reports. Whereas, with regards to insect-pests of other tree species included in the investigation, no appreciable research work has been reported.

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Table 1: Surveillance of foliage pests in important tree species (Roving survey)

Month and Fortnight	Per cent leaf damage/tree											
	Teak		Sisham		Hed		Sadad		Khair		Kesuda	
	DN	DS	DN	DS	DN	DS	DN	DS	DN	DS	DN	DS
April - I	1.67	2.33	0.00	0.00	0.00	1.67	0.00	0.00	0.00	0.00	10.00	1.67
April- II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	1.33
May- I	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May- II	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.67	1.67
June- I	17.67	13.33	5.00	0.00	5.00	6.67	15.00	26.67	5.00	1.67	15.00	7.00
June- II	33.33	19.67	15.33	13.33	15.00	26.67	41.67	44.67	11.00	3.33	23.33	16.67
July- I	44.00	38.33	33.33	30.00	31.67	34.33	54.33	68.33	23.33	9.67	38.33	31.67
July- II	51.67	46.67	59.00	53.33	40.00	45.00	75.33	72.67	30.00	19.67	51.67	30.00
August- I	67.00	63.33	61.67	68.33	60.00	48.33	76.33	68.33	36.67	32.67	60.00	51.67
August- II	68.00	68.33	66.67	71.67	53.33	59.33	71.00	63.33	26.67	35.67	70.33	60.00
September- I	73.33	72.67	72.67	73.67	55.00	54.67	64.33	61.00	23.33	20.00	69.33	66.00
September- II	68.33	66.67	70.33	67.33	60.00	54.67	55.00	58.33	25.00	21.67	60.00	51.67
October- I	50.00	65.00	55.00	61.67	46.00	55.00	51.00	63.33	23.67	25.00	61.67	51.67
October- II	40.00	58.33	43.33	53.33	35.00	46.67	45.67	51.67	17.67	25.67	63.33	45.67
November- I	28.33	43.33	35.00	52.67	29.33	39.00	41.67	42.33	15.67	18.33	55.33	43.33
November- II	20.67	25.00	21.67	43.33	22.00	28.67	38.33	28.67	11.67	13.33	44.33	33.33
December- I	10.00	18.33	15.00	31.00	14.33	27.33	25.67	21.33	8.33	8.33	33.33	21.67
December-II	3.33	6.67	8.33	16.67	6.67	21.67	19.33	18.33	3.33	4.33	15.00	19.33
January-I	0.00	5.00	0.00	9.33	1.67	16.00	11.00	11.00	0.00	0.00	8.33	11.67
January-II	0.00	0.00	0.00	1.67	0.00	8.33	5.00	3.33	0.00	0.00	8.33	10.00
February-I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	10.00
February- II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.67
March- I	0.00	0.00	1.67	1.67	1.67	0.00	0.00	0.00	0.00	0.00	5.00	8.33
March- II	0.00	1.67	6.67	6.67	5.00	3.33	3.33	1.67	0.00	0.00	5.00	6.67
Mean	**29.53**	**25.14**	**24.58**	**24.96**	**15.72**	**11.76**	**24.53**	**20.53**	**12.32**	**18.60**	**29.49**	**24.49**
SD	**31.98**	**28.84**	**26.36**	**26.94**	**17.95**	**14.52**	**25.47**	**24.31**	**15.47**	**20.16**	**25.96**	**21.08**
T Test (Probability)	**0.87**		**0.66**		**0.53**		**0.95**		**0.79**		**0.47**	
T' Table value at 0.05	**2.074**											
Significance at 0.05	**NS**		**NS**		**NS**		**NS**		**NS**		**NS**	

DN : Dangs North **DS :Dangs South**

Status of watershed development to combat rural water augmentation for food and livelihood opportunities in Medak division of Northern dry zone of Andhra Pradesh: A research study

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ABSTRACT

The present investigation was carried out to know the impact of watershed development works on the food and livelihood opportunities of the villagers in the Medak division of northern dry zone of Andhra Pradesh. In this division three forest ranges were selected and form each range two Vana Samrakshana Samithi (VSSs) were selected to ascertain the impact of watershed development. Most of the villages sampled falls under dry zones with an average annual rainfall below 580 mm. The soil and moisture conservation (SMC) works, were implemented in the study area under various schemes *viz.*, JBIC, RIDF, APCFM, APPTDF, FDA, IWLDP, DPADP Hariyalli – II and MGNREGA. Percolation tanks and continuous contour trenches are most common SMC structures followed by check dams and rock filled dams *etc.*, in the sampled areas. Implementations of SMC works had better impact on water sources with higher water yield and thus increased the irrigation potential of bore wells from 1-1.5 to 1.5-3.5 inches in the sampled VSSs. This has lead to a moderate increase in farming income of the villagers due to increase in the agricultural activity in terms of area and number of crops grown/year. Increase in cropping area, fodder availability, increase in tree density and natural regeneration were also noticed in the sampled areas after the implementation of SMC works. The positive impact of SMC works had directly resulted in increase in household income, employment generation, scope for allied agricultural activities etc. There is a decline in number of BPL families in villages. In almost all villages sampled, before the implementation of SMC works villagers had to travel to a distance of 0.5-1.5 kms to fetch drinking water but, now the drinking water problem is completely solved due to sufficient recharging of ground water resources. Therefore impact is more visible in terms of large quantity of water harvest and enriched greenery around the structures built.

Keywords: SMC works, watershed development, water augmentation, cropping pattern and VSSs

INTRODUCTION

The conventional soil conservation approaches and technologies in India were started in the form of public works to control the soil erosion for minimizing the siltation of multipurpose reservoirs. Most of the benefits accrued to down stream people through canal irrigation. Many state Governments enacted Soil Conservation Acts/Land Improvement Acts and armed themselves with measures to implement soil and water conservation effectively. Water is one of the requirements for both economic development and quality of life yet, water scarcity is becoming epidemic. Conservation of water in the agricultural and forestry sectors is essential as water is necessary for the growth of crops and plants. Depleting water table and rise in salinity due to over exploitation of ground water and over use of chemical fertilizers and pesticides is a common scenario in India. Soil and Moisture Conservation (SMC) is crucial in successful implementation of all forestry related programmes and in forming systems especially in drier zones. Sustainable productivity is dependent on soil and moisture conservation activities. Drastic reduction in rainfall and erratic rains, both with respect to intensity and frequency prolonged dry spells, denudation of the tree cover, severe summer coupled with decrease in annual average number of rainy days and decline in ground water table are the compelling factors which have led to major emphasis to SMC works in the afforestation programmes as well. SMC measures are executed to prevent the unchecked flow of rain water which causes soil erosion. The rain water is divided into overland flow, surface flow and sub surface flow. The surface and sub surface flow increases the availability of ground water in different geological formations. SMC measures are needed to increase availability of ground water.

In India, it is estimated that almost 1.5 m ha of land is being out of cultivated area every year due to faulty land and water management practices. If this is allowed to continue, it would lead to tremendous problems of depletion and degradation of resources like soil, water and plant nutrients through run off and soil erosion resulting in silting up of major reservoirs and causing floods. According to the latest estimates, about 187.8 m ha (57% of land area) has been degraded in the country. Soil erosion accounts for 87 % of the total degraded land in India. The indiscriminate and unscientific soil and water management has rendered a major portion of land erosion prone. The undulating topography with high intensity of rainfall have caused high rate of soil erosion, resulting in the sedimentation of river banks, siltation of drainage channels and irrigation channels around reservoirs.

Many states have taken-up development of degraded areas under the watershed approach. A shift in the approach to watershed development took place in 1995-96 with the adoption of new guidelines formulated by Government of India. The rise in population, growing industrialization and increasing agriculture activities have pushed up the demand for water over the years. Efforts have been made to meet this demand by constructing dams, reservoirs and digging wells. The idea of ground water recharging by harvesting rain water has gained momentum particularly in arid and semi-arid regions of India. Over the years, SMC techniques have been developed primarily in agriculture land, however of late, adoption of SMC measures is made part of afforestation programmes, especially after introduction of Joint Forest Management (JFM) concept. During the earlier plan periods, major emphasis was given to tree planting by contour trenches for water conservation and soil stabilization. During 9^{th} and 10^{th} five-year plans, importance has been given for SMC as a separate component

under State, Central and externally aided schemes by fixing percentage of the total sanctioned plantation cost.

In order to achieve the objectives of development in villages, people's participation is essential. It is required to involve them actively in project activities by respecting their traditional knowledge and experience. As a consequence, JFM programme has been implemented from 1993 onwards in various states. Village Forest Committees are engaged in regeneration of degraded forests, enrichment planting, cultural operations, soil and moisture conservation works, raising of multi-purpose plantations *etc* in JFM areas. In Andhra Pradesh, SMC work was introduced and implemented for the first time in afforestation projects by Andhra Pradesh Forest Development Corporation (APFDC). Since 1993, after implementation of JFM, SMC works have been implemented in degraded forest areas treated on ridge to valley concept.

SMC measures have been carried out and are also in progress under various schemes/ projects like ODA, CIDA, NAP, JBIC and APCFM *etc*. under the Ninth plan mid term appraisal by Planning Commission (Report of the Technical Committee on DPAP and DDP, Ministry of Rural Development, 1994) on impact of watershed development programme indicated beneficial effects such as increase in cropping intensity, crop productivity, change in cropping pattern and increase in ground water recharge as a result of conservation measure. Reduction in soil erosion and run-off losses, lesser siltation effect and reduction in sedimentation at watershed level were observed. Hence the present investigation was carried out to know actual the impact of watershed development works on the food and livelihood opportunities of the villagers in the Medak division of northern dry zone of Andhra Pradesh

METHODOLOGY

The present study was undertaken in Northern part of Andhra Pradesh State during 2008-09 to assess the impact of watershed development works implemented by various Line Departments on rural water augmentation and their livelihood security of the villagers in the forest fringe areas of Medak district of northern dry zone of Andhra Pradesh. From this District, three forest Ranges were selected and from each Range two villages were chosen (Table -1) and the data were collected as per the pre-structured schedule.

Table–1: Details of sampled sites for the study on watershed development for impact assessment in selected watershed villages of Medak division northern Andhra Pradesh

Division	Range	Name of the VFC / VSS	Scheme
Medak	Medak	Venkatpur	RIDF, APCFM, IWDP
		Shetpally	RIDF, MGNREGA, DPADP, APPTDP
	Narsapur	Kondapur	JBIC, FDA, APCFM, APPTDP
		Nallavalley	JBIC, APCFM
	Zaheerabad	Teumkumta	JBIC, APCFM, MGNREGA, DPADP
		Picharagad thanda	APCFM, Hariyalli - II

RIDF - Rural Infrastructure Development Fund, **APCFM** - Andhra Pradesh Community Forest Management; **IWLDP-** Integrated Wasteland Development Programme; **MGNREGA** – Mahatma Gandhi National Rural Employment Guarantee Assurance Scheme; **DPADP-** Drought Prone Area Development Programme; **FDA** - Forest Development Agency; **APPTDP** - Andhra Pradesh Participatory Tribal Development Project; **JBIC** - Japanese Bank for International Co-operation.

Location and climatic conditions

Location and general information of sampled sites selected for the research study in Northern part of Andhra Pradesh are presented in (**Table-2**).

RESULTS AND DISCUSSION

SMC works carried out under different schemes

In Medak division, SMC works were implemented under APCFM, RIDF, IWLDP, NREGA, DPADP, APPTDP, FDA, and HARIYALLI schemes. Percolation tanks (PTs) followed by checkdams (CDs) are the most common SMC structures in the sampled VSSs. The main watershed development programmes are: Drought Prone Area Development Programme (DPADP) funded by central and state on 50:50 basis with an objective of drought proofing by taking up of soil and moisture conservation, water harvesting structures, afforestation and horticulture programmes on a comprehensive micro watershed basis. The other schemes are Employment Assurance Scheme (EAS) and Integrated watershed Development Programme (IWDP).

SMC structures

In Medak division Percolation tanks and continuous contour trenches are most common SMC structures followed by check dams and rock filled dams *etc.*, in the sampled areas. Checkdams have been constructed with straight drop spill way at the bottom of down hill to avoid the erosion losses. These straight drop spillways are either had a concrete basement or filled with stones. Details of SMC works carried out under different schemes in selected forest fringe villages are given in Table-3. In this division,

SMC works were implemented under RIDF, APCFM, IWDP, MGNREGA, APPTDP and DPADP schemes. The size of catchment area approximately ranged from 30 ha to 500 ha in most of the forest fringe villages. However, in recent years, more emphasis is given to percolation tanks irrespective of the schemes. This was done to increase employment for the local villagers by involving them under construction works as construction of PTs requires less skilled manpower compared to CDs. These finding receives support from Janardhana *et al* (2006) where they reported watershed development programmes through ridge to valley concept by catchment area treatment using most common SMC structures such as gully plug, rock fill dams, contour trenching and bunding, check dams, percolation tanks and subsurface dams.

Impact of SMC works

Ecological Impact

The details of impact of SMC works carried out in selected forest fringe villages of Andhra Pradesh on various ecological parameters are given in Tables-4 & 5.

a) Water sources

There was increase in the number of borewells and their water yield after the initiation of SMC works in almost all the sampled VSSs of Medak division. The water yield of borewells was increased on an average ranges from 1.5-3.5 inches. Presently there are no such studies conducted on impact of watershed development works on the livelihood security of the villagers in the Medak division of northern dry zone of Andhra Pradesh. Thus, these findings receive support from Agarwal and Narain (1997) where they reported rainwater harvesting by runoff conservation structures (gully plug, rockfill dams, check dam and bench trenching) is basically intended to slow or stop the running water (contour trenching and subsurface dams) and to infiltrate into the underground. Besides this they observed, in drought prone areas rainwater harvesting is undertaken to address the serious problems of drought and water scarcity. Water conservation measures in Wagarwadi watershed, Maharastra, are responsible for raising the water table by about 2 m in the wells located within 200 m on the down stream side of nala (i.e. stream) bunds and in other wells located adjacent to the water conservation structures. Water conservation structures of Wagarwadi watershed are responsible for groundwater recharge estimated at 6 ha m per year and a rise of 0.5 to 2.5 m of the water table at different locations (Gore *et al.* 1995).

b) Increase in wetlands

There was an increase in the area of wetlands of sampled VSSs in Medak division. The increase was directly attributed to increase in the number of borewells with sufficient water yield. After increase in water yield, villagers relied more on borewells, as sufficient quantity of water was available following SMC works in these villages. However, in some of the VSSs due to lack of power supply during summer no crop was taken even though there was sufficient quantity of water available in borewells. Among the sampled VSSs, the major impact was in Venkatpur and Shetpally of Medak range, which had only 50 ha and 35 ha wetlands before the initiation of SMC works; now the village has 110 ha and 80 ha of area under wetlands and cultivating two crops in a year. This may be due to either increase in the number of open wells or borewells coupled with increase in water yield by implementing SMC works.

c) Change in cropping pattern and fodder availability

The change in cropping pattern, number of crops in a year and crop yields in selected forest fringe villages as an impact of SMC works is given in Table-6. There was an increase in the area under cultivation of agricultural crops following SMC works in all the sampled VSSs and also there was an increase in the number of crops cultivated per year from an average of 1 crop to 2 crops in a year depending upon the intensity of rainfall during monsoon season. However, there was no significant change in the type of crops cultivated by following SMC works. The only notable change was in the substitution of paddy, vegetables and sugarcane crop in place of dry crop like Jowar and redgram in Teumkumta and Picharagad thanda VSSs of Zaheerabad range and Kondapur of Narsapur range. On the other hand, there was marginal increase in the crop yields due to increase in irrigation facilities. Besides this there is an increase in the fodder availability in the VSSs and that can be attributed to increased area under cultivation and also to the increase in the number of crops in a year.

d) Increase in tree density and eco-restoration

A marginal increase in tree density in the reserve forest areas of sampled VSSs was observed due to the impact of SMC works. The increase was a minimum of 15% in Kondapur VSSs of Narsapur range. The increase was a maximum of 25% in Shetpally of Medak range and Teumkumta and Picharagad thanda VSSs of Zaheerabad range (Table–5). The villagers attributed that the increase in tree density to decrease in dependency on forest. Moreover, there was also an increase in the natural regeneration and improvement in green cover wherever SMC structures are built. SMC structures (runoff conservation structures) such as gully plug, rock fill dams, contour trenching, bunding, check dams, percolation tanks and subsurface dams and structures will enables the slow or stop the running water and infiltrate into the underground and this results into increase in the number of borewells and their water yield, area under cultivation of agricultural crops (wetlands and dryland), number of crops cultivated per year, crop yields, fodder availability and tree density after the initiation of SMC works in almost all the sampled VSSs of Medak division was observed due to the impact of SMC works. These finding receives support from Janardhana *et al* (2006) where they reported watershed development programmes through ridge to valley concept by catchment area treatment in the Swarnamukhi River basin. They reported, positive changes on various ecological parameters such as ground water recharge and land productivity.

Impact on livelihood of the villagers

The details of impact on various socio-economic parameters due to SMC works at selected forest fringe villages of Medak division, northern Andhra Pradesh are given in Table-7.

a) Increase in household income

There was a moderate increase in the family income of forest fringe villagers after the implementation of SMC works. This increase was mainly due to increase in the agricultural activity in terms of area and number of crops grown in a year. There was also significant decline in the number of BPL families in the forest fringe villages of sampled division.

b) Employment generation

During 1997 to 2000, the occurrence of consecutive droughts leads to migration of many of the villagers particularly younger generation to cities in search of jobs and livelihood. However, large sections of younger generation are in hesitation to return to villages and take up agriculture. This has become a worrying fact to the village elders. But, after the implementation of SMC works and other village development programmes there was an increased interest in the younger generation towards the agricultural activities that in turn resulted in employment generation for agriculture labourers. However, in Medak range, apart from agriculture labour there was also better income generation through NTFP, particularly collection and selling of Seethaphal (*Annona squamosa*) fruits and *Butea monosperma* leaves (Table-7).

c) Livestock and dairy

The details of livestock population and major source of income in the selected forest fringe villages before and after the SMC works is given in Table-8. Before the SMC works were undertaken agriculture is the primary occupation of villagers in the forest fringe villages of Venkatpur and Shetpally VSSs of Medak range, Picharagad VSS of Zaheerabad range. However, frequent occurrence of drought in these ranges lead to less or no agricultural activity and subsequently migration of villagers to cities. Whereas, in Narsapur range, agriculture and NTFP are the major source of income for the villagers. Before the SMC measures were undertaken in the ranges of Medak division, villagers had sold out many of their cattle and sheep due to drought, fodder shortage and water problems. But even though there is sufficient fodder and water availability now after the implementation of SMC works, there is no significant rise in livestock population due to increased awareness about the ill effect of grazing as a consequence of JFM programme. The population of cows and buffaloes are just sufficient to meet the requirement of a household. On the other hand, there was a decline in the population of sheep due to non-availability of shepherds.

d) Drinking water availability

Before the implementation of the SMC works, there was a severe problem of drinking water availability in some of the villages studied. In the sampled forest fringe villages of this division, villagers had to travel to a distance of 0.5 to 1.5 km to fetch drinking water before the implementation of SMC works. Now, the drinking water problem has been completely solved in all the forest fringe villages due to recharging of the bore wells and open wells after the implementation of the SMC works. Presently, there are no such studies conducted on impact of watershed development works to combat rural water augmentation for food and livelihood opportunities in medak division of northern dry zone of Andhra Pradesh. Thus, these findings receive support from success stories of rainwater harvesting reported by Mishra *et al.* (1980); Dhruvanarayana and Sastry (1986); Mittal *et al.* (1986), Grewal *et al.* (1989); Samra *et al.* (1995) and Sikka *et al.* (1996).

e) Any other observation

Most of the SMC structures built were 2-3 km away from the villages and therefore there was no significant man-animal conflict in the sampled villages. However, there were few instances of crop damage by wild boar, bear, wolf, rabbit etc.

CONCULSION

Implementation of SMC works had better impact on water sources with higher water yield and thus increased the irrigation potential in forest fringe villages of Medak division of northern dry zone of Andhra Pradesh. This has lead to change in cropping pattern, higher crop yields and higher returns to the farmers. Increase in cropping area, fodder availability, increase in tree density and natural regeneration were also noticed. The positive impact of SMC works had directly resulted in increase in household income, employment generation, scope for allied agricultural activities *etc*. There is a decline in number of BPL families in forest fringe villages. In almost all villages sampled, the drinking water problem is almost solved due to sufficient recharging of ground water resources. Therefore impact is more visible in terms of large quantity of water harvest and enriched greenery around the structures built.

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Table – 2: Location, general information, climatic conditions of sampled sites under impact study in Medak division, Northern Andhra Pradesh

Range	Name of the VSS	Type of land treated	Soil type	Average rainfall year (mm)	No. of Rainy Days	Temperature		Monsoon	
						Max (°C)	Min (°C)	S-W Monsoon Months	N-I Monsoon Months
Medak	Venkatpur	Reserve Forest	Mixture of Red & Block soil with loamy	580	70	40	24	June-Sept	Sept-Nov
	Shetpally	- do -	- do -	580	70	40	24	June-Sept	Sept-Nov
Narsapur	Kondapur	- do -	- do -	580	70	40	24	June-Sept	Sept-Nov
	Nallavalley	- do -	- do -	580	70	40	24	June-Sept	Sept-Nov
Zeehrabad	Teumkumta	- do -	Block soil with Loamy	580	70	40	24	June-Sept	Sept-Nov
	Picharagad thanda	- do -	- do -	580	70	40	24	June-Sept	Sept-Nov

Table–3: Different SMC works carried out for rainwater harvesting and watershed development in selected forest fringe villages of Medak division, Andhra Pradesh

Range	Name of the VSS	Scheme	Catchment area (ha)	SMC structures built					Approximate volume of water harvested/ year (m^3)
				Type	Dimension (ht x length)	Nos.	Cost	Year	
Medak	Venkatpur	RIDF	270	PT	2m x 36m	2	90,000	2004-05	2,560
		IWLDP	270	CD	1.5m x 18m	2	60,000	2004-05	1,822
		APCFM	60	CCT	3m x 1m x 10m	3000 cu.m	1,50,000	1999-00	18,000
	Shetpally	RIDF	225	PT	1.7m x 22m	1	1,00,000	2002-03	4,114
		RIDF	150	CD	1.5m x 9m	1	50,000	1999-00	405
		RIDF	60	CCT	1m x 1.5m x 2.5m	-	1,80,000	1999-00	54,000
		NREGA	30	Staggered trenches	1m x 0.1m x 2.5m	21.42 cu.m	1,50,000	2007-08	1,125
		DPADP	500	PT	2m x 17m	1	85,000	1995-96	2,890
		RIDF	228	CD	1m x 12m	1	45,000	1998-99	360
		APPTDP	-	OHT	-	1	1,50,000	1989-90	-

Contd...Table–3: Different SMC works carried out for rainwater harvesting and watershed development in selected forest fringe villages of Medak division, Andhra Pradesh

Range	Name of the VSS	Scheme	Catchment area (ha)	SMC structures built					
				Type	Dimension (ht x length)	Nos.	Cost	Year	Approximate volume of water harvested/ year (m^3)
Medak	Venkatpur	APPTDP	-	OHT	-	1	1,00,000	2000-01	-
Narsapur	Kondapur	FDA	10	CCT	0.5m x 10m	428 cu.m	30,000	2005-06	3,000
			110	CD	2.5m x 14m	2	85,000	2000-01	2,100
		APCFM	225	PT	2m x 12m	4	80,000	1999-00	8,160
		APPTDP	-	OHT	-	1	4,00,000	1999-00	40,000 (Capacity of OHT)
			80	PT	2.5m x 18m	1	2,00,000	1980-81	40,000
	Nallavalley	APCFM	150	CCT	1m x 0.5m x 10m	6642 cu.m	4,65,000	2004-05	45,000
		FDA	310	CD	1.75m x 25m	1	3,00,000	2001-02	5,760
		APCFM	210	PT	2m x 20m	2	1,41,000	2005-06	36,000

Contd...Table–3: Different SMC works carried out for rainwater harvesting and watershed development in selected forest fringe villages of Medak division, Andhra Pradesh

Range	Name of the VSS	Scheme	Catchment area (ha)	SMC structures built					
				Type	Dimension (ht x length)	Nos.	Cost	Year	Approximate volume of water harvested/ year (m^3)
Zeehrabad	Teumkumta	NREGA	290	CCT	0.5m x 10m	4285 cu.m	3,00,000	2005-06	7,500
		DPADP	500	CD	2m x 20m	1	1,00,000	2003-04	162
		FDA	230	RFD	2m x 12m	2	27,019	1996-97	6,835
		APCFM	251	PT	2m x 18m	1	22,500	2004-05	6,120
		FDA	260	CD	1.5 x 10m	3	1,50,631	1997-98	1,420
		FDA	220	CCT	0.5m x 10m	3482 cu.m	12,040	1996-97	17,410
		FDA	240	CCT	0.5m x 10m	1689 cu.m	5,246	1999-00	8,445
		FDA	270	CCT	0.5m x 10m	1724 cu.m	5,600	2000-01	8,620
		FDA	280	CCT	0.5m x 10m	1296 cu.m	32,536	2002-03	46,480

Contd...Table–3: Different SMC works carried out for rainwater harvesting and watershed development in selected forest fringe villages of Medak division, Andhra Pradesh

Range	Name of the VSS	Scheme	Catchment area (ha)	SMC structures built					
				Type	Dimension (ht x length)	Nos.	Cost	Year	Approximate volume of water harvested/ year (m^3)
Zeehrabad	Pichara gad thanda	DPADP	500	PT	5m x 35m	1	50,000	1980-81	30,625
		APCFM	-	Open well	-	4	2,00,000	1996-97	-
		APCFM	559	PT	2m x 12m	10	67,515	1999-00	20,400
		APCFM	250	CD	2m x 10m	1	40,000	2000-01	600
		Hariyalli - II	500	CD	2m x 12m	2	30,00,000	2006-07	720
		APCFM	220	PT	2m x 25m	4	3,20,000	2007-08	816
		APCFM	255	CCT	0.5m x 10m	360 cu.m	25,000	2007-08	7,500

PT- Percolation Tank ;CD- Checkdam ;CCT-Continuous Contour Trench ; RFD- Rock Filled Dam; OHT – Over Head Tank

Table–4: Impact of SMC works on water resources in selected forest fringe villages of Medak division, Andhra Pradesh

Range	Name of the VSS	Before SMC works					
		No. of Bore wells	Water yield (inch)	Depth digging (ft)	No. of open wells	Water level (ft)	Depth digging (ft)
Medak	Venkatpur	40	1.5	250	-	-	-
	Shetpally	15	1.0	250	-	-	-
Narsapur	Kondapur	15	1.0	250	-	-	-
	Nallavalley	35	1.0	250	-	-	-
Zeehrabad	Teumkumta	30	2.0	225-350	2	8-10	110
	Picharagad thanda	15	2.0	350	17	10	100-120

Range	Name of the VSS	After SMC works					
		No. of Bore wells	Water yield (inch)	Depth digging (ft)	No. of open wells	Water level (ft)	Depth diggin g (ft)
Medak	Venkatpur	60	2.0	220	-	-	-
	Shetpally	35	1.5	220	-	-	-
Narsapur	Kondapur	30	1.5-2.0	150-200	-	-	-
	Nallavalley	70	2.0-2.5	150-200	-	-	-
Zeehrabad	Teumkumta	70	3.0-3.5	200	14	15-20	90
	Picharagad thanda	25	3.0-3.5	250-300	30	15-20	75-80

Table–5: Impact of SMC works on various ecological parameters in selected forest fringe villages of Medak division, Andhra Pradesh

Range	Name of the VSS	Before SMC works			
		No. of wells recharged	Dry lands (ha)	Wet lands (ha)	Agro-forestry (ha)
Medak	Venkatpur	-	70.00	50.00	50.00
	Shetpally	-	175.00	35.00	40.00
Narsapur	Kondapur	-	43.75	14.58	4.17
	Nallavalley	-	141.75	40.50	8.10
Zeehrabad	Teumkumta	-	43.33	6.07	6.07
	Picharagad thanda	-	200.00	250.00	50.00

Range	Name of the VSS	After SMC works					
		No. of Bore wells	Water yield (inch)	Depth digging (ft)	No. of open wells	Water level (ft)	Depth digging (ft)
Medak	Venkatpur	5	30.00	110.00	100.00	20	5
	Shetpally	15 (5)	125.00	80.00	95.00	25	15 (5)
Narsapur	Kondapur	5	33.33	33.33	16.67	15	5
	Nallavalley	3	121.50	81.00	20.25	20	3
Zeehrabad	Teumkumta	5	24.32	25.47	13.32	25	5
	Picharagad thanda	3	142.00	300.00	100.00	25	3

Table- 6: Change in cropping pattern in selected forest fringe villages of Medak division, Northern Andhra Pradesh due to rainwater harvesting & watershed development

Range	Name of the VSS	Before SMC works			
		Area	Crops	Yield (kg/ha)	No. of crops / year
Medak	Venkatpur	170.00	Paddy Ground nut	3,500 3,500	One or two
	Shetpally	250.00	Maize Paddy	2,500 4,000	One
Narsapur	Kondapur	62.50	Jowar Ground nut Sunflower	3,000 3,500 800	One
	Nallavalley	190.35	Maize Paddy	5,000 3,000	One
Zeehrabad	Teumkumta	55.47	Jowar Red gram	3,000 2,500	One or two
	Picharagad thanda	500.00	Jowar Red gram	3,200 2,500	One

Range	Name of the VSS	After SMC works			
		Area	Crops	Yield	No. of crops / year
Medak	Venkatpur	240.04	Paddy Sugarcane Maize	3,500 8,200 1,000	Two
	Shetpally	300.00	Maize Paddy	3,500 4,200	Two
Narsapur	Kondapur	83.33	Paddy Vegetables Maize	4,000 2,400 6,000	Two or three
	Nallavalley	222.75	Maize Paddy	6,000 4,500	Two
Zeehrabad	Teumkumta	63.11	Sugarcane Wheat Paddy	8,500 5,000 6,000	Two
	Picharagad thanda	542.00	Sugarcane Wheat Jowar	8,500 4,000 4,000	One or two

Table–7: Impact on livelihood of the villagers due to SMC works in selected forest fringe villages of Medak division, Andhra Pradesh

Range	Name of the VFC	Before SMC works			
		Family income (Rs.)	BPL house holds	Employment generation	Drinking water problems
Medak	Venkatpur	10,000	70	Agricultural work	Yes (1.5 km)
	Shetpally	10,000	700	Agricultural work	Yes (1.0 km)
Narsapur	Kondapur	15,000	30	Agricultural work	Yes (1.0 km)
	Nallavalley	18,000	100	Agricultural work	Yes (0.75 km)
Zeehrabad	Teumkumta	20,000	30	Agricultural NTFP	Yes (0.5 km)
	Picharagad thanda	20,000	50	Agriculture	Yes (1 km)

Range	Name of the VFC	After SMC works			
		Family income (Rs.)	BPL house -holds	Employment generation	Drinking water problems
Medak	Venkatpur	35,000	30	Agriculture & NTFP	No
	Shetpally	35,000	400	Agri. Income & SMC work	No
Narsapur	Kondapur	30,000	20	Agri. Income & SMC work	No
	Nallavalley	25,000	35	Agri. Income & NTFP	No
Zeehrabad	Teumkumta	38,000	15	Agri. income, NTFP & SMC work	No
	Picharagad thanda	35,000	25	Agri. Income & SMC work	No

Table–8: Impact of SMC works on livestock population and allied enterprises (major source of income) in selected forest fringe villages of Medak division Andhra Pradesh

Range	Name of the VSS	Before SMC works				
		Cows	Buffaloes	Goat / Sheeps	Total	Major source of income
Medak	Venkatpur	500	800	450	1750	Agriculture
	Shetpally	50	90	500	640	Agriculture
Narsapur	Kondapur	500	250	1000	1750	Agriculture & NTFP
	Nallavalley	300	500	1000	1800	Agriculture & NTFP
Zeehrabad	Teumkumta	200 (1)	70	500	770	Agriculture & NTFP
	Picharagad thanda	70	80	400	550	Agriculture

Range	Name of the VSS	After SMC works				
		Cows	Buffaloes	Goat / Sheeps	Total	Major source of income
Medak	Venkatpur	300	11,000	1,160	12,460	Agriculture, Dairy & NTFP
	Shetpally	50	90	100	230	Agriculture, NTFP & SMC work
Narsapur	Kondapur	300	150	250	700	Agriculture, NTFP & SMC work
	Nallavalley	150	200	500	850	Agriculture & NTFP
Zeehrabad	Teumkumta	100 (20)	60	300	460	Agriculture, NTFP & SMC work
	Picharagad thanda	50	60	200	310	Agriculture

In vitro Dry Matter Degradation and Methane Gas Production from Three Tropical Grass Species using Inoculum from Cattle, Sheep and Goats

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INTRODUCTION

The green house gas emissions from agricultural sectors accounts for about25.5% of total global anthropogenic emission. Methane is one of the most important green house gas(Sejian *et al.*, 2011; EPA, 1999). Methane is an important gas among gasses produced by ruminants at fermentation and it has been reported (Babayemi and Bamikole, 2006) to be an energy loss to the animals, and when emitted, it contributes to the desruction of Ozone layer. Excretion of methane from rumen of livestocks (Cattle, buffalo, sheep, goats, camel etc.) can represent a loss of up to 15% of the digestible energy of the feed consumed depending od the type of diet. This impacts on the profitability of livestock production through reduced fedd conversion effeciency. Methane when excreted contributes to approximately 30 – 40% unit of total methane produced from agricultural sources(Moss et al., 2000). Although reductions in green house gas emission from livestock industries are seen as high priorities, strategies for reducing emissions should not reduce the economic viability of the enterprises. Methane reduction strategies include nutrtional manipulations, feed processing, addition of growth promoters, ionophores and organic acids in feeds, animal management etc. Dietary manipulations results in methane reduction by decreasing fermentation of organic matter in the rumen and shifting the site of digestion from the rumen to the lower guts, diverting hydrogen away from methane production during ruminal fermentation, inhibiting methanogenesis by ruminal bacteria or by optimising rumen fermentation and thereby decreasing methane emission per unit organic matter digested(Benchaar et al.,2001). Understanding the relationship of diets to enteric methane production is essential to identify viable reduction strategies. Panicum maximum, Andropogon and Brachiaria are common tropical grasses consumed by cattle, sheep and goats in Nigeria.The objective of this study therefore is to compare the in vitro dry matter degradation and methane production by cattle, sheep and goats when fed the three tropical grasses and suggest ways of reducing methane production without having negative impact on the productivity of livestock.

MATERIALS AND METHODS

500 mg samples were weighed into 125 ml Erlenmeyer flasks. The samples were then incubated in a buffered medium containing rumen liquor (40ml). Dry matter degradability was estimated after 24 and 48 hour incubation treating the content of the syringe with neutral detergent solution according to the procedure of van Soest and Robertson (1985) to obtain NDF. The determination of dry matter degradability was calculated thus: % DMD = 100 – neutral detergent residue. Methane production was determined according to the method of Fievez *et al.*, (2005). The dry matter

degradation characteristics was described with the equation: mL gas $gDM^{-1} = a + b (1-e^{-ct})$, where: a = intercept, b = potential gas production and c = rate of gas production

RESULTS AND DISCUSSION

Figures 1 and 2 shows the result of the dry matter degradation (DMD)of the three grass species at 24 and 48hr of incubation using inoculum from cattle, sheep and goats. DMD result at 24hr showed that Panicum maxima had the highest DMD value irrespective of inoculum source. Intermediate value was recorded for Brachiaria while Andropogon had the least value. Also, least values of DMD from Panicum and Brachiaria was observed with inoculum from sheep at 24hr incubation. At 48hr incubation period, while Panicum still had the highest DMD value irrespective of the source of inoculum, inoculum from sheep performed better when compared to inoculum from goats. This result implies that when inoculum from goats was used for incubation most of the nutrients were rapidly degraded within 24 hours. However, when inoculum from sheep was used for incubation the rate of degradation was slow during 24hr period but by the end of 48hr incubation, more of the nutrients were fermented. Inoculum from cattle had the highest ability to degrade all the grasses considered compared to inoculum from other animals. This might probably be due to the type and concentration of microbes present in each of the inoculum. According to Getachew et al, (2004), the rate and extent at which different chemical constituents are is a reflection of microbial growth and accessibility of feed to microbial enymes.

Significant observations ($p<0.05$) were recorded for b fraction and rate of fermentation; c of the different grasses using inoculum from different sources(Table 1). Lowest values of b (17.06%) and c ($0.024h^{-1}$) were observed when inoculum from goats was used in the incubation of Brachiaria while highest values of b and c were recorded when inoculum from cattle was used in the incubation of Panicum (21.10% and $0.048h^{-1}$respectively). This results indicate that the rate and extent of fermentaton of Panicum was fastest and highest with inoculum from cattle but least rate and extent of fermentation was recorded when Brachiaria was incubated using inoculum from goats. This results showed similar trend with the observation recorded in DMD results.

Results of methane production from the different forages when incubated with inoculum from different ruminants (Figures 3 and 4) revealed that Panicum as a forage produced the highest volume of methane gas irrespective of the inoculum source. At 24 and 48 hr incubation periods, inoculum from sheep and goats yielded similar volumes of methane. Different trend was observed when cattle was the source of inoculum for incubation ; at 24 hr incubation volume of methane production from the three forages differ while at 48 hr incubation, Andropogon and Brachiaria produced similar quantity of methane. However, throughout the incubation period, Panicum rated highest in the quantity of methane produced. Based on the result of this study, it is suggested that in order to reduce methane production from enteric fermentation, more attention should be given to cattle and probably other large ruminants. It is also suggested that where livestock production is based on Panicum as the main forage source, strategies for methane reduction should be exploited such as feed processing, use of feed additves, restricted feeding and other and other feed management practices.

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Table 1: In vitro dry matter degradation characteristics of three tropical grasses using inoculum from cattle, sheep and goats

Forage	Inoculum source	b (%)	c (Hr^{-1})
Panicum	Cattle	21.20a	0.048a
	Sheep	20.42ab	0.042abc
	Goats	19.72ab	0.046ab
Andropogon	Cattle	20.11ab	0.030bcd
	Sheep	19.86ab	0.028bcd
	Goats	18.50ab	0.028bcd
Brachiaria	Cattle	18.85ab	0.028bcd
	Sheep	18.84ab	0.026cd
	Goats	17.60b	0.024d
SEM		0.35	0.00

[a,b,c] Means along the same row with different superscript are significantly different ($P<0.05$)

b = insoluble but degradable fraction, c = rate of degradation.

Figure 1: Dry matter degradation of of three tropical grasses using inoculum from cattle, sheep and goats at 24 hour incubation period

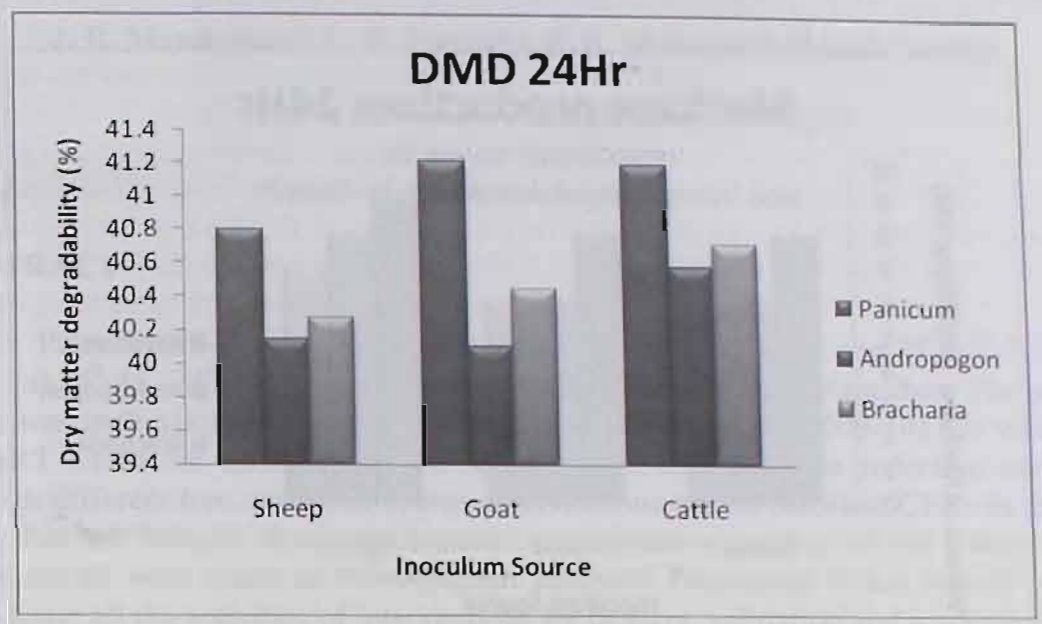


Figure 2: Dry matter degradation of of three tropical grasses using inoculum from cattle, sheep and goats at 48 hour incubation period

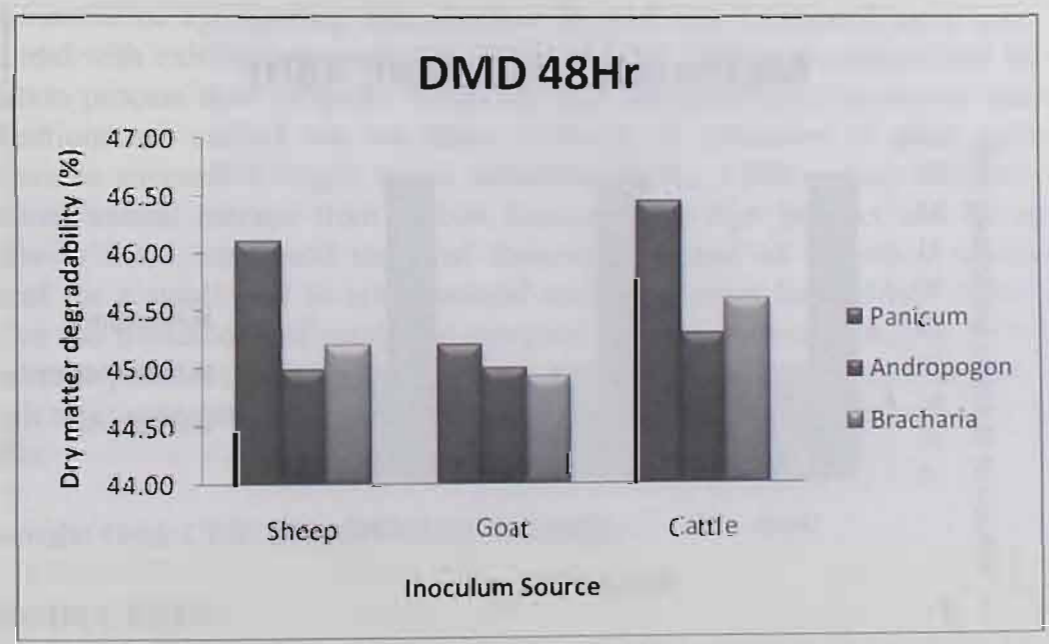


Figure 3: Methane gas production of three tropical grasses using inoculum from cattle, sheep and goats at 24 hour incubation period

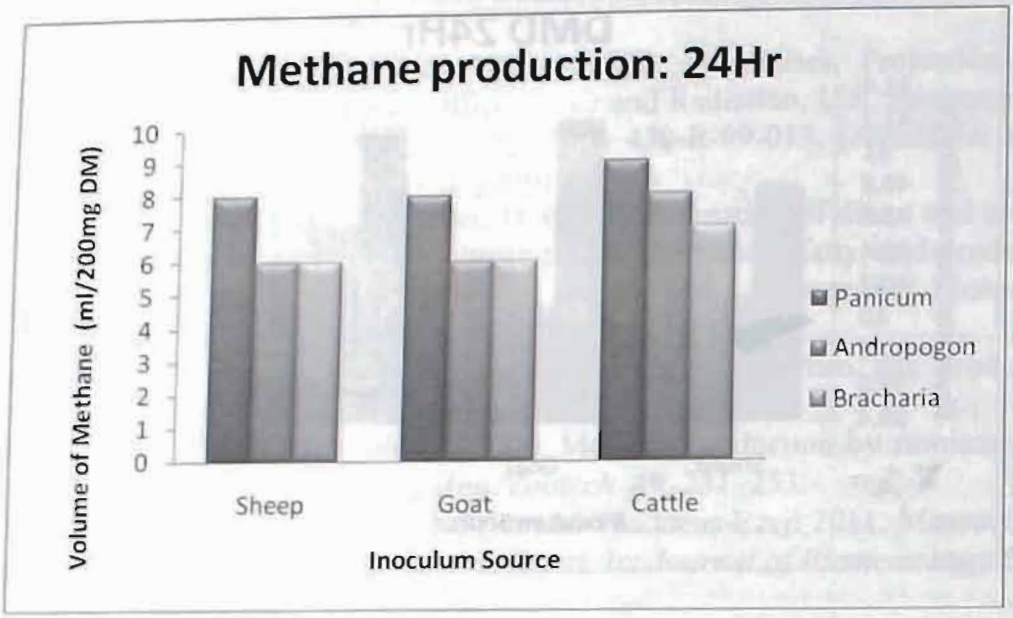
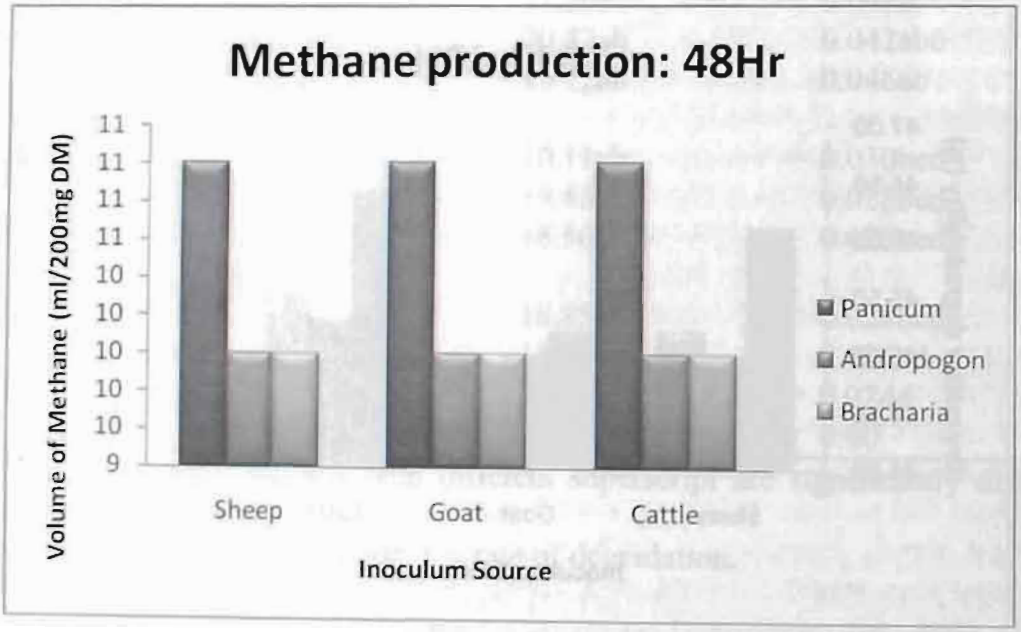


Figure 4: Methane gas production of three tropical grasses using inoculum from cattle, sheep and goats at 48 hour incubation period



Improvement in livelihoods and benefits of small and marginal farmers through Agroforestry interventions with carbon finance

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ABSTRACT

Palanakhurd-Nurda-Bhimal grid area of 5000 ha falls in Long.73^0 51'-73^0 57'E and Lat.24^0 45'-24^0 49' N, Mavali block of Udaipur district of Rajasthan. The present study was undertaken in NAIP project on carbon finance from 2009-1011 to validate a SMART CDM for different carbon sequestration and emission reduction measures through different tree, crop and energy interventions and to calculate CERs in the grid area. For the benefit share mechanism a cooperative society of the 2000 famers beneficiaries were made as 'Gramyajaan Sahakari Paryavaran Vikas Samiti", which coordinate all the activities of interventions by farmers, validation and marketing of the carbon credits. Most of farmers are tribal traditionally dependent on seasonal rainfed cropping and herding of livestock. The important approved CDM agroforestry interventions made as agri-horticulture, agri-silviculture, industrial wood block plantation, road and canal plantation and other wasteland plantations with species like citrus, mango, sapota, guava, pomegranate, teak, jamun, neem, soobabool, bamboo etc. Among crop interventions vegetables cultivation, improved crop seeds and carbon assimilation tillage and crop residue utilization practices followed. In pasture and wasteland babool, churel, thor, neem, mahua, khirni etc. planted along with grasses. The potential of agroforestry interventions in grid area calculated more than 30000 CERs and with existing two years interventions 5000 CERs were assimilated for which validation process is in progress. Presently only afforestation/reforestation and energy interventions are carried out but there is scope of validation of other agricultural measures in successive stages to get additional CERs. CDM project will provide an additional annual income from carbon finance other than product and environment benefits to these small and marginal farmers. The aim of the study to develop a protocol for a small grid in arid-semiarid ecological zone for SMART CDM and to improve the livelihoods of small and marginal farmers without changing their current agricultural practices but just to augment and refine the existing practices mainly through tree interventions in terms of produce, self sufficiency and income for better benefits.

Keywords: Grid, CER, SMART-CDM, Rajasthan

INTRODUCTION:

Global climate change has evidently emerged a serious challenge for survival and sustainability of mankind. It is certain beyond doubt that the climate is changing very fast. Climate has also been changing in the past, but its rate of change has been unprecedented in the last 15 – 20 years. A number of debates have reached this conclusion, that no one could stop the climate from changing, but could do a lot for

mitigating some of its effects and devise / create adaptation mechanisms to it. Agriculture, especially the small holder producers have been at the receiving end of the climate change effects, resulting into not only in the fluctuating and unstable productivity, loss of natural resources and consequent livelihoods, but also to their bare survival. Such changes are negatively affecting the livelihood systems and are creating uncertainties in looking for alternatives.

Among many of the causes which are attributed to contribute to the climate changes, green house gas emissions are noted to be on top of the list. Reducing emissions and sequestering carbon are thought to be the best answers to this nagging problem. The forestry sector has a good potential to sequester carbon. However, managing natural forests alone for maximizing carbon sequestration will compromise their other ecological functions. Hence, the need for production forestry, which means any plantation carried out outside the natural forest area for meeting various demands of the country. Production forestry in India can bridge not only the constantly increasing gap between the demand and supply of industrial timber, but also help the nation enhance carbon sequestration. In addition, it can help conserve bio-diversity by reducing large-scale removals of fuel-wood from natural forests, and also create much needed employment opportunities in rural areas, which can curtail poverty driven forest degradation.

There is a vast literature available on the subject, much of which has been synthesized in various reports of the Intergovernmental Panel on Climate Change (IPCC, 2000, 2001 and 2007), United Nation Framework Convention on Climate Change (UNFCCC, 2000 and 2001) and in FAO reports on Assessing carbon stocks and modeling of carbon sequestration through land use changes (FAO, 2004). Having gone through this massive literature, this proposal additionally reviews only more recent information, till to date.

The general land use pattern in India is characterized by agricultural land reduction on account of real estate development, leading to high input high energy use production systems to keep pace with the food production; and agricultural expansion into forest margins which are carbon poor, nutrient impoverished and bio-diversity threatened landscapes for their survival. One of the greatest challenges in India is to preserve natural resources in the context of rising agricultural production needs and, to reduce poverty (Singh, 2009). The rise in agricultural production, especially with high inputs, including energy, will most likely have a negative effect on natural resources. It will accelerate land degradation, increase the threats from climate change, and compromise sustainable development. This will mean promoting production systems that are not only efficient, but also respectful to the environment. A more pressing challenge is how to convert agricultural landscapes to more sustainable production systems without causing livelihood - environment conflict.

The challenge is to implement policies and programs that can respond to development priorities, which at the same time help to reduce vulnerability to poverty and climate change, limit emissions, and increase carbon sinks (Garrity, 2009). One of the production technologies that is affordable and reasonably meets these important criteria is land use practices based on agroforestry and conservation agriculture principles. Although agroforestry systems in providing multiple benefits are widely recognized, the specifics of how these systems can best be implemented are generally misunderstood, or inappropriately applied in many ambitious investment projects. The

fact that bringing trees on agricultural landscapes can create a net carbon sink (both in biomass and soils) means generation of additional income benefits, as carbon emission offsets, as part of emerging emission trading systems and carbon markets that aim at green house gas mitigation. A recent UNFCC report (UNFCC, 2008) has concluded that the carbon sequestration in grasslands and agroforestry plantations have significant potential for C reductions from the agriculture sector at non-prohibitive costs'. Beyond mitigating climate change, the other benefits of having trees on the landscape include the maintenance and improvement of soil productivity, biodiversity and ecosystem services, many of which are highly correlated with the carbon stocks in soil and biomass. Most importantly, agroforestry practices can serve as viable carbon sinks because they capture and store carbon in soils and biota, reduce deforestation, produce low-carbon bio-solids that serve as substitutes for high carbon fossil fuels, and they reduce carbon losses through erosion. Another important feature of this is the fast growth nature of trees, which could enable the practice to easily respond to climate change.

The Kyoto protocol, which recognizes sinks and sources attributable to afforestation, reforestation and deforestation (ARD) to be counted in achieving carbon emission reductions , has been receiving increased attention since 1997. The IPCC and the Kyoto protocol, both recognize agroforestry as a potential carbon sink. The estimated potential runs to a minimal of 3.1 t per ha per year when an unproductive cropland and a grassland is converted to agroforestry (Verchot, 2007). Additionally, half a ton of carbon can be gained on each ha by simply better management of trees on the croplands (IPCC, 2000). Once established, trees on agricultural landscape (agroforestry) also provide buffer against the climate vagaries and enhance the natural resources and their in-situ conservation, mainly the land, water and soil nutrients, further enhancing the productivity potential and enhanced carbon sequestration (Singh, 2008). Farmers are known to be the most efficient producers of sequestered carbon, stored in trees grown for fruits, timber and other tree products, as well as reduced emissions by adopting the conservation agricultural (CA) practices in the farming (Verchot, 2009 and Singh, 2009). These are approximately 1.5 billion ha of arable farmlands in the developing countries that are suitable for conversion to highly productive carbon rich agroforestry landscapes that can at the same-time contribute to food security, income generation and yet sequester substantial amounts of carbon in sinks (Garrity, 2009; Garrity, *et al.* 2008). So is the case for India throughout its all ecological conditions, for the farmlands as well as for the waste, marginal and degraded lands.

In recent months the need for and potential of carbon sequestration within such schemes has been re-emphasized (UNFCC, 2008, IFAP, 2008). These authors have also highlighted the need for improved approaches to climate change mitigation to be seen within the context of adaptation plans, the Convention on Biodiversity and the UN Convention on Combating Desertification. These developments are very encouraging with respect to the proposed SMART-CDM protocol, which has a lot of similarities and overlap with the various other suggestions, such as the earlier mentioned "Reformed-CDM" and the convergence of REDD and AFOLU within the Kyoto protocol. According to the Finance Times, carbon trading is the fastest growing commodity market in the world today, and that has the potential to generate trillions of dollars annually over the next half decade. However, through this opportunity and within the existing CDM based markets, only large companies, corporate houses, etc

have been able to access and benefit from it. The small holders who do sequester carbon and also reduce emissions substantially have usually been left isolated, mainly because they do not have the capacity to comply with the rigid and expensive market requirements. They are also in most cases not organized as a group, which further precludes their participation (Verchot, 2007). This fact is of enormous importance to the Indian small holders. As an alternative solution to this problem, a new grid based approach has been developed and validated by the International Centre for Research in Agroforestry (ICRAF), and a detailed tool box for its application has been prepared (Verchot, 2007).

The Kyoto Protocol was adopted at the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto in 1996, wherein, the developed countries alongwith some countries falling under "Economies In Transition" (EIT), categorized as Annex- I countries, were required to reduce their emission by an average of 5% relative to 1990 levels by the year 2012. For this, carbon sequestration is considered as one of the important strategies through sink enhancement. The Kyoto Protocol potentially offers an opportunity for capital investment and technology transfer for commercial forestry, under the afforestation / reforestation activities of the Clean Development Mechanism (CDM). In carbon sequestration through sink enhancement by way of growing more trees, the industrialized countries, through CDM options, are allowed to buy carbon credits that are generated by carbon sequestration projects in developing countries. It gives the industries, targeted for emitting GHGs, the flexibility to continue using fossil fuel for some time, which will act as a buffer in the process of switching over to more efficient energy source, if they invest in sequestering carbon.

By way of investment from developed countries, the CDM projects could also lead to a large positive impact on programs which are aimed at forest conservation and regeneration, through afforestation / reforestation, reclamation of degraded lands and socio-economic development of rural communities, in addition to the global environmental benefits. Now this is being looked upon as a major benefit with market instruments favoring the active involvement of industry in the mechanism. The potential for CDM related projects is quite high in India. Although it is not mandatory for Indian industries to meet any sort of targets under Kyoto protocol, they prefer to favor this phenomenon as it strengthens their claim for using the wastelands for this purpose in the country. India has the biggest scope for generating Certified Emission Reductions (CERs). The country currently has the largest number of CDM projects, but China is largest in terms of carbon tonnage. The Government of India has set up a National Designated Authority (NDA) to deal with the CDM projects in the country. The small holders, who do sequester carbon and also reduce emissions, individually as well as collectively, and qualify for the minimum tradable carbon amount are usually left isolated from this opportunity, mainly because they do not have the capacity to comply with the rigid and expensive requirements of the carbon market schemes, especially the CDM protocol. Moreover, in most cases, they are also not organized in groups, which further preclude their participation in such ventures. This fact is of enormous importance to the Indian small holders, who comprise the majority of farmers, collectively contribute to a substantial load of carbon sequestration, and yet are unable to benefit from such opportunities, and are left wandering alone. The scientific community has also not been able to assist them in this issue so far. A large number of CDM projects developed so far globally, are related to energy sector and

industrial processes with high global warming potential. In agriculture, the number of projects registered is only 6.08 % of total projects developed so far. Moreover, a majority of these projects are actually related to manure management in large-scale livestock/ animal production units, and are not related to core agriculture involving small holders. Similarly, so far the number of projects in Afforestation / Reforestation (A/R) sector is also only 0.07 %. A recent review of all such applications in India indicates that of the 1253 applications filed, 394 reached the registry stage. Of this, 235 were related to energy sector (producing electricity from agricultural residue, energy efficiency and generation), 112 projects were related to hydro and wind power and none from agriculture sector, or afforestation and reforestation, which relates to carbon sequestration (UNEP, 2009). None of these applications are from the small holders. Projects, related to agriculture and A/R will ensure greater participation of farming communities in the emission reduction activities, resulting in sustainable development benefits. Appropriately designed CDM projects in these two sectors can provide useful additional revenue to rural communities, which will be in addition to the existing streams of revenue from either agriculture, or plantations. However, to realize such additional revenue, concerted efforts are required from various organizations and new methodologies need to be developed to suit the situation specific context of India.

The carbon trade market is essentially a Euro market, wherein CDM is a baseline credit system, means what level of carbon be without the CDM mechanism. This market is largely controlled by Euro oil and oil prices as it has no definite structure. The CDM is a very small proportion of the carbon market, the largest one is under EU regulations, wherein the identified companies are to reduce carbon emissions and they trade among themselves. The CDM supplies only 25%, as primary CERs; the buyers can trade it again as secondary CERs, so in reality the primary CER volume is smaller than the secondary CERs. The lower primary CER volume is also because it is difficult to buy them as they have to come from a developing country, which may have poor and unknown credit rating. In view of the unstable livelihoods in the face of ever changing climate, and the complexities in the carbon trade markets, which so far have totally excluded the agriculture sector from it, an alternative protocol called "SMART-CDM" (Specific, Measurable, Achievable, Realistic, and Tangible) has been developed by ICRAF. The new protocol emphasizes on taking into consideration the below ground carbon sequestration (carbon addition in the soil carbon pool) as a better way of sequestering carbon, and promotes farming practices, which are adaptable to and are in harmony with the existing CDM rules. The protocol neither contradicts, bypasses, nor proposes any conflicting procedures, or shortcuts to the carbon trading rules in the Kyoto compliance carbon markets, such as the CDM. It is not a modification of any fiduciary regulations of the CDM and voluntary markets as well. In general, this protocol advocates a gradual transition and transformation of "field crop agriculture" based livelihood systems to agroforestry based livelihood systems, including the field crops, and promotes the adoption of the emission reducing interventions in the farming- house hold operations. The agroforestry based systems have been documented to provide an insulation effect from climatic vagaries to the farming and at the same time sequester significant amount of carbon, both in the above and the below ground biomass.

STUDY AREA & METHODOLOGY:

The study is undertaken in NAIP project site at Palanakhurd-Nurda-Bhimal grid area of 10 km X 5 km (5000 ha.) falls Long.73^0 51'-73^0 57'E and Lat.24^0 45'-24^0 49' N, in Mavali block of Udaipur district of Rajasthan from 2009-1011, which allows meeting the minimum tradable volume requirements of the carbon market. For the benefit share mechanism a cooperative society of the 2000 famers beneficiaries were made as 'Gramyajaan Sahakari Paryavaran Vikas Samiti", which coordinate all the activities of interventions by farmers, validation and marketing of the carbon credits. Since it is community based approach, it does address the social and gender concerns in the sustainable development pathway. There could be a number of land use units/ systems and a number of small holders operating those units: in this approach, farmers are allowed to continue doing their normal farming practices, but are encouraged to incorporate carbon sequestering and/ or emission reducing practices. Carbon stocks are measured in each of the major land use units at the beginning of the project and after a certain time intervals, which is decided on the basis of land uses and the prevailing ecological conditions of the selected area. Through the time sequence carbon analysis, any positive carbon balance could be put up for trading in the market and the accrued benefits could be proportionally shared by the community in the grid. The possible interventions are to be carried out in the grid area under CDM approved methodologies

a. Tree based interventions: wood plantations in private holdings; horticulture in private lands; commercial timber; agroforestry; road side plantations/ avenue plantations; silvi pasture interventions in common lands

b. Agriculture based interventions: Utilizing crop residues (cotton/ sunflower etc.) instead of burning; Zero tillage maize after paddy fallows (reduction in tillage operations, reduction in number of irrigations); SRI Paddy and aerobic rice as an alternative to flooded rice under bore-wells; Vermi-compost substituting commercial fertilizers

c. Energy based interventions: a. Electricity Consumption reduction, 1) Promotion of solar appliances at village level like solar lighting, cooking, street lighting etc. 2) Capacitors for water lifting devices (irrigation pumps)
b. Electricity/ heat generation 1) biogas and power generation (calf rearing units, dung , biogas) 2)biomass briquettes/ pellets

d. House hold level: Replacement of Edison bulb with florescent lights (CFL); Fuel wood with biogas; Smokeless chulhas

The important approved CDM agroforestry interventions made as agri-horticulture, agri silviculture, industrial wood block plantation, road and canal plantation and other wasteland plantations with species like citrus, mango, sapota, guava, pomegranate, teak, jamun, neem, subabool, bamboo etc. Among crop interventions vegetables cultivation, improved crop seeds and carbon assimilation tillage and crop residue utilization practices followed. In pasture and wasteland babool, churel, thor, neem, mahua, khirni etc. planted along with grasses.

The approach allows meeting all the qualifying criteria sat up for carbon trading in different carbon markets, as it does not contradict, or bypass any of the essential

qualifications of the Kyoto compliance, and the voluntary carbon trade markets. In order to operationalize such a new protocol, a detailed step by step frame work and a methodological tool box on how to proceed in this venture has been developed at ICRAF. The proposed project is based on the above approach and has six main components. They are the following: Scaling up best practices, including the adoption of agroforestry and emission reducing interventions; Carbon assessment; Carbon finance; Institutions; Capacity building and Impact. **Best Practices**: Apply a number of carbon sequestration (agroforestry) and emission reducing interventions for generating/ enhancing multiple streams of livelihoods and better environmental impact for small holder farmers at the community level, through targeting, farmer testing, and out scaling of the profitable portfolios. **Carbon Assessment**: Test and apply strategies, tools and methods for measuring and monitoring baseline and carbon sequestration from above and below ground biomass as well as emission reduction, beginning from the initiation of the project activities on farm and on the landscape around the project site. **Carbon Finance**: Develop carbon financing mechanisms by working with the existing conditional mechanisms for carbon incentives that facilitate, recognize and reward small holders for establishing and managing trees at farm and at the landscape level for carbon sequestration and for reducing emissions through other practices, based on acceptable standards and voluntary carbon markets. **Institutions:** Establish a viable Special Purpose Vehicle (platform) for small holders to access emerging carbon finance markets through building support linkages with appropriate institutions for managing transactions, negotiations and harmonization of capacities. This body would also be able to provide forward and backward linkages between the community and the carbon finance markets. The body will be operated by professionals, but controlled and managed by the community.

In general, this protocol advocates a gradual transition and transformation of "field crop agriculture" based livelihood systems to agroforestry based livelihood systems, including the field crops, and promotes the adoption of the emission reducing interventions in the farming- house hold operations. The agroforestry based systems have been documented to provide an insulation effect from climatic vagaries to the farming and at the same time sequester significant amount of carbon, both in the above and the below ground biomass.

Table 1. Summary of grid area for physical, social and agricultural details

Total geographical area	5000 ha.	Open well source	70%
Total agricultural land	3900 ha.	Tube well source	20%
Total area under rainfed	3500 ha.	Small tanks/streams	10%
Total area under irrigation	400 ha.	No. of households	2100
Total area under horticultural crops	2000 ha.	No. of hamlets	60
Total area under forests/wasteland	700 ha.	No.Village Panchyat	3 total and 2 partially
Total fallow land avilable	300 ha.	Population of grid	11000
Average land holding	1-2 acre	Social status	80% tribals
Major agricultural crops	Wheat, Maize, Jawar, Bajara, Mustard, Taramira, Til, vegetables	Occupation	Agriculture, poultry, animal husbandry

DISCUSSION:

Though the interventions in the grid area started from June 2009 and after two year the change in soil carbon level in intervention area is under study but the estimates of Certified Emission Reduction (CERs) are based on the verified methodologies and practices which will be carried out in total grid area as per land use pattern. The major intervention is tree based i.e. agroforestry and community forestry based which will sequester about 2/3 rd CERs (19033 CERs) and from energy measures (6345 CERs) from the grid area. The agricultural interventions are in adoption but there estimates yet to be done, which will further increase at least 6000 CERs for the grid.

These practices has to be validated in the arid- semiarid ecologies to develop a SMART CDM which can be come adoptable protocol in other region of India. This type of community based CDM project are in practice in other parts of continent e.g. Africa among small holders. In this grid area also a farmer cooperative society named 'Gramayjan Sahkari Paryavaran vikas samiti" has been formed to implement the interventions and develop a benefit share mechanism as per the interventions carried out by th individual farmers. These kind of project not only promote the agroforestry in the region but also provide an additional livelihood and benefits to the small and marginal farmers as they will sell their carbon credits. The indirect benefits village environment amelioration, soil and water conservation and food security will further strengthen the communities. The project has wider scope for implementation in other areas with the support from ICAR, SAUs or other such agencies in formulation and initiation of such projects for the benefits of the farmers.

In the case of A/R projects, the transaction costs are high and returns are low. Some of these costs are also to be met much before the approval of the project, whereas the returns will be realized much later, only after the issuance of Certification of Emission Reduction (CER). Many of the existing methodologies as such are not applicable in the Indian situations, particularly in A/R and agriculture sectors. This is mainly because that the land holdings in India are small, fragmented and scattered. Most agricultural land in India is primarily for livelihood support system and a few as a venture for commercial business. Hence, any CDM methodology should take cognizance of such realities and come up with the procedures that provide opportunities for additional revenue to small farmers without imposing any additional costs on them, or adversely impacting their livelihoods, including land use patterns. Non existence of such a methodology to comply with the CDM mechanism and to support plantation activities on small and marginal farmers / common lands could be one of the reasons for not materializing of the expected CDM projects in India with the involvement of communities. Preventing deforestation, decreasing logging and preventing the drainage of wet-lands or peat lands are some of the noted practices that decrease emissions. In contrast, growing trees, minimizing, or avoiding agricultural tillage, or changing cropping practices and re-establishing grasslands sequester carbon.

Table: 2. Possible generic CDM intervention taken up in NAIP Mavali grid area, Udaipur

Sr. No	Kind of intervention	Existing units (no/ area, etc.) (in ha)	Potential area (ha)	CERs	Remarks
	(A) Tree based interventions (Agroforestry)				
1	Private land used for agri horticulture (e.g. Citrus, Sapota, Guava, pomegranate)	100 ha.	3900 ha.	6436	20% of the total area planted (mean annual biomass production=5 t/ha)
2	Private land used for commercial timber (e.g. teak on the bunds/ borders)- Agri-silviculture	50 ha.	3900 ha.	348	10% of the total area Planted at 2 m distance, making 500 plants in a ha: MABP =1.08 kg/tree/year
3	Private land used for /industrial wood (e.g. Eucalyptus/ Leucaena etc,) and fuel wood in degraded lands	50 ha.	3900 ha.	4017	10% of the total area planted. Average annual dry matter production is 10.3 t/ha
4	Tree planting on roadside (e.g. with Neem)	5 km	40 km	92	100% of the potential area planted at spacing of 4 m; per year biomass = 2.78 kg/ tree
5	Tree planting along the canal banks, and water holding structures etc .(e.g. Neem)	3 km	20km	46	100% of the potential area planted at spacing of 4; per year biomass = 2.78 kg/ Tree
6	Tree planting on degraded lands, including the grasslands and JFM lands	50 ha	710 ha.	8094	100 % of the available area planted
	Subtotal (A)			19033	
	(B) Energy based interventions				
7	Energy efficient stoves	100	2500	5575	Energy efficient stoves will reduce the emissions to the extent of 2.23 tons of CO2 / year.
8	Capacitors for agricultural use	50	500	450	Av. 5 HP, 7hrs/day, 220 days/annum. Using capacitor save 35 % energy, Emission reduction 0.9 t CO2 /capacitor)
9	CFL	500	5000	220	All households on an average using 2 edison bulbs of 60W for 6 hr/day. Bulbs replaced in the cluster is about 2000. Carbon credits for each bulb equals 0.11 t CO2
10	Solar lantern	-	200	100	Solar lantern 3 W for 5 hr/day credit 0.5 t CO2
	Subtotal (B)			**6345**	
	Total (A+B)			**25378**	

CONCLUSION:

Unlike the industry, the emission reductions in agriculture and A/R sector at an individual farm level are quite small, and by this limitation the small holders are deprived of accessing the benefits from the carbon market. Hence, the aggregation of a number of farmers has become inevitable for preparing a CDM project. However, the aggregation of a large number of small farm units and small quantity of emission reductions at each unit, despite of their good equity value, makes these projects commercially unviable for project developers. The process of CDM project cycle is also lengthy and complicated, involving a large number of organizations and endlessly debatable thorny features like proving of the additionality, etc.

At present, local research institutions have limited capacity to acquire and run new and emerging techniques and to undertake measurements for productive understanding of carbon sequestration at the national and sub-national (regional) levels. Also there is an inadequacy about the knowledge of carbon finance markets and trading protocols, beyond the existing CDM mechanisms. Thus, there is a need to build the capacity of the researchers to study the impact of climate changes on carbon dynamics, carbon assessment protocols and carbon finance markets, especially in view of carbon trading in the emerging markets. The small scale project on carbon finance through grid approach and cooperative societies can make an impact on their livelihoods and amelioration of their rural environment.

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Carbon sequestration potential of *Tectona grandis* L. under agroforestry systems in Tamil Nadu

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ABSTRACT

Tectona grandis L. a long rotation species is cultivated as block plantation in farmlands of Tamil Nadu. Under agroforestry, the trees are grown in bunds or in wide rows of 8 m width. Within row spacing normally varies from 1.5 to 2 m. In the present study, teak plantations of ages from 5 to 18 were sampled in farm fields both under block planting system as well as under bund planting or wide-row planting. The total number of plantations sampled was 30. Mean stem wood biomass produced was 85.5 MT ha^{-1} under block plantation with mean age of 13 years and it was 9.3 MT ha^{-1} under boundary planting system at mean age of 11 years. Correspondingly, MAI of stem wood biomass production was 6.6 MT ha^{-1} $year^{-1}$ under block plantations and 0.85 MT ha^{-1} $year^{-1}$ under boundary planting. The total biomass accumulated was 180 and 22.8 MT ha^{-1} respectively under block and boundary planting. With reference to litter accumulation, it varied from 250 to 900 g m^{-2} and amounts to mean litter accumulation of 5.75 MT ha^{-1}. However, there was no litter accumulation observed under boundary planting, as the litter produced is ploughed in during field preparation for annual crops. The results on carbon sequestration potential (MT C ha^{-1}) of *Tectona grandis* plantations in Tamil Nadu revealed that greater amount of total carbon in biomass was sequestered under block plantation by registering 90.1 MT C ha^{-1} at an average age of 13 years. The amount of carbon in biomass sequestered under boundary planting was 33.3 MT C ha^{-1} at an average age of 11 years. There was additional contribution from litter amounting to 2.9 MT C ha^{-1} under block plantation. SOC was varying due to various land management practices. Data also revealed that in teak, thinning is a good practice for timber production, but minimizes the total carbon sequestration potential of the stand.

Keywords: Carbon sequestration potential, *Tectona grandis*, Agroforestry systems

INTRODUCTION

The concentration of CO_2 and other greenhouse gases (GHGs) in the atmosphere has considerably increased over the last century and is set to rise further. Carbon is accumulating in the atmosphere at a rate of 3.5 Pg (Pg = 10^{15} g or billion tons) per annum, the largest proportion of which is resulting from the burning of fossil fuels and the conversion of tropical forests to agricultural production (Paustian *et al.*, 2000). The targets of reducing the levels of CO_2 could be achieved through two major processes: (1) reducing anthropogenic emissions of CO_2; and (2) creating and/or

enhancing carbon sinks in the biosphere. Trees in plantations and in agroforestry systems play an important role as carbon sinks.

With reference to important plantation species in India, Casuarina, *Eucalyptus* spp., *Tectona grandis* and *Acacia spp*. are the main species having larger area under the plantations compared to other species. On a global basis, the total area under teak plantation extends to 2,253,540 ha, of which 44% is grown in India (Pandey and Brown, 2000). Carbon dynamics in such plantation ecosystems is very relevant for issues related to global change, especially its relation to the greenhouse effect. This issue has heightened interest in estimating the biomass, which in turn provides estimates of carbon pools. Consequently, biomass represents the amount of carbon that can be added to the atmosphere as CO_2 when the forest/plantations are cleared and/or burned. Further, changes in the cover, use and management of forest plantations produce sources and sinks of CO_2. To estimate the magnitude of these sources and sinks requires reliable estimates of the carbon contents in biomass of the forests/plantations (Brown, 1986). Further, the significance of agroforestry with regards to carbon sequestration and other CO_2 mitigating effects is being widely recognized, but there is still paucity of quantitative data on specific systems. There are sound reasons to believe that agroforestry can contribute significantly to carbon sequestration. It is important that research attention is focused on this aspect of agroforestry systems (Nair and Nair, 2002). The study on carbon sequestration gains importance in recent days also in the context of carbon credit systems, as afforestation and reforestation were added as eligible activities under the Clean Development Mechanism of Kyoto protocol (Kant and Katwal, 2003). With this backdrop, the present study was conducted to assess the carbon sequestration potential of teak (*Tectona grandis* L.) under different ages, site conditions and management systems including agroforestry systems in bund planting.

MATERIALS AND METHODS

Teak plantations were perambulated across the state in diverse growing conditions depicting a range of soil types and rainfall pattern and plantations of ages from 5 to 18 were sampled in farm fields. In the present study, block plantations with different management regimes as well as in bund planting was compared. In the selected plantations, sample plots were laid out and girth of all the trees in the sample plots were measured. The mean trees in each plantations were felled for biomass and carbon pool estimation.

The sample trees were cut at the ground level with the help of a bow saw and total height was recorded. All the branches and twigs were removed from the main stem. Leaves were also separated from the twigs. Green weight of main stem, branches, twigs and needles were recorded separately in the field. Representative samples from each component were taken and fresh weight of samples of all the components was measured in the field itself. The samples were transported to laboratory for dry weight estimation and carbon analysis. The main bole was cut into billets to make more accurate estimation of dry matter production in stem by minimizing the axial variations in stem from stump to canopy height. A 5 cm thick disc was taken from the cut ends of each billet. The bark and wood of the disc were separated and fresh weight recorded in the field. All the discs and bark were packed in paper bags and taken to laboratory for dry weight estimation and carbon analysis. All the samples were brought to the

laboratory and oven dried at 60° C till constant weight is recorded. Dry weight of different components was calculated on the basis of fresh and dry weight of the representative samples. Dry weight of wood and bark of each billet was estimated using mean wood: bark ratio of two successive discs. The dry weight of each billet was added separately to obtain the dry weight of bark and wood of the main bole.

In all the plantations studied for carbon sequestration, composite soil samples were collected up to 30 cm depth for estimations of soil carbon. The soil organic carbon content in the 0.2 mm sieved soil samples was estimated following Walkley and Black's wet oxidation method (Jackson, 1962).

Soil samples were analyzed for bulk density, organic carbon and texture. Soil organic carbon stock Qi (Mg m^{-2}) in a soil layer or sampling level i with a depth of Ei (m) depends on the carbon content Ci (g C g^{-1}), bulk density Di (Mg m^{-3}) and on the volume fraction of coarse elements Gi given the formula (Batjes, 1996).

$$Qi = Ci\ Di\ Ei\ (1 - Gi)$$

Where,

Qi – Soil organic carbon stock (Mg m^{-2})
Ei – Depth (m)
Ci – Carbon content (g C g^{-1})
Di – Bulk Density (Mg m^{-3})
Gi – Coarse fragments.

RESULTS AND DISCUSSIONS

Dry matter production: Out of 30 plantations sampled for carbon sequestration studies, 10 were block plantations with an espacement of 2 x 2 m, except one plantation with 2 x 4 m spacing. Remaining 20 plantations were raised as boundary planting in the farmland in single row with 2 m spacing between trees within the row, excepting one where the spacing between trees was 4 m. The age of sampled plantations ranged from 8 to 18 years under block plantations and from 5 to 18 years under boundary planting. Mean stem wood biomass produced was 85.5 MT ha^{-1} under block plantation with mean age of 13 years and it was 9.3 MT ha^{-1} under boundary planting system at mean age of 11 years. Correspondingly, MAI of stem wood biomass production was 6.6 MT ha^{-1} $year^{-1}$ under block plantations and 0.85 MT ha^{-1} $year^{-1}$ under boundary planting. Total biomass accumulated was 180 and 22.8 MT ha^{-1} respectively under block and boundary planting (Table 1 and 2). With reference to litter accumulation, it varied from 250 to 900 g m^{-2} and amounts to mean litter accumulation of 5.75 MT ha^{-1}. However, there was no litter accumulation observed under boundary planting, as the litter produced is ploughed in during field preparation for annual crops.

Plantation number Pl.No.2 and 3 are the adjoining plots, Pl. No.2 has spacing of 2 x 2 m without thinning operation and Pl. No. 3 has 2 x 4 m with one mechanical thinning done at 10 years age. After 5 years of thinning operation, there was greater difference in total dry matter production as well as stem wood production in these two plots. Total dry matter produced was 183 MT ha^{-1} in un-thinned plot and it was 136.0 MT ha^{-1} in thinned plot. Total stem production was also higher in un-thinned plot (100.1 MT ha^{-1}) than in thinned plot (69 MT ha^{-1}). However, on per tree basis, greater amount of dry matter accumulated in stem wood (55.2 kg per tree) in thinned plot,

when compared to that of in un-thinned plot (40.0 kg per tree). In terms of commercial volume, it was 0.104 m^3 per tree (3.67 cft per tree) in thinned plot and 0.051 m^3 per tree (1.81 cft per tree) in un-thinned plot, illustrating the benefits of thinning.

Table 1: Dry matter production (MT ha^{-1}) of different biomass components of *Tectona grandis* in block plantation in farmlands of Tamil Nadu

Pl. No.	Planting configuration	Tree density per ha	Age (years)	Leaf	Branch	Stem	Bark	AGB	BGB
1.	Block plantation	1736	8	3.9	13.9	72.1	11.6	101.6	20.3
2.		2500	15	3.7	32.9	100.1	16.5	153.1	30.6
3.		1250	15	3.9	29.9	69.0	10.6	113.3	22.7
4.		2500	12	9.8	30.8	30.2	9.9	80.7	16.1
5.		2500	18	10.1	166.2	311.3	33.8	521.4	104.3
6.		2500	13	9.6	29.1	30.2	9.9	78.8	15.8
7.		2500	13	6.2	33.2	52.0	11.5	103.0	20.6
8.		2500	12	13.5	48.2	48.1	8.2	118.1	23.6
9.		2500	11	12.3	34.6	72.4	12.1	131.4	26.3
10.		2500	10	2.5	15.8	69.4	12.7	100.4	20.1
	Mean	**2299**	**13**	**7.6**	**43.5**	**85.5**	**13.7**	**150.2**	**30.0**

Mean stem wood biomass produced was 85.5 MT ha^{-1} under block plantation with mean age of 13 years and it amounted to 9.3 MT ha^{-1} under boundary planting system at mean age of 11 years, which on an average accounts for 57% of AGB. Mean annual productivity (MT ha^{-1} $year^{-1}$) of total and stem wood biomass for four important tree species is presented in Fig 1 for comparison.

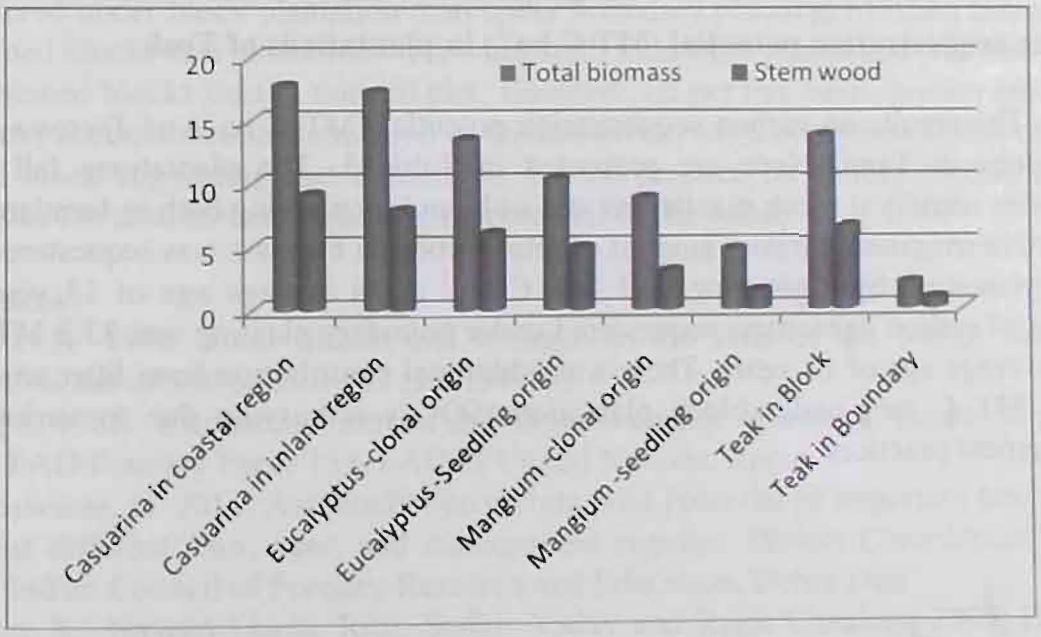

Fig 1: Mean annual dry matter productivity (MT ha^{-1} $year^{-1}$) of total and stem wood biomass of the four important tree species compared (Source: Buvaneswaran, 2011)

Table 2: Dry matter production (MT ha^{-1}) of different biomass components of *Tectona grandis* in boundary planting in farmlands of Tamil Nadu

Pl. No.	Planting configuration	Tree density per ha	Age (years)	Leaf	Branch	Stem	Bark	AGB	BGB
1.	Boundary planting	200	5	0.1	0.8	1.4	0.3	2.5	0.5
2.		200	14	0.6	2.1	4.3	0.9	7.9	1.6
3.		200	10	0.9	3.1	2.8	0.6	7.5	1.5
4.		200	12	1.2	3.8	5.5	1.0	11.4	2.3
5.		200	12	1.3	1.5	4.6	0.8	8.3	1.7
6.		200	13	0.5	2.5	3.1	1.9	8.0	1.6
7.		200	8	0.6	2.3	9.3	4.7	16.9	3.4
8.		200	12	1.4	18.3	10.9	1.8	32.5	6.5
9.		200	12	0.7	7.8	9.4	2.8	20.7	4.1
10.		200	11	0.3	1.6	5.7	1.2	8.7	1.7
11.		200	10	0.5	0.9	2.6	1.5	5.5	1.1
12.		200	14	1.1	7.6	5.5	1.9	16.0	3.2
13.		200	15	1.9	6.1	4.9	1.8	14.7	2.9
14.		200	12	0.5	1.5	5.5	1.9	9.3	1.9
15.		100	5	0.1	0.3	1.4	0.5	2.4	0.5
16.		200	9	1.4	7.3	7.4	4.3	20.3	4.1
17.		200	12	3.9	13.4	86.1	50.4	153.8	30.8
18.		200	18	0.8	5.8	11.1	2.5	20.2	4.0
19.		200	12	1.1	4.5	0.8	0.3	6.7	1.3
20.		200	7	0.2	1.3	3.9	0.9	6.3	1.3
	Mean	**195**	**11**	**0.9**	**4.6**	**9.3**	**4.1**	**19.0**	**3.8**

Carbon sequestration potential (MT C ha^{-1}) in plantations of Teak

The results on carbon sequestration potential (MT C ha^{-1}) of *Tectona grandis* plantations in Tamil Nadu are presented in Table 3. The plantations fall in two categories namely i) block plantations and ii) boundary planting both in farmlands with supportive irrigation. Greater amount of total carbon in biomass was sequestered under block plantation by registering 90.1 MT C ha^{-1} at an average age of 13 years. The amount of carbon in biomass sequestered under boundary planting was 33.3 MT C ha^{-1} at an average age of 11 years. There was additional contribution from litter amounting to 2.9 MT C ha^{-1} under block plantation. SOC was varying due to various land management practices.

Table 3: Carbon sequestration potential (MT C ha^{-1}) of *Tectona grandis* plantations in Tamil Nadu

Carbon Pool	Block plantation	Boundary planting
Above ground	75.1 ± 20.9	9.5 ± 3.6
Below ground	15.0 ± 4.2	1.9 ± 0.75
Litter	2.9 ± 1.6	Nil
SOC	16.4 ± 2.1	21.9 ± 4.0
Total Carbon	**109.4**	**33.3**

The CO_2 absorption rate is directly proportional to the growth rate. Most researchers estimate carbon storage by assuming the carbon content of dry biomass to the constant 50 per cent by weight, Brown (1986); Montagini and Porras (1998); Jha *et al.* (2003); Singh *et al.* (2006); and Chauhan *et al.* (2009). This method was followed in the present study as well to estimate carbon stock value in biomass components.

Different research workers reported carbon stock in different ecosystems and plantations which ranged from 31.07 MT C ha^{-1} (Dadhwal and Nayak, 1993) to 61.06 MT C ha^{-1} (Chhabra *et al.*, 2002). A 10-year-old *Poplar* plantations in China sequestered 72 MT C ha^{-1} at the density of 1111 stem ha^{-1} (Fang *et al.*, 2007). Similar result was reported for 8-year-old *Populus deltoides* plantations in Tarai, central Himalaya by Singh and Lodhiyal (2009). Mean above ground tree biomass carbon for *Shorea robusta, Albizzia lebbeck, Tectona grandis* and *Artocarpus integrifolia* were estimated to 5.22, 6.26, 7.97 and 7.28 MT C ha^{-1} respectively at 6 years age (Jana *et al.*, 2009). To conclude, in teak, as observed in the present study, a) while comparing block plantation and boundary planting, greater amount of total carbon in biomass was sequestered under block plantation than under boundary planting; b) when thinned and un-thinned blocks of a plantation were compared, total stem production was also higher in un-thinned blocks than in thinned plot. However, on per tree basis, greater amount of dry matter accumulated in stem wood in thinned block, when compared to that of in un-thinned block suggesting that thinning is a good practice for timber production, but minimizes the total carbon sequestration potential of the stand.

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Role of Agroforestry Systems in Climate Change

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ABSTRACT

Agroforestry systems can be better climate change mitigation option than ocean and other terrestrial options because of the secondary environmental benefits such as food security and secured land tenure, increasing farm income, restoring and maintaining above ground biodiversity ,watershed hydrology and soil conservation. Approximately 1.2 billion people (24% of the world's population) depend directly on agroforestry products and services in rural and urban areas of developing countries (Leakey and Sanchez, 1997). Indian National Forest Policy (1988) emphasizes that at least 33% of total geographical area should be under forests. But India's designated forest land constitutes over 23.41% of total land area of the country. Deforestation over the period 1980-1990 reached 8.2% of total forest area in Asia, 6.1% in Latin America and 4.8% in Africa. In India loss of nearly 4.5 million ha since 1950, mainly for agriculture and diversion for development projects (anonymous 2006a). Hence agroforestry will be playing a key role to enhance the green cover as well as MAD (Mitigation Adaptation and Development) challenges.

INTRODUCTION:

- Rising levels of greenhouse gases are already changing the climate. According to the Intergovernmental Panel on Climate Change (IPCC) Working Group I (WGI) Fourth Assessment Report, from 1850 to 2005, the average global temperature increased by about **0.76°C** and global mean **sea level rise by 12 to 22 cm** during the last century. These changes are affecting the entire world, from low-lying islands in the tropics to the vast Polar regions(IPCC-2007)
- Climate change predictions are not encouraging; according to the IPCC WGI Fourth Assessment Report, a further **increase in temperatures of 1.4°C to 5.8°C by 2100** is projected.
- CO_2 plays a leading role. It contributes to 50% of total green house effect. In 1988 an estimated 6 Giga tonnes of CO_2 was released into the atmosphere from anthropogenic sources and tropical deforestation.
- About two-thirds of the global terrestrial carbon, exclusive of that sequestered in rocks and sediments is sequestered in the standing forests. This include forest under storey plants, leaf and forest debris and forest soils. There are some non natural stocks in form of long lived wood products, waste dumps. This form of carbon stock is gaining importance with increased global timber harvest and manufactured wood products over the past several decades.

- The problem of increasing atmospheric CO_2 can be addressed in a number of ways, Agroforestry is one of the potential options.

Agroforestry has been defined in various ways. The World Agroforestry Centre (www.icraf.cgiar.org) defines it as "a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels." The Association for Temperate Agroforestry, AFTA (www.aftaweb.org) defines it as "an intensive land-management system that optimizes the benefits from the biological interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock." Several other definitions are also available (Nair, 1993). In essence, they all refer to the practice of the purposeful growing of trees and crops, and/or animals, in interacting combinations, for a variety of benefits and services (Nair et al., 2008, 2009a).

Role of Agroforestry in adapting and Mitigation to climate change

1. Agroforestry systems play a critical role in moderating the microclimate.
2. Agroforestry systems are highly effective in soil and water conservation.
3. Agroforestry systems have the capacity to enhance the use efficiency of rain water.
4. Agroforestry systems provide economically viable and environmentally friendly means to improve soil fertility.
5. Agroforestry systems have the potential to limit carbon emissions and sequester carbon.
6. Agroforestry systems offer a major pathway for sustainable diversification of agricultural systems and incomes.

Agroforestry Systems as Carbon Sinks

Agroforestry for carbon sequestration is attractive because : (i) it sequesters carbon in vegetation and in soils depending on the pre-conversion soil C, (ii) the more intensive use of the land for agricultural production reduces the need for slash-and-burn or shifting cultivation, (iii) the wood products produced under agroforestry serve as substitute for similar products unsustainably harvested from the natural forest, (iv) to the extent that agroforestry increases the income of farmers, it reduces the incentive for further extraction from the natural forest for income augmentation, and finally, (v) agroforestry practices may have dual mitigation benefits as fodder species with high nutritive value can help to intensify diets of methane-producing ruminants while they can also sequester carbon.

Standing Biomass

Plants fix atmospheric carbon in cell tissues as they grow thereby transforming carbon from the atmosphere to the biotic system. As a matter of fact drawing CO_2 out of the air and sequestering it into biomass is the only known practical way to remove large volumes of this green house gas form the atmosphere. Yadava (2011) reported maximum biomass carbon stocked in system *Populous deltoids* + wheat block plantation (31.86 tha^{-1}) and minimum was found in system *Populous deltoids* + lemon

grass block plantation (30.97 tha^{-1}). He also observed the maximum CO_2 mitigation in the same system *Populous deltoids* + Wheat block plantation (116.92 tha^{-1}) and minimum in system *Populous deltoids* + Lemon grass block plantation (113.15 tha^{-1}). Biomass production and carbon sequestration by tree components was maximum recorded in the *Populous deltoids* (2.06 tha^{-1}) of *Populous deltoids* + Wheat block plantation systems and (1.96 tha^{-1}) in system *Populous deltoids* + Lemon grass block plantation (Table 1).

Table- 1. Biomass carbon stock (tha-1) under different agroforestry systems

Systems	Treatments	Above ground tree biomass carbon stock (tha^{-1})				Total above ground tree biomass (tha^{-1})	Crop (tha^{-1})	Grass (tha^{-1})	Tree roots (tha^{-1})	Grand total (tha^{-1})
		Stem	Branch	Leaf	Litter					
Populous deltoids + wheat block plantation	S_1	21.38	0.92	0.73	0.20	23.23	2.80	-	5.83	31.86
Eucalyptus hybrid + wheat boundary plantation	S_2	3.65	0.06	0.03	0.02	3.76	2.71	-	0.71	7.18
Populous deltoids + wheat boundary plantation	S_3	5.19	0.17	0.13	0.14	5.63	2.92	-	1.38	9.93
Populous deltoids + lemon grass block plantation	S_4	20.63	0.68	0.53	0.20	22.04	-	3.45	5.48	30.97
Dalbergia sissoo + wheat block plantation	S_5	10.76	1.82	0.87	0.06	13.51	2.83	-	2.80	19.14
Dalbergia sissoo + lemon grass block plantation	S_6	10.76	1.79	0.83	0.06	13.42	-	3.38	2.82	19.62

*Source Yadava (2011)

A summary of aboveground CS rates in some major AFSs around the world (Table 2) presented by Nair et al. (2009a) shows that the estimates of CSP in AFSs are highly variable, ranging from 0.29 to 15.21 Mg ha_1 yr_1. As can be expected, these values are a direct manifestation of the ecological production potential of the system, depending on a number of factors, including site characteristics, land-use types, species involved, stand age, and management practices. Moreover, biomass production—based upon which these data seem to have been derived—may not represent the UNFCCC-stipulated measure of CS (''secure storage in long-lived pools''). Notwithstanding the above limitations, in general, AFSs on the arid, semiarid, and degraded sites have a lower CSP than those on fertile humid sites; and the temperate AFSs have relatively lower CSP compared with tropical systems.

Table 2 Reported values of carbon sequestration in the vegetation (aboveground) of some agroforestry systems

Agroforestry/land-use system and location	Age (year)	Mean vegetation C ($Mgha^{-1} yr^{-1}$)	References
Fodder bank, Segou, Mali, West African Sahel *(Gliricidia sepium* (Jacq.) Kunth ex Walp.,*Pterocarpus lucens* Willd. and P. *erinaceus* Poir.)	7.5	0.29	Takimoto *et al.* (2008a)
Tree-based intercropping, Canada: hybrid poplar + barley *(Hordeum vulgare* L.)	13	0.83	Peichl *et al.* (2005)
Parklands, Segou, Mali, West African Sahel	35	1.09	Takimoto *et al.* (2008a,b)
Agroforest, WesternOregon, USA *[Pseudotsuga menziesii* (Mirb) Franco + *Trifolium subterraneum* L.]	11	1.11	Sharrow and Ismail (2004)
Agrisilviculture, Chhattisgarh, Central India	5	1.26	Swamy and Puri (2004)
Silvopasture, Kerala, India	5	6.55	Kumar *et al.* (1998a, 1998b)
Home and outfield gardens	23.2	4.29	Kirby and Potvin (2007)
Shaded coffee, Southwestern Togo	13	6.31	Dossa *et al.* (2007)
Indonesian homegardens, Sumatra	13.4	8.00	Roshetko *et al.* (2002)
Cacao *(Theobroma cacao* L.) agroforests, Mekoe, Cameroon	26	5.85	Duguma *et al.* (2001)
Cacao agroforests, Turrialba, Costa Rica	5	10.34	Beer *et al.* (1990)
Cacao agroforests,	10	11.08	Beer *et al.* (1990)
Turrialba, Costa Rica **Woodlots, Puerto Rico**	4	12.04	Parrotta (1999)

Source: Adapted from Nair *et al.* (2009a), copyright Wiley InterScience

SOME STUDIES AT NAVSARI AGRICULTURAL UNIVERSITY

At Navsari agricultural University **Carbon sequestration potential** and **Stand level Carbon Sequestration of different species of trees** has been studied. The results of biomass accumulation throw light on carbon (C) sequestration potential among different species. Considering 50% of biomass on dry weight basis as a fair estimate of elemental carbon content, the mean tree C sequestration potential of *Albizia procera* was found to be maximum (169.58) which was at par with *Casuriana equisetifolia* (165.94) followed by *Eucalyptus tereticornis* (102.11kg). The least carbon sequestration was recorded in *Gmelina arborea* (17.18Kg) (Table 10). Out of the 169.58Kg carbon sequestration in *Albizia procera* 134.32, 29.33, 3.13, 2.80 Kg carbon was sequestrated by stem, branch, twig and leaves respectively. In case of *Casuriana*

equisetifolia the contribution accounts to 126.93, 27.84, 6.18, 4.99 Kg respectively. *Eucalyptus tereticornis* sequestered 78.21, 17.49, 4.47, 1.93 Kg in its stem, branch, twig and leaves respectively, while the carbon sequestration in various components of *Gmelina arborea* was 11.27, 4.41, 1.22, 0.29 Kg respectively. (Table 3). Carbon sequestration on stand basis also was consistent with that of mean tree carbon sequestration. It showed considerable variation, which ranged from 189.93 Mg/ha in *Albizia procera* to 19.25 Mg/ha in *Gmelina arborea*. *Albizia procera* stored maximum carbon (189.93 Mg/ha) which was at par with *Casuriana equisetifolia* (185.85 Mg/ha) closely followed by *Eucalyptus tereticornis* (114.36 Mg/ha). (Table 4)

Table 3: Mean tree carbon sequestration potential of MPTs at Instruction farm, NAU

Species	Stem (Kg)	Per tree (Kg)
Albizia procera	134.317	169.577
Casuriana equisetifolia	126.931	165.939
Eucalyptus tereticornis	78.214	102.112
Gmelina arborea	11.269	17.184

***Sreedevi (2010)**

Table 4: Stand level Carbon sequestration potential of 20 year old MPTs at Instructional farm, NAU

Species	Stem (Mg/ha)	Per ha (Mg/ha)
Albizia procera	150.43	189.928
Casuriana equisetifolia	142.27	185.852
Eucalyptus tereticornis	87.60	114.363
Gmelina arborea	12.62	19.246

***Sreedevi (2010)**

Soil Carbon

- Introducing trees in Agricultural farms may be useful technique to increase the soil carbon status because the presence of trees.
- Various interacting factors which influences carbon stock in the soil under agroforestry are addition of :-
  a). Litter
  b). Maintenance of higher soil moisture content
  c). Reduced surface soil temperature
  d). Proliferated root system.
  e). Enhanced biological activities.
  f). Decreased risk of soil erosion.
- In this system tree species are widely accepted by farmers which have minimum interaction with agriculture crops.
- Cultivation of fast growing trees with arable crops under agri-silviculture systems help in improving S.O.C. and sequestering carbon particularly in highly degraded barren lands.

- The literature on soil carbon sequestration (SCS) potential of AFS is scanty, although rather plentiful reports are available on the potential role of agricultural soils to sequester C. Reviewing the available information on SCS in AFS worldwide, summarized in Table 3, Nair et al. (2009a) reported that the estimates varied greatly across systems, ecological regions, and soil types. The study revealed a general trend of increasing SCS in agroforestry compared to other land-use practices (with the exception of forests); overall, the land-use systems were ranked in terms of their SOC content in the order: forests > agroforests > tree plantations > arable crops. [Agroforests are complex multistrata systems, similar to homegardens in structural complexity,but larger in size (Nair et al., 2009a).] The authors noted that the estimated values of SCS in AFS varied greatly and were a reflection of several factors including biophysical and socioeconomic characteristics of the system parameters as well as the lack of uniformity in study procedures.(Table 7)
- Karnal Das and Itnal *et al.*, (1995) at Central Soil Salinity Research Institute studied the SOC contents after six years of plantation with different land use systems at different depth of soil i.e; 15 cm and 30 cm and found that agroforestry practices store more SOC in soil as compared to sole cropping. (Table 5)
- Similarly Liyanage and Dssanayaka (1993) studied the effect of mixed cropping on soil organic carbon at 15 cm depth and found that mixed farming system has more SOC than mixed cropping compared to mixed cropping and monoculture system. (Table 6).

Table 5: SOC contents after six years of plantation with different land use-systems

Land used systems	Organic carbon (g kg –1) in	
	0.15cm	0.30cm
Sole cropping	4.2	3.9
Agro forestry	7.1	7.2
Agri-horticulture	7.3	7.3
Agri –silviculture	3.8	4.7

Central Soil Salinity Research Institute, Karnal Das and Itnal *et al.*, (1995)

Table 6: Effect of mixed cropping on soil organic carbon in 0-15 cm depth

Copping system	Soil organic C ($g\ kg^{-1}$)
Mixed cropping system	8.6
Coconut only	14.2
Coconut + Cocoa	13.6
Coconut + Coffee	12.7
Coconut + Pepper	12.0
Coconut + Clone	14.6
Coconut + Cinmamon	
B) Mixed farming system	16.3
C) Monoculture system	6.6

Table 7: Some reported values of soil organic carbon (SOC) stock in agroforestry systems

Agroforestry system/species	Location	Age (year)	Soil depth (cm)	Soil C ($Mg\ ha^{-1}$)	References
Mixed stands, *Eucalyptus* + *Casuarina* (Q, C + *Leucaena* (L), *Eucalyptus* + L	Puerto Rico	4	0-40	61.9, 56.6, and 61.7	Parrotta (1999)
Agroforest *[Pseudotsuga menziesii* (Mirb) Franco + *Trifolium subterraneum* L.]	Western Oregon, USA	11	0-45	95.89	Sharrow and Ismail (2004)
Agrisilviculture *(Gmelina arborea* Roxb. + eight field crops)	Chhattisgarh, Central India	5	0-60	27.4	Swamy and Puri (2005)
Tree-based intercropping: hybrid poplar + barley	Ontario, Canada	13	0-20	78.5	Peichl *et al.* (2005)
Silvopastoral system: *Acacia mangium* Willd. + *Arachis pintoi* Krapov. & W. C. Gregg	Pocora, Atlantic coast, Costa Rica	10-16	0-100	173	Amezquita *et al.* (2005)
Alley cropping *Leucaena-4* m wide Rows	Western Nigeria	5	0-10	13.6	Lai (2005)
Alley cropping: hybrid poplar + wheat, soybeans, and maize rotation	Southern Canada	13	0-40	125	Oelbermann *et al.*(2006)
Alley cropping system: *Erythrina poeppigiana* (Walp.) O. F. Cook + maize and bean *(Phaseolus vulgaris* L.)	Costa Rica	19	0-40	162	Oelbermann *et al.*(2006)
Gliricidia sepium + maize	Zomba, Malawi	10	0-200	123	Makumba *et al.* (2007)
Agroforest (home and outfield gardens)	Ipeti-Embera Panama,		0-40	45.0	Kirby and Potvin(2007)
Shaded coffee, Coffea robusta L. Linden + Albizia spp.	Southwestern Togo	13	0-40	97.27	Dossa *et al.* (2008)
Sivopasture: slash pine (Pinus elliottii Engelm.) + bahiagrass (Paspalum notatum Fliigge)	Florida, USA	8-40	0-125	6.9-24.2	Haile *et al.* (2008)

Faidherbia albida (Delile) A. Chev.Parkland	Segou, Mali	35	0-100	33.3	Takimoto *et al.* (2008a)
Live fence (Acacia nilotica (L.) Willd., Acacia Senegal (L.) Willd., Bauhinia mfescens L., Lawsonia inermis L., and Ziziphus mauritiana Lam.)	Segou, Mali	8	0-100	24	Takimoto *et al.* (2008a)
Fodder bank (See Table 2 for species list)	Segou, Mali	6-9	0-100	33.4	Takimoto *et al.* (2008a)
Homegardens	Kerala, India	35+	0-100	101-126	Saha *et al.* (2009)
Dehesa system	Central Spain	30+	0-100	27-50	Howlett (2009)
Shaded cacao systems	Bahia, Brazil	30	0-100	302	Gama-Pvodrigues *et al.* (2010)

Carbon storage under agroforestry systems

Rai *et al.* (2001) registered maximum total C storage in *A. nilotica* + *established pasture* (19.7 t C/ha) based Silvi-pastoral system (age 5 years) which has maximum followed by *D. sissoo* + *established pasture* (17.2 t C/ha) and *H. binata* + *established pasture* (17.0 t C/ha).(Table – 8)

Kaur *et al.* (2002) stated that total C storage maximum *Acacia/Dalbergia/Prosopis* + *Desmostacya* (6.8-18.5 t C/ha) based Silvi-pastoral system (age 6 years) which followed by *Acacia/Dalbergia/Prosopis* + *Sporobolus* (1.5-12.3 t C/ha). (Table – 9)

Singh and Dhaliwal (2005) recorded maximum total C storage *Emblica officinalis* + *Vigna radiata* (12.7-13.0 t C/ha) based Agri-silvicultural system (age 8 years) as compare to *Hardwickia binata* + *Vigna radiata* (8.6- 8.8 t C/ha) and *Colophospermum mopane* + *Vigna radiata* (4.7- 5.3 t C/ha). (Table – 10)

Anonymous (2006) analysised the total C storage under three agroforestry systems and found that Silvi-pastoral system obtained the highest (2.17 t C/ha) total c storage which wasfollowed by Agri-horti-pastoral (1.15 t C/ha) and Horti-pastoral (1.08 t C/ha) system. (Table – 11)

Dhayni *et al.* (2009) observed potential C storage for Agroforestry systems in different eco-regions of the world and stated that highest C was recorded in Silvi-pastural System 133-154 (Mg C/ha) as compare to Agri-silvicultural System 112-128 (Mg C/ha). (Table – 12)

Table 8: Total C storage under agroforestry systems

Agroforestry system and components	Total C storage (t C/ha)
Silvi-pastoral system (age 5 years)	
Acacia nilotica + natural pasture	9.5-17.0
A. nilotica + established pasture	19.7

Dalbergia sissoo + natural pasture	12.4
D. sissoo + established pasture	17.2
Hardwickia binata + natural pasture	16.2
H. binata + established pasture	17.0

Rai *et al.* (2001)

Table 9: Total C storage under agroforestry systems

Agroforestry system and components	Total C storage (t C/ha)
Silvipastoral system (age 6 years)	
Acacia/Dalbergia/Prosopis + Desmostacya	6.8-18.5
Acacia/Dalbergia/Prosopis + Sporobolus	1.5-12.3

Kaur *et al.* (1992)

Table 10: Total C storage under agroforestry systems

Agroforestry system and components	Total C storage (t C/ha)
Agri-silvicultural system (age 8 years)	
Emblica officinalis + Vigna radiate	12.7-13.0
Hardwickia binata + Vigna radiate	8.6- 8.8
Colophospermum mopane + Vigna radiate	4.7- 5.3

Singh (2005)

Table 11: Total C storage under agroforestry systems

Agroforestry system and components	Total C storage (t C/ha)
Silvi-pastoral system	2.17
Agri-horti-pastoral	1.15
Horti-pastoral	1.08

Anonymous(2006)

TABLE 12: Potential C storage for Agroforestry systems in different eco-regions of the world

COUNTRY	Eco region	System	Mg C/ha
Africa	Humid tropic high	AGRI SILVICULTURAL SYSTEM	29-53
South America	Humid tropic low		39-102
	Dry low land		39-195
South East Asia	Humid tropical		112-128
	Dry low land		68-81
Australia	Humid tropics low	SILVI-PASTURAL SYSTEM	28-51
North America	Humid tropics high		133-154
	Humid tropics low		104-198
	Dry low land		90-175
Northern Asia	Humid tropical low		15-18

Dhyani *et al.* (2009)

FARM FORESTRY

- It involves the growth and management of trees on private farm lands for the purpose of supply of wood and non-wood products, provides a balanced mix of economic, social and environmental outcomes.
- Of the 80% potential that the tropics possess to conserve and sequester carbon, forestation and agro forestry/farm forestry account for 50%.
- Farm forestry compares favorably to reforestation or afforestation activities not only in terms of utilizing substantial amounts of atmospheric carbon but costs.
- Unlike traditional carbon sequestration techniques, farm forestry has the potential of being presented by policy makers as a primary instrument for people's welfare and industrial growth.

Singh *et al;* (2000) at TERI, New Delhi studied the total carbon sequestrated under farm forestry in UP during the period 1979-94 and found that Farm Forestry practices in sequestering of carbon at tremendous amount. (Table 13)

Table 13:Total carbon sequestered under farm Forestry in UP during the period 1979-94

Year	Number of tress planted (in Million)	Numbers of trees @ 80% survival (in million)	Trees converted to ha. @ 1500/ha	Volume of wood produced per ha/year (m3)	Quantity of carbon sequestered @ 0.5 tonnes per M3 of wood (in tonnes)
1979-80	16.3	13.04	8693		
1980-81	66.7	53.36	35773	53889	26949
1981-82	146.8	117.44	78293	141904	70952
1982-83	254.0	203.20	135467	302064	151032
1983-84	252.3	201.84	134560	812859	406429.3
1984-85	355.0	284.00	189333	1701531	850765.3
1985-86	151.5	121.20	80800	2685872	1342936
1986-87	144.8	115.84	77227	4023888	2011944
1987-88	136.8	109.44	72960	4525920	2262960
1988-89	142.2	113.76	75840	4832432	2416216
1989-90	110.3	88.24	58827	4726923	2363461
1990-91	62.6	50.08	33387	4627520	2313760
1991-92	32.2	25.76	17173	4280773	2140387
1992-93	18.4	14.72	9813	3780784	1890392
1993-94	16.9	13.52	9013	3093413	1546707
	1906.8	1525.44	1016960	39589781	19794891

Singh *et al.*, (2000)

Wood products in carbon locking

- When forest are cut, wood is converted to different products, which decay at different rates and release the locked carbon back into the atmosphere.
- Due to agroforestry farmers will use wood products made of their own farm wood and which will reduce pressure on natural Forest.
- It is recognized that if durable wood is used for construction, furniture, wood based panels, paper board, also called as non-emitting sources then these products retain carbon during their lifetime and act as carbon sinks.
- Conversion of trees into durable products or non-durable wood into durable wood will extend their carbon sequestration.
- Thus post-harvest approach that reduces waste and puts most of the wood into long-lived products by applying various preservatives is an effective strategy to reduce global atmospheric carbon dioxide.
- Only 0.8% remain locked in wood products at the end of 100 years.
- Kumar (1998) reported that wood preservative treatment would be causing an increase of 3.6 times more life as compared to untreated wood. (Table 14)

Table 14: Influence of preservative treatment on life cycle of wood under different uses

Product / use	Quantity used (Million m^3)	Expected life				
		Expected life		Expected life		Increases
		Yrs/ unit	Total M^3 yrs (million)	Yrs/ unit	Total M^3 yrs (million)	Yrs/ unit
Plywood	1.0	5	5.0	15	15.0	3.0
Other panels	0.5	5	2.5	15	280.0	3.0
Housing	7.0	10	70.0	40	30.0	4.0
Mines	3.0	2	6.0	10	-	5.0
Furniture	0.2	15	3.0	30	17.5	3.0
Packaging	3.5	2	7.0	5	15.0	2.6
Cooling tower	1.0	3	3.0	15	10.0	5.0
Marine	1.0	2	2.0	10	10.0	5.0

Timber Development Association. Kumar (1998)

Afforestation and reforestation

- Afforestation have tremendous potential for carbon sequestration not only in above ground carbon biomass but also root carbon biomass in deeper soil depths.

- Reforestation of 75 million ha most degraded lands with suitable trees and grasses/crops may sequester about 4Pg of carbon.

- If 10 million ha area is reforested per year, $400x10^6$ ha of new forest will be created by the year 2040.By the time the new forest mature(40-100 year after plantation) 25 to 50Gt of CO_2 will have been sequestered from the atmosphere.

- Raising trees on degraded lands in arid areas irrigating with saline water also may help in C sequestration to a greater extent.

- We have about 175.00 million ha degraded land, 22.00 million ha under special problematic area. Thus these areas have high potential for afforestation.
- We have 19.44 million ha under barren & unculturable land, 11.04 million ha under pasture or grazing land, 3.62 million ha under miscellaneous tree crops and groves, 13.82 million ha culturable wastelands and 24.90 million ha under old and current fallows. It means total 72.82 million ha can be brought under afforestation or some kind of agroforestry systems. (Hand Book of Agriculture).

If this entire land is under silvi-pastoral system consisting of some grasses and trees like *Prosopis* or *Acaia*, we get biomass of 2Mg/ha^{-1}yr^{-1} for tree and 4 Mg/ha^{-1}yr^{-1} for the grass in cycle of 7 years (Gupta and Rao,1994) along with dramatic increase in soil carbon.

Agroforestry is the best option for MAD challenges

From the above discussion its clear that agroforestry systems have carbon sequestration potential but today with enormous increase in population we have other challenges like Food security, Poverty alleviation, health and nutrition, conserving biological diversity etc. In this situation agroforestry suits best option as despite of sequestering carbon it provide food security, helping in poverty alleviation, providing nutrition and conserving biological diversity which seems one capsule for all diseases.

Agroforestry and food security

Farmland in the developing world generally suffers from the continuous depletion of nutrients as farmer's harvest without fertilizing adequately or fallowing the land. Nowhere is this truer than in Africa. Small – scale farmers have removed large quantities of nutrients from their soil without using sufficient amount of manure or fertilizer to replenish fertility. This has result in high annual nutrient depletion rate of 22 kg nitrogen, 2.5 kg phosphorus, and 15 kg potassium per hectare of cultivated land over the past 30 year in African countries – an annual loss equivalent to $ 4 billion worth of fertilizer (Sanchez 2002).After years of experimentation with a wide range of soil fertility replenishment practices, three types of simple, practical fertilizer tree systems have been developed that are now achieving widespread adoption. These are (1) improved fallows using trees and shrubs such as sesbania (*Sebania sesban*) or tephrosia (*Tephrosia Vogelii*), (2) mixed intercropping with wild sunflower (*Tithonia diversifolia*) or *Gliricidia* (Place *et al.* 2002). They provide 50 to 200 kg N ha^{-1} to the associated cereal crops. Yield increases are typically two – to- three times that with current farmer's practices. Roughly one quarter of the farmland in the developing world has been degraded. Agricultural reform must address the risks of land degradation due to over – cultivation, desertification, declining water supplies, and loss of biodiversity. The potential of agroforestry to rehabilitate degraded land, and to conserve soil and water on the working lands of the tropics, has long been recognized (Young 1997). Tree – based soil conservation systems have real promise in this regard.

Agroforestry and poverty alleviation

Nearly three – quarters of the poor people who live on less than $1 a day are found in the rural areas o developing countries (Dixon et al. 2001). Increasingly, we see the science of agroforestry as means to advance the business of smallholder agroforestry. A 1% yield increase is associates with a 1% drop in the number of people living on less than $ 1a day. A new approach is needed: a research and development strategy to reduce dependency on primary agricultural commodities, and to establish production of added – value products based on raw agricultural materials, with link to growing and emerging markets. Small holder timber production is increasingly appreciated as an important source of many countries wood supplies. In Bangladesh, it is estimated that 90% of the wood used is produced on agricultural land. In India, half of the timber now emanates from private farmland. Tree crop played a critical role as a

spring board for economic growth in southeast Asia during the past three decades (Tomic *et al.* 1994). Indeed, tree crop such as cacao (*Theobroma cacao*), coffee (*Coffea spp.*), and tea (*Camellia sinensis*) have also been mainstays of the economies of a number of African and India .

Agroforestry for health and nutrition

Advance in agroforestry have many links with improving the health and nutrition of the rural poor. The expansion of fruit tree cultivation on farms can have a significant effect on the quality of child nutrition. In Africa, for example, more than 80% of the population depends on medicinal plants for their medical needs. Two – thirds of the species from which medicinal are tree.

Agroforestry for conserving biological diversity

Agroforestry impinges on biodiversity in working land-space in at least three ways. First , the intensification of agroforesty systems can reduced exploitation of nearby or even distant protected areas (Murniati *et al.* 2001 ; Garrity *et al.* 2003). Second , the expansion of agroforestry systems can increase biodiversity in working landscapes. And third , agroforestry development may increase the species and within – species diversity of trees in farming system. Agroforestry will play a major role in the two key dimensions of climate change : mitigation of greenhouse gas emission and adaptation to changing environmental conditions .

CONCLUSION

Agroforestry practices play an important role to influence biomass level, carbon storage as CO_2 mitigation potential. It is evident from the foregoing that different agroforestry systems can sequester more carbon as compared to sole agricultural land use systems. Tree component in agroforestry systems can be significant sinks of atmospheric carbon due to their fast growth and high productivity. Area specific agroforestry models should be promoted a measure for mitigating climate change through higher C sequestration in addition to other benefits like improved socio-economic condition and sustainable management of the land resources.

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Biomass production and Carbon Sequestration in different Short rotation tree species on shallow soils

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ABSTRACT

Global warming and climate change are important environmental issues affecting human lives and systems of planet earth and has captured the world's attention during the recent past. Much of the increase in global average temperature since the mid – 20th century is due to the increase in the concentration of greenhouse gases (GHGs). Carbon dioxide (CO_2) is the most important anthropogenic GHG. In nature, plants, through the process of photosynthesis, fix atmospheric CO_2 into various parts and return a part of that carbon to the atmosphere through respiration. Carbon sequestration in agroforestry systems can be broadly divided into sequestration in above ground and in below ground plant parts. The carbon sequestered in each part differs greatly depending on various factors viz., agro climatic region, the type of system, site quality, previous land use etc., The practice of establishing woodlots has been expanding due to the shortage of fuel wood, pulp wood industrial wood and also due to the enhanced demand for poles. Woodlots are being raised mostly on large farms due to the high labour costs, less income from crops and high risk in growing field crops under rain fed conditions where crop failure is a common phenomenon.

Here an attempt is made to measure carbon sequestration rate and assesses the biomass productivity in ten selected tree species. These ten trees species are raised in medium soil at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. Ten tree species are 1. *Casuarina equisetifolia* 2. *Eucalyptus tereticornis* *Tectona grandis* 4. *Dalbergia sissoo* 5. *Anogeissus latifolia* 6. *Albizia lebbeck* 7. *Grevillea robusta* 8. *Hardwickia binnata* 9. *Acacia nilitica* 10. *Azadirachta indica* in were planted at 2 x 2 m with three replication in randomised block design. Observations on height, dbh and crown spread were recorded every year during the period 1990 to 2010. The biomass was worked out by extracting selected number of trees. The findings revealed that biomass productivity was in the order of *Eucalyptus tereticornis>Dalbergia sisso > Albizzia lebbeck >Anogeissus latifolia > Grevillea robusta > Casurina equeisetifolia> Hardwickia binnata > Acacia niloitica > Tectona grandis > Azadirachta indica.* The carbon content in the different tree species was in the order of *Anogeissus latifolia Dalbergia latifolia > Albizzia lebbeck > Dalbergia sissoo > Grevillea robusta > Casurina equeisetifolia > Hardwickia binnata > Acacia niloitica > Tectona grandis .*

Keywords: Carbon Sequestration, Biomass, Woodlots, Productivity

INTRODUCTION

Global warming and climate change are important environmental issues affecting human lives and systems of planet earth and has captured the world's attention during the recent past. Much of the increase in global average temperature since the mid – 20th century is due to the increase in the concentration of greenhouse gases (GHGs). Carbon dioxide (CO_2) is the most important anthropogenic GHG. Its annual emissions grew by about 80% between 1970 and 2004. global increases in CO2 concentrations are primarily due to fossil fuel use, with land – use change providing another significant but smaller contribution. Global GHG emissions will continued to grow over the next few decades with the climate change mitigation policies and related sustainable development practices currently in place. Active absorption of atmospheric carbon dioxide (CO_2) from the atmosphere through photosynthesis and its subsequent storage in the biomass of growing trees or plants is referred as carbon sequestration (Baes *et al.* 1977). Carbon dioxide (CO_2) is a dominant greenhouse gas. Increased atmospheric CO_2 is attributable mostly to fossilfuel combustion and deforestation world wide (Hamburg *et al.*, 1997). Trees act as a sink for CO_2 by fixing carbon during photosynthesis and storing excess carbon as biomass. The net long term CO_2 source / sink dynamics of forests change through time as trees grow, die and decay. The rate of carbon storage increase in young stands, but then declines as the stand ages. The rate of carbon storage begins to decline at approximately age 20 and is close to zero by age 100 (Veld and Plantinga, 2005).

Increasing the atmospheric CO_2 concentration stimulates the photosynthetic rate of trees and can result in increased growth rates and biomass production. Scientific evidence suggests that increased atmospheric CO_2 could have positive effect such as improved plant productivity. (Keutgen and Chen, 2001) A. study reported by Warran and Patwardhan on carbon sequestration potential of trees that the standing biomass in India is estimated to be 8375 million tons (Mt) for the year 1986, of which the carbon storage would be 4178 Mt. The total carbon stored in forest, including soil is estimated to be 9578 Mt (Warran and Patwardhan, 2008).

In view of the dwindling forest cover agroforestry is widely considered as a potential way and low cast method to sequester atmospheric carbon and recognized as one of the strategy for climate change mitigation (Alavalapati and Nair, 2001). Different agroforestry systems may sequester varying amount of carbon depending on tree species, growing condition and management practices. Further, allocation of sequestered carbon in different tree components may also very. Nirmal Kumar *et al.* (2009) wherein the carbon content reportedly varied from 37.8% in *Sterculia orens* to 46.6% ub *A. nilotica*. The carbon content of *B. monosperma* was reported to be 38.6% to 41.42%.

Hence the study was under taken to assess carbon sequestration rate and above ground biomass productivity of short rotation tree species.

MATERIAL AND METHODS

An experiments involving ten tree special *viz.* 1. *Casuarina equisetifolia* 2. *Eucalyptus tereticornis* 3. *Tectona grandis* 4. *Dalbergia sissoo* 5. *Anogeissus latifolia* 6. *Albizia lebbeck* 7. *Grevillea robusta* 8. *Hardwickia binnata* 9. *Acacia*

nilotica 10. *Azadirachta indica* and were planted on red gravelly soil at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad under rainfed conditions. The soil of the study area belong ot degraded red soils with pH of 6.4 and N:P:K 172, 18.6 and 164.7 kg / ha respectively. The general climate of the area is tropical lies in northern transitional zone of Karnataka. During the monsoon rainfall of the location is 800 mm which is received in 42 rainy days. The mean annual maximum temperature raised from 36.82 ^{0}C to 28.62 ^{0}C and annual minimum temperature varied from 22.4 ^{0}C to 14.1 ^{0}C. At the end of 20 years, sample trees were felled and biomass productivity in different part of tree species was assessed and presented in table.

Carbon content in the above ground biomass

The carbon content of different biomass such as stems, branches and leaves samples were estimated by taken samples. A certain amount of biomass samples have been collected from the particular stem, branches and leaves and after being properly dried at 70 ^{0}C for about 7 day to a constant weight, the dried samples were powdered Carbon content in all the samples were estimated by dry ashing method and carbon content has been estimated as per the formula viz.,

Carbon = Biomass x carbon %

From the total dry biomass, total carbon content and amount of CO_2 sequestrated in tree was calculated. For calculating CO_2 equivalent, total carbon was multiplied with a factor of 3.6663 which has the basis of atomic weight ratio of CO_2 to C. For calculating CO_2 sequestration rate of individual tree species, total CO_2 was divided by age of the trees (20 years) and are presented in the table: 3.

RESULT AND DISCUSSION:

Growth and biomass of trees:

The plant height was significantly higher in *Eucalyptus tereticornis, Casurina equisetifolia* and *Grevillea robusta* and was followed by *Tectona grandis* as compared to other tree species. Similarly, *Eucalyptus tereticonrnis* had higher dbh (24.50 cm) followed by *Albizzia lebbeck* (22.08 cm) *Casurina equisetifolia* (20.8) and *Hardwickia binnata* (19.46 m) and the least was in *Anogeissus latifolia* (14.39 cm). Crown area was significantly higher in *Albizzia lebbeck* (15.26 m2/pl) as compared to other tree species. The crown area was lowest in *Azadirachta indica* (6.56 m2/pl). and *Dalbergia sissoo* (6.64 m^2 / pl) (Table 1).

Biomass productivity differed significantly among the different trees species. Stem biomass was significantly higher in *E. tereticornis* followed by *Casurina equisetifolia* as compared to other trees species. The lowest stem biomass was observed in *A.indica* and *D. sissoo*. Biomass in small branches was significantly was higher in *Albizzia lebbeck, Casurina equisetifolia* and was followed by *E.tereticornis*. The lowest small stem biomass was observed in *A. indica, H. binnata* and *T. grandis*. Leaf and twig biomass was significantly higher in *A. indica* and *Casurina equisetifolia* as compared to other trees species the lowest twig and leaf biomass was also observed in

A. indica and *T. grandis* this may be due to genetic variation in growth of trees species and their response to the site conditions. Similar variations in growth and productivity of trees species were reported by Mishra and Bhat. (2003)

Carbon content of trees :

The distribution of carbon content in the different parts in presented in Table 2. The carbon content varied significantly among the tree species as well as different parts of the tree. The highest 'C' content was found in the stem wood of *E. tereticornis* (47.86 %) and lowest was in the stem of *A. indica* (44.58 %). Among the small branches of tree species. Significantly highest carbon content was recorded in *A. lebbeck* (49.60%), *E. tereticornis* (48.20%) and lowest was in *C. equisetifolia* (45.86%). The carbon content was highest in foliage of *A. lebbeck* (50.60 %) followed by *A. nilotica* (49.32%) and lowest was in *E. tereticornis* (45.63%). Irrespective of tree components, on average maximum carbon content was observed in *A. lebbeck* (48.98%) followed by *E. tereticornis* (47.75) and lowest was in *C. equisetifolia* (45.59%).

The total dry biomass, carbon content, equivalent CO_2 and CO_2 sequestrated rate were highest in *E. tereticornis, A. lebbeck* and *D. sissoo* and lowest was in *A. nilotica* and *A. indica* and *T. grandis.* The significantly variation in 'C' content in selected tree species may be due their genetic make up, crown architecture and chemical and anatomical uniqueness of each kind of wood. (Lamlon and Savidge, 2003, Ford 1985). The difference in carbon allocation among tree components might be due to complex phenomenon working between carbon organ (Leaves) and carbon sink organic (Stem, branches etc) of a tree (Genard *et al.*, 2008). The findings of the present study, the foliage and branches have maximum capacity to capture carbon are in conformity with of Hiquera and Martinez (2006). Among all the tree species, *E. tereticornis, A. lebbeck* and *D. sissoo* appears to be the most efficient in capturing carbon and removing CO_2 from atmosphere while *Azadirachta indica* and *T. grandis* are the least. This may be due to the difference in the growth habit and the crown structure etc.,

Carbon (c) in relation to tree growth

The carbon content in trees increased with increase in mean tree height and diameter at breast height. The growth attributes are key rate in biomass productivity and carbon content. The higher amount carbon is stored in wood components (pole / stem). Both *A lebbeck* and *E. tereticornis* are to be most efficient in capturing C and removing CO_2 from atmosphere.

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Table 1: Height, DBH, Crown area and Biomass production of different tree species

Tree species	Height (m)	DBH (cm)	Crown area (m^2/pl)	Timber / Pole (kg/tree)	Small branches (kg/tree)	Leaf & twigs (kg/tree)	Total Biomass (kg/tree)
1. *Casuriana equisetifolia*	13.84	20.80	7.50	85.6	17.80	12.86	116.26
2. *Eucalyptus tereticornis*	15.62	24.50	7.70	132.6	16.86	12.36	161.82
3. *Tectona grandis*	10.24	15.06	7.14	40.86	22.31	10.21	73.38
4. *Dalbergia sissoo*	9.08	15.05	6.64	88.4	32.2	15.26	135.86
5. *Anogeissus latifolia*	9.85	14.39	7.43	66.8	30.64	17.36	114.80
6. *Albizia lebbeck*	9.44	22.08	15.26	82.6	34.80	16.31	133.71
7. *Grevillea robusta*	12.46	18.67	7.45	88.7	18.2	11.62	118.52
8. *Hardwickia binnata*	9.85	19.46	6.63	60.4	21.6	13.4	95.4
9. *Acacia nilitica*	7.75	15.58	12.10	45.8	28.6	10.40	84.80
10. *Azadirachta indica*	7.64	15.61	6.56	40.6	20.6	9.60	70.80
SEm ±	0.21	1.28	1.58	2.25	1.41	0.74	3.23
CD 5%	0.62	3.82	4.72	6.68	4.19	2.19	9.57

Table 2: Carbon content (%) in different components of tree species

Tree species	Timber/pole stem (%)	Small branches (%)	Foliage (leaf & twigs (%)	Mean (%)
1.Casuarina equisetifolia	44.84	45.86	46.12	45.60
2. Eucalyptus tereticornis	47.86	48.20	45.63	47.23
3.Tectona grandis	44.86	47.93	44.32	45.70
4. Dalbergia sissoo	46.21	47.45	46.18	46.61
5. Anogeissus latifolia	45.67	46.80	48.62	47.03
6. Albizia lebbeck	46.75	49.60	50.60	48.98
7. Grevillea robusta	46.82	47.76	48.32	47.63
8. Hardwickia binnata	45.8	46.88	49.26	47.31
9. Acacia nilitica	46.72	47.28	49.32	47.77
10. Azadirachta indica	44.58	46.82	46.65	46.01
SEm ±	0.99	1.06	1.23	0.88
CD 5%	2.95	3.16	3.67	2.63

Table 3: Total dry biomass, carbon sequestrated, equivalent CO_2 and CO_2 sequestration

Tree species	Total Carbon Sequestration (kg/tree)	Equivalent CO_2	CO_2 removed from atmosphere	
			(kg/tree/year)	(tons/ha./year)
1.Casuarina equisetifolia	53.00	194.31	9.71	19.42
2. Eucalyptus tereticornis	76.43	280.21	14.01	28.02
3. Tectona grandis	33.53	122.93	6.15	11.07
4. Dalbergia sissoo	63.32	232.15	11.61	23.22
5. Anogeissus latifolia	53.99	197.94	9.89	17.80
6. Albizia lebbeck	65.49	240.10	12.00	21.60
7. Grevillea robusta	56.45	206.96	10.35	17.60
8. Hardwickia binnata	45.13	165.46	8.27	14.06
9. Acacia nilitica	40.51	148.52	7.42	11.87
10. Azadirachta indica	32.57	119.41	5.97	8.96
SEm ±	2.93	8.52	1.22	1.43
CD 5%	8.72	25.31	3.63	4.26

Status of rainwater harvesting and watershed development: a tool for mitigating global warming for food and livelihood opportunities in Gulbarga district of Nothern dry zone of Karnataka

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ABSTRACT

The present study was conducted in forest fringe areas of northern dry zone of Gulbarga division, Karnataka to know the impact of rainwater harvesting and watershed development for food and livelihood opportunities of the villagers. A total of six villages which represents three ranges from Gulbarga division, Karnataka were sampled *viz*., Bedsur and Sugur from Chitapur range, Soudgar thanda and B.N. thanda from Yadagir range and Sheribiknalli, Jawaharnagar thanda from Chincholi range were selected for the impact assessment of rainwater harvesting and watershed development works. Most of the villages *viz*., sampled have semi arid to arid climate with an average annual rainfall below 580 mm and soil type in sampled areas varied from red to black soil with loamy. The soil and moisture conservation (SMC) works were implemented in the study area under various schemes *viz*., JBIC, DPADP and KSFMBC. The SMC structures such as percolation tanks, farm ponds, gokata, check dams, boulder checks and gulley checks *etc*., were built in the sampled area. In all the sampled villages catchment areas ranges from 70 to 500 ha. Implementation of SMC works had better impact on water sources (borewells and open wells are the major sources of irrigation for agriculture) with higher water yield and thus increased the irrigation potential in villages. This has lead to change in cropping pattern, higher crop yields and higher returns to the farmers. Increase in cropping area, fodder availability, increase in tree density and natural regeneration were also noticed. The positive impact of SMC works had directly resulted in increase in household income, employment generation, scope for allied agricultural activities etc. There is a decline in number of BPL families in villages. In almost all villages sampled, the drinking water problem is almost solved due to sufficient recharging of ground water resources. Therefore impact is more visible in terms of large quantity of water harvest and enriched greenery around the structures built.

Keywords: SMC works, Rainwater Harvesting, Watershed Development, Catchment Area, Livelihood Opportunities, Schemes

Introduction

Conservation of water in the agricultural and forestry sectors is essential as water is necessary for the growth of crops and plants. Depleting water table and rise in salinity due to over exploitation of ground water and over use of chemical fertilizers and pesticides is a common scenario in India. Soil Moisture Conservation is crucial in successful implementation of all forestry related programmes especially in drier zones.

Soil and moisture conservation is a critical component in any farming system. Sustainable productivity is dependent on soil and moisture conservation activities. Drastic reduction in rainfall and erratic rains, both with respect to intensity and frequency prolonged dry spells, denudation of the tree cover, severe summer coupled with decrease in annual average number of rainy days and decline in ground water table are the compelling factors which have led to major emphasis to SMC works in the afforestation programmes as well.

In India, it is estimated that almost 1.5m ha of land is being out of cultivated area every year due to faulty land and water management practices. If this is allowed to continue, it would lead to tremendous problems of depletion and degradation of resources like soil, water and plant nutrients through run off and soil erosion resulting in silting up of major reservoirs and causing floods. According to the latest estimates, about 187.8 m ha (57% of land area) has been degraded in the country. Soil erosion accounts for 87% of the total degraded land in India. The indiscriminate and unscientific soil and water management has rendered a major portion of land erosion prone. The undulating topography with high intensity of rainfall have caused high rate of soil erosion, resulting in the sedimentation of river banks, siltation of drainage channels and irrigation channels around reservoirs.

Many states have taken-up development of degraded areas under the watershed approach. A shift in the approach to watershed development took place in 1995-96 with the adoption of new guidelines formulated by Government of India.

The rise in population, growing industrialization and increasing agriculture activities have pushed up the demand for water over the years. Efforts have been made to meet this demand by constructing dams, reservoirs and digging wells. The idea of ground water recharging by harvesting rain water has gained momentum particularly in arid and semi-arid regions of India.

Over the years, SMC techniques have been developed primarily in agriculture land, however of late, adoption of SMC measures is made part of afforestation programmes, especially after introduction of JFM concept. During the earlier plan periods, major emphasis was given to tree planting by contour trenches for water conservation and soil stabilization. During 9th and 10th five-year plans, importance has been given for SMC as a separate component under State, Central and externally aided schemes by fixing percentage of the total sanctioned plantation cost.

In order to achieve the objectives of development in villages, people's participation is essential. It is required to involve them actively in project activities by respecting their traditional knowledge and experience. As a consequence, JFM programme has been implemented from 1993 onwards in various states. Village Forest Committees are engaged in regeneration of degraded forests, enrichment planting, cultural operations, soil and moisture conservation works, raising of multi purpose plantations etc in JFM areas.

The Ninth plan mid term appraisal by Planning Commission (Report of the Technical Committee on DPAP and DDP, Ministry of Rural Development, 1994) on impact of watershed development programme indicated beneficial effects such as increase in cropping intensity, crop productivity, change in cropping pattern and increase in ground water recharge as a result of conservation measure. Reduction in soil erosion and run-off losses, lesser siltation effect and reduction in sedimentation at watershed level were observed. These projects have also generated employment and increase in family income.

Soil erosion by run-off is the principle cause of land degradation. The consequences of land degradation are further more disastrous in arid areas, where the eco-system is very fragile and in such situations rain fall is the only source, which helps in sustaining the entire ecosystem. Thus Gulbarga is one such district in northern dry zone of Karnataka where in addition to successive droughts, erratic rains have led to major emphasis on SMC works. In Karnataka, SMC measures have been carried out and are also in progress under various schemes / projects like IWDP, DPADP, JNP, JBIC, FDA, AJA-JS, NHM and Hariyalli-I *etc*., These measures have exerted an influence on the soil water regime, improvements in availability of water, solving drinking water problems of local people and livestock, socio-economic conditions of villagers in forest fringe areas, but there are no studies yet to assess the impact of rainwater harvesting and watershed development for food and livelihood opportunities of the villagers. Hence the present study was conducted in forest fringe areas of northern dry zone of Gulbarga division, Karnataka to know the impact of rainwater harvesting and watershed development for food and livelihood opportunities of the villagers

METHODOLOGY

The present study was undertaken in Gulbarga district, Northern part of Karnataka State during 2008-09 to assess the impact of rainwater harvesting and watershed development works implemented by various Line Departments on water augmentation, livelihood of the villagers in the forest fringe areas and changes in cropping pattern in Northern Karnataka State.

Representative Divisions and locations were selected for the study in watershed areas / villages (Table-1). In northern part of Karnataka, Gulbarga District has been chosen for the sampling, data collection and field survey. From this District, three forest Ranges were selected and from each Range two villages were chosen and the data were collected as per the pre-structured schedule *viz*., Bedsur and Sugur from Chitapur range, Soudgar thanda and B.N. thanda from Yadagir range and Sheribiknalli, Jawaharnagar thanda from Chincholi range were selected for the impact assessment of rainwater harvesting and watershed development works.. The data collection on impact assessment due to various watershed works implemented by various Line Departments such as Watershed Department, Forest Department, Zilla Panchayat, NGOs and other agencies. The study involved visiting the offices of different watershed implementing agencies, departments, schemes, NGOs in respective Districts and collection of relevant information from the office records. Besides selecting few project sites for field evaluation, visiting the selected villages coming under project areas, interaction with the villagers, group discussion *etc*.,

Table–1: Details of sampled sites for the study on status of rainwater harvesting and watershed development in the forest fringe areas of Gulbarga division northern Karnataka

Division / District	Range	Name of the VFC / VSS	Scheme
Gulbarga	Chitapur	Bedsur	JBIC, DPADP
		Sugur	JBIC, DPADP
	Yadgir	Soudagar thanda	JBIC, DPADP
		B.N. thanda	JBIC, DPADP, MGNREGA
	Chincholi	Sheribiknalli	KSFMBC, DPADP
		Jawaharnagar thanda	KSFMBC, DPADP

JBIC- Japanese Bank for International Co-operation; **DPADP**- Drought Prone Area Development Programme; **KSFMBC**- Karnataka Sustainable Forest Management Biodiversity Conservation; **MGNREGA** – Mahatma Gandhi National Rural Employment Guarantee Assurance Scheme;

The detailed observations made in each division are presented in subsequent headings.

Location and climatic conditions

Location and general information of sampled sites selected for the research study in Northern part of Gulbarga District, Karnataka having black soil which receives an overall average rain fall of > 580 mm per year.

SMC works carried out under different schemes

In this divisions, some of the soil and water conservation works were carried out under various schemes are JBIC, KSFMBC, DPADP and MGNRAGA.

SMC structures

The SMC structures such as percolation tanks (179 No's), farm ponds (35 No's), check dams (45 No's) boulder checks (946.74 cubic meters) continuous counter trenches (4800 cubic meters), gulley checks (25 No's) and gokata (1 No) *etc.*, were built in the sampled area. Under JBIC and DPADP scheme more numbers of percolation and check dams were constructed. In all the sampled forest fringe villages, catchment area ranges between 70-500 ha (**Table-2**).

Impact of SMC works

Ecological Impact

a) Water sources

As a result of effective water conservation measures the borewells in the down stream have been recharged sufficiently. The implementation of SMC work resulted in significant harvest of the run off water, which in turn increased the irrigation potential in forest fringe villages. Prior to SMC works, the level of the water table was less but

soon after construction of the SMC structures, water table increased and the riparian bore wells and open wells got recharged. Thus water level in wells increased and water yield in borewells increased by 1.0 – 2.0 inches to 1.5 – 4.0 inches. Borewells and open wells are the major source of irrigation for agriculture in Gulbarga divisions. After the implementation of SMC works there is considerable increase in the number of bore wells and open wells. In Bedsur VFC (Chitapur Range), the number of open wells increased from 35 to 80. Whereas in other villages sampled, the number of open wells and borewells increased irrespectively. In general about 2 to 50 borewells have been added in all the villages sampled following the implementation of SMC works (**Table–3**).

These finding are in conformity with Khan (1992) were they reported the reduction of surface runoff by constructing suitable structures or by changes in land management. Further, this reduction of surface runoff was increased the infiltration and helped in water conservation. Beside this they observed appropriate structures were needed to avoid excessive runoff, help in flood control in lower catchment, improving soil moisture availability and this has increased the water table in the watershed.

Gaur *et al.* (1994) conducted study on various soil and water conservation measures on an area of 564 ha in Purna catchment in Parbani district where they reported the improved underground water storage and helped in raising the water table from 0.3 m to 2.5 m in wells at different locations.

b) Increase in wetlands

The increase in wetlands is attributed to the increase in irrigation potential due to the increase in level of water table and water yield. In all the selected VFCs, the number of bore wells increased and subsequently the extent of wetland is also increased from 2.02 ha to 121.5 ha in some of the VFCs studied. Maximum increase of about 121.5 ha in wetland is noticed in Bedsur VFC of Chitapur range, Gulbarga division (**Table–4**).

c) Change in cropping pattern and fodder availability

In some of the villages farmers have shifted from the cultivation of dryland crops like redgram, jowar, greenram and bengalgram *etc.* to wheat, sugarcane, and paddy. Earlier, in most of the selected VFCs, they were taking only one crop per year during monsoon season. After the implementation of SMC works they are taking two crops per year and there is also an increase in the crop yields. The average increase in yield of redgram is from 2000 kg to 3200 kg / ha in Bedsur VFC of Chitapur range. There was also an increase in the fodder availability in all the forest fringe villages due to increase in the cultivated area and number of crops cultivated in a year (**Table-5**).

d) Increase in tree density and eco-restoration

After the implementation of SMC works and water conservation measures in forest area, the stunted native rootstocks have got rejuvenated and there is considerable increase in natural regeneration and the vegetation. The increase was a minimum of 15% in Soudagar thanda of Yadagir range and Jawaharnagar thanda of Chincholi range. While maximum of about 25% increase in tree density was observed in Bedsur and Sugur of Chitapur range and B. N. thanda of Yadagir and Sheribiknalli of Chicholi range (**Table-4**).

Impact on livelihood of the villagers

The details of impact on various socio-economic parameters due to SMC works at selected forest fringe villages of Gulbarga division are given in (**Table–6**).

a) Increase in household income

The change in cropping pattern increases in area under wetland and crop yields have increased the income of the villagers. The difference between former and present income per annum per household is nearly ranges between Rs.4,000/- to Rs.16,600 in sampled forest fringe villages after the implementation of SMC works.

b) Employment Generation

Earlier in Soudagar thanda and B. N. thanda of Yadagri range, villagers were migrating to neighboring districts in search of labour works. But after implementation of SMC works they are involved in agricultural activities. In all the villages sampled, SMC works have generated employment in the field of agriculture and allied activities due to change in the cropping pattern and construction of SMC structures and plantation works have generated employment of approximately 600 man days in forest fringe villages (**Table-6**).

c) Livestock and dairy

Before the initiation of JFM activity, agriculture was the main occupation and also the major source of income in all the villages. But after initiation of JFM programme coupled with SMC work the increased irrigation potential encouraged villagers to change the cropping pattern and to grow fodder species. As a result of increased fodder availability helped people to rear milch animals (crossbred cows) thus dairy has become the major source of income. Earlier there was higher number of sheep / goats. Now as consequence of JFM programme there is an increased awareness about ill effect grazing which led to reduction in number of sheeps/goats and on the other hand increased the number of milch animal's result of increased fodder availability people started practicing stall feeding for milch animals thus dairy has become the major source of income. Whereas, the number of buffaloes remained more or less same in some of villages except Bedsur and Sugur VFCs of Chitpur range (**Table-7**).

d) Drinking water availability

Before the implementation of SMC works there was insufficient supply of drinking water in the forest fringe villages. Later, after the implementation of SMC works, there is sufficient availability of drinking water in all the forest fringe villages (**Table-6**). Presently, there are no such studies conducted on impact of rainwater harvesting and watershed development for rural livelihood security of villagers in the Gulbarga division, Karnataka. Thus, these findings receive support from success stories of rainwater harvesting reported by Mishra *et al.* (1980); Dhruvanarayana and Sastry (1986); Mittal *et al.* (1986), Grewal *et al.* (1989); Samra *et al.* (1995) and Sikka *et al.* (1996).

c) Any other observation

There was less scope for the man-animal conflict in the sampled villages. Because most of the SMC structures built were 3-4 km away from the villages. However, there were few instances of crop damage by wild boar.

CONCLUSION

Implementation of SMC works had better impact on water sources with higher water yield and thus increased the irrigation potential in forest fringe villages of Gulbarga division, Karnataka. This has lead to change in cropping pattern, higher crop yields and higher returns to the farmers. Increase in cropping area, fodder availability, increase in tree density and natural regeneration were also noticed. The positive impact of SMC works had directly resulted in increase in household income, employment generation, scope for allied agricultural activities etc. There is a decline in number of BPL families in forest fringe villages. In almost all villages sampled, the drinking water problem is almost solved due to sufficient recharging of ground water resources. Therefore impact is more visible in terms of large quantity of water harvest and enriched greenery around the structures built.

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Table–2: Different SMC works carried out for rainwater harvesting and watershed development in selected forest fringe villages of Gulbarga division, Karnataka

Range	Name of the VSS	Scheme	Catchment area (ha)	SMC structures built					Approximate volume of water harvested/ year (m^3)
				Type	Dimension (ht x length)	Nos.	Cost	Year	
Gulbarga	Bedgur	JBIC	150	CD	2m x 10m	2	1,87,000	1999-00	1,200
		DPADP	500	Gokata	0.5m x 35m	1	3,35,000	2000-01	1,312.50
		JBIC	70	Boulder checks	0.75m x 175m	238.18 cu.m	1,27,300	2005-06	1,190.90
			370	PT	1.5m x 8m	100	10,39,400	2006-07	28,800
	Sugur	DPADP	500	PT	1.5m x 15m	15	4,50,000	1995-96	15,187.50
			500	PT	1m x 10m	2	29,000	1990-00	600
		JBIC	180	CCT	1m x 1.5m x 10m	4800 cu.m	1,25,000	2000-01	24,000
			200	CD	15m x 6m	1	38,000	2000-02	16,200
		NREGA	150	FP	2.5m x 10m	10	1,50,000	2002-03	7,500
Yadagir	Soudagarthanda	DPADP	500	FP	2.5m x 10m	10	40,000	1999-00	7,500
			500	CD	2.0m x 12m	6	1,80,000	1999-00	4,320
		JBIC	200	PT	2m x 10m	34	72,100	2006-07	20,400
			170	Boulder checks	0.75m x 50m	21 Rmt	27,000	2006-07	1,087.99

Contd...Table–2: Different SMC works carried out for rainwater harvesting and watershed development in selected forest fringe villages of Gulbarga division, Karnataka

Range	Name of the VSS	Scheme	Catchment area (ha)	SMC structures built					
				Type	Dimension (ht x length)	Nos.	Cost	Year	Approximate volume of water harvested/ year (m^3)
Yadagir	B.N. thanda	JBIC	180	Boulder checks	0.75m x 45m	475 cu.m	26,900	2004-05	1,425
		DPADP	500	CD	0.75m x 6m	40	2,00,000	2006-07	3,240
		NREGA	150	FP	2.5m x 10m	15	2,25,000	2006-07	11,250
		JBIC	130	Boulder checks	0.75 x 55m	160.56 cu.m	36,000	2006-07	481.68
			180	PT	1m x 8m	26	2,55,000	2006-07	4,992
Chincholi	Sheribiknalli	KSFMBC	220	Gulley check	0.70m x 4m	25	46,000	2001-02	840
		JBIC	150	PT	1.75m x 12m	1	30,000	2003-04	756
			170	Boulder checks	0.50m x 2.0m	52 cu.m	27,800	2005-06	156
		DPADP	500	CD	1.75m x 15m	1	55,000	1999-00	945
	Jawaharnagar thanda	KSFMBC	158	PT	1.5m x 20m	1	49,000	2001-02	1,350
		JBIC	157	Gulley check	0.70m x 4m	2	3,680	2004-05	6,720
		DPADP	500	CD	1.75m x 12m	1	30,000	1999-00	540

PT- Percolation Tank ; FP- Farm Pond; CD- Checkdam

Table–3: Impact of SMC works on water resources in selected forest fringe villages of Gulbarga division, Karnataka

Range	Name of the VSS	Before SMC works					
		No. of Bore wells	Water yield (inch)	Depth digging (ft)	No. of open wells	Water level (ft)	Depth digging (ft)
Chitapur	Bedgur	10	1.5	250	30	2.5	20
	Sugur	8	2.0	300	15	2 to 3	30
Yadagir	Soudagarthanda	20	2.0	300	2	4	30
	B.N. Thanda	4	2.0	250-300	6	6	40-45
Chincholi	Sheribiknalli	4	1.0	350	2	3	25
	Jawaharnagar thanda	1	2.0	350	2	5	35

Range	Name of the VSS	After SMC works					
		No. of Bore wells	Water yield (inch)	Depth digging (ft)	No. of open wells	Water level (ft)	Depth digging (ft)
Chitapur	Bedgur	30	2.5	200	80	3.5	15
	Sugur	25	3-4	200-250	50	3-4	20-25
Yadagir	Soudagarthanda	40	2.5-3.0	250	6	5	25
	B.N. Thanda	15	2-3.5	200	8	10	35
Chincholi	Sheribiknalli	12	1.5	300	16	5	20
	Jawaharnagar thanda	12	3.0	300	4	6	30

Table–4: Impact of SMC works on various ecological parameters in selected forest fringe villages of Gulbarga division, Karnataka

Range	Name of the VSS	Before SMC works			
		No. of wells recharged	Dry lands (ha)	Wet lands (ha)	Agro-forestry (ha)
Chitapur	Bedsur	-	698.62	50.62	60.75
	Sugur	-	1490.40	32.40	16.20
Yadgir	Soundagar thanda	-	26.32	12.15	6.07
	B.N. Thanda	-	9.72	6.07	3.64
Chincholi	Sheribikhalli	-	10.12	6.07	4.05
	Jawaharnagar thanda	-	97.20	Nil	4.05

Range	Name of the VSS	After SMC works				
		No. of wells recharged	Dry lands (ha)	Wet lands (ha)	Agro-forestry (ha)	Increase in tree density (%)
Chitapur	Bedsur	5	648.00	182.25	182.25	25
	Sugur	10	1506.60	64.80	48.60	25
Yadgir	Soundagar thanda	-	30.37	20.25	10.12	15
	B.N. Thanda	-	12.15	10.12	5.67	25
Chincholi	Sheribikhalli	-	12.15	10.12	5.26	25
	Jawaharnagar thanda	-	109.35	6.07	6.07	15

Table- 5: Change in cropping pattern in selected forest fringe villages of Gulbarga division, Northern Karnataka due to rainwater harvesting & watershed development

Range	Name of the VSS	Before SMC works			
		Area	Crops	Yield (kg/ha)	No.of crops / year
Chitapur	Bedgur	810.00	Redgram Jowar	2,000 3,000	One
	Sugur	1539.00	Redgram Jowar	2,000 3,000	One
Yadgir	Soudagarthanda	40.50	Redgram Greengram	2,100 1,100	One
	B.N. thanda	19.44	Groundnut Sunflower	3,200 700	One
Chincholi	Sheribiknalli	20.25	Bengalgram Jowar	1,400 3,000	One
	Jawaharnagar thanda	101.25	Jowar Redgram	2,800 2,000	One

Range	Name of the VSS	After SMC works			
		Area	Crops	Yield	No.of crops / year
Chitapur	Bedgur	1012.50	Sugarcane Redgram Sunflower	2,500 3,200 800	Two
	Sugur	1620.00	Wheat Sugarcane	2,400 3,100	Two
Yadgir	Soudagarthanda	50.62	Groundnut Paddy	3,400 4,500	Two
	B.N. thanda	27.94	Paddy Redgram	4,200 2,200	Two
Chincholi	Sheribiknalli	27.54	Blackgram Wheat	1,500 2,800	Two
	Jawaharnagar thanda	121.50	Redgram Jowar	2,200 3,000	Two

Table–6: Impact on livelihood of the villagers due to SMC works in selected forest fringe villages of Gulbarga division, Karnataka

Range	Name of the VFC	Before SMC works			
		Family income (Rs.)	BPL house holds	Employment generation	Drinking water problems
Chitapur	Bedsur	18,400	150	Agriculture & Dairy	Yes (3.5 km)
	Sugur	16,000	50	Agriculture	Yes (1.5 km)
Yadgir	Soundagar thanda	14,000	60	Agriculture	Yes (1 km)
	B.N. Thanda	12,000	75	Agriculture	Yes (3 km)
Chincholi	Sheribikhalli	10,000	10	Agriculture & NTFP	Yes (3 km)
	Jawaharnagar thanda	6,000 to 10,000	80	Agriculture & Agri. Labour	Yes (2 km)

Range	Name of the VFC	After SMC works			
		Family income (Rs.)	BPL house -holds	Employment generation	Drinking water problems
Chitapur	Bedsur	35,000	50	Agriculture & Dairy	No
	Sugur	25,000	250	Agriculture & Dairy	No
Yadgir	Soundagar thanda	20,000	25	Agriculture & SMC work	No
	B.N. Thanda	20,000	35	Agriculture & SMC work	No
Chincholi	Sheribikhalli	17,000	5	Agriculture NTFP & SMC work	No
	Jawaharnagar thanda	10,000 to 15,000	40	Agriculture & Contract labour	No sufficient

Table–7: Livestock population and allied enterprises (major source of income) in selected forest fringe villages of Gulbarga division Karnataka

Range	Name of the VSS	Before SMC works				
		Cows	Buffaloes	Goat / Sheeps	Total	Major source of income
Chitapur	Bedsur	500	800	450	1,750	Agriculture
	Sugur	100 (2)	119	1,500	1,719	Agriculture
Yadgir	Soudagar thanda	70 (10)	12	375	457	Agriculture
	B.N. thanda	60 (8)	12	385	452	Agriculture
Chincholi	Sheribiknalli	40	13	250	303	Agriculture
	Jawaharnagar thanda	45 (5)	8	560	613	Agriculture

Range	Name of the VSS	After SMC works				
		Cows	Buffaloes	Goat / Sheeps	Total	Major source of income
Chitapur	Bedsur	300	11,000	1,160	12,460	Agriculture, Dairy & SMC work
	Sugur	150 (10)	900	800	1,850	Agriculture, Dairy & SMC work
Yadgir	Soudagar thanda	30 (20)	15	175	220	Agriculture & SMC work
	B.N. thanda	30 (15)	10	180	220	Agriculture, NTFP & SMC work
Chincholi	Sheribiknalli	35	20	250	205	Agriculture, NTFP & SMC work
	Jawaharnagar thanda	40 (12)	9	275	324	Agriculture & Labour

Role of social factors in adoption of Homegarden-based agroforestry practices in Western Himalaya

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ABSTRACT

The role of social factors in adoption of agroforestry practices, specifically the homegarden, has been ignored until recently. There is meagrely any study to indentify the role of social factors in adoption of home-garden agroforestry. Thus the current study was carried out in Mandi district of Himachal Pradesh to identify the social factors influencing the adoption of homegarden agroforestry. The study reveals that the caste, family size and mobility of the household head, each individually, significantly influenced the adoption of home-garden agroforestry. Binary logistic regression analysis also reveals that in addition to these variables, number of non-resident members also influenced the adoption of homegarden agroforestry practice. Based on logistic regression, the higher caste households and farmers with higher mobility had the higher likelihood of adoption of home-garden based agroforestry. However the family size and number of non-residents had significant but negative influence on adoption of the home-garden based agroforestry practice.

INTRODUCTION

There are many agroforestry practices across the world (Chundawat and Gautam, 1993). Most are site specific and vary from one place to other even within the same country or region (Nair 1993). Homegardens is a very old tradition which might have evolved over a long time when the hunter/gatherer deliberately or accidentally dispersed seeds of high value species in the vicinity of their camp-site, starting with ancient civilisations, possibly as early as 7000 B.C. and continuing to modern times (Soemarwoto, 1987). These homegardens are not static but are adaptable to new bipophysical and socio-economic conditions. Trees in homegardens play an important role in the livelihoods of the rural people. The homegardens fulfill the livelihood objectives (Sood, 2003): secure provision of food and essential subsistence goods, cash for purchase of outside goods and services, savings (resource accumulated to meet future planned needs and emergencies), social security (secure access to subsistence goods and productive resources) and reduce vulnerability (reducing critical risk factors). For example, in Java (Indonesia), 60% of all food comes from home-gardens (Hoskins, 1990). The homegardens of Kerala (India) (Chundamannil *et al.*, 1993; Nair and Krishnankutty, 1985; Soemarwoto, 1987), Bangladesh (Leuschner and Khaleque, 1989), Java (Christanty and Iskandar, 1985; Soemarwoto, 1987) and Kandyan gardens of Sri Lanka (Jacob and Alles, 1989; Soemarwoto, 1987) are well documented and play

important role in the livelihoods of the people and reducing the pressure on existing forests for tree products. The existence of homegarden based agroforestry systems has also been documented in Himalayan region (Mughal *et al.*, 2000; Nautiyal *et al.*, 1998; Singh *et al.*, 1998). Notwithstanding their role in improvement of the livelihoods of the people and environmental amelioration, the comprehensive empirical work on factors influencing choice homegardens is almost lacking (Sood, 2003). Therefore current empirical work on role of social factors in adoption of homegarden based agroforestry systems was taken in Mandi district of Indian province of Himachal Pradesh located in Western Himalaya.

MATERIALS AND METHODOLOGY

The study was carried out in Mandi district of Himachal Pradesh where the agroforestry systems are existent. Data were collected using a prestructured schedule and personal interviews with the head of the household. Multistage sampling was used to select households. Out five forest divisions, two forest divisions, Joginder Nagar and Suket, were selected to obtain realistic representation of households from different agroclimatic zones. A list of villages located in the hills and foothill was prepared which were further subcategorised into programme and non-programme. Two villages from each subcategory (programme and non-programme) for hill and foothill villages were chosen in each selected forest division using simple random sampling with replacement method. In this way, there were eight sample villages in each of selected forest divisions and 16 villages in total. A list of households in each of the selected villages was prepared. A list of large (> 1ha) and small (<1ha) farmers from each selected village was prepared. Amongst large and small farmers 1/3rd of households were chosen for large as well small farmers using simple random sampling in each selected village. Famers with no tree were dropped from the sample. In this way 349 farmers were selected which were divided into two categories: homegarden adopters and non-adopters. A chi-square test of association was used to test the association between adoption of home-garden based agroforestry and each independent variable at 0.05 level of significance. To identify key factors influencing agroforestry binary logistic regression analysis was used. The model specification for binary logistic regression is as:

Logit is defined as natural log of odds and the model was specified as:

$$\text{Logit} = \text{Ln}\,(P/1\text{-}P) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \text{----------} + \beta_k X_k = Z \quad \text{----------1}$$

Where

P is the probability of homegarden adoption
1-P is the probability of non-adoption
β_0 is the intercept term
β_1, β_2, β_3, and β_k are the coefficients associated with independent variables
X_1, X_2, X_3 and X_k are the predictors in the equation

Table 1 shows the abbreviations and coding scheme for the independent variables used in the regression analysis. The model was validated using model Chi-square and Hosmer and Lameshow goodness-of-fit test and cases correctly classified.

Standardised regression coefficients depicted the importance of the predictors in the model.

Table 1. Variables in the Model

Variable Name	Abbreviation and Variable Coding Scheme	Units	Mean	Standard Deviation
Age	AGE	Years	52.33	14.03
Family size	SIZE	Number	5.00	2.38
Caste	CAST (Lower caste-reference =1, Upper Caste =2)	Score	1.67	0.47
Number of non-resident members	NNR	Number	0.63	1.50
Primary Occupation of Head	PO (Farming-reference =1, Non-farming =2)	Score	1.49	0.50
Family Literacy (Literacy index)	LI	Score	1.49	1.08
Mobility	MOB	Scale	4.67	2.89

RESULTS

Caste, family size and mobility of household head, each individually, significantly influenced the adoption of home garden based agroforestry systems (Table 2). It was found that 59.1% of the households in upper castes adopted homegardens compared to 46.5% in the lower caste. Amongst the medium sized households 60.4% adopted homegardens compared to 56.5% in small sized households. The lowest adoption (26.7%) was amongst the large sized households. With increase in mobility the adoption gradually increased from immobile (22.7%) to slightly mobile (45.8%), moderately mobile (63.5%) and highly mobile (63.8%). Age of househead, family literacy, primary occupation and number of non-residents did not influence the adoption of homegarden based agroforestry practices.

Table 2. Association between choice of homegarden-based agroforestry and social factors

Count % of Row % of Col	Age			Caste		Family size			Non-residents	
	Young (23-40)	Middle aged (41-60)	Old (61 or above)	Lower caste	Upper caste	1-3 (Small)	4-7 (Medium)	8 and above (Large)	No	Yes
Non-adopters	24 15.3 33.8	77 49.0 46.7	56 35.7 46.9	61 38.9 53.5	96 61.1 40.9	40 25.5 43.5	84 53.5 39.6	33 21.0 73.3	110 70.1 43.3	47 29.9 49.5
Adopters	47 24.5 66.2	88 45.8 53.3	57 45.8 50.4	53 27.6 46.5	139 72.4 59.1	52 27.1 56.5	128 66.7 60.4	12 6.3 26.7	144 75.0 56.7	48 25.0 50.5
	χ^2=4.730, d.f.=2, p<0.094, CFLF=0			χ^2=4.969, d.f.=1, p<0.026, CFLF=0		χ^2=17.160, d.f.=2, p<0.0001, CFLF=0			χ^2=1.062, d.f.=1, p< 0.303, CFLF=0	

Count % of Row % of Col	Family Literacy				Primary Occoupation		Mobility			
	Low (0.00 - 0.50)	Medium (0.51-1.50)	High (1.51-2.50)	Very High Literacy (2.51-6.0)	Farming	Non-farming	Immobile (0)	Slightly mobile (1-3)	Moderately mobile (4-6)	Highly Mobile (7-9)
Non-adopters	33 21.0 55.0	61 38.9 40.7	46 29.3 47.4	17 10.8 40.5	87 55.4 49.2	70 44.6 40.7	17 10.8 77.3	17 10.8 54.2	38 24.2 36.5	38 24.2 36.2
Adopters	27 14.1 45.0	89 46.4 59.3	51 26.6 52.6	25 13.0 59.5	90 46.9 50.8	102 53.1 59.3	5 2.6 22.7	54 28.1 45.8	66 34.4 63.5	67 34.9 63.8
	χ^2=4.140, d.f.=3, p<0.247, CFLF=0				χ^2=2.520, d.f.=1, p<0.112, CFLF=0		χ^2=19.628, d.f.=2, p<0.0001, CFLF=0			

Binary logistic regression model has been given in Table 3.

Table 3. Variables in the model and their significance

Step	Variable In:	Coefficients (β)	EXP (β)	Improvement in -2LL (Chi-square)	D.F.	Significance of change (p)	Standardised coefficients
1	CAST	0.496	1.642	15.098	1	<0.0001	0.496
2	SIZE	-0.153	0.858	5.797	1	<0.016	-0.352
3	NR	-0.196	0.822	4.643	1	<0.031	-0.278
4	MOB	0.103	1.109	4.068	1	<0.040	0.307
	Constant	0.285				<0.064	

The model provided a good fit as Hosmer and Lameshow test (Chi-square= 6.177, p< 0.627) was non-significant (Table 4). Further the model was significant in prediction the adoption of home-garden based agroforestry practice (Model Chi-square = 29.606, p < 0.0001); Table 4). The model predicted 62.8% of the observations correctly (Table 5). Based on this model, the higher caste households and farmers with higher mobility had the higher likelihood of adoption of home-garden based agro forestry systems (Table 3). However the farmers with larger families and higher number of non-residents were less likely to adopt home-garden based agro forestry systems (Table 3). Based on this model the caste was the most important factor affecting adoption of homegarden agroforestry practice followed by family size, mobility and number of non-resident members respectively (Table 3).

Table 4. Model Summary

Statistic	Value	D.F.	p
Initial –2LL	255.248	-	-
Model –2LL	225.642	-	-
Model Chi-square	29.606	4	<0.0001
Hosmer and Lameshow Chi-square	6.177	8	<0.627
Nagelkerke R^2	0.110	-	-
N	349	-	-

Table 5. Classification accuracy of different models

Type household	Number of observations	Predicted membership		Overall prediction
		Adopter	Non-adopter	
Adopter	192	143 (74.5%)	49 (25.5%)	
Non-adopter	157	81 (51.6%)	76 (48.4%)	62.8%

CONCLUSIONS

The study implies that social factors play an important role in adoption of homegarden agroforestry. In the current study caste family size, mobility, number of non-resident members respectively were the important factors influencing the choice of homegarden agroforestry practices. Higher caste households and households with higher mobility of the head formed the potential adopters. The constraint of lower caste households and households with lower mobility needs to be identified so that they can also be encouraged to adopt these agroforestry practices.

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Experience gained by the Safed Musli growers about its cultivation

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ABSTRACT

The entire Dang district is full of number of plant species having medicinal value. These valuable plants have not received due attention of the common rural people and a handful of knowledgeable persons have exploited these species for their own benefits Now a days world has developed a new sense and interest for Ayurvedic medicine. Safed Musli is common medicinal plant cultivated on a small area by most of the tribal farmers and getting good income in comparison to their traditional crop. Therefore, an investigation was carried out to know Experience gained by the Safed Musli growers about its cultivation.

For attaining the objective the present investigation was carried out in Dang district of Gujarat state. Fifteen villages from the district and ten Safed Musli growers from each village were selected. The study was confined to total 145 respondents. Keeping in view the objectives of the study interview schedule was prepared and the respondents were interviewed. Distribution of respondents according to their experience (in years) of the cultivation of Safed Musli and Feedback based on experience of tribal farmers pertaining to cultivation of Safed Musli was worked out.

Major Finding

1. The great majority of the respondents had experience of 4 to 6 years of Safed Musli cultivation.
2. Equal number of positive and negative experience they expressed as the feedback. Regarding positive experiences they said that the cultivation of Safed Musli is (i) easy in cultivation (ii) high value of the produce and (iii) remunerative production from the small area (iv) more profitable crop.

Key words: Respondents, tribal farmers, remunerative.

INTRODUCTION

The entire Dang district is full of number of plant species having medicinal value. These valuable plants have not received due attention of the common rural people and a handful of knowledgeable persons have exploited these species for their own benefits Now a days world has developed a new sense and interest for Ayurvedic medicine. Safed Musli is common medicinal plant cultivated on a small area by most of the tribal farmers and getting good income in comparison to their traditional crop. Therefore, an investigation was carried out to know Experience gained by the Safed Musli growers about its cultivation. The Asiatic flora includes tropical, sub-tropical and temperate species in the several regions. Many of the cultivated and wild plants yield products are used in modern medicines and in aroma industries (Haq, 1995).

MATERIALS AND METHODS

For attaining the objective the present investigation was carried out in Dang district of Gujarat state. Fifteen villages from the district and ten Safed Musli growers from each village were selected. The study was confined to total 145 respondents. Keeping in view the objectives of the study interview schedule was prepared and the respondents were interviewed. Distribution of respondents according to their experience (in years) of the cultivation of Safed Musli and Feedback based on experience of tribal farmers pertaining to cultivation of Safed Musli was worked out.

RESULTS AND DISCUSSION

Experience of farmers regarding Safed Musli cultivation

Experience counts everywhere. Experience helps the farmers not only to make them perfect but also increases their income and level of satisfaction. Hence, experience gained by Safed Musli growers were given due importance in the questionnaire and accordingly the information is given in the table 1.

Table:1 Distribution of respondents according to their experience (in years) of the cultivation of Safed Musli (N=145)

Sr. No	No. of years of experience	No. of Respondents	Percentage
1	3	08	5.52
2	4	29	20.00
3	5	56	38.62 } 82.07
4	6	34	23.45
5	7	18	12.41
	Total	145	100.00

Viewing the above data in table 1 it is clear that great majority (82.07 per cent) respondents had experience of 4 to 6 years of Safed Musli cultivation. A good number (38.62 per cent) of the respondents had experience of five years while 23.45 per cent respondents had six years' experience. A very small part (5.52 per cent) of the respondents had three years' experience. The highest experience of seven years' was with the 12.41 per cent of the respondents.

Feedback based on experience of tribal farmers pertaining to cultivation of Safed Musli

The respondents were asked to give their feedback based on their experience regarding cultivation of Safed Musli. The responses received are depicted in table 2. They expressed positive as well as negative experiences about Safed Musli cultivation.

The table shows equal number of positive and negative experience they expressed as the feedback. Regarding positive experiences they said that the cultivation of Safed Musli is (i) easy in cultivation (72.41 per cent) (ii) high value of the produce (61.38 per cent) (iii) remunerative production from the small area (49.66 per cent) (iv) more profitable crop (46.21 per cent) (v) short duration crop (35.17 per cent) (vi) low

expenditure compared to high market price (28.28 per cent) and (vii) suitable to the type of soil and atmosphere of Dang district (24.14 per cent).

Likewise negative experiences mentioned by them in its magnitude are (i) unavailability of stable market (82.07 per cent) (ii) financial difficulties to increase area under cultivation (75.17 per cent) (iii) Delay in payment by the middlemen (47.59 per cent) (iv) high fluctuation in prices of the product (26.90 per cent (v) storage is not easy at village level (21.38 per cent) (vi) more risk as no security of price (17.93 per cent) and (vii) process of preparing Safed Musli for market is cumbersome (13.10 per cent).

Table: 2 Feedback based on experience of tribal farmers pertaining to cultivation of Safed Musli (N = 145)

Sr. No.	Feedback+ve or -ve	Feedback based on experience	No. of Respondents	Per cent
1	-ve	Unavailability of stable market	119	82.07
2	-ve	Financial difficulties to increase area under cultivation	109	75.17
3	+ve	Easy cultivation	105	72.41
4	+ve	High value to the produce	89	61.38
5	+ve	Remunerative production from the small area	72	49.66
6	-ve	Delay in payment by the middlemen	69	47.59
7	+ve	More profitable crop	67	46.21
8	+ve	Short duration crop	51	35.17
9	+ve	Low expenditure compared to high market price	41	28.28
10	-ve	High fluctuation in prices of the product	39	26.90
11	+ve	Suitable to the soil and climate of Dang district	35	24.14
12	-ve	Storage is not easy at village level	31	21.38
13	-ve	More risk as no security of price	26	17.93
14	-ve	Process of preparing Safed Musli for market is cumbersome	19	13.10

If we divide the feedback experiences into two groups based of the frequency of respondents or the percentage receiving more than 50 per cent were (I) more important feedback and (II) less important feedback. Cutting line at 50 per cent than we can see form the table that only first four feedback can be said as the more important feedback based on the experience of farmers about Safed Musli cultivation. Further it is surprising that out of these four more important feedback, two are negative and two are positive. The negative two feedback are (i) unavailability of stable market (82.07 per cent) and (ii) financial difficulties (75.17 per cent) while the positive two feedback are (i) easy in cultivation of Safed Musli crop mentioned by 72.41 per cent of the respondents and (ii) the high value of the produce of Safed Musli receiving 61.38 per cent weightage.

Among the other group of feedback (i.e. less important feedback receiving frequency less than 50 per cent) there are several considerable feedback which likely

needs to bring to the notice of the new entrants in the cultivation of Safed Musli crop. Those are (i) remunerative production of Safed Musli crop from the small area (49.66 per cent) (ii) Delay in payment of the produce by the middlemen (47.59 per cent) and (iii) more profitable crop (46.21 per cent).

Feedback receiving very low frequencies should not be ignored. Last three feedback (Sr. No. 12, 13 and 14 in the table 2) receiving frequencies less than 25.00 per cent were negative in natural and are (i) storage problems (21.38 per cent) (ii) no security of price of produce (17.93 per cent) and (iii) procedure of preparing the Safed Musli for marketing (13.10 per cent).

This experience will help and guide the farmers whether to start new cultivation of Safed Musli or otherwise.

ACKNOWLEDGEMENTS:

The authors are grateful to Hon'ble Vice Chancellor, Navsari Agricultural University, Navsari for providing necessary technical and financial supports for conducting the research. The authors are also grateful to Programme Coordinator, Krushi Vigyan Kendra, N.A.U., Waghai for his kind cooperation throughout the period of investigation.

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Ignoring element of farmers experience/preference: A cause for non-adoption of agroforestry models in eastern plains zone of Eastern Uttar Pradesh

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ABSTRACT

Shisham (*Dalbergia sissoo*) planted by farmers as agroforestry tree on large scale in eastern Uttar pradesh has of late shown high mortality. Farmers explored Teak (*Tectona grandis* Linn.f.) as an alternative to shisham. However, considering the severe fuel wood problem in the region and edapho-climatic limitations for teak, scientists of AICRP on Agroforestry Centre at the ND University of Agri. & Tech., Faizabad, developed *C. equisetifolia* based agri-silvi system which farmers are not willing to adopt as they still have a preference for teak followed by shisham. A study conducted on three different farmers' fields on 11-year old farmer planted teak on the boundary of wheat fields as an agroforestry tree as also sole teak plantation in sodic soils (pH>8.5) of Faizabad district (mean annual rainfall of 1200mm) showed significantly ($p<0.05$) better teak growth in agroforestry than in its sole plantation. While in agroforestry system values for tree height, bole height, , crown length, crown width and diameter at breast height were 9.67m,3.96m, 3.61m, 2.42m and 22.09cm, respectively, the corresponding values in sole teak plantations were 8.42m,2.72m,2.51m,2.53m and 20.15cm. The number of leaves/ branch was also significantly higher (39.1) under agroforestry than in sole plantation (19.4) system. It is significant to note that despite the edapho-climatic conditions of Faizabad being considered as limiting for teak, tree height of 8.42m attained in sole plantation, though lower than that in agroforestry system, was comparable to that of 4.13 and 8.83m, respectively for 7.5 and 13.5 year old trees, attained in sole plantation at Seoni in Madhya Pradesh with a similar mean annual rainfall of 1228.6mm. Thus, farmers of eastern plains zone are adopting teak as agroforestry tree for meeting their small timber and fuel requirements and rejecting *C. equisetifolia* despite its high energy value. Another possible reason for non-adoption of *C. equisetifolia* based agri-silvi system could be the lack of an industry in the region for processing of *C. equisetifolia* and thereby depriving farmers from better economic returns. It is thus obvious that ignoring farmers experience/preference will result in non-adoption of agroforestry models and thereby create hindrance in promoting agroforestry in a state like Uttar Pradesh where tree cover has been reduced drastically to 4.46% after creation of Uttaranchal (now Uttarakhand) state.

Keywords : *Tectona grandis, C. equisetifolia*, Sodic soils

INTRODUCTION

The forest cover in India at present is pegged at about 21% of the geographical area and through various programmes, efforts are being made to achieve

the target of 33%. According to 2011 report of the Forest Survey of India however, the country's forest cover has declined by 367 sq km between 2007 and 2009 (Anonymous, 2012). Although the figure may not seem alarming but it is contrary to the general impression that afforestation and conservation programmes pursued on large scale throughout the country are yielding positive results. With increasing population pressure, increased demand for fuel, fodder, fruits and other timber and non-timber products has resulted in ruthless exploitation of forests. Furthermore, in quest for sustaining self sufficiency in food grains not only the area for growing trees as sole plantation has been declining continuously but also raising of highly input-intensive HYVs is resulting in degradation of natural resources. Under these circumstances, adopting agroforestry with multitude of benefits through its service and productive functions is one of the most important options. The major service function of agroforestry is its role in soil resilience and management including control of erosion and maintenance and improvement of soil health through physical, chemical and biological fertilities of soil. The productive function is to obtain tree products from the farmland which include fuel wood, fodder and fruit along with construction wood, small timber and several other products such as gums, resins and medicinal products etc. The products so obtained serve to diversify the output from farmland providing a broader economic base for better livelihood and food security. Additionally, enhancement of biodiversity and potential to sequester carbon to mitigate the effect of climate change are other major contributions of agroforestry. Thus agroforestry will be helpful in meeting increasing requirements of fuel, fodder, fruits, medicinal plants and timber etc. on one hand, and ensuring food security as well as environment conservation and ecological security on the other. This is all the more relevant in the state of Uttar Pradesh where forest cover was reduced by 40% as a result of carving out the state of Uttarakhand (the then Uttaranchal) in the year 2000. Consequently, the forest cover in Uttar Pradesh still continues to be quite low which in November 2009 has been reported to be only 14341 sq km constituting mere 5.95% of the geographical area (World Forestry Day, 2011) as compared with the desired 33%. Within the state, benefits of agroforestry have long been realized by farmers of western Uttar Pradesh where they have successfully incorporated poplar (*Populus deltoides*) as an agroforestry tree which has extensively been planted in their farmlands and area under it is increasing with the passage of time. The eastern Uttar Pradesh (popularly called as "Purvanchal) however, has lagged behind in adopting agroforestry, although farmers had earlier planted shisham (*Delbergia sissoo*) on a large scale which of late has shown high mortality for reasons not yet known. Keeping these points in view, scientists working under AICRP on Agroforestry Centre at ND University of Agriculture & Technology, Faizabad have developed 3 different agroforestry models especially for eastern plains zone of eastern Uttar Pradesh. These models included: *D. sissoo*, *Emblica officinalis* based agri-silvi-horti system, *C. equisetifolia* based agri-silvi system and *C. equisetifolia* based silvi-horti system. *C. equisetifolia* based models, were preferred by the scientists because of wide spread fuel wood problem in the region (Anonymous, 2004) and despite farmers' first choice for teak followed by shisham, development of teak based models was not considered due to unfavourable edapho-climatic limitations for its growth. However, results presented herein from the study conducted on farmers' fields on teak planted by them shows that their first preference for teak is based on their sound experience.

MATERIALS AND METHODS

The study on growth of teak planted as agroforestry component with wheat and as a sole plantation was conducted over a period of 3 years in nearby villages of Faizabad district with a mean annual rainfall of 1200mm. Soils of the area are characterized as sodic in nature having pH >8.5 and ESP>15. The fields of nine different farmers were selected with 3 plots each of 4, 6 and 8 year aged teak planted as agroforestry component on boundary of wheat fields along with its sole plantation as well as that of sole wheat crop with no trees on the boundary. The data presented herein are those collected on 8-year old plantations at the end of 3-year study period, that is, when plantation had attained the age of 11 years. Ten randomly selected and earmarked trees in each plot were used for recording observations on the morphological growth parameters of teak. These included tree height, bole height, diameter at breast height (DBH), crown length, crown width and number of leaves per branch. Some yield attributing characters and yield of wheat as sole crop and with teak as agroforestry component on boundary of wheat fields, were also recorded. Teak growth measurements were made using tape, graduated bamboo pole, height measuring multimeter, caliper and scale. Sampling for measurements on wheat crop was done by means of quadrat of $1.0m^2$ placed randomly at ten places in each plot. Five plants were randomly selected from within each of ten quadrats in a plot for recording observations on plant height, ear length and number of grains per ear. Grain yield however, was recorded on the basis of harvest from net plot area of the entire plot. For the purpose of test weight, 1000 grains were randomly selected from the produce obtained from the net plot.

RESULTS AND DISCUSSION

As the purpose here is to demonstrate that in spite of edapho-climatic conditions being characterized as unfavourable, teak grows relatively well in the sodic soils of the region, only relevant data on the growth of teak is being presented herein. The growth parameters of teak viz., tree height, bole height, diameter at breast height (DBH), number of leaves per branch and crown length showed significantly ($p<0.05$) higher values indicating thereby better teak growth in wheat based agroforestry system as compared to its sole plantation (Table 1). There were however, no differences in the crown width under sole and agroforestry plantations. The tree height in agroforestry system was 9.67m while in sole plantation it was only 8.42m. This finding is in conformity with results reported by Buvaneswaran *et al.* (2001) who observed that teak in a 20 year old forest (sole) plantation attained the height of only 14m whereas in farmers' fields 13m height was attained at the age of 12 years. The tree height of 9.67m attained under agroforestry system in a sodic soil (pH>8.5) in the present study was comparable with that of 10.84m reported for 9 year old teak in agroforestry system elsewhere under favourable conditions in an irrigated silty clay loam soil having pH value of 7.83 (Anonymous, 2007). It is of interest to note that the tree height of 8.42m under sole plantation , though less than that recorded under agroforestry system, is comparable to that reported for sole teak plantation (4.13 and 8.83m, respectively for 7.5 and 13.5 year old trees) under similar mean annual rainfall of 1228.6mm at Sheoni in Madhya Pradesh (Shukla, 2009).

The bole height and DBH of teak recorded as 3.96m and 22.09cm, respectively in agroforestry plantations were also significantly ($p<0.05$) higher than 2.72m and 20.15cm observed in sole plantations. Similar results were reported by Buvaneswarn *et al.* (2001) who found higher DBH values of 8.31, 15.06 and 27.70cm at the age of 5, 9, 12 years old *Tectona grandis* in farmers' fields whereas, it was only 18cm at the age of 20 years as forest (sole) plantation. The DBH of 20.15cm recorded for sole teak plantation in the present study was considerably higher than that of 13.6cm reported for 9 year old teak in agroforestry system under more favourable soil conditions having pH value of 7.83 (Anonymous, 2007). Similar results were obtained by Mutanal et al. (2001) wherein teak showed higher values as an agroforestry component with groundnut and sorghum crops. Heque and Osman (1993) measured height and DBH in 26 years old plantation in pure teak and in mixed plantation. It was found that teak had significantly greater diameter and height in the mixed plantation than in sole plantation. In the present investigation, number of leaves/ branch was also significantly higher (39.1) under agroforestry than in sole plantation (19.4) system. The results indicate that teak in agroforestry system had significantly ($p<0.05$) better growth than in sole plantation. The better teak growth in farmers' land could be attributed to the fact that the trees share the benefit of intensive land management practices like irrigation, fertilizer and other cultural operations while the trees in sole plantation do not receive such benefits since they are grown under natural rain fed conditions.

Data on some of the soil physical and chemical properties (Table 2) revealed that teak as agroforestry component improved quality of sodic soil by lowering bulk density, soil pH and electrical conductivity and increasing porosity, organic carbon as well as available nitrogen, phosphorus and potash as compared with its sole plantation.

From the results of present study it is quite obvious that despite edapho-climatic conditions being considered as limiting, teak shows relatively good growth as an agroforestry component in sodic soils of eastern plains zone of eastern Uttar Pradesh and also brings about an improvement of soil health. Even as sole plantation, its growth is comparable with other sites like at Seoni in Madhya Pradesh with a more favourable soil pH of <7 and a similar mean annual rainfall of 1228.6mm. It is for these reasons that farmers in the region prefer teak among timber species as first choice for meeting their requirements of small timber/poles and fuel rather than *C. equisetifolia* despite its high energy value. Furthermore, there is no industry in that region for processing *C. equisetifolia* which offers economic returns to the farmers, whereas there is a considerable demand for teak everywhere. Same holds true for shisham (*D. sissoo*) which is the second choice of farmers after teak. Thus farmers are reluctant to adopt *C. equisetifolia* based agri-silvi model.

Quicker and higher adoption rate of agroforestry models by farmers will increase the forest/ tree cover in an area at a faster pace. Therefore, it is important to incorporate farmers experience and choice while developing agroforestry models for a particular region. Also the models need to be market oriented so that the end user gets better economic returns. For this purpose, proximity to the industry utilizing products of agroforestry trees is necessary. Thus development of agroforestry models using farmer participatory approach with participant defined priorities and goals will be of great help in extending the agroforestry to the new areas. This "bottom up" approach of transfer of technology will make participants much more responsive to whatever is

offered to them by extension agents in terms of education and training (Glendinning *et al.*, 2001).

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Table 1. Morphological growth parameters of 11-year old teak (*Tectona grandis* Linn. f.) with agroforestry and sole plantation systems in sodic soils of eastern plains zone of eastern Uttar Pradesh

Agroforestry system	Tree Height (m)	Bole Height (m)	DBH (cm)	Number of leaves per branch	Crown length (m)	Crown width (m)
Tectona grandis + wheat	9.67 [a]	3.96 [a]	22.09 [a]	39.10 [a]	3.61 [a]	2.42
Tectona grandis (sole)	8.42 [b]	2.72 [b]	20.15 [b]	19.40 [b]	2.51 [b]	2.53
S. Em. ±	0.30	0.04	0.43	0.76	0.83	0.14
CD (p<0.05)	0.88	0.12	1.20	2.18	0.23	0.41
CV (%)	14.36	5.90	8.46	9.95	10.66	23.69

ab Dissimilar superscript shows significant difference

Table 2. Soil properties under agroforestry and sole plantations of 11-year old Teak (*Tectona grandis* Linn. F.) in sodic soils of eastern plains zone of eastern Uttar Pradesh

Sr. No.	Soil properties	*Tectona grandis* + wheat	*Tectona grandis* (Sole)
A	**Physical**		
1	Bulk density (g cm3)	1.33	1.39
2	Porosity (%)	49.42	47.14
B	**Chemical**		
1	Organic carbon (%)	0.27	0.24
2	pH	8.54	8.74
3	EC (d Sm-1)	0.36	0.38
4	ESP	24.20	23.61
5	Available N (Kg ha-1)	180.4	176.8
6	Available P2O5 (Kg ha-1)	11.13	9.36
7	Available K2O (Kg ha-1)	207.3	203.6

Greenscaping with Trees in Urban Vicinity

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INTRODUCTION:

Constant struggle for survival in this hi-tech world is drifting us far away from the wonderful nature, as the pace of urban-development is being transformed from the eco-friendly human being to machine-friendly. Our natural resources depleting by deforestation, ripping of hills and exposing them to erosion, pollution of rivers, streams and lakes with little understanding of the natural environment which supports human life. Life in urban areas is constantly becoming difficult with the exploding problems of atmospheric pollution and massive population explosion, producing a disastrous effect on our daily life style and health.

The understanding and need of maintaining biodiversity and ecological balance, have given thrust to green scaping with vital beautiful tree species for different landscape purposes. Psychologists have found that access to plants and green spaces provides a sense of rest and allows workers to be more efficient. Interaction with trees and natural spaces offers a variety of mental, physical and social benefits for humans, ranging from stress reduction, quicker healing, and mitigation of Attention Deficit Disorder in children to decreasing crime and curbing air pollution. The application of the art and technique of landscaping with proper selection of trees can spell magic to our surroundings enhancing aesthetic beauty besides, improving and conserving environment. Besides, trees provide source of natural beauty, conserve natural resources, reduce maintenance costs, preserve biological diversity, check soil erosion and prevent species extinctions along with solving many environmental problems. City-wide, the placement and quality of trees in terms of canopy, texture, flowering habit, etc influence both biological and physical urban environments. Strategy of systematic and thematic tree plantation with post plantation care can offer 'A Live Green Technology," with a potential of becoming a key part of the urban infrastructure.

BENEFITS OF LANDSCAPING WITH TREES

An orderly and well maintained planting scheme of both trees and accessory vegetation produces highest visual quality ratings for urban streets, shopping areas, parking areas as well as for city squares (Kathleen 2006). Trees are an essential feature of landscape garden, for road side planting, public parks, along railway lines, in school and colleges, government building and banks, historical and religious places and private home compounds. The benefits of green scaping with trees around educational

buildings gardening inculcate many values in the growing children including improving creative ability, developing quest for natural phenomenon, creation of social wellbeing and spatial awareness and restores calmness in mental behavior (Richard, 2005). Parks, garden spaces, street trees, and landscaped traffic islands provide more than a pretty panorama, effectively reducing the stress of our daily lives by invoking a feeling of tranquillity(Jennifer, 2006). Interaction with trees and natural spaces offers a variety of mental as well as social benefits for humans, besides environmental moderation as illustrated below:

ENVIRONMENTAL MODERATION

Green scaping with trees increases the awareness towards nature developed eco-friendly concept and upsurge the feeling of responsibility towards plants, birds and animals. It also helps in soil-moisture retention; prevent erosion, modifying air temperature, creating microclimate and removal of noise and dust pollution. It also provide habitat for birds and animals. A landform devoid of vegetation show erosive rate of around 500 tons/m^2/year. A green belt planting of around 183 m can reduce airborne particulate matter by as much as 75 percent. An acre of green area reduces 12-27 tones of dust, 1.5 tons of CO_2 and releases 2.5 tons of O_2. One fully developed large tree in a landscape can change the microclimate and brings down the temperature by 2 to 5°C (Booth, 1998). A study in Chicago determined that the city's trees filtered 234 tons of particulate pollution and cleansed the air of 98 tons of nitrogen dioxide, 93 tons of sulfur dioxide, and 17 tons of carbon monoxide (Barton, 2009).Tree also plays major role in temperature regulation. Vegetated areas specially with trees also provide relief from the 'heat island effect' casued by the heat trappin quality of concrete and buildins. Air under a tree's canopy can be as much as 5-10°F cooler compared to barren location (Kaltheen, 1998). The average temperature of concrete urban area devoid of green belt is higher compared to a thickly vegetated area. For *eg*, microclimate of Navsari city *Vs* Navsari Agricultural University campus, where the former is cooler. Well planned landscape around building or residence adjoins aesthetic value to it as well as affix real estate value of about 30%.

EFFECTS ON MIND

Pleasant view of greenery and flowers stimulate creativity and has soothing effect on body, mind and soul. Studies have indicated that exposure of green spaces reduce instances of aggression and violence (James, 2001). Flowers are known to have emotional stress busting effect in humans.Scientists assert that green spaces increase our ability to concentrate, both on the tasks at hand and on our subconsciously-viewed surroundings. Studies have shown that stressed individuals feel better after exposure to natural scenes with hue tree plantation and flowers.

EFFECTS ON BODY HEALTH

Cities with high numbers of parks (trees are the main components) battle obesity and diabetes well. Even relatively passive contact with nature such as viewing it from a window—lowers blood pressure and anxiety levels (Kaltheen, 1998, 2006). Road side avenues offer a desired destination that prompts people to walk there and motivate people to explore once there.Flower and garden views provides more rapid healing according to some studies in hospital. Some trees provides herbal medicines e. g. Neem, Ginko, Moringa, *Madhuka indica*, *Murraya koeingi* , Kadam, etc.

EFFECTS ON SOCIETY

Maintained green scapes play important role in improving social culture by increasing workplace productivity, driving safety, reducing crime and prosperity. In the business environment, green spaces improve productivity and morale among workers. Studies show that desk workers with a view of nature—either out a window, or around them in the form of indoor plants feel more relaxed overall, and those with no visibility of plants suffer the most stress and anxiety. A study of 98 vegetated and un-vegetated apartment buildings in Chicago, US (2009) showed that vegetated spaces cut crime by half, in addition to inspiring pride for surroundings that translated into less litter and less graffiti (Barton, 2009). Vegetated landscapes invite more people to use them, ensuring more eyes on the watch to prevent crime in outdoor spaces. Roadside vegetation or avenues also serve a social benefit by reducing fatigue, anger, aggression, frustration and stress of automobile drivers. Well designed landscapes and streets and shopping areas foster a community's sense of place, and raise opinions about the quality of goods and services offered. Further, face value and economic value of any building in well maintained landscape area may be 10-25% higher than the one without it (Kaltheen 2006).

EFFECTS ON CHILDREN

Richard Louv (2009) in his book, 'Last Child in the Woods' has truly reviewed the benefits plants offer to the child. Views of trees from the home improves self-discipline among inner city girls, including enhanced concentration, inhibition of impulsive behavior, and delay of gratification. After creative play in verdant settings, children overall demonstrate increased ability to concentrate, complete tasks, and follow directions.

FUNCTIONAL AND ARCHITECTURAL APPLICATION OF TREE PLANTATION

Selection, placement and grouping of trees can greatly influence their functional as well as architectural use (Booth, 1985). Functional application of tree plantation may include:

1. Creation of space or outdoor rooms, block unsightly views, stabilize steep slope, direct the movement through the landscape, visually unify a group of building and modify exposure to sun and wind.

2. Environmental moderation: cleansing the air, retain moisture in the soil, prevent erosion and loss of soil and provide habitat for birds and animals.
3. Contribution in increasing real estate value of buildings and their sites.

Trees can be architecturally used in the landscape which functions as structural components like ceilings, walls, windows, doors etc and for creation of varied degree of space likes semi open space (with one side with taller trees and d other side planted with small plants), canopied space can be obtained by growing mass of shade trees with a dense canopy, and vertical space can be created by using tall, narrow trees which are vertical in orientation and open to sky. It gives upward movement. Trees can also be used to establish interlinked sequences of spaces. Trees may also be used to complete spatial definition and organization that has been suggested by design elements. Trees can be very well used to screen unattractive or unwanted objects. Depending on objectives, a vegetative screen may be completely opaque to totally screen a view or it may have some of transparency to provide partial screening. Tree plantation scheme can be very well used for ensuring privacy control. It is the technique of encircling a well defined area with trees that view from outside is prevented. The purpose is to isolate the space from its surroundings and for recreational activities for the family.

Criteria for selection of tree species for green scaping in urban vicinity is mainly based on foliage density and shade effects, variation, duration and synchronization in flower colour, canopy-form, elevation, texture, abiotic stress tolerance, pollution tolerance, etc. Visual characteristics like size, canopy form, flower colour and texture affect the overall aesthetic quality that is displayed with tree plantation scheme.

SELECTION CRITERIA FOR TREE SPECIES IN URBAN LANDSCAPE

Criteria for selection of trees species for urban landscape can be based on their use as discussed below:

i. Shade and dense foliage

Evergreen trees with dense foliage provide shade through out year in landscape. Summer season is very hot and these trees serve as cool and shady resting place during hot sunny days in summer. Example of such trees are *Albizzia lebbeck, Alstonia scholaris, Azadirechta indica, Ficus spp, Peltophorum pterocarpus, Eugenia operculata, Eugenia jambolana, Mangifera indica, Samanea saman, Mimusops elengi, Polyalthia longifolia, Grevillea robusta, Thespesia populnea, Pongamia glabra. Bauhinia purpurea, Ixora parviflora,Calophyllum inophyllum, Parkia roxburghii, Kigellia pinnata, Saraca indica, Sterculia alata, Pterospermum acerifolium, Grewia columnaris, Tamarindus indica, Filicium decipiens, Putranjiva roxburghii, Santalum album, Swietenia mahagoni*, etc.

ii. Flower colour:

An appropriate choice of the flowering tree species and different flower colour combinations would ensure pleasing colours all around in our garden avenues and countryside. Flowers of tropical trees are very rich in colours one can have all different kind of colour combination from the available tree species throughout year.

Red: *Poinciana regia, Butea monosperma, Bombax ceiba, Erythrina indica, Spathodea campanulata, Saraca indica, Cordia sebestena, Amherstia nobilis, Callistemon lanccolatus, Colvillea racemosa, Firmiana coloratea* etc.

Pink: *Cassia renigera, C. marginata, C.grandis, C.nodosa, C.javanica, Kleinhova hospita, Gliricidia maculata, Bauhinia purpurea. Bauhinia variegate, Lagerstroemia flos-reginae, L.thorelii, Tabebuia avalandi. T.heterophylla, T.rosea, Couroupita guianensis, Chorisia speciosa, etc.*

Yellow: *Peltophorum pterocarpum, Cassia fistula, C.siamea, C.spectabilis, Tabebuia spectabilis, Tecoma argentea, Tecomella undulata. Cochlospermum gossypium, Markhamia platycalyx, Heterophrama spp., Thespesia populnea,* etc.

Blue: *Jacaranda mimosaefolia, Solanum macranthus, Milletia ovalifolia, Clitoria arborea, Guaiacum officinal*, etc.

White: *Millingronia hortensis, Plumeria Spp., Nyctanthes arbor-tristis, Mimusops elengi, Azadirachta indica, Melia azedirach, Erythrina alba, Crataea religiosa, Gustavia augusta, Bauhinia variegata Var candida, Dillenia indica. Ixora parviflora, Alstonia scholaris, Pterosoprmum acerifolium, Calophyllum inophyllum, Wrightia tinctoria, Holarrhena antidysenterica, Anthocephalus cadamba, Citharexylum quadrangulare*, etc. Most of the white flowered species are scented one.

Different schemes of trees for year round flowering

Sr. No.	Months	Scheme of planting of Tree Species	Flower colour scheme
1	May – June	Gulmohar + Amaltas + Pink Cassia	Red + Yellow + Pink
2	July – August	*Lagerstomea spaciosa + Lagerrstomea spaciosa + Cassia siamea + Peltophorum*	Mauve + Pink + Yellow
3	September + October	*Cassia grandis + Spathodia + Acessia aericuliformis*	Pink + Red + Golden Yellow

4	November + December	*Bauhinia variegata* + *Bauhinia purpurea*	White + Light Mauve + Deep Mauve
5	January + February	*Cocolospermum gossipium* + *Gliricidia* + *Bauhinia*	Yellow + Light Pink
6	February + March	*Erythrina indica* + *Tecoma argentea*	Red + Yellow
7	March – April	*Jacaranda* + *Bombax cieba* + Pink Cassia	Blue + Red + Pink

iii. **Height:** Height of tree is important as it directly affects the scale and proportion depending upon the surrounding location, roadside or buildings.

a. **Large trees**: Height of large trees is around 15-22 mt. Eg. *Adansonia digitata, Anthocephalus cadamba, Azadirachta indica, Alstonia scholaris, Ficus sp., Casuarina equisetifolia, Couroupita guinensis, Peltophorum pterocarpum, Polylthia longifolia, Samanea saman, sterculia foetida, Terminalia cattapa, Tubebuia rosea, T. arjuna, Cassia sp., Acasia auriculiformis, Teak etc.* These are dominant visual elements on a landform. Also used as focal point and for screening cold wind and hot sun.

b. **Intermediate Trees**: intermediate trees have 12-15 m height. These are used for screening cold wind and hot sun. They are also used to develop enclosed area. Some examples are *Butea monosperma, Calophyllum inophyllum,Delonix regia, Kigellia pinnata, Jacaranda,Mimusops elengi, Markhemia, Tecoma argentia, Spathodia campanulata, Thuja actinophylla, Thespesia populnea, Madhuca indica, Dalbergia sisoo, Mangifera indica, Azadirecta indica Bauhinia purpurea, Cassia fistula, Cassia nodosa,C. renigera, C. siamea etc.*

c. **Small trees and Ornamentals**: Height of small tree is 5-8 m. Eg. *Brassica actinophylla, Cochlospermum gossypium, Calophyllum inophyllum, Plumeria alba, P. rubra, Cytha rexilon, Erythrina blackeii, Gliricidia, Largestroemia indica, Nyctanthus arbortritis, Saraca indica, Ixora parviflora, Tubebuia avalandi*, etc. They are useful in creating edged for complete enclosure and also work as ceiling. They can also be also planted on both sides of path.

iv. **Canopy form:**

The form of an individual plant or group of plants is the overall shape and growth habit. Different canopy forms are given below.

1. Fastigiate or Oval: This type is upright, narrow and tapers to a point at its top. Example: Thuja, Middle aged Eucalyptus and Casuarina.
2. Columnar: This is same as fastigiate form but has rounded top. Example: *Casurina equisetifolia, Polyalthia longifolia, Eucalyptus* sp., etc.

3. Spreading: This plant form is at least as broad as it is tall, with generally horizontal habit. Examples: *Samanea saman, Poinciana regia, Anthocephalus cadamba, Bombax cieba, Terminalia catapa*, Palms etc.
4. Round: This form has rounded or spherical canopy. Example: *Mimusops elengi, Azadirchta indica*, Mango, *Anthocephalus cadamba*, etc.
5. Pyramidal or conical: It has cone like appearance. Example: Christmas tree, Deodar, Juniperus, etc.
6. Weeping: A weeping plant form has predominantly pendulous or downward arching branches. Example: *Calistemon chinensis, Weeping willow. Callistemon lanceolatus, Salix babylonica, Pongamia glabra, Ficus nitida*
7. Picturesque: It may be irregular, windblown and has unique sculptural shape. Example: *Butea monosperma*.
8. Umbrella: The canopy has umbrella shape. Example: *Samanea saman, Albizzia lebbeck*, gulmohar, *etc.* Shrub: *Cassia biflora, Calliandra, etc*

v. Foliage type

It includes the form of the foliage and type of the growth and can be classified as:

1. Evergreen: Leaves remain on plant throughout the year. These are grouped at various locations throughout the design which visually break up composition and if clustered together they unify composition. Evergreen dark foliage is also used as background for light green foliage or for deciduous plants. They are used to screen objectionable views, cold wind and hot sun.
2. Deciduous: These loose their vegetation in late winter, summer and regain in monsoon. This emphasis the season as they have different appearance in all seasons. These can be utilized to create mobility in garden. Deciduous trees have typical structure of branches. The habit and pattern of bare branches themselves create a unique design. Generally, type of foliage influences seasonal interest, visibility and unity of a design. They also relate directly to the texture.

vi. Plant texture: It is the visual roughness and smoothness of plant. It is influenced by leaf size, twig and bark size, bark configuration, the overall habit of growth and the distance at which the plant is viewed. Texture affects a number of factors in a planting composition, including unity and variety, perception of distance, colour tone, visual interest and mood of a design. It has following classes:

a. **Coarse texture**: Coarse texture is created by large leaves, thick, massive branches and loose open habit of growth. Examples are *Kigellia pinnata, Butea monosperma, Canophyllum inophyllum, Madhuca indica, Tectona grandis, Anthocephalus cadamba, etc.* It is highly visible, bold and aggressive so used as a focal point. Because of its strength, it causes the sensation of "moving toward" and make as outer space feelling smaller.
b. **Medium texture**: Medium texture results from medium sized leaves, branches and moderately dense habit of growth. They are less transparent and form basic

texture of a design, serving transitional element between coarse and fine textures. Example: *Spathodia campenulata, Tecoma argentia, Saraca indica, Mimusaps elengi, Cassia fistula*, etc.

c. **Fine texture**: It is produced by many small leaves, tiny, thin branches and twigs and a tight, dense growth habit. They are soft and delicate in appearance. It increases distances due to its structure and also act as a neutral background to provide refined, smooth surface character. Example: *Cassia seamea, Delonix regia, Jacaranda*, Pink cassia, *Peltophorum, Casuarina, Samania saman*, etc.

vii. Fruit bearing avenue trees:

Some trees have beautiful canopy as well as bearing edible fruits. These trees can be incorporate in landscape gardening of road side avenues as well as home compounds. Eg.*Eugenia jambolana, E. operculata, Mangifera indica, Morus alba, Cocus nucifera, Averrhoa carambola, Phyllanthus emblica, Tamarindus indica, Aonla, Bad, Artocarpus heterophyllum, Punica granatum, Citrus spp. Annona reticulata, A. squamosa*, Date Palm, Areca nut etc

viii. Pollution tolerance:

All trees purify air and can be rightly termed as 'oxygen banks' for human beings. However, with high level of pollutants in air even the growth of plants becomes stunted and becomes difficult for survival. Some tree species are highly tolerant to air pollution. Such trees can function as biological filters. They filter contaminants from air and cleanse the atmosphere. Some of the tropical tree species like *Albizzia lebbeck, Alstonia scholaris, butea monosperma, Ficus benjamina, Madhuca indica, Pongamia glabra, Lagerstroemia flos-reginae, Ficus religiosa, Peltophorum pterocarpum, and Terminalia arjuna* can be planted in industrial areas since they are tolerant to dust and smoke. For noise reduction *Mangifera indica, Butea monosperma, Madhuca indica, Terminalia arjuna, Alstonia scholaris and Azadirachta indica* are very suitable.

ix. Special landscape effects:

Some trees change the colour of leaves once a year like *Schleichera oleosa, Lagerstroemia flos-reginae, Terminalia catappa, Ficus religiosa*. etc. and provide mobility to the garden. Some species possess very unusual characters like *Adansonia digitata* has large trunk, *Kigellia pinnata* has long pendulant flowers and fruits, *Coroupita guinenesis* has peculiar flowers (shape and fragrant) and fruits, *Aurocaria cookie* has pyramidal canopy and beautiful branching arrangement and leaves, suitable specimen tree in the lawn. Pods of *Peltophorum pterocarpum* , *Lagerstroemia* sp. and *Kleinhovia hospita* are ornamental. *Santalum album* wood is fragrant, while branches and trunk of some trees are coloured like *Terminalia crenulata* (Blackish trunk), *Mesua ferrae* (Redish brown) and *Wrightia tinctoria* (ivory white), etc. Some trees has important medicinal values like *Azadirachta indica* (Diabetes, wound healing, Fever), *Cassia fistula* (constipation), *Terminalia arjuna* (Blood purifier & Heart disease), *Syzyzium spp.* (urinary problems), *Moringa oleifera* (Arthritis), *Ficus*

religiosa (as gargle in salivation) *Puntranjiva roxburghii* (repeated miscarriages). *Hydnocarpus laurifolia* (Leprosy), *Holarrhina antidesenterica* (dysentery) etc.

x. Tolerance to Abiotic stress:

Trees like *Dalbergia sissoo, Butea monosperma, Cochlospermum gossypium, Crataeva religiosa, Albizzia lebbek, Tecomella undulata, Azadirachta indica, Tamarindus indica, Ficus spp., Cassia fistula, C. siamea* can be grown in a very dry localities. Some species are suitable for wetland, e.g. *Dillenia indica, Barringatonia spp, Ficus elastica, Syzygium spp., Pongamia, Michella champaca, Terminalia arjuna, Holoptelia integrifolia, Thespesia populnea, Acasia nilotica*, etc. Few species of the trees are salt tolerant like *Peltophorum, pterocarpum, Thespesia populnea, Ficus spp., Cocas nucifera, Acasia auriculiformis, Eucalyptus spp., Casuarina equisetifolia, Salvadora persica, Prosopis cineraria, P. juliflora*, etc. Some of the trees are fire proof since the bark is thick enough to ignore the hottest blaze, e.g. *Tecomella undulata, Tectona grandis, Terminalia crenulata*, etc. Some of the tree species are highly efficient in soil conservation. e.g. *Gliricidia* is highly efficient for nitrogen fixation in soil.

It is apparent from above that tropical trees can meet the major requirement of landscape gardening in the urban vicinity. As such they provide a rich source of taxa furnishing sky line to landscape, back ground to magnifying architecture and screen for privacy: from road traffic. Besides, these green friends bestow us with shade, protection against aggressive winds and a strong component of garden design in home compounds and complement office buildings, whereas some species are source of cut flowers, timber, fruits and product of minor uses. Trees serve human life on this planet, besides, meeting all different requirements of landscape gardening in India. Trees are a rich source of taxa furnishing sky line to landscape, back ground to magnifying architecture, screens for privacy and a mode to add change and colour in life. These are our true green friends bestowing us with infinite benefits. Thus, careful eco-friendly plantation of these beautiful trees has the potential to play magic on this mechanized earth transforming it into a beautiful colorful aspiring green-scape.

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Recent threats of insect and disease infestation to eucalypts culture in North India: R&D efforts at WIMCO to minimize their impact

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India leads in eucalypts culture with approximately 4 million ha plantation area. Eucalypts is also the leading tree being planted on farmland in numerous regions across the country including North India. The tree is well known for its rapid growth, genetic diversity, ease to vegetative propagation, coppice regeneration and suitability for numerous uses. The demand for its wood is increasing since it being now a main raw material for paper pulp, panel industry and host of other domestic and industrial uses. It is also a favorite tree for growing in agroforestry in North India and is being extensively planted on farm boundaries and in blocks.

Of recent, the eucalypts culture in North India including many other parts of the country, is adversely affected due to three major insect and diseases infestations in its nurseries and field plantations viz., infestation of gall insect (*Leptocybe invasa* gen.), little leaf (Mycoplasma like organisms-MLOs) and Cylindrocaladium leaf blight- CLB (*Cylindrocladium quinqueseptatum*). The infestation of all the three agents both in nursery plants and field planted trees has been very heavy in the recent years rendering a serious set back to its plantation activities. As a result, its wood availability has sharply declined, prices gone up and the industry is left with little option as to import eucalypts and other tree's wood in appreciably quantity from many other countries to meet their production needs. We, at Wimco have been first to initiate eucalypts research (outside Government institutions) in early 1980's and have been following these developments very closely. The objective of present study was to overcome these three major challenges through research and development means including developing new clones having fast growth and high degree of resistance against these disease and insect infestation. Our research initiatives have led to developing and screening of many clones, two of which, W-14 (WIMCO-14) and W-15(WIMCO-15) have shown a very high degree of resistance to infection of CLB, gall wasp and little leaf both in nursery as well as in field conditions. This presents excellent opportunities for disease and insect avoidance on this species and sustaining its culture in future.

Keywords: Eucalypts culture, Gall wasp, CLB, MLOs, Clones

INTRODUCTION

Eucalypts is one of the main planted forest trees across many regions in the country. It is very fast grown, mostly grown for a short rotation of 4-5 years, repeatedly harvested from coppice origin without making fresh plantation every time and is suitable for being grown by farmers with little post planting care as a cash crop to supplement their income from limited land resources. It is increasingly grown for meeting the diverse uses from

industrial raw material to domestic needs for small timber and firewood. The tree is also planted on forest land in many states. Its planting is mainly promoted by paper and pulp industrial units, many state forest departments, and private nursery growers who have started growing its nurseries as business option in view of rising demand for its planting stock. India with its 3.9436 Mha plantation area represents 22% of the global planted eucalypts and therefore leads in its culture (www.git.forestry.com). State of Forest Report 2009 records 107.4 million eucalypts trees as ToF (tree outside forests) which represents 1.95% of the total tree stock found on non forest areas in the country (FSI 2009). Of recent, the usage and share of eucalypts wood has significantly increased due to its increased availability from farmlands and also as a result paper and pulp industry largely replacing with it the traditional raw material like bamboo that was earlier obtained from government forests. The role of this tree in meeting the domestic and industrial demand is very significant in view of widening gap between its demand and supply scenario.

Eucalypts is a very important raw material for wood based industry in North India. Some reconstituted wood based industrial units which have been recently allowed to establish in Uttrakhand were given special permission based on the use of only eucalypts and poplar wood grown on the farm land. Many of the reconstituted wood based industrial units which were functioning without registration in this region for quite some time were regularized with quantification of the raw material availability from eucalypts, poplar and a few other trees grown on the farm land in each state. Wood based industry located in North Indian plains viz., Punjab, Haryana, Western UP and part of Uttrakhand presently consumes approximately 15,000 tones eucalypts wood per day (with around 5000 tones around Rudrapur, Uttrakhand alone) for paper pulp, veneer and particle board manufacturing in addition to some other domestic and industrial uses. The industry has now started experiencing shortage in its wood availability, as the demand for its wood suddenly increased on establishing new units, wood availability declined on fast and early harvestings, and the pace of establishing new plantations seriously affected as the large scale infestation of these insect and diseases disrupted the production of healthy planting stock. This paper presents the research and development efforts undertaken at WIMCO for facing these challenges and also in developing resistance clones for sustaining eucalypts culture in the region.

WIMCO in eucalypts R&D and its culture

WIMCO Ltd., established in 1923, is one of a very few old wood based industrial establishments, that is still operating after 88 years of existence. The company was the first, outside government sector, to start forestry R&D and field operations during 1970's. The company is well known for its poplar program in North India and Kadam program for eastern states and also for introduction and promotion of root trainer technology (Dhiman 2011). The company was a pioneer to start systematic R&D on eucalypts (in corporate sector) through its subsidiary Wimco Seedlings Ltd. established in 1984 which was latter on merged with WIMCO Ltd. in 2007. Eucalypts improvement programme was started with the aim to produce improved eucalypts clones for pulp & paper industry, timber panel, firewood etc. The work includes species and provenance trials; hybridization, selection of candidate plus trees; centralization of selected candidate plus trees at R & D Centre, Bagwala; vegetative propagation techniques including budding, grafting, rooting etc; and planting stock production of seedlings and clonal origin. Wimco was first in India to report

rooting of cuttings of selected euclaypts clones (Chandra and Yadav 1986). Around a dozen clones were included in the routine production system. Clonal planting stock of these improved clones has been regularly supplied to the farmers, government departments, research organizations and industries. Upgraded seed obtained from these selected clonal eucalypts plantations is regularly collected and supplied to the paper mills, state forest departments, and farmers.

Eucalypts improvement programme was started with the selection of candidate plus trees from Uttar Pradesh. An eight digit code was designed for keeping track of the selected candidate plus trees. Trials indicated that patch budding is better option for clonally assembling the mother trees when compared with the cleft grafting as lateral technique invariably resulted in mortality of grafted shoots. In 1986, all the selected mother plants were clonally assembled at R & D Centre, Initial rooting varied widely from 0-63% which was significantly improved with rejuvenation by serial propagation and application of 10000 ppm IBA formulation. Results of 120 months old trial of 25 provenances comprising of six eucalypts species namely *E. grandis*, *E. salinga*, *E. camaldulensis*, *E. urophylla*, *E. brassiana* and Mysore gum as control established in 1985 indicated that provenance 13022 NW of Caboolture and 12970 SFR 194 Herberton Range, Qld. of *E. grandis* and 13026 NW of South of Calliope, Qld. of *E. salinga* yielded higher wood volume than rest of the provenances (Chandra *et. al* 1998). A provenance trial of 31 seed sources procured from Australia confirmed that *E. grandis* grows much better in Tarai Region than many other species. At 20 years age, a candidate plus tree of *E. grandis* (CSIRO No. 12081) produced timber volume of 1.339 cum(ob) with a height of 25 m and girth of 162 cm (Dhiman and Gandhi 2005)

Open pollinated seed were collected from the selected candidate plus trees during May-June 1985 and seedlings were raised. A population of 115000 seedlings comprising of 97 half sib families (81 *Mysore gum*, 7 *E. tereticornis*, 3 *E. camaldulensis* & 6 from the F1 hybrid of *E. tereticornis* X *E. camaldulensis*), 3 control and one clonal eucalypts population were planted during 1986 at 4.0m X 1.25m spacing in compartment Number 84 & 85 of Pipal Parao Range of Central Tarai Forest Division, Haldwani. Annual measurements of 100 plants of each progeny were recorded for height & diameter growth and resistance to disease & insect. 111 candidate plus trees were selected from these families during the year 1991. These 111 CPTs were centralized at R & D Center by patch budding on seedlings for further experimentation and improvement work. Sixty control crosses among different species & provenances were tried in 1987 and success obtained was 62 percent. A trial of 476 seedlings produced from seeds of 29 crosses and open pollinated collected were field planted in 1988. Similarly, 6 crosses were made in 1989 and their trial was established at R & D Centre. Out of these crosses, two individuals (crosses between Mysore hybrid parents of two land races) have been screened based on height & diameter growth of over 24 m & 24 cm respectively at 8 years age. First clonal trial of 8 clones (2 of *E. camaldulensis* and 6 that of *Mysore gum*) with a control of seedling population of Mysore gum was established at R & D Center Chandain Farm during 1989. The results obtained at 48 months age indicated better growth of two Mysore gum clones and one *E. camaldulensis* clone when compared with other clones including seedling population of Mysore gum. Out of these trials around a dozen clones were routinely introduction in production system and for supply of clonal planting stock to the growers.

Fig.-I. Candidate plus trees selected from 9-21 years old plantations and centrally assembled at R&D Center during 1986 (left) and union of budded candidate tree on seedling (right). All these old trees were found gall infected in 2008.

Three threats to eucalypts culture in North Indian plains

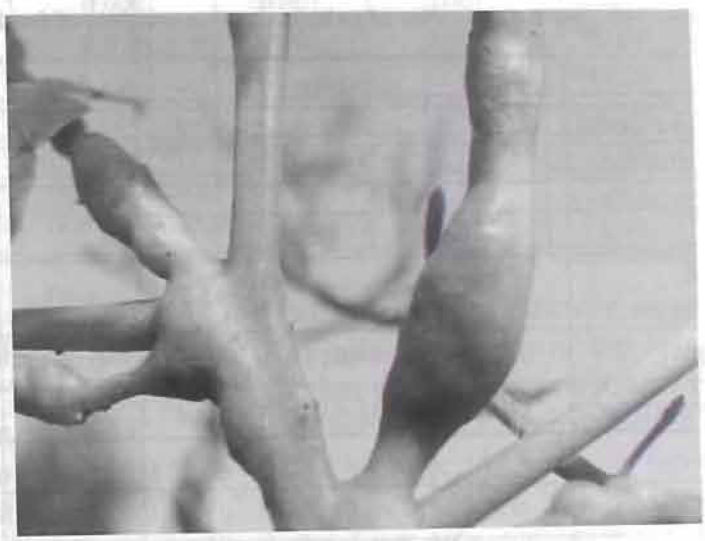
Of recent, the eucalypts culture in North India including many other parts of the country, is adversely affected due to three insect and disease infestation to nursery planting stock and field trees viz., infestation of gall insect (*Leptocybe invasa* gen.), Cylindrocladium leaf blight- CLB (*Cylindrocladium quinqueseptatum*) and little leaf (Mycoplasma like organisms-MLOs). The infestation of all these agents has been very severe in the recent years rendering a serious set back to eucalypts culture. As a result, eulcaypts wood availability has sharply declined, prices gone up and its nursery production is adversely affected. The major nursery stock produced so far was of seedling origin which exhibits a very high degree of susceptibility to all of these infestations, some widely accepted clones like BCM 3, BCM 7, and BCM 10 and WIMCO's series clones viz., W-36, W-104 and W-T10 have developed a very high degree of susceptibility to these agents, most of these clones have now been taken out of production system and search for new ones have earnestly started to sustain eucalypts culture in the region. Threat of these agents to eucalypts culture and R&D efforts made thereto are discussed below.

Gall wasp infestation

Gall infestation by *Leptocybe invasa* gen. & sp. n. on eucalypts is of recent origin in its growing locations in India. In a very short period of around 10 years of being first recorded in Mandya District, Karnataka during 2001, it has now spread to almost all the eucalypts growing locations in the country. In North India, the insect appears to have entered with the planting stock imported from South India. Galls on eucalypts were first noticed on clone BCM-316 during 2007 in Uttrakhand and thereafter a field survey conducted in part of North Indian plains during Dec., 2008 confirmed its wide spread infestation over all the 30 surveyed locations in Punjab, Haryana, Uttrakhand and Uttar Pradesh (Dhiman et al 2010). It has also been confirmed from Haryana (Jagdish Chander 2011), adjoining state of Gujarat (Shivesh Kumar et al 2007) and has also been recorded by

the senior author in Bihar and West Bengal. Nursery seedlings both in government and private sectors are now seriously getting infested with gall as a result their availability for field plantations has significantly declined. The increased susceptibility of even many of the branded and accepted clones from ITC and WIMCO has restricted clonal choice to a few relatively less susceptible clones *viz* BCM 413, BCM 411, K25, BCM 2045 etc. for planting stock production. Many traders are importing planting stock from private nurseries in South India and supplying it to the growers in North India. Most of such planting stock develop galls in due course and the productivity of field plantations is seriously affected. The infestation is more serious to nursery seedlings, young plantations and coppice shoots, even old plantations have also been found infested with the gall (Dhiman et al 2010). Coppice shoots of even relatively resistance clones also show a very high degree of gall formation in different locations.

Fig.-II. Heavy infestation of gall wasp on eucalypts shoots



Number of field and nursery trials conducted for monitoring gall wasp infestation for developing resistance clones at WIMCO has started yielding useful results. Wide variation has been noticed for gall infection in relation to age of trees, species, clones and locations. The screening of ramets of CPTs assembled at R & D Centre for the gall infestation during 2008 indicated that the insect has infested even 24 year old trees which recorded gall infestation to varying degree. In a trial of 8 clones established during 2009, clone No. BCM 2135 recorded minimum gall formation in comparison to other clones viz., BCM 411, BCM 413, BCM 316, BCM 2045, BCM 2070, K25 and Urograndis when observed during the month of September and November 2010. In another trial of 14 clones, clones No. EG 11, EG12, EG 13, EG14 and EG15 registered a high degree of resistance to gall in comparison to K23, K25, Urograndis, BCM 316, BCM 411, BCM 413, BCM 2045, BCM 2135, BCM 2070. In another field trial of 22 provenance of 9 species viz., *E. urophylla, E. pellita, E. camaldulensis, E. citridora, E. alba, E. moluccana, E. longirostata, E. grandis, E. tereticornis.* Four provenances viz., *E. citridora* (13550), *E. alba* (17833), *E. longirostata* (20464) and *E. citridora*(19961) have shown no infection to gall wasp whereas, other have shown some degree of gall infestation.

Data presented in Table-I for gall formation and fresh infection of insect on planting stock of eucalypts species revealed significant variation in the mean values of number of galls/leaf and number of fresh infection spots in top leaves on all the three months of data recording. Planting stock of *E. tereticornis* registered significantly higher number of galls/leaf and number of fresh infection spots in top leaves when compared with planting stock of *E. camaldulensis*, Hybrid of *E. urophylla* X *E. grandis* (Urograndis), Hybrid of *E. tereticornis* X *E. camaldulensis* and *E. grandis*. Among clonal planting stock of different species, Maximum number of galls/leaf were recorded on hybrid of *E. tereticornis X E. camaldulensis*, whereas, minimum number of galls/leaf and number of fresh infection spots in top leaves were noticed on clonal planting stock of *E. grandis*.

Table-1. Gall infestation on different eucalypts species during different months

Species	Gall Infestation					
	No. of galls/leaf			No. of fresh Infection spots/ top leaf		
	Aug.	Sept.	Oct.	Aug.	Sept.	Oct.
E. camaldulensis (3 clones)	2.41	2.02	1.14	7.77	0.001	0.25
E. tereticornis (1 clone)	3.97	3.58	2.33	4.29	8.83	1.33
E. urophylla X E. grandis (2 clones)	1.03	0.79	0.31	6.91	5.31	1.79
E. tereticornis X E. camaldulensis (2 clones)	4.49	5.12	4.67	6.83	0.42	0.46
E. grandis (2 clones)	0.001	0.001	0.001	0.001	0.001	0.001
Seedlings of *E. tereticornis*	11.45	15.43	12.63	11.26	19.12	10.12
Mean	3.13	3.49	2.72	5.94	3.94	1.64
SE Diff.	0.93	0.73	0.68	0.84	0.86	0.36
CD at 0.05	2.14	1.68	1.57	1.94	1.98	0.83
CD at 0.01	3.12	2.45	2.28	2.82	2.88	1.21

Maximum number of galls/leaf have been registered during the month of September i.e. 3.49 galls/leaf followed by that in during August and October with an average 3.13 and 2.72 galls/leaf respectively. Whereas, maximum number of fresh infection spots in top leaves were registered during the month of August i.e. 5.94 fresh infection spots in top leaves followed by that in during September and October with an average 3.94 and 1.64 fresh infection spots in top leaves respectively.

Table-2. Gall infestation on different clones during different months

Clone	Gall infestation					
	No. of galls/leaf			No. of fresh Infection spots/ top leaf		
	Aug.	Sept.	Oct.	Aug.	Sept.	Oct.
ITC BCM 413	0.001	0.001	0.001	8.29	0.001	0.001
ITC BCM 411	7.23	6.09	3.45	9.12	0.001	0.001
ITC BCM 316	3.97	3.58	2.33	4.29	8.83	1.33
ITC BCM 2045	4.79	6.30	5.56	6.49	0.001	0.33
ITC BCM 2135	1.08	1.00	0.62	6.33	3.45	1.08
K-25	0.001	0.001	0.001	7.12	0.001	0.75
ITC BCM 2070	4.19	3.91	3.78	7.71	0.83	0.17
Unnamed	0.98	0.58	0.001	7.50	7.16	2.50
W-14	0.001	0.001	0.001	0.001	0.001	0.001
W-15	0.001	0.001	0.001	0.001	0.001	0.001
Seedlings	11.45	15.43	12.63	11.26	19.12	10.12
Mean	3.06	3.35	2.58	6.21	3.58	1.48
SE Diff.	1.15	0.89	0.99	1.03	1.67	0.65
CD at 0.05	2.40	1.86	2.06	2.15	3.49	1.35
CD at 0.01	3.27	2.53	2.82	2.93	4.75	1.85

Data presented in Table-II for gall infestation indicates significant variation for number of galls/leaf and number of fresh infection spots in top leaves among different clones under study. Maximum fresh infection of gall was noticed on clone BCM 411 i.e. 9.1 followed by that in BCM 413 with an average 8.3 fresh infection spots in top leaves during August, clone BCM 316 i.e. 8.8 fresh infection spots in top leaves followed by BCM urograndis with an average 7.2 fresh infection spots in top leaves during September 2011 whereas clone BCM urograndis i.e. 2.5 fresh infection spots in top leaves followed by BCM 316 with an average 1.3 fresh infection spots in top leaves during October 2011 .Observations reveals that clone W-14, W-15, BCM 413, K-25 had registered significantly lower number of galls/leaf during the dates of observations when compared with that in seedling population of *E. tereticornis* (control) and also with clone BCM 411, BCM 316, BCM 2045 and BCM 2070. Clone BCM 411 of *E. camaldulensis* species had recorded maximum number of galls/leaf during the month of August, whereas, clone BCM 2045 of *E. tereticornis* X *E. camaldulensis* hybrid had registered highest number of galls/leaf during the month of September and October. No gall formation was recorded on clone W-14 and W-15 though fresh infection of wasp on the midrib of leaves was recorded which failed to develop galls in these two clones. Clone BCM 316 of *E. tereticornis* had registered lower number of galls/leaf and fresh Infection spots on top leaves when compared with seedling population of *E. tereticornis*. In *E. camaldulensis* species, clone BCM-411 registered higher number of galls/leaf and number of fresh infection spots on top leaves when compared with clone BCM-413 and clone K-25. Clone BCM 2070 of *E. tereticornis* X *E. camaldulensis* hybrid had registered lower number of galls/leaf and fresh infection spots on op leaves in comparison to BCM 2045 clone of same species.

Screening of 24 clones belonging to three eucalypts species along with seedlings of *E. tereticornis* & *E. grandis* as a control at nursery stage for infestation of gall insect during

September & November 2008 led to inter- and intra-species variation in all the studied parameters. Clones of *E. tereticornis* recorded higher gall infestation followed by clones of *E. camaldulensis* and urograndis. Seedling population of *E. tereticornis* registered 45 percent gall infestation where seedling population of *E. grandis* registered 28 percent gall infection. Planting stock of W-36, W-104, W-T10 clones of *E. tereticornis* species registered 100 percent gall infestation whereas clone BCM 2135 of urograndis registered least infestation of gall insect i.e. only 4 percent.

A trial involving seedlings of 18 provenances comprising 10 of *E. urophylla*, 2 each of *E. pellita* & *E. citriodora*, 1 each of *E. camaldulensis*, *E. alba*, *E. moluccana* & *E. longirostata* along with seedlings of four species namely *E. grandis*, *E. citriodora*, *E. camaldulensis* & *E. tereticornis* as a control produced at R & D Center, Bagwala, Rudrapur, U. S. Nagar during August 2009 and kept under two environmental conditions viz. under poly houses and under open conditions indicates that seedlings maintained under poly house conditions registered lower infestation of gall insect when compared with the seedlings maintained under open conditions. Provenance No. 17841 of *E. urophylla* & Kennedy river provenance of *E. camaldulensis* were moderately affected, seedlings of control plot *E. tereticornis*, *E. camaldulensis* & *E. grandis* were highly affected with infestation of gall insect, whereas, other provenances including seedlings of *E. citridora* (control plot) under study were completely resistant against gall induction. Maximum infestation of gall insect was noticed during June 2010 whereas maximum infection of CLB disease was recorded during August. Seedlings of all these 18 provenances along with seedlings of four species namely *E. grandis*, *E. citridora*, *E. camaldulensis* & *E. tereticornis* are being monitored for gall infection in a field trial planted at 4m X 3m spacing during July 2010.

A field trial of 14 clones comprising 5 of *E. grandis*, 4 of *E. camaldulensis*, 2 of urograndis, 2 that *E. tereticornis* X *E. camaldulensis* hybrid and 1 of *E. tereticornis* monitored for infestation of gall insect at 90 days age revealed that clone W-11, W-12, W-13, W-14 & W-15 were resistant to gall insect and only fresh infection of gall were recorded on clone BCM 316 of *E. tereticornis*, clone BCM 411, BCM 413, K-23 & K-25 of *E. camaldulensis*, Unnamed clone & BCM 2135 of urograndis, whereas gall formation were recorded on clone BCM 2045 & BCM 2070 of *E. tereticornis* X *E. camaldulensis* hybrid.

Two parasitoids viz., *Quadrastichus mendeli* and *Megastigmus* sp. were introduced from the Director of Biological Control, Bangaluru, Karnataka and released in the nurseries and plantations in USN, Uttrakhand during the first week of June 2010. These parasitoids are reported to feed on the young ones of the gall wasp and check its population. However, the gall infestation has now spread to new locations and these parasitoids have appeared to have little impact so far on the spread of gall wasp. A number of insects and ants have been recorded on shoots showing fresh infestation of the gall. The visiting of so many insects, mainly house wasps, ants and many other insects appear to have developing parasitism for the gall wasp and it is hoped that they may check its population, if found effective. The observations on the number of gall formation on young nursery plants around the year indicate that there was no gall formation during the months between December 2009 to June 2010. Maximum 1.96 galls/plant were recorded during the month of November 2010 followed by September 2010.

Cylindrocladium leaf blight

Cylindrocladium leaf blight caused by *Cylindrocaladium quinqueseptatum* and commonly called as CLB is most serious and widespread disease of eucalypts nurseries and field grown trees reported from many eucalypts grown locations in India. This disease develops in warm and humid conditions and its high incidence is recorded during rainy season. According to *Whyte* (1993), CLB is becoming recognized as a greatest threat to eucalypts culture during monsoon in South East Asia. The disease has been found to attain significant proportions during some years in North India and in many other parts of country. The disease has been extensively studied in Kerala where it repeatedly infects eucalypts plants (Sharma *et. al.* 1984) and invariably reported from Punjab in North India (Rattan and Dhanda 1985). Severe infection of CLB is repeatedly being noticed in Tarai Region and surrounding locations and was monitored during 2008 (Dhiman and Gandhi 2012) and again during 2010 and 2011when warm and humid climatic conditions created predisposing factors for widespread infestation of the disease. During 2008, a total rainfall of 2382 mm and over 400 mm rainfall occurred during July, September, October and November months and CBL was observed to occur on wide scale. Similarly during the late rainfall for extended period during 2010 and 2011, CLB caused heavy mortality to nursery seedlings and also to multiplication gardens maintained for cloning purposes. CLB begins to appear on leaves of lower branches near the ground and spreads upward to leaves of upper branches and subsequently it increases manifolds, which leads to the mortality of nursery stock.

A detailed monitoring of CLB on eucalypts nursery stock at WIMCO's R&D Center indicates planting stock of different species showing varying degree of its infection. The disease rating is assessed as per the method suggested by Kolte (1985). Observations have been recorded on percent mortality, number of leaves completely infected, number of leaves partially infected, number of leaves without infection, disease rating (overall and each for upper, middle, lower portions), height and collar diameter of plants

Data recorded revealed that planting stock of *E. tereticornis* recorded maximum CLB infection and higher overall disease rating than that recorded in *E. camaldulensis, E. urophylla* X *E. grandis, E. tereticornis* X *E. camaldulensis* and seedlings population of *E. tereticornis*. Some progenies of *E. grandis* recorded no infection of CLB. Maximum number of completely infected leaves/plant and overall disease rating were higher on hybrid of *E. urophylla X E. grandis* (urograndis) followed by *E. tereticornis*. Maximum number of completely infected leaves/plant were registered during the month of August, whereas maximum overall disease rating was recorded during the month of September. Disease infection and rating was noticed more during September 2008 than during August 2008 months. Planting stock of species *E. citridora* grown sometimes on a limited scal ein Uttar Pradesh and Uttrakhand shows heavy infection and rating for this disease

Table-3. Species-wise infection of CLB during different months

Species	Infection of CLB			
	No. of completely infected leaves		Overall disease rating	
	Aug.	Sept.	Aug.	Sept.
E.camaldulensis (3 clones)	3.30	0.73	1.92	2.30
E. tereticornis (1 clone)	4.33	1.92	2.11	2.83
E. urophylla X E. grandis (2 clones)	3.87	3.21	2.14	3.75
E. tereticornis X E. camaldulensis (2 clones)	3.08	1.25	1.95	2.62
E. grandis (2 clones)	0.00	0.00	0.00	0.00
Seedlings of *E. tereticornis*	3.16	2.99	1.98	4.08
Mean	2.80	1.53	1.61	2.40
SE Diff.	0.37	0.19	0.23	0.17
CD at 0.05	0.81	0.41	0.50	0.37
CD at 0.01	1.13	0.58	0.70	0.52

Another monitoring of CLB during 2011, indicates significant intra-species variation in the mean value of number of leaves completely infected and disease rating recorded on both dates of observation i.e. 1st week of August and September 2011. Unnamed clone of urograndis registered maximum number of completely infected leaves whereas clone W-14 & W-15 have recorded least number of completely infected leaves on both the dates of observation. The mean value for number of completely infected leaves recorded during 1st week of August was significantly higher in clonal planting stock of unnamed urograndis clone when compared with clone W-14, W-15. Whereas, the observations recorded during the 1st week of September indicates that unnamed urograndis clone recorded significantly higher number of completely infected leaves than all other clones under study. Clone BCM 413 recorded maximum overall disease rating during 1st week of August, whereas, unnamed urograndis clone registered maximum disease rating during 1st week of September. Clone W-14 & W-15 recorded no disease on both the dates of observations. The mean value for overall disease rating recorded during 1st week of August was significantly higher in clone BCM 413 when compared with clone W-14, W-15 and K-25 at 0.05 CD level. Whereas, the data recorded during 1st week of September indicates that overall disease rating of unnamed clone of urograndis was significantly higher than all other clones under study except seedling population of *E. tereticornis*.

Another experimentation with 18 provenances comprising 10 of *E. urophylla*, 2 each of *E. pellita* & *E. citridora*, 1 each of *E. camaldulensis*, *E. alba*, *E. moluccana* & *E. longirostata* along with seedlings of four species namely *E. grandis*, *E. citridora*, *E. camaldulensis* & *E. tereticornis* as a control at R & D Center, Bagwala, Rudrapur, U. S. Nagar during August 2009 by keeping seedlings under two environmental conditions viz. under poly houses and under open conditions and monthly observations for growth, where CLB infection were recorded at monthly interval from September 2009 to August 2010, indicates that seedlings maintained under poly house conditions registered lower disease infection when compared with that of seedlings maintained under open conditions. Maximum infection of CLB disease was recorded during August.

Table-4. CLB infection on different clones and during different months.

Clone	Infection of CLB			
	No. of completely infected leaves		Overall disease rating	
	Aug.	Sept.	Aug.	Sept.
BCM 413	3.42	0.33	2.30	2.04
BCM 411	3.50	2.16	1.97	2.81
BCM 316	4.33	1.92	2.11	2.83
BCM 2045	2.66	1.42	1.74	2.74
BCM 2135	3.41	2.08	2.25	3.17
K-25	3.00	0.25	1.50	2.05
BCM 2070	3.50	1.08	2.08	2.50
Urograndis clone	4.50	4.33	2.02	4.33
W-14	0.00	0.00	0.00	0.00
W-15	0.00	0.00	0.00	0.00
Seedlings	3.16	2.99	1.98	4.08
Mean	2.86	1.50	1.63	2.41
SE Diff.	0.66	0.11	0.31	0.16
CD at 0.05	1.34	0.22	0.63	0.32
CD at 0.01	1.82	0.30	0.85	0.44

Little leaf Disease

Little leaf disease is emerging a serious threat to eucalypts culture in many regions of the country. It has been recorded on *E. tereticornis, E. globulus, E. grandis* and has been reported to be caused by Mycoplasma like organisms MLO (Rajan, 1987, Tewari 1992) which reduces the photosynthetic area of leaves and ultimately reduce the growth rate of plants. MLOs particularly affect the juvenile leaves of eucalypts plants. The symptoms of disease is characterized by stunting of plants, reduction in growth of affected plants, yellowing and reduction in leaf size with excessive proliferation of auxiliary shoots. Balasundaran *et. al.,* 1983 reported that little leaf which occurs on 4 and 5 years old plantation is graft transmissible. Little leaf of eucalypts now is in the epidemic form in the nursery as well as in field plantations. It was noticed on massive scale during the year 2008 (Kulkarni 2010). Adults and nymphs of thrips suck sap from growing tips and leaves and act as carrier of the disease. The damage caused to young and fresh growth of eucalypts shoots results in stunted growth of the plants with greatly reduced leaves, pale narrow laminae and axilary buds are stimulated to give a bushy form to the trees finally leading to distortion, wilting of foliage, mostly at the tips followed by leaf fall. Relative resistance to the little leaf disease was also reported with certain genotypes /population.

Little leaf on eucalypts nursery and field planted young trees in North India is being recorded since last year i.e, 2010. It was first recorded on clone BCM 316 and urograndis clone during September 2010 at our R&D Center. The center did not import eucalypts plants in the recent past and the source of this infection is not known. It is likely that locality may have received clonal stock from already infected locations and the same might have been transmitted by the thrips in our center. It has rapidly spread to many locations and started affecting eucalypts culture in a big way. The disease is being mainly recorded during summer and rainy season when eucalypts grow fast and get subsidized in post monsoon season, though in some clones symptoms persists even during winters. A detailed monitoring of the disease at WIMCO's R&D Center revealed wide variation among species and clones to this emerging threat. Observations have been recorded on eucalypts nursery of seed and clonal origin grown and maintained at R & D center.

Fig.-IV. Little leaf disease on eucalypts fast spreading in North India

Table-5. Little leaf disease recorded on different species during different months

Species	Infection of little leaf		
	No. of little leaves/plant		
	Aug.	Sept.	Oct.
E.camaldulensis (3 clones)	8.72	0.22	0.54
E. tereticornis (1 clone)	23.34	16.9	3.87
E. urophylla X E. grandis (2 clones)	15.91	9.06	6.58
E. tereticornis X E. camaldulensis (2 clones)	7.52	0.12	0.62
E. grandis (2 clones)	0.001	0.001	0.001
Seedlings of *E. tereticornis*	25.07	24.71	13.48
Mean	**11.27**	**6.04**	**3.28**
SE Diff.	**2.78**	**2.80**	**0.81**
CD at 0.05	**6.41**	**6.46**	**1.87**
CD at 0.01	**9.33**	**9.39**	**2.72**

Data recorded for the occurrences of little leaf disease on the planting stock of eucalypts during August, September and October 2011 presented in Table-V, reveals inter species differences in the mean value of number of leaves infected per plant. Planting stock of *E. tereticornis* registered maximum number of little leaves/plant on all the three dates of observations followed by planting stock of hybrid of *E. urophylla* X *E. grandis*, *E. camaldulensis*, hybrid of *E. tereticornis* X *E. camaldulensis* and *E. grandis*. Planting stock of *E. tereticornis* registered significantly higher number of little leaves/plant when compared with planting stock of other species under study. Maximum number of little leaves /plant were registered during the month of August i.e. 11.27 little leaves/plant followed by that in during September and October with an average 6.04 and 3.28 little leaves/plant respectively.

Table-6. Little leaf disease on different clones during different months

Clone	Infection of little leaf		
	No. of little leaves/plant		
	Aug.	Sept.	Oct.
ITC BCM 413	11.91	0.25	0.001
ITC BCM 411	9.91	0.42	0.001
ITC BCM 316	23.34	16.9	3.87
ITC BCM 2045	9.62	0.001	0.92
ITC BCM 2135	12.91	4.27	3.25
K-25	4.33	0.001	1.67
ITC BCM 2070	5.42	0.25	0.34
Unnamed	18.91	13.85	9.91
W-14	0.001	0.001	0.001
W-15	0.001	0.001	0.001
Seedlings	25.07	24.71	13.48

Mean	11.04	5.51	3.00
SE Diff.	3.64	3.32	1.17
CD at 0.05	7.60	6.92	2.44
CD at 0.01	10.35	9.45	3.33

Seedling population of *E. tereticornis* have registered maximum infected number of leaves per plant with little leaf disease followed by clone BCM 316 on all the three dates of observations. The mean value of number of infected leaves per plant with little leaf disease recorded during 1st week of August was significantly lower in clone W-14 & W-15 when compared with that in seedling population of *E. tereticornis* (control) and also with those clone BCM 2045, BCM 411, BCM 413, BCM 2135, unnamed clone of urograndis & BCM 316 and mean value of number of infected leaves per plant with little leaf disease recorded during 1st week of September was significantly lower in clone W-14, W-15, K-25, BCM 2045, BCM 2070, BCM 413, BCM 411 & BCM 2135 when compared with that in seedling population of *E. tereticornis* (control) and also with those clone BCM 316 and unnamed clone of urograndis, whereas number of infected leaves per plant with little leaf disease recorded during 1st week of October was significantly lower in clone W-14, W-15, BCM 411 & BCM 413 when compared with that in seedling population of *E. tereticornis* (control) and also with those clone BCM 2045, BCM 2135, unnamed clone of urograndis, K-25 & BCM 316.

Conclusion

Based on our research endeavors and field observations at WIMCO on gall infestation, CLB and little leaf disease in North India, the following conclusions are made:

Gall wasp

- Gall insect has invaded almost all eucalypts growing locations in North India. We have yet to find a report of its not occurrence from any of eucalypts growing location.
- It has infested all species planted in the field except *E. citridora* which is planted on a limited scale in some parts in Uttrakhand and Uttar Pradesh.
- Gall formation varies widely among the trees existing in any locality, some trees show heavy infestation while others almost with no gall formation
- Gall infestation decreases with increase in age and trees of old age appears to have less impact of gall infestation than the young seedlings and saplings..
- Heavy infestation of gall occurs on coppice shoots even of relatively resistance clones.
- A lot of insects including ants, wasps, lady bugs etc have been seen on shoots having fresh gall insect infection.
- The impact of introduced parasitoids has visibly not helped in checking the infestation of gall insect even after 1.5 year of their introduction in the region.
- Gall infection occurs on leaf midrib and/or petiole and/or shoots and it varies with clones and species.
- Insect infection occurs only on tender and juvenile top leaves and the fresh growth of shoots is adversely affected with heavy infection.

- Insect infection occurs in foliage of some newly developed clones but gall development fails to occur
- Chemical control with various chemicals applied to control the insect infestation has proved ineffective.
- Maximum gall formation is recorded during September to November period.
- Developing resistant or nearly resistance clones is the only option available for finding solutions to this problem.
- No fresh infection is recorded during winter months

CLB

- CLB occurs during humid and warm season.
- Species and clonal variation occurs for CLB infection
- The infestation is very heavy under prolonged rainy season.
- Plants of different ages are affected by CLB, though damage is more in young plants than in old trees
- Large scale mortality is recorded in clonal and seedling stock in the nurseries.
- Tall plants are less affected than the small ones
- Crowded population of seedlings are more affected than those kept in well aerated places.
- Plants maintained in polythene bags are more affected than in root trainers
- Plants maintained in large sized root cavities (root trainers) are less affected than those maintained in small cavities.

Little leaf disease

- The disease is recorded in North India since the year 2010
- It is fast spreading to new eucalypts growing locations
- Wide variation is reported for its infection on different species and clones
- Its occurrence recorded on nursery seedlings and field planted trees
- It is mainly recorded during summer and rainy season
- Infected plants are not preferred by the growers
- It is recorded on the fresh growing shoots

Gall infestation, and little leaf infestation are recent phenomenon, whereas, CLB infestation on eucalypts nursery seedlings and plantation trees has been reported for some time now in North India. The first two are now established threats, whereas the third one is climate sensitive and impacts euclaypts culture during warm and humid seasons and locations. These three together has posed a serious threat to eucalypts culture as numerous nursery growers raising eucalypts with traditional mode of seedling production have now almost abandoned nurseries resulting thereby a large vacuum in its culture across many states in North India. Kulkarni (2008) estimated that the economical loss due to gall wasp in south alone is loosing productivity at the rate of 25% which amount to around Rs. 1000 million per annum, whereas, the loss is estimated to approximately Rs. 250 million in the state of Haryana alone (Jagdish Chander 2011). The loss has now increased many folds since the pest and these two additional diseases have spread to new locations on a wide scale. There is a need to develop clones showing higher degree of resistance to these threats

in order to fight against these challenges in eucalypts culture. The two newly developed clones viz., W-14 and W-15 at WIMCO could help in checking this threat atleast in some locations where these new clones could be found suitable for field planting.

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Forest Biotechnology: current status and future perspective

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ABSTRACT:

Forest has played an indispensable part in the rise of human civilization. Forest trees have unquestionably entered the genomic era. Biotechnological tools viz., Transgenic technology, RNA interference, Functional genomics, Marker Assisted Selection etc. has paved road for successful exploitation and integration of scientific fields with an increased sense of urgency for delivery of cutting edge research in tree biotechnology, both in academia and industry. Next generation sequencing platform has revolutionize our level of intellect by generating whole genome and transcriptome database within short time span, which was merely a dream years ago. The whole genome sequencing data of Populus, Eucalyptus, Spruces, Pines, Acacia etc. submitted by several groups worldwide, fueling a multitude of inter-disciplinary studies and applications in sustainable forest production and conservation. Engineering trees for manipulation of various characters viz. Lignin biosynthesis, abiotic and biotic stress tolerance, herbicide resistance has been done successfully by the various groups around the world. Rational use of biotechnology will synergistically facilitate the sustainable growth of forest and people. The social discussion about risks vs. benefits of GMOs must move from a generic consideration of GMOs to the merits of modifying trees with specific traits to be used in specific environment. The credible issues center is on which genes can be effectively used to modify which traits for which environments.

Keyword: Forest biotechnology, Transgenic tree, RNAi.

Introduction:

Research on genetically engineered trees is being currently carried out in a number of countries. Field trials with transgenic trees (often called genetically modified or GM trees) have been carried out for more than 20 years. Tests have been conducted in several countries, including Australia, Belgium, Brazil, Canada, China, France, Finland, Germany, Italy, Japan, New Zealand, Norway, Portugal, Spain, Sweden, The Netherlands, UK, and USA (Viswanath *et al.* 2011). WRM (World Rain Forest Movement) has produced information sheets on the countries where GE tree research; in many cases including field trials- is taking place. The sheets contain information on the species being manipulated and with what aim, on those carrying out the research and those who support it, on the regulatory framework for research and field trials and on the organizations actively opposing this activity at the national level (www.wrm.org). More than 700 field trials of GM trees were recently reported from a search of publicly accessible databases. A wide diversity of sources of transgenes and regulatory elements, and intended traits, have been tested, including expression of reporter genes; insect, disease, and herbicide resistance; modified wood properties;

modified flowering and fertility; and modified growth rate and stature (Viswanath *et al.* 2011).

Whole Genome sequencing projects:

Genome projects in most model and some non-model organisms begin with a reference genome sequence. This has not been true in forest trees owing to funding limitations and the large size of so many tree genomes. This situation changed with the sequencing of the genome of black cottonwood (*Populus trichocarpa*). This tree was chosen for sequencing by the us Department of energy Joint Genome Institute (JGI) because of its relatively small genome size and its potential importance as a feedstock for biofuels. Sequencing was done using the whole-genome shotgun approach (WGS approach) and conventional sanger sequencing. With this sequence now serving as a reference, additional *Populus* species are being sequenced using NGS (Next generation sequencing) platforms. Sequencing of the *Eucalyptus grandis* genome is also underway at the JGI, and a preliminary 8× draft coverage was released in 2010 (*Eucalyptus*DB). Likewise, sequencing of the American chestnut has recently begun (*Fagaceae* Genomics Web). Reference genome sequences for the handful of major economic species will help us to better understand gene function and diversity in these species, but, potentially more importantly, these sequences will serve as references for the eventual sequencing of the thousands of species of non-economic but significant ecological value. Recent reports of the sanger sequencing of *Picea glauca* and *Pinus taeda* BAC clones and short-read sequencing of *P. taeda* genomic DNA showed the presence of both known and novel conservative repeats. These repeats constitute only a small portion of the genome; this implies that much of the repetitive fraction of conifer genomes is ancient and diverged, thus simplifying assembly of the genome through *de novo* genome sequencing. Recently, swedish and US funding agencies announced funding for sequencing of the *Picea abies* and *P. taeda* genomes, respectively, and many more will surely follow in short order (Neale and Kremer,2011).

Whole Transcriptome profiling:

Transcriptome profiling in forest trees viz., *Poplus*, *Pinus*, *Picea*, *Eucalyptus*, *Quercus*, *Castanea* using various microarray technologies for groups of traits (growth, wood properties, abiotic stress and biotic stress) to which expression studies have been applied. Most activity has occurred in *Populus*, clearly owing to its having a reference sequence and well-developed gene expression arrays from various sources. There are a surprisingly large number of studies in *Pinus* and *Picea*, the conifers with the most abundant EST collections (Neale and Kremer, 2011). *de novo* assembly and analysis of transcriptome from mature neem (*Azadirachta indica*) fruit with sequencing by synthesis method using Solexa/Illumina GAIIx has been done by Krishnan *et al.* (2011). Annotated transcripts for the neem fruit when compared with those for the other species, yielded the best overlap with *Ricinus communis* (3.79), *Vitis vinifera* (3.35) and *Citrus sinensis* (2.06). The lowest overlap indices were observed for the mosses: *Physcomitrella patens* and *Selaginella moellendorfii* (0.15). Despite the great efforts of many researchers, an understanding of the complexity of the expression of genes in forest trees is still in its earliest days. The main constraints and limitations are the resource and time demands of monitoring gene expression across different ecological contexts and along the different developmental stages that trees undergo during their lives. There are many technical challenges associated with accurate transcriptome

profiling in all organisms, and these challenges are magnified for tree species that lack reference sequences and have large genomes, potentially with many uncharacterized paralogues. Even the *Populus* genome is not fully annotated, making inference and comparison challenging. Studies to date highlight the differences among tissues, developmental state and inductive condition in species. Similarities and differences in expression are seen, as expected, but no pattern unique to trees emerges. Likewise, comparative studies with *A. thaliana* have been done in a few cases for both *Populus* and *Picea*11 and, here again; interesting but no definitive patterns emerge. With the recent development of RNA sequencing (RNA-seq) technology using NGS there should be a rapid advance in the depth and breadth of transcriptome profiling experiments in forest trees (Neale and Kremer,2011).

Transgenic Approaches in Forest trees:

Procedures for genetic transformation of forest trees differ little from those for other plant species and are mainly confined to the use of Agrobacterium, with a few reports on particle bombardment-mediated transformation. Differentiation of transformed cells is a prerequisite to obtaining transgenic plants and two systems are being used in forest trees: organogenesis and embryogenesis. Such transformation procedures, including the use of selectable markers and screening methods, are well established. The major obstacles to efficient production of transgenic trees are: (i) difficulties in plant regeneration from Agrobacterium-infected or particle-bombarded explants; (ii) incomplete development beyond the in vitro stage of rooted plants for establishing field trials; and (iii) transgene instability during the long lifespan of forest trees, including transgene silencing and somaclonal variation (Harfouche *et al.* 2011).

Abiotic stress resistance:

Drought, which is often associated with osmotic or salinity stress, is a major factor involved in decreases in forest productivity. Enhancing drought and salinity tolerance is of particular importance when reforesting marginal arid and semi-arid areas, which are prone to degradation. Molecular control of plant response to abiotic stress is complex, usually involving coordinated expression of several genes. The use of known abiotic-stress-associated genes from other species to enhance tolerance in forest trees has been limited. However, recent studies in genomics, transcriptomics and proteomics inseveral forest tree species, as well as release of the draft Eucalyptus grandis genomic sequence (www.eucagen.org), have provided new tools for improving abiotic stress tolerance in trees (Harfouche *et al.* 2011) Overexpression of a pepper ERF/AP2 transcription factor, CaPF1, in eastern white pine resulted in a significant increase in tolerance to drought, freezing and salt stress (Tang *et al.* 2007). The increased tolerance was associated with polyamine biosynthesis. Moreover, overexpression of the choline oxidase (codA) gene from Arthrobacter globiformis resulted in increased tolerance to NaCl in several lines of Eucalyptus globules (Yu *et al.* 2009).

Biotic stress resistance:

Genetically engineered insect resistance can be environmentally beneficial because of the reduced need for synthetic insecticides. Hybrid triploid poplars [(*Populus Tomentosa X P. bolleana*) X *P. tomentosa*] transformed with a cowpea

trypsin inhibitor gene (CpTI) exhibited resistance to three defoliating insects: forest tent caterpillar (*Malacosoma disstria*), gypsy moth (*Lymantria dispar*) and willow moth (*Stilpnotia candida*) (Zhang *et al.* 2005). Forest trees play host to a wide range of fungal, bacterial and viral pathogens. Trees engineered for disease resistance can provide both environmental and commercial benefits. Enhanced disease resistance has been achieved using a variety of genes derived from plants and microorganisms, with varying degrees of success. For example, Chinese white poplar (P. tomentosa) expressing a chitinase gene from Beauveria bassiana (Bbchit1) exhibited increased resistance to a pathogenic fungus (*Cytospora chrysosperma*) (Jia *et al.* 2010). Testing for disease resistance in a natural setting is imperative and multi-year field trials will be needed to verify the durability of resistance against ever-evolving pathogen populations.

Wood property manipulation:

Tremendous efforts have been devoted to developing genetically engineered trees, with the emphasis on reducing lignin quantity, to improve wood-pulp production efficiency. However, lignin chemical reactivity also is a critical barrier to wood-pulp production, because lignin removal from wood is either initiated by chemical degradations or, in most cases, accomplished entirely through chemical reactions. Thus, the current tree biotechnology emphasis on low lignin quantity must be expanded to include greater lignin reactivity and, ultimately, a combination of low and reactive lignin traits. Lignin quantity and reactivity [which is associated with its syringyl/guaiacyl (S/G) constituent ratio] are two major barriers to wood-pulp production. To verify our contention that these traits are regulated by distinct monolignol biosynthesis genes, encoding 4-coumarate–CoA ligase (4CL) and coniferaldehyde 5-hydroxylase (CAld5H), we used *Agrobacterium* to cotransfer antisense *4CL* and sense *CAld5H* genes into aspen (*Populus tremuloides*). Trees expressing each one and both of the transgenes were produced with high efficiency. Lignin reduction by as much as 40% with 14% cellulose augmentation was achieved in antisense *4CL* plants; S_G-ratio increases as much as 3-fold were observed without lignin quantity change in sense *CAld5H* plants. Consistent with our contention, these effects were independent but additive, with plants expressing both transgenes having up to 52% less lignin, a 64% higher S/G ratio, and 30% more cellulose. An S/G-ratio increase also accelerated cell maturation in stem secondary xylem, pointing to a role for syringyl lignin moieties in coordinating xylem secondary wall biosynthesis. The results suggest that this multigene cotransfer system should be broadly useful for plant genetic engineering and functional genomics (Li *et al.* 2003). The antisense *4CL* (4-coumarate: CoA ligase) gene was transformed into triploid Chinese white poplar (*Populus tomentosa*) mediated by *Agrobacterium tumefaciens*. PCR and Southern blot analysis indicated that antisense *4CL* gene had been integrated into the genome of the transgenic Chinese white poplars and found repression of *4CL* expression could result in remarkable reduction of lignin content in transgenic poplars, with most reduction of 41.73% compared with that of wild type (Caihong *et al.*, 2004).

RNAi nterferance:

RNA interference (RNAi) is a post-transcriptional gene regulatory mechanism by which a double-stranded RNA (dsRNA) induces sequence-specific gene silencing

[1]. The RNAi pathway consists of multiple steps, including the cleavage of the dsRNA by Dicer to form a 19-nucleotide short interfering RNA (siRNA) with 3' overhangs, the incorporation of the siRNA molecule into the RNAinduced silencing complex (RISC), and the recognition of the target gene transcript(s) by the RISC-siRNA complex to induce mRNA degradation or translational repression. In mammals and many other organisms, chemically synthesized siRNA molecules can be introduced into cells to knockdown the expression of a specific gene. Because of the simplicity and low cost, siRNA-based gene silencing has quickly become an important technique in functional genomics (Wang *et al.*, 2010). The efficiency and stability of RNA interference (RNAi) in perennial species, particularly in natural environments, is poorly understood. Li *et al.* (2008) studied 56 independent poplar RNAi transgenic events in the field over 2 years. A resident BAR transgene was targeted with two different types of RNAi constructs: a 475-bp IR of the promoter sequence and a 275-bp IR of the coding sequence, each with and without the presence of flanking matrix attachment regions (MARs). RNAi directed at the coding sequence was a strong inducer of gene silencing; 80% of the transgenic events showed more than 90% suppression. In contrast, RNAi targeting the promoter resulted in only 6% of transgenic events showing more than 90% suppression. Results suggest that RNAi can be highly effective for functional genomics and biotechnology of perennial plants.

Marker Assisted Selection and QTL mapping:

The primary goal of tree breeding is to increase the quantity and quality of wood products from plantations. Major gains have been achieved using recurrent selection in genetically diverse breeding populations to capture additive variation. However, the long generation times of trees, together with poor juvenile-mature trait correlations, have promoted interest in marker-assisted selection (MAS) to accelerate breeding through early selection. MAS relies on identifying DNA markers, which explain a high proportion of variation in phenotypic traits. Genetic linkage maps have been developed for most commercial tree species and these can be used to locate chromosomal regions where DNA markers co-segregate with quantitative traits (quantitative trait loci, QTL). MAS based on QTL is most likely to be used for within-family selection in a limited number of elite families that can be clonally propagated. Limitations of the approach include the low resolution of marker-trait associations, the small proportion of phenotypic variation explained by QTL and the low success rate in validating QTL in different genetic backgrounds and environments. This has led to a change in research focus towards association mapping to identify variation in the DNA sequence of genes directly controlling phenotypic variation (gene-assisted selection, GAS). The main advantages of GAS are the high resolution of marker-trait associations and the ability to transfer markers across families and even species (Guimarães *et al.* 2007). QTL mapping in forest trees has been applied to numerous species and traits for more than 20 years. The traits that have been most intensively studied are complex and are usually related to the fitness of trees. Regardless of species, they fall into four categories: growth and biomass, apical bud phenology, resistance to biotic or abiotic stresses, and wood properties (Neale and Kremer, 2011).

Future directions for forest tree genomics research:

All forest biology research (genetics, ecology, physiology, entomology and pathology) is well positioned to take advantage of rapid advances in '-omics'

technologies. We must acquire reference genome sequences for many genera of tree species. This is an obvious priority, and one that should be easily accomplished in the near future. The molecular bases for biotic interactions between trees and their associated species (fungi, insects and birds) remain largely unknown. It is our hope that technological advances will change this situation rapidly. NGS technologies should be used for assessing adaptive differentiation and species divergence in natural populations. as outlined previously, the tracking of population differentiation at the molecular level remains an important challenge in the population genomics of trees. Tree genetic engineering provides an opportunity for sustainable production of forest products. However, the development of GM trees could be hindered by regulatory and social hurdles. Responsible use and development, as well as science-based oversight of GM tree technologies, are essential for regulatory and public acceptance. Consumer acceptance of and willingness to eat food containing GM derived products was dependent on explaining the reason for the modification and other non-scientific factors, such as knowledge and trust. Given this, greater transparency and outreach could lead to greater public acceptance of GM trees destined for pulp and bioenergy production, thus reducing impacts on native forests.

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Growth performance of twelve eucalyptus clones in South Gujarat

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ABSTRACT

A research trial comprising of twelve Eucalyptus clones initially screened for gall resistance was established at a spacing of 1m X 1m. at the Department of Forestry nursery, ASPEE College of Horticulture and Forestry, N.A.U, Navsari, Gujarat. Data were recorded on the growth parameters viz; height, collar diameter, girth at breast height, volume production, leaf area and leaf water potential to know more about clonal response to high density and their production potential.

Maximum height (9.50 m) was observed in clone no. BCM 2253 followed by clone P 411 (9.00 m) and P 413 (8.50 m). Clone BCM 2253 was recorded for maximum basal diameter (72.50 mm) followed by P 411 (71.50 mm) and JKSC 08 (67.50 mm). Whereas clone P 411 has shown maximum girth (58.75 mm) at breast height followed by clone no. BCM 2253 (57.50 mm) and clone BCM 271 (55.50 mm). Volume production was observed maximum (13066.16 cc) in Clone no. BCM 2253 followed by clone P411 (12039.35 cc). The clones were also studied for the leaf and leaf water potential. Maximum leaf area was observed in the clone *E. torellina* (54.26 sq cm) followed by clone P413 (43.02 sq cm). Pre dawn water potential (Ψpd) was maximum in clone *E. pellita* (11.40 Bar) followed by Clone BCM 2153 (8.83 Bar).

The data collected gave a clear idea of clonal performance under high density plantation and may be used to select clones for further studies.

Keywords: Eucalyptus, Clonal Evaluation, Growth Parameters, Leaf Water Potential (Ψpd)

INTRODUCTION:

The State of Gujarat is one of the fastest growing states of India, especially in industrial sector. The demand for wood and wood products is increasing with the increasing industrialization and population. There is net difference of 1 lakhs metric tonnes of pulp wood in demand and supply in Gujarat. Bamboos, Eucalyptus and Casuarina poles are also in good demand especially for construction industry. This demand is satisfied mainly by importing the wood from other states like Andhra Pradesh, Karnataka and Tamilnadu. On other hand the climatic conditions prevailing in South Gujarat are quite favorable for Eucalyptus and Casuarina cultivation. Hence a comprehensive tree improvement programme has been initiated at Navsari Agricultural University, Navsari for development of high quality planting material of Fast growing tree species, especially Eucalyptus and Casuarina. Several high yielding clones were collected and deployed in various trials for clonal evaluation with the objective of

screening clones for better adaptability and yield under south Gujarat conditions. The current experiment is one part of the tree improvement project of the University and aims at identification of clones for short rotation forestry under high density conditions.

Materials and Methods:

The trial was established during October, 2010 at Department of Forestry, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari ($20^0$55.334'N, $072^0$54.456' E and 13.72 m above msl). The trial was comprised of twelve Eucalyptus clones collected from three different sources viz., ITC, Bhadrachalam, Andhra Pradesh, JK paper Mills, Songadh, Gujarat and Pragati Biotech, Ludhiana, Punjab. The ramets of twelve clones were planted in the trial as per the RBD design with three replications and with planting distance of 1 m X 1 m. The complete trial was surrounded by a guard row of local eucalyptus clone. Two rows of the same Local clone were also raised in between three replications. The data on growth parameters was recorded during June 2011, ie. nine months after planting.

The height of the shoots was recorded from the ground level to the apex of the leading shoot by using measuring scale. Basal shoot diameter of the plants in the trial was measured with the help of digital calliper at collar region (5 cm above ground level). In same way the stem diameter was recorded at breast height (1.37 m). Volume for ramets of each clone was calculated by using formula suggested by Rowan and Peter (2001): $(\pi.r^2.H)/3$, where π: 3.14, r: half of the collar diameter (radius), H: height of the plant.

Twenty fully expanded leaves per ramet were selected for estimation of leaf area. The leaves were randomly detached from different ramets and collected in envelopes. These leaves were brought to the laboratory and the leaf area was determined using portable leaf area meter (CI-203, INC. USA). Each leaf was placed under arm of the leaf area meter and thereafter scanned to determine the leaf area digitally. Same procedure was repeated for rest of the samples. Leaf area is expressed in cm^2.

Leaf water potential (Ψ_{pd}) was measured using a scholander pressure chamber (Model 1000 Pressure Chamber, PMS Instrument Company, USA). The leaves were enclosed in a plastic bag just before detachment from the plant. The leaves were subjected to pressurization immediately after detachment. At least five leaves were sampled starting from predawn to dusk. All the precautions were followed as recommended by Turner (1988) while sampling the leaves.

The data obtained for natural variation were subjected to statistical analysis using Randomized Block Design as described by Panse and Sukhatme (1967) and Chandel (1984). The statistical analysis for each parameter was carried out on mean values.

Results and Discussions:

The observations on various parameters were recorded before onset of monsoon of 2011 i.e. nine months after planting. The reason for selecting this particular period was to compare the clones when there is no rainfall and water is least available to the plants. Measurements of height (H), Basal diameter, Volume, Breast height diameter,

Leaf area and Leaf water potential (Ψ_{pd}) are presented in Table: 1 and are depicted in Fig. 1-6.

The analysis of variance attributed highly significant differences for all the traits, indicating a large amount of variation among 12 Eucalyptus clones. Variation with respect to these characters among the clones were plant height (4.50- 9.50 m), basal diameter (32.00-72.50 mm), volume (1205.76-13066.16 cm^3), Breast height diameter (25.00-58.75 mm), leaf area (21.75-54.26 cm^2) and Pre dawn leaf water potential Ψ_{pd} (-5.27) – (-11.40 Bar) (Table: 1).

The height (m) war recorded maximum (9.50) for the clone BCM 2253. Clone P 411 (9.00), clone P 413 (8.50) and clone BCM 2153 (8.40) were statistically at par with the BCM 2253. Control clone JK 08 showed 7.60 m height which is significantly less than the above mentioned test clones. Lowest height was observed in clone Pellita (4.50). Data for Basal diameter (mm) was recorded on 12 clones out of which BCM 2253 showed the maximum (72.50) basal diameter. Clone P 411(71.50), BCM 271 (67.25) and the control/check clone JK 08 (67.50) outperformed others and were statistically at par with the BCM 2253. As in case of height, clone Pellita was again registered for lowest basal diameter growth, too. Since the volume production is based on the height and diameter of the plant, the clones exhibiting higher height and diameter excelled in volume production too. Maximum volume (13066.16 cm^3) was recorded on clone BCM 2253, which was statistically at par with the volume of clone P 411 (12039.35 cm^3). The check clone JK 08 could produce 9060.86 cm^3. Lowest volume was produced by Pellita (1205.76 cm^3). Maximum leaf area (cm^2) was observed in clone Torellina (54.26), which was significantly higher than all other clones. Lowest leaf area was observed in clone BCM 2153(21.75). Significantly lower predawn leaf water potential (Ψ_{pd}) was observed for clone Pellita (-11.40 Bar). The maximum value for Ψ_{pd} was recorded for the clone BCM 411 (- 5.27 Bar). Other clones which showed lower Ψ_{pd} were BCM 2153 (-8.83 bar), Torellina (-7.0 bar).

The potential benefits of producing clonal planting stock for reforestation are many and well documented (Brix and Driesche, 1977; Libby, 1983; Zobel and Talbert, 1984). Some forest tree species are clonally propagated with little difficulty. Experience has shown that cloned propagules do not duplicate faithfully, the growth and development of trees from which they were derived. In such cases, the utilization of vegetative propagules in production plantations may result in various degrees of reduction in potential benefits of cloning. Thus well planned field testing of vegetative propagules is necessary in order to knowledgeably assess the real benefits of utilizing clonal planting stock.

The variation in these characters can also be ascribed to the genetic makeup of the clones. Basically, all differences among trees are the result of three things: the differing environment in which the trees are growing, the genetic differences among the trees and the interactions between the tree genotypes and the environment in which they grow. Some genetic variations are predictable and useful, whereas other types are random and are more difficult to use. Genetic variability is complex, but if its type and magnitude are known and if it is well used, it can be manipulated to obtain good gains.

Amrinder Kaur and Saxena (2002) have studied various clones of Eucalyptus developed by ITC and TERI. They observed differences in height, diameter and clear bole height in different clones of Eucalyptus. Further they report that the ITC clones were better in performance than other test clones. Sidhu and Singh (2001) had under taken a study of 137 Eucalyptus seed sources in Punjab. They have recorded growth performance of these clones in field trials at the age of nine months and have observed significant differences for height but not for collar diameter. Kulkarni (2004) reported that the ITC, Bhadrachalam has established seven Clonal testing areas as multi location trials. The girth at breast height at one year age ranged from 11.24 cm to 15.92 cm. whereas the height ranged from 3.80 m to 6.0 m. The performance of BCM 2253, BCM 2153, P 411, JK 08 and BCM 271 in our trial at Navsari is superior to the ITC Trials for both GBH and height.

The variation in height, collar diameter and other morphological characters in different Poplar clones were reported by Riemenschneider et al. (1992) and Auclair and Bouvarel (1992). Christersson (1998) opined that it is more effective for a stand to have many small leaves rather than fewer larger ones, even if the total leaf area is the same. Interestingly, the top four good growing clones in our trial have shown lower individual leaf area with more number of leaves. In consonance with our finding Huse *et al* (2008) also found significant variations in leaf area recorded on 23 clones of willow at establishment year.

Leucaena lucocephala (subabool) is one another fast growing tree species. The area under subabool cultivation is increasing tremendously in Andhra and Tamilnadu. Kulkarni (2004) have under taken an experiment on subabool to study the spacing effect. He reported that at the spacing of 1 m X 1 m and at 1 year age, the average girth of subabool was 9.2 cm and height 4.3 m. It gives idea that the performance of eucalyptus in our trial is better and it can produce good yield in South Gujarat.

The water status of plants and how to measure it, has received much attention in recent years and for good reason. Plant moisture stresses, or plant water potential, indicates the demand for water within a plant. Plant water potential integrates the soil moisture tension in the rooting zone (the water supply), the resistance to water movement within the plant, and the demands for transpiration imposed by the environment (heat load, humidity, wind, etc.). Plant water potential measurement indicates the water status of a plant from the "plant's point of view". Water potential also tells how the environment affects the plant. This information can be used to evaluate how much need the plant has for water or how well it is adapted to its environment. The predawn water potential can indicate the soil water potential accessed by the root system (Crombie *et al.* 1988.) Water potential more specifically the predawn leaf/stem water potential is express as (Ψpd) and the unit is Bar, and is expressed in negative value, Cleary et al. (2009). In our study the observations on Ψpd were recorded during June, 2011 when there was no rain and only restricted irrigation was provided to the plants. The observations recorded on 12 clones under investigation shows that the values ranged from -11.40 bar to -5.27 bar. Up to -5.00 bar the plants are considered to be under no severe stress (Kallarackal *et al* 2002). Up to 10.00 bar very mild and beyond -10.00 bar, the plant is considered to be under stress. It was found that pellita clone experienced the stress more severely as compare to other clones. It was clearly revealed by its growth and development. But more interestingly the better

performing clones BCM 2153 and BCM 2253 also showed little stress as compared to the rest ones. This finding was of great importance to understand the irrigation need of these good performing clones and it may be concluded that if these clones were well irrigated they might have performed more excellently as compare to their present growth.

Conclusion:

Based on the findings, it may be concluded that the clones namely BCM 2253, P 411and BCM 271 are some better performing clones than the rest one. The Control clone JK 08 is also one good clone with good growth. BCM 2153 and BCM 2253 may produce higher yield if their irrigation requirement is quantified well and if they are treated that way. Hence an in-depth study highlighting the irrigation requirement (water potential: Ψpd) of Eucalyptus clone is pre requisite to move forward with tree improvement programme.

Acknowledgement: Sincere thanks are due to the Environment project for providing the pressure chamber instrument used in the research work.

Table 1. Variation in different morphological and leaf parameters studied on Eucalyptus clones

Clone	Height (m)	Basal Diameter (mm)	Volume (CC)	Breast Height Diameter (mm)	Leaf Area (Sq. cm)	Leaf Water Potential (Ψ_{pd}) (Bar)
JK08 (control)	7.60	67.50	9060.86	54.00	30.51	5.97
BCM 271	7.90	67.25	9418.53	55.50	33.19	5.30
P526	7.20	48.00	4340.74	39.00	34.37	5.68
BCM 413	7.50	57.00	6376.16	46.75	28.78	6.17
SRO16	7.30	62.50	7461.59	53.25	41.17	6.07
BCM 2153	8.40	62.50	8585.94	53.00	21.75	8.83
P413	8.50	59.00	7742.32	51.00	43.02	6.10
BCM 2253	9.50	72.50	13066.16	57.50	29.51	6.27
E. pellita	4.50	32.00	1205.76	25.00	39.52	11.40
BCM 411	7.90	66.00	9004.58	54.00	21.91	5.27
P411	9.00	71.50	12039.35	58.75	26.49	5.93
E. torellina	6.30	51.00	4287.75	40.00	54.26	7.00
SE(m)	0.426	3.009	923.974	2.201	1.903	0.336
CD	1.259	8.883	2727.410	6.496	5.619	0.991

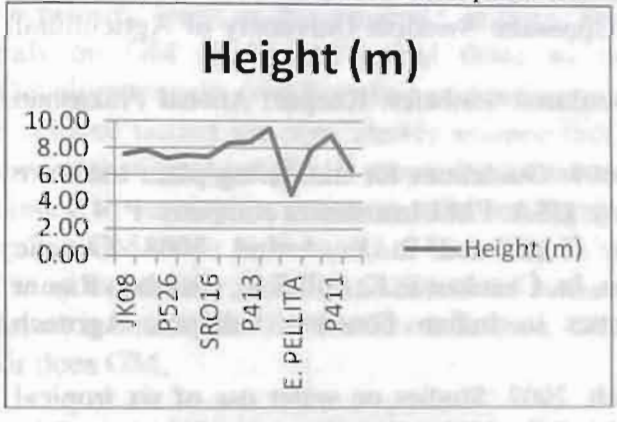
Plate 1: Five month old ramets of Clone BCM 2253 and P41, Trial View.

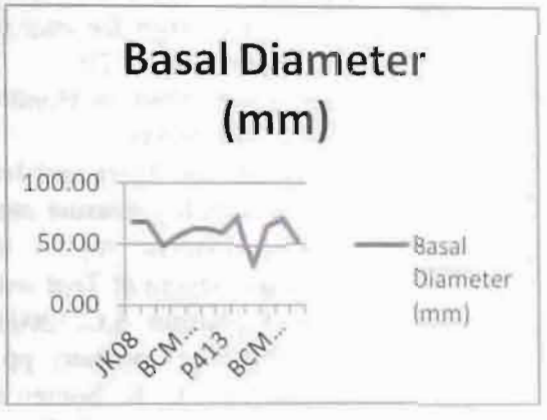
Clone No. BCM 2253

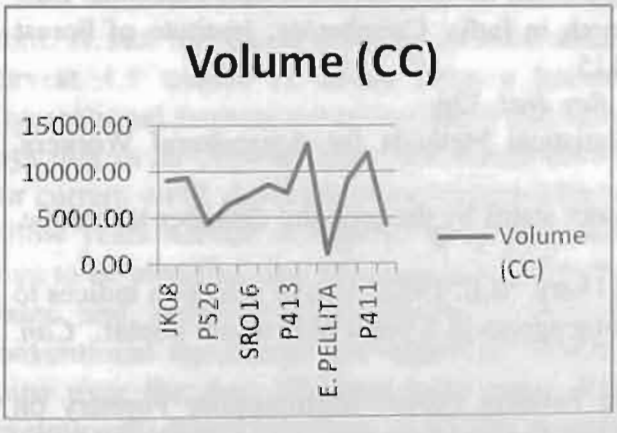
Clone No. P411

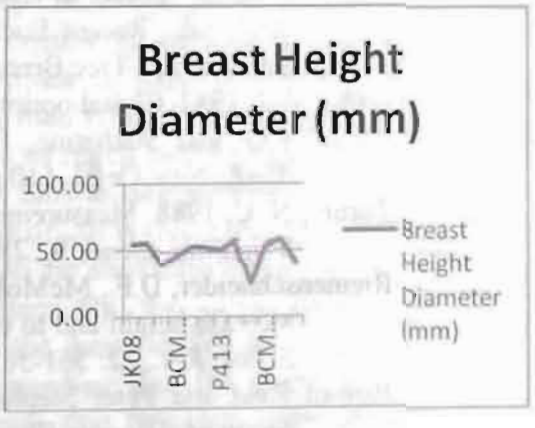
Trial View (at 5 month age)

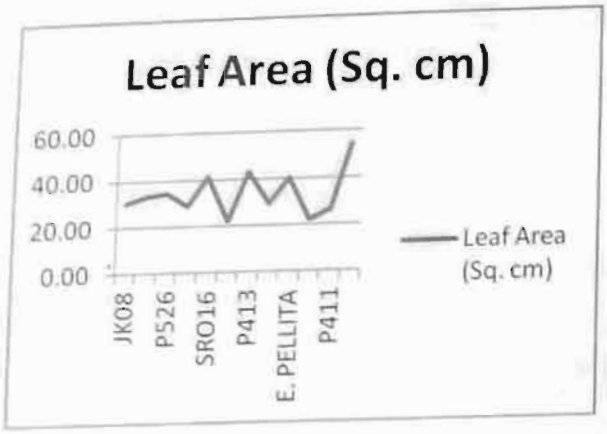
Fig.1: Variation in 12 Eucalyptus clones for Height (m), Basal Diameter, Volume, Breast height diameter, leaf area and leaf water potential.

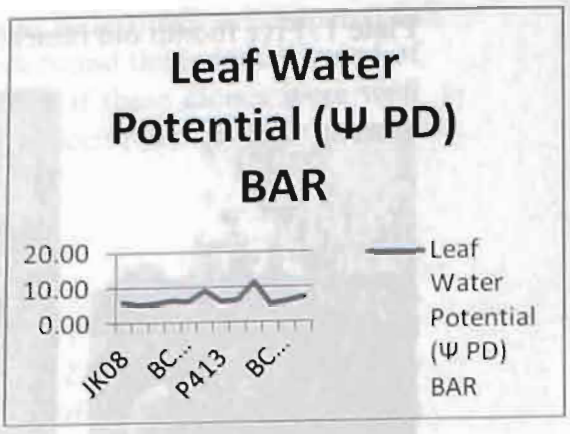












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Perspective vision of genetically modified crops in European Union in general and U.K in particular

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By in large the European Union (EU) governments, academia and the conscientious members of the public hold the considered conviction that in a realistic vision of the planet approximately a billion people go hungry every day, and by mid-century the global population is projected to reach 9 billion. The world by then will need 50 per cent more food and it will have to grow it in an increasingly difficult, drought prone environment. They are hearing, like the rest of the world an echo of wartime and all its constituents governments are worried about food security. Lately, the EU citizens have also started to realize that GM crops will not go away. These will come because they are must. In U.K. the Liberal- Conservative coalition's has decided to approve a field trial of GM potatoes last month and its new environment secretary, Caroline Spelman has explicitly remarked that promoting biotechnology will be one of the priority areas of the present regime. She welcomed and applauded all the new trials on GM crops and called these as indispensible tools by announcing that "Developments in crop breeding and precision agriculture that might have been viewed as science fiction are now clearly science fact". Her further remarks that it was not science that has kept the Bt crops out, rather it was politics that has barred the fruits of science to reach to a common man are highly acclamatory. Hitherto, much of racket against GM crops in Europe has been kicked by the organic lobby – proud providers of fine if expensive food, and shameless self-mythologisers. It is the only lobby that claims it could feed the world on its own. Conventional agriculture doesn't clam this; nor does GM.

This much hyped organics is faith-based agriculture and losing at the reality front. A fact not dwelt upon by its own adherents is that organic farmers do well to harvest 4.5 tonnes of wheat from a hectare and sometimes manage only three. Conventional farmers get more than 9 and sometimes better than 10. Simple arithmetic says that in an organic future we would need at least twice as much land to maintain our current yield, never mind increasing it by half. Even that fails to take account of the fallow years needed in organic rotation systems. Every sod of cultivable earth would have to be ploughed up, releasing gales of carbon dioxide into the atmosphere, guzzling water and reducing wild places to ecological pauperism. On the other hand, conventional agriculture too would be hard-pressed to fill the granaries. Huge yield-gains over the past 50 years have come from selective breeding, but the graph is leveling off. Plant breeding is a slow, unpredictable process that has little hope of feeding every mouth by 2050.

And it's not just a question of yield. There has to be an end to waste. This means defeating pests and weeds while simultaneously cutting back on fertilsers, chemicals

and water, and shrinking the farm industry's huge carbon footprint. So how can it be done? Earlier putting their foot against transgenic a small section of British Scientific lobby pointed out that GM crops are grown on lonely 4% of the world's agricultural land, but neglects to mention that this is rising rapidly and that by 2009 it was accounting for 77% of the world's soya (much of which is used to feed European livestock), almost half of the cotton, more than a quarter of the maize and a fifth of the oilseed rape. In 2009, 14m farmers in 25 countries grew 134m hectares of GM crops. Looking at this subtle data and realities Europe in general and U.K. in particular has woken up and has made GM crops a cynosure of botanical researches in the last 5 years. The academia at the University of Leeds is carrying a war against potato cyst nematodes since they feel it is fight worth winning since every year the nematodes hit UK potato farmers for around £65m in crop losses and pesticide costs. Worldwide, nematode damage totals some £60 billion. The Leeds group led by Professors Howard Atkinson and Peter Urwin from the University's Centre for Plant Sciences took a protein that occurs naturally in rice and maize, and put it in the roots of potato plants. The protein impairs the worms' digestion so they languish and can't breed effectively. In glass house trials another gene has stripped the nematode of its ability to detect the plant odour that attracts it to feed. **Fantastic Results**: fewer nematodes find the roots, and those that do fail to thrive. Up goes the crop. Down goes the need for pesticide. Up goes the science.

The implication of the above projects are extended further elsewhere e.g. in anther research project currently underway on banana plants. These are not the squashy yellow supermarket favourites. They are green cooking bananas and plantains – one of the staple foods of Africa. Their roots, too, swarm with nematodes, costing 6 m tones of fruit a year, which is why the Leeds group is partnering a team in Uganda to repeat the work they have done with potatoes. "We'll test here in the glasshouse followed by its appraisal and field-trials in Uganda." says Professor Atkinson. "

What had interested the contemporary scientists in UK is the potential of the GM crops to influence the soil. For this reason they measure the effects of the GM crop on all nematodes, including the friendly ones that eat bacteria. "What we showed," says Atkinson, "Is that our GM potatoes had less influence on soil communities than conventional oilseed rape." Work in another UK lab John Innes Centre (JIC) at Norwich where Prof. Cahie Martin is trying to convince the world that GM is the way forward while working on tomato and his descries has become a talk of EU scientific fraternity. The BT tomatoes are identical to every tomato but are deep imperial purple. The colour imported from snapdragons and tomatoes extend the lives of cancerous mice by a full 30% while adding two weeks to their own shelf life.

In yet another milestone achievement in Europe and will be of real consequence is on nitrogen fertilizer which over the years has proved to be an environmental nightmare. The manufacture, transport and application of it account for at least a third – some say half-of agriculture's carbon footprint. As farming worldwide is the second largest emitter of greenhouse gases, after power generation and heating. It makes nitrogen a powerful driver of climate change. Even that may not be the worst of it. Most crop plants take up only half the fertilizer fed to them, leaving the rest to leach into aquifers, rivers and the sea. This is an authentic disaster. According to the UN, by

2004 the oceans contained some 150 "dead zones" where over-enrichment by fertilizers and sewage triggered vast algal blooms that sucked all the oxygen out the water and suffocated the fish. One zone in the Gulf of Mexico was twice the size of Wales. According to Robert Diaz, Professor of marine science at the University of Maryland, these dead zones would become a worse threat to fish stocks than overfishing. Thus it happens, bizarrely, that the future of fish may lie in the hands of plant scientists. Logically, one of the best ways they can help is by creating heavier crops. The recent bulging harvest of American maize show why. Through better plant breeding and soil science, and with no increase in the application rate of fertilizer, yields shot up from 1.5 tons per hectare in the 1920s to a record 11 tons in 2009. The data between 1975 and 2005 show the amount of nitrogen needed to grow a tone of corn fell by 30%. Not much of this was due to biotechnology – GM maize has been grown only since 1996 – but the message is clear. Heavier harvests mean less fertilizer per kilo of food. However the dream is a crop that fixes its own nitrogen and needs no feeding at all. This is the long and difficult road on which European scientists are embarking through biotechnological means. In the short term, biotech companies are trying to make plants at least use nitrogen more efficiently, and so need less of it. This has already been done experimentally with rice and oilseed rape. Whatever happens, food in future will owe as much to science as to husbandry. The question is: which science? "It's not a choice between organics and GM," say British scientists. "It's a choice between feeding the world through chemistry or through biology.

Unfortunately, in the earlier years, Europe's addiction to chemicals was not be easy to break e.g., worldwide potato late blight is a 3.5 billion problem, and farmers in Britain spend 50m a year on chemical controls, spraying 12 to 18 times a year. "In the wet summer of 2007," says Professor Jones of the Sainsbury Lab. "Europe actually ran out of chemicals to control late blight. Farmers had been spraying from helicopters because the ground was too muddy for tractors. Some organic farmers had their entire crops wiped out."

The good news is that a GM solution now exists; and the EU's own European Food Safety Authority had declared the GM potatoes safe, the bad is that no European farmers can get their hands on it instantly because of the political wire. The most recent completed trial of blight-resistant potatoes in Britain was two years ago, and the world's largest chemical company. BASF, last year suspended it research. The reason was the political shut-out in Brussels. Although the EU's own European Food Safety Authority had declared the GM potatoes safe, there was no way through the political wire. As the academic means realistic and the truth has to prevail there is sense of urgency to break this political pause. It is rightly summoned up by Meurtg Raymond, deputy president of the National Farmers Union and himself a potato grower who last month remarked that "Farmers need access to every tool in the box to be able to produce more and impact less on the environment. We need new varieties that have better resistance to pests and diseases, and will be less reliant on sprays and fertilizer. What we need now is the applied research and field trials that turn the genetic discoveries and smart breeding techniques into crops famers can grow."

AMLA (*Emblica officinalis*)-ANJAN *(Hardwickia binata)* based agroforestry system

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ABSTRACT

A field experiment on amla + anjan based agroforestry system was conducted at Main Agricultural Research Station, UAS, Dharwad on red soil during 2002. The Amla sources viz, 1. Amla (buded) 2. Kanchan 3. NA-7 4. Krishna and 5. Amla (local) were planted at 5 x 5 m and Anjan was planted in between two amla plants. Sesamum was grown in alley of Amla + Anjan. The recommended package of practices for Sesamum and silvicultural practices for amla and anjan followed by proper growth and development. Sesamum yield was lower in amla (local/buded) + Anjan as compared to other treatments. Amla yields were lower in improved varieties viz, Kanchan NA-7 and Krishna. The net return and B.C. ratio was significantly higher in NA-7 + Anjan + FC (Rs.4878/ha/yr and 1:08:1 respectively) followed by Krishna + Anjn + FC (Rs.4404/ha/yr and 1.68:1 respectively) as compared to other sources tried. Anjan is one of the important fodder and short rotation tree and it thrives in a dry climate and is capable of establishing itself and growing on dry shallow soil and rocky ground where most other species would succumb. This is due partly to the early development of the taproot and the ability to penetrate hard soil and fissures in solid rock (the stem usually dying back annually during development of the taproot) and partly to its ability to withstand mutilation. Hence Amla var NA-7 / krishna and Anjan is sustainable agroforestry system for degraded soils.

Keywords: Agroforestry, Amla, Anjan, Krishna, Vitamin - C

INTRODUCTION :

Amla is one of the important fruit indigenous to Indian Sub continent and finds a prominent place in ancient Indian scriptures such as Ramayana, Kadambari as 'Amrit Phal' because of its significant medicinal and nutritional value. The fruit has high antioxidant value as it contains a chemical has high antioxidant value known as gallic acid which refers to the oxidation of vitamin C. Fruit is rich source of vitamin C in fresh as well as dried or processed farm. It can be cultivated on commercial scale in problematic soils. It can be cultivated on salt affected wasteland which offer good scope to increase fruit production in the country (Tewari *et al.* 2004) and amla has now become an important fruit in the present situation. (Pathak and Pathak 2001) It can be grown successfully with short legumes *viz.*, Moth, Guar and Cowpea, Black gram (Singh 2006). There is need of integration of anola in agri – horticulture system to sustain productivity (Singh *et al* 2005). The legume crops have beneficial effect in the system in terms of soil fertility build up and residual effect on plant (Pathak 2000). The amla based agro – horti cultural system has shown quite encouraging results in the farm of multiple outputs with assured income generation (Osman 2003).

Amla genotypes available in this region have relatively high content of vitamin C and total phenols. It can be stated that the natural wealth of Amla available has great diversity in physiochemical fruits. Which offer unique scope of further improvement of Amla through selection of superior genotypes. These genotypes have immense potential to be used either for clonal multiplication, further evaluation and selection as a commercial variety or as superior gene source for further hybridization programmes for combining useful traits.

Hardwickia binata is a moderate-sized to large tree, up to 24-30 m tall, girth 1.8-3 m with a clean cylindrical bole up to 12-15 m; graceful, drooping slender branches; crown conical in early life, becoming broader later. Bark of saplings almost silvery white and smooth, gradually changing as the tree gets older to dark grey and rough with irregular vertical cracks, 1.2-2.5 cm thick, exfoliating in narrow flakes. In isolated situations, or on poor soils, the tree tends to branch low down and produce a short bole, but when grown in a fairly crowded crop on favourable soil it produces a long, straight, cylindrical bole with an elevated crown. Leaves small, 2-6 cm long by 2-3 cm wide, alternate, pinnate, almost kidney shaped and greyish-green. Flowers small, pale yellowish-green in axillary and terminal lax panicled racemes. The pod flat and samaroid, 5-7.6 x 1-1.5 cm, oblong lanceolate, coriaceous, narrowed at both ends, with parallel longitudinal veins, containing 1 seed near the apex.. The tree is distributed in isolated patches, varying in extent in the drier parts of the Indian Peninsula. Overlying soil does not have to be deep since the taproot has a capacity for growing through fissures in solid rock. *H. binata* thrives in a dry climate characterized by a long drought, scanty to moderate rainfall, and intense heat during the hot season. In the cold season, frosts, generally mild, occur only in certain portions of its area of distribution, particularly in low-lying areas.

Hence an experiment was conducted the suitability of Amla clone with Anjan under rainfed conditions.

MATERIAL AND METHOD:

A field experiment was initiated from 1999 to known performance amla with Anjan at Main Agricultural Research Station, UAS, Dharwad under rain fed conditions from 2002. The experiment consisted of five amla sources viz. 1. Amla buded) 2. Kanchan 3. NA – 7 4. Krishna 5. Amla (local) and seedlings were planted at 5 m x 5m apart. In between two plants of amla, anjan was planted along alley. The soil of experimental site was red soil with having pH of 6.8 and available nitrogen of 168.2 Kg ha-^{1} available phosphorus of 16.32 kg/ha^{-1} and high available potassium 235.6 kg ha^{-1}. The annual rainfall of 782 mm was received in 56 rainy days. The mean monthly maximum temperature is 36.3 ^{0}C and mean monthly minimum temperature is 14.1 ^{0}C in the months of April and December respectively. The experiment was laid out with four replication in randomized block design. The field crop sesamum was grown for five year in between alleys of amla + anjan.

. The fruit yield was started after 6th years and the fruit yields were collected from each tree. The data on height, dbh and spread of amla and anjan were collected and present in tables. At the end of experiments value of Anjan tree was assessed based on poles and biomass. The income from field crop and fruits of amla were worked out based on prevailing market rates. The cost of each inputs, plantation cost

and maintenance cost worked out. The economic analysis was made based on cost and returns.

The field crop Sesamum (Var. DS - 1) was grown in alleys. The recommended package of practices were followed for crop. Seeds were sown at 60 x 30 cm spacing and applied the fertilizer dose of 40:25:25 NPK kg ha^{-1} respectively. The uniform silvicultural operations *viz* soil working around trees, pruning of side branches were done during *Kharif*. The fertilizer @ 50 : 100 : 50 NPK gm $plant^{-1}$ was applied to amla to all the treatments for first three year. All the plants were maintained under uniform cultural operations during the period throughout experimentation.

RESULT AND DISCUSSIONS

Growth parameters of Amla:

There was significant differences among growth parameters. The height of amla (local) was significantly higher followed by amla (buded) as compared to other sources. Girth of amla was higher (52.6 cm) in local followed by local (buded) and lowest in NA – 7 (27.0 cm). Similarly crown area were significantly higher in Amla (local) and Amla ((buded) as compared to Kanchan, NA – 7, Krishna.

The better growth amla (local) and amla (budded) are to these sources were acclimatized with local situation and thereby higher productivity of these sources to the local conditions. However, Amla Kanchan, NA – 7 and Krishna have attained poor growth. This may be due to these clones / sources have brought from out side its local habitant, hence have took more time to adopt to new site conditions.

Amla Fruit yield:

The fruit yield was significantly higher with Amla (budded) followed by Amla (local) as compared to other sources. Average fruit yield were higher local sources compared improved one in degraded soil. Fruit yield were lower, but their size, these facts fetched higher prices than local one. Similar observations were recorded by Kumar *et al* (2002)

Grain Yield Sesamum:

Cropping have significantly effected by growth parameters of anola. Sesamum grain yield was significantly higher in Kanchan, NA – 7 and Krishna sources and was lowest in the Amla (local) and Amla (budded).

Similarly Singh (1997) reported positive correction of ground storey crops on over the storaged component (Amla) Similar results were reported by Saroja *et al.* (2003) and Korwar *et al.* (2006) in anola based agri - horticulture and Shukla *et al.* (2008) in case of ber based agri – horticulture system.

Growth of Anjan

Height, girth and crown area of Anjan were significantly higher when grown with Amla local varieties, Kanchan, NA – 7 and Krishna was more compared to Amla (local) and Amla (budded). As the slow growth of these sources favoured the growth of Anjan.

Economic analysis

Gross returns was significantly higher in Amla NA-7 + Anjan + FC as compared to other agroforestry combinations. The average net returns were higher in Amla + anjan + Sesamum (Rs.8676/ha/yr) followed by Krishna + Anjan + Sesamum (Rs.8202/ha/yr) as compared to other treatment combinations. Net returns and Benefit Cost Ratio were higher in NA-7 + Anjan + Sesamum (Rs.4878/ha/yr) and 1.80:1 respectively followed by krishna (amla) + anjan + Sesamum (Rs.4403/ha/yr) and 1.68:1 respectively.NA-7 and Krishna with Anjan are sustainable agroforestry system.Similar results were reported by Nandal and Ravikumar (2010).

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Table 1: Growth and yield parameters of amla as influenced by agroforestry systems

Agroforestry systems	Amla				Anjan		
	Height (m)	Girth (cm)	CA (m2 / pl)	Fruit yield (kg/pl/yr)	Height (m)	Girth (cm)	CA (m^2/pl)
1. Amla (budded + Anjan + FC	6.83	52.6	11.33	32.6	6.9	44.30	2.96
2. Kanchn + Anjan + FC	3.75	28.0	10.13	12.6	5.7	55.6	2.51
3. NA – 7 + Anjan + FC	3.80	20.0	9.83	13.8	6.7	51.30	3.23
4. Krishna + Anjan + FC	3.76	27.2	9.28	14.2	6.3	41.60	2.99
5. Amla (local) + Anjan + FC	7.36	61.6	12.83	28.6	6.7	37.30	2.73
CD (0.05)	1.86	3.64	1.38	4.58	NS	2.26	1.08

Table 2: *Sesamum* grain yield (kg/ha) of as influenced by different agroforestry system

Agroforestry system	2002-03	2003-04	2004-05	2005-06	Average grain yield (kg/ha)	
					2006-07	2007-08
1. Amla (buded + Anjun)	200	180	165	150	130	165
2. Kanchn + anjan + FC	220	230	210	190	185	207
3. NA – 7 + Anjan + FC	225	235	215	200	180	211
4. Krishna + Anjan + FC	200	210	205	190	180	197
5. Amla (local) + Anjan + FC	190	160	150	130	120	150
SEM + CD (0.05)	12.32	14.7	10.8	11.6	10.20	11.80

Table 3. Economic evaluation of Amla + Anjan based Agroforestry systems

Agroforestry systems	Average Gross Returns (Rs/ha/yr)	Average Cost (Rs/ha/yr)	Average Net Returns (Rs/ha/yr)	Discounted @ 12% interest			
				Average Gross Returns (Rs/ha/yr)	Average Cost (Rs/ha/yr)	Average Net Returns (Rs/ha/yr)	BC:R
1. Amla (budded) + Anjan + FC	7910	3799	4111	3748	2302	1446	1.62
2. Kanchan + Anjan	8110	3799	4310	3908	2302	1606	1.69
3. NA – 7 + Anjan + FC	8676	3799	4878	4145	2302	1843	1.80
4. Krishna + Anjan + FC	8202	3799	4403	3889	2302	1587	1.68
5. Amla (local) + Anjan + FC	6853	3799	3054	3275	2302	973	1.42

Bamboo Plantation Based Interventions for Sustainable Natural Resource Management in Degraded Gully Lands

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ABSTRACT

India is having 3.67 m ha of ravine lands which constitute 1.12% of total geographical area of the country. Rehabilitation of degraded ravine lands with various kinds of vegetation is immensely important to increasing the desired level (33%) of forest cover, to counter impacts of climate change and to conserve land & water resources for sustaining and improving the production and productivity of these degrade ravine lands. Bamboo is one of the fastest growing plants having extensive fibrous root system, connected rhizome system, dense foliage, the leaf litter produced on the soil surface, etc. are some the important valuable characteristic features of bamboo for controlling soil erosion in degraded ravine lands. A research and development project entitled "Hydrologic and economic evaluation of bamboo plantations in gullied lands under major ravine systems (Mahi, Chambal, Yamuna) of India" has been implementing in 2008-12, with financial assistance by National Bamboo Mission, Ministry of Agriculture, Govt. of India. A part of this project, experiments was conducted to study the effect of bamboo based interventions for sustainable natural resource management in degraded gully lands. The experiment data reveal that higher survival percentage and plant growth were recorded in bamboo plantation with supportive staggered trenches. Lowest runoff was occurred in bamboo plantation with small earthen check dams. The bamboo plantation based interventions absorbs more than 80% of rainfall that is either utilized by the plant or percolated deep, to recharge the ground water. At, 2010-11 prices, a net income of Rs. 29,400 ha^{-1} $year^{-1}$ can be realized during 7^{th} to 10^{th} year. This increases to Rs.41,400, Rs.48,000 ha^{-1} yr^{-1} from 11^{th}, 20^{th} year onwards respectively. The net present worth of 20 year bamboo plantation works out to be Rs.5197 $ha^{-1}year^{-1}$ (8% discount rate) at 2010-11 prices. Similarly, the benefit cost ratio works out to be 1.66 at 8% discount rate.

Keywords: Bamboo, Gully Lands, Runoff, Soil Loss, Economics

INTRODUCTION

Ravines are the network of gullies. India is having 3.67 m ha of ravine lands which constitute 1.12% of total geographical area of 328 m ha (NCA, 1976). Very extensive degradation of land has occurred along some of the major river systems of the country in various states in the form of deep gullies. There is hardly any historical record to show when the deterioration started, but it is reasonable to assume that indiscriminate use of land leading to disturbance of ecosystem has been one of the main

causes for formation of ravines (Sharma et al., 1980). Erratic, short-duration and high intensity rainfall, erodible nature of soil, weak geology of alluvium, steep slopes and uneven terrain, faulty agricultural practices, illicit cutting of trees and bushes and overgrazing have combined to aggravate the situation. National Commission on Agriculture (1976) estimated that 3.67 million hectares of land are damaged by these ravines. A rough estimate suggests that about 8,000 ha is added to these ravines annually (Sharma et al., 1980). Out of 3.67 million hectares of ravine lands in India, 2.36 million hectares (64%) are spread over in the states of Uttar Pradesh, Madhya Pradesh, Bihar, Rajasthan and Gujarat (Dhruvanarayana, 1993) (Table 1). There are 4 major areas of severe ravine erosion on the map of India (Fig. 1). The largest is the Yamuna-Chambal Ravine Zone. The ravines flank the Yamuna river for nearly 250 km and in Agra and Etawah attain a depth of more than 80 m. Nearly 389,000 ha are affected along the Yamuna in southern Uttar Pradesh. The Chambal ravines flank the river Chambal in a 10km wide belt, which extends southwards from the Yamuna confluence to 480 km to the town of Kota in Rajasthan. Ravines also affect basins of several Chambal tributaries, e.g., Mej, Morel, Kalisindh, etc. Altogether, about 5,000 km^2 area is affected. In Gujarat, ravine belt covers 500,000 ha and extends from the southern bank of the Tapti, banks of the Narmada, Watrak, Sabarmati and Mahi basins. Besides these river basins, ravines are also found in Chhota Nagpur, Bihar, Mahanadi and upper Sone Valley, Indo-Gangetic plains, Siwaliks and Bhabar tract and Western Himalayas even up to the Kashmir Valley (Dhruvanarayana, 1993).

The National Commission on Agriculture has repeatedly indicated that gullied lands not only create problems where they exist, but are also the root causes for degradation of adjacent arable lands affecting production potential in a major way (Figure.2.). Most of the gullied and ravine lands are not inferior in their capabilities but are abandoned due to various other reasons. Being alluvial in nature and located nearby rivers the ravines are highly susceptible to erosion and quite often face consequences of severe floods. Ravines have a variety of a gully net works and combinations with varying conditions of gully beds, gully side slopes, and gully intensities due to which no uniform and cost effective land development package can be made available or implemented till now and the problem remains as such. Rehabilitation of ravine lands with various kinds of vegetation is immensely important to increasing the desired level (33%) of forest cover as targeted in National Forest Policy, Government of India. The increase in vegetation in degraded ravine lands enhances the flora and fauna and thereby restoring natural ecosystem to counter impacts of climate change and to conserve land & water resources for sustain and improves the production and productivity of degraded ravine lands.

India has one of the richest bamboo resources in the World, second only to China in bamboo production. According to Forest Survey of India (FSI), in India bamboo grows in 8.96 million ha of forest area, which constitutes about 12.8% of total forest area of the country. Of this, nearly 28% occur in the North Eastern States, followed by 20.3% in Madhya Pradesh, 9.90% in Maharashtra, 8.7% in Orissa, 7.4% in Andhra Pradesh, 5.5% in Karnataka and the balance is spread over in other states. Bamboo has always been known as an enduring, versatile and renewable resource. There are more than 100 vital species of bamboo in India, which grows naturally at heights ranging from sea level to over 3,500 meters in varied habitats (Tewari, 1992). Bamboo is known to be one of the fastest growing plants in the world, with a growth rate ranging from 30 to 100 cm per day in growing season. It can grow to a height of 36

m with diameter of 1-30 cm (United Nations 1972). A culm can reach its full height in matter of two to three months. Considering the above characteristics, it is easy to believe that bamboo is the fastest growing. Highest yielding renewable natural resources (Lessard and Chouinard 1980). There is a growing realization that the potential of bamboo in the country has not been tapped to its fullest, hence wider and alternative utilities of Bamboo is being 'rediscovered' in India with increased attributes and potential towards ecological and soil conservation utilities.

Researchers have clearly established the importance of bamboo plant as an effective means for natural resource conservation. Certain studies (Simon & Collison, 2002) on runoff mechanism on riparian lands have revealed that the concentration of runoff in topographically defined linear features, like valley bottoms, is an important process when considering off-site damages from soil erosion. Various other research findings have reported positive utility of bamboo plantation for enhancing natural resource conservation (Lawler, 1993; YanHui *et al.*, 1995). The utility of Bamboo plantation as effective soil & water conservation measure has been successfully demonstrated in Mahi ravines (Sharma *et al.*, 1980; Kurothe & Nambiar, 2001). They reported that Bamboo based vegetation was observed to be quite promising both in terms of controlling runoff and soil loss and economic returns. From 7th year onward, a net income of Rs 8000 - 10000 was obtained. Zhou *et al.* (2005) reported that soil erosion was low in bamboo plot (178.15 kg/ha or 117.13%) as against other forest plantation types. Average ranges of annual interception and stem flow in bamboo plantations have been reported as 13 - 15% and 4 - 6%, respectively which (Lu SY et al., 2007) looks a bit higher than those under natural hard-wood forests, due to special canopy characteristics. Deng and his team studied five different conversion models to compare the soil conservation efficiency (Deng et. al., 2003). Out of the five models, bamboo grooves intercropped with fodder grass was most in soil erosion. Extensive fibrous root system, connected rhizome system, its comparatively dense foliage, the leaf litter produced on the soil surface, etc. are some the important valuable characteristic features of bamboo for controlling soil erosion. The comparatively dense foliage protects against beating rains, and its habit of producing new culms from underground rhizomes allows harvesting without disturbing the soil (Ben-zhi *et.al.*, 2005). In India, different bamboo based agroforestry models such as, bamboo + ginger (Jha & Lalnumawia,2004), bamboo + soyabean (Sheshadri, 1985) bamboo + turmeric, bamboo + Pigeon pea (Shanmughareland Francis, 2001) were successfully established in managing the different type of degraded lands . Sole bamboo plantation have also been used to rehabilitate the land in different parts of the world (Christanity *et. al.*, 1996), for illustration, in India *Dendrocalamus strictus* shows positive land rehabilitating and restoring ability.

Because of dense surface roots, bamboos have vast potential as a vegetative measure to conserve soil, and thus provide good protection against sheet and gully erosion. Scientific literature on this aspect is rarely available as most of the studies deal with production and management aspects. Bamboo, which is a fast growing woody grass species, has been used traditionally as a gully plug to control deepening of gullies. It is well established that staggered plantation of bamboo in gully beds plays an active role in controlling erosion by regulating hydrological flow and soil movement. However, available quantified information on such effects is very limited. Also it is not known as to what may be the alternate utilization pattern of bamboo species from conservation point of view on degraded gullies and ravines. Such information is of vital

importance in the current scenario when bamboo is being established as one of the major vegetation of versatile utility for natural resource conservation and for value addition

Many countries and regions have initiated efforts to harness the potential of bamboo plantation from environmental point of view. In India, the National Bamboo Mission has clearly emphasized on the conservation value of bamboo plantations. Looking into this scenario, research and development study is essentially needed and may provide valuable data to scientifically establish conservation value of bamboo for rehabilitation of severely degraded lands or ravines. Keeping these considerations in view a research and development project entitled "Hydrologic and economic evaluation of bamboo plantations in gullied lands under major ravine systems (Mahi, Chambal, Yamuna) of India" has been implanting in 2008-12, with financial assistance by National Bamboo Mission, Ministry of Agriculture, Govt. of India. A part of this project, experiments was conducted to study the effect of bamboo based interventions for sustainable natural resource management in degraded gully lands of Mahi ravine system in Gujarat.

MATERIALS & METHODS

STUDY AREA:

This study was conducted to evaluate the production and conservation potential of bamboo in degraded ravine lands. This study is carried out in highly degraded ravine lands of Mahi ravine system located at Khorwad village of Anand Taluka of Anand district, Gujarat (Fig.2). Mahi ravine system is the one of three major ravine systems of India. Khorwad village has an established Tree Growers' Cooperative Society (TGCS), with 217 hectares of highly degraded lands comprising various categories of gullies/ravines which are ultimately draining into adjacent Mahi River. The natural stretches of shallow, medium, and deep gullies are available for various treatments. It comprises of two hamlets namely Khorwad and Navapura and is inhabited by 355 households (population about 3094). In TGCS land a natural watershed (10 ha) which is denuded and has an extensive gully network has been selected for this study. Though there is wide spatial variation of soil properties within and between the top, slope and bed soils but bed soil is poor in terms of texture (Sandy), saturated hydraulic conductivity (287 mm/day), organic matter (0.1%). pH and EC of all soil samples are within normal range but relatively lower pH (6.9) of top/hump clearly reflects higher base removal by rain. Irrespective of the spatial distribution, Soil is overall very poor in organic carbon with relatively higher content on slope (0.20) followed by top (0.16) and minimum in the bed area (0.10).

METHODOLOGY:

In gullied watershed was selected in the highly degraded ravine lands of Khorwad. In this watershed, four micro watersheds having similar morphological conditions, soils, rainfall and other weather parameters were identified and these were delineated by using Differential Geographical Positioning System (DGPS) and Google Earth. In this study three treatments namely, (i) Bamboo plantation (*Dendrocalamus strictus)* at 4 x 4 m spacing with supportive staggered trenches in degraded gully beds, (ii) Bamboo plantation in staggered fashion with close spaced rows & close spaced plants (at 2x2 m spacing) to act as live check dam, (iii) Treating gully beds with small earthen check dams (made of sand bags etc) and bamboo plantation (2 rows one each at

upstream and downstream edge at 2 X 2 m spacing) were imposed. The control was kept without any plantation and soil and water conservation measure. Four micro watersheds were selected and named as W1, W2, W3, & W4. Treatment T1, T2, T3 were imposed in W1,W2,W3 watersheds and W4 was kept as control. Under treatment-1; Bamboo (*Dendrocalamus strictus)* was planted in staggered fashion at 4 m x 4 m spacing in gully beds of W1 watershed. For each plant, a staggered trench of size 2 m length, 0.5 m width and 0.5 m depth was constructed at nearer to the plant. Under treatment-2; Bamboo (*Dendrocalamus strictus)* were planted in staggered fashion with close spaced rows & close spaced plants (at 2x2 m spacing) at W2 Watershed to act as live check dam. Total 10 live check dams were planted along the gully bed. Under treatment-3; 11 earthen check dams made of gunny bags (bori bund) were constructed along the gully bed in W3 watershed. For each earthen check dam, two rows (one each at upstream and downstream edge at 2X 2 m spacing) of bamboo were planted. W4 watershed kept as control without any plantation and conservation measures.

SURVIVAL PERCENTAGE AND GROWTH PARAMETERS OF BAMBOO

The growth parameters such as number of plants survived, bamboo clump diameter at ground level, Culm height and the collar diameter were collected from the bamboo plantations site at Khorwad and Vasad of Mahi Ravine system and these were analyzed.

RUNOFF & SOIL LOSS

The treated and control micro watersheds at Khorwad site of Mahi Ravine system were individually gauged at their outlets by utilizing regular brick masonry hydraulic control structures with mechanical water stage level recorders. The rainfall data were collected by for each treatment event based rainfall (depth, duration, and intensities), runoff (depth, duration, and rates), soil & nutrient losses. Periodic changes in gully bed profile gully cross sections and gully head advancements (before and after monsoon) were collected and analyzed.

BAMBOO YIELD & ECONOMICS

The present study is confined to financial analysis as against the economic analysis which encompasses a broader perspective of economy or society. The financial analysis attempts to identify and quantify costs and benefits to individuals by utilizing resources over a specified time period (Gittenger, 1982). It depends on prices of inputs and outputs in local market. The methodology of discounted (over time) cash flow is used with a focus on calculating net benefit and return to the actual equity capital invested in the technology. In the case of bamboo, this type of analysis can, for example, be used where the objective is to maximize economic output per unit time. The criteria for evaluation is as under,

Benefit-Cost Ratio This is simply the total of the present worth of expected benefits divided by the total of the present worth of expected costs. Only technologies with a ratio of greater than 1 are economically efficient in terms of resource use.

Net Present Worth (sometimes referred to as Net Present Value)

This is the difference between the present worth of the expected benefits less the present worth of the expected costs. All technologies which result in a positive net present worth are economically efficient in terms of resource use.

Internal Rate of Return

This is defined as the average earning power of the value of resources used from the application of the technology. Only technologies that give a rate of return higher than the existing market interest rate are resource efficient.

The formal mathematical statements of these criteria are given below:

$$\text{Benefit-cost ratio} = \frac{\sum_{t=1}^{n} B_t(1+r)^t}{\sum_{t=1}^{n} C_t(1+r)^t}$$

$$\text{Net Present Worth} = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t}$$

Internal rate of return is that discount rate 'r' such that $\sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} = 0$

where,

B_t = benefits in each year, t = 1, 2, ...n

C_t = costs in each year, t = 1, 2, ...n.

n = number of years.

r = interest (discount) rate.

RESULTS & DISCUSSION

The data on survival percentage, growth parameters of bamboo in various gullies rainfall, runoff and soil loss, sediment data, economics were analyzed and presented in the following sections.

SURVIVAL PERCENTAGE AND GROWTH PARAMETERS OF BAMBOO

The annual mean survival and growth parameters of bamboo at Mahi ravines are presented in table 2. From the table, it is revealed that mean survival at the two sites varies between 72 to 80 per cent. It is further observed that the bamboo saplings planted during 2008 attained a height of 131 cm and 115.9 cm in two years at Research Farm, Vasad and Khorwad community land, respectively. Similarly, the average clump diameter was observed to be 79.4 cm and 46.8 cm at Vasad farm and Khorwad community land, respectively. The average collar diameter was about similar, 0.87 cm and 0.90 cm during 2011 at Khorwad and Vasad farm, respectively. Number of culms were observed to be slightly higher (8 Nos.) at Vasad farm as against 6 Nos at Khorwad.

RUNOFF & SOIL LOSS

The average annual rainfall of the Khorwad is 870 mm. The total rainfall of Khorwad for the year 2010 is 980 mm. Total rainy days are 28. The

treatment/watershed wise runoff & soil loss is presented in Fig.3. From the figure 3 it is observed that lowest runoff (8%) and soil loss (5.25 t/ha)) is recorded in W3 watershed i.e. treatment T3 (Bamboo plantation with earthen check dams made of sand bags) followed by W1 watershed (runoff 13 %, & soil loss 9.95 t/ha) i.e. treatment T1 (Bamboo plantation with staggered trenches) in comparison to control watershed W4 (runoff 29 %, & soil loss 15.57 t/ha). The physiographic conditions of these watersheds are more are less similar and these imply that the varying runoff and soil loss behavior of watersheds is mainly due to conservation measures. The watershed treated with earthen check dams made of sand bags (*bori* bunds) having more runoff retention capacity than the watershed treated with staggered trenches due to that lowest runoff & soil loss was occurred in that watershed.

BAMBOO YIELD & ECONOMICS

Kurothe & Nambiar (2001) reported that Bamboo based vegetation was observed to be quite promising in terms of economic returns. From 7th year onward, a net income of Rs 8000 - 10000 was obtained at the base year prices of 2001. Based on the growth behaviour of bamboo in degraded ravine lands at CSWCRTI, RC, research farm, Vasad (Fig.4), it is estimated that 400 clumps with 3000 to 4000 old and 1000 to 1500 new culms are available in one hectare. From the bamboo plantation in ravines 30 per cent of old culms (1000 old culms/ha/year) can be harvested from a seven year old plantation. The cost items of cultivating bamboo plantation in ravines are spread over a period of five years. Since a major portion of costs accrue in the initial four years and a little in the fifth year, only these costs are considered (Table 3). After that expenditure only on cleaning of bamboo clump is done. The total cost over a period of five year works out to be Rs. 1,01,167 ha^{-1}, out of which Rs. 46,428 ha^{-1} is spent in the first year (Table 3). Harvesting commences from 7th year onwards. On an average 3 to 4 good culms per clump of bamboo are harvested from 7th year. Considering sale price per piece of green bamboo as Rs. 35/-, a net income of Rs. 29,400 ha^{-1} can be realized during 7th to 10th year (Table 4). This increases to Rs. 41,400, 48000 ha^{-1} yr^{-1} from 11th, 20th year onwards respectively. The net present worth of a 20 year bamboo production cycle works out to be Rs.5197 ha^{-1}year^{-1} (8% discount rate). Similarly, the benefit cost ratio works out to be 1.66 at 8% discount rate. The internal rate of return reveals that bamboo performance in Mahi ravines generates an internal rate of return to the tune of 16.7%, which is substantially higher than the discount rates considered in the analysis

CONCLUSION

Rehabilitation of ravine lands with various kinds of vegetation is immensely important to increasing the desired level (33%) of forest cover, to counter impacts of climate change and to conserve land & water resources for sustains and improves the production and productivity of these degraded ravine lands. Bamboo is one of the fastest growing plants having extensive fibrous root system, connected rhizome system, dense foliage, the leaf litter produced on the soil surface, etc. are some the important valuable characteristic features of bamboo for controlling soil erosion in degraded ravine lands. The study conducted on bamboo based interventions in ravine reclamation proved to be quite promising both in terms of controlling runoff and soil loss and economic returns. Experiment data reveal that higher survival percentage and plant growth were recorded in bamboo plantation with supportive staggered trenches. Lowest runoff was generated in bamboo plantation with small earthen check dams. The

bamboo plantation based interventions absorbs more than 80% of rainfall that is either utilized by the plant or percolated deep, to recharge the ground water. At 2010-11 prices, a net income of Rs. 29,400 ha^{-1} can be realized during 7^{th} to 10^{th} year. This increases to Rs. 41,400, 48000 ha^{-1} yr^{-1} from 11^{th}, 20^{th} year onwards respectively. The net present worth is from RS.5197 $ha^{-1}year^{-1}$ (8% discount rate). Similarly, the benefit cost ratio works out to be 1.66 at 8% discount rate. In spite of bamboo potential in degraded ravine lands in terms of controlling runoff and soil loss and economic returns, it has not been tapped to its fullest, hence wider and alternative utilities of Bamboo is being 'rediscovered' in India with increased attributes and potential towards ecological and soil conservation utilities in degraded ravine lands.

ACKNOWLEDGEMENT:

The authors acknowledge Director, CSWCRTI, Dehradun for providing valuable guidance for this study. The authors are also thankful to Shri. Kameswar Ojha, Deputy Director General & Shri. R.P. Meena, Asst. Director, National Bamboo Mission, Ministry of Agriculture, Govt. of India for providing financial assistance for conducting this study. The authors are also thankful to Shri. Anand Kumar & Shri. D.G. Damor, Technical assistants of the CSWCRTI, RC, Vasad for collecting the data.

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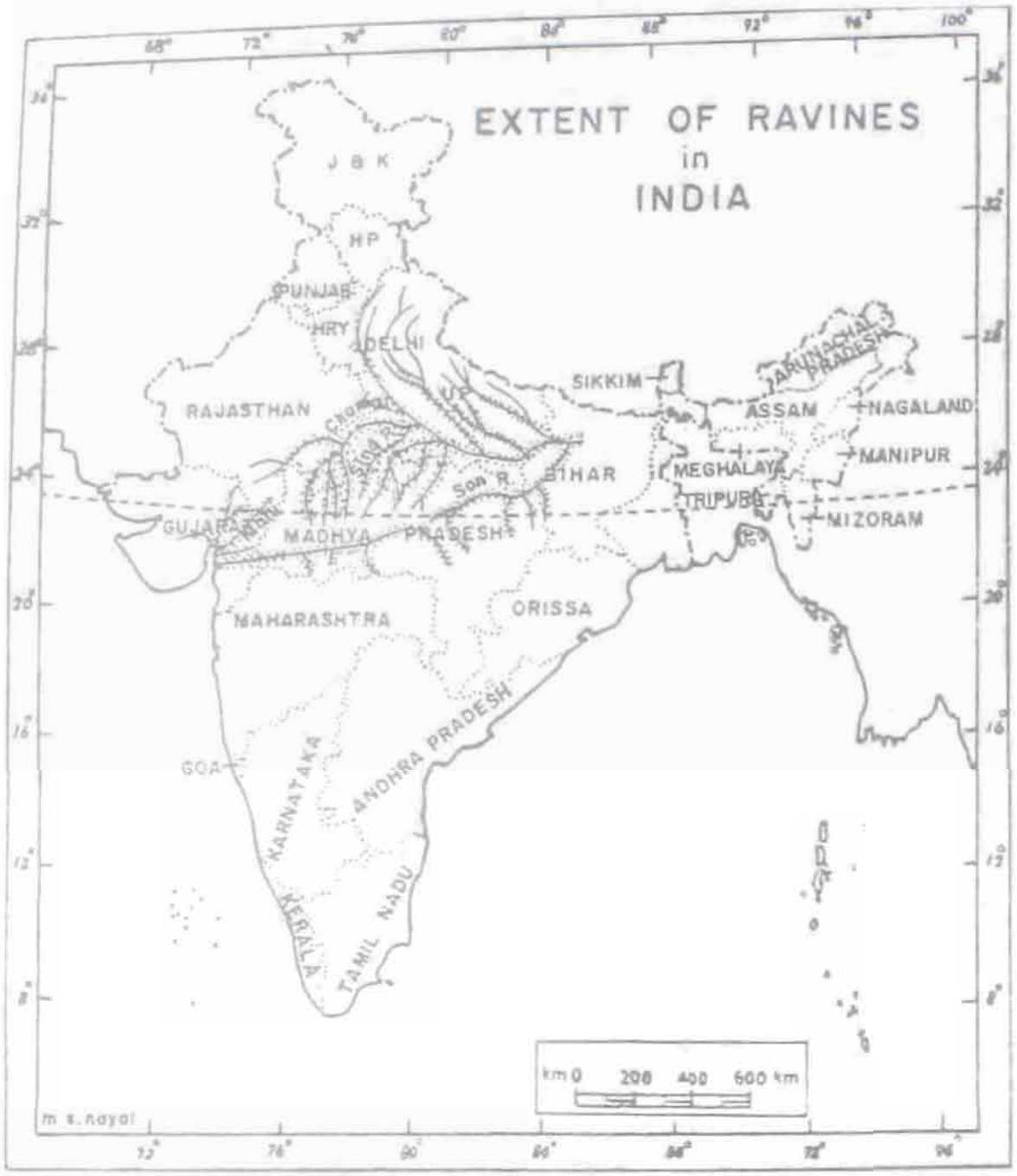


Fig.1 Extent of ravine lands in India
(Source: V.V.Dhruvanarayana, 1993)

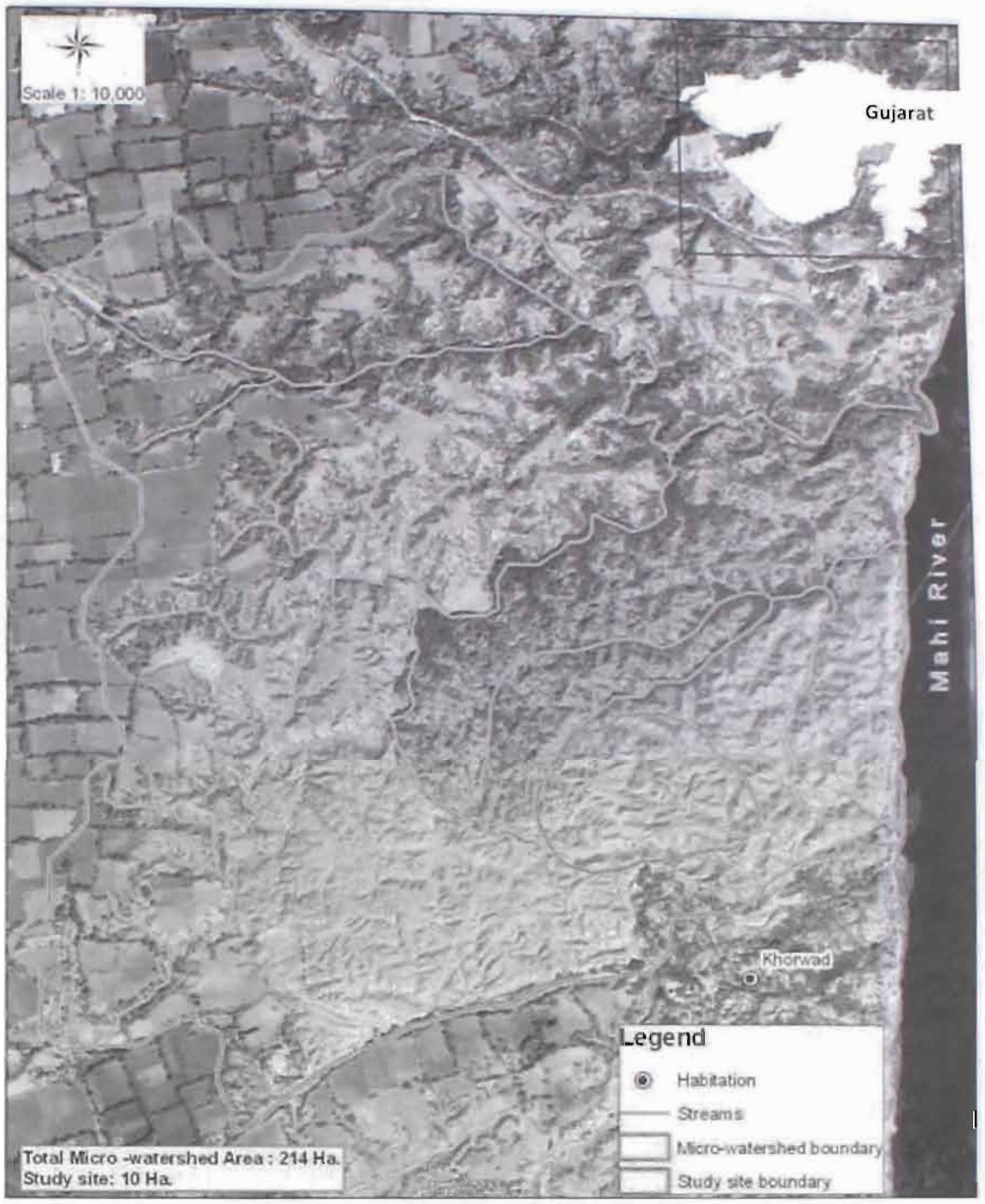
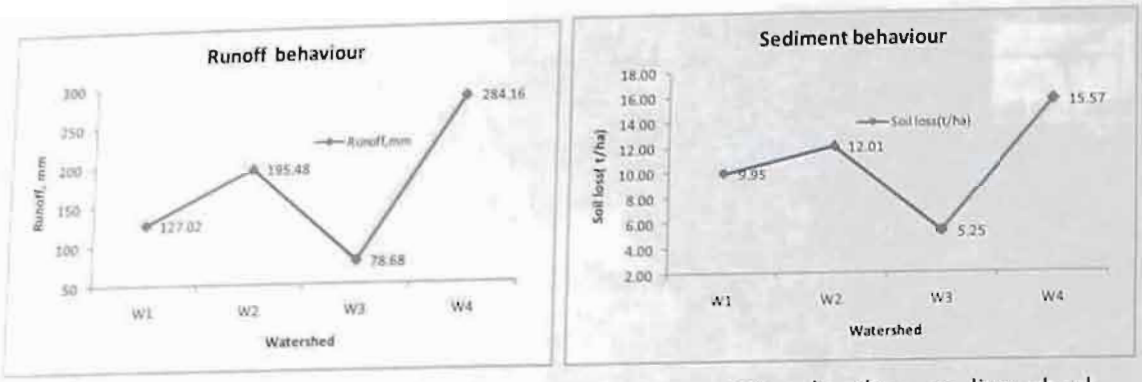


Figure 2. Degraded ravine lands along the Mahi River affecting the adjacent cultivated lands in Gujarat



W1 : bamboo plantation with trenches

W2 : bamboo as live check

Figure 3. Runoff and soil loss behavior under various treatments in degraded ravine

Figure 4. Growth of bamboo in degraded Mahi ravines in Gujarat

Table 1. State wise area under degraded ravine lands

State	Ravine area (million ha)
Uttar Pradesh	1.230
Madhya Pradesh	0.683
Bihar	0.600
Rajasthan	0.452
Gujarat	0.400
Maharastra	0.020
Punjab	0.015
Tamil Nadu	0.060
West Bengal	0.104
Total	**3.669**

(Source: V.V.Dhruvanarayana, 1993)

Table 2 : Growth parameters of bamboo at Research Farm, Vasad and Khorwad community land

Plantation date - July 2009

S. No.	Parameters	Research farm		Khorwad	
		2010	2011	2010	2011
1	Survival percentage (%)	80	80	74	72
2	Av. Height clump(cm)	115.4	131.0	100.5	115.9
3	Av. clump diameter (cm)	14.5	79.4	14.5	46.8
4	Av. Collar dia (cm)	0.9	1.2	0.87	1.1
5	Ratio of culms to clump	4.6	8	4.6	6

Table 3: Unit cost for cultivating 1 ha bamboo plantation in ravine land (2010-11 prices), Mahi Ravines

Sr. No	Items	Units	I year	II year	III year	IV year	V year	Total
	Material							
1	Planting material including 20% mortality replacement in second and third year		800	80	80		960	
2	Manure and fertilizers	Lumsum	95					95
3	Plant protection	Lumsum	600					600
4	Irrigation, 12 Nos.	Rs. 800/ irrigation	9600	9600	9600	6400		35200
	Sub total		11095	9680	9680	6400		36855
	Labour	**Mandays**						
1	Land preparation	Lumsum	6650					6650
2	Digging of trench , refilling @ Rs 45 per trench	400 Nos	18000					18000
3	Planting and staking	400 Nos	6000	600	600			7200
4	Soil working and others			3600	3600	3600	3600	14400
5	Watch &ward	Lumsum	3000	3000	3000	3000	3000	15000
	Sub total		33650	7200	7200	6600	6600	61250
	Contingency	5%	1683	432	432	330	330	3062
	Grand total		46428	17312	17312	13330	6930	101167

Table 4: Yield and Income of bamboo plantations, Mahi Ravines

Year	Yield (Poles No ha^{-1})	Net Income(Rs ha^{-1})
VII to X	1200	32,400
XI to XIX	1600	44,400
XX	1600	48,000

Integrated nutrient management in Castor under *Pongammia* based agrisilvi system

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ABSTRACT

One of the need based alternative land use system replacing the traditional farming system is a tree based system of cropping i.e. agro forestry which acts as sustainable land management system especially in dry land areas. *Pongamia pinnata* is a multipurpose tree and is a good nitrogen fixing tree also. This tree species is suitable for agroforestry system because of its fast growth and nitrogen fixation. It is the best suited tree for energy or biofuel plantation and castor being an important oilseed crop for southern Telangana region, field experiments were conducted during *kharif* 2010 and 2011 in sandy loam soils at Hyderabad to study the influence of integrated nutrient management in castor grown under sesame. The treatments mainly comprise of combination of organic (neem cake and farmyard manure) and inorganic(urea) nitrogenous fertilizers in different proportions applied to castor crop grown in the alleys of Pongamia(four year old).There was significant response to the INM treatments over control in all the parameters during both the years. Higher seed yield, stalk yield, nitrogen content, N,Pand K uptake from the soil were reported in the treatment wherein 75 % recommended nitrogen was applied through urea and 12.5 % nitrogen through organic source neem cake and 12.5 % through farm yard manure but, similar results were observed in 100 % recommended nitrogen applied in the form of urea. The influence of INM on oil content was found non significant. Hence it can be concluded that substitution of inorganic nitrogenous fertilizers with organic sources to an extent of 25 % was found better for successful growing of castor in Pongamia plantation in sandy loam soils of southern Telangana region of Andhra Pradesh.

Keywords: Agrisilvi System, Biofuel, Integrated Nutrient Management

INTRODUCTION:

One of the need based alternative land use system replacing the traditional farming system is a tree based system of cropping *i.e.*, agroforestry which acts as sustainable land management system especially in dry land areas.

Pongamia pinnata is a multipurpose tree species (MPTS) and it is a good nitrogen fixing tree also. This tree species is sustainable for agroforestry farming because of its fast growth and nitrogen fixation. It is the best suited tree for energy plantations.

Since the gestation period is high in *Pongamia* and because of wider spacing between the trees the interspaces can be effectively used for intercropping. Castor (*Ricinus communis* L.) being one of the important non edible oil seed crop of the country and state as well, is largely cultivated under rainfed condition. Castor is the

second most important oilseed crop of Andhra Pradesh in terms of acreage and economy after groundnut. The average yields of the crop were 1346 kg ha^{-1} and 510 kg ha^{-1} for India and Andhra Pradesh respectively (CMIE, 2010) which was regarded as very low though occupying first rank in area in the country. For improved production of castor, application of required quantities of fertilizer is imperative through sustained soil health. Soil fertility build up through agroforestry and practice of integrated nutrient management were suggested as potential means to increase the soil fertility especially in dry lands (Reddy *et al.* 1991). For efficient production and management of castor in dry lands it is necessary to seek alternate practices like integrated nutrient management and soil and moisture conservation.

Keeping these facts in view, a comprehensive study is therefore planned in which different combinations of organic manures and inorganic fertilizers were applied to *Pongamia* + Castor agri-silvi system.

MATERIAL AND METHODS

The experiments were conducted during *Kharif* 2009-10 and 2010-11 in sandy loam soils at students' farm, College of Agriculture, Rajendranagar, Hyderabad. The soil was red sandy loam in texture and neutral in soil reaction, low in organic carbon and available nitrogen and medium in available phosphorous and potassium. The experiment was laid out in Randomized block design with three replications and nine treatments viz., T1-Control; T2-100% Recommended Dose of Nitrogen (RDN) (Inorganic);T3-75% RDN (Inorganic); T4-75% RDN (Inorganic) + 25% RDN (FYM); T5-75% RDN (Inorganic) + 25% RDN (Neem cake); T6-75% RDN (Inorganic) + 12.5% RDN (FYM) +12.5% RDN (Neem cake); T7-50% RDN (Inorganic) + 25% RDN (FYM); T8-50% RDN (Inorganic) + 25% RDN (Neem cake); T9-50% RDN (Inorganic) + 12.5% RDN (FYM) +12.5% RDN (Neem cake) and the requisite amount of nitrogen was applied through urea as per the treatments based on the recommended dose *i.e.*, 60 kg N ha^{-1}. The nitrogen was applied in three equal splits, first dose as basal and the remaining doses at 30 and 60 days after sowing (DAS). Whereas uniform dose of 40 kg P_2O_5 and 30 kg K_2O per hectare were applied through single superphosphate and muriate of potash respectively as basal dose to all the experimental plots. The amount of rainfall received during crop growth period was adequate for normal growth of crop. The vegetative stage of crop was healthy due to uniform distribution of rains but the incessant rains received during crop growth coincided with flowering and capsule formation stages and contributed to severe incidence of castor semilooper and *Botrytis,* this in turn affected the seed yield of castor drastically and hence low yields were recorded in the second year of the experiment. Initially soil samples were drawn at random from 0-30 cm depth of the experimental field and the composite soil sample was analysed for different physico-chemical properties and the results are presented in Table 3.1.

The results of physico-chemical analysis revealed that the soil was red sandy loam in texture and neutral in soil reaction, low in organic carbon, low in available nitrogen (139 kg ha^{-1}) and high in available phosphorous (49 kg ha^{-1}) and medium in available potassium (144 kg ha^{-1}).

RESULTS AND DISCUSSIONS

Seed yield, stalk yield and oil content

Among the treatments, significantly higher seed yield and stalk yield was recorded with the application of 75% RDN through urea and 12.5% RDN through FYM and 12.5% RDN through neem cake, but was on par with 100% RDN through urea and 75% RDN through urea and 25% RDN through neem cake(Table 1). These results were in agreement with the findings of Reddy et al. (1993) and Rao et al. (2000). Nitrogen content and N,P,K uptake was higher with 75% RDN through urea and 12.5% RDN through FYM and 12.5% RDN through neem cake over control, and it was followed by 100% RDN through urea. Whereas the influence of INM on oil content was found non significant. Raghavaiah and Babu (2000) also reported similar results. Significant increase in the seed yield and stalk yield was recorded in the INM treatments over the control (Table 3). However, harvest index was not influenced by INM treatments. The influence of INM on the oil content of castor was found non significant. Similar results were also observed by Baby and Reddy (1998). But the oil yield per hectare was significantly higher with the application of 75% RDN through urea and 12.5% RDN through FYM and 12.5% RDN through neem cake over all the other treatments. Effect of integrated nutrient management treatments on the tree parameters of *Pongamia* was found non significant (Table 4). The effect may be seen over a long run.

Initial and Final Nutrient Studies

Integrated nutrient management practices have brought about significant differences in the available nitrogen content in the soil after harvest over control. Available N content in the soil after harvest was analysed statistically and presented in the Table 2. The available nitrogen content was significantly higher in T_6 (75% RDN-Inorganic + 12.5% RDN-FYM +12.5% RDN-Neem cake) and it was on par with T_4 (75% RDN-Inorganic + 25% RDN-FYM), T_5 (75% RDN-Inorganic + 25% RDN-Neem cake) and T_9 (50% RDN-Inorganic + 12.5% RDN-FYM +12.5% RDN-Neem cake).

The available N content in soil after the harvest of crop ranged from 138.77 to 173.62 kg ha^{-1}. Available N was notably higher under all INM treatments including control than that of initial value. This may be attributed to low dry matter produced due to heavy rains and also due to the addition of leaf litter to the soil. Being a legume tree, *Pongamia* has ability to fix N, hence available N content further increased during both the years. Similar results were obtained by Rao (2005) and Vani (1995) in *Hardwickia binata* and *Faidherbia albida* based agri-silvi system respectively.

The higher available N content was also attributed to the use of organic manures like FYM and neem cake which slows down the mineralisation of organic matter and thus increased the availability of nutrients. These results were in accordance with Mathukia and Modhwadia (1995) and Devi *et al.* (2002).

Plant Uptake of N, P and K at Harvest

Uptake of nitrogen, phosphorus and potassium by castor crop was significantly influenced by different integrated nutrient management treatments. It was analysed statistically and presented in Table 2.

Significantly higher nitrogen uptake by the castor crop was recorded in the T_6 (75% RDN-Inorganic + 12.5% RDN-FYM +12.5% RDN-Neem cake) (46.51 kg ha^{-1}) over T_2 (100 % RDN-Inorganic) (39.57 kg ha^{-1}) during both the years. Significantly

lower nitrogen uptake was recorded in the T_1 (control) (24.05 kg ha^{-1}). The higher uptake of nitrogen in T_6 treatment was attributed to high dry matter production in that treatment and also due to synergistic effect of FYM and neem cake where FYM on decomposition produces acids which played vital role in mineralization of nitrogen. Similar findings were recorded by Rao and Venkateshwarlu (1998), Reddy *et al.* (1993) and Pooran Chand *et al.* (2004). Application of fertilizers might have helped in maintenance of nutrients at optimum level in the plant enabling quick establishment of plant with good root development.

Maximum phosphorus and potassium uptake by the castor crop was recorded in T_6 (75% RDN-Inorganic + 12.5% RDN-FYM +12.5% RDN-Neem cake) (8.03 kg ha^{-1} & 41.54 kg ha^{-1} respectively) and it was on par with all the INM treatments except with T_3 and control. The higher phosphorus uptake in T_6 (75% RDN-Inorganic + 12.5% RDN-FYM +12.5% RDN-Neem cake) was mainly attributed to the high drymatter production in that treatment and also due to the application of organic sources like FYM and neem cake. The minimum phosphorus uptake was recorded in the T_1 (control) (5.27 kg ha^{-1} & 27.43 kg ha^{-1} respectively) during both the years.

Hence it can be concluded that for improving the yield and quality of castor with the sustained soil productivity, combined usage of organic manures and chemical fertilizers in the Pongamia based alleycropping was found to be beneficial.

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Table.1 Seed yield, stalk yield and oil content of castor as influenced by INM treatments

Treatments	Seed yield kg/ha		Stalk yield kg/ha		Oil content	
	I year	II year	I year	II year	I year	II year
T1-Control	136.10	120.10	589.20	586.66	52.11	52.37
T2-100% Recommended Dose of Nitrogen (RDN) (Inorganic)	349.72	319.60	1402.00	1361.73	50.26	50.63
T3-75% RDN (Inorganic)	183.67	153.80	682.36	656.14	51.38	52.53
T4-75% RDN (Inorganic) + 25% RDN (FYM)	228.50	208.00	911.50	883.23	51.99	50.96
T5-75% RDN (Inorganic) + 25% RDN (Neem cake)	350.20	324.17	1363.40	1347.31	50.87	50.78
T6-75% RDN (Inorganic) + 12.5% RDN (FYM) +12.5% RDN (Neem cake)	367.16	346.30	1455.50	1423.93	52.22	52.43
T7-50% RDN (Inorganic) + 25% RDN (FYM)	196.00	166.00	752.60	732.89	51.76	51.64
T8-50% RDN (Inorganic) + 25% RDN (Neem cake)	213.20	182.20	797.80	771.38	52.08	51.98
T9-50% RDN (Inorganic) + 12.5% RDN (FYM) +12.5% RDN (Neem cake)	231.00	194.00	837.00	804.31	52.26	52.07
S.Em.±	14.74	10.19	39.22	34.66	0.80	1.64
CD (P=0.05)	42.60	30.82	112.2	86.75	NS	NS

Table.2 Nutrient content in soil and plant uptake of castor as influenced by INM treatments

Treatments	N uptake kg/ha		Puptake Kg/ha		K uptake kg/ha		Available nitrogen content kg/ha after harvest	
	I year	II year	I year	II year	I year	II year	I year	II year
T1-Control	27.32	24.05	6.42	5.27	28.42	27.43	142.22	138.77
T2-100% Recommended Dose of Nitrogen (RDN) (Inorganic)	41.26	39.57	8.63	7.43	42.96	41.15	156.24	153.25
T3-75% RDN (Inorganic)	32.98	30.16	6.88	5.97	29.66	27.86	151.63	147.66
T4-75% RDN (Inorganic) + 25% RDN (FYM)	34.66	32.57	8.96	7.07	38.67	37.25	174.10	170.01
T5-75% RDN (Inorganic) + 25% RDN (Neem cake)	36.01	34.73	8.34	7.48	38.58	37.43	174.11	170.45
T6-75% RDN (Inorganic) + 12.5% RDN (FYM) +12.5% RDN (Neem cake)	48.27	46.51	8.88	8.03	43.31	41.54	176.23	173.62
T7-50% RDN (Inorganic) + 25% RDN (FYM)	35.01	33.12	9.16	7.13	40.11	38.41	158.11	154.46
T8-50% RDN (Inorganic) + 25% RDN (Neem cake)	36.89	35.79	8.22	7.62	39.22	37.47	159.09	157.39
T9-50% RDN (Inorganic) + 12.5% RDN (FYM) +12.5% RDN (Neem cake)	38.92	37.56	8.87	7.59	38.67	37.21	167.27	164.57
S.Em.±	1.67	1.34	0.58	0.33	1.85	1.45	5.7	4.61
CD (P=0.05)	4.97	3.83	1.73	1.00	5.52	4.39	17.11	14.32

Table.3 Tree parameters of Pongamia as influenced by INM treatments

Treatments	Tree height (m)		Diameter at breast height (m)		Canopy spread E-W direction (m)		Tree yield (Kg/ha)	
	I year	II year	I year	II year	I year	II year	I year	II year
T1-Control	4.61	4.62	9.24	9.27	4.49	4.58	3.28	3.30
T2-100% Recommended Dose of Nitrogen (RDN) (Inorganic)	4.85	4.85	8.96	9.06	4.52	4.64	3.68	3.70
T3-75% RDN (Inorganic)	4.82	4.82	9.27	9.37	4.36	4.44	3.75	3.80
T4-75% RDN (Inorganic) + 25% RDN (FYM)	4.06	4.07	9.69	9.78	4.16	4.26	3.36	3.40
T5-75% RDN (Inorganic) + 25% RDN (Neem cake)	4.36	4.36	9.51	9.62	4.12	4.28	3.78	3.90
T6-75% RDN (Inorganic) + 12.5% RDN (FYM) +12.5% RDN (Neem cake)	5.03	5.04	8.84	8.94	4.32	4.46	3.65	3.80
T7-50% RDN (Inorganic) + 25% RDN (FYM)	4.24	4.25	8.63	8.74	3.98	4.00	3.16	3.20
T8-50% RDN (Inorganic) + 25% RDN (Neem cake)	3.82	3.82	9.16	9.33	4.21	4.34	3.65	3.70
T9-50% RDN (Inorganic) + 12.5% RDN (FYM) +12.5% RDN (Neem cake)	4.81	4.82	9.01	9.18	4.51	4.62	3.54	3.60
S.Em.±	0.51	0.54	0.46	0.54	0.63	0.68	0.97	0.91
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Study on growth, yield and quality parameter of oil palm under different levels of moisture regime, n and k fertigation

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ABSTRACT

Investigation was carried out during the 2010-2011 at Soil and Water Management Research Farm, Navsari Agricultural University, Navsari to evaluate the effect of different levels of moisture regime, N and K fertigation on growth, fresh fruit bunch (FFB) and oil yield of oil palm. The treatments comprising of 2 levels each of moisture regime (1.0 and 1.2 PEF), N and K (1.2 and 2.4 kg/palm) fertigation triplicated in factorial randomized block design. The soil of experimental site was clay in texture, low in available N and P, medium in available S and Zn and high in available K, Fe, Mn and Cu. Among all the growth attributing characters *viz.*, number of leaves, length of longest leaves, spread and girth were not influenced significantly due to different treatments. However, FFB yield was significantly influenced by moisture regime and N levels. The higher FFB yield was observed in the I_2 level of moisture regime (66.08 kg/tree) and N_2 level of N (62.50 kg/tree), as compared to lower level. The quality parameter like oil content in mesocarp and kernel of oil palm fruit was not differ significantly due to different treatments. The significantly higher oil yield from both the component of oil palm fruit and its total were higher in I_2 moisture regime as compared to I_1. The mesocarp, kernel and total oil yield under the treatment I_2 were 11.0, 1.3 and 12.3 kg/year/plant, respectively.

Keywords: Nitrogen, Potassium, Moisture regime, Oil palm

INTRODUCTION

Oil palm (*Elaeis guineensis Jacq.)* has been recognized widely accepted as the highest oil yielding perennial crop (Abraham, 1994). It is grown in humid tropics with evenly distributed rainfall of 2500-4000 mm/annum or with an assured irrigation source. It has been reported to yield 9-32 times more oil *i.e.* (4-6 t/ha/year) for period of 3 to 25 years of life span, compared to other traditional annual oilseed crops of the country (Chadha and Rethinam, 1991). It produces two types of oils. *i.e.*, palm oil and palm kernel oil. Palm oil is derived from the fleshy mesocarp of the fruit, which contains about 45-55 % of oil and the palm kernel oil is obtained from the stony seed which contains about 50 % of oil. Oil palm can also substantially contribute to the nutritional and energy requirements of the common man. The net area under oil palm available during 2009-10 is 1.64 lakh ha. Production of FFB during 2004-05 was 1.45 lakh tonnes and it was increasing to 2.91 lakh tonnes during 2008-2009.

Irrigation and fertilizers are critical inputs for higher yield in oil palm. Irrigation studied at Pedavegi revealed application of irrigation through drip at PEF 1.0 and 1200:600:1200 g N, P_2O_5 and K_2O per palm recorded higher FFB yield after fourth

year of planting under rainfed condition of Palode (Anon., 2006). However, requirement of nutrients and irrigation is depend upon the soil and agro-climatic conditions of the area (Nair and Sreedharan, 1983).

The oil palm is newly introduced oil yielding crop in the country and hence oil palm research in India is in infant stage. Very little information is available with regards to nutrient and water requirement of oil palm under Indian conditions and more so for Gujarat conditions. Keeping in view, the present investigation was aimed to study the effect of levels of moisture regime, N and K fertigation on growth, yield and quality parameter of oil palm

MATERIAL AND METHODS

The present study was conducted at Soil and Water Management Research Farm, N.A.U., Navsari during 2010 - 11. This place is situated at 20° 57' N latitude, 72° 54' E longitude and has an altitude of about 10 m above the mean sea level. The climate of this zone is typically tropical. The temperature ranges from a maximum of 37-40 ^{0}C in May and and minimum of about 10 ^{0}C in December to January. The average annual rainfall of the tract is about 1500 mm of which major portion is received during July to August. According to Seventh Approximation, the soil of the experimental field is classified under the order *'Inceptisols'* comprising members of fine, montmorillonitic, isohyperthermic family of *Vertic Ustrochrepts*. The soil develops deep cracks and becomes hard when dry, while plastic and sticky when wet. The average thickness of solum range 2.5 to 3.0 m. The soil of the experimental field had pH 7.4, EC 0.21 dS/m, and Organic C 0.59%. The soil was low in available N and P, medium in available S and Zn and high in available K, Fe, Mn and Cu. Eight treatment combinations comprising each of two levels of moisture regimes *viz.*, 1.0 PEF and 1.2 PEF, N 1200 and 2400 g/tree/year and K 1200 and 2400 g/tree/year were evaluated in factorial randomized block design with three replications. Oil content in mesocarp and kernel of oil palm was determined with the help of Soxhlet apparatus by using petroleum ether as a solvent (Tiwari *et al.* 1974).

Ten year old oil palm *cv.* Tenera planted at 9 × 9 m (triangular planting) was selected for this experiment. In each treatment, equally growing two plants were selected for recording all the observations during the course of present study. In all the treatment a common dose of biocompost @ 15 t/ha and P_2O_5 @ 600 g/palm/year through single super phosphate was applied as basal dose by soil application method, while N and K were applied through drip as per treatments using urea and muriate of potash. N and K were applied in eight splits at 15 days interval in month of April-May and October-November, respectively.

RESULTS AND DISCUSSION

Growth parameters and yield

The data on different growth parameters *viz.*, number of leaves per plant, longest leaf, spread and girth as well as FFB yield as influenced by different treatments are presented in Table 1.

The different growth parameters *viz.*, number of leaves per plant, longest leaves, spread and girth were not affected significantly due to levels of moisture regimes. However, FFB yield was significantly affected by moisture regime. The fresh fruit bunches (FFB) yield was significantly higher (66.08 kg/palm) in 1.2 PEF (I_2) treatment

as compared to 1.0 PEF (I_1) treatment. An increase in yield under 1.2 PEF treatments (I_2) could be due to matching the water requirement of the crop.

The effect of N on growth and yield parameters was similar to that observed in moisture regime. Here, only fresh fruit bunch yield was affected significantly by levels of N and it was higher with N_2 (62.5 FFB kg/palm) as compared to N_1 (58 FFB kg/palm). Timely availability of N in required quantity seems to be responsible for increase in the growth and yield of oil palm. The possibility of making N available at right time and quantity to oil palm is much more improved when crop is irrigated by drip method.

The K application at two rates did not show any significant effect on growth parameters *viz.*, number of leaves per palm, longest leaves, spread and girth as well as FFB yield. This might be due to initial high K content in experiment soil.

Similar beneficial effects of moisture regimes and fertilizer application were also reported by Rajasekhar *et al.* (1988), Reddy *et al.* (2009) and Krishna Rao (2009) for oil palm crop under different agro climatic conditions of south India.

Oil content and yield

The oil content and yield was determined from mesocarp and kernel of oil palm fruit separately and the results are presented in table 2.

None of the factor individually or interactively affected significantly the oil content in mesocarp as well as kernel. However, individual treatment of moisture regime affected significantly the mesocarp, kernel and total oil yield. The mesocarp, kernel and total oil yield under the treatment I_1 were 9.0, 1.0 and 10.1 kg/y/p, respectively. The respective values of oil yield under I2 were 11.0, 1.3 and 12.4 kg/y/p. This implies that oil yield is directly related with FFB yield.

CONCLUSION

From the results of present study it can be concluded that achieving higher FFB yield under South Gujarat conditions, it is essential to irrigate the crop at 1.2 PEF through drip along with fertigation of N @ 2.4 kg/palm and K_2O @ 1.2 kg/palm. Apply P @ 0.6 kg/palm before monsoon per year.

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Table- 1: Growth parameters and FFB yield of oil palm under different treatments

Treatments	No. of leaves/palm	Longest leaves (m)	Spread (m)		Girth (m)	FFB (kg/palm)
			E-W	S-N		
Irrigation (Drip)						
I_1: 1.0	49.79	6.46	11.05	11.33	2.94	54.42
I_2: 1.2	50.08	6.68	11.41	11.63	3.02	66.08
SEm±	1.24	0.07	0.17	0.16	0.03	1.46
CD @ 5%	NS	NS	NS	NS	NS	4.43
Nitrogen levels (kg/palm)						
N_1: 1.2	49.12	6.47	11.09	11.35	2.94	58.0
N_2:2.4	50.74	6.67	11.36	11.59	3.01	62.50
SEm±	1.24	0.07	0.17	0.16	0.03	1.46
CD @ 5%	NS	NS	NS	NS	NS	4.43
Potassium levels (kg/palm)						
K_1: 1.2	48.39	6.51	11.14	11.37	2.97	59.08
K_2: 2.4	51.48	6.63	11.32	11.58	2.99	61.42
SEm±	1.24	0.07	0.17	0.16	0.03	1.46
CD @ 5%	NS	NS	NS	NS	NS	NS
CV (%)	8.65	3.93	5.44	4.93	4.46	8.41
Interactions	NS	NS	NS	NS	NS	NS

Table: 2 Effect of moisture regime and fertigation on oil content and yield of mesocarp and kernel of palm fruit

Treatments	Oil/ Mesocarp (%)	Oil/Kernel (%)	MOY/ Y/P (kg)	KOY/Y/P (kg)	Total yield (kg/Y/P)
Irrigation (Drip)					
I_1: 1.0	53.5	45.8	9.0	1.0	10.1
I_2: 1.2	54.2	46.7	11.0	1.3	12.4
SEm±	0.97	0.85	0.36	0.043	0.40
CD @ 5%	NS	NS	1.1	0.1	1.2
Nitrogen levels (kg/palm)					
N_1: 1.2	53.2	46.2	9.5	1.1	10.7
N_2:2.4	54.2	46.2	10.5	1.2	11.8
SEm±	0.97	0.82	0.36	0.04	0.40
CD @ 5%	NS	NS	NS	NS	NS
Potassium levels (kg/palm)					
K_1: 1.2	53.3	45.9	9.8	1.2	11.0
K_2: 2.4	54.4	46.6	10.3	1.2	11.5
SEm±	0.97	0.82	0.36	0.04	0.40
CD @ 5%	NS	NS	NS	NS	NS
CV (%)	6.21	6.38	12.40	12.70	12.17
Interactions	NS	NS	NS	NS	NS

MOY = Mesocarp oil yield, KOY = Kernel oil yield

Effect of alley width and organic manure on productivity of groundnut and in-situ moisture conservation under Dryland Ecosystem

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ABSRTACT

An experiment was conducted during the *kharif* season of 2000-01 to 2005-06 to find out suitable alley width and organic manure for groundnut crop on medium black clay soil (*vertisols*) at Main Dry Farming Research Station, Targhadia (Rajkot). The pod and haulm yield of groundnut were improved with the increase in levels of alley width and recorded significantly highest under 9.6 m alley width. Whereas, significantly higher green bio mass of gliricidia and soil moisture content were obtained under 6.0 m alley width. Application of FYM @ 5.0 t/ha recorded significantly higher pod yield of groundnut While lopping of gliricidia applied as mulch recorded significantly higher soil moisture content (%). Interaction effect was found non-significant in respect of pod and haulm yield of groundnut and green bio mass of glyricidia. Whereas, significantly higher soil moisture content was recorded under lopping of gliricidia applied as mulch with 9.6 m alley width. Growing of groundnut with glyricidia at the alley width of 9.6 m gave the highest net returns of Rs. 15668 / ha with the benefit: cost ratio of 1.12. While application of FYM @ 5 t/ha gave the highest net returns of Rs. 14230 / ha as compared to control.

Keywards: Alley cropping, Alley width, Organic manure, Groundnut, Gliricidia, Economics

INTRODUCTION

Low and unstable crop yield are common phenomena in dry farming area due to low, erratic and uneven distribution of rainfall and high rate of evaporation. Also low soil moisture and humidity in the canopy have its own limitation in successful crop production in dry land area. Alley cropping is one of the most important alternate land use system for arable land. Alley cropping or hedgerow intercropping is an agro forestry practice in which perennial, preferably leguminous trees or shrubs are grown simultaneously with an arable crop. The trees, managed as hedgerows, are grown in wide rows and the crop is planted in the interspace or 'alley' between the tree rows. During the cropping phase the trees are pruned and the prunings used as green manure or mulch in the crop to improve the organic matter status of the soil, in-situ moisture conservation and to provide nutrients, particularly nitrogen, to the crop. Alley cropping is used to enhance or diversify farm products, reduce surface water runoff and erosion, improve utilization of nutrients, reduce wind erosion, modify the microclimate for improved crop production, improve wildlife habitat, and enhance the aesthetics of the area (Kang *et al.* 1990).Groundnut found more potential and compatible with subabul and perennial pigeon pea under alley cropping (Khistaria *et al.*1998). Gliricidia is one of the few forage tree species capable of leaf yields comparable to those of leucaena. The half life of pruning of *Gliricidia sepium* reported by Wilson *et al.*(1986) to be 20

days, has been found to be relatively short compared with that of *Leucaena leucocephala* and *Fleminigia macrophylla* (Budelman 1988).The present study was therefore plan to find out suitable alley width with organic manure for groundnut crop under alley cropping.

MATERIALS AND METHODS

A field experiments was conducted on medium black clay soil (*vertisol*) at Main Dry Farming Research Station, Junagadh Agricultural University, Targhadia (Rajkot) during the rainy (*kharif*) season of 2000-01 to 2005-06. The soil was clayey, medium in available nitrogen and phosphorus and high in available potassium with mildy alkaline and non-saline. The experiment was laid out in Split-plot design with 3 replications. There were three main plot treatments with Gliricidia hedgerows width 6.0, 7.8 and 9.6 m. Main plot size was 20 m x 12 m, 20 m x 15.6 m and 20 m x 19.2 m for alley width 6.0, 7.8 and 9.6 m, respectively. Gliricidia hedgerows were established using 3-months old seedlings grown in polythylene bags in the year of 2001-02. Seedlings were planted in an inter-row spacing of 0.50 m in the hedgerows and spacing between the hedgerows as per alley width. The alley-cropped treatment consisted of two hedgerows with 20 m long alley between each as per alley width treatments. There were three organic manures (Farm yard manure @ 5.0 t/ha, lopping of gliricidia applied as mulch in between rows of groundnut at 45 days after of sowing and control) which made up subplot treatments. Sub plot size was 6.0 m x 12.0 m, 6.0 m x 15, 6 m and 6.0 m x 19, 2 m for alley width of 6.0, 7.8 and 9.6 m, respectively. Groundnut (GG-20) was sown at onset of monsoon every year with 60 cm distances between row and applied 12.5 kg N + 25.0kg P_2O_5/ha. Agronomic practices and plant protection measures were followed as and when required. The total rainfall received during the crop season (June to November) was 372.5, 411.6, 311.0, 803.2, 878.9 and1136.2 mm in 18, 33, 11, 41, 35 and 38 rainy days in the year of 2000, 2001, 2002, 2003, 2004 and 2005, respectively.

Productivity of groundnut, green bio-mass of gliricidia and moisture content (%) were pooled over four years (2001-02,2003-04,2004-05 and 2005-06) because pod yield of groundnut was recorded below average in remaining years (2000-01 and 2002-03) and gliricidia was not established in first year (2000-01).Economics of alley width and organic manure was worked out on the basis of pooled results of productivity of groundnut and gliricidia in terms of net returns/ha and B:C ratio considering the prevailing market price of produce and cost of cultivation.

RESULT AND DISCUSSION

1. Pod and haulm yield of groundnut:

A. Effect of alley width (W):

Effect of alley width on pod and haulm yield of groundnut was found to be non significant during all the four years of experimentation, but it was turned out significant in pooled results (Table-1). Pod and haulm yield of groundnut was increased with increases in alley width during all the four years except in the year of 2001-02 in respect of haulm yield and turned out significant in pooled results. Significantly highest pod and haulm yield of groundnut was recorded under 9.6 m alley width (W_3) as compared to -6.0 m alley width (W_1), but both were remaining at par with 7.8 m alley width (W_2) in pooled results. The pod and haulm yield of groundnut was reduced by

12.71 and 8.48 %, respectively in 6.0 m alley width compared to that of 9.6 m alley width. This might be due to close spacing between the hedge rows reduces the amount of land available for the crop and can results in increased competition for growth factors of light, moisture and nutrients between hedgerow and crop. Similar observations were reported by Pandey *et al.* (2001)

B. Effect of organic manures (O):

Effect of organic manure on pod yield of groundnut was found significant in three out of four years as well as in pooled results (Table-1). Significantly highest pod yield was recorded under application of FYM @ 5 t/ha (O_1) during all the three years and in pooled results as compared to lopping of gliricidia applied as mulch(O_2) and control (O_3) except in the year of 2003-04. In this year, lopping of gliricidia applied as mulch (O_2) was remained at par with application of FYM @ 5 t/ha (O_1).In case of haulm yield of groundnut, effect of organic manure was found significant during three out of four years, but it was turned out non significant in pooled results. Significantly highest fodder yield was recorded under application of FYM @ 5 t/ha (O_1) during all the three years as compared to control (O_3), but it was remained at par with lopping of alley crop (O_2). There were no significant difference between lopping of gliricidia applied as mulch (O3) and control (O3) in respect of pod and haulm yield. Similar results were reported by Supriadi *et al.* (1990).

C. Interaction effect (W x O) :

Interaction effect of alley width and organic manure was found non-significant during all the four years and in pooled results in respect of pod and haulm yield of groundnut

2. Green bio mass of glyricidia:

A. Effect of alley width (W):

Effect of alley width on green bio mass of glyricidia was found significant during the year of 2005-06 and in pooled results (Table-2). Green bio mass of glyricidia was decreased with increases in alley width during first three years and turned out significant difference in fourth year and in pooled results. Significantly highest green bio mass of glyricidia was recorded under 6.0 m alley width (W_1) in fourth year and in pooled results. But it was remained at par with 7.8 m alley width (W_2), which was at par with 9.6 m alley width (W_3) in pooled results. The results are in accordance with those of Ella *et al.* (1989)

B. Effect of organic manures (O):

Effect of organic manures on green bio mass of glyricidia was found to be non significant during all the four years and in pooled results.

C. Interaction effect (W x O):

Interaction effect of alley width and organic manure was found non-significant during all the four years as well as in pooled results in respect of green bio mass of glyricidia.

3. Soil moisture content (%):

A. Effect of alley width (W):

The differences in soil moisture content (%) were found to be non-significant due to different alley width during all the eight sampling of soil, but it was turned out significant in pooled results (Table-3). Significantly highest soil moisture content was recorded under 6.0 m alley width (W_1) as compared to 7.8 m (W_2), but it was remained at par with 9.6 m alley width (W_3) in pooled results.

B. Effect of organic manures (O) :

The differences in soil moisture content (%) were found to be non-significant due organic manures application during all the eight sampling of soil except in one sampling in 2004-05, but it was turned out significant in pooled results (Table-3). Significantly highest soil moisture content was recorded under the application of lopping of glyricidia as mulch (O_2) as compared to control (O_3), but it was remained at par with application of FYM @ 5 t/ha (O_1) in pooled results. The addition of mulch can lower soil temperatures, reduce evaporation and improve soil structure resulting in better in-situ moisture conservation.

C. Interaction effect (W x O):

Interaction effect of alley widths and organic manure was found non-significant during all the eight sampling of soil in respect of soil moisture content, but it was turned out significant in pooled results .Significantly highest soil moisture content was recorded under the combination of 9.6 m alley width and lopping of alley crop (W_3O_2) and remained at par with W_1O_1, W_1O_2 and W_1O_3 (Table-4).

4. Economics:

Economics of different treatment was worked out on the basis of pooled results and presented in table-5. The data indicated that growing of groundnut with glyricidia at the alley width of 9.6 m gave the highest net returns of Rs. 15668 / ha with the benefit: cost ratio of 1.12. While application of FYM @ 5 t/ha gave the highest net returns of Rs. 14230 / ha with benefit: cost ratio of 0.93.

CONCLUSION

It can be concluded that the farmers of North Saurashtra Agro-climatic Zone are advised to grow groundnut GG-20 with glyricidia at the alley width of 9.6 m and apply FYM @ 5 t/ha for getting higher yield of groundnut and net returns in the alley cropping system under dry farming conditions.

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Table 1a: Effect of different treatments of alley widths and organic manures on pod yield of groundnut

Sr No	Treatments	Pod yield of groundnut (q/ha)				
		2001-02	**2003-04**	**2004-05**	**2005-06**	**Pooled**
A	**Alley widths (W) :**					
1	6.0 m Alley width (W_1)	14.39	16.95	4.98	4.90	10.30
2	7.8 m Alley width (W_2)	16.50	17.01	5.61	5.57	11.17
3	9.6 m Alley width (W_3)	17.62	17.52	5.99	6.08	11.80
	S.Em. ±	1.13	0.67	0.27	0.27	0.34
	C.D. at 5 %	NS	NS	NS	NS	1.03
	C.V. %	21.05	11.73	14.59	14.68	18.55
B	**Organic manures (O) :**					
1	Farm yard manure @ 5 t/ha (O_1)	16.85	18.21	6.10	6.02	11.80
2	Lopping of gliricidia applied as mulch (O_2)	16.35	16.80	5.54	5.32	11.00
3	Control (O_3)	15.31	16.46	4.94	5.21	10.48
	S.Em. ±	0.57	0.43	0.14	0.21	0.19
	C.D. at 5 %	NS	1.32	0.42	0.64	0.54
C	**Interaction effect (W x O) :**					
	S.Em. ±	0.99	0.74	0.24	0.36	0.33
	C.D. at 5 %	NS	NS	NS	NS	NS
	C.V. %	10.58	7.47	7.43	11.28	10.20

Table 1b: Effect of different treatments of alley widths and organic manures on haulm yield of groundnut

Sr No	Treatments	Haulm yield of groundnut (q/ha)				
		2001-02	2003-04	2004-05	2005-06	Pooled
A	**Alley widths (W) :**					
1	6.0 m Alley width (W_1)	48.97	39.36	18.83	20.29	31.86
2	7.8 m Alley width (W_2)	47.25	40.63	21.37	23.57	33.21
3	9.6 m Alley width (W_3)	47.40	42.26	24.77	24.80	34.81
	S.Em. ±	1.61	0.91	1.39	1.38	0.67
	C.D. at 5 %	NS	NS	NS	NS	2.08
	C.V. %	10.11	16.67	19.24	18.03	12.13
B	**Organic manures (O) :**					
1	Farm yard manure @ 5 t/ha (O_1)	46.47	43.28	23.07	24.76	34.40
2	Lopping of gliricidia applied as mulch (O_2)	49.38	40.72	21.57	22.32	33.50
3	Control (O_3)	47.75	38.26	20.33	21.57	31.98
	S.Em. ±	0.91	0.99	0.51	0.85	0.77
	C.D. at 5 %	NS	3.04	1.58	2.61	NS
C	**Interaction effect (W x O) :**					
	S.Em. ±					
	C.D. at 5 %	1.58	1.71	0.89	1.47	0.72
	C.V. %	NS	NS	NS	NS	NS
		5.73	7.27	7.09	11.10	7.52

Table.2: Effect of different treatments of alley widths and organic manures on green bio mass of glyricidia

Sr No	Treatments	Green bio mass of glyricidia (q/ha)				
		2001-02	2003-04	2004-05	2005-06	Pooled
A	**Alley widths (W) :**					
1	6.0 m Alley width (W_1)	7.74	18.47	59.72	77.32	40.81
2	7.8 m Alley width (W_2)	5.50	11.80	43.80	63.39	31.13
3	9.6 m Alley width (W_3)	5.08	13.00	39.06	52.66	27.45
	S.Em. ±	1.33	1.85	5.18	3.14	2.80
	C.D. at 5 %	NS	NS	NS	12.34	9.69
	C.V. %	35.38	38.53	32.71	14.63	29.32
B	**Organic manures (O) :**					
1	Farm yard manure @ 5 t/ha (O_1)	6.31	13.57	46.05	64.40	32.58
2	Lopping of gliricidia applied as mulch (O_2)	6.65	14.90	47.32	64.25	33.28
3	Control (O_3)	5.37	14.81	49.22	64.71	33.53
	S.Em. ±	0.58	1.80	3.31	3.18	1.24
	C.D. at 5 %	NS	NS	NS	NS	NS
C	**Interaction effect (W x O) :**					
	S.Em. ±	1.00	3.13	5.74	5.51	2.15
	C.D. at 5 %	NS	NS	NS	NS	NS
	C.V. %	28.40	37.53	20.91	14.81	22.49

Table 3: Effect of different treatments of alley widths and organic manures on soil moisture content (%)

Sr No	Treatments	Soil moisture content (%)								
		27.8.01	**23.6.03**	**1.8.03**	**6.9.03**	**3.7.04**	**24.8.04**	**11.8.05**	**30.9.05**	**Pooled**
A	**Alley widths (W) :**									
1	6.0 m Alley width (W_1)	27.02	39.39	34.17	35.66	34.07	34.75	37.15	34.93	34.64
2	7.8 m Alley width (W_2)	25.19	36.88	33.77	33.46	30.06	32.63	34.25	34.05	32.54
3	9.6 m Alley width (W_3)	25.31	37.85	34.31	33.59	32.43	34.94	35.17	33.98	33.45
	S.Em. ±	0.97	1.57	1.79	1.57	1.07	1.43	1.20	0.70	0.47
	C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	1.36
	C.V. %	11.30	12.36	15.79	13.77	9.97	12.53	10.12	6.10	11.91
B	**Organic manures (O) :**									
1	Farm yard manure @ 5 t/ha (O_1)	25.23	37.39	34.22	34.55	32.17	33.60	35.24	35.00	33.43
2	Lopping of gliricidia applied as mulch (O_2)	26.63	39.35	34.87	34.32	32.75	35.50	35.76	34.13	34.17
3	Control (O_3)	25.66	37.37	33.15	33.84	31.64	33.22	35.57	33.83	33.04
	S.Em. ±	0.43	0.90	0.64	1.06	0.67	0.52	0.87	0.75	0.27
	C.D. at 5 %	NS	NS	NS	NS	NS	1.60	NS	NS	0.75
C	**Interaction effect (W x O) :**									
	S.Em. ±	0.75	1.55	1.11	1.84	1.15	0.90	1.51	1.30	0.46
	C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	1.30
	C.V. %	5.03	7.07	5.63	9.29	6.19	4.56	7.37	6.54	6.75

Table.4: Interaction effect of alley widths and organic manure on soil moisture content (%) in pooled results

T/O	O_1	O_2	O_3	Mean		
W_1	34.75	34.66	34.52	**34.64**		
W_2	32.86	32.53	32.22	**32.54**	S.Em. ±	C.D. at 5 %
W_3	32.67	35.31	32.37	**33.45**	0.46	1.30
Mean	**33.43**	**34,17**	**33.04**			

Table 5:Economics of different treatments of alley width and organic manures for groundnut under dry farming conditions

Sr No	Treatments	Yield of groundnut (q/ha)		Green bio mass of glyricidia (q/ha)	Gross Returns (Rs./ha)	Cost of cultivation (Rs./ha)	Net Returns (Rs./ha)	Benefit : Cost ratio
		Pod	Fodder					
A	**Alley widths (W) :**							
1	6.0 m Alley width (W_1)	10.30	31.86	40.81	26447	14030	12417	0.89
2	7.8 m Alley width (W_2)	11.17	33.21	31.13	28085	13970	14115	1.01
3	9.6 m Alley width (W_3)	11.80	34.81	27.45	29478	13910	15568	1.12
B	**Organic manures (O) :**							
1	Farm yard manure @ 5 t/ha (O_1)	11.80	34.40	32.58	29525	15295	14230	0.93
2	Lopping of gliricidia applied as mulch (O_2)	11.00	33.50	33.28	27882	15052	12830	0.85
3	Control (O_3)	10.48	31.98	33.53	26622	13970	12652	0.91

Price :

1. Pod of groundnut : 1850 Rs./q
2. Fodder of groundnut : 200 Rs./q
3. Green bio mass of glyricidia : 25 Rs./q
4. Farm yard manure : 200 Rs./tone

Role of Agroforestry interventions in increasing the status of natural gum yielding species in south east region of Rajasthan

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ABSTRACT

Non wood forest products are important livelihood sources for local dwellers and industrial application have been expanded tremendously in recent years. Rise in population of human beings, livestock and overdependence of people in existing forest resources add abrupt climatic changes resulted a great impact to the rich diversity of forest flora in South east region of Rajasthan , It also drastically reduce the population of important natural gum yielding species *viz. Lannea coromendelica, Sterculia urens, Boswellia serrata, Albizzia lebbek, Mangifera indica, Acacia nilotica* and *Acacia senegal.* Gums obtained from most of these species are commercially important and have diverse uses (cosmetics, food, pharmaceutical, paper, textile and paint industries). To enhance the diversity of these species, agro forestry can play an important role since agriculture practices of this region is largely rain dependent. People have sufficient marginal land may be used for adopting agro forestry practices. Silvipastoral system is most suitable looking the phytogeographical condition of the area. Grasses species of *Cenchru ciliaris, Dicanthium annulatum, Cynodon dactylon Heteropogon contours* can be grown in this region to meet the fodder requirement of the area In between the grasses, the gum tree species can be raised at spacing of 5x4 mt. especially species of *Lannea coromendelica, Sterculia urens, Boswellia serrata, Acacia nilotica* and *Acacia Senegal.* However from the older trees of these species in natural stands, for obtaining the maximum gums from these species, different tapping techniques have been applied to enhance the gum production . Bore hole method of tapping of 4cm hole yielded higher gum yield when injected with ethephon 300 mg/ml and 400mg/ml in *Sterculia urens, Lannea coromendelica* and *Boswellia serrata.* The effect of chemical is also not giving any adverse effect on the health of the tree. After collecting, the products are sun dried for 3-4 days to remove moisture , particles of dust and bark .Grading is based on colour and purity. Application of sulphuric acid in low concentration does not support any significant result. Tree tapped with V shaped rill method of tapping with ethephon application of 400mg/ml also show more yield in *Boswellia serrata.* Ethephon induces gummosis without affecting the health of tree.

Keyword :- Gum, Agroforestry ,Tapping Techniques, Chemical Methods

INTRODUCTION

Owing to rich diversity of forest flora in Hadauti region, the forest trees of *Lannea coromendelica, Sterculia urens, Boswellia serrata, Albizzia lebbek ,Mangifera indica Acacia nilotica, Acacia senegal, Azadirachta indica,* and *Terminalia bellerica* are widely distributed in this region and can be utilized for gum extraction. Gums obtained from most of these species are commercially important and have diverse uses

.Moreover there is no proper method for gum extraction and these species are not commercially exploited for gums production. The basic idea of this study is to find out the highest gum yielding species of the region and evaluate the species yield in different locations. Generally people collect the products after it comes out of the injury. The small incisions and removing bark can be practiced to increase the yield and making it commercially viable option for extraction. It can help in providing employment to local dwellers and improving the socio-economic conditions of the people. People have not taken gum collection as a source of livelihood. Most of these trees are scattered in forest and non-forest areas and hardly is being exploited for gum collection. Higher grade gums are used for clarification of liqueurs, finishing of silk and preparation of water colours and intermediate grade used in confectionary, pharmaceutical, printing inks, sizing, finishing textile fabrics, dyeing and inferior grade are used in calico printing, sizing paper and in paint industry. These species are exploited indiscriminately by the locals for timber, fuel wood and fodder resulted in dwindling population in the forests. Meanwhile these forests are not being tapped commercially for gum collection; moreover there is no proper method for its collection from the forests. Development of proper tapping methods may enhance the gum yield. Increase in the yield would promote the locals involvement in gum collection, it provides an employment opportunity to local people. However, higher gum yielding trees helps in their multiplication and plantation in private waste lands of the local communities for encouraging Silvipasture system and enhance the fodder availability in the area ,Species like *Lannea coromendelica* in the farm land of this region has potential in raising the farm income with tapping of gums from the trees found in the field bunds and pasture. Marginal farmers may be encouraged to raise potential gum yielding trees in their waste land not utilized for agriculture and horticulture purposes .

Climate of this region is sub humid and this area is included in semi arid and sub humid region. The vegetation of area is mostly composed of mixed deciduous type forests, with clear indications of the adverse effect of climatic, edaphic and biotic factors on plant communities present in various localities of the area. The western parts of Deccan Plateau have dense forests, deciduous trees are mostly found on hill tops. The forests of the area includes *Adina cordifolia, Aegle marmelos, Boswellia serrata, Buchanania lanzan, Cassia fistula, Dendrocalamus strictus, Diospyros melanoxylon, Lagerstroemia parviflora, Lannea coromandelica, Nyctentheis arbor-tristis* and *Sterculia urens* etc. are more abundant in the middle zone, while *Acacia leucophloea, Holoptelea integrifolia* and *Butea monosperma* etc. are at the foot or out skirts. *Anogeissus pendula* is the dominant species of these forests extending right from the base to the top of the hills. Besides the tree species the perennial shrubs like: *Lantana camara, Zizyphus nummularia* and *Carissa congesta* are very common. This region is mainly dominated by tropical dry deciduous mixed miscellaneous forest. The four districts of this area are marginally agrarian and commercial agriculture crops are not cultivated. The main species taken for gum extraction in this study are *Acacia catechu, Acacia nilotica, Lannea coromandelica ,Sterculia urens, Albizzia lebbek, Azadirchta indica.* Due to increasing population of livestock and human being the forests are shrinking and put adverse impact on these species like *Lannea coromandelica, Sterculia urens, Boswellia serrata, Acacia Senegal* and *Anogeissus latifolia* are dwindling, however these species yield gums of high commercial value. The conservation of these species is important both for biodiversity conservation point of view and extraction of gums for industrial purposes which would improve the socio-

economic condition of marginal farmers. The substantial waste lands are available in this region for raising these species. Therefore main objectives of the study are:-

- Identification and selection of high gum yielding trees in the natural forests and private lands.
- Development of standardize methods for gum collection.
- Establishment of model plantations of highest gum yielding trees.

Materials & Methods

South-east Rajasthan is situated at the edge of Malwa plateau at 23°45' to 25°53' North latitudes and 75°9' to 77°26' East longitudes in eastern corner of Rajasthan state. Its total area is 24156.6 sq. Kms. and from administrative point of view, it is known as Kota division, includes Kota, Bundi, Jhalawar and Baran district. Its eastern, southern and south western limits touch with Madhya Pradesh (Predominantly Malwa and Gwalior region), while northern and north western boundaries are adjoining with neighbouring Sawai Madhopur, Tonk, Bhilwara and Chittorgarh districts of state. Hadoti plateau is quite unique due to its historical and cultural heritage as well as geographical location and physiography. The average surface elevation of land surface 300 mts. above M.S.L. This region is mainly composed of low hills and discretely distributed plateau area with shallow plains. Its central region is traversed by river Chambal and its tributaries, which is surrounded by hills while southern region has got plateau surface, far south-western and eastern parts have got upland topography. On the basis of physiography, altitude and topography. South east region can be distributed into 5 specific geographical zones, namely - Hilly tracts, Riverian zone, Shahabad upland, Jhalawar plateau and Dag-Gangdhar upland .The potential gum yielding species were selected and marked from the following regions

Species	Region
Acacia Senegal	Mishroli(Bhawani Mandi)
Lannea coromendelica	Khanpuria (Jhalawar)
Boswellia serrata	Mandawar& Bagher forest
Sterculia urens	Mandawar & Bagher forest
Anogeissus latifolia	Shababad (Baran)

The two tapping methods were applied for extracting gum: - Bore hole and V shaped blazed method. In bore hole 5 cm hole is made with borer of 1.5-2.0cm diameter. each hole is made 1 meter above the ground .V shaped blaze is made 1.25 cm deep and 3-4 cm wide .Each arm of the V shaped rill should be 6-7 cm in length. Two chemicals ethephon and sulphuric acid have been applied of different concentrations .The concentrations are given as follows.

Chemical	Concentration
Ethephon	200mg/ml (E_1)
	300mg/ml (E_2)
	400mg/ml (E_3)
Control	Distilled water((E_0)
Sulphuric acid	0.2% ((S_1)
	0.4%((S_2)
	0.6%((S_3)
Control	Distilled water((S_0)

The total number of trees selected for the study were 80(5x2x4x2).Sixteen trees were required of each species. Chemical were sprayed through syringe with dose of 2-4 ml. Gum Collections were done in two seasons i.e. Jan-March and April –June. Trees selected for gum collection having diameter of more than 30 cm. Gums were collected in four intervals i.e. 15 days after spray then three collections after every 10 days intervals.

RESULTS AND DISCUSSION

The results in table 1 clearly indicated that chemicals concentrations and tapping techniques had significant effect on gum production in *Srerculia urens*. Ethephon application enhances gum production in *Sterculia urens*. Sixteen tree were selected of this species in Mandawar forest of Jhalawar forest division .Bore hole method with application of ethephon showed the highest yield than sulphuric acid spray. It was noticed that trees treated with 400mg active substance have yielded highest gum yield of 107 and 120 gm in tapping season I and II respectively. However tapping season II had more gum production than season I due to rise in temperature facilitate gum production. These finding are in line with Nair (1995).Ethephon application leads to schizolysigenous formation of gum cavities in the axial parenchyma of sapwood. Associated with the formation of cavities, many vessels of secondary xylem become clogged with gummy material (Bhatt,1987).Ethephon induces gummosis in *Sterculia urens* without adversely affecting health of the tree(Babur and Menon,1989).

V shaped blazing method also showed higher gum yield and maximum in 400mg /ml ethephon from the results it is found that sulphuric acid concentration showed gum oozing in bore hole method of tapping. However, there is no gum production in V shaped blazing method with sulphuric acid concentration.

In *Lannea coromendelica* also exhibited enhancement of gum production with ethephon spray on trees growing in farm fields and more gum production than *Sterculia urens* in 300mg active substance of ethephon per ml. The maximum production of gum observed were 140gm and 260 gm in season I and season II, respectively. Therefor ethephon prodution enhanced gum production in *Lannea coromendelica*. These finding supported by Bhatt (1987). This observation is replicated in V shaped tapping technique also. Sulphuric acid concentration showed the highest yield than ethephon in 0.4% concentration. There is no yield observed in blaze method of tapping with sulphuric acid spray (Table 2).

In *Boswellia serratta* also ethephon application did affect the gum production.In Bore hole tapping method, maximum gum production of 140 g & 158g was observed in 300mg active substance of ethephon per ml. in Jan-March & April –May tapping season, respectively. Affect of summer season tapping with ethephon application enhanced gum production. These findings supported by Bhatt(1987) in *Anogeissus latifolia and Bhatt et al.* (1989) in *Commiphora wightii.* Whereas, in Jan-March tapping minimum gum production 100gm recorded in 200 mg active ethephon substance per ml. Whereas in April-June tapping season minimum gum production estimated in 400 mg active ethephon substance per ml (Table 3).

In contrast to previous tapping method, Ethephon application in V shaped blaze tapping had affected in a doze of 400mg/ml active substance and showed maximum yield of 160gm in June –March tapping season and 141 gm in April – May tapping

season. However, in 200active substance &300 mg active substance of ethephon per ml did not much affect the gum production (Table3).

In bore hole method with 0.6% sulphuric acid concentration also showed maximum yield in both tapping seasons i.e. 52 & 70gm/tree per hole with successive three collections application of sulphuric acid concentration in V shaped blaze tapping did not much affect the gum production

The chemical treatment in *Acacia Senegal* and *Anogeissus latifolia* with different tapping techniques did not give satisfactory results.

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Table – 1: Effect of Tapping methods and chemical concentrations on gum yield of *Sterculia urens*

Sterculia *urens*	**Bore hole tapping**	
Ethephon concentration	**S_1 Yield (g)**	**S_2Yield (g)**
E_1	32	40
E_2	45	55
E_3	107	120
E_0	10	20
	V shaped blaze tapping	
	S_1Yield (g)	**S_2 Yield (g)**
E_1	25	30
E_2	35	45
E_3	90	105
E_0	10	18
Sulphuric acid Concentration	**Bore hole tapping**	
	S_1Yield (g)	**S_2 Gum yield (g)**
S_1	25	40
S_2	30	55
S_3	50	80
S_0	6	10
Sulphuric acid Concentration	**V shaped blaze tapping**	
	S_1Yield (g)	**S_2 Yield (g)**
S_1	0	0
S_2	0	0
S_3	0	0
S_0	0	0

Table – 2 : Effect of Tapping methods and chemical concentrations on gum yield of *Lannea coromendelica*

Lannea coromendelica	Bore hole tapping	
Ethephon concentration	**S_1 Yield (g)**	**S_2 Yield(g)**
E_1	46	79
E_2	140	260
E_3	63	92
E_0	15	7
	V shaped blaze tapping	
	S_1 Yield (g)	**S_2 Yield (g)**
E_1	26	38
E_2	168	190
E_3	46	95
E_0	25	11
Sulphuric acid Concentration	**Bore hole tapping**	
	S_1 Yield (g)	**S_2 Gum yield (g)**
S_1	100	168
S_2	260	393
S_3	89	130
S_0	8	15
Sulphuric acid Concentration	**V shaped blaze tapping**	
	S_1 Yield (g)	**S_2 Yield (g)**
S_1	13.5	0
S_2	0	0
S_3	0	7
S_0	0	03

Table - 3 : Effect of Tapping methods and chemical concentrations on gum yield of *Boswellia seratta*

Boswellia seratta	**Bore hole tapping**	
Ethephon concentration	**S_1Yield (g)**	**S_2Yield (g)**
E_1	100	146
E_2	140	158
E_3	117.5	120
E_0	20	28
	V shaped blaze tapping	
	S_1Yield (g)	**S_2 Yield (g)**
E_1	34	23
E_2	13.5	16
E_3	160	141
E_0	15	1
Sulphuric acid Concentration	**Bore hole tapping**	
	S_1Yield (g)	**S2 Gum yield (g)**
S_1	10	15
S_2	16	25
S_3	52	70
S_0	5	10
Sulphuric acid Concentration	**V shaped blaze tapping**	
	S_1Yield (g)	**S_2 Yield (g)**
S_1	10	12
S_2	0	1
S_3	6	11
S_0	0	0

Organic Agriculture: Will it be sustainable towards food security of the future?

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-A trend driven by public perception that food produced minus pesticides is healthier and better for the planet. We appraise the science to see is it true and sustainable for the food and feed for the millions of people?-

"Organic proponents assert that better plants are produced from minerals derived from manure breakdown, so that organic food is superior and improves human health. Hundreds of rigorous tests have failed to reveal better-tasting properties or improved nutritional value, but have consistently shown that organic produce has lower nitrate and protein contents. Conventionally farmed food seems to be better for children below 17, although rodents apparently favor organic food. Overall cancer rates have dropped 15% during the era of synthetic pesticides while stomach cancer rates have dropped 50–60%, probably an effect of plentiful, cheap conventional fruits and vegetables. But this may not be the whole story, because food mycotoxins from contaminating fungi (which can be controlled by specific fungicides) definitely contribute to European cancer rates — fumonisin and patulin are both reported to be higher in organic products, and failure to use effective fungicides on organic farms has led to these farms acting as repositories of disease. Organic farms may be protected from the full effects of disease outbreak because they are surrounded by conventional farms using proper fungicides."

Anthony Trewavas: Nature 2001

What is an organic food?

Organic food is a conventional food crop (genetically exactly the same plant variety as the regular version) but grown according to a different set of standards. In this sense, organic food is really is identical, but it's prepared in such a way to conform to different philosophical standards for example in USA ,the USDA's National Organic Program committee has set the requirements for foods to bear a "certified organic" label. Basically it forbids the use of modern synthetic fertilizers and pesticides in favor of organic equivalents, and for animals it requires that they have not been kept healthy through the use of antibiotics. There are other rules too, and the basic goal is to require the use of only natural products throughout the growth, preparation, and preservation stages. What is its essence which the organic agriculturist wants to convey? They advocate that it includes care for the soil and ecosystem surrounding organic farms and it relies on biological and mechanical control excluding GM crops to deal with pests and on organic materials as fertilizers.

History:

Time since immemorial, conventional agriculture has evolved as a package to be comprised of a diverse set of technologies using the best available knowledge, whose ultimate goal is the safe, efficient provision of foods in abundance and at lowest prices. As with all technologies, problems often arise in the practices of conventional

agriculture — but rejection of a technology because of problems also means losing its potential benefits. In 1939, Lord Northbourne coined the term organic farming in his book *Look to the Land* (1940), out of his conception of "the farm as organism," to describe a holistic, ecologically-balanced approach to farming—in contrast to what he called *chemical farming*, which relied on "imported fertility" and "cannot be self-sufficient nor an organic whole." In the same year Sir Albert Howard, book–*An Agricultural Testament* laid the foundation for the organic movement. The opening remarks read, "The maintenance of the fertility of the soil is the first condition of any permanent system of agriculture". It also got the inspiration from the philosophical views of Rudolf Steiner and later Lady Eve Balfour, who in the 1940s founded the Soil Association. This association in the United Kingdom licenses about 70% of organic production and sends inspectors to check that its regulations are being followed. In retrospect the chronicled compilations like *King's farmers of Forty Centuries* (1911) and George Perkin's *Man and Nature* (1864) opined that the quality of civilization, and its possible longevity, can be judged by the quality of its soil. Thus we are flabbergasted by the current proliferations of the new genres of soil centered agroecology terms and inclusions-organic, permaculture, polyculture, conservation agriculture, biological farming and integrated farm management. Ironically, when one goes through the pages of *Omnivore Dilemma* (2007) authored by Micheal Pollen on the natural history of agriculture one is surprised to find the following words, "Organic gardening and farming struggled along in obscurity until 1969, when a review in the *Whole Earth* brought to the attention of hippies trying to figure out how to grow vegetables without patronizing the military-industrial complex. According to the U.S. Department of agriculture (USDA) though organic agriculture has been growing rapidly in recent years by a factor of 10 from 1996 to 2009 but it still accounts for a tiny 0.7 percent of total farmland in the United States. Although its supporters assert that organic agriculture is superior to other farming methods, the concurrent lack of scientific studies divulge that this claim cannot be substantiated. Nevertheless, organic food has garnered an extraordinary amount of attention from the media and environmentalists, who boast of its civic virtues and benefits to the environment.

What is the essence of "organic"? As mentioned in the preceding text, the standard definition is that its methodology includes care for the soil and ecosystem surrounding organic farms and it relies on biological and mechanical control to deal with pests and on organic materials for fertilizers. Only two principles really distinguish organic farming from other farming methods those are soluble mineral inputs are prohibited and synthetic herbicides, pesticides and genetic modification(s) of the host plant are rejected in favor of natural pesticides in combinations with conventionally bred varieties.

Agriculture based on these principles results in a more costly product, mainly because of lower yields combined with an inefficient use of land. Organic food is more expensive than conventional food, not only due to its lower crop yields and more expensive organic fertilizers and pesticides in larger quantities, but mainly because it's such a big fad and has been made to look in such a high demand. Why is that? Is organic food healthier? Does it make an important political statement? The usual arguments put forwarded by organic agriculturists boil down to three points namely (i) that the cultivation method is better for the environment; (ii) that it benefits small farmers rather than big evil companies; and (iii) that it's somehow healthier to eat; Rather than accepting these emotionally satisfying benefits at face value, let's instead

take a skeptical look and see what the data actually show. Let's subject these claims to logical appraisal as *ipso facto* some axioms are hidden behind the label and are descanted here.

A few Res Gestae against organic foods

Organic food is always better for the environment: There is a widespread belief that low yielding organic agricultural systems are friendlier to the environment and more sustainable than high yielding farming systems. The current aims of organic systems—maintenance of soil fertility, avoidance of pollution, use of crop rotation, animal welfare concerns and wider environmental aspects — would be hard to quarrel with. But the rules and regulations that have to be followed to achieve these ends caused one leading organic researcher to admit that in organic farming "there is very little science" and "this gives rise to a great deal of illogicality and confusion particularly in some areas of production". Although reduction in pesticide use leads to higher reported levels of some insects and reported sightings of birds on organic farms, current synthetic pesticides are very unstable and only transient declines of most field insects are reported even at full pesticide's dosage. Similarly, the lower levels of aphids observed on organic farms could well reflect lower nitrogen and protein content of organic crops and lower yield. It is also often overlooked that some conventional mixed farming can maintain more species diversity e.g. conventional mixed farming in smaller plots (providing more field margins) or farming based on the traditional ley system (sowing wheat with legumes) maintains conventional yields and low costs. The benefits for wildlife equal to those provided by organic farming but at far lower cost to the consumers.

Organic farming practices may not necessarily conserve the environment on its own and competitive organic farmers may be forced to keep their fields clear of weeds through frequent mechanical weeding—a method that damages nesting birds, worms and invertebrates—and high use of fossil fuels, which greatly increases pollution from nitrogen oxides. A single treatment with innocuous herbicide, coupled with no till surface conventional farming, avoids this damage and retains organic material in the soil surface. Similarly, although use of manure means higher, beneficial levels of earthworms in organic fields, there are numerous problems with the use of manure including possible effects on human health. Use of soluble mineral salts prohibited by organic regulations is another contentious issue. The minerals taken out of farmland as food produce must balance those put back by some other means. Organic farmers typically rely on legume nitrogen fixation, rain water or mineral recycling in the farm. The few detailed accountings suggest slow but accumulating mineral deficits, particularly of potassium and phosphate, in organic farmlands only. Organic farms are required to try to balance manure and straw production for its intensive use on the farm. Excess organic manure or straw is thus usually not available to provide for inevitable deficits with year-to-year climate and agriculture variation. . Since organic farming is half as productive as conventional farming, it requires far more land to produce the same amount of food. It has been estimated that modern high –yield farming has saved 15 million square miles of wildlife habitat, and if the world switched to organic farming, we'd need to cut down 10 million square miles of forest. Less- productive farming also led to even less food for the world's under nourished strata of the population. Many so called environmentalists generally favor organic farming, but in the second breath they protest deforestation to make room for more organo-agriculture.

How do they reconcile these directly conflicting views? If you want to feed a growing population, you *cannot* do both, and soon won't be able to do either. If you support rainforest preservation, logically you should oppose organic farming, particularly in the developing world. On the other hand , if you demand organic soybeans, then you should have the courage to stand up and say that you don't care whether people around the world have enough to eat or not.

Norman Ernest Borlaug, the American plant geneticist who won a Nobel Peace Prize for breeding the high-yield, disease-resistant wheat varieties (triggering agriculture's 'Green Revolution'), is despairing of the organic fad. "This shouldn't even be a debated. Even if you could use all the organic material you have – the animal manures, the human waste, and the plant residues – and get them back on the soil, you couldn't feed more than four billion people."Organic pesticides, it is asserted, work with nature and are environmentally unstable, unlike synthetic pesticides. About 60% of natural and synthetic chemicals are known rodent carcinogens, and around 20 different chemicals are used to maintain the safety of processed organic food. Approved pesticides for organic farmers include copper sulphate, which has caused liver damage in vineyard workers, kills worms and is persistent in soil (banned by the European Commission after 2002). Further, rotenone has recently shown to induce Parkinson's disease and *Bacillus thuringiensis* spores, have been correlated to fatal lung infections in mice. Organic pesticides are to be used more sparingly, yet more frequent treatments of crops with copper sulphate than good conventional practice have been reported on organic farms. Natural pyrethroids have to be used at much higher doses than some of the prohibited, equally unstable and much more effective synthetic pyrethroids, such as bioresmethrin. Organic farms turn to natural fertilizers for growing crops, which often translates into using animal feces combined with other components instead of chemically constructed fertilizers. Hence the warning for organic food may always loom over some of the foods - such as lettuce, parsley, and others which may harbor significant harmful bacteria which in turn be passable to the consumers. While foods produced through conventional farming have similar risks, critics warn that the threat is heightened in organic foods. Soluble minerals are not used on organic farms. In some of the packages of practices under organics crude rock phosphate has been be allowed, potassium chloride is banned; sylvanite, another form of potassium chloride, is permitted. The main alternative mineral source for crop nutrients is animal or green manure. Manure treatment used on any mixed farming proves soil quality, but conventional crop rotation seems equally effective. Manure breakdown cannot be synchronized with crop canopy growth, as is desirable, but continues throughout the growing season. Ploughing in of legume crops (a necessary part of the organic method to build soil fertility) and continued manure breakdown leads to nitrate leaching into aquifers and waterways at identical rates to conventional farms. Degradation of organic material from manure in the soil produces significant amounts of nitrous oxide and methane, the most potent greenhouse gases. Manure is variable in composition, yielding unpredictable nutrition for crop growth as there is only a poor relationship between available nitrogen for crop growth and organic content of soil. Organic regulations recommend hay for animal feeding, but hay-fed animals infected with *Escherichia coli* O157 incubate this dangerous organism longer than 'conventional' animals fed with grain. What has shaken the whole world last month was the detection of superbug strain *(O104:H4)* of *E. coli with Shiga* toxin which has been linked to organic food in Germany. Besides, it was found in classical experiments in Canada that

in addition to reduced efficacy against aphids compared to novel synthetic insecticides, organic approved insecticides had a similar or even greater negative impact on several natural enemy species in lab studies, were more detrimental to biological control organisms in field experiments, and had higher environmental impact quotients at field use rates.

Beneficial to small and Marginal farmers

Buying organic food benefits small farmers, and represents a blow to the big food corporations . Let's take for granted the position that major food producers deserve to be struck with a blow. We are sure the starving millions in Africa appreciate the sentiment. But the facts and figures reveal something different e.g. California alone produces over $600 million in organic produce, most of it coming from just five farms, who are also the main producers of most non-organic food in the state. More than 80 percent of organic milk is controlled by just one major milk producer. A decade ago when the major food producers realised that organic food was coming in the big way, they smelt higher prices charged for fewer products, and started producing organic. Nearly all organic crops in this world are either grown, distributed or sold exactly by same companies who produce conventional crops. They just want to fleece the consumers. The irony is that the organic food companies supply a smaller amount of food per acre planted, and enjoy dramatically higher profits, which is why anti-corporatists hate corporations in the first place. For affluent humans in industrialized countries, organic food is pretty much a harmless luxury. Although there is no convincing evidence that food is any healthier or more nutritious than the other food, if that label of organic makes you feel healthier and more virtuous then you can justify the extra cost. Growers and vendors can charge premium prices, sometimes triple what they get for conventionally grown crops. It appears that the organic boom is just a marketing phenomenon, it is fragile. Further, most people in the world are not affluent, and their food budgets are limited. If they are convinced by green marketers that they need to choose higher priced organic produce, they and their children are liable to end up eating fewer fruits and vegetables and sometimes nothing at all as occurred when Zambia rejected emergency food for starving citizens because the grain have been genetically engineered. In *Denialism*, a book about the spread of unscientific beliefs Michael Spencer criticizes the "organic fetish" as a "pernicious kind of denialism" being exported to poor countries. Total reliance on organic farming would force the people to devote twice as much land per crop. To get high yield from food crops requires disturbing nature to deliver just what the crops need. First crops need fertiliser, which is often nitrogen in the form of nitrate and ammonia, because most plants can't draw nitrogen directly from the atmosphere. (Legumes are a famous exception – their root nodules hold bacteria that turn atmospheric nitrogen into nitrate). Just prior to World War I, German chemists Fritz Haber and Carl Bosch learned to make ammonia synthetically. Their chemical reaction is still used today to produce more than 450 million tones of artificial fertiliser per year, and sustains the agriculture which feeds about 60 per cent of the Earth's population. Second, there has to be a way of stopping all the other robust plant and insect species from competing with or consuming your crop. Non-organic farmers make use of chemicals (herbicides and weedicides) to achieve these goals. "An organic universe sounds delightful but it could consign millions of people in Africa and throughout much of Asia to malnutrition and death. Take that away, and all that nitrogen has to be produced organically – effectively using

land to produce manure rather than food. Alex Avery, director of food research and education at the Hudson Institute, a conservative U.S. think tank, estimates that this would require doubling the amount of land now in cultivation. That would mean tearing down our remaining forests, he argues. Even so, the poor yield of organic farming means that food production would be a major problem. In Australia, for instance, organic farming yields 50 per cent or less per square kilometer because of pest problems and phosphate-depleted soils. (Phosphate is locked away in the ancient clays; conventional farmers help themselves to highly soluble chemically-made superphosphate. Organic farmers can't use a chemical, so they use poorly soluble rock phosphate).

Further some of the advocates of organic growers live in a world of fantasy by adopting their own criteria to label themselves or their produce as organic. Organic farmers have long sprayed dried Bt. bacteria on their crops because the same is considered a natural pesticide. When the bacterial gene that makes the Bt. toxin is engineered into cotton and corn, the transgenic plants are able to kill the pest by themselves. Here the means and ends are same. Does that also mean Europe use no organic seeds produced by radiation or chemical mutagenesis? In the market world natural now means anything the seller wants to charge extra to distract your attention with. It is certain that conventional farming methods yield more product than organic farms, concluding that organic farming is inefficient. The results point out in no uncertain terms that while organic farming may be attractive to consumers who can afford the foods, one of the negative effects of organic farming is that it may not be able to feed everyone within the world.

Since organic farms are not located as prevalently throughout the world as conventional farms hence the environmental impact of shipping the organic foods to merchants may be health hazard in the long run. Although organic farming strives to have as small as possible environmental impact the food may still be shipped using less than environmentally friendly methods. Some environmentalists make the claim that it may be better to purchase foods that are produced locally, regardless of whether they come from an organic farm, because of the lack of environmental impact of shipping.

Healthier to eat?

It is often opined that the quality of the organically produced food is superior to that of conventionally produced food. However, there is no such conclusive proof to justify the nutritional superiority of the organically produced food, over conventionally produced food. If the conventionally produced foods are blamed to contain traces of chemical residues, the organically produced foods are equally to be blamed for their contamination with harmful bacteria and other organisms inimical to the health of the consumers.

Some supporters of organic growing claim that the danger of non-organic food lies in the residues of chemical pesticides. This claim is even more ridiculous since the organic pesticides and fungicides are less efficient than their modern synthetic counterparts, up to seven times as of it must be used. Organic pesticides include rotenone, which has been shown to cause the symptoms of Parkinson's disease and is a natural poison used in hunting by some native tribes; pyrethrum, which is carcinogenic; sabadilla, which is highly toxic to honeybees; and fermented urine, on our eatables is a natural repulsive agent to mind irrespective of the fact whether it causes any disease or

not. Supporters of organics claim that the much larger amounts of chemicals they use is fine because these chemicals are natural. But just because something is natural doesn't mean that it is safe or healthy- consider the example of hemlock, mercury, lead toadstools, box jellyfish neurotoxin, asbestos not to mention a nearly infinite number of toxic bacteria and viruses (E. *coli*, salmonella, bubonic plague, small pox). If any product is claimed to be natural it does not mean that a product is healthful.

In the USA two major outbreaks of *E. coli* resulted in numerous deaths and illnesses which were ultimately traced to organically grown spinach and lettuce in 2006. According to the Center for Global Food Issues, organic foods make up about 1% of all the food sold in the United States but it accounts for 8% of *E. coli* cases. The recent outbreak of superbug in Germany has been traced to organic food (discussed elsewhere).

On the other hand that to date, no verifiable untoward toxic or nutritionally deleterious effects resulting from the consumption of foods derived from genetically modified foods have been discovered anywhere in the world. GM foods are so exhaustively vetted and are safer to eat than the products of conventional and organic farming. New GE crops are tested by the concerned governmental agencies in a comprehensive way where as new crops varieties, created by breeding or raised through organic farming go through no such process. Consumers may be less likely to take the same precautions with organic foods that they do with other types of food. For example, some consumers may buy organic apples and then assume that there is no need to wash the apple thoroughly, prior to eating it because of its organic origins. This issue, of course, is not the fault of organic farmers, but it is a cited concern nonetheless

Organic farmers are bound to an ideology that demands they only use natural techniques. In some cases, such purism gets in the way of practices of those latest innovations which are better for the environment and are more sustainable. For example, as in the earlier mentioned case of Bt. spray the organics often demonise the genetically modified (GM) cotton crops that carry an inbuilt supply of Bt. protein, and which therefore require its less spraying .However the truth is these GM varieties spare farmers – and the environment – from the risks of pesticide overuse. For instance, according to Richard Roush, the Dean of land and food resources at the University of Melbourne, cotton farmers in India have reduced their use of pesticides and accidental poisonings by 80 per cent since the introduction of genetically modified Bt. cotton. Organic farming is essentially a marketing tool, and cannot replace conventional farming for food security, quality and quantity of crop outputs.

Organic farming should be considered for lesser endowed regions of the country. It should be started with low volume high value crops like spices and medicinal aromatic crops. A holistic approach involving integrated nutrient management, integrated pest management, enhanced input use efficiency and adoption of region-specific promising cropping systems would be the best farming strategy for India. Concurrently, genetically-modified foods have a bigger potential to solve many of the hunger and malnutrition problems in a country like ours as well as to help protect and preserve the environment, by increasing yield and reducing reliance upon chemical pesticides and herbicides. Though looking apart, but it makes a felicitous case for treating GE crops as the most favored convergent technique for feeding most people with the least harm to the land i.e., to meet the appetites of the world's population without drastically hurting the environment. This visionary new approach of genetic engineering seems to be most appropriate. Where GE can be used to develop seeds with

enhanced resistance to pest, pathogens, value addition to nutrition of the produce, inducing it to be drought tolerant ,the traditional or even organic farming can manage the overall spectrum of pests more effectively. An appraisal of the two phenomena deciphers as that while organic agriculture suffers from innate constraints conducive to its growth and logical winnowing, not apparent to an ordinary citizen, the GE can rectify the same wherein a scientific path is treaded with utmost caution and precautions. Yet there are many challenges ahead for governments, especially in the areas of safety testing, regulation, international policy and food labeling. With a growing population and precarious food situation, India cannot afford to take risk with organic farming alone. So it is right time for the advocates of organic farming to use the most powerful technologies available to create an environmentally friendly, sustainable, and high yield farm and GM technology is the only way to meet their objectives and when it comes to the reality of feeding the world, one would have to agree with Roush: "If improving sustainability and reducing the environmental footprint is the goal, we need to be prepared to use the best tools we have."In the same way that the introduction of genes from wild species, through breeding revolutionized growers' management of pests, the introduction of GE in organic farming can control diseases, insects, and nematodes for which presently there is no solution in so called organic farming which was originally formulated as an ideology, but today's global problems — such as climate change and population growth — need agricultural pragmatism and flexibility, not ideololog.