STUDIES ON GROWTH PERFORMANCE AND ECONOMIC EVALUATION OF GAMHAR (*Gmelina arborea* Roxb.) BASED AGROFORESTRY SYSTEM IN EAST SINGHBHUM DISTRICT IN JHARKHAND

Sanjeet Kumar

DEPARTMENT OF SILVICULTURE & AGROFORESTRY

FACULTY OF FORESTRY
BIRSA AGRICULTURAL UNIVERSITY
KANKE, RANCHI, JHARKHAND

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Sanjeet Kumar

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Registration No. – F/BAU/ 3761/2002

2012

DEDICATED

TO

MY REVEREND FATHER

SRI. BASUDEO PASWAN

AND

MY SWEET MOTHER

LATE CHANDRAKALA DEVI

WHOSE PERPETUAL AFFECTION AND EVERLASTING BLESSING INSPIRED ME FOR HIGHER AMBITION IN LIFE.

- SANJEET KUMAR

BIRSA AGRICULTURAL UNIVERSITY
KANKE, RANCHI (JHARKHAND)

Dr. M.S. MALIK
M.Sc.(Forestry), Ph.D. (Forestry),
Chairman & University Professor

Department of Silviculture & Agroforestry
Faculty of Forestry
Birsa Agricultural University
Kanke, Ranchi-834 006
(Jharkhand)

Dated :……………………..

CERTIFICATE

This is to certify that the thesis entitled **"Studies on growth performance and economic evaluation of Gamhar (*Gmelina arborea* Roxb.) based agro forestry system in East Singhbhum District in Jharkhand"** submitted in partial fulfillment of the requirements for the Degree of Master of Science in Forestry (Silviculture & Agro forestry) of the Faculty of Post-Graduate Studies, Birsa Agricultural University, Ranchi (Jharkhand) is the record of bonafide research work carried out by Mr. Sanjeet Kumar under my supervision and guidance. No part of the thesis has been submitted for any other Degree or Diploma.

It is further certified that such help or information received during the course of investigation and preparation of the thesis has been duly acknowledged.

ENDORSED

(M.S. Malik)
Chairman, Department of
Silviculture & Agro forestry

(M.S. Malik)
Chairman
Advisory Committee

BIRSA AGRICULTURAL UNIVERSITY

RANCHI- 834006 (JHARKHAND)

(Certificate of the Advisory Committee Members and Endorsement of Dean, Forestry)

CERTIFICATE

We,the undersigned,members of the Advisory Committee of **Mr. Sanjeet Kumar,** a candidate for the Degree of **Master of Science in Forestry** with the major in **Silviculture & Agro forestry** have gone through the manuscript of the thesis entitled **"Studies on growth performance and economic evaluation of Gamhar (*Gmelina arborea* Roxb.) based agro forestry system in East Singhbhum District in Jharkhand"** may be submitted by **Mr. Sanjeet Kumar** in partial fulfillment of the requirements for the degree.

____

(M.S. Malik)
Chairman
Advisory Committee

Members of Advisory Committee

1. ______________________
(R.B. Sah)

2. ______________________
(S.K. Singh)

3. ______________________
(K. Sinha)

ENDORSED

____

(M.H. Siddiqui)
Dean
Faculty of Forestry

BIRSA AGRICULTURAL UNIVERSITY

RANCHI- 834006 (JHARKHAND)

(Certificate of approval by the Chairman of the Advisory Committee and External Examiner)

CERTIFICATE

This is to certify that the thesis entitled **"Studies on growth performance and economic evaluation of Gamhar (*Gmelina arborea* Roxb.*)* based agroforestry system in East Singhbhum District in Jharkhand"** submitted in partial fulfillment of the requirements for the Degree of **Master of Science in Forestry (Silviculture & Agroforestry)** of the Faculty of Post-Graduate Studies, Birsa Agricultural University, Ranchi, Jharkhand was examined and approved on...............................

(M.S. Malik)
Chairman
Advisory Committee

External Examine

Members of Advisory Committee

1. *(R.B. Sah)*

2. *(S.K. Singh)*

3. *(K. Sinha)*

(M.S. Malik)
Chairman of the Department
Silviculture & Agroforestry

(Z.A. Haider)
Director Residence Instruction-cum
Dean, Post-Graduate Studies

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I am thankful to my beloved nephew Ayush and Meethi for their love and affection.

Above all, I offer my heart devotion to the "Almighty".

Place:-

Date:- (Sanjeet Kumar)

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Abstract

The present experiment was conducted on the "Studies on growth performance and economic evaluation of Gamhar (*Gmelina arborea)* based agroforestry system in East Singhbhum District in Jharkhand" with the objectives 1. To find out the growth of tree species of Gamhar planted in the boundary of agricultural field. 2. To assess the soil fertility status under Gamhar. 3. To analyze the economic feasibility of Gamhar based agroforestrey system. The study was carried out at Zonal Research Station, Darisai, Birsa Agricultural University, Ranchi. The experiment was conducted with one tree species namely *Gmelina arborea* (Gamhar) were selected in agroforestry experiment along with the intention of growing Agricultural crops namely Gram (*Cicer arietinum*), Pea (*Pisum sativum),* Indian mustard *(Brassica nigra)* and Fruit crops namely Mango (*Magnifera indica*), Aonla (*Emblica officinalis*), Papaya (*Carica papaya*) and the experimental plots were arranged in Fixed Plot Survey Design with three replications.

The data were recorded for various parameters on tree as well as on horticultural and agricultural crop twice from February, 2011 to February, 2012. The size of plot is 6.0m X 16.0m, and spacing of tree species is 2.0m on the line of farm boundaries, the Spacing of agricultural crops is 30cm X 30cm and the spacing of horticultural tree is 5.0 m X 5.0m. The growth parameters like height (m), diameter at breast height (cm), increment (m), volume (m^3), and basal area (m^2) and the yield parameters. The soil properties such as pH, Available N, P, K, Organic carbon percent are estimated in the laboratory. The financial analysis is calculated as per the market price and cost of plantation. During the experimental period, standard cultural practices like weed, hoeing and watering were done at weekly interval *i.e.* after 7 days (weeding) or when it is required (watering) to maintain the proper growth of agricultural crops.

The height of gamhar was found maximum in gamhar+gram (11.79m) and minimum in gamhar+pea (11.16m) in agrisilviculture system. The diameter of gamhar less under sole plantation than agri & silvicultural system. Volume and basal area of gamhar less under sole tree plantation than agrisilviculture system. Basal area of *Gmelina arborea* (0.0092sq.m/plant) in the agrisilviculture system is highest. Among the agri silvicultural system, the gamhar has recorded different increment with different agriculture crops which ranged from 0.34m to 0.43m. The ascending order of increment was gamhar+Indian mustard=gamhar+gram→gamhar+pea→gamhar. Considerable improvement has taken place in soil which in evident from the increased levels of Organic carbon, available N, P, K and pH value in agrisilvicultural and agrihorticultural system as compared to control plots.

In hortisilvicultural system, the yield of Papaya (553.11q/ha) were statistically significantly higher than Papaya (476.53q/ha) planting in sole cropping. Yield in hortisilvicultural system has more than in sole planting. The production of Mango and Aonla fruit has not start till date. The seed yield of Pea (7.32q/ha), Gram (11.25q/ha) and Indian mustard (4.44q/ha) were statistically significantly higher than Pea (7.03q/ha), Gram (9.29q/ha) and Indian mustard (4.17q/ha) planting in sole cropping.

In agroforestry system, highest financial yield of gamhar (Rs. 72,972.00 of total boundary plants), papaya (Rs. 9,40,287.00 per ha), pea (Rs. 29,280.00 per ha), gram (Rs. 61,875.00 per ha), and Indian mustard (Rs. 15,540.00 per ha) whereas in sole plantation, the financial yield of gamhar (Rs. 21,406.00 of total boundary plants), papaya (Rs. 8,10,101.00 per ha), pea (Rs. 28,120.00 per ha), gram (Rs. 51,095.00 per ha), and Indian mustard (Rs. 14,595.00 per ha).

Dedicated

To

My Reverend Father

Sri. Basudeo Paswan

And

My Sweet Mother

Late Chandrakala Devi

Whose perpetual affection and everlasting blessing inspired me for higher ambition in life

- Sanjeet Kumar

Chapter-1

INTRODUCTION

Man's desire to live in co-existence in a community created settled agriculture. Acceleration in human and livestock population necessitated acquisition of more and more land under cultivation continued to meet the ever increasing demand for food, fodder, vegetables, fuel wood, timber, medicines etc. Further, demographic pressure has forced man to seek unconventional methods of agriculture to utilize land to the maximum extent. National Forest Policy (1988) has set a goal that 33% of the country's geographical area should be under forest and tree cover. Under Tenth Five Year Plan, the Government of India has set a target to increase the country's forest cover up to 25%. According to the latest report of Forest Survey of India (2011), the forest cover in the country is 692,027km^2, constituting 21.05% of its total geographical area. In terms of density classes, area covered by very dense forest is 83,471km^2 (2.54%), that with moderately dense forest is 320,736 km^2 (9.76%) and open forest is 287,820km^2 (8.75%). The only solution to achieve these targets is through the practice of agro-forestry. Therefore in the quest of optimizing productivity, the multi-tier system came into existence.

The pressure on the agricultural lands has increased manifolds due to the increasing population, expansion of urban area and the industralization process. With this not only the agricultural production has been affected but the environment has also been disturbed. Under all these circumstances agro-forestry has shown that beside sustainable agriculture it can also help promote a better environment.

Agro-forestry is sustainable land-management system, which increases the overall yield of the land, combines the production of crops (including tree crops) and forest plants or animals simultaneously or sequentially on the same unit of land and applies management practices that are compatible with the cultural patterns of local population (King and Chandler, 1978).

Agro-forestry, has made its place in all the developed and the developing countries of the world. The practice of introducing trees in any form to the farming world has played a significant role in enhancing productivity on per unit area basis. Agro-forestry has the capability to increase the productivity and at the same time maintain the nutrient balance as well as protect the nature. Due to its technical and economic potential, it can sustain agricultural production. It has two major roles to play, the productive role and the service roles.

According to Nair (1989), agroforestry is a sustainable land use system particularly practiced in tropical world to solve the problems of fodder and fuel wood or timber for over-increasing human and livestock population. It also generates additional income and conserves the productivity of land.

Although agroforestry practice provide several benefits but they too have adverse effects on the agricultural crops due to several factor such as competition for space, light, nutrient and organic chemicals released as leaf leachates which affect the crop plants (Rice, 1984).

In agroforestry system both the plant components (tree and agricultural crop) depends on the same reserve of growth resources such as light, water and nutrients thereby having influences on each other. These are termed as tree crop interactions which may be positive (complementary) or negative (competitive).

Trees are grown scattered in agricultural fields for many uses such as shade, fodder, fuel wood, fruit, vegetables and medicinal uses. Some of the practices are very extensive and highly developed in India. There are strong convictions for the acceptance of these trees on agricultural fields since time immemorial. Farmers retain trees of *Acacia nilotica,A. catechu, Butea monosperma, Dalbergia sissoo, Mangifera indica, Zizyphus mauritiana* and *Gmelina arborea* are preferred in Jharkhand with crops. Other most common trees found on farmer's fields are *Azadirachta indica, Moringa oleifera, Tamarindus indica*, *Anacardium occidentale*, *Cocos nucifera* and fruits like, mango, guava, anola and pomegranate.

Trees grown in agricultural fields or on field bunds are also often and usually grown on farm boundaries. In Jharkhand, *Eucalyptus*, *Moringa oleifera* and *Acacia auriculiformis* are commonly grown along field boundaries or bunds of paddy fields; other trees which are found grown as boundary plantations or live hedge include *Acacia nilotica*, *Dalbergia sissoo* and *Prosopis juliflora*. At many places succulents like *Agave* and many cacti are grown as common live fence. Many of the boundary plantations also help as shelter-belts and wind-breaks, particularly in fruit orchards.

Agro-forestry could be even more advantageous if the production of associated components is increased due to influence of trees. This is possible because trees are capable of improving productivity of soil in many ways. A large number of trees are known to fix nitrogen symbiotically. Thus positive role played by the tree component could be beneficial to the productivity of crop component grown along with the trees.

The major yield-decreasing effects at the tree-crop interface arise from competition for light, water and nutrients. While the availability of light may be the most limiting factor in many situations, particularly those with relatively fertile soils and adequate water availability, the relative importance of light will decrease in semi-arid conditions as well as on sites with low-fertility soils. Since crops differ in their responses to poor nutrition, competition for light or water may either be reduced or amplified by a shortage of nutrients. The effect of nutrient competition is more severe for the crop components than for trees, because the crop-root system is usually confined to the soil horizons that are also available to the roots of the trees but trees can exploit soil volume beyond the reach of the crop.

In agroforestry systems several tree species have been identified as fast growing which involves more or Less intimate and interacting association of agriculture/horticulture crops and woody perennials on same unit of land and are also categorized as high biomass yielders. Further studies are required to know how much growth and biomass can be achieved in a particular situation with special reference to climate, tree density, durations and intercropping. Keeping this in mind the tree species namely *Gmelina arborea* (Gamhar) were selected in agroforestry experiment along with the intention of growing agricultural crops namely Gram (*Cicer arietinum*), Pea (*Pisum sativum),* Indian mustard *(Brassica nigra)* and Fruit crops namely Mango (*Magnifera indica*), Aonla (*Emblica officinalis*), Papaya (*Carica papaya*) with the following objectives:

1. To find out the growth of tree species of Gamhar planted in the boundary of agricultural field.

2. To assess the soil fertility status under Gamhar.

3. To analyze the economic feasibility of Gamhar based agroforestry system.

Chapter-2

REVIEW OF LITERATURE

2.1 Effect of the tree growth under intercrops

Agroforestry is a modern tool to develop sustainable land use and to increase food production by growing woody species (trees, shrubs, palms, bamboos, etc.) with agricultural crops and/or animals in some form of spatial arrangement or temporal sequence (Rizvi *et al*., 1999).

Agro-forestry is a sustainable management system for land that increases overall production, combines agricultural crops, tree crops and forest plants and / or animals simultaneously or sequentially and applies management practices that are compatible with the cultural patterns of local population (Bene *et al.*, 1977).

Singh and Osman (1987) have suggested different type of agroforestry system for small holding to increase soil productivity and land sustainability. Agroforestry is a collective name for land use system and technology where woody perennials (tree, shrubs, palms, bamboo etc.) are deliberately used on same land management unit along with agricultural

Gill et al. (1992) have studied growth of *Leucaena leucocephala* and mango based intercropped agroforestry system at Jhansi. Both *Leucaena* and mango growth (height and diameter) was found better in inter- crops than fallow plots.

Sharma (1987) reported growth performance of *Dalbergia sisoo* tree intercropped with wheat and paddy at FRI, Dehradun under semi-arid condition and noticed on hectare basis a mean height of 10.36 m, dbh 53.45 cm, total timber 1.25 cubic meter, small timber 7.08 cubic meter and fuel wood 77.45 q.

Patel and Singh (1994) have studied dynamics of growth of ten trees species of agroforestry system in Gujarat and noticed maximum height growth in *Albizzia lebbeck* (9.10m) followed by *Melia azedarach* (8.8m) and *Eucalyptus hybrid* (6.73 m) at five year age, whereas the maximum girth growth was found in *Melia azedarach* (66.0 cm) followed by *Albizzia lebbeck* (39.67 cm) and *Eucalyptus hybrid* (37.00 cm) at five year age.

Mohsin *et al*. (1996) evaluated growth and biomass production of poplar (*Populus deltoides*) stands in different age groups, intercropped with Mentha and Cympobogon species at Tarai region of Kumuan, India. Poplar stand intercropped with mint and Cymbopgon species attained better height and DBH than tree under monoculture plantation at both early and advance stages of tree growth

Fuwaoe and Akindel (1997) estimated biomass yield of *Gliricidia sepium*, *Gmelina arborea* and *L. leucocephala* in Nigeria. Among three species, the higher above ground biomass was observed on *G. arborea* followed *by L. leucocephala* and *G. sepium*.

Datta and Dhiman (2001) studied growth and timber production of 12 trees species in associations with different crop in sub-humid tropics of Tripura, India. After 12 years of planting, *Acacia auriculiformis* attained maximum height (18.1m) and basal girth (92.8 cm) followed by *Eucalyptus hybrid* and *Gmelina arborea*. The lowest height and diameter growth were observed in *Morus alba*.

Toky and Khosla (1984) have studied comparative growth performance of agroforestry trees in subtropical region of Western Himalayas and observed height, diameter and bole volume of six years old trees of 41 indigenous and 5 exotic species and noticed best growth in *Grevellia robusta*, *Eucalyptus globulus*, Populus sps, *Albizia lebbeck* and *Melia azedarach*. However, maximum diameter was found in *Ailanthus excelsa*. *Albizia lebbeck* was found as most promising species

Dwivedi *et al.* (1990) studied growth performance and biomass production of *Eucalyptus tereticornis* trees grown in agricultural field bunds. The above ground biomass of *E. tereticornis* at 6-years age grown on two sides of the field boundary in single row was found in the order of 16.63 and 27.22 (dt/ha), respectively. The measurement in case of field bund plantation revealed that the growing stock of 1.5m^3/ha/yr to 3.5m^3/ha/yr can be obtained which is much more than the average production (0.7 cu. m/ha/yr of forest department.

Sharma and Jain (1977) prepared standard volume tables for *Gmelina arborea* Roxb. using linear regression techniques and concluded that d2x acts as more reliable predictor as difference between estimated and observed volume was no significant.

Malik, M.S.(2004) have Studied the allelopathic effect of tree on production of agricultural crops and reported that the leaf extracts from 1-3 years old plantation of *Eucalyptus globules* exerted less allelopathic toxicity on potato, bean and maize crops, hence intercrops can be grown under Eucalyptus during this period.

Paramathma *et al.* (2000) have studied allelopathy effect of agroforestry trees. The introduction of trees into agroecosystems has assisted on combating deforestations, but has disadvantage of getting reduced crop yield due to competition and allelopathic interactions with trees.

Datta and Dhiman (2001) studied productivity of upland rice (AR-U) and groundnut (JL-24) under twelve multipurpose trees in humid subtropical region of Tripura, India. The yields of both crops were lowest in agricultural system than sole crops.

Malik *et al*. (2005) studied the growth of yield of intercrops potato, maize and bean and observed that Eucalyptus globules with potato intercrop gave higher yield followed by other intercrops and Silvicultural manipulating.

2.2 Effect of intercrops on the tree growth

The groundnut pod yield was 1149 $kgha^{-1}$ in pure stand and 719-743$kgha^{-1}$ in agroforestry system with *Tectona grandis* (Mutunal *et al.*, 2000).Maize grown with *Acacia auriculiformis* gave highest grain yield (1020$kgha^{-1}$) compared to rice, sesame, pigeon pea, groundnut. The productivity of black gram consisted of 652 and 1100 kg ha^{-1} of grain and crop residues respectively under *Acacia auriculiformis* (Bora *et al.*, 1999).

Reddy *et al.* (2000) reported that the groundnut yield was not affected by perennial legumes (*Calliandra callothyrsus*, *Sesbania grandiflora, Leucaena leucocephala* and *Gliricidia sepium*). Suresh and Rai (1987) observed a reduction in the dry fodder yield of cowpea in agroforestry systems.

Peri *et al.* (2001) reported 11.2tones ha^{-1} fodder yield in lucerne in the open field and 7.9 tons ha^{-1} under pine trees. Singh *et al.* (2004) concluded that wheat crop produced higher grain yield under kapok (*Ceiba pendadra*) tree at wider tree spacing of 8 m x 4m as compared to narrow tree spacing of 4m x 4m. Out of the four tree spacing i.e. 8m x3m, 6m x 4m, 5m x 5m and 4m x 6m; Populus planted at 8 m x 3 m and 6 m x 4 m proved to be the best tree spacing for no or little adverse effect on the production of medicinal plant species (Partap and Vaishnu, 2005)

Ravi (2005) also observed the reduction in growth and yield of the intercrops under *Ailanthus excelsa* based agroforestry system when compared to pure cropping. Performance of eleven agricultural crops under three different spacing's (5mx2.5m, 10mx2.5m, 15mx2.5m) were tested by Nandal and Hooda (2005). They found that the yield of all crops decreased with increasing age of poplar. The yield of all crops increased with increasing poplar spacing, however a spacing of 10m X 2.5m seems to be the ideal for getting optimum growth and yield of agricultural crops.

Chauhan *et al*. (1995) observed in irrigated poplar-based agro-ecosystem, light is major limiting factor causing reduction in grain yield particularly in the rainy season and in late planted Rabi crops. On an average, a reduction in grain yield of wheat was 20% under 1year-old poplar plantation, which increased to 54% in a 4-year-old plantation. Therefore, the selection of suitable varieties which can tolerate shade is important for optimizing yields in poplar systems.

Singh *et al*. (2002) assessed the impact of aboveground and belowground competition on growth and productivity of wheat crop which was evaluated under fertilized and non-fertilized conditions in a *leucaena leucocephala* based alley cropping system in sub-humid climate of India. To examine the impact of aboveground and belowground competition, three competition situations were created in both fertilizer and no fertilizer condition: crop + *L*. shrub neighbuor, crop+L. hedge neighbour and sole crop treatment. Size (width) of the alley was 8m. Photosynthetic active radiation (PAR) was reduced 48 % under shrub neighbour. However, PAR in crop + hedge neigbhbour treatment did not differ from that in sole crop treatment (open area). Grain yield of wheat crop was 24% lower in crop + hedge and 42% lower in crop + shrub neighbour treatment compared to sole crop. Fertilization increased yield of the crop 1.65 times under hedge and 1.64% under shrub neighbour. Similarly relative growth rate of the crop was increased 5% under hedge neighbour as well as shrub neighbour due to nitrogen fertilization. Nitrogen uptake and photosynthetic rate was 1.39 times and 1.72 times, respectively greater under *Leucaena* shrub in fertilizer compared to no fertilizer condition. Root/Shoot ratio of wheat crop declined 12% under *Leucaena* shrub neighbour under fertilizer condition. Soil organic carbon in crop + shrub neigbhour treatment being equal to that in crop + hedge neighour treatment and was 8.7% greater compared to sole crop plot. However, C/N ratio declined. Growth in *Leucaena* shrub was 19% and N uptake 3.4 times compared to the wheat crop.

Verma *et al*. (2002). studied the impact of growing *Morus*, *Grewia* and almond on wheat growth and yield, it was studied in the mid hills (1250m above mean sea level) of Himachal Himalayas. Four tree-crop combinations- Morus + wheat (T_1), Morus +almond +wheat (T_2) (T_3), Grewia + wheat (T_4) along with one, no tree absolute control'(T_5) and two nitrogen level-N1 recommended level (80kg ha-^{1}) and N2: 25 percent more than the recommended (100 kg ha^{-1}) were used. Wheat growth a yield attributes- number of tillers per plant, number of plants m^{-2} plant height, grain and straw yield, soil moisture and percent relative illumination at different active growth stages of the wheat as well as phenophases of trees were recorded. Combination (Grewia +almond +wheat) at nitrogen level N_2 gave the maximum grain and straw yields. Mean grain yield was lower by 28, 21 and 25 percent over the T_5, *i.e*. no tree absolute control' at T_1, T_2, T_3 and T_4, respectively. Crop yield below the tree crown T_1, T_2, T_3 and T_4, respectively over outside the crown was however, less by 19, 17, 17 and 18 percent. Percent relative illumination and available soil moisture were also higher under T_3 Grewia + almond + wheat especially, during the active growth stages, i.e. panicalinitiation, milking and harvesting of wheat. The net return was highest at T_3N_2. Cost: benefit ratio was 2.34 and 1.99 at T_3N_2 and T_5TN_2, respectively. Studies, hence indicated Grewia plus almond has better component combination with wheat to form agri-hort-silvicultural system in the mid hills of Himachal Himalayas.

Singh *et al*. (1999) reported that the tall stature crops like sorghum, pigeon pea and gingerly significantly reduced the subabul leaf yield by 21% compared to small stature crops like black and groundnut.

Dhyani and Tripathi (1999) studied tree growth survival and crop yield under Mandrain (*Citrus reticulata*), Alder (*Alnus nepalensis*), Cherry (*Prunus cerasoides*) and *Albizia*. The crop sequence was (a) soybean-linseed (b) groundnut-mustard and (c) sole tree. A positive effect of intercropping on height and diameter growth, crown width and timber volume was observed in alder, *albizia* and cherry. *Alder* and *Albizia* attained maximum growth and woody biomass. The better growth and timber volume were observed in the tree and crop situation, which was mainly ascribed due to application of fertilizers and weeding.

Khattak *et al*., (1980) revealed that the yield of wheat in association with *Dalbergia sissoo* was significantly higher than *Eucalyptus camaldulensis, Populus deltoides* and *Bambax ceiba.*

In the semi and areas of Africa 30.40% higher yield of maize have been reported with *Leucaena leucocephala*, *Gliricidia sepium* and *Cassia siamea* intercropped as hedgerows and pruning used as mulch and green manure (Koning, 2002).

Dwivedi and Sharma (1989) reported 20% higher yields of grain and wood in agroforestry areas of Haryana and Western UP than from pure crops.

Sharma *et al*., (1994) also observed similar reduction in yield of pearl millet and cluster bean crops grown under trees species. The greater reduction in yield under *Casuarina* than Haldu and *Gmelina arborea* might be due to its higher canopy diameter which resulted in decrease in incoming radiation to agricultural crop underneath. Allelophatic effect of *Casuarina* on intercrops could also be another possible factor responsible for the decrease in yields.

Mehta *et al*., (1996) have found significantly higher grain yield of gram, mustard, and Indian been crops and control in open fields than those grown in association with trees.

Puri *et al*., (2002) studied growth and yield of soybean intercropped under five different clones of *Populus deltoides* (Clones 65/27, G3, G48, S7C1 and D121) in agrisiliviculture system. Shoot as well as root biomass and grain yield of soybean was not affected by any clone for the first two years. The biomass and seed yield of soybean were significantly reduced under poplar clones in subsequent year, i.e. decreasing trend in crop yield was obtained with an increase in age of the clones. In fourth year crop productivity declined from 41.9 to 51.9 % under different clones. The greatest reduction was associated with clone D121, while lowest was observed under clone G3.

Dhyani and Tripathi (1999) observed lower crop yields in soybean-linseed and groundnut-mustard cropping sequence under different agrisilvicultural systems in northeast India. Crop yields increased with an increase in distance from tree base in Alder, Mandarin and Cherry. However, in *Albizia* crop yield was not reduced in the proximity of trees.

A trial on agrisilvicultural system was carried out from 1996 to 1998 by Mohapatra (2002). Four common Kharif field crop like Paddy (Var. Heera), Green gram (Var K – 851), Black gram (Var T-9) and Ground nut (Var somrati) were grown in allies of four tree species *viz. G. arborea, Eucalyptus tereticornis, D. sissoo,* and *A. auricaliformis* and in a slopy barren land. The mean annual increment of tree growth (height and girth) was maximum in *Eucalyptus tereticornis* followed by *D. sissoo*. The productivity of Kharif field crops were invariably maximum under canopy of *D. sissoo* followed by *A. auriculiformis*, but lowest field of above crops were obtained from the inter space of *Eucalyptus tereticornis*.

In another study in an agri-horticultural system, groundnut produced maximum plant height with *Citrus reticulate*, Guava, Anar and Ber (*Anon.*,1994). Gill (2000) reported that Sorghum, wheat, chickpea and pigeon pea showed greater plant height under closely spaced multipurpose tree species *viz Hardwickia binata* and *Euacalyptus tereticornis*.

Gill and Ajit (1995) reported that wheat, oat, peas, okra and groundnut attained maximum plant height as pure crops than as intercrops in mango based cropping system. But in the number of leaves per plant, pods per plant and branches per plant were higher in association with mango (*Mangifera indica*) as compared to sole crop.

The results of the experiment conducted with *Acacia nilotica* and four agricultural crops *viz*., cowpea, Sesame, and horsegram and sorghum as intercrops revealed that the growth and yield attributes of the intercrops viz., plant height, basal girth, number of leaves, dry matter production, stalk and grain yield were greatly reduced under trees than when grown alone. Among the four intercrops, cowpea proved to be the most compatible crop with *Acacia nilotica* (Palani, 1996). It was found that the gradual increase in the shade of rubber tree to a progressive decrease in height, number of branches and pods, seeds per plant and grain yield in pigeon pea (Brahmam *et al*., 1997).

The ground pod yield was 1149 kg ha^{-1} in pure stand and 719-743 kg ha^{-1} in agroforestry system with *Tectona grandis* (Mutunal *et al*., 2000). Maize grown with *Acacia auriculiformis* gave the highest grain yield (1020kg ha^{-1}) compared to rice, sesame, pigeon pea and groundnut. The productivity of black gram consisted of 652 and 1100kg ha^{-1} of grain and crops residues respectively under *Acacia auriculiformis* (Pal *et al*. 2000). Reddy *et al*. (2000) reported that groundnut yield was not affected by perennial legumes (*Calliandra Callothyrsus, Sesbania grandiflora, Leucaena leucocephala* and *Gliricidia sepium*). Suresh and Rao (2000) observed a reduction in the dry fodder yield of cowpea in agroforestry systems.

2.3 Soil fertility status under Agroforestry system.

Agroforestry has shown its potentials as a land management alternative for maintaining the soil fertility and productivity in the tropics. It is known that the soil organic matter and other biotic factors are important in maintaining the productivity especially in the fragile humid tropical uplands (Kang, 1993). Home gardens can serve as models for the design of improved agroforestry practices (Kumar and Nair, 2004).

Pandey *et al.* (2002) studied the impact of neem plantation on soil properties was of in 4- and 8- year-old neem plantations at two different sites. An increase in organic carbon, available N, P and k was 0.11 %, 38.90 kg ha^{-1}, 5.14 kg ha-^{1} and 62.55 kg ha-^{1} respectively under 4-year-old neem plantation over control (without tree) after 3 years and increase was 0.18 % 35.75 kg ha^{-1}, 3.96 kg ha-^{1} and 67.55kg ha-^{1} for organic carbon, available N, P and K, respectively under 8 year old plantation. The increment in organic carbon and available P, N and K was lower in 15-30 cm soil depth compared to 0-15 cm. The soil pH was slightly lower in both the plantation in compare to control.

Verinumbe (1987) reported higher dry matter yield of maize and sorghum under the influence of forest soil in Sahel (Africa) than in ordinary field soils. Higher crops yields were obtained in the soil under Neem followed by *Prosopis* and *Eucalyptus* than in ordinary soils.

Vishwanath *et al.* (1998) studied effect of *Acacia nilotica* tree on associated rice crop growth, yield and physico-chemical properties of soil. They indicated that the crop parameter except grain yield were not affected by trees. Grain yield reduced by 28.3% under the tree canopy an it gradually increased away from the tree canopy.

Litter is a major source of organic matter in soil under different plantation. It not only replenishes the organic carbon and nutrient pool on plantation floor but also improves the physical health of the soil. Litter forms is an important pathway for recycling of nutrients to the soil from trees. The decomposition of litter adds organic and inorganic elements in the soil through the process of nutrient cycling (Mudrick *et al.*, 1994).

The litter production is comparatively higher than unmanaged plantation. (Toky and Singh, 1993), while a few studies are available in agroforestry system (Mohsin *et al.*, 1996).

Raizada *et al.*, (2003) reviewed litter production and C-flux through litter felled in ten important species raised under plantations in different agroecological zones of India. The litter production ranged from 1.3 to11.27Mg^{-1}yr^{-1}, while C-flux varied between 0.58 to 2.22 Mg ha^{-1}yr^{-1}. Among different species litterfall and C-flux was highest in *Shorea robusta* followed by *Pinus roxburghii*, *Eucalyptus sps*, *Tectona grandis* and *Acacia auriculiformis*.

Shanmughavel and Francis (2002) investigated litter production and nutrient return behaviour of bamboo in an agroforestry system. Bamboo intercropped with Pigeon pea produced higher quality of litter than pure bamboo stand alone. Litter fall followed bimodal pattern with principal peak in the winter and another in the late summer, of the total annual production. Leaf production accounted for 58% and twig litter 42%. The annual litter production was 13.5 Mgha^{-1} in pure bamboo stand and 15.7 Mg ha^{-1} in intercropped bamboo. The highest concentration of N, P, Ca and Mg were found in leaf litter while K was highest in twig litter. On an annual basis 89, 6, 78, 42 and 49 Kgha^{-1} (agroforestry system) of N, P, K, Ca and Mg, respectively were returned through litter fall. Maximum amount of nutrients were returned through leaf litter and lowest from twig litter.

Basavaraja and Rao (2000) have studied integration of tree in agroforestry system to find out positive or negative interaction between trees and crops. Micro-climatic amelioration and maintenance of improvement in soil productivity are the major positive interaction, while competition for light, water and nutrient and allelopathy are the major negative interactions in agroforestry systems. The balance between negative and positive interaction in a given agroforestry system. In such situations agroforestry system have to be managed through planting optimum density of trees proper spatial arrangement and pruning and thinning of tree crown and roots to reduce the negative effect of trees.

There was fertility build –up below trees which contributes to better growth of under vegetation compared to sites away from the tree canopy (Zinke, 1962; Tiedemann and Klemmedson, 1973; Christies, 1975). However, the magnitude of soil fertility amelioration varied among species. Soil fertility studies under 14 years old tree old communities of *Prosopis cineraria*, *Prosopis juliflora* and bare site showed slight reduction in EC and pH, but improved in organic matter, total N and total P_2O_5 under *P. cineraria* (Singh and Lal, 1969).

Gupta and Sexena (2004).studied the effect of *Gmelina arborea* with intercrop on soil properties in Nigeria and observed that like yam and maize with *Gmelina arborea* had little effect on soil properties although measurable, but not significant increase in soil N and P and marginal increase in soil acidity were noticeable. An increase in nitrogen with intercrops was reported under *Gmelina arborea* (Ojenijyi and Agbede, 1980); *Leucaena leucocephala* with maize and cowpea (Kang, 1993).

A definite increase in organic carbon, phosphorus and potash was discernible after the harvest of intercultivated crops (FAO, 1981). While increased organic carbon content and available phosphorus were also observed by Chandrasekhariah (1987), he failed to obtain any change in pH or available potash. Experiments carried out at Dharwad revealed organic content to be more at a depth of 0.15 m after five years of planting under *Dalbergia sissoo*, *Derris indica* and *Acacia nilotica*. While available phosphorus was more under *Azadrachta indica*, available potassium registered an increase under *Derris indica* and *Acacia nilotica* (Chandrasekhariah, 1987).

Increase in soil available phosphorus was evident under *Dalbergia sissoo* (Chandrasekhariah, 1987), *Leucocaena leucephala* with pearl millet, sorghum and maize (Rawat and Hazara, 1987) than those in the treeless open

For instance, in a silvopastoral system involving four MPTs, George and Kumar (1998) observed that tree growth over five years had substantially improved the soil chemical properties. Also, among the four MPTs, N-fixing trees such as *Acacia auriculiformis* and *Leucaena leucocephala* showed relatively higher concentrations of soil N, available P and K.

Thiyageshwari *et al*. (1998) reported that the available phosphorus was significantly higher under fodder grass intercropped with *Gmelina arborea* based silvipastoral system. Thiyageshwari *et al*. (1998b) reported that the available nitrogen ranged from 252 to 449 kg ha-^{1} under teak based silvipastoral system. The lowest value of 252 kg ha^{-1} was recorded in the open field and 25 per cent increase in the available nitrogen was recorded under hybrid Napier grass intercropped with teak.

Madheswaran (2002) observed that available nitrogen, phosphorus and potassium were more under intercropping than in open. Kathirvel (2003) reported that soil fertility *viz*; available nitrogen, phosphorus and potassium were improved under teak based agroforestry system.

Ravi (2005) observed the soil available nitrogen, phosphorus and potassium were more under fodder cowpea intecropped with *Ailanthus*. The highest (18.9$kgha^{-1}$) available phosphorus was recorded at 2m x 2m spacing and it deceased gradually as spacing increased between *Jatropha curcas*. The highest available potassium status was found to be 269$kgha^{-1}$ 2mx2m geometry of *Jatropha curcas* (Mohsin Basha, 2006), Low density of tree (*Cassia siamea*, bamboo, neem) contributed for higher in C:N and C:P ratios in agroforestry systems (Prabhu and Sreemannarayana, 2007).

Rai (2003) reported that the improvement in soil nutrients in agri-silvicutural system was more pronounced as compared to sole cropping except available potassium. Mohanraj (2004) reported improvement of available nitrogen, phosphorus and potassium under *Simaruba* based Agroforestry system.

Kathirvel (2003) reported that soil fertility *viz*., available nitrogen, phosphorus and postassium were improved under teak based agroforestry system. Rai (1984) reported the improvement in soil nutrients in agri–sivlicultural system was more pronounced as compared to sole cropping except available potassium. Mohanraj (2004) reported improvement of available nitrogen, phosphorus and potassium under Simarauba based Agroforestry system

Toky and Singh (1993) studied litter dynamics in short rotation high density tree plantation at Hissar, India. In four year old stands exotic species *viz. L. leucocaphala* and *Eucalyptus tereticornis* recorded maximum litter fall (7.5Mgha^{-1}yr^{-1} and 7.2Mg ha^{-1}yr^{-1}), which was about two times higher than *A. nilotica* (4.22Mgha^{-1}yr^{-1}). Litter fall increased with age of the stand. The quantity of litter in eight years old stands were 11.9Mgha^{-1}yr^{-1} in *L. leucocephala*, 9.1Mgha^{-1}yr^{-1} in *E. tereticornis* and 5.4Mgha^{-1}yr^{-1} in *A. nilotiea*.

Kumar *et al*. (1995) have studied nutrient turnover by different tree species in Agroforestry system. Plantations of *Dalbergia sissoo, Albizia lebbeck, Populus deltoides*. *Prusopis cineraria, L. leucocephala* were established in 1983 in the experimental area of the Department of Agroforestry CCSHAV, Hisar. After 8 years, soil sample were collected from 80 cm depth and 20 cm intervals to study soil characteristics (soil physical properties, pH, organic carbon, CEC, exchangeable Ca and Mg, available NPK and available Zn, Mn, Fe, Cu extractable by DTPA (diethylene triamine pent acetic acid) under the different tree species. The highest Carbon and exchangeable Mg were observed under *D. sissoo*. Highest available N, P and Fe under *E. tereticarnis* was observed, where as highest available K under *L. leucocephala* the highest exchangeable Ca, Zn and Mn under *P. cineraia* and highest Cu under *P. deltoides* was noticed. The maximum content of C, available P, Zn and exchangeable Ca was observed under *P. deltoides* of available N under *L. leucocephala* of available K under *A. lebbeck* of exchangeable Mg under *P. cineraria* and Fe, Cu and Mn under *D. sissoo*.

Miah *et al*. (1997) studied effect of legume trees on soil chemical properties under agroforestry system. Change in topsoil and chemical properties after 20 month experiment in an agroforestry system in the Phillipines using three multipurpose tree legumes (*Gliricidia sepium, Acacia auriculiformis* and *A. mangium*) intercropped with upland rice and mung bean (*Vigna radiata*) showed positive change in fertility except for soil pH and exchangeable Mg. Positive variation was observed in agroforestry and monoculture tree treatments. There was an increase in organic C by 9%, total N by 11.6% on available P by 11.2%, in exchangeable K by 10.6%, exchangeable Ca by 17.8% and CEC by 1.7%. The results indicated *G. sepium* as best species to build up soil fertility (except for exchangeable K). *Acaia auriculiformis* is intermediate (but best in exchangeable K) and *A. mangium* is the least favorable. The soil chemical properties did not vary much across or along the tree rows.

Khonje (1989) evaluated a few tree species like *Leucaena leucocephala*, *Gmelina arborea* and *Eucalyptus* in Malawi under different cropping system with food crops such as maize. The soil had a pH of 5.0, total organic carbon 1.95 and total nitrogen 0.38% as compared with the pH 6.0, total organic carbon 0.87 and 0.05% total nitrogen under mono cropping.

Hussain *et al*. (1988) studied leaves of leguminous trees as nutrients source for agricultural crops. A pot experiment was conducted in which sorghum was grown in 12Kg soil supplemented with $100KgNha^{-1}$ supplied as urea or as leaves of *Bauhinia* *purpurea, Cassia fistula, L. leucocephala* (green manures). The crop was harvested at flowering and dry weight production and uptake of N, P, K, Ca and Mg recorded. In comparison with untreated controls all the supplements significantly increased dry weight production and uptake of all nutrients except P. All parameter were maximum in the *L. leucocephala* treatments, which was significantly better than all other treatments. The exception was urea treatments, where the increase in dry weight production and Mg uptake was not significantly different from that promoted by *L. leucocephala*. All other treatment was similar to or inferior to the urea treatment.

Yamoah *et al*. (1985) have studied decomposition and nitrogen contribution by prunings of selected legumes in all alley cropping systems. Prunings of *Gliricidia sepium*, *Flemingia congesta* and *Cassia siamea* released 252, 70 and 120 KgN per hectare, respectively. The corresponding maize yield responses were 15-25 and 50 % relative to the control treatment without pruning's.

Nitrogen accumulates under the tree at increasing rates of 0.015 to 0.018 percent annually (Parfait, 1976) compared to barren site available phosphorus was thrice as much under *P. cineraria* and twice as much under *P. juriflora*, micronutrients like Zn, Mn, Cu were also enhanced under the tree canopies (Aggarwal *et al*., 1976).

2.4 Production of leaf litter in Agroforestry

Crop production management techniques using *L. leucocephala* leaves as a source of N for maize were investigated by Read *et al*., 1985. In field trials applications of 50-100KgNha^{-1} as *L. leucocephala* leaves increased grain yields by 15% in one trial but not in another, and the residual effect in the next season increased yields by 33-40% split application of leaves or application of fresh or dried leaves showed no differential effect, and incorporation had no advantage over surface application. In pot trial incorporating leaves into the soil was more effective than surface application. *L. leucocephala* leaves were not as effective as inorganic N in increasing yields in the year at application, but residual effects of inorganic N were slight. Buried leaves decomposed more quickly than surface applied leaves and fresh leaves decomposed more quickly than dried ones.

2.5 Economics of Agroforestry system

The agro-silvi-horticulture system integrating *leucaena*, lemon, papaya and turmeric on class I irrigated land provided sustainable mean net returns of Rs. 17066 per year against from double cropped agricultural system. *Eucalyptus tereticornis* (Smith) in top and Bhabbar grass (*Eulaliopsis binata*) in the understorey on a sandy loam class III land gave four years (1985–1988) mean air dry grass yield of 4.2 ton (used for paper pulp) from October and 1.19 ton $ha^{-1}yr^{-1}$ (used for fodder) from June cut. Bhabbar grass raised under Acacia species on a 25 to 30% sloping gravelly class IV land provided yield varying from 2.18 to 4.31 from October cut and 0.50 to 1.1 ton $ha^{-1}yr^{-1}$ from June cut with 6 years mean of 3.9 ton $ha^{-1}yr^{-1}$ which at 1988 prices provided net returns of Rs. 2402 ha^{-1} (Grewal *et al*., 1992).

Wannawong *et al*. (1991) have studied benefit cost analysis of selected agroforestry system on Northern Thailand. The potential productivity and financial return from selected agroforestry systems and traditional monocrops located in the Phuwiang. The agroforestry system studied the combination of *Eucalyptus, Leucaena* and *Acacia* intercropped with *Cassava* or Mungbeans. Parameters considered were tree growth, charcoal production and crop yield. They have considered agroforestry system more preferable financially than traditional monocrops.

Rao *et al*. (2000) have studied growth and biomass production of some important multipurpose tree species on rainfed sandy loam soil on the agroforestry system in Andhra Pradesh. Evaluation of tree species of 9-years after planting showed that *D. sissoo*, *L. leucocephala*, *A. auriculiformis* and *E. camaldulensis* were fast growing and suitable for this Southern Telengana Zone (AP). Data on biomass production (small wood and logs) showed that *D. sissoo* yielded maximum biomass (214.6 t ha^{-1}) followed by *L. leucocephala* (187.8 t ha^{-1}) and *Acacia auriculiformis* (162.4 t ha^{-1}). Maximum mean annual biomass production was also found for *D. sissoo* (23.8 t ha^{-1}) followed by *L. leucocephala* (20.9 t ha^{-1}) and *A. auriculiformis* (12.0 t ha^{-1}) and *E. camaldulenisis* (9.9 tha^{-1}). Cost benefit analysis showed that highest return was obtained from *D. sissoo* (4.4) followed by *L. leucocephala* (4.0), *A. auriculiformis* (3.1) and *E. camaldulensis* (2.9).

Marawar *et al*. (1995) carried of an economic analysis of *Eucalyptus* plantation on 23.39 ha of marginal land at Central Research Farm, Akola (Maharastra) and revealed that input output ratio was 1.04. Return was less due to sale of *Eucalyptus* as pulp wood rather than timber.

Rasul and Thapa (2007) reported that it is essential to evaluate agricultural land-use systems from both societal and private perspectives in the pursuit of promoting particularly environmentally sustainable systems. Horticulture, timber plantation, and agroforestry, considered to be suitable land-use systems particularly for mountaineous areas, held the middle ground between these two systems. Annual cash crops provided the highest financial return at the cost of a very high rate of soil erosion.

Mathur and sharma (1983) studied the economics of poplar plantation grown by forest department on Government land and by cultivators in their own farms. The annual returns were discounted at 12%, 15%, 20% and 25%. The Net present value (NPV) per hectare in case of poplar plantation with and without agriculture in the forest land and on farmers land with agriculture at 8, 10 and 12 year rotation was calculated. The NPV and benefit/cost (B/C) ratio was found maximum *i.e.* 11046 and 3.22 respectively at 12% interest rate with 8 year rotation in case poplar plantation combined with agriculture on farmland as compared to Rs. 7235 and 2.15 and Rs. 3208 and 1.51 in case of poplar plantation with agriculture on forest land and poplar plantation without agriculture in forests land respectively. They concluded that cultivation of agriculture crop with poplar at 8 years rotation ensures high economic returns.

Mutanal *et al.* (2000) reported that growing of tree +fruit plants+ field crops generated 46% more income compared to growing of field crops +fruit plants only. Jain and Singh (2000) observed that poplar based agroforestry was economically viable and more profitable than many of the crop rotations in northern region of India. This land use system was also capable of providing employment opportunities on farms. Sensitivity analysis indicated that this system was not highly risky.

Chaturvedi and Pandey (2001) reported the economics of intercropping maize-wheat -turmeric or pigeon pea-turmeric during first 10 year of a poplar (*Populus deltoides*) plantation. The cumulative benefit -cost ratio at the end of the 10^{th} year (after tree planting) was 5.01 with maize –wheat -turmeric and was 6.68 under pigeon pea-turmeric indicating that the latter cropping system was more profitable. However, both cropping system improve income and generate a steady cash flow for many years.

Vergara (1985) observes that agroforestry is a land use system combining agriculture and tree crop of varying longevity arranged either temporarily or spatially (inter cropping) to maximize and sustain aggregated yield.

2.6 Improved agroforestry as a sustainable cultivation system

It is widely believed that agroforestry has a considerable potential as a land management alternative for maintaining the soil fertility and productivity in the tropics. In addition, low input costs in many agroforestry systems render them available also for poorer farmers, who normally suffer most from the effects of erosion. Agroforestry is applicable to a wide range land types and has a potential for erosion control through the soil cover provided by the tree canopy and litter. Field crop production mainly affects the upper soil strata, while agroforestry exploits the entire soil profile (Young, 1989).

Chapter-3

MATERIALS AND METHODS

The present study on "Studies on growth performance and economic evaluation of Gamhar (*Gmelina arborea)* based agroforestry system in East Singhbhum District in Jharkhand." was carried out at Zonal Research Station, Darisai of Birsa Agricultural University, Ranchi from February, 2011 to February, 2012. Details of the study area and methods adopted for conducting experiments are presented below:

3.1 Location and topography

The experiment was conducted at field of Zonal Research Station, Darisai of Birsa Agricultural University, Ranchi. The site is situated at the distance of 28 km from Jamshedpur on Tata Ghatsila road (National Highway 33). The altitude of site is about 622m above mean sea level. Geographically the site is located at $21^0$58' and $23^0$36' N latitude and $85^0$0 and $86^0$54' E longitude in Chhotanagpur plateau. Darisai is situated on Zone VI (South Eastern Plateau Zone). The topographically the site is almost plain basic igneous rocks and granite in small pockets are the main geological sequence on which parent material and soil have developed.

FIG.-3.1: LOCATION MAP OF RESEARCH SITE

3.2 Surrounding Vegetation

The experimental site falls under degraded Sal belt which represented tropical moist deciduous Sal forest of Chhotanagpur. In the surrounding area along with the reminants of Sal (*Shorea robusta*) artificially raised tree species such as Akashi (*Acacia auriculiformis*), Arjun (*Terminalia arjuna*), Chakundi (*Senna siamea*), Gamhar (*Gmelina arborea*), Mangium (*Acacia mangium*), Shisham (*Dalbergia sissoo*), Populus (*Populus* spp.), Subabul (*Leucaena leucocephala*), Teak (*Tectona grandis*), Jacaranda (*Jacaranda mimosifolia*), Kadam (*Anthocephalus cadamba*), *etc.* are existing.

3.3 Climate

The climate is classified as sub-humid with mean daily temperature of about 22.8^0C. The mean temperature of the coldest month (January) is 7^0C and the hottest month (May) is 38^0C. The mean relative humidity is about 70.88% in the area. The monsoon breaks out in the middle of June and last till mid October. The annual rainfall in the area varies from 900-1500 mm. The mean wind velocity and evaporation varies from 3.61km/hr to 4.39km/hr and 130 mm to 140mm, respectively. The details of monthly meteorological data obtained from meteorological observatory of Zonal Research Station, Darisai, BAU during the experimental period (February, 2011 to February, 2012) are presented in Table 3.1.

Table-3.1: Monthly Meteorological data at Darisai from February, 2011 to February, 2012

Month	Temperature (^{0}C)		Average relative humidity (%)		Rainfall (mm)	Average evaporation (mm/day)
	Average maximum	Average Minimum	7.00 A.M	2.00 P.M.		
February, 2011	30.5	13.5	75	64	63.1	1.20
March, 2011	37.8	20.5	60	57	64.8	2.17
April, 2011	42.8	24.5	64	45	134.1	2.72
May, 2011	37.2	25.6	74	65	157.1	4.13
June, 2011	37.4	27.6	84	71	124.4	5.73
July, 2011	36.0	26.8	87	60	112.9	5.14
August, 2011	33.3	27.7	90	71	104.1	3.7
September, 2011	32.9	25.3	70	42	91.4	3.29
October, 2011	33.4	26.6	84	81	102.1	3.43
November, 2011	32.0	15.0	74	77	82.2	2.4
December, 2011	29.0	9.0	69	67	45.0	3.29
January, 2012	28.5	11.1	77	51	54.0	2.7
February, 2012	32.5	11.5	74	61	58.1	1.15

3.4 General characteristics of soil

The soil of the field site is sandy loam to gravelly loam in texture, shallow soil depth (25-50cm), 0.3 percent and 3-5 percent slopes and slightly to moderately eroded, well drained with low water holding capacity and poor consistency. The soil colour varied from 7.5 YR 5/4 to 2.5YR 6/4 (brown to light yellowish brown). Medium in nutrient content, neutral to slightly acidic in reaction (pH 6.6).

3.5 General Characteristics of Gamhar, Agricultural crops and Horticultural crops

The general characteristics of the Gamhar, agricultural crops and horticultural crops selected for the study are given below:

Gamhar (*Gmelina arborea*)

Gmelina arborea native to Asia commonly called as Gamhar white teak, belonging to the family verbenaceae. It is generally found scattered in mixed forest of moist region of the country extending into comparatively dry regions of central India. Occasionally, it occurs in evergreen as well as Sal forest. It is a moderate sized to large deciduous tree with straight trunk and numerous spreading branches. It usually attains a height of about 18m with a clear bole of 6m to 9 m and girth of 1.5 m to 2.5 m. Bark is smooth and pale ashy or grey in colour. Leaves are simple, broadly ovate and acuminate. The leaf fall occurs from January to February and up to March it becomes completely leafless, Flowers are reddish / brown and yellow in colour and its appears from February to April.

In its natural habitat absolute maximum shade temperature varies from 30.5^0C to 47.2^0C while minimum varies from 2.2^0C to 14.6^0C. It can grow where rainfall varies between 1750 mm and 2300mm. Gamhar prefers moist fertile valleys with sandy loam soil and does not thrive where drainage is bad. It is a light demanded and in tolerant of shade. It does not stand excessive drought. The coppicing power of Gamhar is vary strong and coppices shoot grow vigorously.

Seeds if carefully stored may be kept for a years. Freshly pulp seeds weight about 1400 to the kilogram and dry seeds number 2500-2600 to the kilogram. Germination capacity varies from 13-85% and plant % from 30-56. It can be propagated by any of three methods, namely direct sowing, stump planting or entire transplanting. The weight of the wood at 12% moisture content is 515 kg/cum.

Gmelina arborea timber is reasonably strong for its weight. It is used in constructions, furniture, carriages, sports, musical instruments and artificial limbs. Once seasoned, it is a very steady timber and moderately resistant to decay and ranges from very resistant to moderately resistant to termites. Its timber is highly esteemed for door and window panels, joinery and furniture especially for drawers, wardrobes, cupboards, kitchen and camp furniture, and musical instruments because of its lightweight, stability and durability. It is also used for bentwood articles. In boat building it is used for decking. *Gmelina arborea* is a popular timber for picture and slate frames, turnery articles and various types of brush backs, brush handles and toys also for handles of chisels, files, saws, screw drivers, sickles etc.

Gmelina arborea leaves are considered good for cattle (crude protein – 11.9%) and are also used as a feed to eri-silkworm. The root and bark of *Gmelina arborea* are claimed to be stomachic, improve appetite, useful in hallucination, piles, abdominal pains, burning sensations, fevers, 'tridosha' and urinary discharge. Leaf paste is applied to relieve headache and juice is used as wash for ulcers. Flowers are sweet, cooling,. They are useful in leprosy and blood diseases. In Ayurveda, it has been observed that Gamhar fruit is acrid, sour, bitter, sweet, cooling, diuretic tonic, aphrodisiac, alternative astringent to the bowels, promote growth of hairs, useful in 'vata', thirst, anaemia, leprosy, and ulcers. *Gmelina* with field crops gives of very satisfactory result. this is a genus comprising about 15 species of trees or upright shrubs, sometime scandent, distributed chiefly in South-East Asia and tropical Australia. Of the three species occurring is India, *G. arborea* is described here in detail and brief notes are given for the other two species.

Characteristic of Horticultural crops

Aonla (*Emblica officinalis*)

Aonla or Indian gooseberry (*Emblica officinalis*) is an indigenous fruit to Indian subcontinent. Owing to hardy nature, suitability to various waste lands, high productivity/unit area, nutritive and therapeutic value aonla have become an important fruit. Its fruits are a rich source of vitamin 'C'. Aonla fruit is highly valued among indigenous medicines. It is acrid, cooling, refrigerant, diuretic and laxative. Dried fruits have been reported to be useful in haemorrhages, diarrhoea, dysentery, anaemia, jaundice, dyspepsia and cough. Trifla and chavanprash are well-known indigenous medicines in Ayurvedic system using aonla. Besides fruits, leaves, bark and even seeds are being used for various purposes.

Aonla is a subtropical plant and prefers dry subtropical climate. A mature aonla tree can tolerate freezing as well as high temperature of 46^0C. Warm temperature seems conductive for the initiation of floral buds. Ample humidity is essential for initiation of fruit growth of dormant fruitlets during July-August. Dry spells result in heavy dropping and delay in initiation of fruit growth. The deep root system, reduced foliage, dormancy of fertilized fruitlets (April-June) makes aonla an ideal plant for and semi-arid conditions. Aonla can be cultivated in marginal soils- slightly acidic to saline/sodic (pH 6.5-9.5) conditions. Heavy soils or high water table areas are not suited for its cultivation.

Aonla has long been raised through seeds and inarching. From seed propagation, there is prolonged juvenility and wide variability. Seeds are sown in raised beds from April onwards and these are transplanted in separate bed for subsequent budding. Propagation of aonla in polybag, polytube, "root trainer" or in-situ orchards needs to be standardized and commercialized.

Grafted or budded aonla plants are planted 7-10m apart during July-August or February. Pits of 1-1.25m size are dug 2 months prior to planting. In each pit 3-4 baskets of well-rotten farmyard manure and 1kg neem cake or 500g bone meal are mixed with soil and filled. In sodic soil, 5-8kg gypsum along with 20kg sand is incorporated. Hedge-row planting is also being tried keeping line-to-line distance of 8m, while plant-to-plant distance is reduced to 4-5m.

The dose of manures and fertilizers depends upon soil fertility, age of plant and production. A dose of 10 kg farmyard manure, 100g N, 50g P and 100g K should be given to one-year-old plants of aonla. Aonla being a deep- rooted, deciduous tree with sparse foliage is an ideal plant amicable for 2 or 3-tier cropping system. Fruits, vegetables, flowers and a few medicinal and aromatic plants are well- suited for intercropping in aonla orchards. Change in seed colour from creamy-white to brown is an indication of fruit maturity. A budded/grafted aonla tree starts bearing third year onwards after planting, whereas a seedling tree may take 6-8 years. Anola fruits are graded into 3 grades. Large-sized, sound fruit are mostly utilized for preserve and candy; small-sized for chavanprash and trifla and blemished fruits for powder and shampoo making. Anola fruits can be stored for 6-9 days at ambient temperature. However, with a salt solution it can be stored up to 75 day. Necrosis a physiological disorder has been observed in aonla fruits. Incidence initiates with browning of mesocarp which extends towards the epicarp resulting into brownish-black appearance of flesh.

Mango (*Mangifera indica*)

Mango (*Mangifera indica*), the king of fruits. It can be grown from alluvial to lateritic soils except in black cotton soil having poor drainage; it grows well in soils with slightly acidic pH. Soils having good drainage are ideal for mango. Mango is a tropical fruit, but it can be grown up to 1,100m above mean sea level. The temperature between 24 and 27^0C is ideal for its cultivation. Higher temperature during fruit development and maturity gives better quality fruits. The areas experiencing frequent showers and high humidity are prone to many pests and diseases. Thus it can be grown best in regions with a rainfall between 25cm and 250cm.

Mango is a highly heterozygous and cross pollinated crop. Mango is propagated on mango rootstock. The nutritional requirement of mango varies with the region, soil type and age. A dose of 73g N, 18g P_2O_5 and 68g K_2O year of age from first to tenth year and thereafter a dose of 730g N, 180g P_2O_5 and 680g K_2O should be applied in 2 split doses during June- July and October respectively, Spraying of zinc sulphate (0.3%) during February, March and May is recommended to correct the zinc deficiency. Spraying of Borax (0.5%) after fruit set twice at monthly intervals and 0.5% manganese sulphate after blooming corrects boron and manganese deficiencies respectively. In India, mango is available from March to mid August. The north Indian cultivars are alternate- bearer whereas south Indian ones are generally regular-bearer. About 20 varieties are grown commercially. They are Alphonso, Chausa, Dashehari, Fazali, Gulab khas, Kesar, Kishenbhog, Largra, Neelum, etc. Sundar Langra is An Important commercial mango variety of north India, it is biennial-bearer and amid-season variety, with good quality fruits. Flesh is firm, Lemon-yellow in colour and scarcely fibrous. It has characteristics turpentine flavour. Keeping quality is medium. In mango, intercropping helps to check weed growth and reduces nutrient losses. Intercropping blackgram-wheat-mango and brinjal-onion-mango gives better monetary benefits. Besides, taking up cover crops like sun hemp, cowpea, pea and berseem help prevent soil erosion.

Mangoes should be harvested with pedicel. Injury to the fruits during harvesting brings down their quality and also makes them prone to fungal attack. Several types of harvesters have been developed. These devices are simple and efficient in harvesting. Yield in mango varies with the variety. However. on an Average mango yield 8 tonnes/ha, yield also varies with the region. The productivity of mango is higher in Andhra Pradesh and Bihar. With the adoption of high-density planting, its yields can easily be increased. The North Indian mangoes Sunder Langra and Dashehari are alternate-bearers whereas most of the South Indian mangoes are regular-bearers. Mango Mallika and Amrapali are also comparatively regular-bearer.

Papaya (*Carica papaya*)

Papaya, papaw or papita (*Carica papaya L.*) originated from tropical America, has become a popular fruit due to its fast growth, high yield, long fruiting period and high nutrient value as well. In addition it has been use as vegetable, fruit processing, and papain production at immature stage. It can be a highly profitable crop now. The papaya plant has male, female, hermaphrodite (bisexual flower) and some other complex forms. Male plants do not bear any fruit, normally the fruit shape from female plant is shorter, but the fruit shape from hermaphrodite (bisexual flower) plant is longer. Papaya is a tropical, plant, very sensitive to frost. Optimum temperature is 25 - 30°C and minimum 16°C. The suitable ph value is between 6 and 6.5. The well-drained or sandy loam soil with adequate organic matter is most important for the papaya cultivation. In high rainfall area, if drainage is poor and roots are continuously drenched for 24 to 48 hours, it may cause the death of the plants. Sticky and calcareous soils are not good as rain water may accumulate in the soil even only for a few hours. In this case, higher raised bed and drainage ditch are recommended.

Papaya is planted during sowing (February–March), monsoon (June-July) and autumn (October-November). Spring planting is done in area where the climatic condition is mild throughout the year. Monsoon planting is preferred in the frost prone areas, and autumn planting generally done in the region where the rainfall is high and virus problem is acute in rainy season. Plants are protected against frost damage by covering them with a polythene-sheet. Planting distance is determined by the integration of light interception, cultivar and economics consideration. A spacing of 1.8m x1.8m is normally followed for most of the cultivars. A closer spacing of 1.33m x1.33m (5,609 plants/ha) is optimum for variety coorg Honey Dew. The spacing of 1.4m x 1.4m or 1.4m x1.6m is best suited for papaya of pusa delicious under subtropical condition of Bihar. Spacing of 1.6mx 1.6m gives highest yield of fruits as well as papain in Tamil Nadu. A closer spacing of 1.2m x 1.2m for Pusa Nanha is adopted for high-density orcharding, accommodating 6,400 plants/ha a large, single-stemmed herbaceous perennial, to 30 ft, <20 ft in cultivation. Leaves are very large (up to 2 ½ ft wide), palmately lobed or deeply incised, with entire margins, and petioles of 1-3.5 ft in length. Stems appear as a trunk, are hollow, light green to tan brown, up to 8" in diameter, and bear prominent leaf scars. Plants are dioecious or hermaphroditic, with cultivars producing only female or bisexual (hermaphroditic) flowers preferred in cultivation. Flowers are solitary or small cymes of 3 individuals. Ovary position is superior. Prior to opening, bisexual flowers are tubular and female flowers are pear shaped. Since bisexual plants produce the most desirable fruit and are self-pollinating, they are preferred over female or male plants. Bisexual flowered plants are self-pollinating, but female plants must be cross pollinated by either bisexual or male plants. A large number of varieties are cultivated. well-known varieties with certain specific plant and fruit characters are, pusa delicious, pusa majesty, pusa giant, pusa dwarf, It is a dwarf-statured dioecious variety with good yield. Fruits are medium-sized with oval shape and are preferred by consumers, Coorg Honey Dew, Taiwan Flesh is yellow-orange to salmon at maturity, the edible portion surrounding the large, central seed cavity in the center. Individual fruits mature in 5-9 months, depending on cultivar and temperature. Plants begin bearing in 6-12 months.

Fruits are hand harvested carefully to avoid scratching the skin, which would release latex and stain the skin. To reduce post-harvest fruit rot, papayas are commonly heat treated postharvest (110-120°F), then rinsed in cool water. Fungicides also may be used, generally in the wax applied during packing. Fruits can be cured at 85^0F and 100% humidity for better color expression prior to shipping. Below 50°F, papayas experience chilling injury. Papayas are extremely perishable; shelf life at room temperature ranges from 3 to 8 days, depending on storage atmosphere.

Characteristics of Agricultural crops

Indian mustard (*Brassica nigra*)

Brassica nigra (black mustard) is an annual weedy plant cultivated for its seeds, which are commonly used as a spice. The plant is believed to be native to the southern mediterranean region of Europe, and has been cultivated for thousands of years. The spice is generally made from ground seeds of the plant, with the seed coats removed. The small (1 mm) seeds are hard and vary in color from dark brown to black. They are flavorful, although they have almost no aroma. The seeds are commonly used in Indian cuisine, where it is known as *rai*. The seeds are usually thrown into hot oil or ghee, after which they pop, releasing a characteristic nutty flavor. The seeds have a significant amount of fatty oil. This oil is used often as cooking oil in India. Ground seeds of the plant mixed with honey are widely used in eastern Europe as cough suppressant. It consisted in mixing ground mustard seeds with flour and water, and creating a cataplasm with the paste. This cataplasm was put on the chest or the back and left until the person felt a stinging sensation. The plant itself can grow from two to eight feet tall, with racemes of small yellow flowers. These flowers are usually up to 1/3" across, with four petals each. The leaves are covered in small hairs; they can wilt on hot days, but recover at night.

Brassica nigra is a annual growing to 1.2 m (4ft). It is hardy to zone 7 and is not frost tender. It is in flower from June to August, and the seeds ripen from July to September. The flowers are hermaphrodite (have both male and female organs) and are pollinated by bees, flies. The plant is self-fertile. Suitable for: light (sandy), medium (loamy) and heavy (clay) soils and prefers well-drained soil. Suitable pH: acid, neutral and basic (alkaline) soils and can grow in very acid soils. It can grow in semi-shade (light woodland) or no shade. It prefers moist soil. Leaves- raw or cooked. A hot flavour, they can be finely chopped and added to salads or cooked as a potherb. The seedlings can also be used as a salad when about one week old, adding a hot pungency to a salad. Immature flowering stems - cooked and eaten like broccoli. Mustard seed is commonly ground into a powder and used as a food flavouring and relish. An edible oil is obtained from the seed. Mustard seed is often used in herbal medicine, especially as a rubefacient poultice. The seed is ground and made into a paste then applied to the skin in the treatment of rheumatism, as a means of reducing congestion in internal organs. The seed is also used internally, when it is appetizer, digestive, diuretic, emetic and tonic. Swallowed whole when mixed with molasses, it acts as a laxative. Mustard is also recommended as an aperients ingredient of tea, useful in hiccup. Mustard flour is considered as antiseptic.

The plant is often grown as a green manure; it is very fast, producing a bulk suitable for digging into the soil in about 8 weeks. Not very winter hardy, it is generally used in spring and summer. It does harbour the pests and diseases of the cabbage family so is probably best avoided where these plants are grown in a short rotation and especially if club root is a problem. Mustard oil (allyl isothiocyanate) is used in commercial cat and dog repellent mixtures. An easily grown plant, black mustard is suited to many types of soils except very heavy clays; it grows best on light sandy loams, or deep rich fertile soils. Succeeds in full sun in a well-drained fertile preferably alkaline soil.

The plant tolerates an annual precipitation of 30 to 170 cm, an annual average temperature range of 6 to 27°C and a pH in the range of 4.9 to 8.2. Black mustard is adapted to a wide variety of climatic conditions; it is often grown in the temperate zone though it is mainly suited to tropical areas, and grown chiefly as a rainfed crop in areas of low or moderate rainfall. Black mustard is often cultivated for its edible seed, though it is going out of favour because it rapidly sheds its seeds once they are ripe and this makes it harder to harvest mechanically than the less pungent brown mustard (*Brassica juncea*). It germinates freely and quickly grows rapidly and makes a very useful green manure. The flowers have a pleasing perfume, though this is only noticed if several flowers are inhaled at the same time. Seed - sow in situ from early spring until late summer in order to obtain a succession of crops. The main crop for seed is sown in April.

Chickpea (*Cicer arietinum*)

The chickpea (*Cicer arietinum*) is a legume of the family Fabaceae, subfamily Faboideae. Its seeds are high in protein. It is one of the earliest cultivated legumes: 7,500-year-old remains have been found in the Middle East. The plant grows to between 20–50cm (8–20 inches) high and has small feathery leaves on either side of the stem. Chickpeas are a type of pulse, with one seedpod containing two or three peas. It has white flowers with blue, violet or pink veins. Chickpeas need a subtropical or tropical climate with more than 400 millimetres (16 in) of annual rain. They can be grown in a temperate climate but yields will be much lower.

Mature chickpeas can be cooked and eaten cold in salads, cooked in stews, ground into a flour called gram flour (also known as chickpea flour and *besan* and used frequently in Indian cuisine), ground and shaped in balls and fried as falafel, stirred into a batter and baked to make farinata. Hummus is the Arabic word for chickpeas, which are often cooked and ground into a paste and mixed with *tahini*, sesame seed paste, the blend called *hummus bi tahini*, or chickpeas are roasted, spiced, and eaten as a snack, such as *lebleb*. In India, as well as in the Levant, unripe chickpeas are often picked out of the pod and eaten as a raw snack and the leaves are eaten as a green vegetable in salads.

Chickpeas (*Cicer arietinum*) do not cause lathyrism. Similarly named "chickling peas" (*Lathyrus sativus*) and other plants of the genus Lathyrus contain the toxins associated with lathyrism. Chickpeas are a helpful source of zinc and protein. Chickpeas are low in fat and most of this is polyunsaturated. Nutrient profile of desi chana (the smaller variety) is different, especially the fibre content which is much higher than the light coloured variety. One hundred grams of mature boiled chickpeas contains 164 calories, 2.6 grams of fat (of which only 0.27 grams is saturated), 7.6 grams of dietary fiber and 8.9 grams of protein. Chickpeas also provide dietary phosphorus (49–53 mg/100 g), with some sources citing the garbanzo's content as about the same as yogurt and close to milk.

Pea (*Pisum sativum)*

The pea is most commonly the small spherical seed or the seed-pod of the pod fruit *Pisum sativum*. Each pod contains several peas. Peapods are botanically a fruit, since they contain seeds developed from the ovary of a (pea) flower. However, peas are considered to be a vegetable in cooking. The name is also used to describe other edible seeds from the Fabaceae such as the pigeon pea (*Cajanus cajan*), the cowpea (*Vigna unguiculata*), and the seeds from several species of *Lathyrus*.

P. sativum is an annual plant, with a life cycle of one year. It is a cool season crop grown in many parts of the world; planting can take place from winter to early summer depending on location. The average pea weighs between 0.1 and 0.36 grams. The immature peas (and in snow peas the tender pod as well) are used as a vegetable, fresh, frozen or canned; varieties of the species typically called field peas are grown to produce dry peas like the split pea shelled from the matured pod. A pea is a most commonly green, occasionally purple or golden yellow, pod-shaped vegetable, widely grown as a cool season vegetable crop. The seeds may be planted as soon as the soil temperature reaches 10°C (50°F), with the plants growing best at temperatures of 13 to 18°C (55 to 64°F). They do not thrive in the summer heat of warmer temperate and lowland tropical climates, but do grow well in cooler, high altitude, tropical areas. Many cultivars reach maturity about 60 days after planting.

Peas have both low-growing and vining cultivars. The vining cultivars grow thin tendrils from leaves that coil around any available support and can climb to be 1–2 m high. A traditional approach to supporting climbing peas is to thrust branches pruned from trees or other woody plants upright into the soil, providing a lattice for the peas to climb. In dense plantings, peas give each other some measure of mutual support. Pea plants can self-pollinate. A variety of diseases affect peas through a number of pathogens, including insects, viruses, bacteria and fungi. In particular, virus disease of peas has worldwide economic importance.

Additionally, insects such as the pea leaf weevil (*Sitona lineatus*) can damage peas and other pod fruits. They are about 3.5 millimetres (0.14 in) to 5.5 millimetres (0.22 in) long and are distinguishable by three light-coloured stripes running length-wise down the thorax. The weevil larvae feed on the root nodules of pea plants, which are essential to the plants' supply of nitrogen, and thus diminish leaf and stem growth.

Fresh peas are often eaten boiled and flavored with butterand/or spearmint as a side dish vegetable. Salt and pepper are also commonly added to peas when served. Fresh peas are also used in pot pies, salads and casseroles. Dried peas are often made into a soup or simply eaten on their own. This food was made from a fast-growing pea that would mature in a short growing season. *Ärtsoppa* was especially popular among the many poor who traditionally only had one pot and everything was cooked together for a dinner using a tripod to hold the pot over the fire.

Processed peas are mature peas which have been dried, soaked and then heat treated (processed) to prevent spoilage in the same manner as pasteurising. Bioplastics can be made using pea starch. Peas are high in fiber, protein, vitamins, minerals, and lutein. Dry weight is about one-quarter protein and one-quarter sugar. Pea seed peptide fractions have less ability to scavenge free radicals than glutathione, but greater ability to chelate metals and inhibit linoleic acid oxidation.

3.6 Treatment and layout of plan

The experiment was conducted in the field have boundary plantation of one tree species namely *Gmelina arborea* (Gamhar) and fruit crops namely Mango (*Mangifera indica*), Anola (*Emblica officinalis*), Papaya (*Carica papaya*). The agroforestry experiment along with the intention of growing agricultural crops namely Gram (*Cicer arietinum*), Pea (*Pisum sativum),* Indian mustard *(Brassica nigra)* and Fruit crops namely Mango (*Magnifera indica*), Aonla (*Emblica officinalis*), Papaya (*Carica papaya*). During the experimental period, standard cultural practices like weeding, hoeing and watering were done at weekly interval *i.e*. after 7 days (weeding) or when it is required (watering) to maintain the proper growth of agricultural crops. The soil characteristic and tree related were measured at six monthly intervals. The observation and measurement in the experimental plot were recorded periodically from February, 2011 to February, 2012.

3.7 Treatment details:

Location	-	ZRS Darisai
Design	–	Fixed Plot Survey Design
Replication	–	Three
Size of plot	-	16.0m X 6.0m
Spacing of tree species	-	2.0m on the line of farm boundaries

Spacing of agricultural crops

Pea (*Pisum sativum*)	-	30cm X 30 cm (line to line 25 cm)
Gram (*Circer arietnum*)	-	30cm X 30cm
Indian Mustard (*Brassica nigra)*	-	30cm X 30cm

Spacing of fruit crops

Mango (*Magnifera indica*)	-	5.0 m X 5.0 m
Aonla (*Emblica officinalis*)	-	5.0 m X 5.0 m
Papaya (*Carica papaya*)	-	2.0 m X 2.0 m

Year of planting

Tree species	-	June, 1999
Agricultural crops	-	December, 2011
Fruit crops	-	June, 2009

Control

Sole Crop

Gamhar	(*Gmelna arborea*)
Mango	(*Magnifera indica*)
Aonla	(*Emblica officinalis*)
Papaya	(*Carica papaya)*
Pea	(*Pisum sativum*)
Gram	(*Circer arietnum*)
Indian Mustard	*(Brassaica nigra)*

Treatment lay out

T_0	=	Gamhar + (Control)
T_1	=	Gamhar + Mango
T_2	=	Gamhar + Aonla
T_3	=	Gamhar + Papaya
T_4	=	Gamhar + Pea
T_5	=	Gamhar + Gram
T_6	=	Gamhar + Indian mustard

3.8 Preparation of experimental plot for agricultural crop and horticultural crop

For agricultural crops each plot was prepared with through ploughing by tractor followed by planking in order to pulverise the soil. The crop residues and crop stubbles were removed by hand picking. Before last ploughing soil was incorporated with well rotten farm yard manure at the rate of 25 tonnes per hectare, and after last ploughing the plot was properly leveled and laid out according to plan.

The Fruit crops namely Mango (*Magnifera indica*), Aonla (*Emblica officinalis*), Papaya (*Carica papaya*) are planted in the year 2009 where as the seeds of agricultural crops namely Gram (*Cicer arietinum*) and Pea (*Pisum sativum)* were sown in the furrow 30 cm apart, whereas the seeds of Indian mustard (*Brassica nigra)* are spread over the field by manually and followed their agronomical package of practices.

3.9 Observations Recorded

The different growth parameters such as height stem girth, crown width, and yield of horticulture crops and germination, crop height, and yield of agricultural crops were recorded for each treatment. The fruit yield of agricultural crops by harvesting mature fruit and taking their weight after the final harvesting. The details of measurement and calculation methods are given below-

3.9.1 Height of tree species

The height of individual tree from ground level to the top of crown was considered as height, which was measured with a graduated bamboo marked in meter. The graduation was done at one meter interval, half meter interval and at an interval of 10 cm. In the case of trees having greater height than poles Haga Altimeter instrument was used. The mean height of tree species is calculated with the help of height of total height with the total number of tree of a plot. The height is expressed in meter.

3.9.2 Diameter at breast height of tree species

The diameter was meausured indirectly by measuring girth because many forestry scientists have preferred the use of tape over caliper in the interest of accuracy (Chaturvedi and Khanna, 1982). Therefore, all trees of each plot were enumerated for girth at breast height (1.37m), over bark (G.BH.OB) and it was expressed in terms of cm. The girth, thus obtained was converted into diameter by the using standard formula d = g/π) where d = diameter, g = girth, π = 3.1415). From total diameter of all trees, the mean diameter was calculated.

3.9.3 Crown diameter

The Crown diameter was measured using two poles and Meter tape. For this first of all, the wider diameter point was marked on ground with bamboo poles and the horizontal distance between two points is measured with tape in cm.

3.9.4 Basal area

The basal area of the species calculated in that particular site. Basal area of tree was calculated using the following formula and is expressed in square meter (m^2) (Chaturvedi & Khanna, 1982)

$$\text{Basal area} = \pi \frac{d^2}{4}$$

Where d = diameter at breast height (d.b.h.) in m

π = 3.14

3.9.5 Volume

The volume of tree in the site was calculated using the following formula and is expressed in cubic meter (cu.m. or m^3) (Chaturvedi & Khanna, 1982)

$$V = \pi \frac{d^2}{4} h$$

Where	d	=	Diameter at breast height (d.b.h.) in m
	h	=	Total height (m)
	π	=	3.14

3.9.6 Height increment

For calculation of height increment, the difference between two height measurements at an interval of 1 year was taken and average height increment of the trees was calculated. The increment in height increment is expressed in terms of centimeter (m).

3.9.7 Height of agricultural crops

Ten randomly selected plants from each plot at maturity were taken for height measurement. For this the height was measured from ground level to neck node with the help of meter scale and expressed in cm. The mean value of 10 plants was taken as the final height.

3.9.8 Yield of agricultural crops

The yield of agricultural crops was measured through sampling techniques taking 12 sample plots of the size 1m X 1m randomly distributed throughout each treatment plot. The crops of sample plots were harvested and the quantities of seeds after removed from husk were taken by weighing machine. The average value of each sample plot was calculated. Total value of sample plots and it was converted on hectare basis.

3.9.9 Plant height of Fruit species

The height of fruit crops from ground level to the top of crown was considered as height, which was measured with a graduated bamboo marked in cm and meter/multimeter. The height is expressed in meter. The mean value of crops was taken as the final height.

3.9.10 Yield of fruit species

The yield of fruit crops was measured by taken weight of the each fruits when they are matured throughout each treatment plot and each crops individually. The average value of each sample plot was calculated total value of sample plots and it was converted on hectare basis.

3.10 General soil properties

Composite soil samples from each treatment plot were taken from a depth of 30 cm with the help of soil auger. The samples were air dried, powdered and sieved prior to chemical analysis. The methods employed for chemical analysis are given below

3.10.1 Soil pH

The pH of the soil was determined by potentiometry (pH meter). For this purpose, soil: water suspension was prepared (1:5) and tested with potentiometry to know the value of pH

3.10.2 Nitrogen

The Available nitrogen present in the soil was estimated by alkaline permanganate method. 20.0 gm of soil was taken in a distillation flask and moistened with 20.0 ml of distilled water. Then 100.0 ml of freshly prepared 0.32% potassium permanganate solution and 2.5% sodium hydroxide were added and distillation was done by collecting the distillate in 20.0 ml of 0.1 N sulphuric acid (with methyl red as indicator) in a beaker. After the distillation was over the contents of the beaker were titrated against 0.1N potassium hydroxide until a straw yellow colour was obtained. From the difference in the titration value the amount of available nitrogen was calculated.

3.10.3 Phosphorus

The available phosphorus content present in the soil was estimated by using sodium bicarbonate as extractant. 5 gm of soil was weighed and transferred to a beaker and added with 25.0 ml of Olsen's reagent (0.042 percent solution of NaHCO3) and 1.0gm of activated charcoal. The contents were shaken in a mechanical shaker for 30 minutes and filtered through Whatman No. 1 filter paper. 5 ml of the filtrate was pipette out in to a 25.0 ml volumetric flask. 1ml of molybedate reagent and 1ml of stannous chloride solution were added and the volume was made up. The colour developed was measured in a spectronic 20 calorimeter at 660 nm. A standard graph was prepared using KH_2PO_4 and the phosphorus was calculated.

3.10.4 Potassium

The available potassium content of the soil was estimated by using ammonium acetate as extractant and 5 gm of soil was added. The content was shaken for 5 minutes in a mechanical shaker and filtered by busing a Whatman No. 1 filter paper. The filtrate was used to estimate the potassium content by using flame photometer. A standard graph was prepared with potassium chloride and the concentration of potassium was estimated.

3.10.5 Organic carbon

Organic carbon content was determined by Walkley and Black's method followed by Bray and Kurtz (1945). For this process, a mixture of 10 ml potassium dichromate (1N), 20 ml concentrated sulphuric acid and 1 gm of 0.2 mm sieved soil samples were titrated with 0.5 N ferrous ammonium sulphate.

3.11 Statistical Analysis

The data recorded on various parameters were subjected to statistical analysis for statistical validity of the results and interpretations. The main objective of t-test was to examine if there is any significant difference between the mean values of different parameter for each provenances/seed source. The significance of different sources of variation was tested by variance ratio of mean sum of square (F-test) at probability level of 5%. Standard of variance (ANOVA), standard error of mean (S.Em), Coefficient of variation, Critical difference, *etc*. were calculated for each parameter for the purpose of interpretation. For statistical calculation Excel Package of M.S. Office was used in a computer.

Chapter – 4

RESULT AND DISCUSSION

4 Growth parameters of Gamhar tree

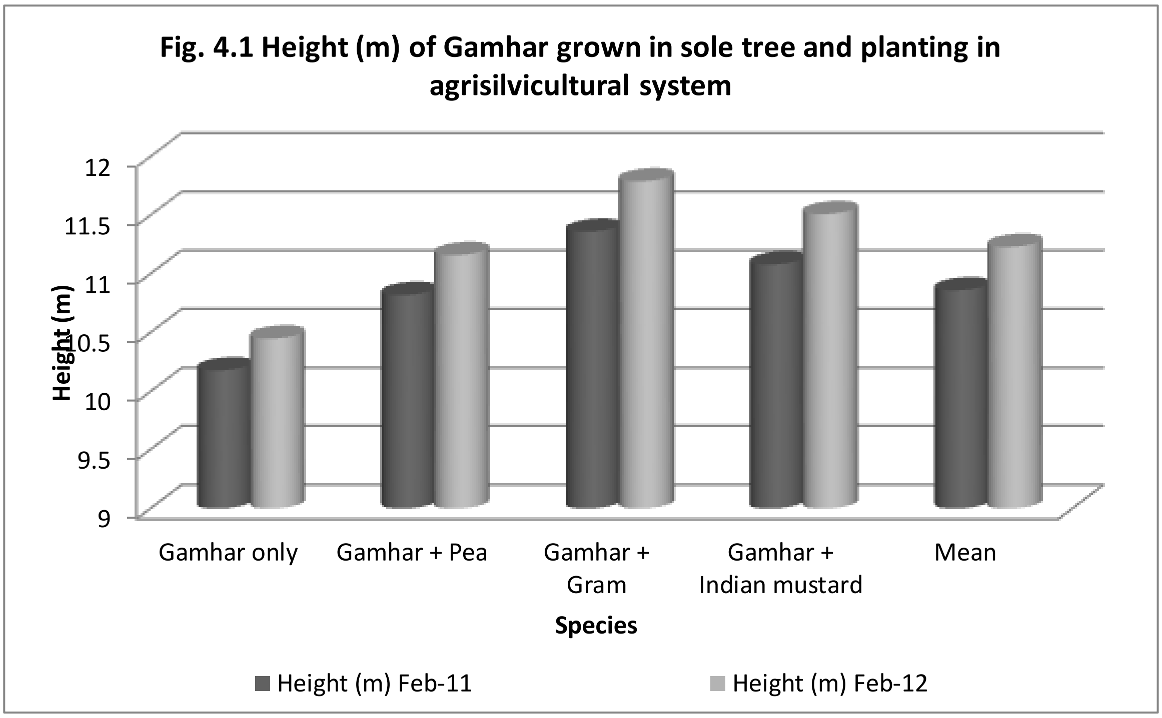
4.1 Height

The height of Gamhar grown in isolation and along with agriculture crops viz. Pea, Gram, and Indian mustard is presented in Table 4.1 and in fig. 4.1. Perusal of the data has indicated that height of *Gmelina arborea* in the sole plantation is 10.18m which is lowest among agrisilvicultural system. Among the agrisilvicultural system, the *gamhar* has recorded different height with different agriculture crops which ranged from 10.82m to 11.36m. The height of Gamhar is found highest in case of gamhar+gram which is 11.36m whereas the minimum highest has obtained in gamhar+pea (10.82m).

After one year in sole tree system gamhar have attained height of 10.45m. The difference in height of gamhar with different agriculture crops was found statistically non-significant. Perusal of the data has indicated that height of gamhar more under agrisilviculture system than sole planting. However, the height of gamhar was found maximum in gamhar+gram (11.79m) and minimum in gamhar+pea (11.16m) in agrisilviculture system.

Table-4.1: Height (m) of Gamhar grown in sole tree and planting in agrisilvicultural system

Treatments	Height (m)	
	February 2011	**February 2012**
Gamhar only	10.18	10.45
Gamhar + Pea	10.82	11.16
Gamhar + Gram	11.36	11.79
Gamhar + Indian mustard	11.08	11.51
Mean	10.86	11.23
S.Em	**0.319**	**0.312**
CV %	**13.479**	**12.751**
C.D. at 5%	**1.007**	**0.984**



Similar to the present study Malik *et al*. (2005) and Malik & Surendran (2000) have reported better growth of tree in Agrisilvicultural system of *E. globules* and potato and also Gill and Roy (1992) reported better height growth in agroforestry than in sole tree planting at National Research Centre on Agroforestry (NRCAF), Jhansi by taking 12 multipurpose tree species. The growth of poplar stand in different age groups intercropped with Mentha and *Cymbopogon* species at Tarai region of Kumuan, India was found better than monoculture plantation (Mohsin *et al*., 1996). Patel and Singh (1996) reported similar result in agroforestry system in Gujarat and noticed maximum height growth of *Albizzia lebbeck* (9.10m) followed by *Melia azedarach* (8.8m) and *Eucalyptus* hybrid (6.73 m) at five years age.

4.2 Diameter

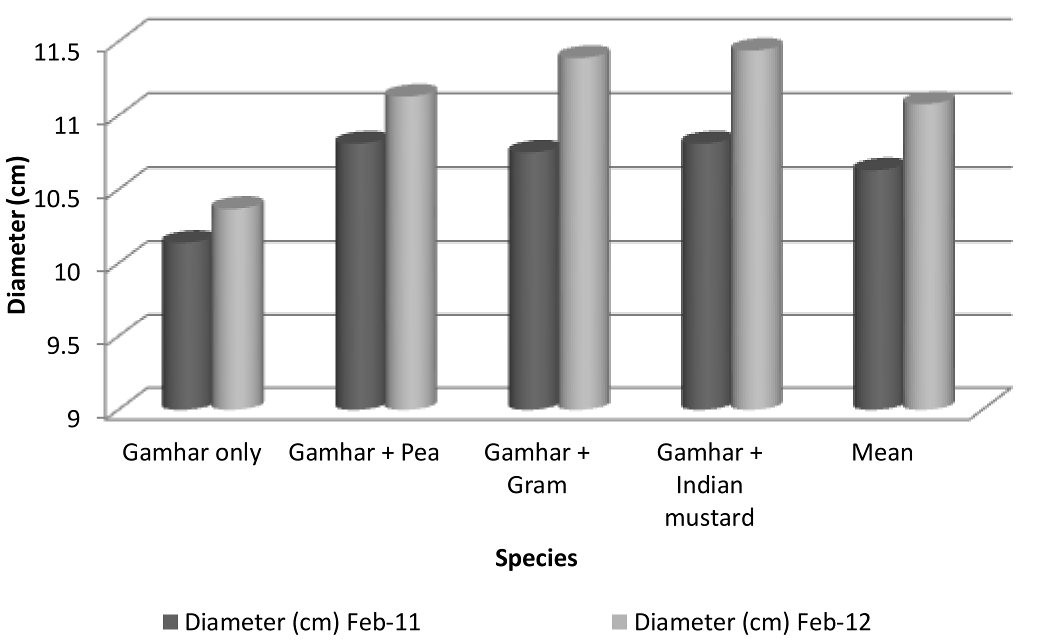
The diameter of Gamhar grown in isolation and along with agriculture crops viz. Pea, Gram, and Indian mustard is presented in Table 4.2 and in fig. 4.2. Perusal of the data has indicated that diameter of *Gmelina arborea* is maximum (10.81cm) in agrisilviculture system where as minimum diameter (10.14cm) found in sole plantation. Among the agrisilvicultural system, the gamhar has recorded different diameter with different agriculture crops which ranged from 10.75cm to 10.81cm. The ascending order of diameter is gamhar→gamhar+gram→gamhar+Indian mustard→gamhar+pea.

After one year in agrisilviculture system the diameter of gamhar have significantly higher (11.44cm) than sole plantation. The diameter of gamhar in agrisilviculture system was found statically significant with sole plantation. Perusal of the data has indicated that diameter of gamhar less under sole plantation than agrisilviculture system.

Table 4.2: Diameter (cm) at DBH of Gamhar grown in sole tree and planting in agrisilvicultural system

Treatments	Diameter (cm)	
	February 2011	**February 2012**
Gamhar only	10.14	10.37
Gamhar + Pea	10.81	11.13
Gamhar + Gram	10.75	11.39
Gamhar + Indian mustard	10.81	11.44
Mean	10.63	11.08
S.Em	**0.174**	**0.184**
CV %	**7.520**	**7.588**
C.D. at 5%	**0.549**	**0.578**

Fig. 4.2 : Diameter (cm) at DBH of Gamhar grown in sole tree and planting in agrisilvicultural system



Similar to the findings of present study, Gill and Roy (1992) reported better diameter and height growth in agroforestry than in sole tree planting at NRCAF, Jhansi. Similarly, better growth of tree species have been reported by different tree species in agroforestry system (Tree+agricultural crop), *i.e*. *Dalbergia sissoo* intercropped with wheat and paddy (Sharma, 1987).

4.3 Crown diameter

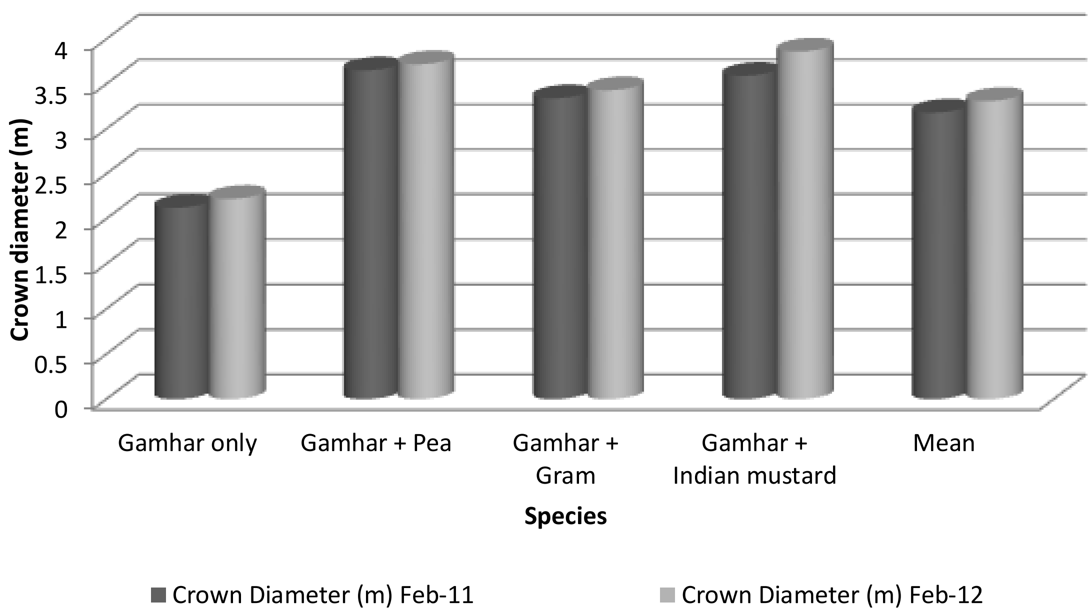
The crown diameter of Gamhar grown in sole plantation and along with agriculture crops *viz*. Pea, Gram, and Indian mustard is presented in Table 4.3 and in fig. 4.3. Perusal of the data has indicated that crown diameter of *Gmelina arborea* is maximum (3.65cm) in agrisilviculture system where as minimum diameter (2.12cm) found in sole plantation. Among the agrisilvicultural system, the *gamhar* has recorded different crown diameter with different agriculture crops which ranged from 3.34cm to 3.65cm. The ascending order of crown diameter is gamhar→gamhar+gram→gamhar+ Indian mustard →gamhar+pea.

After one year in agrisilviculture system the crown diameter of *gamhar* have significantly higher (3.86cm) than sole plantation. The crown diameter of *gamhar*+ Indian mustard was found statistically significant with sole plantation and with gamhar+gram. Perusal of the data has indicated that diameter of gamhar less under sole plantation than agrisilviculture system.

Table 4.3: Crown diameter (m) of Gamhar grown in sole tree and planting in agrisilvicultural system

Treatments	Crown Diameter (m)	
	February 2011	**February 2012**
Gamhar only	2.12	2.22
Gamhar + Pea	3.65	3.72
Gamhar + Gram	3.34	3.43
Gamhar + Indian mustard	3.59	3.86
Mean	3.18	3.31
S.Em	**0.172**	**0.143**
CV %	**17.568**	**14.045**
C.D. at 5%	**0.384**	**0.319**

Fig. 4.3: Crown diameter (m) of Gamhar grown in sole tree and planting in agrisilvicultural system



Similar to the present findings Kaushik *et al*. (2002) have found crown spread of *Dalbergia sissoo* (40.10m^2), *A. indica* (24m^2) and *M. alba* (10.90 m^2) in Agri silvihorticultural system in Arid- India.

4.4 Volume

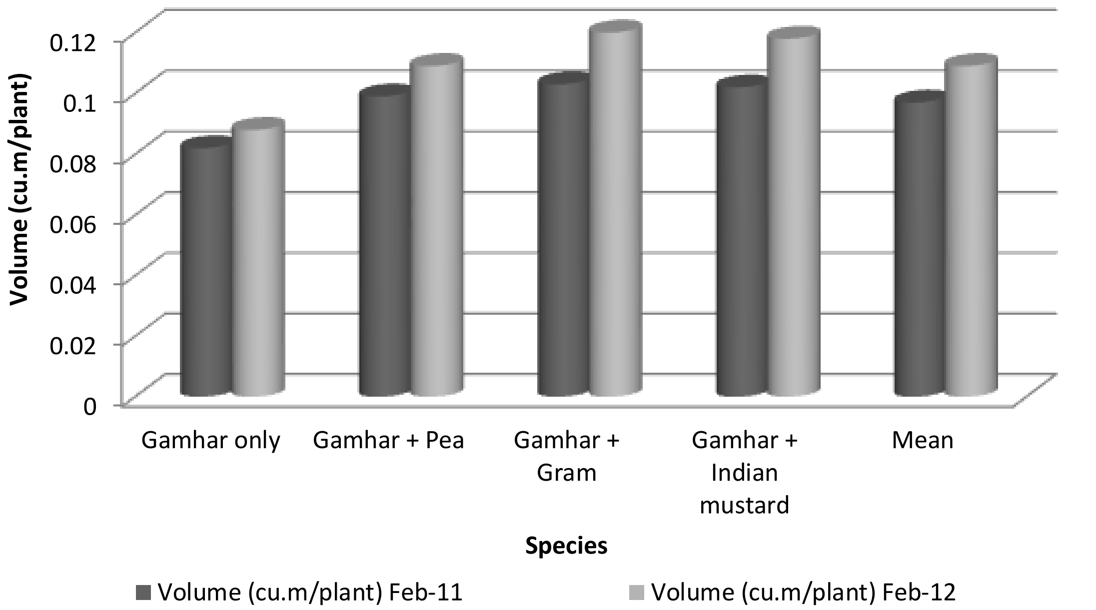
The volume of Gamhar grown in isolation and along with agriculture crops viz. Pea, Gram, and Indian mustard is presented in Table 4.4 and in fig. 4.4. Perusal of the data has indicated that volume of *Gmelina arborea* (0.103cu.m/plant) in the agri silviculture system is highest. Among the agri silvicultural system, the gamhar has recorded different volume with different agriculture crops which ranged from 0.099cu.m/plant to 0.103cu.m/plant. The volume of Gamhar is found highest in case of gamhar+gram which is 0.103cu.m/plant whereas the minimum volume has obtained in gamhar+pea (0.099cu.m/plant).

After one year in agrisilviculture system gamhar+gram have significantly higher (0.120cu.m/plant). The difference in volume of gamhar with different agriculture crops was found statistically non-significant except in gamhar+gram (0.120cu.m/plant). Perusal of the data has indicated that volume of gamhar less under sole tree plantation than agrisilviculture system. However, the volume of gamhar was found maximum in gamhar+gram (0.120cu.m/plant) and minimum in gamhar+pea (0.109cu.m/plant) in agrisilviculture system. Further there is an increase of 16.5% in tree volume in the combination of gamhar+gram over a period of one year.

Table-4.4: Volume (cu.m/plant) of Gamhar grown in sole tree and planting agrisilvicultural system

Treatments	Volume (cu.m/plant)	
	February 2011	February 2012
Gamhar only	0.082	0.088
Gamhar + Pea	0.099	0.109
Gamhar + Gram	0.103	0.120
Gamhar + Indian mustard	0.102	0.118
Mean	0.097	0.109
S.Em	**0.003**	**0.003**
CV %	**14.620**	**13.429**
C.D. at 5%	**0.010**	**0.010**

Fig. 4.4: Volume (cu.m/plant) of Gamhar grown in sole tree and planting agrisilvicultural system



4.5 Basal area (sq.m)

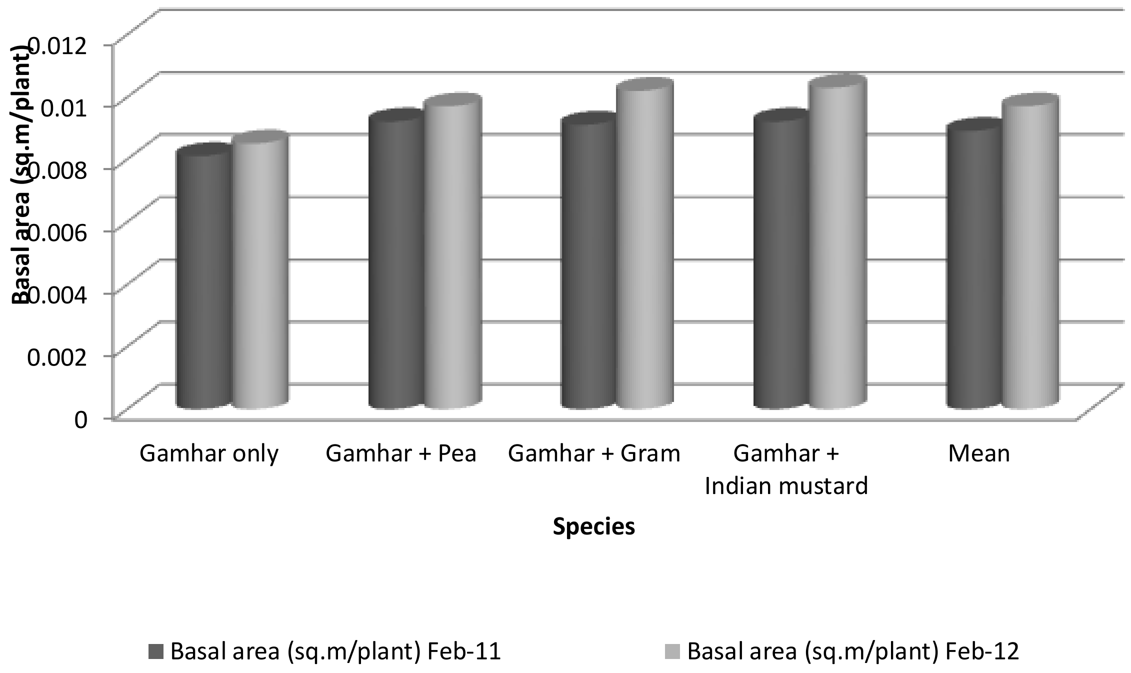
The basal area of Gamhar grown in isolation and along with agriculture crops viz. Pea, Gram, and Indian mustard is presented in Table 4.5 and Fig. 4.5. Perusal of the data has indicated that basal area of *Gmelina arborea* (0.0092sq.m/plant) in the agrisilviculture system is highest. Among the agrisilvicultural system, the *gamhar* has recorded different basal area with different agriculture crops which ranged from 0.0091sq.m/plant to 0.0092sq.m/plant. The basal area of Gamhar is found highest in case of gamhar+Indian mustard and gamhar+pea which is 0.0092sq.m/plant whereas the minimum basal area has obtained in gamhar+gram (0.0091sq.m/plant).

After one year in agrisilviculture system gamhar+Indian mustard have significantly higher basal area (0.0103sq.m/plant). The difference in basal area of gamhar with different agriculture crops was found statistically significant. Perusal of the data has indicated that basal area of gamhar less under sole tree plantation than agrisilviculture system. However, the basal area of gamhar was found maximum in gamhar+Indian mustard (0.0103sq.m/plant) and minimum in gamhar+pea (0.0097sq.m/plant) in agrisilviculture system whereas in sole plantation the gamhar obtained minimum basal area *i.e*. 0.0085sq.m/plant.

Table-4.5: Basal area (sq.m/plant) of Gamhar grown in sole tree planting in agrisilvicultural system

Treatments	Basal area (sq.m/plant)	
	February 2011	**February 2012**
Gamhar only	0.0081	0.0085
Gamhar + Pea	0.0092	0.0097
Gamhar + Gram	0.0091	0.0102
Gamhar + Indian mustard	0.0092	0.0103
Mean	0.0089	0.0097
S.Em	**0.001**	**0.001**
CV %	**15.091**	**15.142**
C.D. at 5%	**0.001**	**0.001**

Fig. 4.5: Basal area (sq.m/plant) of Gamhar grown in sole tree and planting in agrisilvicultural system



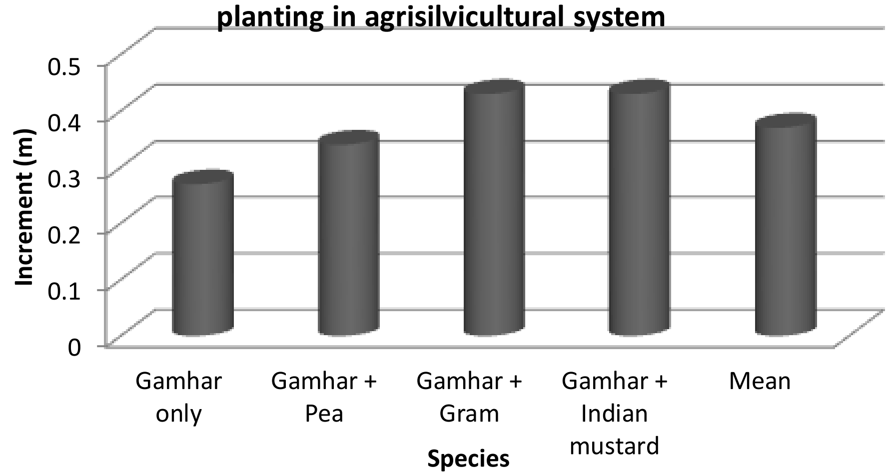
4.6 Increment

The increment of Gamhar grown in isolation and along with agriculture crops *viz*. Pea, Gram, and Indian mustard is presented in Table 4.6 and Fig. 4.6. Perusal of the data has indicated that increment of *Gmelina arborea* (0.43m) in agrisilvicultural system is highest. Among the agri silvicultural system, the gamhar has recorded different increment with different agriculture crops which ranged from 0.34m to 0.43m. The increment of Gamhar is found highest in case of gamhar+gram and gamhar+Indian mustard which is 0.43m whereas the minimum increment has obtained in gamhar+pea (0.34m) in case of agrisilviculture system and in case of sole plantation the gamhar was obtained minimum increment *i.e.* 0.27m. The ascending order of increment was gamhar+Indian mustard=gamhar+gram→gamhar+pea→gamhar.

Table-4.6: Increment of Gamhar grown in sole tree and planting in agrisilvicultural system

Treatments	Increment (m)
Gamhar only	0.27
Gamhar + Pea	0.34
Gamhar + Gram	0.43
Gamhar + Indian mustard	0.43
Mean	0.37
S.Em	**0.016**
CV %	**19.672**
C.D. at 5%	**0.050**

Fig. 4.6: Increment (m) of Gamhar grown in sole tree and planting in agrisilvicultural system



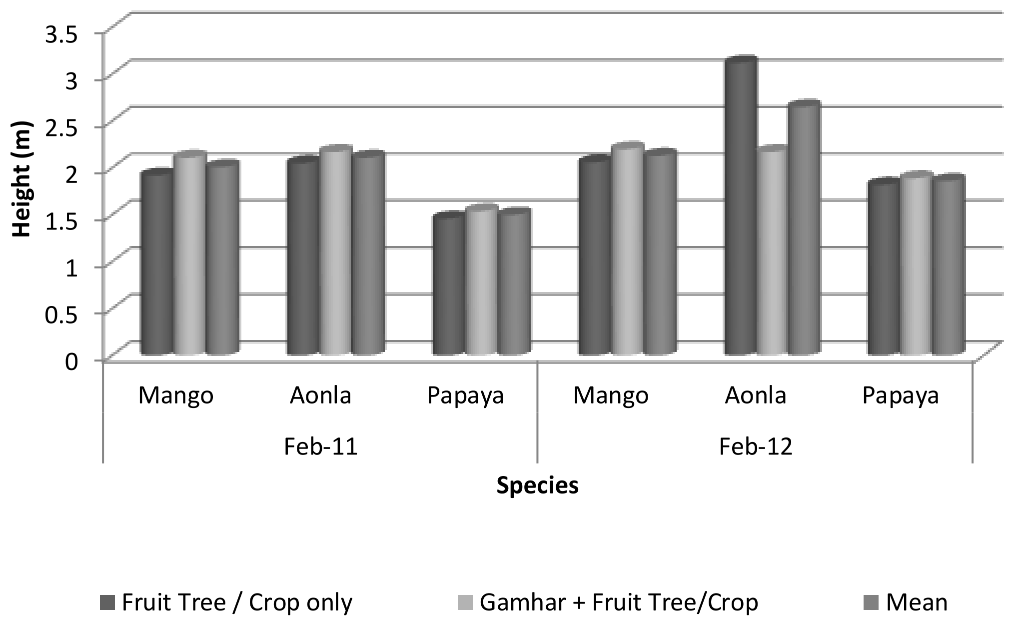
4.7 Height of horticultural and agricultural crops

The height of horticultural crops *viz*. Mango, Aonla and Papaya evaluated in terms of height i.e., in isolation as well as with gamhar tree is presented in Table 4.7 and in Fig. 4.7. Perusal of the data has indicated that in hortisilvicultural system, the height of Mango (2.06m), Aonla (3.12m) and Papaya (1.82m) were statistically significantly higher than Mango (1.92m), Aonla (2.05m) and Papaya (1.46m) planting in sole cropping. The data indicated that height in hortisilvicultural system has more than in sole planting. Similar observation had been observed by Gill (1992) regards higher growth of height and less of mango in horticultural crops based intercropped agroforestry system.

Table-4.7: Height (m) of Fruit tree species in hortisilvicultural system

Treatments	February 2011			February 2012		
	Mango	**Aonla**	**Papaya**	**Mango**	**Aonla**	**Papaya**
Fruit Tree only	1.92	2.05	1.46	2.06	3.12	1.82
Gamhar + Fruit Tree	2.11	2.17	1.54	2.20	2.17	1.89
Mean	2.01	2.11	1.50	2.13	2.65	1.86
S.Em	**0.005**	**0.005**	**0.011**	**0.005**	**0.011**	**0.011**
CV %	**0.566**	**0.574**	**1.785**	**0.589**	**1.030**	**1.489**
C.D. at 5%	**0.015**	**0.016**	**0.034**	**0.016**	**0.035**	**0.036**

Fig. 4.7: Height (m) of Fruit tree species and agriculture crops in hortisilvicultural and agri-silvicultural system

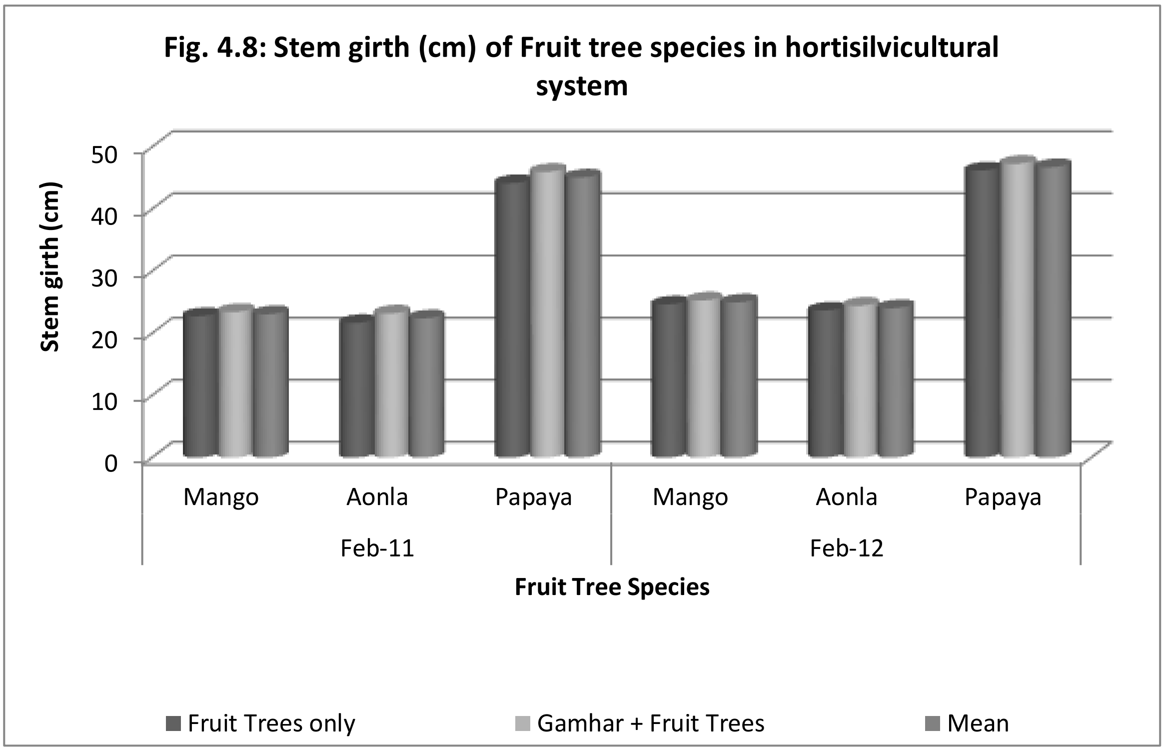


4.8 Stem girth (cm) of horticultural and agricultural crops

The stem girth of horticultural crop *viz*. Mango, Aonla and Papaya evaluated in both the conditions *i.e*. in isolation as well as with gamhar tree is presented in Table 4.8 and in Fig. 4.8. Perusal of the data has indicted that in hortisilvicultural system, the stem girth of Mango (24.65cm), Aonla (23.66cm) and Papaya (46.20cm) were statistically significantly higher than Mango (22.76cm), Aonla (21.66cm) and Papaya (44.18cm) planting in sole cropping. Stem girth of hortisilvicultural system has more than in sole planting and similar observation has been recorded by gill (1992).

Table-4.8: Stem girth (cm) of Fruit tree species in hortisilvicultural system

Treatments	February 2011			February 2012		
	Mango	**Aonla**	**Papaya**	**Mango**	**Aonla**	**Papaya**
Fruit Trees only	22.76	21.66	44.18	24.65	23.66	46.20
Gamhar + Fruit Trees	23.42	23.19	45.98	25.28	24.44	47.29
Mean	23.09	22.42	45.08	24.97	24.05	46.75
S.Em	**0.128**	**0.524**	**0.515**	**0.358**	**0.259**	**0.395**
CV %	**1.354**	**5.721**	**2.800**	**3.510**	**2.640**	**2.069**
C.D. at 5%	**0.402**	**1.650**	**1.623**	**1.127**	**0.817**	**1.244**

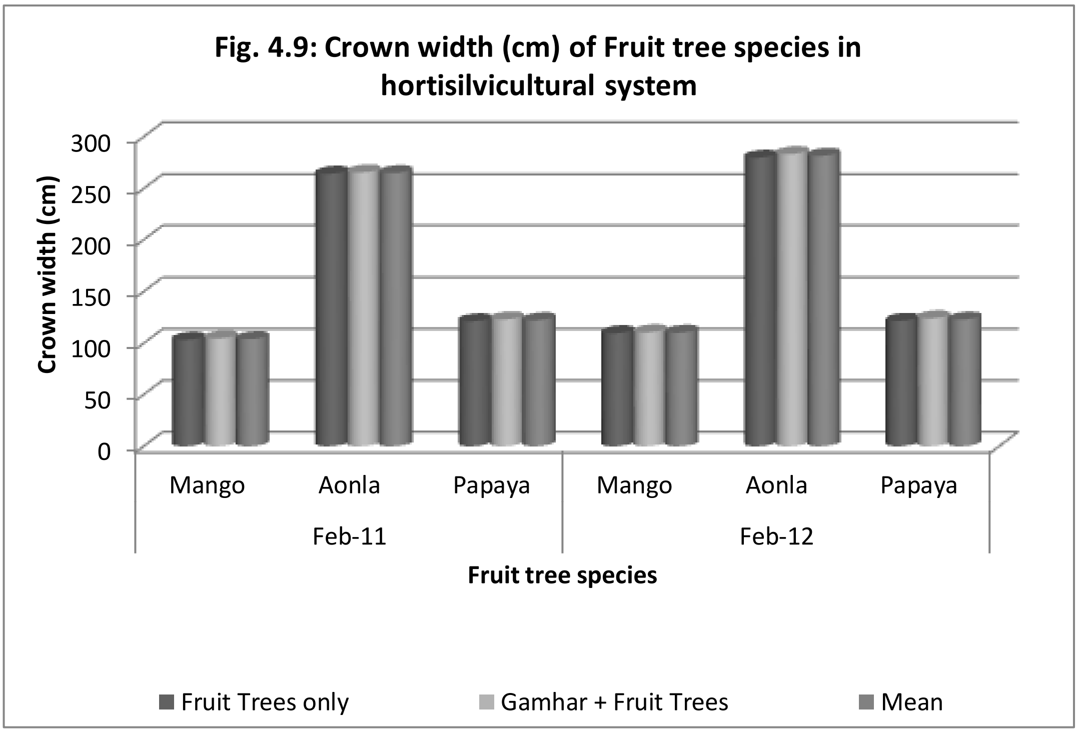


4.9 Crown width (cm) of horticultural and agricultural crops

The crown width of horticultural crop *viz*. Mango, Aonla and Papaya evaluated in both the conditions *i.e*. in isolation as well as with gamhar tree are presented in Table 4.9 and in Fig. 4.9. Perusal of the data has indicted that in hortisilvicultural system, the crown width of Mango (109.60cm), Aonla (279.64cm) and Papaya (121.54cm) were statistically significantly higher than Mango (103.30cm), Aonla (264.12cm) and Papaya (121.17cm) planting in sole cropping. Crown width of hortisilvicultural system has more than in sole planting.

Table 4.9: Crown width (cm) of Fruit tree species in hortisilvicultural system

Treatments	February 2011			February 2012		
	Mango	**Aonla**	**Papaya**	**Mango**	**Aonla**	**Papaya**
Fruit Tree only	103.30	264.12	121.17	109.60	279.64	121.54
Gamhar + Fruit Tree	104.61	265.43	123.05	110.54	283.17	124.05
Mean	103.96	264.78	122.11	110.07	281.41	122.80
S.Em	**0.480**	**0.437**	**0.419**	**0.069**	**1.253**	**0.385**
CV %	**1.131**	**0.404**	**0.841**	**0.154**	**1.091**	**0.768**
C.D. at 5%	**1.512**	**1.376**	**1.322**	**0.218**	**3.949**	**1.213**

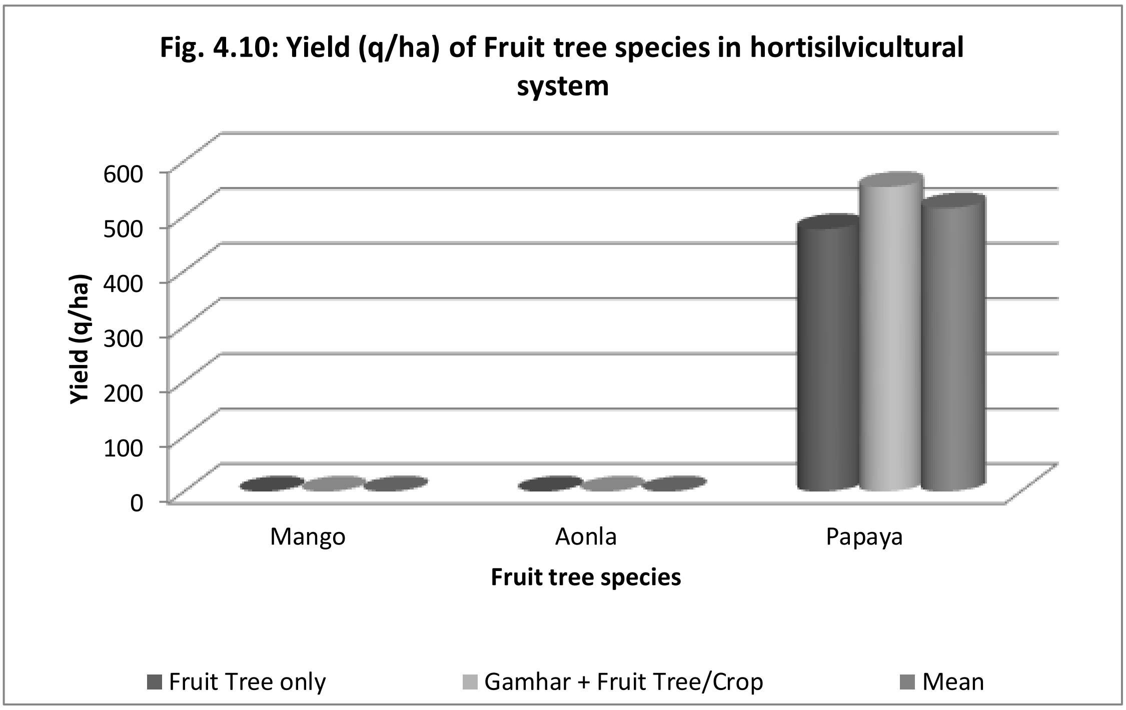


4.10 Yield of horticultural and agricultural crops

The yield of horticultural crops *viz*. Mango, Aonla and Papaya evaluated in both the conditions *i.e*. in isolation as well as with gamhar tree are presented in Table 4.10 and in Fig. 4.10. Perusal of the data has indicted that in hortisilvicultural system, the yield of Papaya (553.11q/ha) were statistically significantly higher than Papaya (476.53q/ha) planting in sole cropping. Yield in hortisilvicultural system has more than in sole planting. The production of Mango and Aonla fruit has not started till date.

Table-4.10: Yield (q/ha) of Fruit tree species in hortisilvicultural system

Treatments	Yield (q/ha)		
	Mango	**Aonla**	**Papaya**
Fruit Tree only	00.00	00.00	476.53
Gamhar + Fruit Tree	00.00	00.00	553.11
Mean	00.00	00.00	514.82
S.Em	**-**	**-**	**21.434**
CV %	**-**	**-**	**10.198**
C.D. at 5%	**-**	**-**	**67.535**



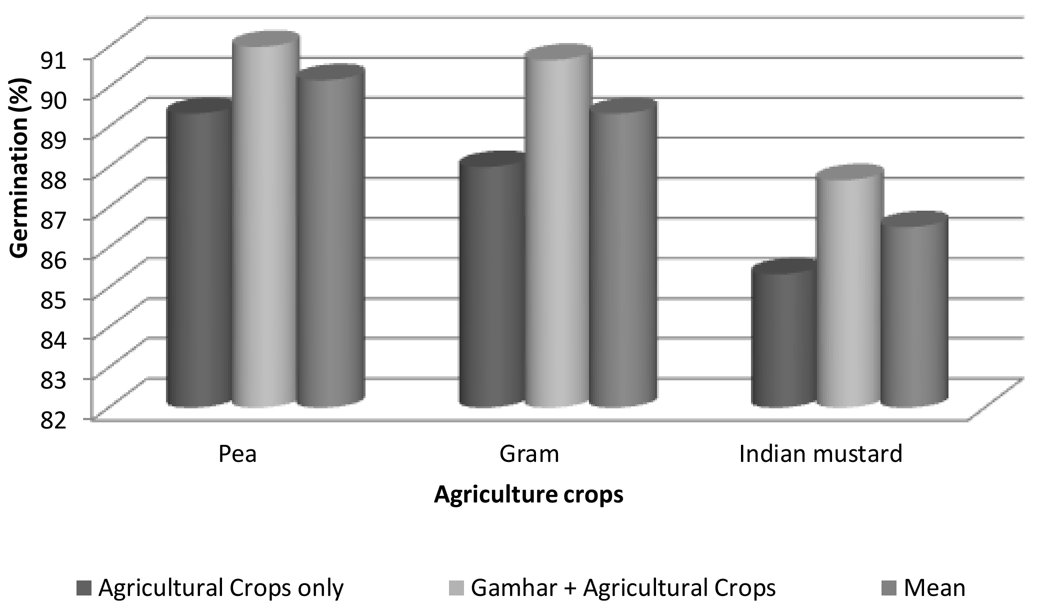
4.11 Germination (%) of agriculture crops in sole and in agri-silvicultural system

The germination (%) of agricultural crops grown in sole plantation and along with agro silvicultural system is presented in Table 4.11 and in Fig. 4.11. Perusal of the data has indicated that germination (%) of all agricultural crops are maximum in agrisilviculture system where as minimum germination (%) found in sole plantation. Among the agrisilvicultural system, the pea, gram and Indian mustard has recorded different germination (%) which is 91%, 90.67% and 87.67% respectively.

Table-4.11: Germination (%) of agriculture crops in sole and in agri-silvicultural system

Treatments	Germination (%)		
	Pea	**Gram**	**Indian mustard**
Agricultural Crops only	89.33	88.00	85.33
Gamhar + Agricultural Crops	91.00	90.67	87.67
Mean	90.17	89.33	86.50
S.Em	**0.236**	**1.027**	**0.850**
CV %	**0.640**	**2.817**	**2.407**
C.D. at 5%	**0.743**	**3.237**	**2.678**

Fig. 4.11:Germination (%) of agriculture crops in sole and in agri-silvicultural system



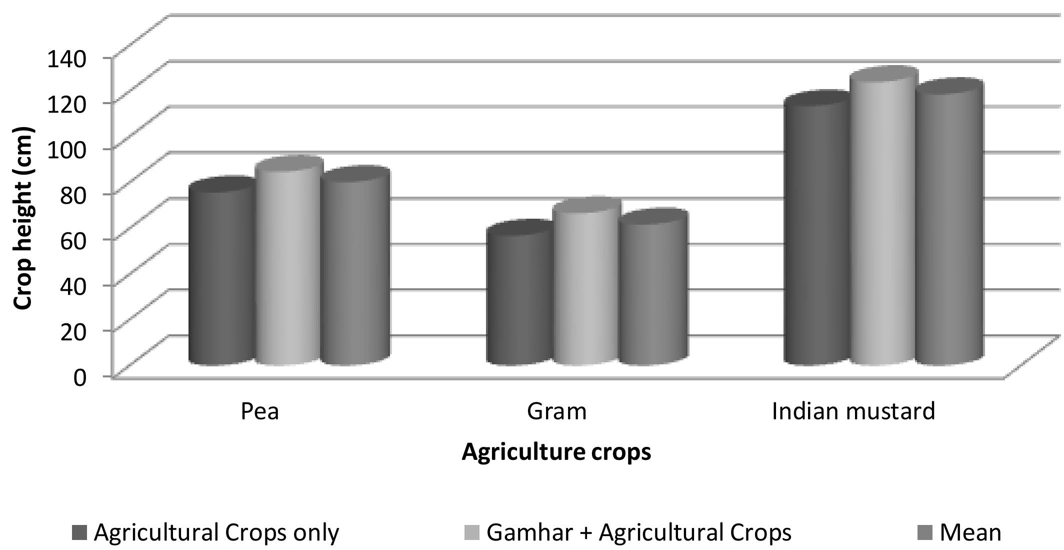
4.12 Crop Height (cm) of agricultural crops at maturity in sole and in agri-silvicultural system

The height of agricultural crops *viz*. Pea, Gram and Indian mustard evaluated in terms of height *i.e*. in isolation as well as with gamhar tree is presented in Table 4.12 and in Fig. 4.12. Perusal of the data has indicted that in agrisilvicultural system, the height of Pea (84.67cm), Gram (66.58cm) and Indian mustard (124.01cm) were statistically significantly higher than Pea (75.66cm), Gram (56.80cm) and Indian mustard (113.38cm) planting in sole cropping. The data indicated that height in agrisilvicultural system has more than in sole planting.

Table-4.12: Crop Height (cm) of agriculture crops at maturity in sole and in agri-silvicultural system

Treatments	Crop Height (cm)		
	Pea	**Gram**	**Indian mustard**
Agricultural Crops only	75.66	56.80	113.38
Gamhar + Agricultural Crops	84.67	66.58	124.01
Mean	80.17	61.69	118.70
S.Em	**0.120**	**0.325**	**0.742**
CV %	**0.368**	**1.290**	**1.532**
C.D. at 5%	**0.379**	**1.024**	**2.339**

Fig. 4.12: Crop Height (cm) of agriculture crops at maturity in sole and in agri-silvicultural system



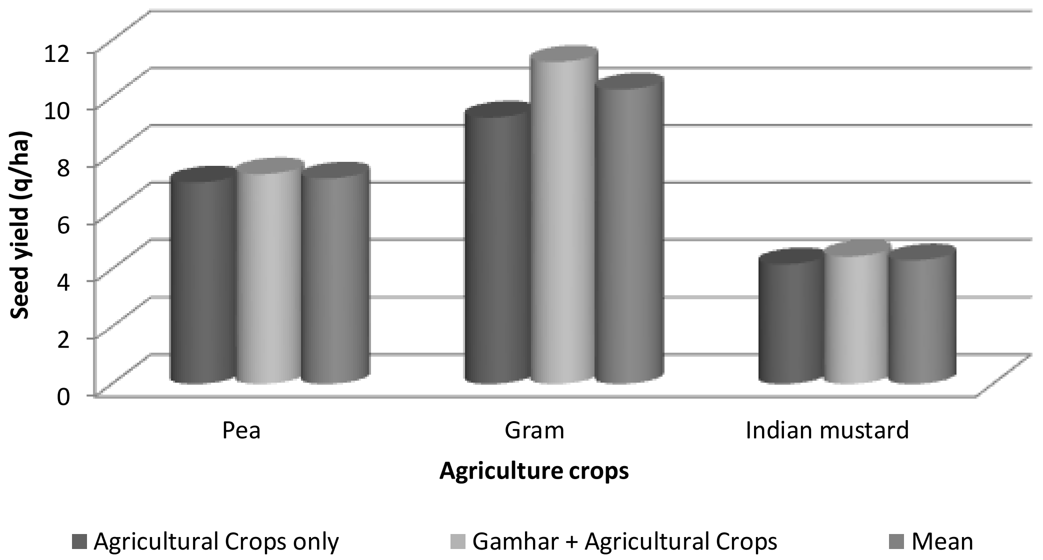
4.13 Seed yield of agricultural crops in sole and agrisilviculture system

The seed yield of agricultural crops, viz. Pea, Gram and Indian mustard evaluated in both the conditions i.e., in isolation as well as with gamhar tree is presented in Table 4.13 and in Fig. 4.13. Perusal of the data has indicted that in agrisilviculture system, the seed yield of Pea (7.32q/ha), Gram (11.25q/ha) and Indian mustard (4.44q/ha) were statistically significantly higher than Pea (7.03q/ha), Gram (9.29q/ha) and Indian mustard (4.17q/ha) planting in sole cropping. Statistically revealed that seed yield in agrisilviculture system has more than in sole planting.

Table-4.13: Seed yield (q/ha) of agriculture crops in sole and in agri-silvicultural system

Treatments	Seed yield (q/ha)		
	Pea	Gram	Indian mustard
Agricultural Crops only	7.03	9.29	4.17
Gamhar + Agricultural Crops	7.32	11.25	4.44
Mean	7.17	10.27	4.31
S.Em	**1.110**	**0.747**	**0.104**
CV %	**3.792**	**17.826**	**5.886**
C.D. at 5%	**0.350**	**2.355**	**0.326**

Fig. 4.13: Seed yield (q/ha) of agriculture crops in sole and in agri-silvicultural system



Similarly, Dhyani and Chauhan (1989) studied the performance of agricultural crops gave higher yield in partial shade as compared to open conditions. Singh and Pradhan (1989) observed that various intercrops with Mandrin (*Citrcus reticulata*) orchards can yield 60.9kg/ha with Ginger, 149 kg/ha with maize and 59kg/ha along with finger millet in agrisilvicultural system. Similarly, Anon (1989) reported that out of various treatment evaluated, Coriander + subabul produced significantly higher yield (10.3 q/ha) than (8.5 q/ha) with Coriander alone.

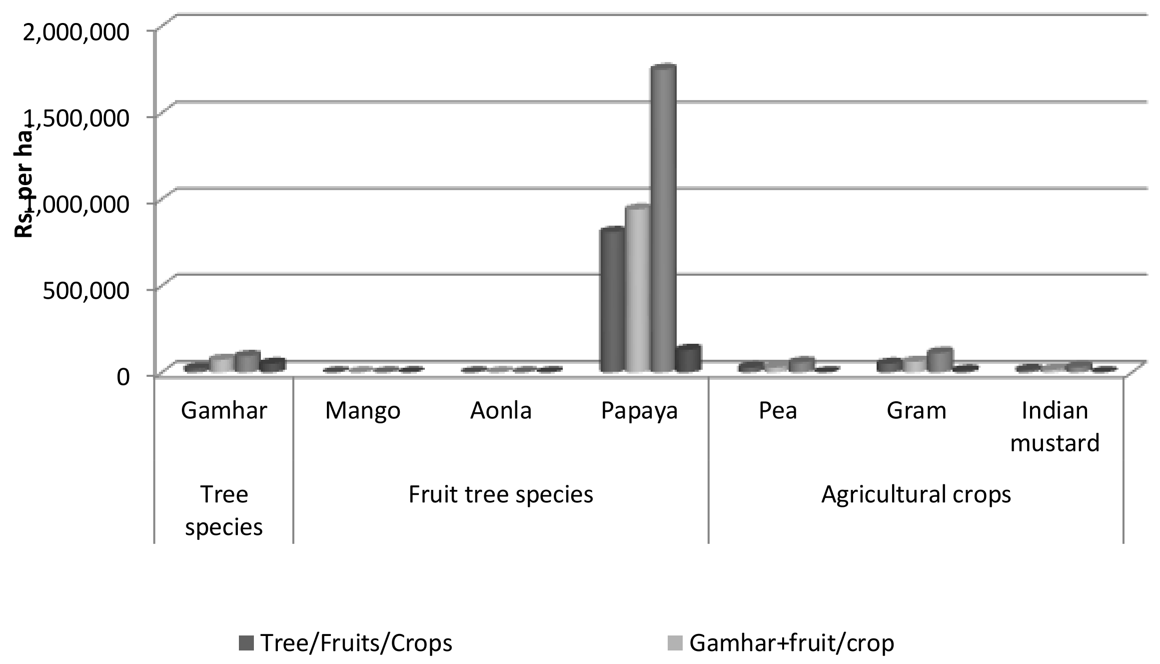
4.14 Financial yield of fuel wood, horticultural and agricultural crops

Productivity in terms of money, i.e. financial yield was calculated for tree, fruit and crop on the basis of market rate (Gamhar Rs. 600/ft^3, Papaya Rs. 17/kg, Pea Rs. 40/kg; Gram Rs. 55/kg; and Indian mustard Rs. 35/kg) and presented in Table 4.14 and in Fig. 4.14. Perusal of the data has indicated that in all cases the agroforestry system gave more income as compared to sole plantation. In agroforestry system, highest financial yield of gamhar (Rs. 72,972.00 of total boundary plants), papaya (Rs. 9,40,287.00 per ha), pea (Rs. 29,280.00 per ha), gram (Rs. 61,875.00 per ha), and Indian mustard (Rs. 15,540.00 per ha) whereas in sole plantation, the financial yield of gamhar (Rs. 21,406.00 of total boundary plants), papaya (Rs. 8,10,101.00 per ha), pea (Rs. 28,120.00 per ha), gram (Rs. 51,095.00 per ha), and Indian mustard (Rs. 14,595.00 per ha) .

Table-4.14: Economic of Gamhar, Fruit tree species and Agriculture crops in hortisilvicultural and agrisilvicultural system

Income	Tree species (in Rs.)	Fruit tree species (Rs. Per ha.)			Agricultural crops (Rs. Per ha.)		
	Gamhar	Mango	Aonla	Papaya	Pea	Gram	Indian mustard
Tree/Fruits/Crops only	21,406	--	--	8,10,101	28,120	51,095	14,595
Gamhar+fruits/crops	72,972	--	--	9,40,287	29,280	61,875	15,540
Gross income	94,378	--	--	17,50,388	57,400	1,12,970	30,135
Net income from agroforestry system	51,566	--	--	1,30,186	1,160	10,780	945

Fig. 4.14: Economic (Rs. Per ha.) of Gamhar, Fruit tree species and Agriculture crops in hortisilvicultural and agrisilvicultural system



Kumar *et al.* (2004) noticed that agricultural fields are one of the potential areas, where large scale planting of trees can be taken up along with the agricultural crops. Agroforestry models adopted by the farmers in Haryana and Uttaranchal states of India are highly lucrative, therefore, attracting farmers in a big way. Net Present Value (NPV) for different models on six years rotation varies from Rs. 26,626 to Rs 72, 705 $ha^{-1}yr^{-1}$, whereas B/C ratio and IRR vary from 2.35 to 3.73 and 94% to 389%, respectively.

4.15 General Soil Properties

The data on general soil properties of control plots (tree, fruit and crops only) as well as agrisilvicultural and hortisilvicultural plots estimated in February, 2011 and February, 2012 are presented in Table 4.15 and in Fig. 4.15 & 4.16. Perusal of the data has indicated that during the month of February, 2011, pH value were 5.6 for sole tree plots, 5.7 for sole crop and 5.3 for sole fruit tree whereas after one year the pH value were 5.6 for sole tree plots, 5.8 for sole crop and 5.4 for sole fruit tree. Level of organic carbon were 0.359% for sole tree plots, 0.437% for sole crop and 0.359% for sole fruit tree whereas after one year the level of organic carbon were 0.360% for sole tree plots, 0.438% for sole crop and 0.359% for sole fruit tree. In agrisilvicultural system, the organic carbon is more as compare to sole planting whereas in hortisilvicultural system, the organic carbon is less as compare to sole planning.

Table-4.15: General soil properties of sole tree planting, agrisilvicultural and hortisilvicultural system at the initiation of experiment and after one year

Treatment	February 2011					February 2012				
	pH	**Organic Carbon (%)**	**Avl. Nitrogen (Kg/ha)**	**Avl P_2O_5(Kg/ha)**	**Avl. K_2O (Kg/ha)**	**pH**	**Organic Carbon (%)**	**Avl. Nitrogen (Kg/ha)**	**Avl P_2O_5 (Kg/ha)**	**Avl. K_2O (Kg/ha)**
a) Tree/Fruit/Crops only										
Gamhar only	5.6	0.359	225	20.8	119.7	5.6	0.360	225.2	20.5	119.8
Crop only	5.7	0.437	275	34.7	135.7	5.8	0.438	276.0	34.8	136.6
Fruit tree only	5.3	0.359	225	26.8	128.0	5.4	0.359	226.0	26.9	127.3
b) Agri-silvicultural and horti-silvicultural system										
***Gamhar* + Crop**	5.8	0.453	290	30.5	139.0	5.3	0.454	290.2	30.7	139.9
***Gamhar* + Fruit**	5.3	0.154	120	17.9	88.9	5.4	0.155	120.2	18.9	89.9

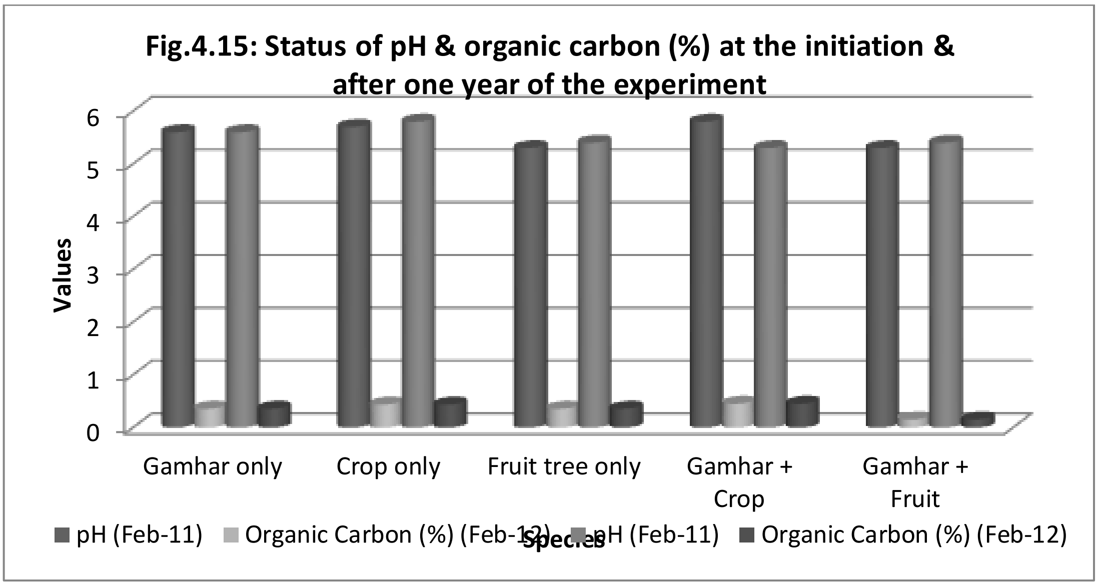


Fig.4.15: Status of pH & organic carbon (%) at the initiation & after one year of the experiment

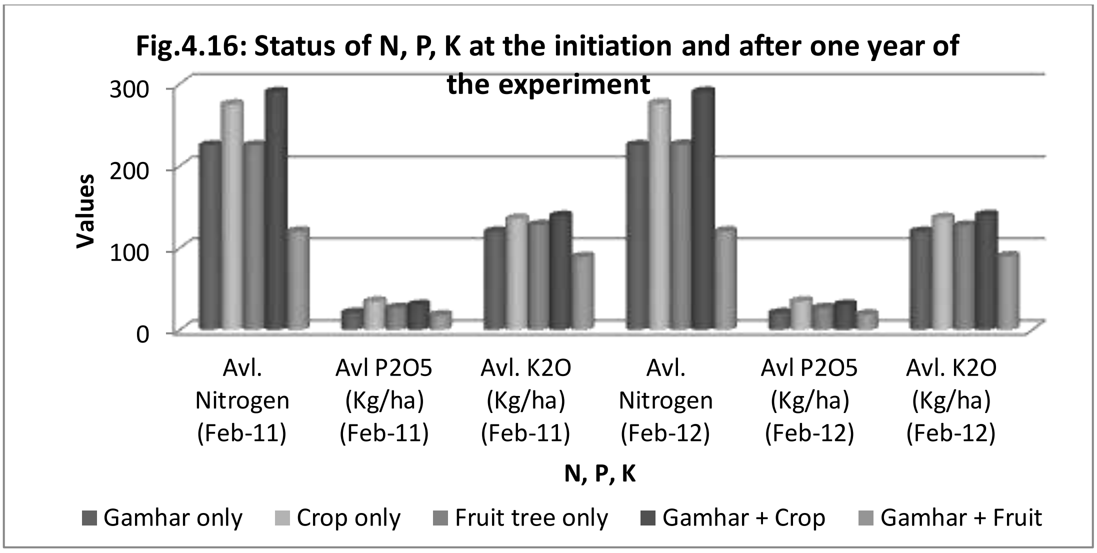


Fig.4.16: Status of N, P, K at the initiation and after one year of the experiment

Level of Organic carbon was found highest in agrisilvicultural and lowest in horti-silvicultural plots than sole planting. Higher level of available Nitrogen, Phosphorus and Potassium were noticed in agrisilvicultural plots as compared to tree/fruit/crop plots only whereas in hortisilvicultural plots it is lesser.

Similarly, Rai *et al.* (2001) also reported higher level of organic carbon in silvipastoral system as compared to pasture alone. Similarly Chauhan *et al.* (1995) observed that in agrisilvicultural system after two year of barseen cropping with and without tree showed an improvement in soil properties in the form of increasing available phosphorus status of the soil.

Chapter – 5

SUMMARY AND CONCLUSION

5.1 SUMMARY:

The present experiment was conducted on the "Studies on growth performance and economic evaluation of Gamhar (*Gmelina arborea)* based agroforestry system in East Singhbhum District in Jharkhand". The study was carried out at Zonal Research Station, Darisai, Birsa Agricultural University, Ranchi. The data were recorded for various parameters on tree as well as on horticultural and agricultural crop twice from February, 2011 to February, 2012. One at the start of experiment (in February, 2011) and other after one year in February, 2012). The results obtained have been summarized as given below:

1. Among the agrisilvicultural system, the Gamhar has recorded different height with different agriculture crops which ranged from 10.82m to 11.36m. The height of Gamhar is found highest in case of gamhar+gram which is 11.36m whereas the minimum highest has obtained in gamhar+pea (10.82m). After one year in sole tree system gamhar have attained height of 10.45m. However, the height of gamhar was found maximum in gamhar+gram (11.79m) and minimum in gamhar+pea (11.16m) in agrisilviculture system.

2. Diameter of Gamhar is maximum (10.81cm) in agrisilviculture system where as minimum diameter (10.14cm) found in sole plantation. Among the agrisilvicultural system, the gamhar has recorded different diameter with different agriculture crops which ranged from 10.75cm to 10.81cm. The ascending order of diameter is gamhar→gamhar+gram→gamhar+Indian mustard→gamhar+pea. After one year, the diameter of gamhar in agrisilviculture system was found statistically significant with sole plantation.

3. The crown diameter of gamhar has different with different agriculture crops which ranged from 3.34cm to 3.65cm. The ascending order of crown diameter is gamhar→gamhar+gram→gamhar+Indian mustard→gamhar+pea. After one year, in agrisilviculture system the crown diameter of gamhar have significantly higher (3.86cm) than sole plantation. The crown diameter of gamhar+ Indian mustard was found statistically significant with sole plantation and with gamhar+gram.

4. The difference in volume of gamhar with different agriculture crops was found statistically non-significant except in gamhar+gram (0.120cu.m/plant). Volume of gamhar less under sole tree plantation than agrisilviculture system.

5. Basal area of gamhar (0.0092sq.m/plant) in the agrisilviculture system is highest. Among the agrisilvicultural system, the gamhar has recorded different basal area with different agriculture crops which ranged from 0.0091sq.m/plant to 0.0092sq.m/plant. After one year in agrisilvicultural system gamhar+Indian mustard have significantly higher basal area (0.013sq.m/plant)

6. Among the agrisilvicultural system, the gamhar has recorded different increment with different agriculture crops which ranged from 0.34m to 0.43m. The ascending order of increment was gamhar+Indian mustard =gamhar+gram> mustard+pea>gamhar.

7. In hortisilvicultural system, the height of Mango (2.20m), Aonla (2.17m) and Papaya (1.89m) were statistically significantly higher than Mango (1.92m), Aonla (2.05m) and Papaya (1.46m) planting in sole cropping.

8. In hortisilvicultural system, the stem girth of Mango (25.28cm), Aonla (24.44cm) and Papaya (47.29cm) were statistically significantly higher than Mango (22.76cm), Aonla (21.66cm) and Papaya (44.18cm) planting in sole cropping.

9. In hortisilvicultural system, the crown width of Mango (110.54cm), Aonla (283.17cm) and Papaya (124.05cm) were statistically significantly higher than Mango (103.30cm), Aonla (264.12cm) and Papaya (121.17cm) planting in sole cropping.

10. In hortisilvicultural system, the yield of Papaya (553.11q/ha) were statistically significantly higher than Papaya (476.53q/ha) planting in sole cropping. Yield in hortisilvicultural system has more than in sole planting. The production of Mango and Aonla fruit has not started till date.

11. Germination (%) of all agricultural crops is maximum in agrisilviculture system where as minimum germination (%) found in sole plantation. Among the agrisilvicultural system, the pea, gram and Indian mustard has recorded different germination (%) which is 91%, 90.67% and 87.67% in pea, gram and Indian mustard respectively.

12. The height of Pea (84.67cm), Gram (66.58cm) and Indian mustard (124.01cm) in agricultural system were statistically significantly higher than Pea (75.66cm), Gram (56.80cm) and Indian mustard (113.38cm) planting in sole cropping.

13. In agrisilvicultural system, the seed yield of Pea (7.32q/ha), Gram (11.25q/ha) and Indian mustard (4.44q/ha) were statistically significantly higher than Pea (7.03q/ha), Gram (9.29q/ha) and Indian mustard (4.17q/ha) planting in sole cropping. Statistically revealed that seed yield in agrisilviculture system has more than in sole planting.

14. In all cases the agroforestry system gave more income as compared to sole plantation. In agroforestry system, highest financial yield of gamhar (Rs. 72,972.00 of total boundary plants), papaya (Rs. 9,40,287.00 per ha), pea (Rs. 29,280.00 per

ha), gram (Rs. 61,875.00 per ha), and Indian mustard (Rs. 15,540.00 per ha) whereas in sole plantation, the financial yield of gamhar (Rs. 21,406.00 of total boundary plants), papaya (Rs. 8,10,101.00 per ha), pea (Rs. 28,120.00 per ha), gram (Rs. 51,095.00 per ha), and Indian mustard (Rs. 14,595.00 per ha).

15. Considerable improvement has taken place in soil which in evident from the increased levels of Organic carbon, available N, P, K and pH value in agrisilvicultural system as compared to control plots. The level of pH, available nitrogen phosphorus and potassium were found more under agroforestry system than control plots (with tree or fruit or crop only). In agrisilvicultural system, the organic carbon is more as compare to sole planting whereas in hortisilvicultural system, the organic carbon is less as compare to sole planning.

5.2 CONCLUSION:

On the basis of the results obtained and discussions, the following conclusions can be arrived at:

1. Growth performance of horticultural and agricultural crop was found maximum under gamhar tree as compare to sole plantation.
2. Growth performance of gamhar was also found better in agroforestry system.
3. The yield of agriculture crop of pea, gram and Indian mustard was found maximum in agrisilvicultural system as compare to sole plantation.
4. A considerable improvement has taken place in the level of soil nutrient because value of pH, organic carbon and available N, P, K were found more in agrisilvicultural system than sole cropping systems.

5. The overall performance of gamhar, horticultural and agricultural crops has better under agroforestry system as compare to grown in sole system.

IMPLEMENTATION

Population explosion in India resulting decreased land holding per capita day by day has necessitated introduction of integrated cultivation in farming system because of increased demand of food, fodder, fuel wood, *etc*. Therefore, under limited resources per unit production of land should be known to every body for future planning and proper distribution of produce throughout the year. Horizontally land can not be extended but vertically it can be increased many fold by applying different land use practices particularly the agroforestry systems. Agroforestry besides producing diverse type of products per unit of land also provides direct and indirect benefit. Concept of agroforestry envisages the practice of forestry on cultivated lands for achieving numerous objectives for the benefits of rural and urban communities. The farmers of Jharkhand were not adopting agroforestry mainly due to lack of awareness about the tree benefits and their concern with the comparison of trees and agricultural crops. A majority of the farmers were not educated; therefore they considered that the trees compete with agricultural crops and degrade the land by taking up all water and nutrients. Hence it was essential that awareness and objective oriented information regarding the ecological and economic benefits of the trees should be disseminated widely to farmers through extension workers, media and press. Should provide technical guidance to the farmers about suitable tree species grown on agricultural land with agricultural crops, their sillvicultural operations and tree management practices along with free supply of seeds, quality, seedlings and fertilizers for the promotion of agroforestry.

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Photograph-1: Gamhar with Papaya


Photograph-2: Boundary plantation of Gamhar with Papaya

Photograph-3: Boundary plantation of Gamhar with Mango

Photograph-4: Boundary plantation of Gamhar with Aonla

Photograph-5: Boundary plantation of Gamhar with Muslard

Photograph-6: Boundary plantation of Gamhar with Gram + Pea