

**HORTICULTURAL, SILVICULTURAL AND MEDICINAL CROPS IN
THREE-TIER AGROFORESTRY SYSTEM**

A

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BY

**VISHNU KANWAR SOLANKI
M.Sc. (Forestry)**

**DEPARTMENT OF SILVICULTURE AND AGROFORESTRY
ASPEE COLLEGE OF HORTICULTURE & FORESTRY
NAVSARI AGRICULTURAL UNIVERSITY
NAVSARI-396 450
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Abstract



**HORTICULTURAL, SILVICULTURAL AND MEDICINAL CROPS IN
THREE-TIER AGROFORESTRY SYSTEM**

Name of Student	Major Advisor
Vishnu Kanwar Solanki	Dr. D. B. Jadeja

**DEPARTMENT OF SILVICULTURE AND AGROFORESTRY
ASPEE COLLEGE OF HORTICULTURE AND FORESTRY
NAVSARI AGRICULTURAL UNIVERSITY
NAVSARI - 396 450**

A B S T R A C T

Field experiment was conducted to find out suitable horticultural, silvicultural and medicinal crops in three-tier agroforestry system at the Agronomy Farm (Block-E), ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat) during rainy season of 2011 and 2012. The experiment was laid out in randomized block design with six treatments and four replications in two experiments.

The seven years old plantation of Sapota (*Manilkara acharas* (Mill.) Fosberg) planted at 10 x 10 m spacing, with five year old plantation of Jatropha (*Jatropha curcas* L.) which was planted at 2.5 x 2.5 m spacing used for intercropping study. Six medicinal plants viz., Basil (*Ocimum sanctum* L.), Kalmegh (*Andrographis paniculata* Well.), Mint (*Mentha arvensis* L), Kalihari (*Gloriosa superba* L.), Kali musli (*Curculigo orchioides* Gaertn) and Safed musli (*Chlorophytum borivillianum* Ker.) were selected for the present study. The observations on growth, development, yield, economics, nutrients and its attributes were recorded during the course of investigation under study for both the years.

Significantly maximum number of branches per plant, crown spread (E-W), crown spread (N-S), fresh and dry weight per plant, fresh and dry weight per plot, economic yield, survival percent and light intensity at crop level were recorded under open field condition while, significantly higher height of plant was observed when the herbal crops were grown as intercrop under Sapota - Jatropha.

In case of tuber medicinal crops, significantly maximum number of tubers per plant, length of tuber, girth of tuber, fresh and dry weight of tuber per plant, fresh and dry weight of tuber per plot, economic yield, survival percent and light intensity were recorded under open field condition while, significantly maximum height of tuber plant were observed under intercrop with Sapota - Jatropha.

In case of nutrients, higher nutrients viz., organic carbon, N, P, K, Ca, Mg, Fe, Mn, Zn, Cu in soil as well as plant were recorded under Sapota – Jatropha in herbal and tuber crops.

Basil, Kalmegh, Mint, Kalihari, Kali musli and Safed musli when grown as intercrop gave higher economic returns.

Dr. D. B. Jadeja

Principal

College of Forestry,

Navsari Agricultural University

Navsari - 396 450.

C E R T I F I C A T E

This is to certify that the thesis entitled
**“HORTICULTURAL, SILVICULTURAL AND MEDICINAL
CROPS IN THREE-TIER AGROFORESTRY SYSTEM”** submitted
by **VISHNU KANWAR SOLANKI** in partial fulfillment of the
requirements for the award of the degree of **DOCTOR OF
PHILOSOPHY (FORESTRY) in AGROFORESTRY** of the
Navsari Agricultural University is a record of bonafide research
work carried out by her under my guidance and the thesis has not
previously formed the basis for the award of any degree, diploma or
other similar title.

Place: Navsari

Date:

(D. B. Jadeja)

Major Advisor

D E C L A R A T I O N

This is to certify that the whole of the research work reported here in the thesis for the partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (FORESTRY) in AGROFORESTRY** is the result of investigation done by the undersigned, under the direct guidance and supervision of **Dr. D. B. Jadeja**, Principal, College of Forestry, Navsari Agricultural University, Navsari and no part of the work has been submitted for any other degree so far.

Place: Navsari

Date: (Vishnu Kanwar Solanki)

Countersigned by

(D. B. Jadeja)
Principal
College of Forestry
Navsari Agricultural University
Navsari

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Date:

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Introduction



I. INTRODUCTION

India is one of the richest floristic regions of the world and is well-known for its ancient heritage regarding medicinal plants. India has 15 agro-climatic zones, 45000 different plants species, out of which 15000 are medicinal. The Indian system of medicine has identified 1500 medicinal plants. In India, a notable livelihood focused venture was undertaken in which formal institutions successfully introduced medicinal plants into the traditional farming system to provide farmers with a regular income. The increasing demand for medicinal plant products is much felt by the people and the diversified agro-climatic conditions of India is a boon for cultivation and is rightly called the botanical garden of the world. India, officially recognized over 3000 plants for their medicinal value. India being one of the 12 mega diversity centers in the world, with this bio-resource wealth, it ranks 10th in the world and 4th in Asia having 15 to 20 thousand plants species with medicinal value of which 30 per cent are considered as endemic to India. Currently, there are about 880 species of medicinal plants in all India trade (Shukla and Sinclair, 2009).

The estimated area under the medicinal crops in India is around two lakh hectares. Nearly 75 per cent of the plant material used in indigenous medicines is collected from forests and wild habitats. India, Brazil and China are the largest exporters of medicinal plants. Trade of medicinal plants from India is estimated to be worth Rs.550 crore and likely to reach Rs.1000 crores in 2011. The World Health Organization estimates the present demand for medicinal plants is about US \$14 trillion a year and projected demand by the year 2050 is US \$ 5 billion (Anonymous, 2000).

The forest of India is Pandora's Box having rich collection of medicinal plants. Forests are the primary sources of medicinal plants. To meet the requirements of expanding regional and international markets and healthcare needs of growing populations, increasing volumes of medicinal plants are harvested from forests and other natural sources. Loss of forest lands for agriculture and plantation, overgrazing, irregular exploitation of herbs in forest and other natural woodlands are contributing for extinction of many species and depletion of the supply of medicinal plants from forests. Over exploitation and consequent depletion of medicinal plants not only affects their supply and loss of genetic diversity within these species but seriously affects the livelihood of indigenous people living in forest fringe (Patra, 2012).

Medicinal plants growing in forests require partial shade, moist soils rich in organic matter, high relative humidity and mild temperatures. Cultivation of such medicinal plants can be taken up in thinned forests, cleared forest patches, and as intercroops in orchards and new forest plantations (Venugopal *et al.*, 2008). There are number of indigenous under storey herbs and shrubs that can be produced as a part of forest farming or in new forest plantation to improve economic return from the forests in India.

Newly established forest plantations can be intercropped with medicinal plants similar to food crops until the trees cover the ground. The participation of the local people with the right to share benefits of the plantations, especially ownership to crops, has helped government to establish plantations without conflict with the local people in many Asian countries. The same approach can be employed for the cultivation of medicinal plants in the new plantations. In the rehabilitation of degraded forest lands, participating, planning and implementation with local communities and economic

benefits from an early stage onwards will ensure commitment of the people. The intensity of shade experienced by the under storey medicinal plants growing in forests and tree plantation affects their growth and chemical composition.

In recent year's attention has focused on the diversified medicinal plant production system for maximizing utilization of resources as compared to the monoculture cropping systems. The improved use of resources results in greater total intercrop yields as compared to sole crops of the same species grown on the same area. Intercropping is also expected to reduce the risk of single crop failure due to pest and disease incidence and increases food security (Oraon *et al.*, 2005).

With shrinking supplies from natural sources and increasing domestic and global demand, these high value crops should be cultivated for their regular supply, for standard quality as well as conservation. The main constraint in conservation of these crops is paucity of good quality land due to production of food and other agricultural crops to feed the staggeringly increasing human and livestock population. The alternate way is to accommodate these crops under agroforestry, intercropping, relay cropping or as a component of the cropping system involving food crops. This allows judicious use of the internal spaces of the trees and crops promoting diversification, enhancing per capita land productivity and cultivation of the crops in demand (Willey, 1979).

In many countries medicinal plants are collected from the wild vegetation. But in response to the combined impacts of dwindling supplies due to overexploitation of the natural resources and increasing demands due to population growth and growing global markets, medicinal plants are also increasingly introduced into farming systems. Such cultivation often takes place in multiple cropping systems including agroforestry

systems. For instance, medicinal plants may be planted in the lower strata of multi-strata systems such as home gardens (Rao *et al.*, 2004).

Medicinal plants in the nature are now under great pressure due to their excessive collection and exploitation (Laloo *et al.*, 2000). Continuous exploitation of several medicinal plant species and substantial loss of their habitats have resulted in the population decline of many high value medicinal plant species over the years (Kala and Sajwan, 2003). The primary threat to medicinal plants is those used by human beings that affect any kind of biodiversity (Rao *et al.*, 2004). There are many other potential causes of rarity in medicinal plant species, such as habitat specificity, narrow range of distribution, land use disturbance, introduction of non-natives, habitat alteration, climatic changes, heavy livestock's grazing, explosion of human population, fragmentation and degradation of population, population bottleneck and genetic drift (Kala, 2000 and 2003; Oostermeijer *et al.*, 2003).

The global importance of medicinal plant materials is evident at national and international markets. During the 1990s, reported annual international import of medicinal plants amounted on an average to 350000mg valued at over \$1 billion. Japan and Korea are the main consumers of medicinal plants while China and India are the world's leading producing nations. (Patra, 2012).

Sapota or sapodilla (*Manilkaha achras* Mill Fosberg) belongs to family sapotaceae, popularly known as chiku, is an important fruit of the tropical regions. It is native to tropical America especially the southern Mexico or Central America. However, it is commercially cultivated for fruits in India, Philippines, Sri Lanka, Mexico, Venezuela, Guatemala and other countries of Central America. In India, sapota is widely cultivated in the states of Karnataka, Gujarat, Andhra Pradesh, West Bengal,

Maharashtra and Tamil Nadu. However, South Gujarat, Coastal Maharashtra and Karnataka are the major areas where it is extensively cultivated. In India, the area under sapota cultivation is about 148000ha with an annual production of 1215000MT (Anon., 2007b). Whereas, in Gujarat sapota occupies about 25833 ha with annual production of 249951MT. In South Gujarat, the area under sapota is 10925 ha with annual production of 97233 MT. (Anon., 2007a).

The fruit is a good source of digestible sugar (12-18%), protein, fat, fiber and minerals viz., Ca, P and Fe. The fruit skin can also be eaten and is richer than the pulp in nutritive value (Gopalan *et al.*, 1977). The mature fruits are used for making mixed fruit jam and they provide a valuable source of raw material for the manufacture of industrial glucose. Sapota has got a wide adaptability for climatic and edaphic conditions, tolerate saline atmospheric winds and saline soil conditions in coastal area in which many other fruit crops suffer due to salinity in soil, water as well as in atmosphere.

Jatropha is a genus of flowering plants in the spurge family, Euphorbiaceae. It is a perennial shrub to small tree of up to 6m height, adapted to all kinds of soil and does not demand any special nutritive regime (Patil and Singh, 1991). This highly drought-resistant species is adapted to arid and semi-arid conditions. It is recommended as a drought resistant plant suitable for erosion control (Heller, 1996). The current distribution shows that introduction has been most successful in the drier regions of the tropics with annual rainfall of 300-1000 mm. It occurs mainly at lower altitudes (0-500m) in areas with average annual temperatures well above 20°C but can grow at higher altitudes and tolerates slight frost.

It can be used to revegetate 33 million hectare of Indian wastelands out of 146 mha under *Jatropha* plantation. There is about 125.86 lakh hectare of wasteland alone in Gujarat state which can be planted under *Jatropha* (Saxena and Pafali, 1999). It is commonly grown as village hedges, roadside plantations and live fencing. *Jatropha* can be easily propagated through direct seeding or cutting. Although *Jatropha* species are well known, there is a need to domesticate them for farming systems under degraded lands and community wastelands. *Jatropha* seed is a rich source of protein, carbohydrate, and fat and is well known for its high fuel value. In the recent past *Jatropha* has evoked much interest all over the world as potential petrocrop (Martin and Mayeux, 1985). The fruit and seeds are anthelmintic, useful in chronic dysentery, urinary discharges and heart diseases. *Jatropha* seed oil is also used for the treatment of tumor. It is easy to establish, grows relatively quickly and lives, producing seeds for 50 years. *Jatropha* the wonder plant produces seeds with an oil content of 37%. The oil can be combusted as fuel without being refined. It burns with clear smoke free flame, tested successfully as fuel for simple diesel engine. The byproducts are press cake a good organic fertilizer, oil contains also insecticide. It is found to be growing in many parts of the country, rugged in nature and can survive with minimum inputs and easy to propagate. Medically it is used for diseases like cancer, piles, snakebite, paralysis, dropsy *etc.* *Jatropha* grows wild in many areas of India and even thrives on infertile soil.

Basil (*Ocimum sanctum* L.) is a common name for the culinary herb of the family Labiateae. It is a religious and medicinally important plant. There are about 160 species in this genus and is distributed in warmer parts of the hemispheres from sea level to 1800m. *Ocimum* species are cultivated commercially in France, England, America and India. These are shrubs, or herbs, perennial or biennial in habit. Depending on the species and cultivar, the leaves may taste somewhat like anise, with a strong,

pungent, often sweet smell. Basil is still considered the "king of herbs". *Ocimum* species are used as herb and find diverse uses in indigenous system of medicine because many species has the antifungal, bactericidal and insecticidal properties. Many species of *ocimum* contain various economically important essential oil used in perfumery and cosmetic industries (Sehgal and Thakur, 2008).

Kalmegh (*Andrographis paniculata* Well) is an herbaceous plant in the family Acanthaceae, native to India and Sri Lanka. It is widely cultivated in Southern and Southeastern Asia, where it is used to treat infections and some diseases, often being used before antibiotics were created. It is grown in barren soil or sandy loam soil with proper drainage condition. *Andrographis paniculata* is an erect annual herb extremely bitter in taste in all parts of the plant body. The plant is known in north-eastern India as Mahatita, literally "king of bitters". As an Ayurveda herb it is known as Kalmegh or Kalamegha, meaning "dark cloud". It is used for cough, headache, edema, earache, pain conditions, inflammation and muscular pain, arthritis, rheumatism, multiple sclerosis, depression, diarrhoea, dysentery, cholera, candida, lupus, diabetes, piles, fevers, fatigue, hepatitis, herpes, leprosy, loss of appetite, swollen lymph nodes and other lymphatic conditions, jaundice, dyspepsia, dermatitis, eczema, burns, pneumonia, bronchitis, tuberculosis, chicken pox, mumps; sluggish liver, spleen, kidneys and adrenal glands; sleeplessness, vaginitis, and constipation. It can be used as a replacement for quinine in treatment of malaria (Kumar *et al.*, 2008).

Mint (*Mentha arvensis* L.) is flowering plants in the family Labiatae. Mints are aromatic, almost exclusively perennial, rarely annual herbs. They have wide-spreading underground and over ground stolons and erect, square, branched stems. While, the species that make up the *Mentha* genus are widely distributed and can be

found in many environments, it grows best in wet environments and moist soils. Mints will grow 10–120 cm tall and can spread over an indeterminate area. Mint was originally used as a medicinal herb to treat stomach ache and chest pains, and it is commonly used in the form of tea as a home remedy to help alleviate stomach pain. Menthol from mint essential oil (40–90%) is an ingredient of many cosmetics and some perfumes. Menthol and mint essential oil are also much used in medicine as a component of many drugs, and are very popular in aromatherapy. Menthol is also used in cigarettes as an additive, because it blocks out the bitter taste of tobacco and soothes the throat. Mint oil is also used as an environmentally-friendly insecticide for its ability to kill some common pests like wasps, hornets, ants and cockroaches (Mohsin Faiz, 2005).

Glory lily (*Gloriosa superba* L.) is an herbaceous perennial climbing plant in the family Liliaceae. They are native in tropical and southern Africa to Asia and naturalized in Australia and the Pacific as well as being widely cultivated. In India, *Gloriosa* is distributed in the Western Ghats but the density is rapidly decreasing due to excessive uprooting by the Herbal Medicine producers. *Gloriosa superba* is an imperative medicinal plant, all parts are used in the medicine, which contains two important alkaloids, colchicine and colchicoside, and leaves are used to treat cancer related diseases, also in ulcer, piles, and scrofula (Evans *et al.*, 1981).

Kali musli (*Curculigo orchioides* Gaertn) is a plant in the family Hypoxidaceae. Kali musli grows as forest herb. Since generations, it is in use as folk medicine. In many parts of India, due to its over exploitation, Kali musli is becoming rare in occurrence. Kali musli is a herbaceous tuberous perennial with a short or elongate root stock bearing several fleshy lateral roots; Leaves sessile or petiolate, linear or linear lanceolate, tips sometimes rooting, scape very short, clavate. According to Ayurveda,

root is heating, aphrodisiac, alternative, appetizer, fattening and useful in treatment of piles, biliousness, fatigue, blood related disorders etc. According to Unani system of medicine, sroot is carminative, tonic, aphrodisiac, antipyretic and useful in bronchitis, ophthalmia, indigestion, vomiting, diarrhoea, lumbago, gonorrhoea, gleet, hydrophobia, joint pains etc. (Irshad *et al.*, 2006).

Safed musli (*Chlorophytum borivillianum* Ker.) is a plant in the family Liliaceae. Safed musli is a medicinal crop and generally grows in the forest (Prajapati *et al.*, 2003). It grows under semi shade condition (Patel *et al.*, 2009). The crop is grown in *Kharif* season in places having warm and humid climatic conditions and adequate soil moisture throughout the crop growth. Optimum time for its planting is middle of June under irrigated condition and onset of monsoon for rain fed condition. Paired fleshy roots used for planting recorded high degree of sprouting and survival in comparison to single root planting.

As such there is no sufficient work on agroforestry system of horticultural, silvicultural and medicinal crops in India. Therefore, development of suitable agroforestry system for horticultural, silvicultural and medicinal crops was felt essential to increase the production per unit area and net income of the farmer with the following objectives.

1. To develop suitable three-tier agroforestry system.
2. To study the effect of silvicultural and horticultural tree crops on growth and yield of medicinal crops.
3. To analyze the cost and benefits of the silvicultural, horticultural and medicinal crops association.

***Review of
Literature***



II. REVIEW OF LITERATURE

Agroforestry is relatively a new area of research; a little work has been carried out on species compatibility at field level and effect of tree species on medicinal plants. Review of literature pertaining to intercropping systems, with respect to importance, spatial arrangements, assessment of yield advantages and economics are presented in this chapter. Since the area available for agriculture is limited and the demand for food has been increasing considerably, replacement of traditional agricultural crops by medicinal crops may become unsustainable in the large content. Therefore, it is necessary to explore the possibilities of growing medicinal crops in areas where traditional agriculture is uneconomical or unsustainable. Alternatively, these crops may be incorporated with the traditional crops as a companion crop in intercropping system.

To have better understanding on the present study, the finding of research work on various medicinal plants with tree species (horticultural and silvicultural) at various locations in India and abroad have been reviewed briefly as follows.

2.1 Intercropping systems and their importance

Intercropping is an age old practice of growing simultaneously two or more crops in the same piece of land. It is a technique of crop intensification in both time and space where in the competition between crops may occur during a part or whole of crop growth period. It has been a common practice followed by the farmers of India, Africa, Sri Lanka and West India (Andrews and Kassam, 1976).

The basic idea of intercropping is not only that two or more crop species grown together can exploit the resources better than either of them grown separately, but

also to cover the inherent risks in agriculture and more so, under dry land condition which is buffered to some extent and is called as “biological insurance” (Ayyar, 1963).

Aiyer (1949) reported that the resources with regard to plant nutrients present in the soil or added to it as manures were utilized to the fuller extent in mixed stand than when component crops were grown separately. The crops with varying root depth, tap different layers of soil for plant nutrients and moisture. The periodical return and distribution of labour requirement throughout the year is of great help to the resource poor cultivators.

Donald (1963) opined that species of contrasting habit, both morphologically and physiologically would together be able to exploit the total environment more effectively than monoculture. If two species grown together are mutually beneficial, then there is cooperation. On the contrary, competition results when they tend to be mutually harmful and this competition is mainly for water, nutrients and light. The relationships of cooperation and competition are density dependent. At low densities there is cooperation and at high densities the active competition comes into existence.

It is observed that crop mixtures provide insurance against risk and give stable returns even under unfavorable weather conditions. The major way the crop mixture can achieve greater stability is from the compensation of one component crop when other fail or grow poorly, because of drought, pest or disease. But, when two species are grown separately as sole crops, there is no possibility of this compensation. Intercropping would ensure low yield fluctuations than sole cropping even under unfavorable conditions (Oguntowara and Norman, 1974).

Rao and Willey (1980) stated that the crop mixtures would also stabilize returns over seasons as they provided more than one commodity and can act as buffer against frequent price changes in any one of the component crops. Price fluctuations are quite common in countries like India.

2.2 Intercropping with medicinal crops

Kundu and Chatterjee (1982) observed that the total yield of turmeric was significantly reduced when intercropped with cereals and pulses. However, the reduction was less when grown with short duration crops. While, intercropping turmeric with maize, chilli, castor and okra; turmeric with maize recorded significantly higher income per hectare than with other crops.

Liyange *et al.* (1984) reported increase in net yield of coconut when it was inter cropped with tuber crops, legumes, cereals, fruit crops, spices and condiments.

The inclusion of medicinal plants like senna and periwinkle in the cropping systems with traditional crops gave higher net returns (Pareek and Gupta, 1984).

Maheshwari *et al.* (1985) revealed that the sole crop of *Rauvolfia serpentina* produced higher number of roots than that under intercropping, but gave extra income when intercropped with soybean, garlic and onion.

George and Nair (1987) indicated that the grain yield of cowpea fell down substantially because of shading. Even the low shade of 25 percent reduced the grain yield by more than 50 percent and with more intense shading, the yield progressively decreased. When the light intensity was reduced by 75 percent, the yield was only one percent of that at full sunlight.

Kothari *et al.* (1987) found that sugarcane + bergament mint intercropping system realized additional income of Rs 7179 ha⁻¹ over sole crop of sugarcane.

Intercropping of groundnut, soyabean, rice, ginger and turmeric with guava produced the highest yield. The highest net economic return per hectare was obtained in guava + ginger (Rs. 7930/ha) followed by turmeric and groundnut with guava (Rs. 4335 and Rs. 3600/ha, respectively). No adverse effect of intercrops was observed on the growth of guava (Anon., 1988).

Rajput *et al.* (1988) conducted an experiment on intercropping of vegetables (potato, brinjal, onion, okra, chilli, tomato, colocasia, bittergourd, Indian squash, cauliflower and long melon); pulses (cowpea, blackgram, pigeonpea, pea and gram) and cereal (wheat) in young mango orchard. All the intercrops grown under the canopy of Mango trees produced normal yield. In case of vegetables, the highest monetary returns (Rs. 4120/ha) were obtained from cowpea + potato + mango whereas, the returns were lowest in control (Rs. 192/ha). In second experiment, blackgram + wheat + mango gave the highest monetary return (Rs. 7992.75/ha) compared to lowest income was obtained from the control (Rs. 729/ha).

From an experiment on agri – horti – silvicultural system it was found that *Dalbergia sissoo* +guava intercropped with rice + pigeon pea was the best combination for higher yield and income (Anon., 1989 a).

An intercropping trial in Khasi mandarin orchard on sloppy land was conducted and five arable crops (groundnut, rice, ginger, turmeric and soybean) were tested and it was revealed that mandarin + ginger land use system gave the highest net returns followed by mandarin + turmeric. No adverse effect of intercrop on the growth of mandarin trees was observed (Anon., 1989 b).

Dhyani and Chauhan (1989) studied the performance of ginger, turmeric and colocasia under natural stands of *Pinus khasya* and reported that all the three plantation crops gave higher yield in partial shade as compared to open field condition and complete shade. *Pinus khasya* gave higher yield and thus proved profitable.

Das (1991) studied various coconut based farming systems and evaluated them on the basis of their economic viability. Studies on inter cropping with rice, millet, grain legumes, oilseed crops, root crops, banana, pineapple, chillies (capsicum) and vegetable mixed cropping with cocoa, black pepper (*Piper nigrum*), tree species and mulberry for sericulture. More profit was indicated from integration of number of subsidizer crops and animal component with coconut than to grow it as a monocrop.

Jaychandran *et al.* (1991) studied the performance of ginger under coconut shade and open conditions and found higher yield of ginger at low shade intensity (25%) as compared to open field. It can be recommended for homestead cultivation as well as for intercropping under coconut and other perennial crops where 25 to 50 per cent shade exist.

Nair *et al.* (1991) observed intercropping of 13 medicinal/aromatic plants in a 12 year-old coconut plantation. The growth and yield of the plants when grown as intercrops in coconut plantation in comparison to the open condition. Growing these medicinal plants as intercrops in 8-20 year old coconut plantations, when no other intercrops are usually recommended. The shade did not adversely affect the growth of the plants. Growing medicinal plants in the interspaces of coconut plantations because an additional source of income to the farmers.

Tikadar *et al.* (1992) reported that intercropping of mulberry with ginger, turmeric and fieldpea increased the profits up to 2.68 times without hampering the leaf yield of mulberry.

Jasural *et al.* (1993) studied the performance of two rhizomatous crops *i.e.* *Gingiber officinalis* (ginger) and *Curcuma longa* L. (Turmeric) in pure stand and as intercrop with 5 year old poplar plantation. Both crops performed better as intercrop than as pure stand. Plant height, tillers per plant and leaves per plant in ginger and leaf length and leaf breadth besides plant height in turmeric were significantly enhanced in intercrops.

Pareek and Maheshwari (1993) noted that pulses like cowpea, greengram, blackgram and gaur during kharif and mustard and oats in subsequent rabi were found to be good companion crops in vetiver.

Rajeswara Rao *et al.* (1993) observed that intercropping greengram with palmarosa did not reduce the biomass and essential oil yields of palmarosa in addition it produced bonus yield of 3.0 q ha⁻¹ of greengram and additional net income of Rs 2845 ha⁻¹ as compared to sole crop of palmarosa. Intercropping of blackgram in palmarosa reduced the yields of palmarosa but gave 4.3 q ha⁻¹ additional yield of blackgram and additional net income of Rs 3840 ha⁻¹ as compared to the sole crop of palmarosa.

Shanmugasundaram and Subrahmaniyam (1993) conducted the study on intercropping of coconut with papaya, pomegranate, annona (*Annona squamosa*), ridge gourd (*Luffa acutangula*), bitter gourd (*Momordica charantia*), coriander (*Coriandrum sativum*), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), *Mentha spp.*, pepper (*Capsicum*) and betelvine (*Piper betle*) forming different layer beneath the coconuts.

Results showed more yields and economic return of the intercrops and soil moisture contents at different depth.

Mutnal *et al.* (1994) conducted a study on silvi-horti-pastoral system under 11 year old Sapota and forest tree species. The result from this study showed significantly higher fodder yield of maize when grown with *Tectona grandis* + sapota + grass combination (42.62 t/ha). The lowest fodder yield (22.67 t/ha) was recorded in *Eucalyptus hybrid* + sapota + grass combination.

Prasanna *et al.* (1995) studied the effects of intercropping in which banana was grown in pure stands, with tapioca (cassava) alone or with tapioca and groundnut or bittergourd. Tapioca was also grown as a sole crop. Intercropping had no significant effect on yield of banana or tapioca. Intercropping banana with tapioca alone gave the best return.

First 2 or 3 years after the initial planting of rubber trees *i.e.* before the trees have grown sufficiently to extend their canopy fully, the wide inter-row space were utilized for growing crop, which would generate an additional income during the first few unproductive years of the rubber trees and also during wet periods when rubber tapping is not possible (Yogarantnam and Iqbal, 1995).

Sharma *et al.* (1996) conducted a trial in a 30 years old coconut stand under rainfed condition. The coconut spaced at 7.5x7.5m was grown as mono-crop or with ginger (*Zingiber officinale*) cv. Madia, turmeric (*Curcuma longa*) cv. Tall Clone or colocasia cv. Gara was planted in April as intercrop. Ginger gave the highest crop value (Rs. 52000/ha) but the low cultivation cost of colocasia made it the most profitable. Coconut yield was increased by all three intercrops with colocasia resulting in the greatest increase (10.6% more than mono-crop).

Sodhi and Ansari (1996) observed improvement in the biological productivity as well as the economic return of the same piece of land. The different formats of farm forestry included peripheral planting on field boundaries, block plantation along with usual agricultural practices being adopted in Haryana. The poplar planting has been selected for in depth study in view of its important contribution towards rural economy and recorded that poplar planting was found to be more profitable than the traditional agricultural crops.

Maheshwari *et al.* (1997) recorded that intercropping of different traditional crops did not bring any marked variation in the root yield of vetiver as compared to sole crop. The essential oil yield of vetiver was not fluctuated significantly due to intercropping. Further, they noted that intercropping of vetiver with tall and medium duration variety of pigeonpea proved to be most suitable, competent and promising (gave Rs 6876 ha⁻¹ additional income over sole vetiver crop).

Singh *et al.* (1997) studied growth, productivity and quality of eight vegetable crops grown in four crop sequences, viz., potato-onion, tomato - cowpea, frenchbean - colocasia and frenchbean - turmeric in young Eucalyptus plantation. The plant height of potato, cowpea and turmeric increased while that of tomato, fababean, frenchbean and colocasia showed a decline, which may be because of shading effect of Eucalyptus. The average leaf area, number of leaves and dry matter content per plant were distinctly reduced in almost all the crops. The number of daughter rhizomes in colocasia and turmeric, pods per plant in all the beans and yield of all the intercrops decreased substantially as compared to open environment. The most deleterious effect was observed in onion, while in turmeric, shade showed minimum yield loss.

Intercropping of radish, okra and cowpea in menthol mint improved the economic returns by Rs 20936, 7439 and 7028 ha⁻¹, respectively over sole crop of mint. (Aparbal Singh *et al.* 1998).

Chaturvedi and Jha (1998) observed that growing agricultural crops in association with Litchi plantation is a wide practice in north Bihar. Paddy-wheat-greengram-ginger and maize-toria-greengram-pointed gourd were studied across an age series of Litchi plantations. Light intensity under tree plantation decreased with increasing canopy depth and tree height. There was a marked reduction in yield of all intercrops with increase in age of the plantations. An overall economic analysis was made of the cropping systems at the end of nine years. The benefit cost ratio under the paddy-wheat-greengram-ginger/litchi system was 2.17 and under the maize-toria-greengram-pointed gourd/litchi system it was 2.73.

Kumar *et al.* (1998) conducted an experiment on a farmer's field and found maximum growth of barely under the canopies of multipurpose trees as compared to these in the adjacent open area. Plant density was more (1000.35⁻²) under *Prosopis cineraria* and the lowest (78.75 m²) in control plant. The number of plants per sq. m under *Prosopis cineraria*, *Tecomella undulata* and *Acacia nilotica* was significantly higher than that under *Acacia albida* in open area. Similarly, the number of culms per sq. m was comparable under *Prosopis cineraria*, *Tecomella undulata* and *Acacia albida* but was significantly higher than that recorded in all agroforestry systems which differed significantly with each other except these in *Prosopis cineraria* and *Acacia albida*. The test weight and grain yield was higher under *Prosopis cineraria*.

Ram and Kumar (1998) revealed that medicinal and spice crops intercropped with geranium showed greater yield advantage in terms of main crop

equivalent yield compared with that of geranium sole cropping. Intercropping systems involving garlic and wild marigold with geranium increased the yield advantages by 26 and 39 percent respectively over sole crop of geranium.

Ravindran and Kulandaivell (1998) observed that reduction in the yield components of cardamom under full sunlight may be attributed to excessive sunlight during summer month combined with high temperature and low humidity and soil moisture, all of which are detrimental to vegetative growth and flower initiation. The decrease in the yield at low light could be due to reduced photosynthesis during winter months. Though cardamom is regarded as shade loving plant, low light condition was not conducive to the optimum growth and productivity.

Singh *et al.* (1998 a) reported that menthol mint (*Mentha arvensis* L.), radish (*Raphanus sativus* L.), okra (*Abelmoschus esculentus* L.) and cowpea (*Vigna unguiculata* L. Walp) when grown as intercrops improved the economic return as compared to sole crop.

Singh *et al.* (1998 b) observed that intercropping of palmarosa with pigeonpea improved the land use efficiency by 47 percent, relative net return by 58 percent and net economic return by Rs 12500 ha⁻¹ over a sole palmarosa crop.

Ram *et al.* (1999) studied the intercropping of patchouli with papaya for higher monetary return five treatments of pure cultures and intercrops grown on sandy loam soil of medium fertility. The highest net returns of Rs. 286300/- was obtained from papaya-patchouli intercropping system as against R. 260820/- from sole crop of papaya.

Kothari *et al.* (2000) reported that menthol mint intercropped with one, two and three rows of onion yielded 89, 81 and 71 percent of 202 kg essential oil per

hectare obtained from sole crop of menthol mint, respectively. Likewise, the onion yield under 1:1, 1:2 and 1:3 row intercropping was 46, 68 and 87 percent, respectively of 30 tonnes onion per hectare obtained from the sole crop.

Nutrient removal in palmarosa + blackgram intercropping system was 33, 46 and 52 percent higher, respectively with regard to N, P and K compared to sole palmarosa. Similarly in geranium intercropping with cowpea, the nutrient removal was 29 percent higher over the sole crop of geranium. This clearly indicated that there is a need to work out the nutrient management practices for various intercropping systems (Prakasa Rao *et al.*, 2000).

Rajeswara Rao *et al.* (2000) revealed that intercropping rose scented geranium with clusterbean was more productive and profitable with gross returns of Rs 149330 and Rs 147230 ha⁻¹ in the first and second year, respectively.

In silvi-pastoral studies conducted with nine trees and shrubs it was revealed that average dry forage yield of grass in interspaces (10 m x 4 m) of different silvi-pastures were lowest with *Acacia tortilis* (1553 kg/ha) and *Dracocephalum nutans* (1945 kg/ha) and maximum (2475 kg/ha) in the plots without trees (control). Among trees *Acacia tortilis* showed maximum height (459 cm) followed by *Acacia indica* (416 cm), *Acacia senegal* (351 cm) and lowest height was recorded in *Prosopis cineraria* (120 cm). The same trend was also noticed regarding the observations on collar diameter and tree canopy (Singh, 2000).

Basavaraju *et al.* (2001) carried out an experiment that the trees planted in agroforestry system reduced the availability of light to finger millet crop due to interception of light by them. Jack intercepted more light compared to tamarind and

mango due to its wider and denser canopy. The yield of finger millet was reduced in agroforestry system compared to control.

Shinde (2001) studied the effect of tree species on the growth and production of forage crops. He observed maximum number of leaves, number of branches, fresh weight, dry weight and water status of leaves when crops were grown in open condition than under Kalam and Arjun. Similarly, maximum root length of forage crops was also recorded in open condition followed by Kalam. However, the higher yield of forage per hectare was recorded in open condition as compared to Kalam and Arjun.

Vyas (2001) studied tree crop interaction in Agroforestry involving the effect of *Prosopis cineraria* (Khejri) leaves on the growth and productivity of *Cassia angustifolia* (senna), under medico-forestry system. *Prosopis* had 44.2, 29.9 and 54.0 percent more growth in height, root length and number of leaves, respectively. Plants growing under the Khejri tree also had higher leaflet number (178.3%), leaf area (15.3%) dry matter of root, stem and leaves. The seed yield of these plants increased by 56.5 percent as compared to plants growing at the site with no tree.

Kaur *et al.* (2002) reported nitrogen mineralization rates were greater in silvopastoral systems compared to grass only system. Soil organic matter was linearly related to microbial biomass carbon, soil N and nitrogen mineralization rates.

Menezes *et al.* (2002) reported that soil and air temperatures were lower under *Z. joazeiro* in comparison to grass patches but *Prosopis juliflora* a little effect on temperature. Losses of P from all litter types were not consistently affected by the presence of trees. Soil net N mineralized was greater under both tree species, in comparison to grass patches.

Parekh *et al.* (2005) studied that intercropping in *Mitragyna parvifolia* and *Adina cordifolia* with three pulse crops namely *Vigna radiate*, *Vigna sinensis* and *Vigna munga*. The maximum fresh weight and water status of leaves were recorded when crops grown under open field, as compared to grown under hed and kalam. Similarly maximum root length, number of branches, number of pods and leaf area were recorded when crop grown under open field as compared to kalam and hed.

Saroj *et al.* (2003) studied on the Ber-based Agri-Horticultural System. The highest yield of Ber was recorded with Indian aloe (13.55 q/ha) while with groundnut- wheat and cluster bean-mustard, the yield level was almost at par (9.62 and 9.80 q/ha, respectively). The minimum yield was recorded under sole plantation (8.09 q/ha). The average stock diameter was recorded maximum (3.23 cm) with Indian aloe crop rotation while lowest in sole plantation (2.92 cm). The maximum yield was found in Indian aloe (55.62 q/ha).

Thakur and Dutt (2003) studied that root number, length and root growth, yield and height were recorded higher in wheat plants growing under *Morus alba* compared to control (without tree).

Baghel *et al.* (2004) studied the intercropping system in bearing orchard of mango under rainfed agro-ecosystem. The crops grown under mango were cowpea, bengal gram, pigeon pea and tomato. They recorded maximum production/ha from mango intercropping with cow pea in kharif and Mango- Bengal gram in rabbi.

Dutt and Thakur (2004) studied monetary status of cropping systems combining medicinal and aromatic herbs with commercial timber species. Four herbal crops namely *Ocimum sanctum*, *Spilanthes acmella*, *Tagetes minuta* and *Withania somnifera* were intercropped for two consecutive years with 6-year old plantation of

Populus hybrid (G-48). Net returns were comparatively more under agroforestry systems combining *Ocimum sanctum* and *Tagetes minuta* with poplar at different spacing in comparison to monocropping. However, in case of *Spilanthes acmella*, the net returns were higher from sole cropping in comparison to agroforestry intervention. The net returns from *Withania somnifera* were negative both when the crop was raised as pure and intercropped with poplars. The combination of *Withania somnifera* + poplar at different spacing, however, resulted in considerable income from the system. From economic perspective point, medicinal and aromatic crops can be categorized as *Spilanthes acmella*>*Ocimum sanctum*>*Tagetes minuta*>*Withania somnifera*.

Gill *et al.* (2004) conducted a field study to evaluate the effect of age of Poplar on Turmeric at farmer's field. The study revealed that the mean GBH of Poplar increased significantly as age of Poplar plantation increased. Fresh rhizome yield of Turmeric decreased significantly as age of Poplar increased. Maximum reduction in fresh Turmeric yield (85.9%) was recorded under four years old Poplar whereas reduction was minimum in one year old Poplar plantation (11%) as compared to pure crop of Turmeric.

Handa *et al.* (2004) conducted an experiment on growth of fruit trees and their effect on crop with four fruit trees viz. Guava, Ber, Pomogranate and Kinnnow along with four crop rotations viz. sorghum-wheat, sorghum-chickpea, groundnut-wheat and groundnut-chickpea. Data on wheat yield under all fruit trees from crop rotation sorghum-wheat, groundnut-wheat and at different distance (75,125,175 cm) from the tree base was analyzed. It was seen that the wheat yield pertaining to different distances from the tree was significantly different. Increase in yield was recorded with increase in distance from tree.

Awasthi *et al.* (2005) revealed that the mixed cropping system was beneficial when main crop taken as mango and under storey crops were bay leaf, black pepper and ginger. They recorded maximum economic returns from ginger as under storey crop.

Mohsin Faiz (2005) recorded higher herbage and oil yield in pure fields of *Mentha* crops than the crops grown under Poplar and Eucalyptus stands. The total addition of nutrients recorded was also higher in poplar and Eucalyptus than pure field of *Mentha* crops.

Nandal and Hooda (2005) reported that yield of various field crop viz. Sorghum, Cowpea, Dhaincha, Moongbean, Groundnut, Turmeric, Wheat, Oat, Berseem, Lentil and Potato decreased with increasing age of poplar under intercropping system. The yield of all crop increased with increasing poplar spacing *i. e.* 5.0 x 4.0 m, 10.0 x 2.5 m and 15.0 x 2.5 m.

Divya *et al.* (2006) conducted an experiment on evaluation of suitable intercrops for *Jatropha curcas* - based agroforestry system and concluded that Cowpea followed by Groundnut were suitable crops for *Jatropha* - based agroforestry system at tree spacing of either 4.0m x 2.0m or 4.0m x 3.0m.

Gill and Ajit (2006) studied the intercropping of wheat with four varieties of mango (Amrapalli, Mallika, Dasher and Langra). The variety Langra gave the highest values followed by Mallika and Dasher. The highest grain and straw yield was recorded with variety Amarpali and lowest with variety Mallika. Maximum yield was registered from the fifth row followed by third row and minimum in the first row from the tree base.

Jaimini *et al.* (2006) worked on khejri based silvipastoral system and indicated higher fodder yield below the Khejri tree canopy (49.50 q/ha) followed by between Khejri rows (40.25 q/ha.) and lowest forage yield was observed in sole Dhaman grass without khejri tree (38.75 q/ha.)

Thakur and Kumar (2006) conducted an experiment growing medicinal and aromatic herbs as intercrops with the hedgerows of *Leuceana leucocephla* and *Morus alba* under alley cropping system for diversification. The impact of tree hedgerows on the growth, production and physiological behavior of two medicinal herbs namely, *Tagetes minuta* and *Ocimum basilicum*. The growth parameters namely plant height, leaf number and leaf area index were found to be more in sole crops relative to that with hedgerows at different plant spacings. Photosynthesis, transpiration and water use efficiency were greater in both the medicinal and aromatic herbs grown under *Morus*.

Medicinal plants such as *Withania somnifera* (ashwagandha), *Cassia angustifolia* (Senna) and *Ocimum basilicum* (Tulsi) were grown in the interspaces at a row distance of 45 cm in 15 year-old mango orchards with plant spacing of 7.0 x 7.0m and 8.0 x 8.0m. The growth of intercrops was poor due to increasing shade of mango trees, indicating less scope for their optimum production (Anon., 2006-2007).

Prajapati *et al.* (2007) studied the growth and productivity of Ginger (*Zingiber officinale*) under Kapok (*Ceiba pentandra*)-based agrisilviculture system. The result revealed that the intercropping of Ginger under *Ceiba pentandra* gave higher yield and income under unpruned condition with FYM @30 tons/ha as compared with 25% pruned and lowest as a sole crop.

Qaisar *et al.* (2007) reported that the fodder crop yield was decreased in combination of trees + fodder crops compared to sole fodder crops. The available nutrients (N, P and K) and soil microbial count were recorded higher in combination of tree + fodder crops.

Thakur and Dutt (2007) revealed that intercropping between rows of widely cultivated poplar (*Populus deltoides*) with high value medicinal and aromatic plants may provide a good opportunity to diversify agroforestry and increase the farm returns. Four medicinal and aromatic herbal species namely, *Ocimum sanctum*, *Spilanthes acmella*, *Tagetes minuta* and *Withania somnifera* were grown successfully as intercrops between the rows of *Populus* hybrid, a commercial industrial tree species.

Kumar *et al.* (2008) conducted an experiment on two main plots viz., open conditions and arecanut shade and seven sub-plots corresponding to the seven different medicinal plants. Seven different medicinal plants viz., *Aloe vera*, *Alpinia galangal*, *Coleus forskholii*, *Stevia rebaudiana*, *Andrographis paniculata*, *Catharanthus roseus* and also *Ocimum sanctum*. Significant differences in the plant height were observed in all the medicinal plants grown under the shade of arecanut and in open conditions. Among the medicinal plants, the best performer under open conditions was *Stevia rebaudiana* which gave a net return of Rs. 89422.3 whereas under the shade of arecanut the best performer was *Catharanthus roseus* which gave returns to the tune of Rs. 11507.3/hectare. *Catharanthus roseus*, *Andrographis paniculata* and *Stevia rebaudiana* were found to be economical under arecanut plantation giving economic returns of Rs. 11507, 5226 and 3897 per hectare respectively.

Nanada and Reghunath (2008) collected *Indigofera tinctoria* and grow as pure crop in open and as an intercrop in shaded situation in a coconut garden. Plant

height was higher in open condition in all the accessions than under shade at all the three growth stage. Plant spread was higher in open condition compared to shade. More number of branches under open conditions at all the three stages of growth, compared to shade condition. More number of leaves was produced by all accessions at all stages of growth under open condition than under shade.

Sehgal and Thakur (2008) studied growing medicinal and aromatic herbs, viz. *Ocimum basilicum* and *Tagetes minuta* and to find out the effects of organic manures, i.e. vermicompost, FYM and enriched manure on the growth performance and productivity of medicinal herbs, intercropped between hedgerows of *Morus*, an important fuel and fodder tree species under agroforestry conditions. The application of organic manures improves performance and production efficiency of medicinal herbs intercropping with trees. The distance of the crop from *Morus* hedgerows also affected the growth and yield of intercropping herbal crops. Out of the three organic manures; comparatively higher yields were obtained in treatments receiving enriched manure than vermicompost and FYM. Medicinal and aromatic plants can be grown successfully in combination with *Morus* hedgerows.

Venugopal *et al.* (2008) studied on performance of patchouli (*Pogostemon patchouli* Benth.) cultivated in open and partial shade of coconut plantation. High cumulative fresh herbage yield (27.23 tons/ha), dry herbage yield (5.063 tons/ha) and oil yield (94.85 kg/ha) from four harvest per year from patchouli crop was obtained under partial shade of coconut plantation. Patchouli under open cultivation recorded vigorous growth initially up to two harvest but further failed to regenerate after third harvest registering cumulative fresh herb yield (19.49 tons/ha), dry herbage yield (4.38 tons/ha) and oil yield (82.09 kg/ha) respectively. The percent oil recovery and

quality of oil in terms of percent patchouli alcohol was superior in patchouli cultivated under partial shade.

Patel *et al.* (2009) conducted an experiment to identify the crop which provides better shade effect on yield of fasciculated root of safed musli. Among the five selected intercrops, safed musli - senna intercrop combination registered maximum net profit with 1:1.80 cost benefit ratio. Safed musli - bajra intercrop did not prove beneficiary on safed musli. Higher cost of production, safed musli as sole crop earned maximum profit. Thus intercrop and shade condition does not help for the fasciculate root yield of safed musli.

Vanlalhluna and Sahoo (2009) conducted a field trial and revealed that the yield of ginger and turmeric was found better under tree-crop association with *Alnus nepalensis*, *Melia azadirachta* and *Gmelina arborea* than pure crops.

Arya *et al.* (2010) carried out an experiment on growth and yield of tree fruits and annual crops under integrated model in arid region of Rajasthan. The growth and yield in tree fruits were more under the integrated model of Aonla + Ber + Karonda + Clusterbean + Brinjal and Aonla + Ber + Karonda + Clusterbean + Fallow. Minimum yield was recorded when tree fruits were grown as sole crop. The growth and yield parameters in Clusterbean, Mothbean and Brinjal exhibited non-significant differences while plant height, number of branches per plant, number of pods/silique/fruits per plant and yield were found to be significantly superior in integrated cropping models Aonla + Ber + Karonda + Cluster Bean + Brinjal and Aonla + Ber + Karonda + Moth Bean + Mustard as compared to sole cropping.

Kumar *et al.* (2010 a) reported the papaya cv. 'Pusa Dwarf' was planted at the distance of 2.0m x 2.0m and two rabi [matricaria (*Matricaria chamomilla*

Chamomile) and isabgol (*Plantago ovata* Husk)] and four kharif crops [kalmegh (*Andrographis paniculata* (Burm. F.) Well. Nees.), ashwagandha (*Withania somnifera*), patchouli (*Pogostemon cablin* (Blanco) Benth) and sweet basil (*Ocimum basilicum*)] were taken as intercrops in between two rows of papaya. The intercrops viz., matricaria, isabgol, patchouli, ashwagandha, kalmegh and sweet basil were planted in between two rows of papaya. The early flower initiation (171.3333 days) and 50% flowering (185.40 days) were taken in sole crop of papaya, followed by papaya + ashwagandha and papaya + sweet basil. The maximum fruit yield (48.94 kg/plant), number of fruit (40.44 per plant) and average fruit weight (1.38 kg/fruit) were recorded under papaya + ashwagandha, followed by papaya + patchouli intercropping system. However, lowest fruit yield, number of fruits/plant and average weight of matured fruit were recorded in sole crop of papaya.

Kumar *et al.* (2010 b) studied that safed musli was grown in tamarind plantation of 6 years old and in open area (as sole crop). Interception *i.e.* photosynthetically active radiation (PAR) in tamarind plantation by safed musli at 90 DAP was 21462 lux compared to 24639 lux in open area. Plant height (11.13) and plant spread (54.50 cm) were higher under intercropping at 90 DAP compared to sole cropping (8.93 cm and 50.36 cm, respectively). Higher dry weight of tuber was recorded in tamarind plantation (9.25 g/plant) compared to sole cropping (5.86 g/plant). Number of tubers per plant and width of tuber were higher under intercropping (16.46 and 0.71 cm, respectively) compared to sole cropping (10.40 and 0.59 cm, respectively). Higher yield in tamarind plantation also resulted in higher benefit:cost ratio (1.94), compared to sole cropping (1.51).

Patil *et al.* (2010) carried out an experiment on arable crops (maize, paddy, fodder maize and sunhemp) horticultural crops Sapota and silvicultural crops *Eucalyptus tereticornis*, *Albizia molucana*, *Casuarina equisetifolia*, *Tectona grandis* and *Dalbergia sissoo*. Economic analysis after 17 years indicated that, benefit cost ratio and internal rate of returns were highest in Agroforestry system with *T. grandis* (1.67:1 and 23.2%, respectively) and were lowest in Sapota + *Casuarina equisetifolia* (0.99:1 and 12%, respectively). The economic analysis at the end of 28 years indicated that benefit cost ratio was higher in Sapota + *T. grandis* + field crops (3.23:1) followed by Sapota+ *Lagerstroemia lanceolata* + field crops (2.71:1) and sole Sapota (2.36:1).

Rathod *et al.* (2010) recorded that in the sole crop of senna there was significantly better growth and growth parameters (plant height, number of branches, canopy spread, dry matter accumulation in leaves, stem and total dry matter production, total economic yield and light transmission etc.) as compared to intercropped senna.

Vanlalhluna and Sahoo (2010) observed growth of three multipurpose tree species viz. *Alnus nepalensis*, *Melia azedarach* and *Gmelina arborea* and yield of three intercrops viz. ginger (*Zingiber officinales*), turmeric (*Curcuma longa*) and maize (*Zea mays*). The tree height increment was in the order of *Melia azedarach* > *Gmelina arborea* > *Alnus nepalensis*. Mean annual increment was higher in *Melia azedarach* compared with *Gmelina arborea* and *Alnus nepalensis* after a 3-year period. Crop yield was higher in plots associated with *Alnus nepalensis* compared with other tree species. The NPK level in general, was maximum under tree-crop association than the corresponding sole crops.

Verma and Thakur (2010) revealed that *Withania somnifera* was grown in association with *Prunus persica* (Peach), *Grewia optiva*, *Morus alba* and *Setaria*

sphacelata. The tree-crop combinations (agroforestry systems) formed were, Peach + Grewia + Setaria + *W. somnifera*, Peach + Morus + Setaria + *W. somnifera*, Peach + Setaria + *W. somnifera*, Grewia + Setaria + *W. somnifera*, Morus + Setaria + *W. somnifera*, and *W. somnifera* as sole crop. The maximum net financial returns accrued from ahwahandha roots, were obtained under Peach + Grewia + Setaria followed by under Peach + Morus + Setaria. The maximum benefit:cost ratio (B:C ratio) values were obtained from Morus + Setaria + *W. somnifera* system on farmers land (financial perspective), whereas, it was lower from Peach + Setaria + *W. somnifera* system assuming the enterprise have been taken on rented land (economic perspective).

Arya *et al.* (2011) recorded variations in growth and yield performances of trees as well as annual crops grown in combination under tree-crop farming. Plant growth and yield of all component crops were higher when grown under conjugation as compared to their sole croppings. Under integrated model, there was 50-53% increase in yield (84.60 to 86.52 q/ha) of ber over its sole cropping (56.32 q/ha).

***Materials and
Methods***



III. MATERIALS AND METHODS

Two field experiments were conducted under rainfed conditions during *kharif* season 2011 and 2012 at Navsari Agricultural University, Navsari, Gujarat to “study the horticultural, silvicultural and medicinal crops in three-tier agroforestry system”. The details of the materials used and techniques adopted during the course of investigation are described in this chapter.

3.1 Experimental Site

The present investigation was carried out at the Agronomy Farm (Block-E), ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat. Geographically, Navsari is situated at 20° 95'N latitude, 75° 90'E longitude and at altitude of 10 metres above the mean sea level. The college farm is located 3 kilometres away in west from Navsari city and 12 kilometres away in the East from the historical place Dandi on Arabian Sea shore.

3.2 Soil characteristics

The soil characteristics of the experimental block, ASPEE College of Horticulture and Forestry is placed under Jalalpur serise, which includes deep moderately drained clayey soils classified as “deep black soil” predominated with montmorillonite clay mineral by its origin. It is medium in fertility. The topography of the experimental plot was fairly levelled. Soil samples were taken from surface level to 30 cm depth covering the whole experimental area before starting the experiment. The soil samples were collected from five randomly selected spots in each plot at 0-30 cm depth and a composite sample was prepared and analyzed for chemical properties of soil as per the methods mentioned below in Table-3.1

Table – 3.1 Methods for soil analysis

Sr. No.	Soil characteristics	Methods employed for determination
1	Soil pH (1:2.5 soil:water ratio)	Potentiometric pH meter (Jackson,1967)
2	EC (dSm^{-1}) at 25°C (1:2.5 soil: water ratio)	Salt bridge (Jackson,1967)
3	Organic carbon (%)	Walkley and Black's rapid titration method (Jackson,1967)
4	Available N (kg ha^{-1})	Alkaline potassium permanganate method (Subhiah and Ashija,1967)
5	Available P_2O_5 (kg ha^{-1})	Olsen's method (Jackson,1967)
6	Available K_2O (kg ha^{-1})	1 N N NH_4OAC Extraction method (Jackson,1967)
7	Available Ca & Mg (mg kg^{-1})	1 N N NH_4OAC Extraction method (Jackson,1967)
8	Available micronutrients (Fe, Mn, Zn, Cu) (mg kg^{-1})	DTPA Extraction method (Lindsay and Norwell, 1978)

Table – 3.2 Methods for plant analysis

Sr. No.	Characteristics	Methods for plant analysis
1	Nitrogen	Kjeldahl's method (Jackson, 1967)
2	Phosphorus	Vanadomolybdo phosphoric acid yellow colour method (Jackson, 1967)
3	Potassium	Flame photometric determination (Jackson, 1967)
4	Calcium & Magnesium	Versenate titration method (Jackson, 1967)
5	Micro nutrients (Fe, Mn, Zn, Cu)	The estimation of Fe, Mn, Zn, Cu were carried out by using Atomic absorption spectrophotometer (Perkin Elmer Model-3110)

Table-3.3 Initial physico-chemical properties of the soil (0-30 cm depth) at experimental soil

Experiment-I Performance of herbal crops (Basil, Kalmegh and Mint) under three-tier agroforestry system

Sr. No.	Properties	Values
A.	Physical properties	
	1. Particle size distribution (Piper, 1956)	
	Sand (%)	11.47
	Silt (%)	23.94
	Clay (%)	64.59
	2. Texture	Clay
B.	Chemical properties (Jackson, 1967)	
	1. pH (1:2.5 Soil water suspension)	7.56
	2. EC (dS m ⁻¹)	0.95
	3. Organic carbon (%)	5.64
	4. Available N (Kg ha ⁻¹)	207.47
	5. Available P ₂ O ₅ (Kg ha ⁻¹)	30.81
	6. Available K ₂ O (Kg ha ⁻¹)	348.25
	7. Ca (mg kg ⁻¹)	6045
	8. Mg (mg kg ⁻¹)	1798
	9. Micronutrients (mg kg ⁻¹)	
	Fe	4.70
	Mn	9.20
	Cu	2.15
	Zn	0.62

Experiment-II Performance of tuber crops (Kalihari, Kali musli and Safed musli) under three-tier agroforestry system

Sr. No.	Properties	Values
A.	Physical properties	
	1. Particle size distribution (Piper, 1956)	
	Sand (%)	11.49
	Silt (%)	23.93
	Clay (%)	64.58
	2. Texture	Clay
B.	Chemical properties (Jackson, 1967)	
	10. pH (1:2.5 Soil water suspension)	7.55
	11. EC (dS m^{-1})	0.93
	12. Organic carbon (%)	5.65
	13. Available N (Kg ha^{-1})	209.50
	14. Available P_2O_5 (Kg ha^{-1})	30.86
	15. Available K_2O (Kg ha^{-1})	350.29
	16. Ca (mg kg^{-1})	6049
	17. Mg (mg kg^{-1})	1800
	18. Micronutrients (mg kg^{-1})	
	Fe	4.74
	Mn	9.22
	Cu	2.18
	Zn	0.65

Table -3.4 Geographical location and climatic conditions of experimental sites

Agro climatic zone	South Gujarat heavy rainfall zone
Agroecological situation	AES III
Longitude	72°54' East
Latitude	20°57' North
Altitude	10 m
Climate	Sub humid
Max. Temperature	27.9 to 34.9°C
Min. Temperature	12.2 to 27.2°C
Annual rainfall	1500-1800 mm
Number of rainy days	95
Wind velocity	16.4 km/hr.
Pan evaporation	2.5 to 7.1 mm/day
Relative humidity	50-100%
Water table	6-12 m

3.3 Climate and weather conditions

The climate of South Gujarat region, where Navsari campus situated is typically tropical, characterized by fairly hot summer, moderately cold winter and more humid and warm monsoon. The average figures of weather data recorded at the meteorological observatory of the Agronomy Farm, N.M. College of Agriculture, Navsari during the period of experimentation are given in Appendix-1 and 2.

The climate of the area is characterized by three well defined seasons viz., monsoon, winter and summer. The monsoon commences from the middle of June and ends by the second fortnight of September. Pre monsoon rains in the last week of May or in the first week of June are not uncommon. Most of the precipitation is received from South West monsoon, concentrated during the month of June, July and August. The winter season starts from November with mild cold and lasts up to February. December and January are the coldest months of the season and the minimum temperature registered during these months of the experimental period were 13.4⁰C and 9.6⁰C respectively. Summer season commence during the middle of February and ends during middle of June. The temperature reached a maximum of 34.9⁰C in the month of May. April and May are the hottest months of summer season. The climate of this area is humid and the mean relative humidity remained above 68.27 per cent throughout the year. The weather condition was favourable for growing rainy, winter and summer crops during this study.

3.4 Plant materials

The seven year old plantation of sapota (*Manilkara acharas* (Mill) Fosberg.) at 10.0 x 10.0m spacing, intercropped with five year old plantation of *Jatropha* (*Jatropha curcus* L.) at 2.5 x 2.5m spacing were used for intercropping study. Six

medicinal plants viz. Basil (*Ocimum sanctum* L.), Kalmegh (*Andrographis paniculata* Well.), Mint (*Mentha arvensis* L.), Kalihari (*Gloriosa superba* L.), Kalimusli (*Curculigo orchoides* Gaertn) and Safedmusli (*Chlorophytum borivillianum* Ker.) were selected for the present study.

3.5 Experimental details:

The experiment was conducted during rainy season, 2011 and 2012 with following details.

3.5.1 Experiment-I Performance of herbal crops (Basil, Kalmegh and Mint) under three-tier agroforestry system

- 1. Location** : Agronomy Farm (Block-E)
ASPEE College of Horticulture and Forestry,
Navsari Agricultural University, Navsari, Gujarat
- 2. Design** : Randomized Block Design (RBD)
- 3. No. of treatment** : Six (6)
- 4. No of replications** : Four (4)
- 5. Plot Size** : 10.0 x 10.0m

6. Horti- silviculture species

(a) *Manilkara achras* (Mill) Fosberg.

(b) *Jatropha curcas* L.

7. Intercrop of medicinal plants (herbal crops)

a. Basil (*Ocimum sanctum* L.)

b. Kalmegh (*Andrographis paniculata* Well.)

c. Mint (*Mentha arvensis* L.)

8. Year of planting

- a. Sapota:-Rainy season – 2004
- b. Jatropha:- Rainy season - 2006
- c. Medicinal plants: - Rainy season - 2011 & 2012

9. Spacing

- a. Sapota – 10.0 x 10.0 m
- b. Jatropha - 2.5 x 2.5 m
- c. Basil – 50.0 x 40.0 cm
- d. Kalmegh – 50.0 x 40.0 cm
- e. Mint – 30.0 x 45.0 cm

10. Manures and fertilizers : FYM- 20 tha^{-1}

Crops	(N:P:K Kg ha^{-1})		
a. Basil	40	15	15
b. Kalmegh	40	20	40
c. Mint	120	50	60

11. Treatment details :

T₁ – *Manilkara achras* Mill. + *Jatropha curcas* L. + *Ocimum sanctum* L.

T₂ – *Manilkara achras* Mill.+*Jatropha curcas* L.+*Andrographis paniculata* Well

T₃ – *Manilkara achras* Mill + *Jatropha curcas* L. + *Mentha arvensis* L.

T₄ – *Ocimum sanctum* L. sole

T₅ – *Andrographis paniculata* Well sole

T₆ – *Mentha arvensis* L. sole

12. Plan layout: As mentioned in Figure- 1.

Figure -1 Plan of Layout of Experiment- I (Herbal Crops)

R-I	R-II	R-III	R-IV	
T ₁	T ₂	T ₁	T ₃	N  Design: Randomised Block Design Replication: 4 Treatment: 6 Plot size: Gross: 10 x 10 m
T ₄	T ₆	T ₂	T ₅	
T ₆	T ₁	T ₆	T ₄	
T ₂	T ₅	T ₄	T ₆	
T ₅	T ₃	T ₅	T ₂	
T ₃	T ₄	T ₃	T ₁	

T₁ – *Manilkara Achras* Mill. + *Jatropha curcas* L. + *Ocimum sanctum* L.

T₂ – *Manilkara achras* Mill + *Jatropha curcas* L. + *Andrographis paniculata* Well

T₃ – *Manilkara Achras* Mill + *Jatropha curcas* L. + *Mentha arvensis* L.

T₄ – *Ocimum sanctum* L. sole

T₅ – *Andrographis paniculata* Well sole

T₆ – *Mentha arvensis* L. sole

3.5.2. Experiment-II Performance of tuber crops (Kalihari, Kali musli and Safed musli) under three-tier agroforestry system

1. Location : Agronomy Farm (Block-E)
ASPEE College of Horticulture and Forestry,
Navsari Agricultural University, Navsari,
Gujarat

2. Design : Randomized Block Design (RBD)

3. No. of treatment : Six (6)

4. No of replications : Four (4)

5. Plot Size : 10m x 10m

6. Horti- silviculture species

(a) *Manilkara acharas* (Mill) Fosberg.

(b) *Jatropha curcas* L.

7. Intercrop medicinal plants

a. Kalihari (*Gloriosa superba* L.)

b. Kalimusli (*Curculigo orchioidea* Gaertn)

c. Safedmusli (*Chlorophytum borivillianum* Ker.)

8. Date of planting

a. Sapota: - Rainy season - 2004

b. Jatropha: - Rainy season - 2006

c. Medicinal plants: - Rainy season - 2011 & 2012

9. Spacing

a. Sapota - 10 x 10 m

b. Jatropha - 2.5 x 2.5 m

c. Kalihari – 30 x 60 cm

d. Kalimusli – 30 x 30 cm

e. Safedmusli – 30 x 30 cm

10. Manures and fertilizers : FYM- 20 tha⁻¹

N : P : K Kgha⁻¹

Crops	N	P	K
a. Kalihari	50	50	70
b. Kalimusli	25	15	10
c. Safedmusli	60	65	20

11. Treatment details

T₁ – *Manilkara achras* Mill + *Jatropha curcas* L. + *Gloriosa superba* L.

T₂ – *Manilkara achras* Mill + *Jatropha curcas* L. + *Curculigo orchoides* Gaertn

T₃ - *Manilkara achras* Mill + *Jatropha curcas* L. + *Chlorophytum borivillianum* Ker.

T₄ – *Gloriosa superba* L. sole

T₅ – *Curculigo orchoides* Gaertn sole

T₆ – *Chlorophytum borivillianum* Ker. Sole

12. Plan layout: As mentioned in Figure- 2.

Figure -2 Plan of Layout of Experiment- II (Tuber Crops)

R-I	R-II	R-III	R-IV	
T ₄	T ₆	T ₂	T ₃	N ↑ Design: Randomised Block Design Replication: 4 Treatment: 6 Plot size: Gross: 10 x 10 m
T ₆	T ₅	T ₁	T ₅	
T ₁	T ₄	T ₄	T ₄	
T ₃	T ₂	T ₅	T ₆	
T ₅	T ₃	T ₆	T ₂	
T ₂	T ₁	T ₃	T ₁	

T₁ – *Manilkara achras* Mill + *Jatropha curcas* L. + *Gloriosa superba* L.

T₂ – *Manilkara achras* Mill + *Jatropha curcas* L. + *Curculigo orchoides* Gaertn

T₃ - *Manilkara achras* Mill + *Jatropha curcas* L. + *Chlorophytum borivillianum* Ker.

T₄ – *Gloriosa superba* L. sole

T₅ – *Curculigo orchoides* Gaertn sole

T₆ – *Chlorophytum borivillianum* Ker. Sole

PLATE I: General view of expwrimental site



3.6 Cultural operation

The following cultural operations were carried out commonly for both the experiments.

3.6.1 Preparation of land

The land was prepared with the receipt of early monsoon. Soil was brought to a fine tilth by giving about four deep ploughing. Weeds stubbles, roots *etc.* were removed. Immediately after the receipt of pre- monsoon showers, beds of 1 - 1.5 m width, 15cm height and of convenient length were prepared.

3.6.2 Manures and fertilizers

Farm Yard manure was applied @ 20tha⁻¹ to all the plots uniformly and was incorporated into the soil at the time of land preparation. Nitrogen, phosphorus and potash were applied at the rate of 40:15:15 Kgha⁻¹ (for Basil), 40:20:40 Kgha⁻¹ (for Kalmegh), 120:50:60 Kgha⁻¹ (for Mint), 50:50:70 Kgha⁻¹ (for Kalihari), 25:15:10 Kgha⁻¹ (for Kali musli) and 60:65:20 Kgha⁻¹ (for Safed musli) respectively at the time of planting.

3.6.3 After care

Weeding and hoeing were done five times at 30, 60, 90 120 and 150 days after planting. Irrigations were applied at an interval of 15 days after the post-monsoon. No Serious pest and disease were observed during experimentation period in both the experiment and both the years.

3.7 Observations recorded

The observations on growth, yield and its attributes recorded during the course of investigation and the procedures adopted are given below. Four plants were randomly selected from each net plot of each replication and observations were recorded.

3.7.1 Sapota

3.7.1.1 Height of plant (cm)

The plant height was measured at the beginning and at the end of experiment. The observations on four plants per treatment were recorded and its average was worked out. The height was measured from ground level to the tip of the stem with the help of 'Ravi Altimeter'.

3.7.1.2 Stem girth (cm)

Stem girth of the plant was measured just above the collar region by the help of measuring tape.

3.7.1.3 Number of primary branches

The total number of branches per plant was recorded by counting the number of lateral branches of four plants from each treatment and average were worked out.

3.7.1.4 Crown spread (E-W & N-S) (cm)

The crown width of tree was measured in centimetre using measuring tape in two direction *i.e.* East-West and North-South direction. Average values were separately calculated both for East-West and North-South direction.

3.7.1.5 Yield (kg/plant)

The final yield per plant was calculated by summing up of all the fruits picked from four plants and then average yield per plant was calculated.

3.7.1.6 Yield (kg ha⁻¹)

From each treatment yield per plant was recorded and extrapolated on per hectare basis as kg/ha. Average values were worked out.

3.7.2 Jatropha

3.7.2.1 Height of plant (cm)

The plant height was measured at the beginning and at the end of experiment. The height of five plants per treatment was record and its average was worked out. The height was measured from ground level to the highest tip of the stem with the help of ‘Ravi Altimeter’.

3.7.2.2 Stem girth (cm)

Stem girth of the plant was measured just above the collar region by the help of measuring tape. Five plants per treatment were recorded and its average was worked out.

3.7.2.3 Number of primary branches

The total numbers of branches per plant were recorded by counting the number of branches of five plants from each treatment and averages were worked out.

3.7.2.4 Crown spread (E-W & N-S) (cm)

The crown width of tree was measured in centimetre using measuring tape in two direction *i.e.* East-West and North-South direction. Average values were separately calculated both for East-West and North-South direction.

3.7.2.5 Yield (kg/plant)

The final yield per plant was calculated by summing up of all the capsules picked from five plants and then average yield per plant was calculated.

3.7.2.6 Yield (kg ha⁻¹)

From each replicate yield per plant was recorded and extrapolated on per hectare basis as kg/ha. Average values were worked out.

3.7.3 Medicinal plants

Experiment-I Performance of herbal crops (Basil, Kalmegh & Mint) under three-tier agroforestry system

3.7.3.1 Morphological observations

3.7.3.1.1 Plant height (cm)

Fifteen plants were randomly selected from net plot area of each treatment per replication and were tagged. The selected plants were used for recording all the

observations. The plant height of the tagged plants was measured in centimetre from base of the plant (ground level) to the top of the tip. The data were recorded at the end of experiment after planting. The mean height per plant for each of the experimental plot was worked out and recorded.

3.7.3.1.2 Number of branches/plant

The total numbers of branches per plant were recorded by counting the number of lateral branches of fifteen selected plants from each treatment and average per plant was calculated.

3.7.3.1.3 Fresh weight per plant (g)

Fifteen plants were randomly selected from each replication and using the electronic weighing machine their weight were recorded in gram. Average values of fresh weight of plant were worked out.

3.7.3.1.4 Dry weight per plant (g)

The selected fifteen plants were dried in the hot air oven at 60 °C for 48 hours and then the dry weight was measured in gram using electronic weighing machine. Average values of dry weight per plant was worked out.

3.7.3.1.5 Fresh weight of plant per plot (kg)

From each plot in a replication fresh weight of plant were recorded using the spring balance and average values in kg/plot were worked out.

3.7.3.1.6 Dry weight of plant per plot (kg)

The dry weights of plant were recorded from each plot in a replication using the spring balance and average values in kg/plot were worked out.

3.7.3.1.7 Crown spread (E-W & N-S) (cm)

The crown width of plant was measured in centimetre using measuring tape in two direction *i.e.* East-West and North-South direction. Average values were separately calculated both for East-West and North-South direction.

3.7.3.1.8 Economic yield (qha⁻¹)

From each treatment in a plot dry herbal yield was recorded and extrapolated on per hectare basis as q/ha. Average values were worked out.

3.7.3.1.9 Survival percent

The survival plants were counted and the survival percent was worked out under various treatments.

Experiment-II Performance of tuber crops (Kalihari, Kali musli & Safed musli) under three-tier agroforestry system

3.7.3.2 Morphological observations

3.7.3.2.1 Plant height (cm)

The plant height of the tagged plants was measured in centimetre from base of the plant (ground level) to the top of the tip. The data were recorded at the end of experiment. The mean height per plant for each of the experimental plot was recorded and average worked out.

3.7.3.2.2 Number of tubers/plant

The total number of tubers per plant was recorded by counting of fifteen sample plants from each treatment and average per plant was calculated.

3.7.3.2.3 Length of tubers (cm)

The length of tuber per plant was measured in centimetre with the help of a scale of fifteen sample plants from each treatment and average per plant was calculated.

3.7.3.2.4 Girth of tubers (cm)

The girth of tubers was measured in centimetre with the help of a measuring tape from fifteen sample plants from each treatment and average per plant was calculated.

3.7.3.2.5 Fresh weight of tuber (g/plant)

Fifteen plants were randomly selected from each treatment in all crops and using the electronic weighing machine their weights were recorded to the nearest gram (g). Average values of fresh weight of tuber per plant were worked out.

3.7.3.2.6 Dry weight of tuber (g/plant)

The selected fifteen plants were dried in the hot air oven at 60 °C for 48 hours and then the dry weight was measured in gram using electronic weighing balance. Average values of dry weight of tuber plant were worked out.

3.7.3.2.7 Fresh weight of tuber (g/plot)

From each plot in a replication fresh weights of tuber were recorded using the spring balance and average values in kg/plot were worked out.

3.7.3.2.8 Dry weight of tuber (g/plot)

The dry weights of tuber were recorded from each replicate in a plot using the spring balance and average values in kg/plot were worked out.

3.7.3.2.9 Economic yield (q/ha)

From each treatment in a plot tuber yield was recorded and extrapolated on per hectare basis as q/ha. Average values were worked out.

3.7.3.2.10 Survival percent

The survival plants were counted and the survival percent was worked out under various treatments.

3.7.3.3 Edaphoclimatic observation

3.7.3.3.1 Weather data:

3.7.3.3.2 Measurement of light intensity (lux)

The light intensity was measured in lux by the digital lux meter. The light intensity was measured in each treatment at 10.00, 12.00 and 16.00 hrs on three randomly selected points of the plot at fortnightly interval throughout the experimental period and average values were worked out.

3.7.3.3.3 Nutrient analysis of soils:

Representative soil sample (0-30cm) from the experimental site were collected before and after the experiment and used for determining the basic physico-chemical properties. The soil samples were dried in shade, processed and used for further analysis.

3.7.3.3.4 Nutrient analysis of plants:

Plant samples used for studying dry matter production were used for estimating nutrient content in whole plant. The samples were powdered and stored in plastic container and were used for further analysis.

3.7.3.4 Plant protection measures:

Plant protection measures were applied whenever required.

3.7.3.5 Economics analysis

3.7.3.5.1 Cost of cultivation:

The cost of the following items was considered for working out the cost of cultivation of herbal and tuber medicinal crops (Appendix- III).

- a. Labour charges
- b. Planting materials
- c. Fertilizers
- d. Miscellaneous (marketing charge, *etc.*)

The prices of the inputs that were prevailing at the time of their use were taken into account to work out the cost of cultivation.

3.7.3.5.2 Gross return:

The gross realization in terms of rupees per hectare was worked on the basis of the yield of each treatment. The price of economic yield of particular crops was accounted on the basis of the prevailing market price.

3.7.3.5.3 Net return:

The net returns per hectare were calculated by deducting the cost of cultivation from gross return per hectare.

3.7.3.5.4 Benefit cost ratio:

The benefit cost ratio was calculated as per following formula:

$$\text{Benefit cost ratio} = \frac{\text{Gross returns}}{\text{Cost of cultivation}}$$

3.7.3.5.5 Land Equivalent Ratio

Originally proposed to help judge the relative performance of a component of a crop combination to sole stands of that species, the term Land Equivalent Ratio is derived from its indication of relative land requirements for intercrops versus monocultures (Mead and Willey, 1980). LER is the sum of relative yields of the component species; i. e.,

$$\text{LER} = \sum_{i=1}^m \frac{Y_i}{Y_{ii}}$$

Where, Y_i is the yield of the “i”th component from a unit area of the intercrop;

Y_{ii} is the yield of the same component grown as a sole crop over the same area;

Y_i/Y_{ii} is the relative yield of component i.

In simple Agroforestry situations, LER can be expressed,

$$\text{LER} = \text{Ci}/\text{Cs} + \text{Ti}/\text{Ts}$$

Where, Ci = crop yield under intercropping

Cs = crop yield under sole cropping

Ti = tree yield under intercropping

Ts = tree yield under sole system

3.8 Statistical analysis

Statistical analysis of the data of various characters studied in present investigation was carried out through the procedure of randomized block design (RBD) by computer system at “The Computer Centre” Department of Agricultural Statistics, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat. The treatment differences were tested by ‘F’ test for significance based on null hypothesis. The appropriate standard error (S.E.m.±) was calculated in each case and critical difference (CD) at 5 per cent level of probability was worked out to compare the treatment means, where the treatment effects were significant (Panse and Sukhatme, 1967). Suitable graphical presentations based on the data is given at the appropriate places.

Experimental

Results



IV. EXPERIMENTAL RESULTS

The results of the field experiments conducted during rainy season of 2011 and 2012 on study “The horticultural, silvicultural and medicinal crops in three-tier agroforestry system” at the Agronomy Farm (Bock-E), ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat). The data recorded on various observations were analyzed and presented in this chapter with different sub-headings.

- 4.1 Growth status of Sapota
- 4.2 Growth status of Jatropha
- 4.3 Experiment-I Performance of herbal crops (Basil, Kalmegh and Mint) under three-tier agroforestry system
- 4.4 Experiment-II Performance of tuber crops (Kalihari, Kali musli and Safed musli) under three-tier agroforestry system

4.1 Growth status of Sapota

The data regarding growth status of Sapota are presented in Table – 4.1. It is evident from the data presented in Table – 4.1 that maximum height, stem girth, number of primary branches, crown spread East-West and crown spread North-South of Sapota plants were recorded at harvesting time with corresponding values of 534.10 cm, 42.30 cm, 3.2, 376.60 cm, and 370.50 cm, respectively. These values were comparatively lower at initial stage i.e. at the time of planting/sowing of inter crops with respective values of 528.50 cm, 40.00 cm, 3.0, 363.70 cm and 360.20 cm. Yield was recorded 70 kg/plant and 70 q/ha in Sapota tree.

Table – 4.1 Growth and yield of Sapota as influenced by Sapota-Jatropha-medicinal crops three-tier agroforestry system

Growth parameter	2011		2012	
	At initial stage	At harvest	At initial stage	At harvest
Height of plant (cm)	528.5	534.1	542.4	557.8
Stem girth (cm)	40.0	42.3	47.5	52.0
Number of primary branches	3.0	3.2	3.5	3.7
Crown spread (East-West) (cm)	363.7	376.6	382.4	390.6
Crown spread (North-South) (cm)	360.2	370.5	375.9	395.4
Yield (kg/plant)	70		75	
Yield (q/ha)	70		75	

In the year 2012, maximum height (557.80 cm), stem girth (52.00 cm), number of primary branches (3.7), crown spread East-West (390.60 cm) and crown spread North-South (395.40 cm) of Sapota plants were recorded at harvesting. These values were comparatively lower at initial stage with respective values of 542.40 cm, 47.50 cm, 3.5, 382.40 cm and 375.90 cm. Yield was recorded 75 kg/plant and 75 q/ha in Sapota tree.

4.2 Growth status of Jatropha

The data presented in the Table – 4.2 shows the growth status of Jatropha under which herbal and tuber medicinal crops were grown in both the years (2011 and 2012). Average values were worked out from five sample trees of Jatropha.

Among various Jatropha plants maximum height of plants (243.30 cm), stem girth (26.10 cm), number of primary branches (3.3), crown spread East-West (180.20 cm) and crown spread North-South (155.80 cm) were recorded at harvesting in the year 2011. These values were comparatively lower at initial stage with respective values of 238.50 cm, 24.80 cm, 3.2, 170.20 cm and 150.40 cm. Yield was recorded 150g/plant and 2.25 q/ha in Jatropha tree.

Looking to the data of second year (2012) trial, it was found that the among Jatropha plants maximum height of plants (262.40 cm), stem girth (29.50 cm), number of primary branches (3.6), crown spread East-West (197.60 cm) and crown spread North-South (168.40 cm) were recorded at harvesting. These values were comparatively lower at initial stage with respective values of 250.70 cm, 27.50 cm, 3.5, 185.50 cm and 162.70 cm. In second year yield was 150g/plant and 2.25q/ha in Jatropha tree.

Table – 4.2 Growth and yield of Jatropha as influenced by Sapota-Jatropha-medicinal crops three-tier agroforestry system

Growth parameter	2011		2012	
	At initial stage	At harvest	At initial stage	At harvest
Height of plant (cm)	238.5	243.3	250.7	262.4
Stem girth (cm)	24.8	26.1	27.5	29.5
Number of primary branches	3.2	3.3	3.5	3.6
Crown spread (East-West) (cm)	170.2	180.2	185.5	197.6
Crown spread (North-South) (cm)	150.4	155.8	162.7	168.4
Yield (g/plant)	150		150	
Yield (q/ha)	2.25		2.25	

4.3 Experiment- I Performance of herbal crops (Basil, Kalmegh and Mint) under three-tier agroforestry system

4.3.1 Morphological observations of herbal crops

4.3.1.1 Plant height (cm)

The mean data pertaining to variation in plant height under Sapota-Jatropha and sole herbal crops are presented in Table - 4.3 and graphically depicted in Figure - 3. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The plant height was recorded maximum when herbal crops were grown under Sapota-Jatropha as compared to sole cropping.

It is evident from data presented for 2011 in Table – 4.3 that significant differences in the plant height was observed in all the herbal medicinal plants grown under Sapota-Jatropha and in sole crops. The plant height of basil (T₁, 69.65 cm) under Sapota-Jatropha was on par with sole crop (T₄, 68.33 cm). Kalmegh (T₂, 63.40 cm) and mint (T₃, 35.13 cm) plant height under Sapota-Jatropha was statistically at par with kalmegh and mint sole crop (T₅, 61.70 cm and T₆, 32.40 cm) respectively.

Further perusal of data revealed that herbal crops (Basil, Kalmegh and Mint) in second year and pooled analysis showed the similar trends as first year.

Percent increase in plant height during the first year was recorded maximum in mint (8.43 %) which was followed by kalmegh (2.76 %) and basil (1.93 %). With regards to the second year and pooled data, it showed the similar trend to those of the results of first year.

Table-4.3 Plant height of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Plant height (cm)		
	2011	2012	Pooled
T₁ - Basil Intercrop	69.65 (1.93)*	71.98 (2.71)*	70.82 (2.33)*
T₂ - Kalmegh Intercrop	63.40 (2.76)*	61.45 (3.02)*	62.43 (2.88)*
T₃ - Mint Intercrop	35.13 (8.43)*	37.55 (9.38)*	36.34 (8.90)*
T₄ - Basil Sole	68.33	70.08	69.21
T₅ - Kalmegh Sole	61.70	59.65	60.68
T₆ - Mint Sole	32.40	34.33	33.37
S. Em ±	2.246	2.708	1.759
CD at 5 %	6.77	8.16	5.08
CV %	8.15	9.70	8.97

*Figure in parenthesis indicates percentage increase over respective sole cropping

Figure - 3 Plant heights of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system.

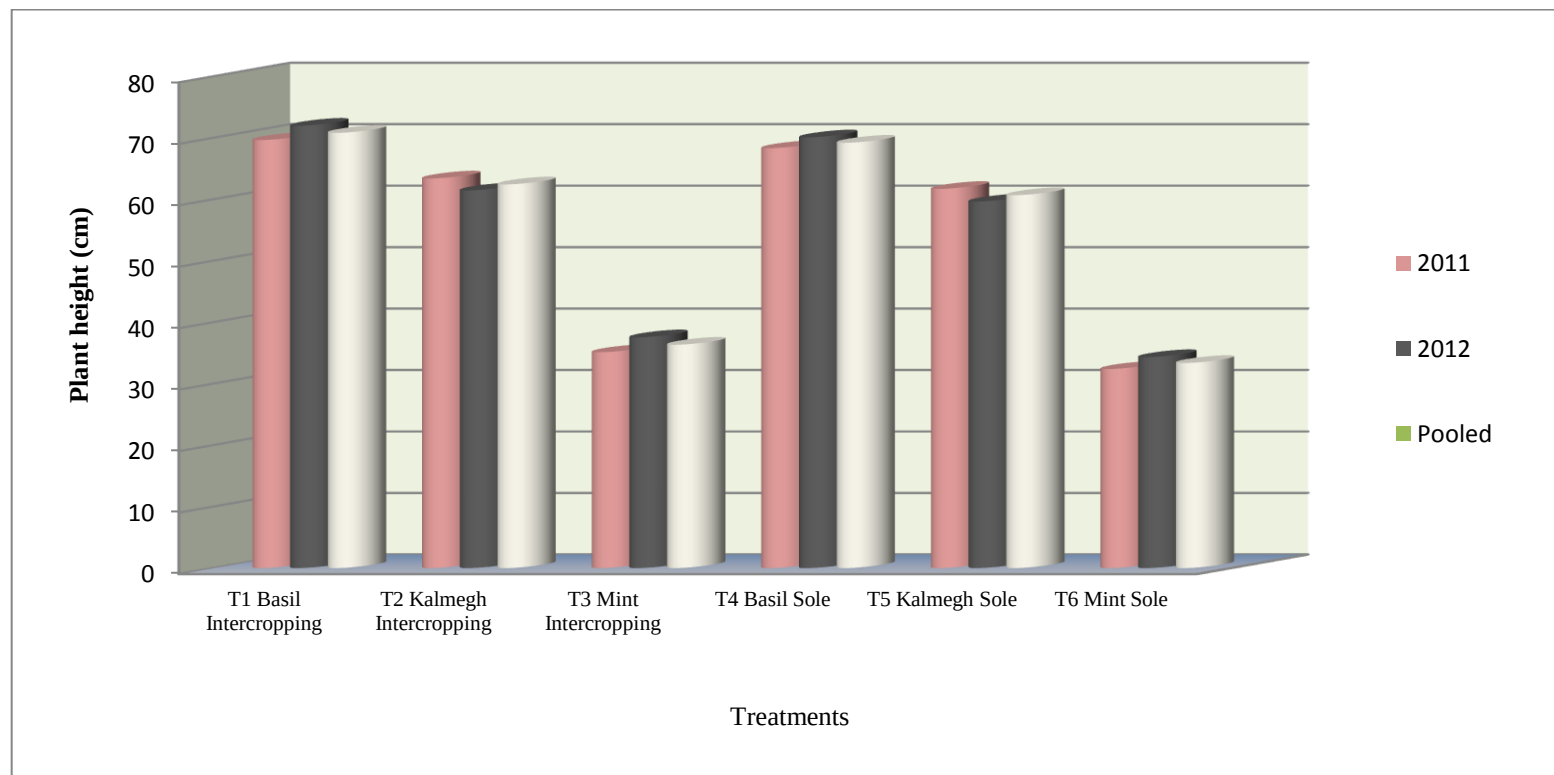


PLATE II : Performance of basil (*Ocimum sanctum* L.) under three-tier agroforestry system.



Manilkara acaras Mill + *Jatropha curcas* L. + *Ocimum sanctum* L.



Ocimum sanctum L. Sole Cropping

4.3.1.2 Number of branches per plant

The data regarding number of branches per plant of different herbal crops are presented in Table – 4.4 and illustrated graphically in Figure - 4. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The number of branches per plant was noted maximum in sole cropping as compared to intercropping under Sapota-Jatropha.

From Table – 4.4, it can be seen that in first year of study, sole basil treatments T₄ (19.03) recorded maximum number of branches per plant which was on same bar with basil grown under Sapota-Jatropha (T₁, 17.70). Sole kalmegh and sole mint (T₅, 15.05 and T₆, 17.53) recorded maximum number of branches per plant which was at par with treatment T₂ (13.30) and T₃ (16.63) respectively.

Second year and Pooled analysis also showed the same trend for kalmegh which recorded significantly higher number of branches per plant in sole kalmegh (T₅, 15.98) followed by kalmegh grown under Sapota-Jatropha (T₂, 13.93).

Percent reduction in number of branches per plant during first year was recorded minimum in mint (5.13 %) followed by basil (6.99 %) and kalmegh (11.63 %). Second year and pooled data showed same trend as that of first year result.

4.3.1.3 Fresh weight per plant (g)

The data with respect to fresh weight per plant of different herbal crops are furnished in Table – 4.5 and depicted in Figure - 5. The results were found significant during 2011, 2012 and in pooled analysis. Maximum fresh weight per plant of all the herbal crops was observed in sole cropping as compared to crops grown under Sapota-Jatropha as intercrops.

Table-4.4 Number of branches per plant as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Number of branches per plant		
	2011	2012	Pooled
T₁ - Basil Intercrop	17.70 (6.99)*	19.35 (6.07)*	18.53 (6.46)*
T₂ - Kalmegh Intercrop	13.30 (11.63)*	14.55 (13.91)*	13.93 (12.83)*
T₃ - Mint Intercrop	16.63 (5.13)*	15.53 (3.84)*	16.08 (4.51)*
T₄ - Basil Sole	19.03	20.60	19.81
T₅ - Kalmegh Sole	15.05	16.90	15.98
T₆ - Mint Sole	17.53	16.15	16.84
S. Em ±	1.040	0.922	0.695
CD at 5 %	3.14	2.78	2.01
CV %	12.58	10.73	11.66

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 4 Number of branches per plant as influenced by Sapota-Jatropha three-tier agroforestry system.

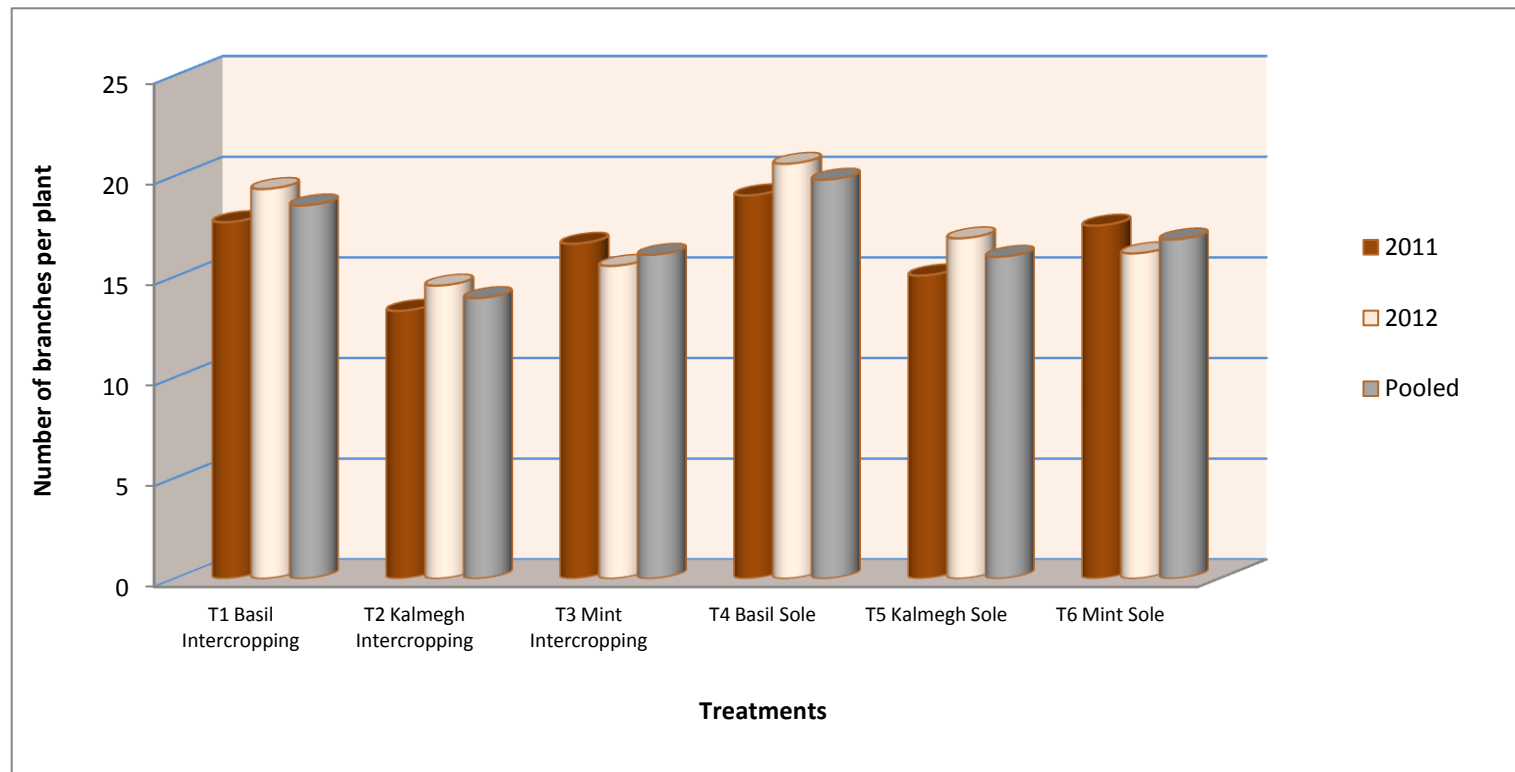
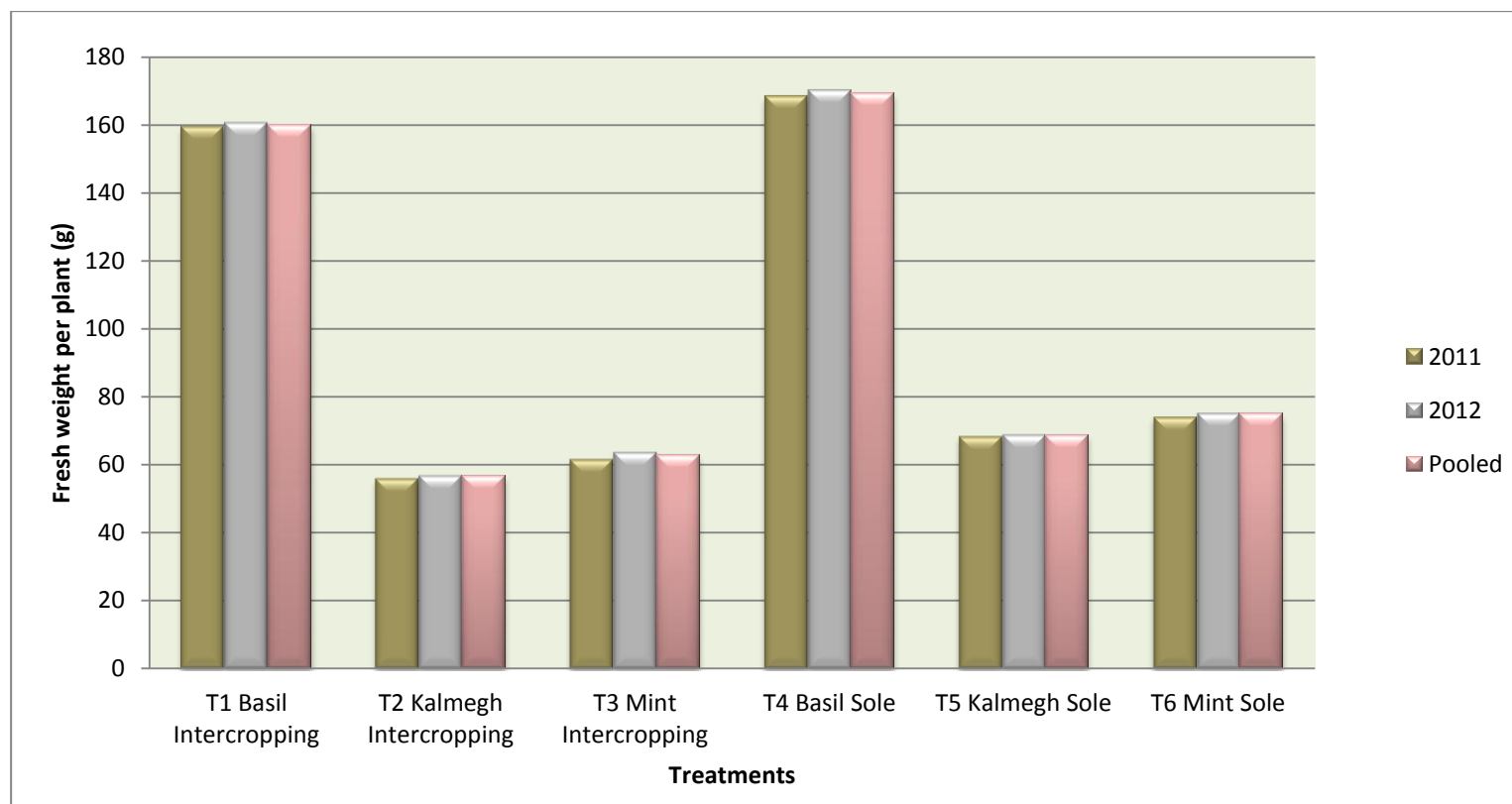


Table-4.5 Fresh weight per plant as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Fresh weight per plant (g)		
	2011	2012	Pooled
T₁ - Basil Intercrop	159.50 (5.30)*	160.53 (5.65)*	160.01 (5.48)*
T₂ - Kalmegh Intercrop	56.10 (18.02)*	56.91 (17.41)*	56.51 (17.71)*
T₃ - Mint Intercrop	61.65 (16.84)*	63.73 (15.29)*	62.69 (16.06)*
T₄ - Basil Sole	168.43	170.15	169.29
T₅ - Kalmegh Sole	68.43	68.91	68.67
T₆ - Mint Sole	74.13	75.23	74.68
S. Em ±	4.517	5.469	3.547
CD at 5 %	13.61	16.48	10.24
CV %	9.21	11.02	10.17

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 5 Fresh weight per plant as influenced by Sapota-Jatropha three-tier agroforestry system.



An appraisal of data presented in Table – 4.5 indicates that the fresh weight per plant recorded higher in sole crop of basil (T₄, 168.43 g) which was on same bar with basil when grown under Sapota-Jatropha (T₁, 159.50 g). Sole kalmegh and mint (T₅, 68.43 g and T₆, 74.13 g) respectively recorded higher fresh weight per plant which was at par with kalmegh and mint when grown under Sapota-Jatropha (T₂, 56.10 g and T₃, 61.65 g) respectively.

In the second year, the similar trend was experienced in all herbal crops basil, kalmegh and mint as that of the first year results. In pooled estimates, maximum fresh weight per plant was found in the sole crop of basil T₄ (169.29 g) which was statistically at par with basil when grown under Sapota-Jatropha (160.01 g). The other sole herbal crops kalmegh and mint (T₅, 68.67 g and T₆, 74.68 g, respectively) recorded significantly higher fresh weight per plants compares to when grown under Sapota-Jatropha (T₂, 56.51 g and T₃, 62.69 g) respectively.

Percent reduction in fresh weight per plants in the first year was recorded minimum in basil (5.30 %) which was followed by mint (16.84 %) and kalmegh (18.02 %). Compares to respective sole crops with regards to the second year and pooled data, it showed the similar trend to those of the results of first year.

4.3.1.4 Dry weight per plant (g)

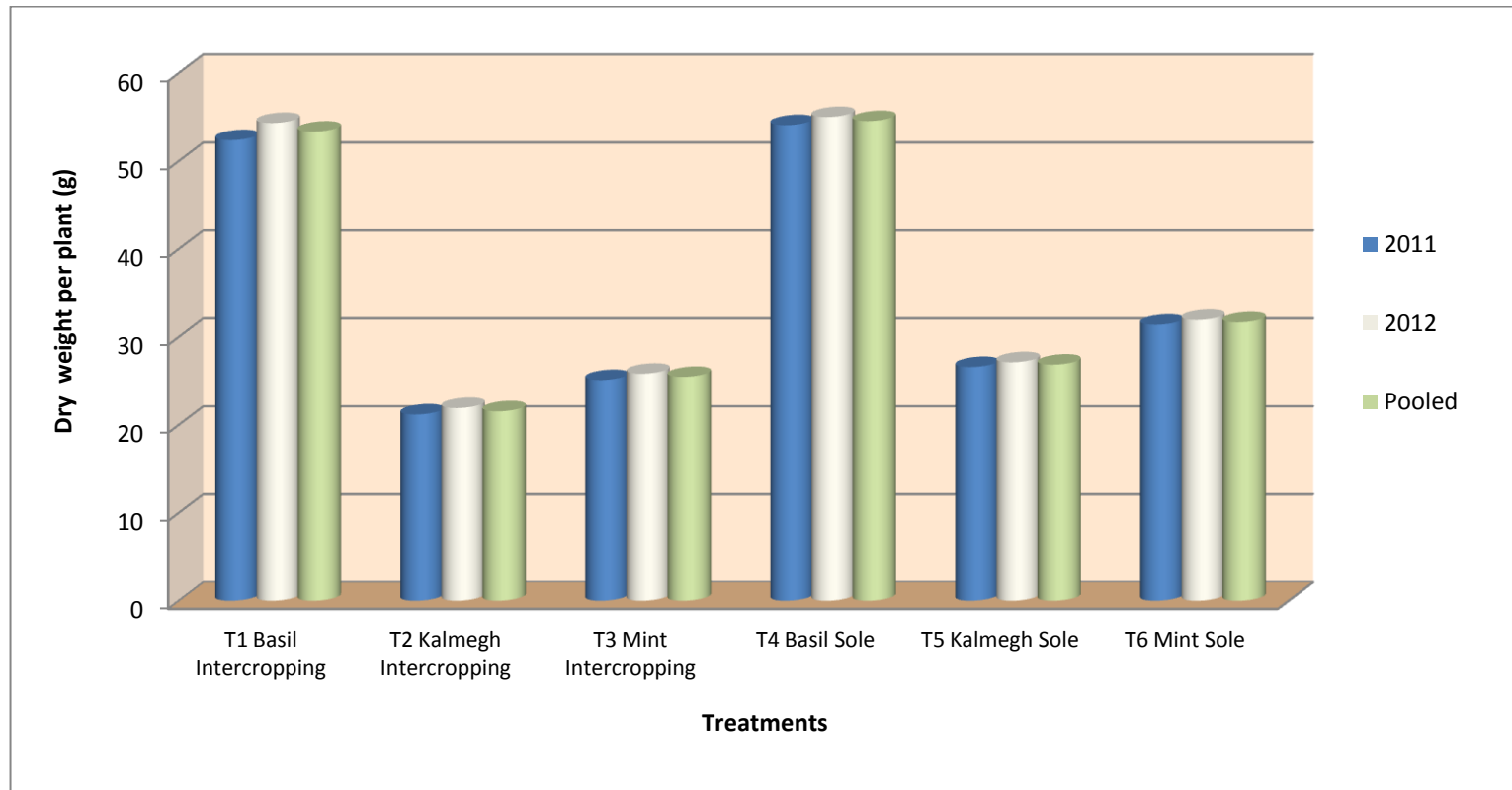
The data concerning with the dry weight per plant of different herbal crops are summarized in Table - 4.6 and Figure - 6. During both the years (2011 and 2012) of study and in pooled analysis results were found significant. In all the herbal crops maximum dry weight per plant was recorded in sole crop as compared to intercropping under Sapota-Jatropha.

Table-4.6 Dry weight per plant as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Dry weight per plant (g)		
	2011	2012	Pooled
T₁ - Basil Intercrop	52.38 (3.16)*	54.33 (1.24)*	53.35 (2.20)*
T₂ - Kalmegh Intercrop	21.18 (20.35)*	21.91 (19.24)*	21.54 (19.81)*
T₃ - Mint Intercrop	25.10 (20.01)*	25.82 (19.11)*	25.46 (19.56)*
T₄ - Basil Sole	54.09	55.01	54.55
T₅ - Kalmegh Sole	26.59	27.13	26.86
T₆ - Mint Sole	31.38	31.92	31.65
S. Em ±	1.560	1.753	1.173
CD at 5 %	4.70	5.28	3.39
CV %	8.88	9.74	9.33

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 6 Dry weight per plant as influenced by Sapota-Jatropha three-tier agroforestry system.



In the first year (2011) data showed maximum dry weight per plant in sole crop of basil (T₄, 54.09 g) which was on same bar with basil grown under Sapota-Jatropha (T₁, 52.38 g). Sole crop of kalmegh and mint (T₅, 26.59 g and T₆, 31.38 g) recorded significantly higher dry weight per plant which was followed by kalmegh and mint grown under Sapota-Jatropha (T₂, 21.18 g and T₃, 25.10 g).

During second year perusal of data presented in Table – 4.6 reveals that the dry weight per plant was higher in sole crop of basil treatment T₄ (55.01 g) which was statistically at par with basil grown under Sapota-Jatropha (T₁, 54.33 g). Kalmegh showed same trend as basil. While sole crop of mint (T₆, 31.92 g) recorded significantly higher dry weight per plant compares to intercrop of mint (T₃, 25.82 g) with Sapota-Jatropha. An analysis of pooled data showed that the trend of result on the same line as that of the first year result.

In case of percent reduction of dry weight per plant during first year minimum was in Basil (3.16 %) which was followed by Mint (20.01 %) and Kalmegh (20.35 %). Similar trend of result was obtained in case of second year and pooled data.

4.3.1.5 Fresh weight of plant per plot (kg)

The fresh weight of plant per plot of intercrops and sole crops are presented in Table – 4.7 and Figure – 7. All the herbal intercrops in their sole stand recorded significantly higher fresh weight of plant per plot than their respective intercropping systems during 2011, 2012 and in their pooled data.

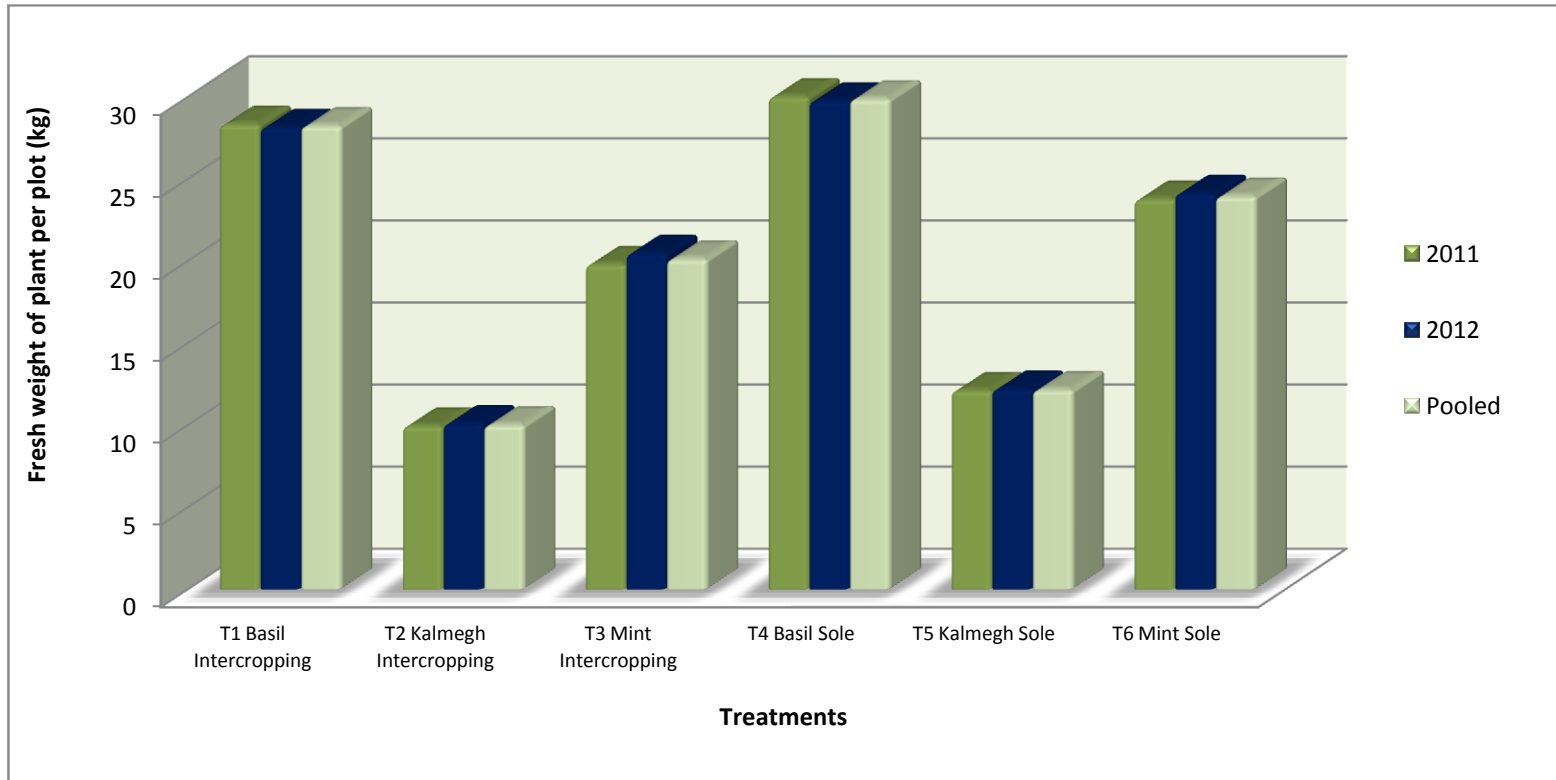
Looking to the mean data of first year trial, it was found that the sole crop of basil (T₄, 29.94 kg) noted maximum fresh weight of plant per plot which was on same bar with basil grown under Sapota-Jatropha (T₁, 28.26 kg). Sole crop of kalmegh and mint

Table-4.7 Fresh weight of plant per plot as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Fresh weight of plant per plot (kg)		
	2011	2012	Pooled
T₁ - Basil Intercrop	28.26 (5.61)*	28.08 (5.42)*	28.17 (5.50)*
T₂ - Kalmegh Intercrop	9.88 (17.94)*	10.03 (17.31)*	9.95 (17.70)*
T₃ - Mint Intercrop	19.72 (16.79)*	20.40 (15.21)*	20.06 (16.00)*
T₄ - Basil Sole	29.94	29.69	29.81
T₅ - Kalmegh Sole	12.04	12.13	12.09
T₆ - Mint Sole	23.70	24.06	23.88
S. Em ±	0.707	1.009	0.616
CD at 5 %	2.13	3.04	1.78
CV %	6.87	9.74	8.44

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 7 Fresh weight of plant per plot as influenced by Sapota-Jatropha three-tier agroforestry system.



(T₅, 12.04 kg and T₆, 23.70 kg) recorded significantly higher fresh weight of plant per plot which was followed by kalmegh and mint grown under Sapota-Jatropha (T₂, 9.88 kg and T₃, 19.72 kg).

Result obtained during 2012 indicate that, sole crops of basil (T₄, 29.69 kg) noted maximum fresh weight of plant per plot which was on same bar with basil grown under Sapota-Jatropha (T₁, 28.08 kg). Kalmegh showed same trend as basil. While sole mint (T₆, 24.06 kg) recorded significantly higher fresh weight of plant per plot which was followed by intercrop of mint (T₃, 20.40 kg) with Sapota-Jatropha. With regards to the pooled data, it showed the similar trend to those of the results of first years.

However, percent reduction in fresh weight of plant per plot during first year was recorded minimum in basil (5.61 %) which was followed by mint (16.79 %) and kalmegh (17.94 %). Second year and pooled data, it showed the similar trend to those of the results of first year.

4.3.1.6 Dry weight of plant per plot (kg)

Data of dry weight of plant per plot of intercrops and sole crops are presented in Table – 4.8 and illustrated in Figure - 8. The results exhibited significant variation during 2011, 2012 and in pooled analysis. Dry weight of plant per plot was maximum in sole crop when compared to herbal crops grown under Sapota-Jatropha.

It is obvious from the data specified in Table – 4.8 that during the first year the maximum dry weight of plant per plot (9.52 kg) was recorded in treatment T₄ sole basil which was at par with basil grown under Sapota-Jatropha (T₁, 9.23 kg). Sole crop of kalmegh (T₅, 4.66 kg) and mint (T₆, 10.03 kg) recorded significantly maximum dry weight

Table-4.8 Dry weight of plant per plot as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Dry weight of plant per plot (kg)		
	2011	2012	Pooled
T₁ - Basil Intercrop	9.23 (3.05)*	9.54 (1.24)*	9.38 (2.19)*
T₂ - Kalmegh Intercrop	3.73 (19.96)*	3.84 (19.16)*	3.79 (19.36)*
T₃ - Mint Intercrop	8.05 (19.74)*	8.24 (19.06)*	8.14 (19.41)
T₄ - Basil Sole	9.52	9.66	9.59
T₅ - Kalmegh Sole	4.66	4.75	4.70
T₆ - Mint Sole	10.03	10.18	10.10
S. Em ±	0.272	0.338	0.217
CD at 5 %	0.82	1.02	0.63
CV %	7.22	8.77	8.05

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 8 Dry weight of plant per plot as influenced by Sapota-Jatropha three-tier agroforestry system.

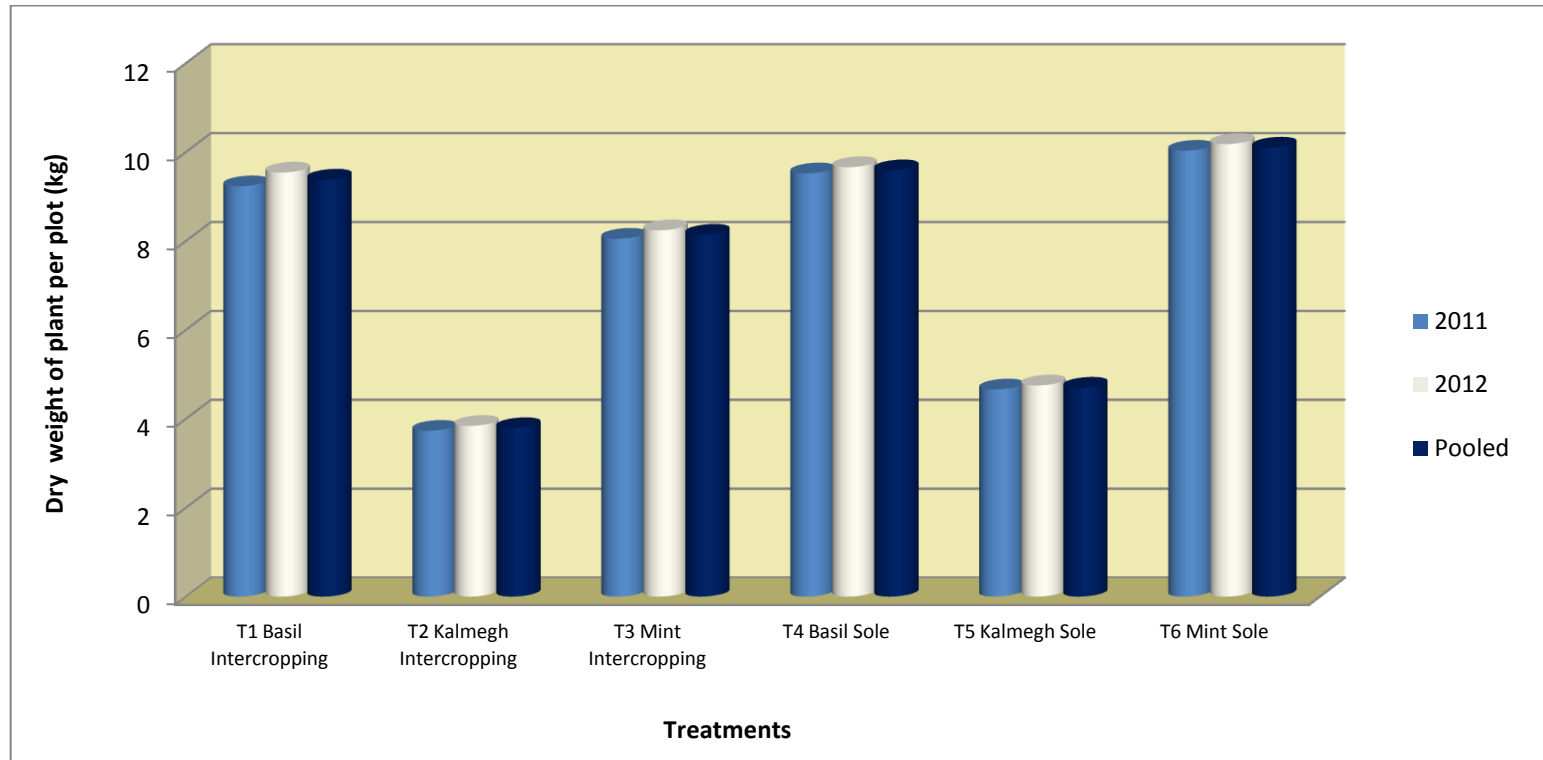


PLATE III : Performance of Kalmegh (*Andrographis paniculata* Well) under three-tier agroforestry system.



Manilkara acaras Mill + *Jatropha curcas* L. + *Andrographis paniculata* Well



Andrographis paniculata Well Sole Cropping

of plant per plot which was followed by kalmegh and mint grown under Sapota-Jatropha (T₂, 3.73 kg and T₃, 8.05 kg) respectively.

During 2012 maximum dry weight of plant per plot was observed in sole crops of basil (T₄, 9.66 kg) which was on same bar with basil grown under Sapota-Jatropha (T₁, 9.54 kg). Kalmegh showed same trend as basil. While sole crop of mint (T₆, 10.18 kg) recorded significantly higher dry weight of plant per plot which was followed by intercrop of mint (T₃, 8.24 kg) with Sapota-Jatropha. Pooled analysis showed the same result and same trend as per the trend of first year result.

Percent reduction in dry weight per plant per plot during first year was observed minimum in basil (3.05 %) it was followed by mint (19.74 %) and kalmegh (19.96 %). Similar trend of second year are pooled results indicated the same trend as that of first year.

4.3.1.7 Crown spread (East-West) (cm)

The observations on the crown spread (East-West) of sole crop and herbal crops grown under Sapota-Jatropha are furnished in Table – 4.9 and illustrated in Figure - 9. The statistical comparison showed that the crown spread (East-West) as affected by intercrops and sole found significant for both the study years and in pooled analysis.

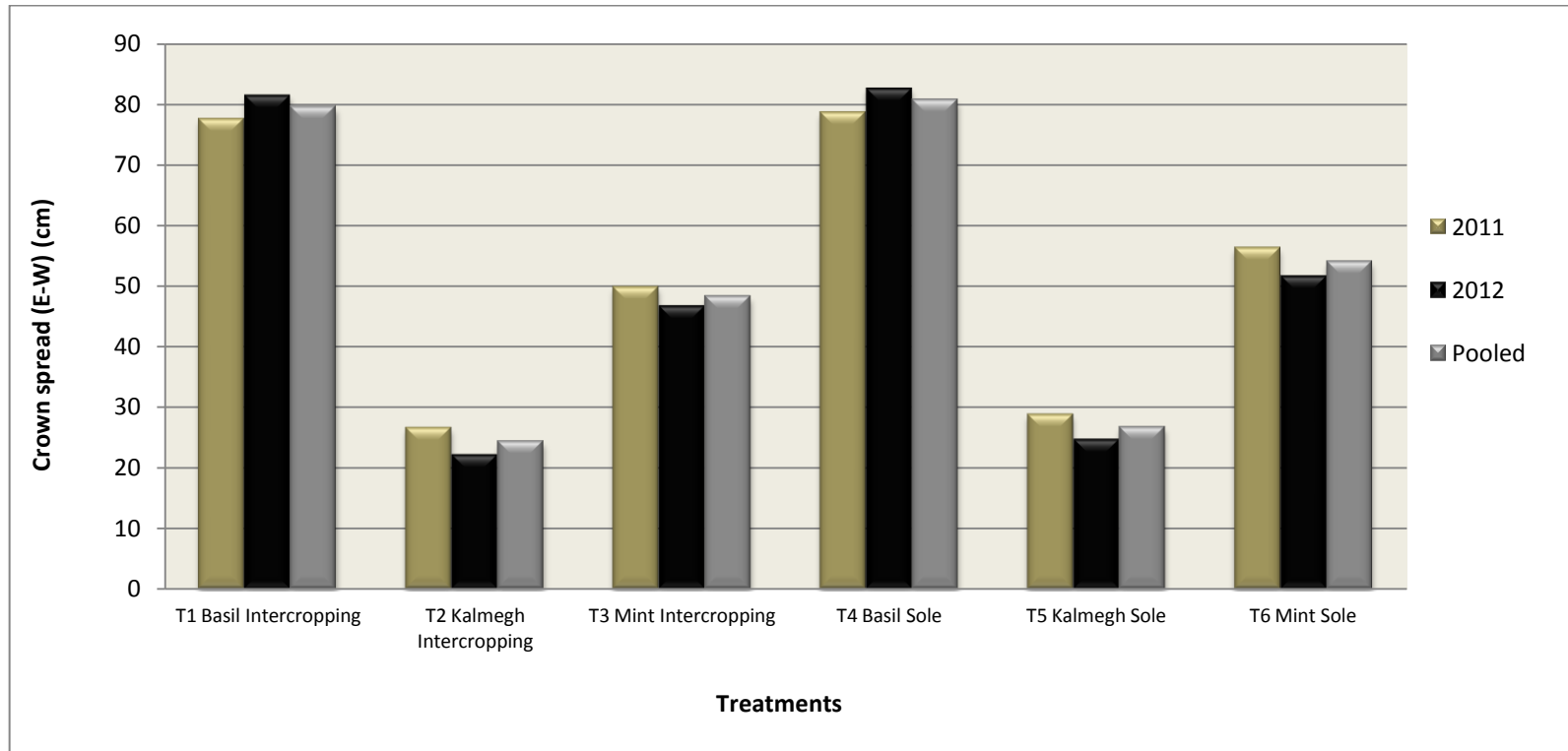
It is revealed from the data given in Table – 4.9 that in first year of study, sole basil treatment (T₄, 78.70 cm) maximum crown spread (East-West) which was on same bar with basil grown under Sapota-Jatropha (T₁, 77.61 cm). The other herbal sole kalmegh and mint (T₅, 28.88 cm and T₆, 56.38 cm) recorded maximum crown spread (East-West) which was at par with kalmegh and mint grown under Sapota-Jatropha (T₂, 26.70 cm and T₃, 49.90 cm) respectively.

Table-4.9 Crown spread (E-W) of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Crown spread (E-W) (cm)		
	2011	2012	Pooled
T₁ - Basil Intercrop	77.61 (1.39)*	81.53 (1.39)*	79.57 (1.39)*
T₂ - Kalmegh Intercrop	26.70 (7.55)*	22.23 (10.18)*	24.46 (8.77)*
T₃ - Mint Intercrop	49.90 (11.49)*	46.80 (9.57)*	48.35 (10.56)*
T₄ - Basil Sole	78.70	82.68	80.69
T₅ - Kalmegh Sole	28.88	24.75	26.81
T₆ - Mint Sole	56.38	51.75	54.06
S. Em ±	2.707	2.858	1.968
CD at 5 %	8.16	8.61	5.68
CV %	10.21	11.07	10.64

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 9 Crown spread (E-W) of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system.



During 2012, crown spread (East-West) was highest in the T₄ treatment sole basil crop (82.68 cm) which was on same bar with treatment T₁ (81.53 cm). The other herbal crops kalmegh and mint showed similar trend as in case of basil. Similar trend was observed in their pooled data.

Percent reduction in crown spread (East-West) was noted minimum in basil (1.39 %) followed by kalmegh (7.55 %) and mint (11.49 %). Similar trend was observed in second year and pooled data.

4.3.1.8 Crown spread (North-South) (cm)

The data regarding to variation in crown spread (North-South) between intercrops and sole crop are tabulated in Table – 4.10 and graphically depicted Figure - 10. The statistical comparison showed that the crown spread (North-South) as affected by intercrops and sole are found compare intercrop are sole crop of the same crop not with different crops for both years (2011 and 2012) and in pooled analysis also.

Maximum crown spread (North-South) was noted sole basil (T₄, 75.20 cm) which was same bar with basil under Sapota-Jatropha (T₁, 74.90 cm). Sole crop of kalmegh and mint reported maximum North-South crown spread (T₅, 24.68 cm and T₆, 42.53 cm, respectively) which was statistically at par with kalmegh and mint grown under Sapota-Jatropha (T₂, 20.88 cm and T₃, 40.92 cm, respectively).

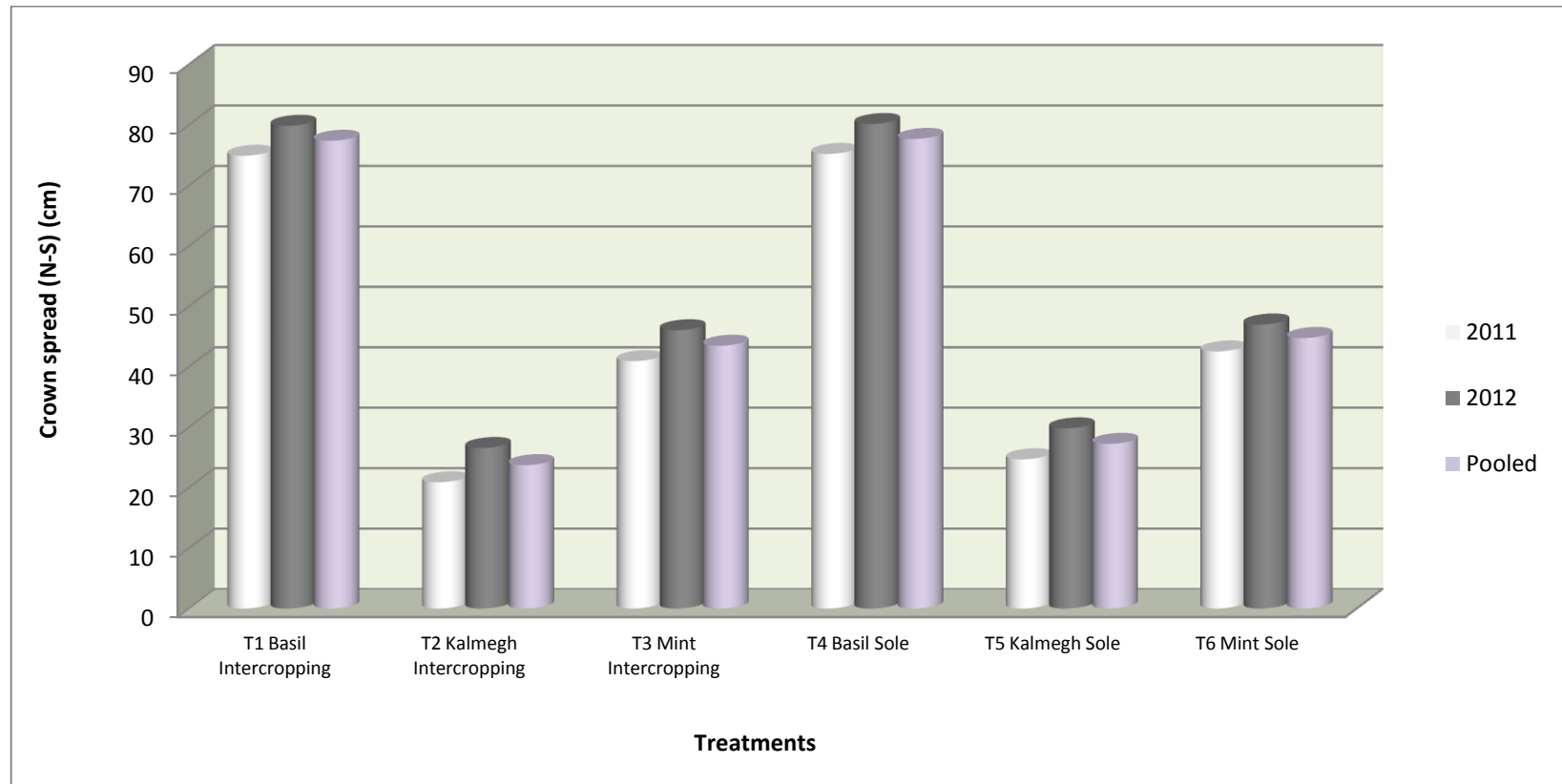
From Table – 4.10 it can be revealed that, during second year of investigation and pooled analysis exhibited similar trend as per the results of first year. However, percent reduction in crown spread (North-South) was observed minimum in basil (0.40 %) which was followed by mint (3.79 %) and kalmegh (15.40 %). Similar trend was recorded in second year and pooled data.

Table-4.10 Crown spread (N-S) of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Crown spread (N-S) (cm)		
	2011	2012	Pooled
T₁ - Basil Intercrop	74.90 (0.40)*	79.85 (0.37)*	77.38 (0.39)*
T₂ - Kalmegh Intercrop	20.88 (15.40)*	26.55 (10.91)*	23.72 (12.92)*
T₃ - Mint Intercrop	40.92 (3.79)*	46.03 (2.02)*	43.47 (2.86)*
T₄ - Basil Sole	75.20	80.15	77.68
T₅ - Kalmegh Sole	24.68	29.80	27.24
T₆ - Mint Sole	42.53	46.98	44.75
S. Em ±	2.129	2.034	1.472
CD at 5 %	6.41	6.13	4.25
CV %	9.15	7.89	8.49

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 10 Crown spread (N-S) of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system.



4.3.1.9 Economic yield (q ha⁻¹)

Results obtained from study indicates that significantly different the economic yield in qha⁻¹ of sole crops and grown under Sapota-Jatropha are obtained and are presented in Table – 4.11 and furnished in Figure – 11. The maximum economic yield was recorded in sole cropping as compared to intercropping of all herbal crops grown under Sapota-Jatropha.

The data corresponding to the economic yield, the sole crop of basil treatment T₄ (27.05 qha⁻¹) noted significantly higher economic yield when compared to basil intercrop under Sapota-Jatropha (T₁, 9.23 qha⁻¹). Sole kalmegh and mint (T₅, 13.30 qha⁻¹ and T₆, 23.25 qha⁻¹) recorded higher economic yield as compared to kalmegh and mint grown under Sapota - Jatropha (T₂, 3.74 qha⁻¹ and T₃, 8.04 qha⁻¹) respectively.

Further perusal of data reveals that herbal crops (basil, kalmegh and mint) in second year and pooled analysis showed the similar trends as that of the first year.

In case of percent reduction of economic yield in first year it was minimum in mint (65.42 %) which was followed by basil (65.88 %) and kalmegh (71.88 %). Similar trends of results were obtained in case of second year and pooled data.

4.3.1.10 Survival percent

The survival percent of herbal medicinal plants grown under Sapota-Jatropha and sole crops are presented in Table-4.12. All the herbal intercrops in their sole stand recorded non-significant results in their respective intercropping systems during 2011, 2012 and in their mean data.

Table-4.11 Economic yield of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Economic yield (q/ha)		
	2011	2012	Pooled
T₁ - Basil Intercrop	9.23 (65.88)*	9.56 (64.98)*	9.40 (65.42)*
T₂ - Kalmegh Intercrop	3.74 (71.88)*	3.86 (71.51)*	3.80 (71.71)*
T₃ - Mint Intercrop	8.04 (65.42)*	8.26 (65.03)*	8.15 (65.23)*
T₄ - Basil Sole	27.05	27.30	27.18
T₅ - Kalmegh Sole	13.30	13.55	13.43
T₆ - Mint Sole	23.25	23.62	23.44
S. Em ±	0.478	0.586	0.378
CD at 5 %	1.44	1.77	1.09
CV %	6.78	8.16	7.52

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 11 Economic yield of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system.

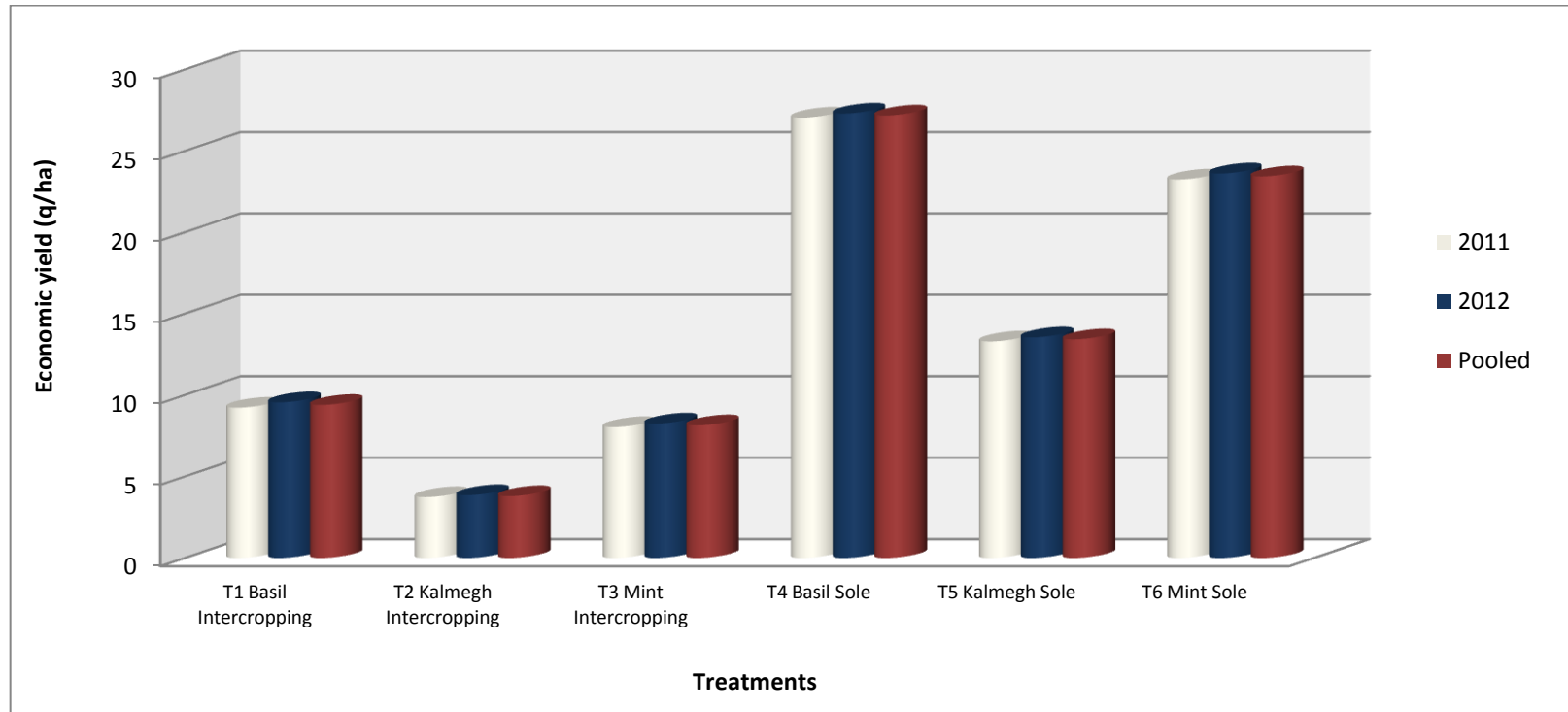


Table-4.12 Survival percent of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Survival percent		
	2011	2012	Pooled
T₁ - Basil Intercrop	91.35 (2.38)*	92.68 (1.51)*	92.01 (1.95)*
T₂ - Kalmegh Intercrop	91.63 (0.89)*	92.05 (1.23)*	91.84 (1.07)*
T₃ - Mint Intercrop	89.63 (2.18)*	90.05 (2.60)*	89.84 (2.39)*
T₄ - Basil Sole	93.58	94.10	93.84
T₅ - Kalmegh Sole	92.45	93.20	92.83
T₆ - Mint Sole	91.63	92.45	92.04
S. Em ±	3.262	2.838	2.162
CD at 5 %	NS	NS	NS
CV %	7.11	6.14	6.64

*Figure in parenthesis indicates percentage reduction over respective sole cropping

PLATE IV : Performance of mint (*Mentha arvensis* L.) under three-tier agroforestry system.



Manilkara acaras Mill + *Jatropha curcas* L. + *Mentha arvensis* L.



Mentha arvensis L. Sole Cropping

4.3.2 Light and nutrients

4.3.2.1 Light intensity (lux)

The light intensity of herbal sole crops and grown under Sapota-Jatropha are presented in Table – 4.13 and Figure – 12. All the herbal crops in their sole stand recorded significantly higher light intensity than their respective intercropping systems during 2011, 2012 and in their mean data.

The result summarized in Table – 4.13 indicates that during 2011 sole crops of basil, kalmegh and mint (T_4 , 28730 lux, T_5 , 28145 lux and T_6 , 27860 lux, respectively) received significantly higher light intensity over their respective intercrop under Sapota-Jatropha (T_1 , 17155 lux, T_2 , 17380 lux and T_3 , 17300 lux) respectively.

In second year and in pooled analysis, the similar scenario of light intensity in basil, kalmegh and mint herbal crops were observed as in the case of first year result.

Reduction percent in light intensity of herbal crops in the first year was found minimum in mint (37.90 %) which was followed by kalmegh (38.25 %) and basil (40.29 %). Second year and pooled data showed the same trend to those of the first year result.

4.3.2.2 Nutrient status in soil after the harvesting of the herbal crops

4.3.2.2.1 Organic carbon status (g kg^{-1}) in soil

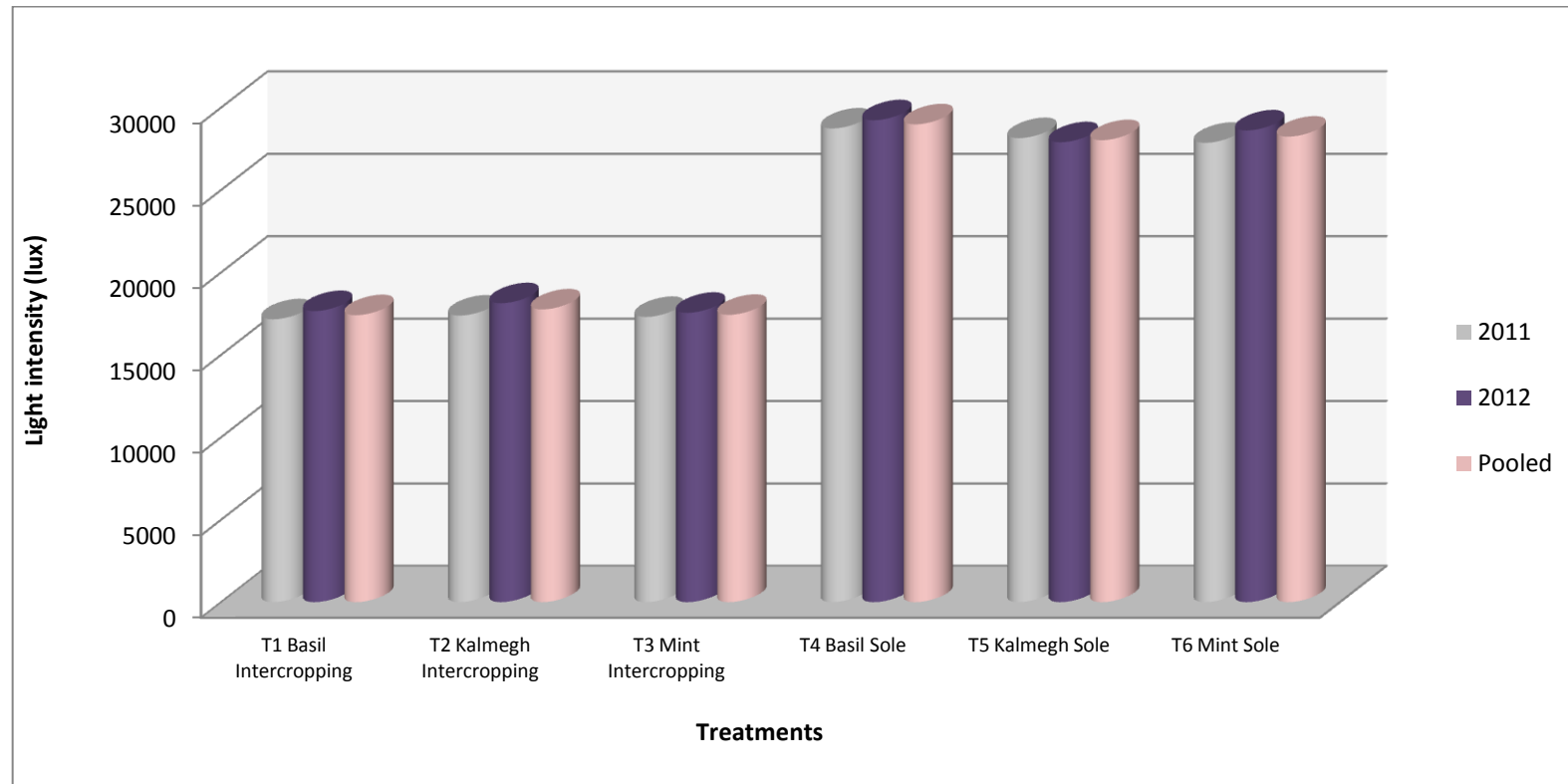
The data regarding organic carbon status of the soil after the harvest of herbal crops during 2011, 2012 and in their pooled analysis are presented in Table – 4.14

Table-4.13 Light intensity at crop level in herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Light intensity (lux)		
	2011	2012	Pooled
T₁ - Basil Intercrop	17155.00 (40.29)*	17655.00 (39.60)*	17405.00 (39.94)*
T₂ - Kalmegh Intercrop	17380.00 (38.25)*	18130.00 (35.01)*	17755.00 (36.63)*
T₃ - Mint Intercrop	17300.00 (37.90)*	17550.00 (38.66)*	17425.00 (38.29)*
T₄ - Basil Sole	28730.00	29230.00	28980.00
T₅ - Kalmegh Sole	28145.00	27895.00	28020.00
T₆ - Mint Sole	27860.00	28610.00	28235.00
S. Em ±	694.977	840.465	545.292
CD at 5 %	2094.44	2532.90	1574.71
CV %	6.11	7.25	6.71

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 12 Light intensity at crop level in herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system.



and Figure - 13. The result reveals that the status of organic carbon in soil at harvest was significant during both the years of experimentation and in their pooled data.

An appraisal of data presented in Table - 4.14 indicates that intercrop of basil (T_1 , 7.10 g kg⁻¹) recorded significantly higher organic carbon status in soil which was followed by sole basil (T_4 , 6.34 g kg⁻¹). While in plots with kalmegh and mint recorded maximum organic carbon status in soil when grown under Sapota-Jatropha (T_2 , 6.78 g kg⁻¹ and T_3 , 6.94 g kg⁻¹, respectively) which was on same bar with sole kalmegh and mint (T_5 , 6.12 g kg⁻¹ and T_6 , 6.27 g kg⁻¹) respectively during 2011.

During 2012, at harvest, significantly higher organic carbon status in soil was observed in basil, kalmegh and mint when these were grown under Sapota-Jatropha (T_1 , 7.25 g kg⁻¹, T_2 , 6.91 g kg⁻¹ and T_3 , 7.07 g kg⁻¹, respectively) compared to sole basil, kalmegh and mint (T_4 , 6.37 g kg⁻¹, T_5 6.15 g kg⁻¹ and T_6 , 6.30 g kg⁻¹) respectively. In pooled analysis the same trend of organic carbon in soil was observed as per the trend of second year results.

Percent increase in organic carbon in soil in the first year was recorded maximum in basil (11.99 %) followed by kalmegh (10.78 %) and mint (10.69 %). With regards to the second year and pooled data, it showed the similar trend to those of the results of first year.

4.3.2.2.2 Available Nitrogen status (kg ha⁻¹) in soil

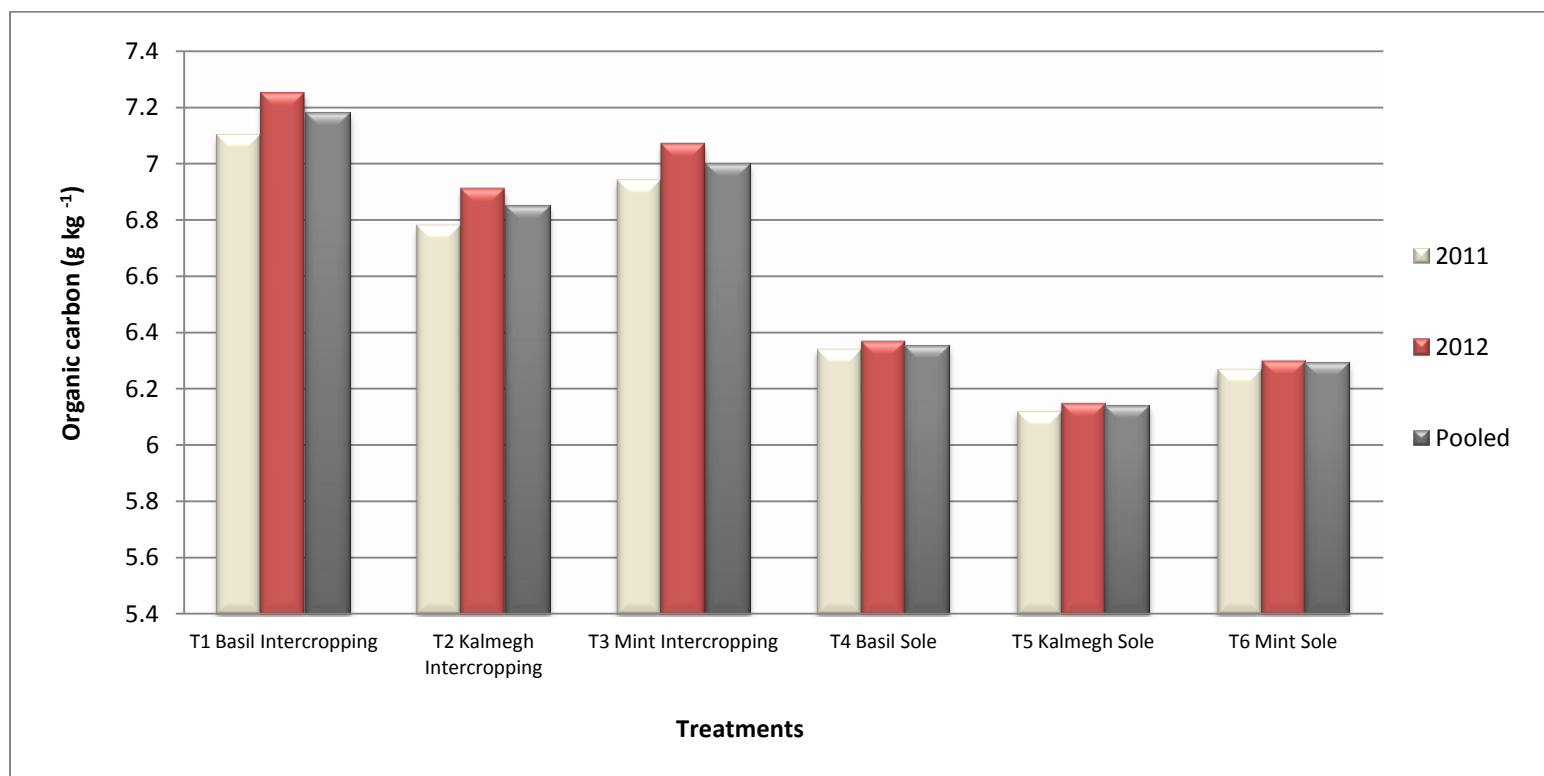
The mean data pertaining to variation in the available nitrogen status in the soil after the harvest of herbal crops are presented in Table – 4.15 and Figure - 14. The results were found significant during both the years (2011 and 2012) and in pooled

Table-4.14 Organic carbon content in soil at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Organic Carbon (g kg ⁻¹)		
	2011	2012	Pooled
T₁ - Basil Intercrop	7.10 (11.99)*	7.25 (13.81)*	7.18 (13.07)*
T₂ - Kalmegh Intercrop	6.78 (10.78)*	6.91 (12.36)*	6.85 (11.56)*
T₃ - Mint Intercrop	6.94 (10.69)*	7.07 (12.22)*	7.00 (11.29)*
T₄ - Basil Sole	6.34	6.37	6.35
T₅ - Kalmegh Sole	6.12	6.15	6.14
T₆ - Mint Sole	6.27	6.30	6.29
S. Em ±	0.224	0.246	0.166
CD at 5 %	0.67	0.74	0.48
CV %	6.78	7.37	7.09

*Figure in parenthesis indicates percentage increases over respective sole cropping

Figure - 13 Organic carbon content in soil at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system.



analysis. The available nitrogen status in the soil was recorded higher when herbal crops are grown under Sapota-Jatropha as compared to sole cropping.

It is evident from data presented in Table – 4.15 that significant difference in the nitrogen status in soil was observed in all the herbal medicinal plants grown under Sapota-Jatropha and in sole crops. Significantly higher nitrogen in soil was recorded when basil, kalmegh and mint grown under Sapota-Jatropha (T_1 , 271.22 kg ha⁻¹, T_2 , 249.73 kg ha⁻¹ and T_3 , 261.08 kg ha⁻¹) followed by sole basil, kalmegh and mint (T_4 , 220.67 kg ha⁻¹, T_5 , 219.46 kg ha⁻¹ and T_6 , 220.60 kg ha⁻¹) respectively.

In second year, significantly higher nitrogen in soil was recorded when basil grown under Sapota-Jatropha (T_1 , 274.73 kg ha⁻¹) which was followed by sole basil (T_4 , 224.43 kg ha⁻¹). Mint showed same trend that of as basil. While maximum nitrogen in soil was noted when kalmegh grown under Sapota-Jatropha (T_2 , 252.49 kg ha⁻¹) are on par with sole kalmegh (T_5 , 222.22 kg ha⁻¹). The results of pooled analysis showed the same trend of the first year result.

Percent increase in nitrogen in soil in the first year was observed maximum in basil (22.91 %) followed by mint (18.35 %) and kalmegh (13.79 %). Similar trend was found in second year and pooled data also.

4.3.2.2.3 Available Phosphorus status (kg ha⁻¹) in soil

The data regarding phosphorus status in soil of different herbal crops are presented in Table – 4.15 and illustrated graphically in Figure - 14. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The phosphorus status in soil was noted maximum under Sapota-Jatropha as compared to sole cropping.

From Table – 4.15, it can be seen that in first year of study, basil grown under Sapota-Jatropha (T_1 , 38.84 kg ha⁻¹) noted significantly higher phosphorus in soil which was followed by sole basil (T_4 , 31.50 kg ha⁻¹). Kalmegh and mint recorded maximum phosphorus in soil when this grown under Sapota-Jatropha (T_2 , 35.56 kg ha⁻¹ and T_3 , 36.70 kg ha⁻¹, respectively) and on the same bar with sole crop (T_5 , 31.22 kg ha⁻¹ and T_6 , 31.45 kg ha⁻¹) respectively.

An analysis of second year data showed that, the significantly higher phosphorus in soil when basil grown under Sapota-Jatropha (T_1 , 40.09 kg ha⁻¹) which was followed by sole basil (T_4 , 31.75 kg ha⁻¹). Kalmegh and Mint recorded similar result as that of basil. In the pooled analysis, the similar scenario of phosphorus in soil of all herbal crops (basil, kalmegh and mint) was observed as in the case of second year.

Maximum percent increase in phosphorus in soil (2011) was recorded in basil (23.30 %) followed by mint (16.69 %) and kalmegh (13.90 %). Same results were found in second year and pooled data.

4.3.2.2.4 Available Potassium status (kg ha⁻¹) in soil

The mean data pertaining to variation in the available potassium status in the soil after the harvest of herbal crops are presented in Table – 4.15 and Figure - 14. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The available potassium status in the soil was recorded higher when herbal crops grown under Sapota-Jatropha as compared to sole cropping.

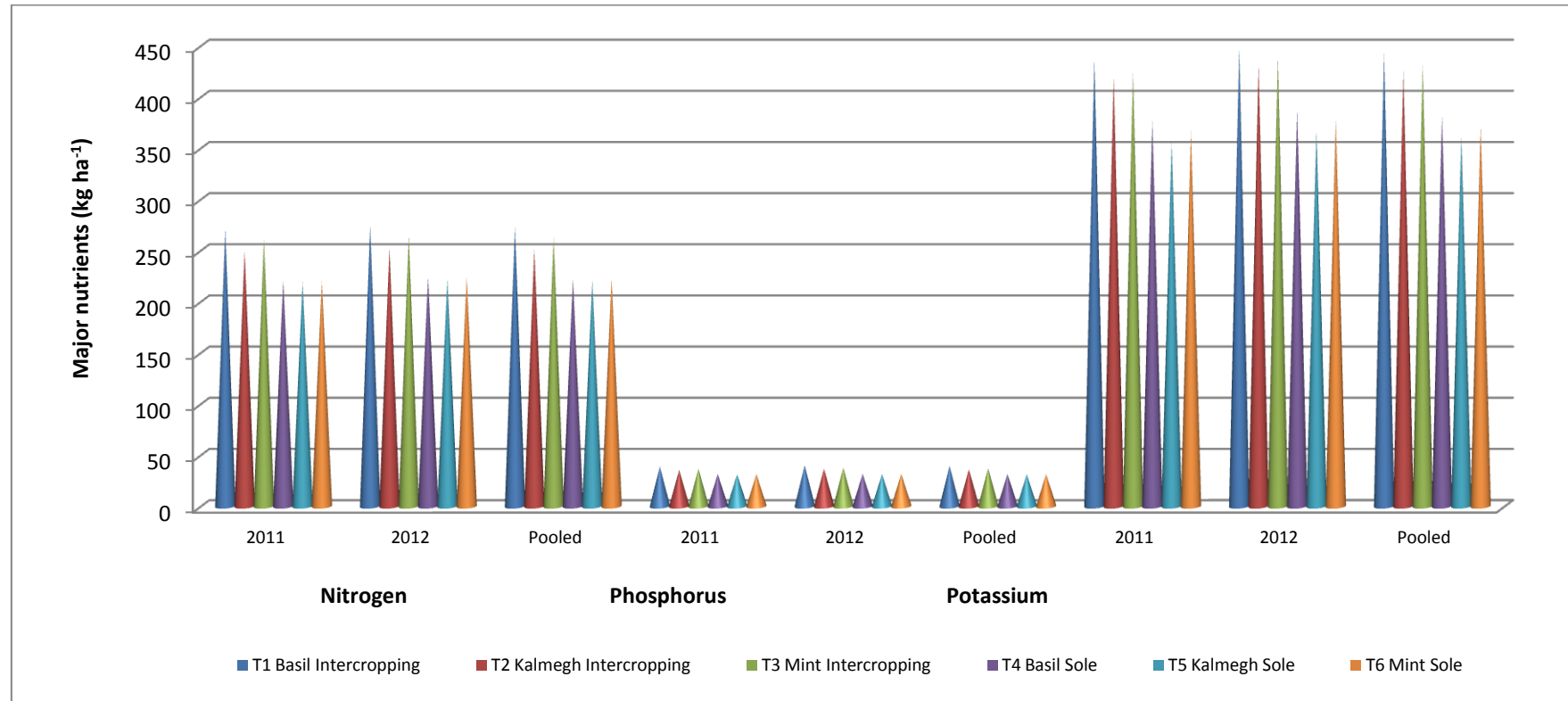
It is evident from data presented in Table – 4.15 that significant difference in the potassium status in the soil was observed in all the herbal medicinal plants grown under Sapota-Jatropha and in sole crops. Maximum potassium in soil was noted when

Table-4.15 Major nutrients available in soil at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Nitrogen (kg ha ⁻¹)			Phosphorus (kg ha ⁻¹)			Potassium (kg ha ⁻¹)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
T₁ - Basil Intercrop	271.22 (22.91)*	274.73 (22.41)*	272.97 (22.66)*	38.84 (23.30)*	40.09 (26.27)*	39.47 (24.79)*	437.78 (16.08)*	448.35 (15.58)*	443.06 (15.83)*
T₂ - Kalmegh Intercrop	249.73 (13.79)*	252.49 (13.62)*	251.11 (13.71)*	35.56 (13.90)*	36.81 (16.97)*	36.19 (15.44)*	419.64 (17.65)*	431.77 (17.48)*	425.71 (17.57)*
T₃ - Mint Intercrop	261.08 (18.35)*	264.59 (17.93)*	262.83 (18.14)*	36.70 (16.69)*	37.95 (19.72)*	37.33 (18.21)*	425.00 (15.79)*	439.50 (16.28)*	432.25 (16.03)*
T₄ - Basil Sole	220.67	224.43	222.55	31.50	31.75	31.63	377.13	387.90	382.51
T₅ - Kalmegh Sole	219.46	222.22	220.84	31.22	31.47	31.35	356.67	367.54	362.10
T₆ - Mint Sole	220.60	224.36	222.48	31.45	31.70	31.58	367.05	377.98	372.52
S. Em ±	8.765	12.710	7.720	1.893	1.604	1.240	20.132	20.247	14.276
CD at 5 %	26.41	38.30	22.29	5.70	4.83	3.58	60.67	61.02	41.23
CV %	7.29	10.43	9.02	11.07	9.17	10.14	10.14	9.90	10.02

*Figure in parenthesis indicates percentage increases over respective sole cropping

Figure - 14 Major nutrients available in soil at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system.



basil grown under Sapota-Jatropha (T_1 , 437.78 kg ha⁻¹) and was at the same bar with sole basil (T_4 , 377.13 kg ha⁻¹). Significantly higher potassium in soil was recorded when kalmegh and mint grown under Sapota-Jatropha (T_2 , 419.64 kg ha⁻¹, T_3 425.00 kg ha⁻¹) as compared to sole kalmegh and mint (T_5 , 356.67 kg ha⁻¹ T_6 , 367.05 kg ha⁻¹).

The results of second year showed the same trend as that of first year results. In pooled analysis, significantly higher potassium in soil was recorded when basil grown under Sapota-Jatropha (T_1 , 443.06 kg ha⁻¹) was followed by sole basil (T_4 , 382.51 kg ha⁻¹) kalmegh and mint.

In the first year percent increase of potassium in soil was recorded maximum in kalmegh (17.65 %) which was followed by basil (16.08 %) and mint (15.79 %). Similar trend was observed in second year and pooled data.

4.3.2.2.5 Secondary nutrients (Ca, Mg) (mg kg⁻¹) in soil

The available calcium and magnesium status of the soil after the harvest of herbal crops under Sapota-Jatropha and sole crops are depicted in Table – 4.16. All the herbal intercrops in their sole stand recorded non-significant results with their respective intercropping systems during 2011, 2012 and in their mean data.

4.3.2.2.6 Micro nutrients (Fe, Mn, Zn, Cu) (mg kg⁻¹) in soil

The data with respect to iron, manganese, zinc and copper status in soil of herbal crops under Sapota-Jatropha and sole crops of basil, kalmegh and mint are furnished in Table – 4.17. The results were found non-significant during 2011, 2012 and in their mean data. Maximum micro nutrients in soil were observed under Sapota-Jatropha as compared to sole cropping.

Table-4.16 Secondary nutrients available in soil at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Calcium (mg kg ⁻¹)			Magnesium (mg kg ⁻¹)		
	2011	2012	Pooled	2011	2012	Pooled
T₁ - Basil Intercrop	6085.16 (0.03)*	6090.16 (0.06)*	6087.66 (0.04)*	1815.50 (0.10)*	1817.54 (0.16)*	1816.52 (0.13)*
T₂ - Kalmegh Intercrop	6082.17 (0.10)*	6086.17 (0.09)*	6084.17 (0.10)*	1814.10 (0.12)*	1815.11 (0.11)*	1814.61 (0.12)*
T₃ - Mint Intercrop	6084.18 (0.04)*	6087.18 (0.01)*	6085.68 (0.03)*	1814.42 (0.07)*	1816.43 (0.14)*	1815.42 (0.11)*
T₄ - Basil Sole	6083.22	6086.72	6084.97	1813.65	1814.66	1814.16
T₅ - Kalmegh Sole	6076.12	6080.62	6078.37	1812.00	1813.03	1812.51
T₆ - Mint Sole	6081.85	6086.35	6084.10	1813.10	1813.80	1813.45
S. Em ±	341.240	402.493	263.839	98.046	121.114	77.913
CD at 5 %	NS	NS	NS	NS	NS	NS
CV %	11.22	13.23	12.27	10.81	13.35	12.15

*Figure in parenthesis indicates percentage increases over respective sole cropping

Table - 4.17 Micro nutrients available in soil at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Iron (mg kg ⁻¹)			Manganese (mg kg ⁻¹)			Zinc (mg kg ⁻¹)			Copper (mg kg ⁻¹)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
T₁ - Basil Intercrop	5.12 (0.79)*	5.22 (2.15)*	5.17 (1.37)*	10.54 (1.05)*	10.56 (1.05)*	10.55 (1.05)*	0.85 (1.19)*	0.88 (4.76)*	0.86 (2.38)*	2.89 (3.21)*	2.91 (3.56)*	2.90 (3.20)*
T₂ - Kalmegh Intercrop	5.06 (0.80)*	5.08 (0.79)*	5.07 (0.80)*	10.34 (0.78)*	10.36 (0.78)*	10.35 (0.78)*	0.79 (3.95)*	0.81 (5.19)*	0.80 (3.90)*	2.74 (3.01)*	2.76 (3.37)*	2.75 (3.00)*
T₃ - Mint Intercrop	5.08 (0.99)*	5.10 (0.99)*	5.09 (0.99)	10.43 (0.68)*	10.46 (0.77)*	10.44 (0.68)*	0.83 (0.00)*	0.84 (0.00)*	0.83 (0.00)*	2.84 (2.16)*	2.86 (2.51)*	2.85 (2.52)*
T₄ - Basil Sole	5.08	5.11	5.10	10.43	10.45	10.44	0.84	0.84	0.84	2.80	2.81	2.81
T₅ - Kalmegh Sole	5.02	5.04	5.03	10.26	10.28	10.27	0.76	0.77	0.77	2.66	2.67	2.67
T₆ - Mint Sole	5.03	5.05	5.04	10.36	10.38	10.37	0.83	0.84	0.83	2.78	2.79	2.78
S. Em ±	0.263	0.173	0.157	0.354	0.417	0.273	0.045	0.046	0.032	0.087	0.102	0.067
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV %	10.38	6.78	8.76	6.82	8.00	7.43	10.95	11.00	10.98	6.27	7.25	6.78

*Figure in parenthesis indicates percentage increases over respective sole cropping

4.3.2.3 Nutrient content in herbal crops

4.3.2.3.1 Organic carbon content (%)

The data regarding the total content of organic carbon after the harvest of herbal crops during 2011, 2012 and in their pooled analysis are presented in Table – 4.18 and Figure – 15. The result reveals that organic carbon content after the harvest of herbal crops was non - significant during both the years of experimentation and in their pooled data.

4.3.2.3.2 Nitrogen content (%)

Results obtained from study indicate that significantly different total uptake of nitrogen at harvest by sole crop and grown under Sapota-Jatropha and are presented in Table – 4.19 and furnished in Figure – 16. The maximum content of nitrogen was recorded in intercropping of all herbal crops grown under Sapota-Jatropha as compared to sole cropping.

In the first year data corresponding to the content of nitrogen by the basil, kalmegh and mint grown under Sapota-Jatropha treatment (T₁, 1.458 %, T₂, 1.126 % and T₃, 1.360 %) noted maximum content of nitrogen which was on same bar with sole basil, kalmegh and mint (T₄, 1.444 %, T₅, 1.120 % and T₆, 1.355 %) respectively.

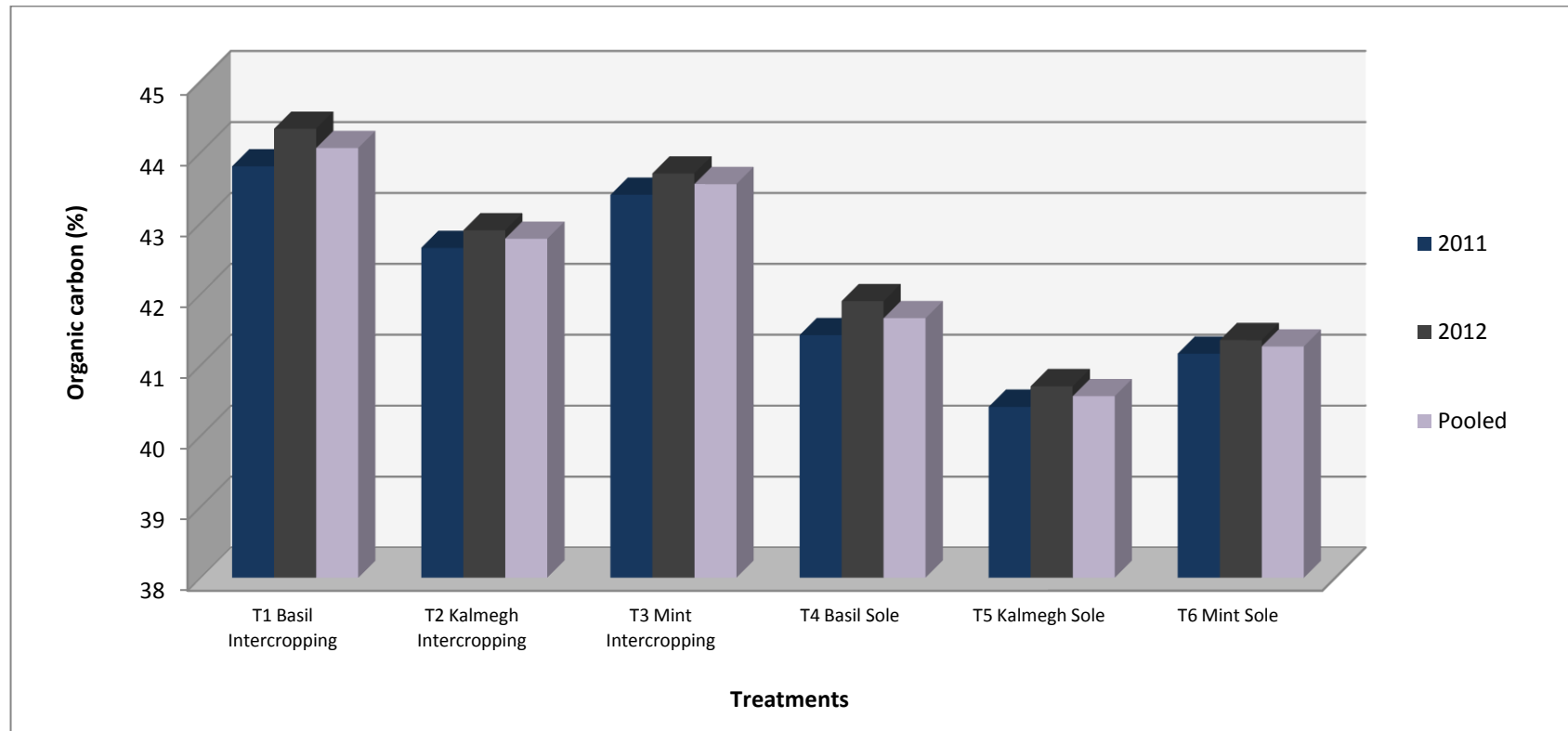
Further perusal of data reveals that herbal crops (basil, kalmegh and mint) in second year and pooled analysis showed the similar trend and result as that of first year.

Table - 4.18 Carbon content in plant at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Carbon Content (%)		
	2011	2012	Pooled
T₁ - Basil Intercrop	43.80 (5.75)*	44.33 (5.80)*	44.06 (5.76)*
T₂ - Kalmegh Intercrop	42.65 (5.54)*	42.90 (5.41)*	42.78 (5.47)*
T₃ - Mint Intercrop	43.40 (5.44)*	43.70 (5.68)*	43.55 (5.55)*
T₄ - Basil Sole	41.42	41.90	41.66
T₅ - Kalmegh Sole	40.41	40.70	40.56
T₆ - Mint Sole	41.16	41.35	41.26
S. Em ±	1.352	1.803	1.127
CD at 5 %	NS	NS	NS
CV %	6.42	8.49	7.53

*Figure in parenthesis indicates percentage increases over respective sole cropping

Figure - 15 Carbon content in plant at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system.



Percent increase in nitrogen content in plant was recorded maximum in basil (0.97 %) which was followed by kalmegh (0.54 %) and mint (0.37 %). Similar trends of results were obtained in case of second year and pooled data.

4.3.2.3.3 Phosphorus content (%)

It can be elucidated from the data depicted in Table – 4.19 and illustrated in Figure - 16 that the content of phosphorus by herbal crops at harvest was significant between intercrops and sole crops during 2011, 2012 and in their pooled data. The total uptake of phosphorus was noted maximum under Sapota-Jatropha as compared in sole cropping.

The data presented in Table – 4.19 show that in first year of study, higher content of phosphorus was found when basil, kalmegh and mint grown under Sapota-Jatropha (T_1 , 0.141 %, T_2 , 0.123 % and T_3 , 0.128 %) which statistically at par with sole basil, kalmegh and mint (T_4 , 0.134 %, T_5 , 0.120 % and T_6 , 0.123 %) respectively.

The mean data of second year (2012) trial and pooled analysis showed the same result and same trend in total content of phosphorus of all herbal crops (basil, kalmegh and mint) as per the trend of first year results.

Percent increase in phosphorus content in plant was recorded maximum in basil (5.22 %) followed by mint (4.07 %) and kalmegh (2.50 %). The second year and pooled result were showed similar trend of first year result.

4.3.2.3.4 Potassium content (%)

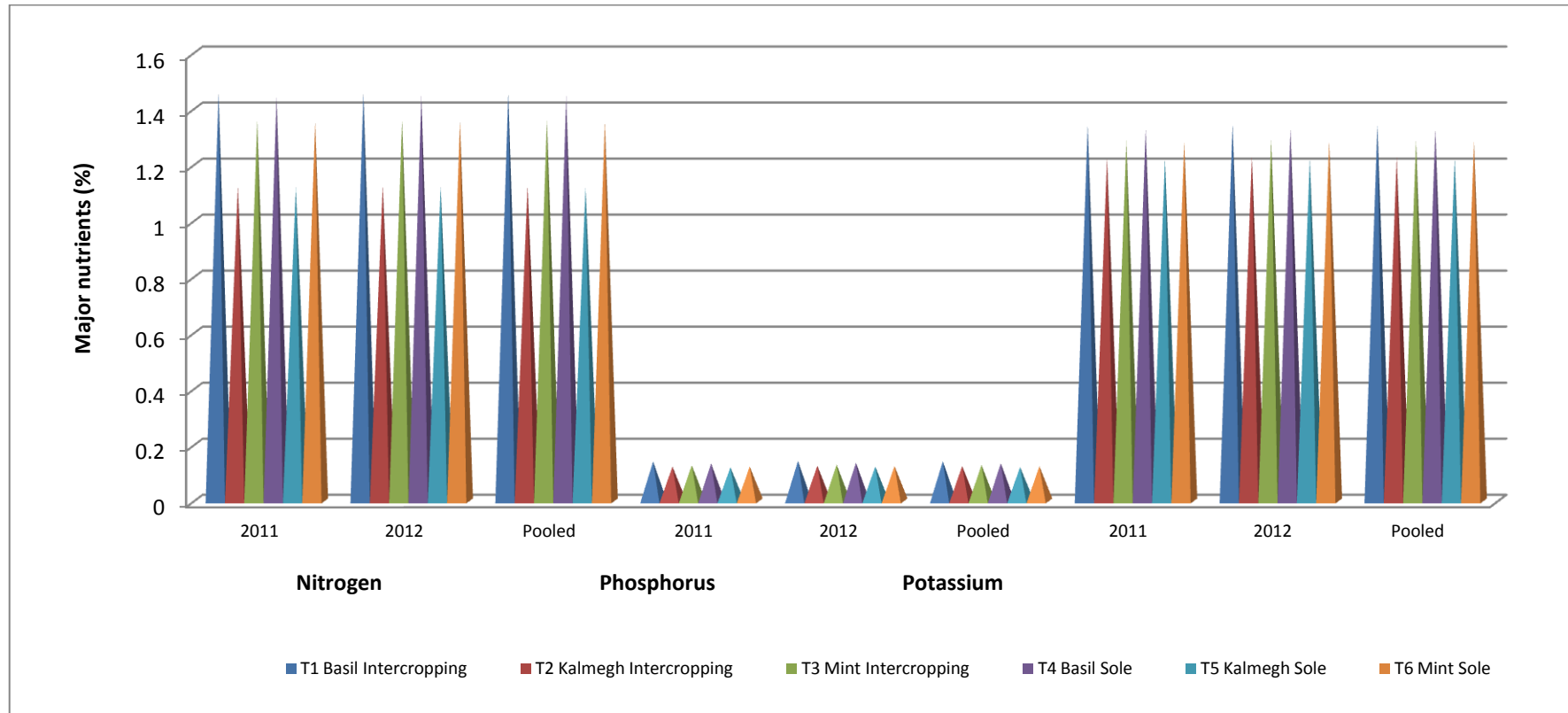
The total content of potassium by herbal crops at harvest between intercrops and sole crops given in Table – 4.19 and depicted in Figure - 16 during 2011,

Table - 4.19 Major nutrients content in plant at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
T₁ - Basil Intercrop	1.458 (0.97)*	1.459 (0.90)*	1.458 (0.90)*	0.141 (5.22)*	0.143 (4.38)*	0.142 (5.19)*	1.344 (1.20)*	1.346 (1.20)*	1.345 (1.20)*
T₂ - Kalmegh Intercrop	1.126 (0.54)*	1.128 (0.45)*	1.127 (0.54)*	0.123 (2.50)*	0.126 (2.44)*	0.125 (3.31)*	1.226 (0.25)*	1.229 (0.41)*	1.228 (0.33)*
T₃ - Mint Intercrop	1.360 (0.37)*	1.361 (0.22)*	1.361 (0.37)*	0.128 (4.07)*	0.130 (4.00)*	0.129 (4.03)*	1.287 (0.23)*	1.290 (0.31)*	1.288 (0.23)*
T₄ - Basil Sole	1.444	1.446	1.445	0.134	0.137	0.135	1.328	1.330	1.329
T₅ - Kalmegh Sole	1.120	1.123	1.121	0.120	0.123	0.121	1.223	1.224	1.224
T₆ - Mint Sole	1.355	1.358	1.356	0.123	0.125	0.124	1.284	1.286	1.285
S. Em ±	0.040	0.049	0.032	0.005	0.005	0.003	0.045	0.054	0.035
CD at 5 %	0.12	0.14	0.09	0.01	0.01	0.00	NS	NS	NS
CV %	6.14	7.50	6.86	6.99	6.91	6.95	6.98	8.45	7.75

*Figure in parenthesis indicates percentage increases over respective sole cropping

Figure - 16 Major nutrients content in plant at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system.



2012 and their pooled data. All the herbal intercrops in their sole stand recorded non-significant results in their respective intercropping systems during 2011, 2012 and in their mean data.

4.3.2.3.5 Calcium content (%)

The total content of calcium at harvest of sole herbal crops and grown under Sapota - Jatropha showed in Table – 4.20 during 2011, 2012 and in their data. All the herbal crops in their intercropping under Sapota-Jatropha recorded significantly higher content of calcium with respective sole cropping.

First year result presented in Table – 4.20 indicates that during 2011 basil, kalmegh and mint when grown under Sapota-Jatropha (T₁, 1.745 %, T₂, 1.456 % and T₃, 1.687 %, respectively) observed higher content of calcium which was on same bar over their respective sole crop (T₄, 1.744 %, T₅, 1.454 % and T₆, 1.685 %).

In second year and in pooled analysis, the similar scenario of total content of calcium in basil, kalmegh and mint herbal crops was observed as in the case of first year results.

Percent increase in content of calcium in plant was noted maximum in kalmegh (0.14 %) which was followed by mint (0.12 %) and basil (0.06 %). Similar trend was found in second year and pooled data.

4.3.2.3.6 Magnesium content (%)

The data regarding total content of magnesium at harvest between intercrops and sole crop are tabulated in Table – 4.20. The statistical comparison showed that content of magnesium by herbal crops as affected by intercropping and sole

Table - 4.20 Secondary nutrients content in plant at harvest of herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Calcium (%)			Magnesium (%)		
	2011	2012	Pooled	2011	2012	Pooled
T₁ - Basil Intercrop	1.745 (0.06)*	1.748 (0.17)*	1.746 (0.06)*	0.469 (0.21)*	0.472 (0.21)*	0.470 (0.00)*
T₂ - Kalmegh Intercrop	1.456 (0.14)*	1.458 (0.14)*	1.457 (0.14)*	0.438 (0.23)*	0.440 (0.00)*	0.439 (0.00)*
T₃ - Mint Intercrop	1.687 (0.12)*	1.690 (0.12)*	1.688 (0.12)*	0.446 (0.22)*	0.450 (0.90)*	0.448 (0.45)*
T₄ - Basil Sole	1.744	1.745	1.745	0.468	0.471	0.470
T₅ - Kalmegh Sole	1.454	1.456	1.455	0.437	0.440	0.439
T₆ - Mint Sole	1.685	1.688	1.686	0.445	0.446	0.446
S. Em ±	0.05	0.06	0.04	0.014	0.017	0.011
CD at 5 %	0.16	0.19	0.12	NS	NS	NS
CV %	6.66	7.76	7.23	6.320	7.370	6.870

*Figure in parenthesis indicates percentage increases over respective sole cropping

cropping are found non-significant for both the years (2011 and 2012) and in pooled analysis also.

4.3.2.3.7 Iron content (ppm)

The mean data pertaining to variation in the total content of iron after the harvest of herbal crops is presented in Table – 4.21. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The total content of iron by crops recorded higher when herbal crops were grown under Sapota-Jatropha as compared to their respective sole cropping.

In the first year data corresponding to the content of iron in the basil, kalmegh and mint intercrop under Sapota-Jatropha treatment (T₁, 134.76 %, T₂, 112.22 % and T₃, 122.33 %) noted maximum content of iron which was on same bar with sole basil, kalmegh and mint (T₄, 134.72 %, T₅, 112.18 % and T₆, 122.24 %) respectively.

Further perusal of data reveals that herbal crops (basil, kalmegh and mint) in second year and pooled analysis showed the similar trends as in case of the first year.

Percent increase in content of iron in plant was maximum in mint (0.07 %) which was followed by kalmegh (0.04 %) and basil (0.03 %). With regard to the second year and pooled data, it showed the similar trend to those of the results of first year.

4.3.2.3.8 Manganese content (ppm)

The data regarding total content of manganese at harvest of different herbal crops is presented in Table – 4.21. The results were found significant during both

the years (2011 and 2012) and in pooled analysis. The total content of manganese was noted maximum in intercropping under Sapota - Jatropha as compared to sole cropping.

The data pertaining in Table – 4.21 shows that in first year of study, higher content of manganese was found when basil, kalmegh and mint were grown under Sapota-Jatropha (T₁, 55.65 %, T₂, 48.54 % and T₃, 52.54 %) which was statistically at par with sole basil, kalmegh and mint (T₄, 55.64 %, T₅, 48.53 % and T₆, 52.51 %) respectively.

The mean data of second year (2012) trial and pooled analysis showed the same result and same trend in total content of manganese of all the herbal crops (basil, kalmegh and mint) as per the trend of first year.

Percent increase in content of manganese in plant was recorded maximum in mint (0.06 %) which was followed by basil (0.02 %) and kalmegh (0.02 %). The second year and pooled data showed similar trend of first year result.

4.3.2.3.9 Zinc content (ppm)

The mean data pertaining to variation in the total content of zinc after the harvest of herbal crops is presented in Table – 4.21. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The total content of zinc was recorded higher when herbal crops are grown under Sapota-Jatropha as compared to sole cropping.

The result summarized in Table – 4.21 indicates that during 2011 when basil, kalmegh and mint were grown under Sapota-Jatropha (T₁, 27.35 %, T₂, 22.26 % and T₃, 26.65 %) had, higher content of zinc which was on same bar over their respective sole crops (T₄, 27.30 %, T₅, 22.25 % and T₆, 26.64 %) respectively.

Table - 4.21 Micro nutrients content in herbal crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Iron (ppm)			Manganese (ppm)			Zinc (ppm)			Copper (ppm)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
T₁ - Basil Intercrop	134.76 (0.03)*	136.22 (0.90)*	135.47 (0.43)*	55.65 (0.02)*	56.15 (0.47)*	55.90 (0.23)*	27.35 (0.18)*	27.60 (0.18)*	27.48 (0.18)*	12.44 (0.16)*	12.69 (0.16)*	12.57 (0.16)*
T₂ - Kalmegh Intercrop	112.22 (0.04)*	114.22 (0.48)*	113.22 (0.26)*	48.54 (0.02)*	49.03 (0.49)*	48.78 (0.23)*	22.26 (0.04)*	22.51 (0.04)*	22.39 (0.04)*	9.45 (0.21)*	10.00 (3.31)*	9.73 (1.78)*
T₃ - Mint Intercrop	122.33 (0.07)*	124.24 (0.94)*	123.24 (0.43)*	52.54 (0.06)*	53.29 (0.06)*	52.92 (0.06)*	26.65 (0.04)*	27.15 (0.97)*	26.90 (0.49)*	12.42 (9.72)*	12.67 (9.51)*	12.55 (9.61)*
T₄ - Basil Sole	134.72	135.01	134.89	55.64	55.89	55.77	27.30	27.55	27.43	12.42	12.67	12.55
T₅ - Kalmegh Sole	112.18	113.68	112.93	48.53	48.79	48.67	22.25	22.50	22.38	9.43	9.68	9.56
T₆ - Mint Sole	122.24	123.08	122.71	52.51	53.26	52.89	26.64	26.89	26.77	11.32	11.57	11.45
S. Em ±	4.52	5.51	3.56	1.647	1.877	1.249	0.848	0.913	0.623	0.403	0.507	0.324
CD at 5 %	13.61	16.62	10.29	4.96	5.66	3.61	2.55	2.75	1.80	1.21	1.53	0.93
CV %	7.34	8.86	8.15	6.31	7.12	6.73	6.67	7.10	6.89	7.27	8.92	8.16

*Figure in parenthesis indicates percentage increases over respective sole cropping

In second year and in pooled analysis, the similar scenario of total content of zinc in basil, kalmegh and mint herbal crops were observed as in the case of first year result.

In the percent increase in content of zinc in plant was recorded maximum in basil (0.18 %) which was followed by kalmegh (0.04 %) and mint (0.04 %). Similar trend was seen in second year and pooled data as first year result.

4.3.2.3.10 Copper content (ppm)

The mean data pertaining to variation in the total content of copper after the harvest of herbal crops are presented in Table – 4.21. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The total content of copper by crops was recorded higher when herbal crops were grown under Sapota-Jatropha as compared to their respective sole cropping.

In the first year basil, kalmegh and mint when grown under Sapota-Jatropha treatment (T₁, 12.44 %, T₂, 9.45 % and T₃, 12.42 %) noted maximum content of copper which was on same bar with sole basil, kalmegh and mint (T₄, 12.42 %, T₅, 9.43 % and T₆, 11.32 %) respectively.

Further perusal of data reveals that herbal crops (basil, kalmegh and mint) in second year and pooled analysis exhibited similar trends as that of the first year.

Percent increase in content of copper in plant was recorded maximum in mint (9.72 %) which was followed by kalmegh (0.21 %) and basil (0.16 %). With regards to the second year and pooled data, it showed the similar trend to those of the results of first year.

4.3.3 Plant protection measures

No severe attack of any pest or disease was recorded in any herbal crops during the entire study.

4.3.4. Economic analysis

The data on cost of cultivation, gross returns, net returns and benefit cost ratio (B:C) as influenced by sole herbal medicinal crops and intercropping with Sapota-Jatropha are presented in Table - 4.22 in both the year 2011 and 2012.

During 2011, herbal medicinal crops namely basil, kalmegh and mint when grown under Sapota-Jatropha recorded higher benefit cost ratio (1:3.01, 1:2.86 and 1:2.31 respectively) as compared to their respective sole crops (1:2.28, 1:2.02 and 1:1.60).

In the year 2012, the intercropping of herbal medicinal crops namely basil, kalmegh and mint when grown under Sapota-Jatropha recorded higher benefit cost ratio (1:3.10, 1:2.87 and 1:2.34 respectively) as compared to their respective sole crops (1:2.34, 1:2.05 and 1:1.65).

Compared to all treatments studied, treatment T₁ basil with Sapota-Jatropha recorded highest B:C in 2011 and 2012 (1:3.01 and 1:3.10). Economically among intercropping Basil > Kalmegh > Mint. Among the sole crop also same trend was seen.

4.4 Experiment- II Performance of tuber crops (Kalihari, Kali musli and Safed musli) under three-tier agroforestry system.

4.4.1 Morphological observations of tuber crops

Table – 4.22 Economics of growing herbal crops (Basil, Kalmegh and mint) under Sapota-Jatropha based three-tier agroforestry system (First year, 2011)

Treatments	Yield (q/ha)			Cost of various products (₹ /ha)			Total cost of production (₹ /ha)	Gross income (₹ /ha)			Grand total (₹ /ha)	Net income (₹ /ha)	BCR	LER
	Sapota	Jatropha	Herbal	Planting material	NPK	Cost of cultivation		Sapota	Jatropha	Herbal				
T ₁ - (Basil Intercrop)	70	2.25	9.23	8800	11173.30	22000	41973.30	70000	5625	50765	126390	84416.70	1:3.01	1.28
T ₂ - (Kalmegh Intercrop)	70	2.25	3.74	1000	11836.80	22000	34836.80	70000	5625	24310	99935	65098.20	1:2.86	1.22
T ₃ - (Mint Intercrop)	70	2.25	8.04	16000	13982.20	22000	51982.20	70000	5625	44220	119845	67862.80	1:2.31	1.29
T ₄ - (Basil Sole)	-	-	27.05	25000	11173.30	29080	65253.30	-	-	148775	148775	83521.70	1:2.28	-
T ₅ - (Kalmegh Sole)	-	-	13.30	1200	11836.80	29080	42116.80	-	-	86450	86450	44333.20	1:2.02	-
T ₆ - (Mint Sole)	-	-	23.25	37037	13982.20	29080	80099.20	-	-	127875	127875	47775.80	1:1.60	-

- | | | | |
|--------------------------------|-------------------|-------------------------|---------------|
| 1. Rate of basil seedling | : 1 Rs /2 plant | 7. Sapota | : 10 Rs/kg |
| 2. Rate of kalmegh seeds | : 2000Rs/kg | 8. Jatropha | : 25 Rs/kg |
| 3. Rate of mint cutting | : 1 Rs / 2cutting | 9. Labour charge | : 120 Rs/day |
| 4. Whole sale price of basil | : 55 Rs/kg | 10. Price of Nitrogen | : 9.75 Rs/kg |
| 5. Whole sale price of kalmegh | : 65 Rs/kg | 11. Price of Phosphorus | : 32.10 Rs/kg |
| 6. Whole sale price of mint | : 55 Rs/kg | 12. Price of Potassium | : 20.12 Rs/kg |
- Conti.....

Table – 4.22 Economics of growing herbal crops (Basil, Kalmegh and mint) under Sapota-Jatropha based three-tier agroforestry system (Second year, 2012)

Treatments	Yield (q/ha)			Cost of various products (₹ /ha)			Total cost of production (₹ /ha)	Gross income (₹ /ha)			Grand total (₹ /ha)	Net income (₹ /ha)	BCR	LER
	Sapota	Jatropha	Herbal	Planting material	NPK	Cost of cultivation		Sapota	Jatropha	Herbal				
T ₁ - (Basil Intercrop)	75	2.25	9.56	8800	11641.95	24100	44541.95	75000	5625	57360	137985	93443.05	1:3.10	1.27
T ₂ - (Kalmegh Intercrop)	75	2.25	3.86	1000	12608.20	24100	37708.20	75000	5625	27020	107645	69936.80	1:2.87	1.20
T ₃ - (Mint Intercrop)	75	2.25	8.26	16000	15598.10	24100	55698.10	75000	5625	49560	130185	74486.90	1:2.34	1.27
T ₄ - (Basil Sole)	-	-	27.30	25000	11641.95	33250	69891.95	-	-	163800	163800	93908.05	1:2.34	-
T ₅ - (Kalmegh Sole)	-	-	13.55	1200	12608.20	33250	47058.20	-	-	94850	94850	47791.80	1:2.05	-
T ₆ - (Mint Sole)	-	-	23.62	37037	15598.10	33250	85885.10	-	-	141720	141720	55834.90	1:1.65	-

1. Rate of basil seedling : 1 Rs /2 plant
2. Rate of kalmegh seeds : 2000Rs/kg
3. Rate of mint cutting : 1 Rs / 2cutting
4. Whole sale price of basil : 60 Rs/kg
5. Whole sale price of kalmegh : 70 Rs/kg
6. Whole sale price of mint : 60 Rs/kg

7. Sapota : 10 Rs/kg
8. Jatropha : 25 Rs/kg
9. Labour charge : 150 Rs/day
10. Price of Nitrogen : 12.68 Rs/kg
11. Price of Phosphorus : 46.25 Rs/kg
12. Price of Potassium : 29.40 Rs/kg

4.4.1.1 Plant height (cm)

The mean data pertaining to variation in plant height of intercrops and sole tuber crops are presented in Table - 4.23 and graphically depicted in Figure - 17. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The plant height was recorded maximum when tuber crops grown under Sapota-Jatropha as compared to sole cropping.

In the first year it is evident from data presented in Table – 4.23 that significant differences in the plant height were observed in all the tuber medicinal plants grown under Sapota-Jatropha and in sole crops. The plant height of kalihari, kali musli and safed musli was recorded maximum (T_1 , 45.53 cm, T_2 , 19.05 cm and T_3 , 27.46 cm) under Sapota-Jatropha and was on the same bar with respective sole crops (T_4 , 44.95 cm, T_5 , 17.26 cm and T_6 , 25.53 cm).

Further perusal of data reveals that tuber crops (Kalihari, Kali musli and Safed musli) in second year and pooled analysis showed the similar trends as that of first year result.

In first year percent increase in plant height was recorded maximum in kali musli (10.37 %) which was followed by safed musli (7.56 %) and kalihari (1.29 %) over their respective sole crops. With regards to the second year and pooled data, it showed the similar trend to those of the results of first year.

4.4.1.2 Number of tubers per plant

The data regarding number of tubers per plant of different tuber crops are presented in Table – 4.24 and illustrated graphically in Figure - 18. The results were

Table - 4.23 Plant height of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Plant height (cm)		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	45.53 (1.29)*	43.40 (7.16)*	44.47 (4.07)*
T₂ – Kali musli Intercrop	19.05 (10.37)*	15.06 (7.19)*	17.06 (8.94)*
T₃ – Safed musli Intercrop	27.46 (7.56)*	30.99 (11.08)*	29.23 (9.43)*
T₄ - Kalihari Sole	44.95	40.50	42.73
T₅ – Kali musli Sole	17.26	14.05	15.66
T₆ – Safed musli Sole	25.53	27.90	26.71
S. Em ±	0.905	1.188	1.707
CD at 5 %	2.73	3.58	6.21
CV %	6.04	8.29	7.20

*Figure in parenthesis indicates percentage increases over respective sole cropping

Figure - 17 Plant height of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system.

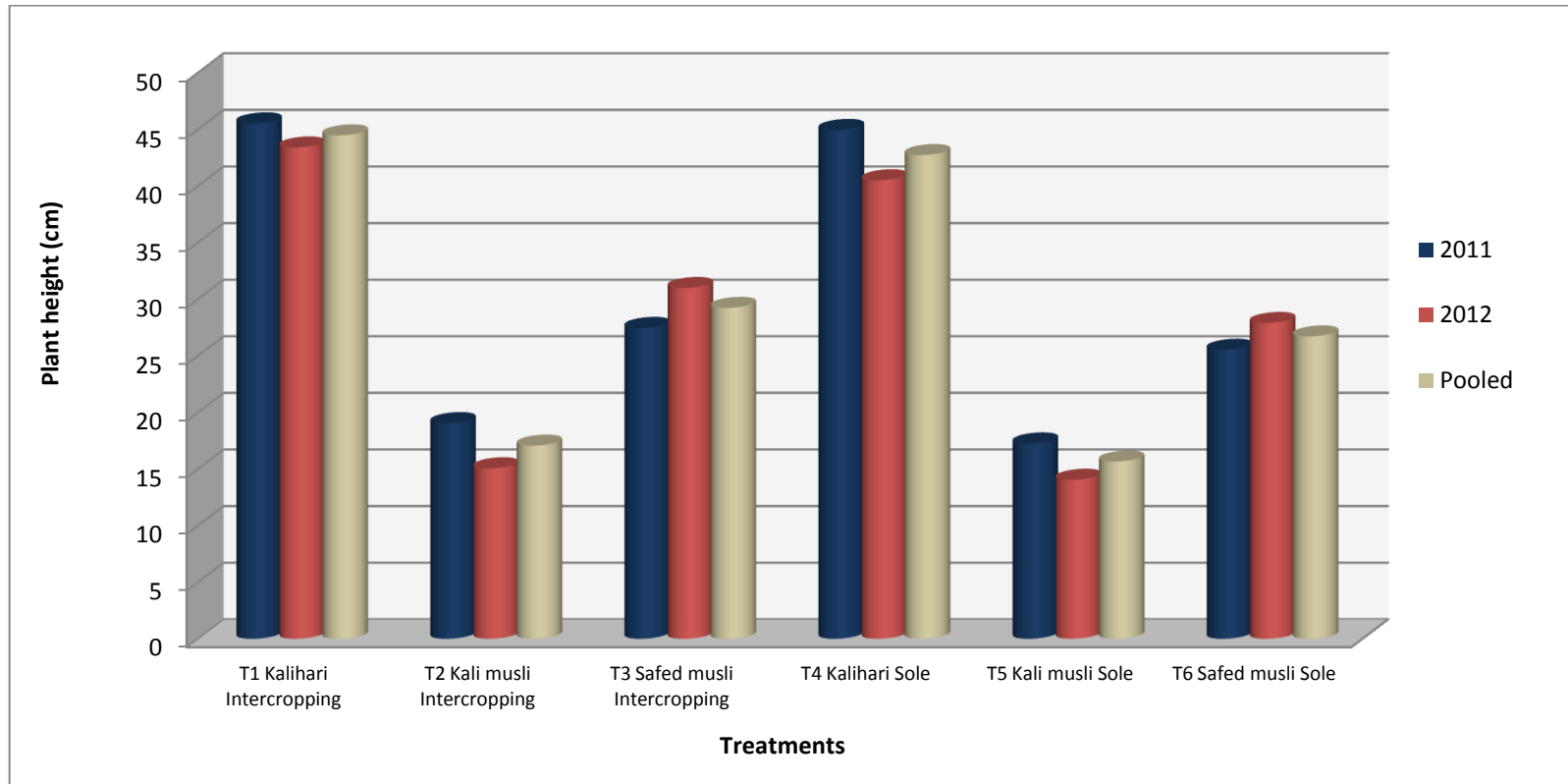
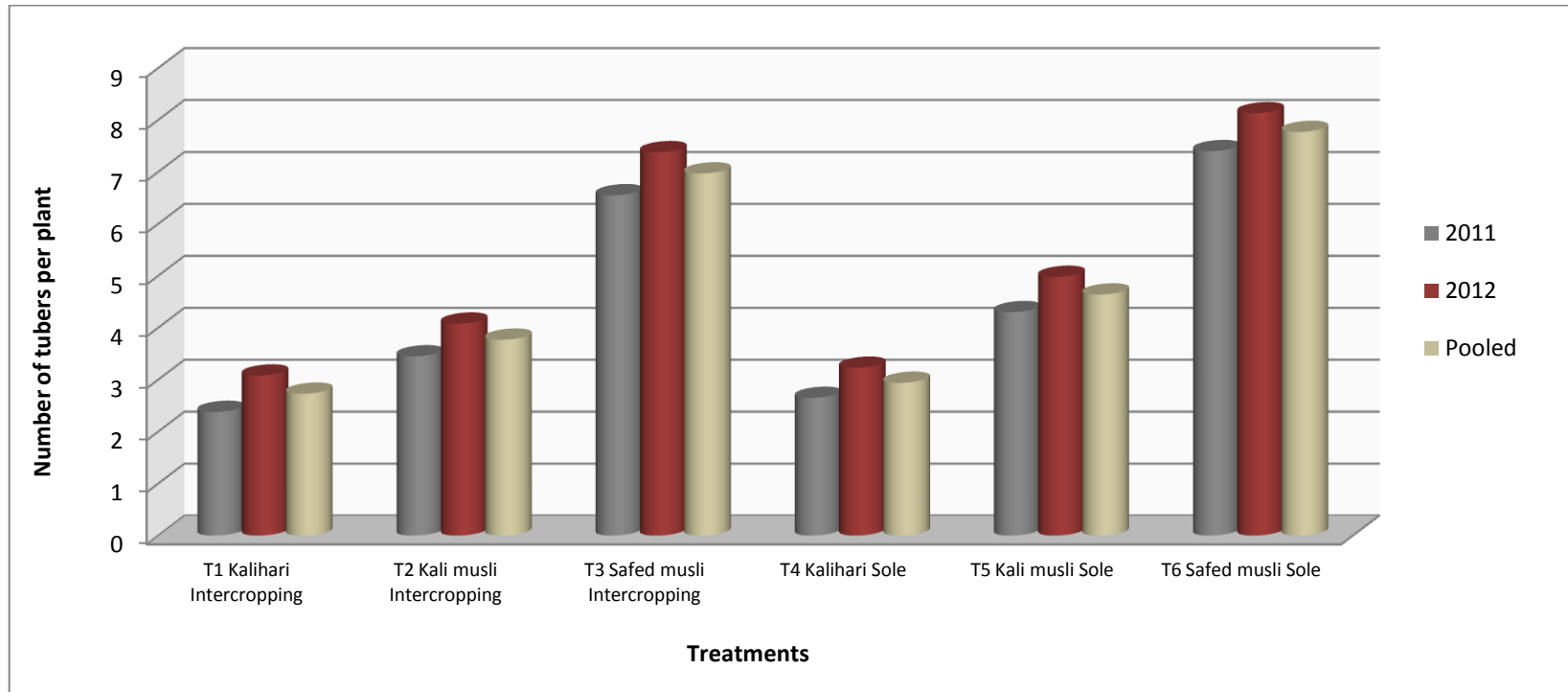


Table - 4.24 Number of tubers per plant as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Number of tubers per plant		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	2.38 (10.19)*	3.08 (4.64)*	2.73 (7.14)*
T₂ – Kali musli Intercrop	3.45 (19.77)*	4.08 (18.07)*	3.77 (18.75)*
T₃ – Safed musli Intercrop	6.55 (11.49)*	7.38 (9.23)*	6.97 (10.30)*
T₄ - Kalihari Sole	2.65	3.23	2.94
T₅ – Kali musli Sole	4.30	4.98	4.64
T₆ – Safed musli Sole	7.40	8.13	7.77
S. Em ±	0.145	0.191	0.120
CD at 5 %	0.44	0.58	0.35
CV %	6.50	7.42	7.06

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 18 Number of tubers per plant as influenced by Sapota-Jatropha three-tier agroforestry system.



found significant during both the years (2011 and 2012) and in pooled analysis. The number of tubers per plant was noted maximum in sole cropping as compared to intercropping under Sapota-Jatropha.

From Table – 4.24, it can be seen that in first year of study, sole kalihari treatments T₄ (2.65) noted maximum number of tubers per plant which was on same bar with kalihari grown under Sapota-Jatropha (T₁, 2.38). While in other tuber crops kali musli and safed musli recorded significantly higher number of tubers per plant (T₅, 4.30 and T₆, 7.40, respectively) in sole cropping followed by intercrop under Sapota-Jatropha (T₂, 3.45 and T₃, 6.55) respectively.

It can be seen from Table – 4.24 that, during second year of investigation and pooled analysis the same trend as per the trend of first year was evident.

In first year the percent reduction in number of tubers per plant was recorded minimum in kalihari (10.19 %) which was followed by safed musli (11.49 %) and kali musli (19.77 %). Similar trend was observed in second year and pooled result.

4.4.1.3 Length of tuber (cm)

The observations on the length of tuber of sole crop and tuber crops grown under Sapota-Jatropha are furnished in Table – 4.25 and illustrated in Figure - 19. The statistical comparison showed that the length of tuber as affected by intercrops and sole are found significant for both the study years and in pooled analysis.

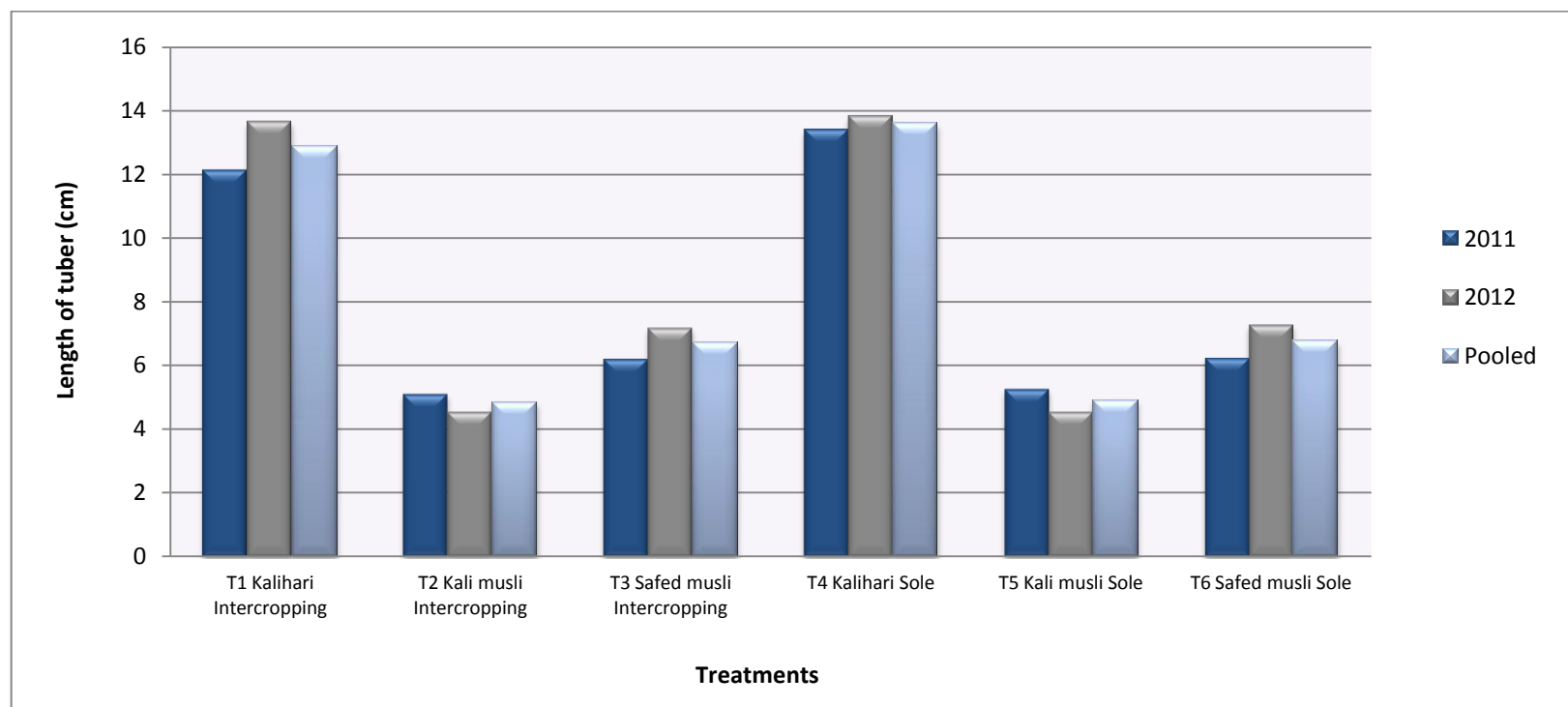
It is revealed from the data given in Table – 4.25 that in first year of study, sole kalihari treatment (T₄, 13.38 cm) noted significantly maximum length of tuber which was followed by kalihari grown under Sapota-Jatropha (T₁, 12.10 cm). In the tuber

Table - 4.25 Length of tuber of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Length of tuber (cm)		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	12.10 (9.57)*	13.65 (1.30)*	12.88 (5.36)*
T₂ – Kali musli Intercrop	5.10 (2.86)*	4.55 (0.00)*	4.83 (1.43)*
T₃ – Safed musli Intercrop	6.20 (0.48)*	7.18 (1.37)*	6.69 (0.89)*
T₄ - Kalihari Sole	13.38	13.83	13.61
T₅ – Kali musli Sole	5.25	4.55	4.90
T₆ – Safed musli Sole	6.23	7.28	6.75
S. Em ±	0.385	0.490	0.312
CD at 5 %	1.16	1.48	0.90
CV %	9.57	11.52	10.65

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 19 Length of tuber of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system.



crops kali musli and safed musli maximum length of tuber (T₅, 5.25 cm and T₆, 6.23 cm, respectively) was in sole cropping and with slightly lower values when grown under Sapota-Jatropha (T₂, 5.10 cm and T₃, 6.20 cm) respectively.

During 2012 higher length of tuber was registered in the (T₄) sole kalihari crop (13.83 cm) which was on same bar with treatment T₁ (13.65 cm). The other tuber crops kali musli and safed musli showed similar trend as in kalihari. Similar trend was observed in pooled data.

During 2011 percent reduction in length of tuber was (0.48 %) in safed musli which was followed by kali musli (2.86 %) and kalihari (9.57 %). Same trend was observed in second year and pooled data.

4.4.1.4 Girth of tuber (cm)

The data regarding variation in girth of tuber between intercrops and sole crop are tabulated in Table – 4.26 and graphically depicted in Figure - 20. The statistical comparison showed that the girth of tuber as affected by intercrops and sole are found significant for both years (2011 and 2012) and in pooled analysis also.

During 2011 maximum girth of tuber was noted in sole crop of kalihari (T₄, 5.93 cm) and kali musli (T₅, 2.18 cm) which was statistically at par with kalihari (T₁, 5.53 cm) and Kali musli (T₂, 1.90 cm) grown as an intercrop. Sole crop of safed musli reported significantly maximum girth of tuber (T₆, 4.93 cm) which was followed by safed musli when grown under Sapota-Jatropha (T₃, 4.20 cm).

A perusal of data presented in Table – 4.26 revealed that, during second year (2012), girth of tuber was significantly maximum in sole kalihari and kali musli (T₄,

Table - 4.26 Girth of tuber of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system.

Treatment	Girth of tuber (cm)		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	5.53 (6.75)*	5.90 (16.67)*	5.71 (12.15)*
T₂ – Kali musli Intercrop	1.90 (12.84)*	2.38 (23.96)*	2.14 (19.55)*
T₃ – Safed musli Intercrop	4.20 (14.81)*	3.88 (3.00)*	4.04 (9.62)*
T₄ - Kalihari Sole	5.93	7.08	6.50
T₅ – Kali musli Sole	2.18	3.13	2.66
T₆ – Safed musli Sole	4.93	4.00	4.47
S. Em ±	0.151	0.207	0.393
CD at 5 %	0.46	0.62	1.43
CV %	7.35	9.40	8.51

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 20 Girth of tuber of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system.

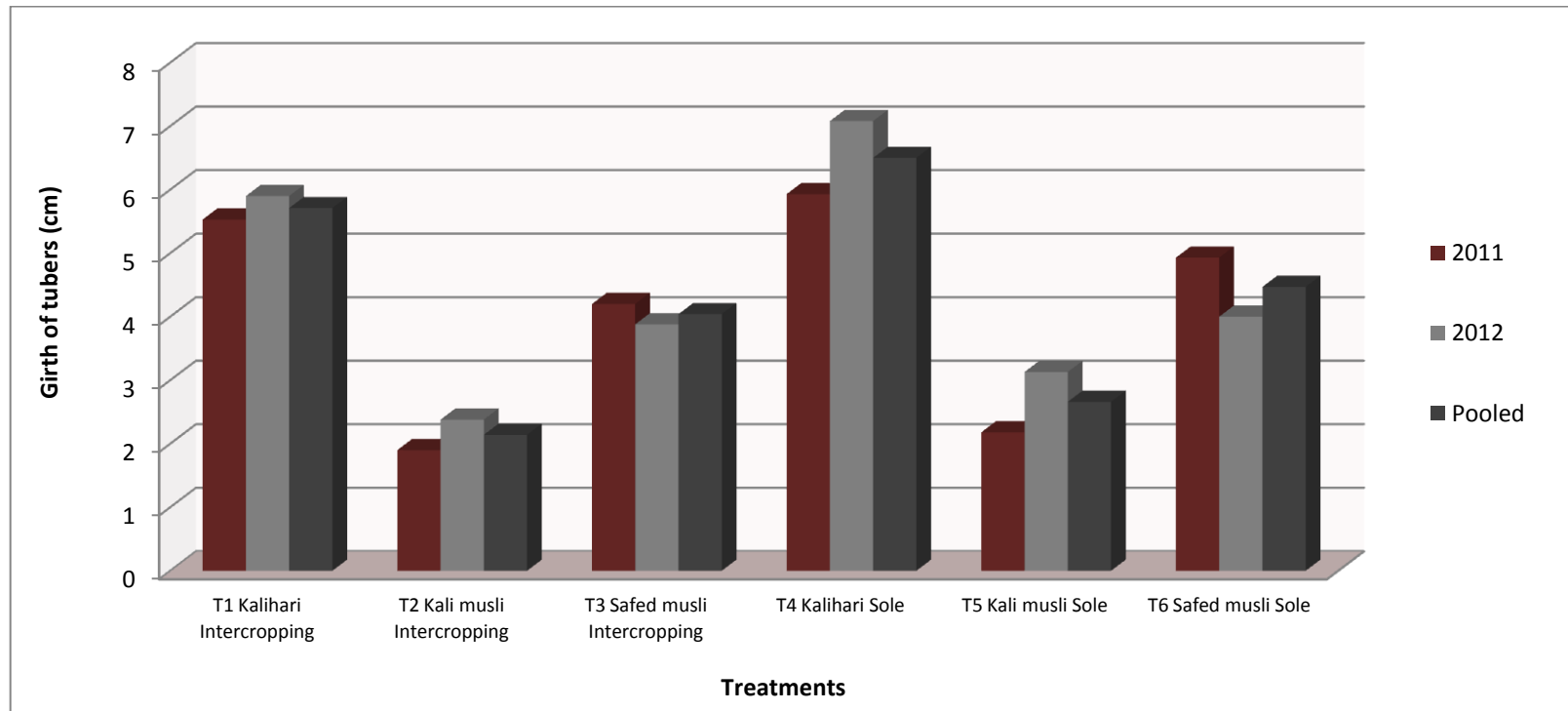


PLATE V : Performance of tuber crops under three-tier agroforestry system



Gloriosa superba L. under Sapota-Jatropha



Curculigo orchioides Gaertn under Sapota-Jatropha



Chlorophytum borivillianum Ker. under Sapota-Jatropha

7.08 cm and T₅, 3.13 cm, respectively) which was followed by intercrop of kalihari and kali musli (T₁, 5.90 cm and T₂, 2.38 cm) respectively. Sole crop of safed musli reported maximum girth of tuber (T₆, 4.00 cm) which was on the same bar with safed musli when grown under Sapota-Jatropha (T₃, 3.88 cm). In pooled analysis, the maximum girth of tuber was recorded in sole tuber crops (kalihari, kali musli and safed musli) which were statistically at par with when these tuber crops were grown under Sapota-Jatropha.

During 2011 percent reduction in girth of tuber was noted minimum in kalihari (6.75 %) which was followed by kali musli (12.84 %) and safed musli (14.81 %). Similar trend was observed in second year and pooled result also.

4.4.1.5 Fresh weight of tuber per plant (g)

The data with respect to fresh weight of tuber per plant of different tuber crops are furnished in Table – 4.27 and depicted in Figure - 21. The results were found significant during 2011, 2012 and in pooled analysis. Maximum fresh weight of tuber per plant of all the tuber crops was observed in sole cropping as compared to grown under Sapota-Jatropha.

During 2011 an appraisal of data presented in Table – 4.27 indicates that the fresh weight of tuber per plant was noted higher in sole crop of kalihari, kali musli and safed musli (T₄, 30.08 g, T₅, 6.58 g and T₆, 36.14 g) which was on same bar with kalihari, kali musli and safed musli when grown under Sapota-Jatropha (T₁, 28.58 g, T₂, 5.79 g and T₃, 34.09 g) respectively.

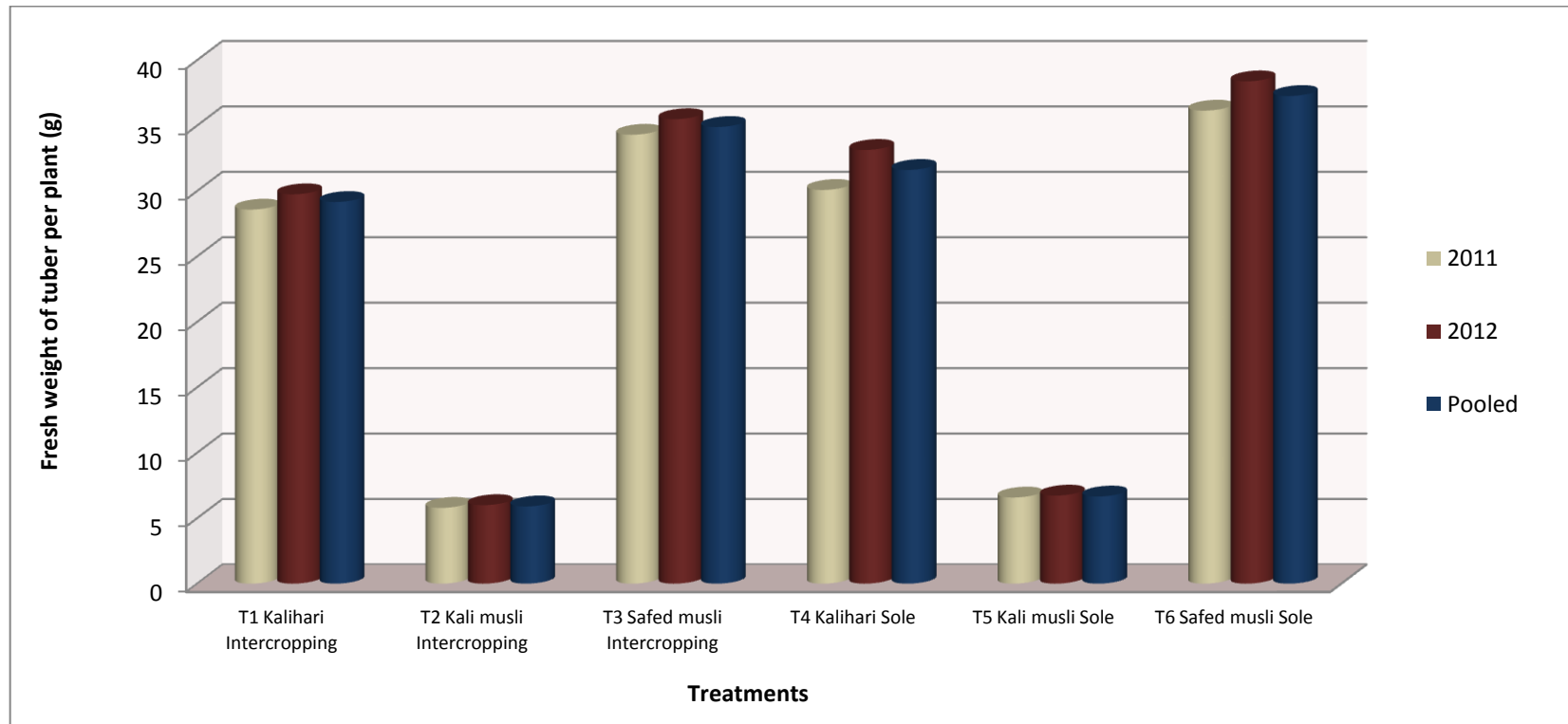
In the second year, significantly maximum fresh weight of tuber per plant was found in the sole crop of kalihari in treatment T₄ (33.14 g) which was followed by kalihari when grown under Sapota-Jatropha (T₁, 29.75 g). The other tuber crops (kali

Table - 4.27 Fresh weight of tuber per plant as influenced by Sapota- Jatropha three-tier agroforestry system

Treatment	Fresh weight of tuber per plant (g)		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	28.58 (4.99)*	29.75 (10.23)*	29.16 (7.75)*
T₂ – Kali musli Intercrop	5.79 (12.01)*	6.00 (10.85)*	5.90 (11.41)*
T₃ – Safed musli Intercrop	34.30 (5.09)*	35.49 (7.53)*	34.89 (6.36)*
T₄ - Kalihari Sole	30.08	33.14	31.61
T₅ – Kali musli Sole	6.58	6.73	6.66
T₆ – Safed musli Sole	36.14	38.38	37.26
S. Em ±	1.152	0.984	0.757
CD at 5 %	3.47	2.97	2.19
CV %	9.77	7.90	8.84

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 21 Fresh weight of tuber per plant as influenced by Sapota- Jatropha three-tier agroforestry system.



musli and safed musli) in sole crop (T₅, 6.73 g and T₆, 38.88 g, respectively) observed maximum fresh weight of tuber per plant which was statistically at par with intercrop under Sapota-Jatropha (T₂, 6.00 g and T₃, 35.49 g) respectively. Pooled estimates showed similar trend as second year result.

Percent reduction in fresh weight of tuber per plant (2011) was recorded minimum in kalihari (4.99 %) which was followed by safed musli (5.09 %) and kali musli (12.01 %). With regard to the second year and pooled data, it showed the similar trend to those of the result of first year.

4.4.1.6 Dry weight of tuber per plant (g)

The data concerning the dry weight of tuber per plant of different tuber crops are summarized in Table - 4.28 and Figure - 22. During both the years (2011 and 2012) of study and in pooled analysis results were found significant. In all the tuber crops maximum dry weight of tuber per plant was recorded in sole crop as compared to their respective intercropping under Sapota-Jatropha.

The statistical analysis of the first year (2011) data showed maximum dry weight of tuber per plant in sole crop of kalihari, kali musli and safed musli (T₄, 15.00 g, T₅, 4.95 g and T₆, 9.65 g) which was on the same bar with the intercrop of kalihari, kali musli and safed musli under Sapota-Jatropha (T₁, 14.48 g, T₂, 4.10 g and T₃, 9.17 g) respectively.

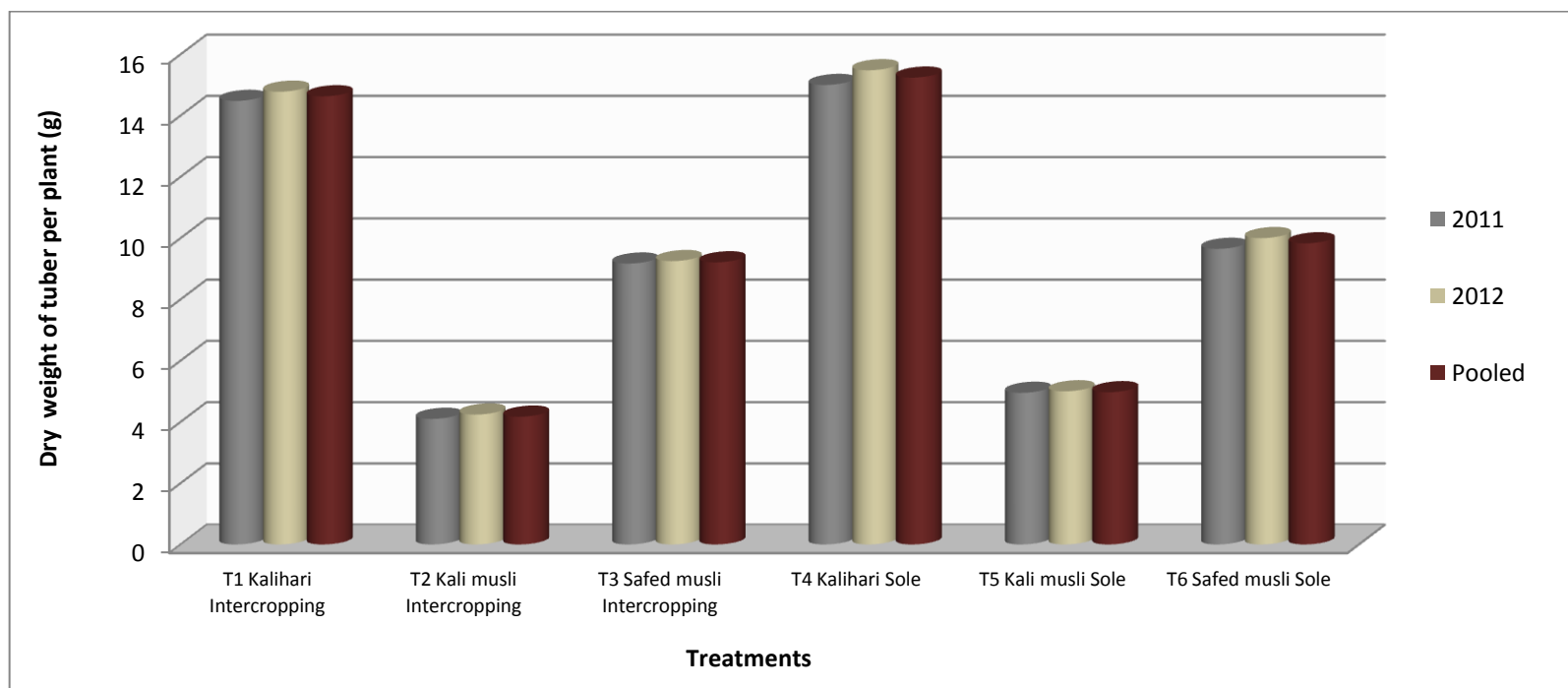
An analysis of second year and pooled data showed that the trend was just in the same line as that of the first year result.

Table - 4.28 Dry weight of tuber per plant as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Dry weight of tuber per plant (g)		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	9.17 (4.97)*	9.25 (7.50)*	9.21 (6.31)*
T₂ – Kali musli Intercrop	4.10 (17.17)*	4.24 (15.20)*	4.17 (16.10)*
T₃ – Safed musli Intercrop	14.48 (3.47)*	14.78 (4.52)*	14.63 (4.00)*
T₄ - Kalihari Sole	15.00	15.48	15.24
T₅ – Kali musli Sole	4.95	5.00	4.97
T₆ – Safed musli Sole	9.65	10.00	9.83
S. Em ±	0.412	0.543	0.341
CD at 5 %	1.24	1.64	0.98
CV %	8.62	11.09	9.96

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 22 Dry weight of tuber per plant as influenced by Sapota-Jatropha three-tier agroforestry system.



During 2011 percent reduction in dry weight of tuber per plant was found minimum in kalihari (3.47 %) which was followed by safed musli (4.97 %) and kali musli (17.17 %). Same result was recorded in second year and pooled data.

4.4.1.7 Fresh weight of tuber per plot (kg)

The fresh weight of tuber per plot under Sapota-Jatropha and sole crops are depicted in Table – 4.29 and Figure – 23. All the tuber crop when grown as sole stand recorded significantly higher fresh weight of tuber per plot their respective intercropping systems during 2011, 2012 and in their mean data.

Looking to the mean data of first year trial, it was found that the sole crops of kalihari, kali musli and safed musli (T₄, 7.94 kg, T₅, 3.15 kg and T₆, 17.34 kg) noted maximum fresh weight of tuber per plot which was on same bar with kalihari, kali musli and safed musli grown under Sapota-Jatropha (T₁, 7.13 kg, T₂, 2.76 kg and T₃, 16.45 kg).

Result obtained during 2012 experimentation indicates that the mean data, sole crops of kalihari (T₄, 7.22 kg) noted maximum fresh weight of tuber per plot which was same bar with kalihari grown under Sapota-Jatropha (T₁, 6.85 kg). Kali musli showed same trend as kalihari. While sole safed musli (T₆, 18.42 kg) recorded significantly higher fresh weight of tuber per plot which was followed by intercrop of safed musli (T₃, 17.03 kg) with Sapota-Jatropha. With regards to the pooled data, it showed the similar trend to those of the result of second year.

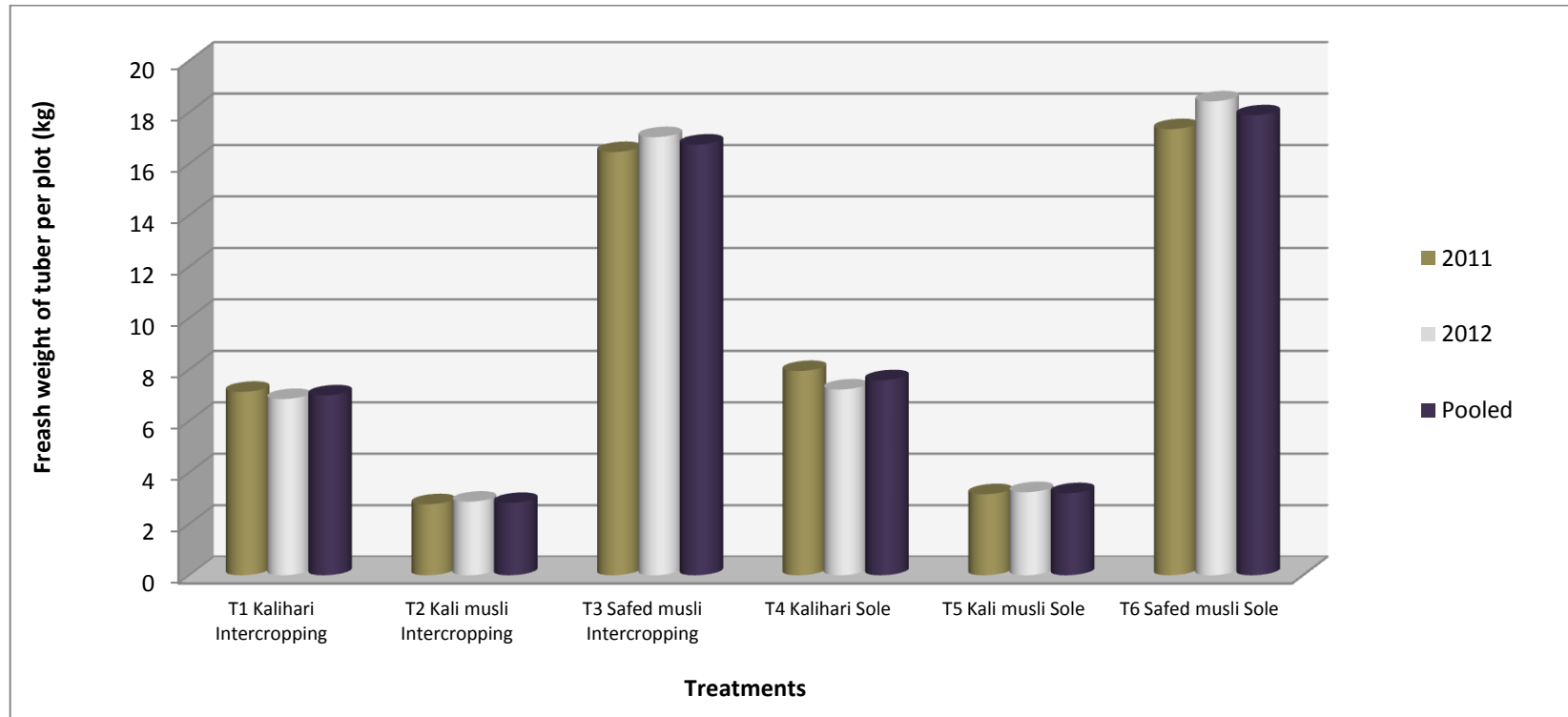
During 2011 percent reduction in fresh weight of tuber per plot was recorded minimum in safed musli (5.13 %) which was followed by kalihari (10.31 %) and kali musli (12.38 %). Similar trend of results were obtained in case of second year and pooled data.

Table - 4.29 Fresh weight of tuber per plot as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Fresh weight of tuber per plot (kg)		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	7.13 (10.31)*	6.85 (5.12)*	6.99 (7.78)*
T₂ – Kali musli Intercrop	2.76 (12.38)	2.86 (11.46)*	2.81 (11.91)*
T₃ – Safed musli Intercrop	16.45 (5.13)*	17.03 (7.55)*	16.74 (6.38)*
T₄ - Kalihari Sole	7.94	7.22	7.58
T₅ – Kali musli Sole	3.15	3.23	3.19
T₆ – Safed musli Sole	17.34	18.42	17.88
S. Em ±	0.337	0.286	0.221
CD at 5 %	1.02	0.86	0.64
CV %	7.38	6.18	6.80

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 23 Fresh weight of tuber per plot as influenced by Sapota-Jatropha three-tier agroforestry system.



4.4.1.8 Dry weight of tuber per plot (kg)

Data related with dry weight of tuber per plot under Sapota-Jatropha and sole crops are presented in Table – 4.30 and illustrated in Figure – 24. The results were observed significant during 2011, 2012 and in pooled analysis. Dry weight of tuber per plot in all the three crops was recorded maximum when tuber crops were grown as sole cropping than their respective intercropping with Sapota-Jatropha.

It is obvious from the data specified in Table – 4.30 that during the first year the maximum dry weight of tuber per plot (3.59 kg) was reported in treatment T₄ sole kalihari which was statistically at par with kalihari grown under Sapota-Jatropha (T₁, 3.46 kg). Similar trend of kalihari result was obtained in case of safed musli. Sole crop of kali musli (T₅, 2.36 kg) recorded significantly maximum dry weight of tuber per plot which was followed by kali musli grown under Sapota-Jatropha (T₂, 1.95 kg). Treatment T₆ sole safed musli (T₆, 4.74 kg) was reported maximum dry weight of tuber per plot which was on same bar with safed musli grown under Sapota-Jatropha (T₃, 4.41 kg).

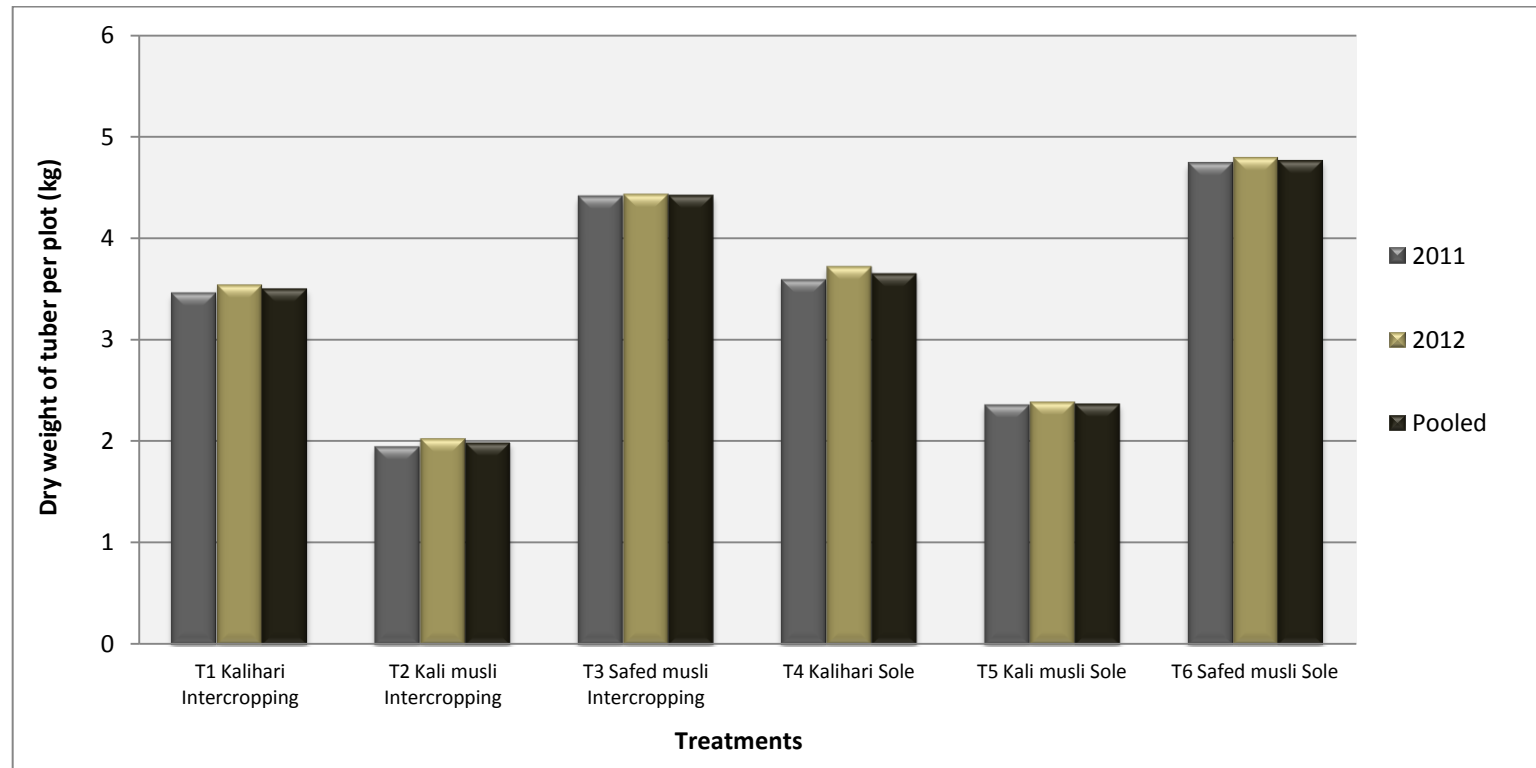
During 2012 maximum dry weight of tuber per plot was observed in sole crops of kalihari (T₄, 3.72 kg) which was on same bar with kalihari grown under Sapota-Jatropha (T₁, 3.54 kg). Whereas the other tuber crops kali musli and safed musli were showed similar trend of results. In pooled analysis, kalihari observed maximum dry weight of tuber per plot (T₄, 3.65 kg) in sole crop which was at par with kalihari when grown under Sapota-Jatropha (T₁, 3.50 kg). While sole crop of kali musli (T₅, 2.37 kg) recorded significantly higher dry weight of tuber per plant which was followed by intercrop of kali musli (T₂, 1.99 kg) with Sapota-Jatropha. Safed musli showed same trend as kali musli.

Table - 4.30 Dry weight of tuber per plot as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Dry weight of tuber per plot (kg)		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	3.46 (3.62)*	3.54 (4.84)*	3.50 (4.11)*
T₂ – Kali musli Intercrop	1.95 (17.37)*	2.03 (15.06)*	1.99 (16.03)*
T₃ – Safed musli Intercrop	4.41 (6.96)*	4.43 (7.52)*	4.42 (7.14)*
T₄ - Kalihari Sole	3.59	3.72	3.65
T₅ – Kali musli Sole	2.36	2.39	2.37
T₆ – Safed musli Sole	4.74	4.79	4.76
S. Em ±	0.108	0.129	0.084
CD at 5 %	0.33	0.39	0.24
CV %	6.32	7.38	6.88

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 24 Dry weight of tuber per plot as influenced by Sapota-Jatropha three-tier agroforestry system.



During 2011 in case of percent reduction in dry weight of tuber per plot was found minimum in kalihari (3.46 %) which was followed by safed musli (6.96 %) and kali musli (17.37 %). Similar trend was recorded in second year and pooled data.

4.4.1.9 Economic yield (q ha^{-1})

Economic yield (q ha^{-1}) of sole crops and intercrop under Sapota-Jatropha are presented in Table – 4.31 and furnished in Figure – 25. The maximum economic yield was recorded in sole cropping as compared to intercropping in all tuber crops when grown under Sapota-Jatropha.

The data corresponding to the economic yield (2011), the sole crop of kalihari, kali musli and safed musli (T_4 8.33 q/ha, T_5 5.52 q/ha and T_6 10.99 q/ha) noted significantly higher economic yield when compared to kalihari, kali musli and safed musli under Sapota-Jatropha (T_1 3.48 q/ha, T_2 1.98 q/ha and T_3 4.41 q/ha) respectively.

Further perusal of data reveals that tuber crops (kalihari, kali musli and safed musli) in second year and pooled analysis showed the similar trend and result as that of the first year.

Percent reduction in economic yield (2011) was minimum in kalihari (58.22 %) which was followed by safed musli (59.87 %) and kali musli (64.13 %). Similar trend of results were obtained in case second year and pooled analysis.

4.4.1.10 Survival percent

The survival percent of plant under Sapota-Jatropha and sole crops showed in Table - 4.32 during 2011, 2012 and in their mean data. All the tuber intercrops

Table - 4.31 Economic yield of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Economic yield (q/ha)		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	3.48 (58.22)*	3.60 (58.19)*	3.54 (58.21)*
T₂ – Kali musli Intercrop	1.98 (64.13)*	2.05 (63.13)*	2.02 (63.54)*
T₃ – Safed musli Intercrop	4.41 (59.87)*	4.45 (59.98)*	4.43 (59.95)*
T₄ - Kalihari Sole	8.33	8.61	8.47
T₅ – Kali musli Sole	5.52	5.56	5.54
T₆ – Safed musli Sole	10.99	11.12	11.06
S. Em ±	0.234	0.341	0.207
CD at 5 %	0.71	1.03	0.60
CV %	8.10	11.57	10.02

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 25 Economic yield of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system.

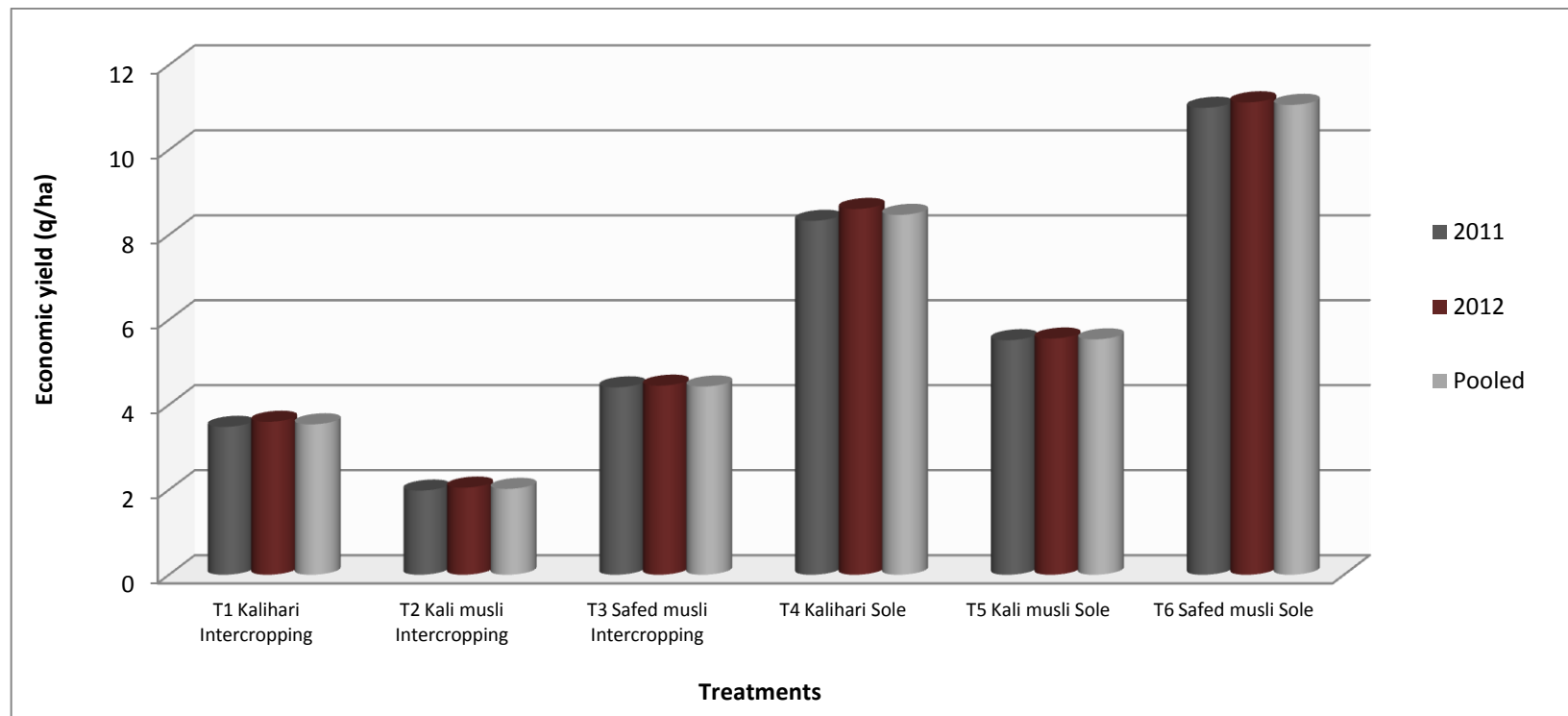


PLATE VI: Economic part of tuber crops



Gloriosa superba (Kali hari) tubers



Curculigo orchioides (Kali musli) tubers



Chlorophytum borivillianum (Safed musli) tubers

Table - 4.32 Survival percent of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Survival percent		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	51.43 (1.66)*	52.13 (2.25)*	51.78 (1.95)*
T₂ – Kali musli Intercrop	73.80 (1.38)*	75.10 (1.55)*	74.45 (1.46)*
T₃ – Safed musli Intercrop	71.35 (1.18)*	72.33 (2.59)*	71.84 (1.90)*
T₄ - Kalihari Sole	52.30	53.33	52.81
T₅ – Kali musli Sole	74.83	76.28	75.55
T₆ – Safed musli Sole	72.20	74.25	73.23
S. Em ±	2.647	2.337	1.765
CD at 5 %	7.98	7.04	5.10
CV %	8.02	6.95	7.50

*Figure in parenthesis indicates percentage reduction over respective sole cropping

in their sole stand was recorded significant results in their respective intercropping systems during 2011, 2012 and pooled data.

It is evident from data presented in Table - 4.32 that significant differences in the survival percent were observed in all the tuber medicinal plants grown under Sapota-Jatropha and in sole crops. The survival percents of kalihari, kali musli and safed musli was higher (T_4 , 52.30 %, T_5 , 74.83 %, T_6 , 72.20 %) under Sapota-Jatropha was same bar with sole crop (T_1 , 51.43 %, T_2 , 73.80 %, T_3 , 71.35 %) respectively. Further perusal of data revealed that tuber crops of second year data and pooled data showed the similar trend of first year results.

Percent reduction in survival percent (2011) was obtained minimum in safed musli (1.18 %) which was followed by kali musli (1.38 %) and kalihari (1.66 %). Similar trend of results were obtained in case of second year and pooled analysis.

4.4.2.1. Light intensity (lux)

The light intensity received by tuber crops grown as intercrops and sole crops are depicted in Table – 4.33 and Figure – 26. All the tuber intercrops in their sole stand recorded significantly higher light intensity of light their respective intercropping stand during 2011, 2012 and in their mean data.

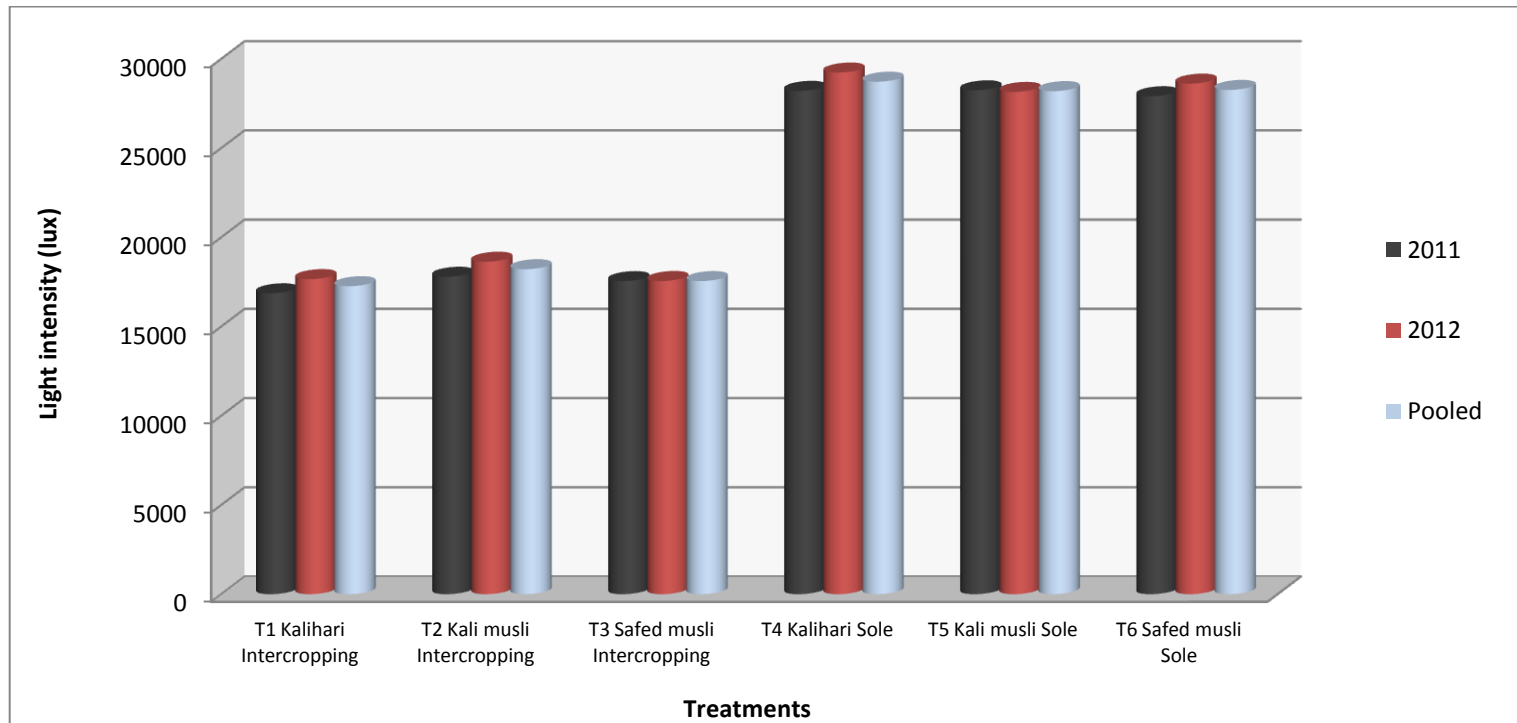
During 2011 sole crops of kalihari, kali musli and safed musli (T_4 , 28205 lux, T_5 , 28235 lux and T_6 , 27905 lux, respectively) received significantly higher light intensity which was followed by their respective intercrop under Sapota-Jatropha (T_1 , 16860 lux, T_2 , 17790 lux and T_3 , 17542.50 lux) respectively.

Table - 4.33 Light intensity at crop level in tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Light intensity (lux)		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	16860.00 (40.22)*	17655.00 (39.60)*	17257.50 (39.91)*
T₂ – Kali musli Intercrop	17790.00 (36.99)*	18630.00 (33.81)*	18210.00 (35.40)*
T₃ – Safed musli Intercrop	17542.50 (37.13)*	17550.00 (38.66)*	17546.25 (37.91)*
T₄ - Kalihari Sole	28205.00	29230.00	28717.50
T₅ – Kali musli Sole	28235.00	28145.00	28190.00
T₆ – Safed musli Sole	27905.00	28610.00	28257.50
S. Em ±	761.229	805.066	553.986
CD at 5 %	2294.11	2426.22	1599.81
CV %	6.69	6.91	6.80

*Figure in parenthesis indicates percentage reduction over respective sole cropping

Figure - 26 Light intensity at crop level in tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system.



In second year and in pooled analysis, the similar scenario of light intensity received by kalihari, kali musli and safed musli tuber crops were observed as in the case of first year.

Percent reduction in light intensity was noted minimum in kali musli (36.99 %) which was followed by safed musli (37.13 %) and kalihari (40.22 %). Same result was recorded in second year and pooled data.

4.4.2.2 Nutrient status in soil after the harvesting of the tuber crops

4.4.2.2.1 Organic carbon status (g kg^{-1}) in soil

The data regarding the organic carbon status of the soil after the harvest of tuber crops during 2011, 2012 and in their pooled analysis are presented in Table – 4.34 and Figure – 27. The result reveals that status of organic carbon in soil at harvest was significant during both the years of experimentation and in their pooled data.

In the first year an appraisal of data presented in Table - 4.32 indicates that intercrop of kalihari, kali musli and safed musli (T_1 , 6.50 g kg^{-1} , T_2 , 6.53 g kg^{-1} and T_3 , 6.64 g kg^{-1}) recorded significantly higher organic carbon status in soil which was followed by sole kalihari, kali musli and safed musli (T_4 , 5.83 g kg^{-1} , T_5 , 5.90 g kg^{-1} and T_6 , 5.94 g kg^{-1}) respectively.

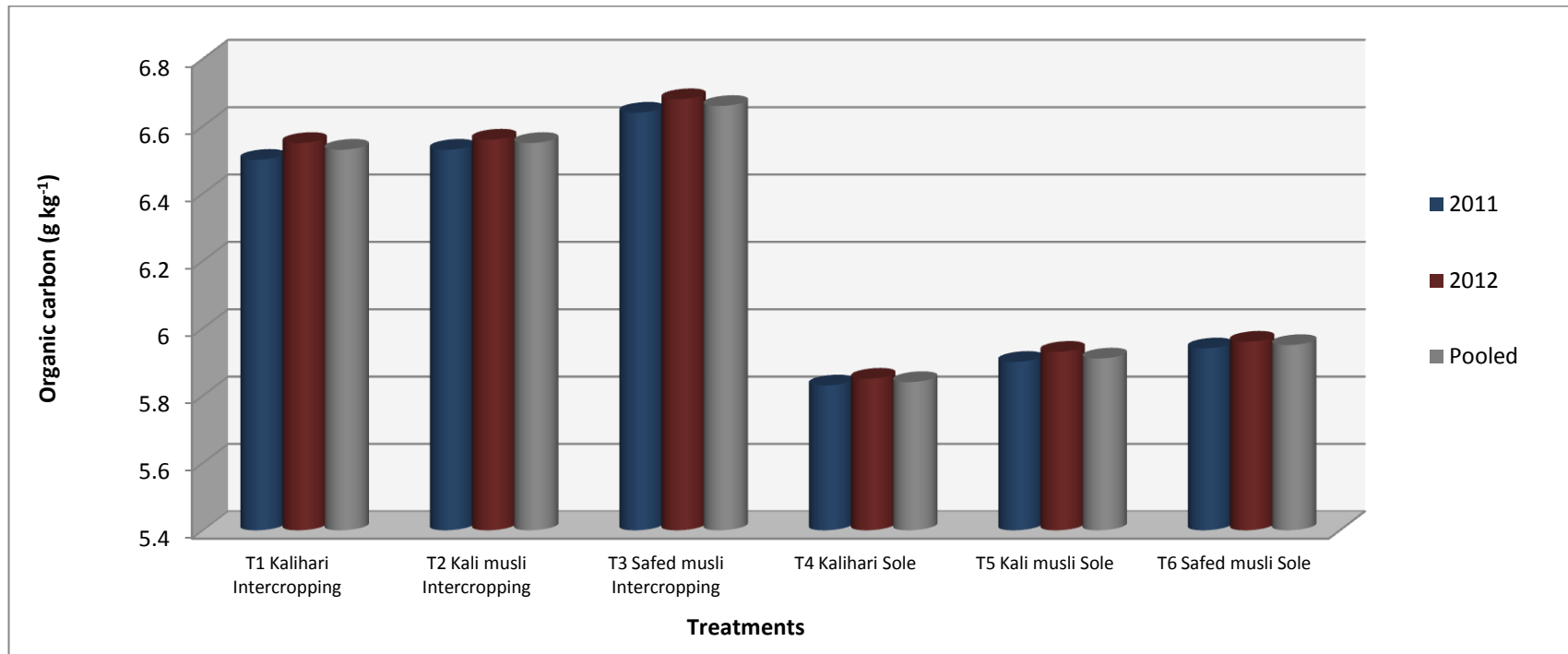
During 2012, at harvest, significantly higher organic carbon status in soil was observed in kalihari when this was grown under Sapota-Jatropha (T_1 , 6.55 g kg^{-1}) which was followed by sole kalihari (T_4 , 5.85 g kg^{-1}). Kali musli showed the same results as kalihari. While safed musli recorded maximum organic carbon in soil (T_3 , 6.68 g kg^{-1}) under Sapota-Jatropha which was on same bar with sole safed musli (T_6 , 5.96 g kg^{-1}).

Table - 4.34 Organic carbon content in soil at harvest of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Organic Carbon (g kg ⁻¹)		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	6.50 (11.49)*	6.55 (11.97)*	6.53 (11.82)*
T₂ – Kali musli Intercrop	6.53 (10.68)*	6.56 (10.62)*	6.55 (10.83)*
T₃ – Safed musli Intercrop	6.64 (11.78)*	6.68 (12.08)*	6.66 (11.93)*
T₄ - Kalihari Sole	5.83	5.85	5.84
T₅ – Kali musli Sole	5.90	5.93	5.91
T₆ – Safed musli Sole	5.94	5.96	5.95
S. Em ±	0.198	0.219	0.148
CD at 5 %	0.60	0.66	0.43
CV %	6.36	7.01	6.69

*Figure in parenthesis indicates percentage increases over respective sole cropping

Figure - 27 Organic carbon content in soil at harvest of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system.



Pooled analysis was observed the same trend of organic carbon in soil as per the trend of first year result.

In 2011 percent increase in organic carbon in soil was recorded maximum in safed musli (11.78 %) which was followed by kalihari (11.49 %) and kali musli (10.68 %). With regards to the second year and pooled data, it showed the similar trend to those of the result of first year.

4.4.2.2.2 Available nitrogen status (kg ha^{-1}) in soil

The mean data pertaining to variation in the available nitrogen status in the soil after the harvest of tuber crops are presented in Table – 4.35 and Figure – 28. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The available nitrogen status in the soil was recorded higher when tuber crops are grown under Sapota-Jatropha as compared to respective sole cropping.

During 2011 significant difference in the nitrogen status in soil was observed in all the tuber medicinal plants grown under Sapota-Jatropha and in sole crops. Significantly higher nitrogen in soil was recorded when kalihari, kali musli and safed musli grown under Sapota-Jatropha (T_1 , $247.48 \text{ kg ha}^{-1}$, T_2 , $259.24 \text{ kg ha}^{-1}$ and T_3 , $269.85 \text{ kg ha}^{-1}$) which was followed by sole kalihari, kali musli and safed musli (T_4 , $218.00 \text{ kg ha}^{-1}$, T_5 , $219.02 \text{ kg ha}^{-1}$ and T_6 , $219.45 \text{ kg ha}^{-1}$).

During 2012, maximum nitrogen in soil was recorded when kalihari grown under Sapota-Jatropha (T_1 , $250.53 \text{ kg ha}^{-1}$) was same bar with sole kalihari (T_4 , $220.00 \text{ kg ha}^{-1}$). While maximum nitrogen in soil was noted when kali musli grown under Sapota-Jatropha (T_2 , $261.99 \text{ kg ha}^{-1}$) was same bar with sole kali musli (T_5 , $222.02 \text{ kg ha}^{-1}$). Safed musli showed similar trend as kali musli. The perusal of data presented in

Table – 4.33 reveals that in pooled analysis the same trend of nitrogen status in soil is evident as per the trend of first year result.

In 2011 in case of percent increase in nitrogen status in soil was noted maximum in safed musli (22.97 %) which was followed by kali musli (18.36 %) and kalihari (13.52 %). Second year and pooled data showed same trend as first year result.

4.4.2.2.3 Available phosphorus status (kg ha^{-1}) in soil

The data regarding phosphorus status in soil of different tuber crops are presented in Table – 4.35 and illustrated graphically in Figure - 28. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The phosphorus status in soil was noted maximum in intercropping under Sapota-Jatropha as compared to sole cropping.

From Table – 4.35, it can be seen that in first year of study, kalihari was recorded maximum phosphorus in soil when these grown under Sapota-Jatropha (T_1 , 34.23 kg ha^{-1}) was same bar with sole crop (T_4 , 31.13 kg ha^{-1}). Kali musli and safed musli grown under Sapota-Jatropha (T_2 , 35.26 kg ha^{-1} and T_3 , 37.50 kg ha^{-1}) noted significantly higher phosphorus in soil which was followed by sole kali musli and safed musli (T_5 , 31.21 kg ha^{-1} and T_6 , 31.21 kg ha^{-1}).

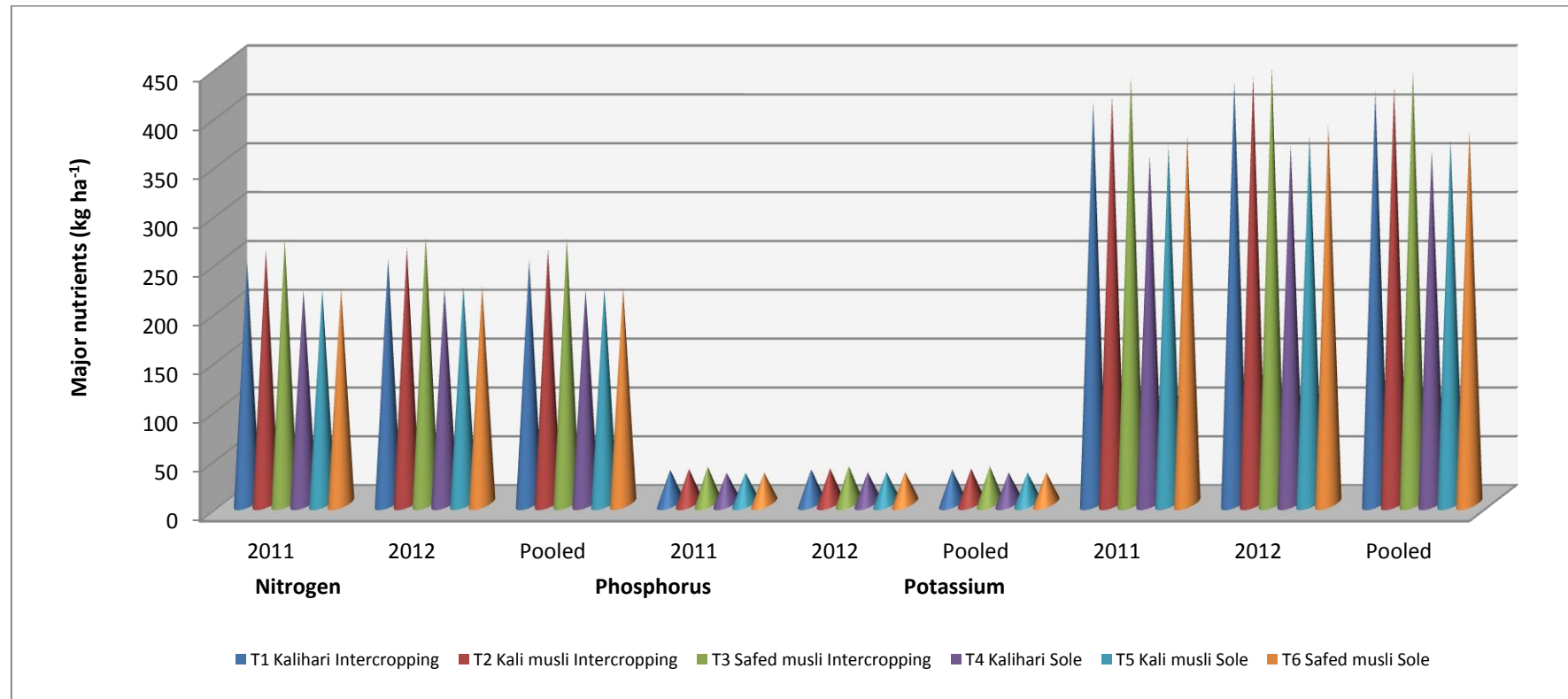
In second year, kalihari and kali musli observed maximum potassium in soil when grown under Sapota-Jatropha (T_1 , 34.73 kg ha^{-1} and T_2 , 35.76 kg ha^{-1} , respectively) which was statistically at par with sole kalihari and kali musli (T_4 , 31.63 kg ha^{-1} and T_5 , 31.71 kg ha^{-1}) respectively. Significantly higher potassium in soil was recorded when safed musli grown under Sapota-Jatropha (T_3 , 38.03 kg ha^{-1}) which was followed by sole safed musli (T_6 , 31.82 kg ha^{-1}). An analysis of pooled mean data

Table - 4.35 Major nutrients available in soil at harvest of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Nitrogen (kg ha ⁻¹)			Phosphorus (kg ha ⁻¹)			Potassium (kg ha ⁻¹)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
T₁ - Kalihari Intercrop	247.48 (13.52)*	250.53 (13.88)*	249.01 (13.70)*	34.23 (9.96)*	34.73 (9.80)*	34.48 (9.88)*	411.86 (15.51)*	432.11 (17.80)*	421.99 (16.67)*
T₂ – Kali musli Intercrop	259.24 (18.36)*	261.99 (18.00)*	260.62 (18.18)*	35.26 (12.98)*	35.76 (12.77)*	35.51 (12.87)*	416.98 (13.72)*	437.23 (15.92)*	427.11 (14.84)*
T₃ – Safed musli Intercrop	269.85 (22.97)*	272.60 (22.54)*	271.23 (22.76)*	37.50 (20.15)*	38.03 (19.52)*	37.76 (19.80)*	437.12 (15.99)*	447.37 (15.49)*	442.25 (15.74)*
T₄ - Kalihari Sole	218.00	220.00	219.00	31.13	31.63	31.38	356.56	366.81	361.69
T₅ – Kali musli Sole	219.02	222.02	220.52	31.21	31.71	31.46	366.67	377.17	371.92
T₆ – Safed musli Sole	219.45	222.45	220.95	31.21	31.82	31.52	376.87	387.37	382.12
S. Em ±	8.734	12.668	7.693	1.146	1.529	0.955	12.336	19.323	11.462
CD at 5 %	26.32	38.18	22.22	3.45	4.61	2.76	37.18	58.23	33.10
CV %	7.31	10.49	9.06	6.86	9.01	8.02	6.26	9.47	8.08

*Figure in parenthesis indicates percentage increases over respective sole cropping

Figure - 28 Major nutrients available in soil at harvest of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system.



showed that, the significantly higher potassium in soil was recorded when kalihari grown under Sapota-Jatropha (T_1 , 34.48 kg ha⁻¹) which was followed by sole kalihari (T_4 , 31.38 kg ha⁻¹). Kali musli and safed musli noted similar trend as kalihari.

During 2011 percent increase in potassium status in soil was found maximum in safed musli (20.15 %) which was followed by kali musli (12.98 %) and kalihari (9.96 %). Second year and pooled data noted similar trend as first year result.

4.4.2.2.4 Available potassium status (kg ha⁻¹) in soil

The mean data pertaining to variation in the available potassium status in the soil after the harvest of tuber crops are presented in Table – 4.35 and Figure – 28. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The available potassium status in the soil was recorded higher when tuber crops grown under Sapota-Jatropha as compared to sole cropping.

It is evident from data presented for 2011 in Table – 4.35 that significant difference in the potassium status in the soil was observed in all the tuber medicinal plants grown under Sapota-Jatropha and in sole crops. Significantly higher potassium in soil was recorded when kalihari, kali musli and safed musli grown under Sapota-Jatropha (T_1 , 411.86 kg ha⁻¹, T_2 , 416.98 kg ha⁻¹ and T_3 , 437.12 kg ha⁻¹) which was followed by sole kalihari, kali musli and safed musli (T_4 , 356.56 kg ha⁻¹, T_5 , 366.67 kg ha⁻¹ and T_6 , 376.87 kg ha⁻¹).

In the second year and pooled data, the similar scenario of potassium in soil of all tuber crops (kalihari, kali musli and safed musli) was observed in the case of first and second year results.

During 2011 percent increase in of potassium status in soil was maximum in safed musli (15.99 %) which was followed by kalihari (15.51 %) and kali musli (13.72 %). Similar result was obtained in second year and pooled data.

4.4.2.2.5 Secondary nutrients (Ca, Mg) (mg kg^{-1}) in soil

The available calcium and magnesium status in the soil after the harvest of tuber crops between intercrops and sole crops showed in Table – 4.36. All the tuber intercrops in their sole stand was recorded non-significant results in their respective intercropping systems during 2011, 2012 and in their mean data.

4.4.2.2.6 Micro nutrients (Fe, Mn, Zn, Cu) (mg kg^{-1}) in soil

The data with respect to iron, manganese, zinc and copper status in soil of tuber crops under Sapota-Jatropha and sole crops of kalihari, kali musli and safed musli are furnished in Table – 4.37. The results were found non-significant during 2011, 2012 and in their mean data. Maximum iron, manganese, zinc and copper in soil was observed under Sapota-Jatropha as compared to sole cropping.

4.4.2.3 Nutrients content in tuber crops

4.4.2.3.1 Organic carbon content (%)

The data regarding to organic carbon content after the harvest of tuber crops during 2011, 2012 and in their pooled analysis are presented in Table – 4.38 and Figure – 29. The result reveals that organic carbon content after the harvest of tuber crops was non - significant during both the years of experimentation and in their pooled data.

Table - 4.36 Secondary nutrients available in soil at harvest of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Calcium (mg kg ⁻¹)			Magnesium (mg kg ⁻¹)		
	2011	2012	Pooled	2011	2012	Pooled
T₁ - Kalihari Intercrop	6068.55 (0.05)*	6071.55 (0.06)*	6070.05 (0.05)*	1813.35 (0.10)*	1814.86 (0.13)*	1814.11 (0.12)*
T₂ – Kali musli Intercrop	6069.12 (0.05)*	6073.12 (0.06)*	6071.12 (0.05)*	1813.67 (0.07)*	1815.68 (0.12)*	1814.67 (0.09)*
T₃ – Safed musli Intercrop	6078.66 (0.07)*	6079.16 (0.05)*	6078.91 (0.06)*	1814.58 (0.07)*	1816.79 (0.14)*	1815.68 (0.10)*
T₄ - Kalihari Sole	6065.67	6068.17	6066.92	1811.50	1812.53	1812.01
T₅ – Kali musli Sole	6066.08	6069.58	6067.83	1812.35	1813.55	1812.95
T₆ – Safed musli Sole	6074.44	6075.94	6075.19	1813.40	1814.16	1813.78
S. Em ±	341.584	402.914	264.111	98.047	121.115	77.913
CD at 5 %	NS	NS	NS	NS	NS	NS
CV %	11.25	13.27	12.30	10.82	13.35	12.15

*Figure in parenthesis indicates percentage increases over respective sole cropping

Table - 4.37 Micro nutrients available in soil at harvest of tuber crops are influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Iron (mg kg ⁻¹)			Manganese (mg kg ⁻¹)			Zinc (mg kg ⁻¹)			Copper (mg kg ⁻¹)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
T₁ - Kalihari Intercrop	4.88 (0.41)*	4.89 (0.62)*	4.88 (0.41)*	10.18 (0.59)*	10.19 (0.49)*	10.18 (0.49)*	0.69 (6.15)*	0.69 (6.15)*	0.69 (6.15)*	2.69 (1.51)*	2.69 (0.75)*	2.69 (1.13)*
T₂ – Kali musli Intercrop	4.92 (0.82)*	4.93 (0.82)*	4.92 (0.82)*	10.20 (0.49)*	10.22 (0.59)*	10.21 (0.49)*	0.70 (4.35)*	0.72 (4.35)*	0.71 (4.41)*	2.70 (1.50)*	2.71 (1.50)*	2.71 (1.50)*
T₃ – Safed musli Intercrop	5.02 (1.01)*	5.04 (1.20)*	5.03 (1.21)*	10.22 (0.49)*	10.24 (0.59)*	10.23 (0.59)*	0.75 (4.17)*	0.76 (4.11)*	0.76 (5.56)*	2.73 (1.87)*	2.75 (2.23)*	2.74 (2.24)*
T₄ - Kalihari Sole	4.86	4.86	4.86	10.12	10.14	10.13	0.65	0.65	0.65	2.65	2.67	2.66
T₅ – Kali musli Sole	4.88	4.89	4.88	10.15	10.16	10.16	0.68	0.69	0.68	2.66	2.67	2.67
T₆ – Safed musli Sole	4.97	4.98	4.97	10.17	10.18	10.17	0.72	0.73	0.72	2.68	2.69	2.68
S. Em ±	0.191	0.286	0.172	0.341	0.443	0.280	0.034	0.030	0.023	0.083	0.098	0.064
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	0.07	NS	NS	NS
CV %	7.76	11.62	9.88	6.71	8.70	7.77	9.61	8.58	9.10	6.21	7.25	6.75

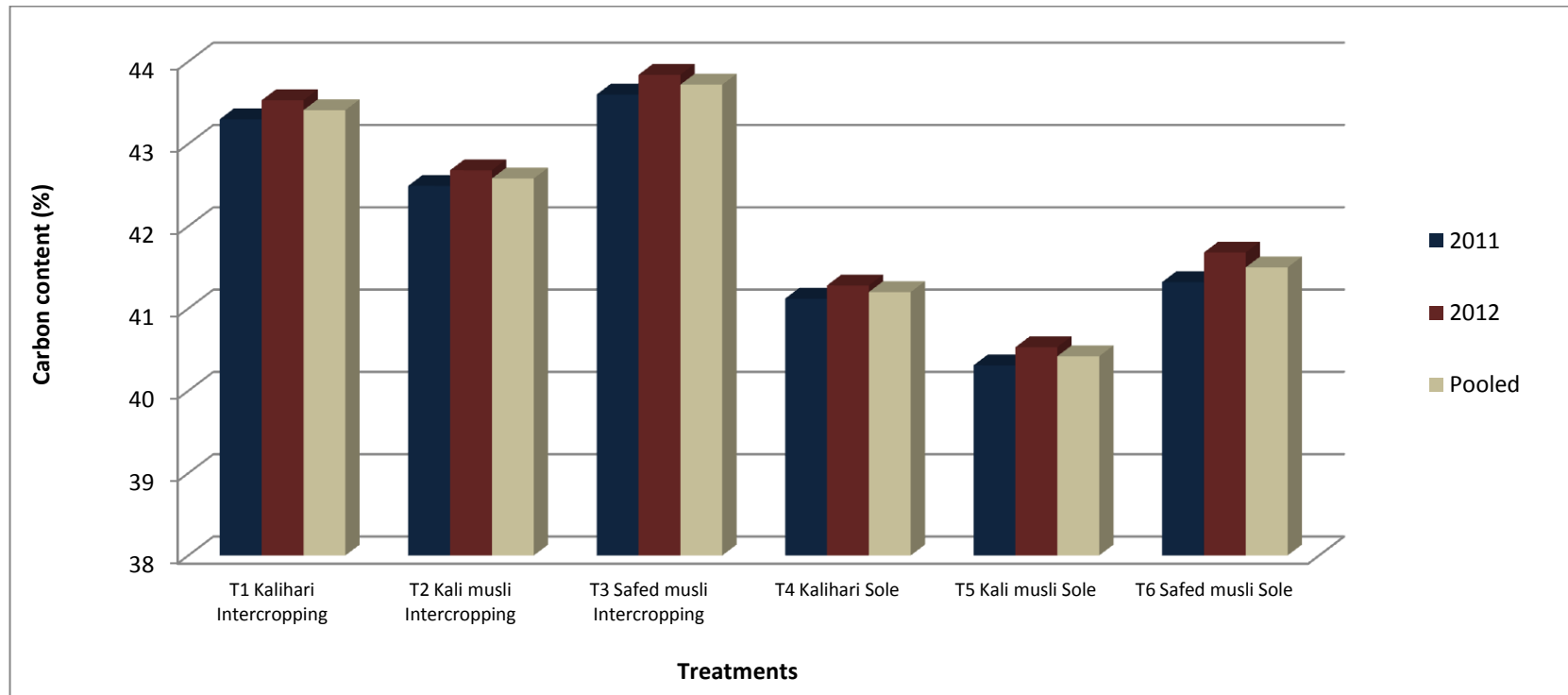
*Figure in parenthesis indicates percentage increases over respective sole cropping

Table - 4.38 Carbon content in plant at harvest of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Carbon Content (%)		
	2011	2012	Pooled
T₁ - Kalihari Intercrop	43.30 (5.30)*	43.53 (5.45)*	43.41 (5.36)*
T₂ – Kali musli Intercrop	42.49 (5.41)*	42.68 (5.30)*	42.58 (5.34)*
T₃ – Safed musli Intercrop	43.60 (5.52)*	43.84 (5.18)*	43.72 (5.35)*
T₄ - Kalihari Sole	41.12	41.28	41.20
T₅ – Kali musli Sole	40.31	40.53	40.42
T₆ – Safed musli Sole	41.32	41.68	41.50
S. Em ±	1.353	1.970	1.195
CD at 5 %	NS	NS	NS
CV %	6.44	9.33	8.02

*Figure in parenthesis indicates percentage increases over respective sole cropping

Figure - 29 Carbon content in plant at harvest of tuber crops as influenced by Sapota- Jatropha three-tier agroforestry system.



4.4.2.3.2 Nitrogen content (%)

Result obtained from study indicates that significantly different total content of nitrogen at harvest of sole crop and grown under Sapota-Jatropha are observed (Table – 4.39 and Figure – 30). The maximum content of nitrogen was recorded in intercropping of all tuber crops grown under Sapota-Jatropha as compared to sole cropping.

In 2011 kalihari, kali musli and safed musli intercrop under Sapota-Jatropha treatment (T₁, 1.086 %, T₂, 1.226 % and T₃, 1.244 %) noted maximum content of nitrogen which was on same bar with its sole crop of kalihari, kali musli and safed musli (T₄, 1.079 %, T₅, 1.215 % and T₆, 1.232 %).

Further perusal of data reveals that tuber crops (kalihari, kali musli and safed musli) in second year and pooled analysis showed the similar trend and result as that of first year.

During first year percent increase in content of nitrogen in plants was recorded maximum in safed musli (0.97 %) which was followed by kali musli (0.91 %) and kalihari (0.65 %). Similar trend of results were obtained in case of second year and pooled result.

4.4.2.3.3 Phosphorus content (%)

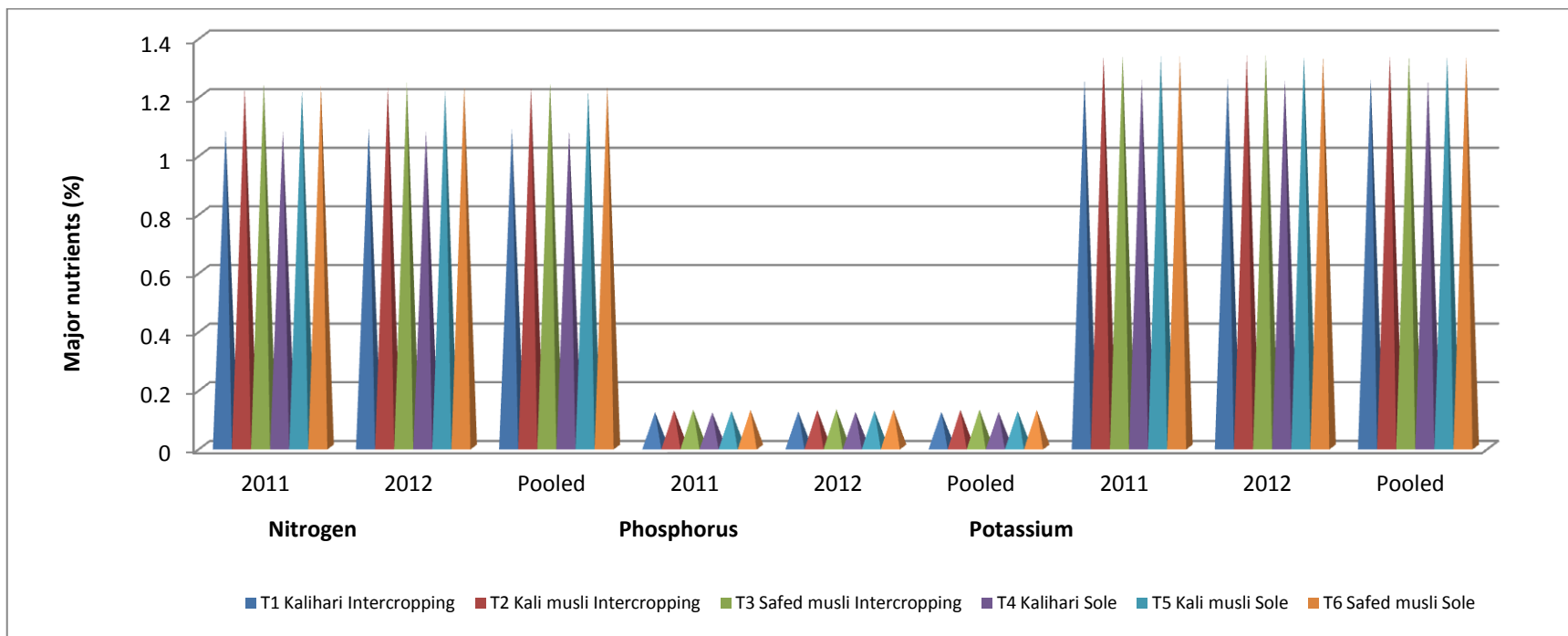
It can be elucidated from the data depicted in Table – 4.39 and illustrated in Figure - 30 that the content of phosphorus by tuber crops after the harvest of crops was non-significant under Sapota-Jatropha and sole crops during 2011, 2012 and in their mean data.

Table - 4.39 Major nutrients content in plant at harvest of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
T₁ - Kalihari Intercrop	1.086 (0.65)*	1.088 (0.83)*	1.087 (0.74)*	0.119 (0.85)*	0.121 (0.83)*	0.120 (0.84)*	1.256 (0.16)*	1.258 (0.32)*	1.257 (0.24)*
T₂ – Kali musli Intercrop	1.226 (0.91)*	1.228 (0.99)*	1.227 (0.90)*	0.126 (2.44)*	0.127 (2.42)*	0.127 (3.25)*	1.335 (0.07)*	1.336 (0.15)*	1.336 (0.15)*
T₃ – Safed musli Intercrop	1.244 (0.97)*	1.244 (0.89)*	1.244 (0.97)*	0.128 (0.79)*	0.129 (0.78)*	0.128 (0.79)*	1.337 (0.22)*	1.338 (0.22)*	1.337 (0.22)*
T₄ - Kalihari Sole	1.079	1.079	1.079	0.118	0.120	0.119	1.254	1.254	1.254
T₅ – Kali musli Sole	1.215	1.216	1.216	0.123	0.124	0.123	1.334	1.334	1.334
T₆ – Safed musli Sole	1.232	1.233	1.232	0.127	0.128	0.127	1.334	1.335	1.334
S. Em ±	0.040	0.042	0.029	0.005	0.006	0.004	0.040	0.059	0.036
CD at 5 %	0.12	0.12	0.08	NS	NS	NS	NS	NS	NS
CV %	6.82	7.14	6.98	7.24	8.76	8.04	6.15	8.95	7.68

*Figure in parenthesis indicates percentage increases over respective sole cropping

Figure - 30 Major nutrients content in plant at harvest of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system.



4.4.2.3.4 Potassium content (%)

The total content of potassium by tuber crops at harvest under Sapota-Jatropha and sole crops is exhibited in Table – 4.39 and depicted in Figure – 30. All the tuber intercrops in their sole stand recorded non-significant results with comparison to their respective intercropping systems during 2011, 2012 and in their mean data.

4.4.2.3.5 Calcium content (%)

The total content of calcium at harvest of tuber crops of sole crops and grown under Sapota-Jatropha is exhibited in Table – 4.40. All the tuber crops in their intercropping under Sapota-Jatropha and their respective sole cropping differed non-significantly with respect to their calcium.

4.4.2.3.6 Magnesium content (%)

The data regarding content of magnesium at harvest under Sapota-Jatropha and sole crop are tabulated in Table – 4.40. The statistical comparison showed that content of magnesium by tuber crops as affected by intercrops and sole crops are found non-significant for both years (2011 and 2012) and in pooled analysis also.

4.4.2.3.7 Iron content (ppm)

The mean data pertaining to variation in the total content of iron after the harvest of tuber crops are presented in Table – 4.41. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The total content of iron by crops was recorded higher when tuber crops grown under Sapota-Jatropha as compared to sole cropping.

Table - 4.40 Secondary nutrients content in plant at harvest of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Calcium (%)			Magnesium (%)		
	2011	2012	Pooled	2011	2012	Pooled
T₁ - Kalihari Intercrop	1.546 (0.26)*	1.548 (0.32)*	1.547 (0.32)*	0.438 (0.23)*	0.440 (0.46)*	0.439 (0.46)*
T₂ – Kali musli Intercrop	1.570 (0.06)*	1.571 (0.00)*	1.571 (0.06)*	0.453 (0.22)*	0.454 (0.00)*	0.453 (0.00)*
T₃ – Safed musli Intercrop	1.575 (0.06)*	1.576 (0.00)*	1.575 (0.00)*	0.457 (0.44)*	0.459 (0.66)*	0.458 (0.44)*
T₄ - Kalihari Sole	1.542	1.543	1.542	0.437	0.438	0.437
T₅ – Kali musli Sole	1.569	1.571	1.570	0.452	0.454	0.453
T₆ – Safed musli Sole	1.574	1.576	1.575	0.455	0.456	0.456
S. Em ±	0.049	0.068	0.042	0.019	0.020	0.014
CD at 5 %	NS	NS	NS	NS	NS	NS
CV %	6.300	8.630	7.550	8.510	9.020	8.770

*Figure in parenthesis indicates percentage increases over respective sole cropping

During 2011 the data corresponding to the content of iron the kalihari, kali musli and safed musli grown under Sapota-Jatropha treatment (T₁, 123.56 %, T₂, 145.54 % and T₃, 146.43 %) noted maximum content of iron which was on same bar with sole kalihari, kali musli and safed musli (T₄, 123.54 %, T₅, 145.50 % and T₆, 146.41 %).

Further perusal of data revealed that tuber crops (kalihari, kali musli and safed musli) in second year and pooled analysis showed the similar trend and result of first year.

During 2011 percent increase in content of iron in plant was observed in kali musli (0.03 %) which was followed by kalihari (0.02 %) and safed musli (0.01 %). Same result was found in second year and pooled result.

4.4.2.3.8 Manganese content (ppm)

The data regarding that total content of manganese at harvest of different tuber crops are presented in Table – 4.41. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The total content of manganese was noted maximum in intercropping under Sapota-Jatropha as compared to sole cropping.

The data pertaining in Table – 4.41 show that in first year of study, higher content of manganese was found when kalihari, kali musli and safed musli grown under Sapota-Jatropha (T₁, 45.34 %, T₂, 56.76 % and T₃, 67.54 %) which statistically at par with sole kalihari, kali musli and safed musli (T₄, 45.30 %, T₅, 56.74 % and T₆, 67.50 %).

The mean data of second year (2012) trial and pooled analysis showed the same result and same trend in total content of manganese of all tuber crops (kalihari, kali musli and safed musli) as per the trend of first year result.

During 2011, percent increase in content of manganese in plant was noted maximum in kalihari (0.09 %) which was followed by safed musli (0.06 %) and kali musli (0.04 %). Similar result was found in second year and pooled data.

4.4.2.3.9 Zinc content (ppm)

The mean data pertaining to variation in the total content of zinc after the harvest of tuber crops are presented in Table – 4.41. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The total content of zinc was recorded higher when tuber crops grown under Sapota-Jatropha as compared to sole cropping.

The result summarized in Table – 4.41 indicates that during 2011 kalihari, kali musli and safed musli when grown under Sapota-Jatropha (T₁, 18.86 %, T₂, 29.76 % and T₃, 30.45 %, respectively) were observed higher content of zinc which was on same bar over their respective sole crop (T₄, 18.84 %, T₅, 29.74 % and T₆, 30.40 %) respectively.

In second year and in pooled analysis, the similar scenario of total content of zinc in kalihari, kali musli and safed musli tuber crops were observed as in the case of first year result.

During 2011 percent increase in content of zinc was maximum in safed musli (0.16 %) which was followed by kalihari (0.11 %) and kali musli (0.07 %). Similar result was found in second year and pooled data.

Table - 4.41 Micro nutrients content in plant at harvest of tuber crops as influenced by Sapota-Jatropha three-tier agroforestry system

Treatment	Iron (ppm)			Manganese (ppm)			Zinc (ppm)			Copper (ppm)		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
T₁ - Kalihari Intercrop	123.56 (0.02)*	124.06 (0.02)*	123.81 (0.02)*	45.34 (0.09)*	45.59 (0.09)*	45.47 (0.09)*	18.86 (0.11)*	19.11 (0.10)*	18.99 (0.11)*	9.34 (0.21)*	9.36 (0.32)*	9.35 (0.32)*
T₂ – Kali musli Intercrop	145.54 (0.03)*	145.79 (0.03)*	145.67 (0.03)*	56.76 (0.04)*	57.01 (0.04)*	56.89 (0.04)*	29.76 (0.07)*	30.01 (0.07)*	29.89 (0.07)*	13.24 (0.30)*	13.26 (0.38)*	13.25 (0.30)*
T₃ – Safed musli Intercrop	146.43 (0.01)*	146.68 (0.01)*	146.56 (0.01)*	67.54 (0.06)*	67.79 (0.06)*	67.67 (0.06)*	30.45 (0.16)*	30.70 (0.16)*	30.58 (0.16)*	13.89 (0.29)*	13.91 (0.36)*	13.90 (0.29)*
T₄ - Kalihari Sole	123.54	124.04	123.79	45.30	45.55	45.43	18.84	19.09	18.97	9.32	9.33	9.32
T₅ – Kali musli Sole	145.50	145.75	145.63	56.74	56.99	56.87	29.74	29.99	29.87	13.20	13.21	13.21
T₆ – Safed musli Sole	146.41	146.66	146.54	67.50	67.75	67.63	30.40	30.65	30.53	13.85	13.86	13.86
S. Em ±	4.248	5.035	3.294	1.765	2.290	1.446	0.818	1.255	0.749	0.403	0.435	0.296
CD at 5 %	12.80	15.17	9.51	5.32	6.90	4.18	2.46	3.78	2.16	1.21	1.31	0.86
CV %	6.13	7.25	6.72	6.25	8.07	7.22	6.21	9.44	8.00	6.63	7.15	6.90

*Figure in parenthesis indicates percentage increases over respective sole cropping

4.4.2.3.10 Copper content (ppm)

The mean data pertaining to variation in the total content of copper after the harvest of tuber crops are presented in Table – 4.41. The results were found significant during both the years (2011 and 2012) and in pooled analysis. The total content of copper by tuber crops was recorded higher when tuber crops grown under Sapota-Jatropha as compared to sole cropping.

During 2011, the data corresponding to the content of copper, the kalihari, kali musli and safed musli under Sapota-Jatropha treatment (T_1 , 9.34 %, T_2 , 13.24 % and T_3 , 13.89 %) noted maximum content of copper which was on same bar with sole kalihari, kali musli and safed musli (T_4 , 9.32 %, T_5 , 13.20 % and T_6 , 13.85 %).

Further perusal of data revealed that tuber crops (kalihari, kali musli and safed musli) in second year and pooled analysis showed the similar trend and result of first year.

During 2011, percent increase in content of copper in plant was recorded maximum in kali musli (0.30 %) which was followed by safed musli (0.29 %) and kalihari (0.21 %). With regards to the second year and pooled data, it showed the similar trend to those of the result of first year.

4.4.3. Plant protection measures

No severe attack of any pest or disease was recorded in tuber crops during the entire study.

4.4.4. Economic analysis

The data on cost of cultivation, gross returns, net returns and benefit cost ratio (B:C) as influenced by sole tuber medicinal crops and intercrop under Sapota-Jatropha are presented in Table - 4.42 in both the year 2011 and 2012.

During 2011, tuber medicinal crops under Sapota-Jatropha kalihari, kali musli and safed musli recorded higher benefit cost ratio (1:3.05, 1:2.20 and 1:2.04) as compared to sole kalihari, kali musli and safed musli (1:2.37, 1:1.44 and 1:2.02).

In the second year trial, the intercropping of tuber medicinal crops under Sapota-Jatropha kalihari, kali musli and safed musli recorded higher benefit cost ratio (1:3.06, 1:2.25 and 1:2.21) as compared to sole kalihari, kali musli and safed musli (1:2.38, 1:1.45 and 1:2.20).

Compared to all treatments studied, treatment T₁ kalihari under Sapota-Jatropha recorded higher B:C (1:3.05 and 1:3.06) in both the years compared to all other treatments viz., T₄, T₂, T₃, T₆ and T₅.

Economically following trend was evident in intercrops Kalihari > Kali musli > Safed musli whereas among the sole crop trend was seen Kalihari > Safed musli > Kali musli.

Table – 4.42 Economics of growing tuber crops (Kalihari, Kali musli and Safed musli) under Sapota-Jatropha based three-tier agroforestry system (First year, 2011)

Treatments	Yield (q/ha)			Cost of various products (₹ /ha)			Total cost of production (₹ /ha)	Gross income (₹ /ha)			Grand total (₹ /ha)	Net income (₹ /ha)	BCR	LER
	Sapota	Jatropha	Tuber	Planting material	NPK	Cost of cultivation		Sapota	Jatropa	Tuber				
T ₁ - (Basil Intercrop)	70	2.25	3.48	12000	13500.90	22000	47500.90	70000	5625	69600	145225	97724.10	1:3.05	1.36
T ₂ - (Kalmegh Intercrop)	70	2.25	1.98	24000	10926.45	22000	56926.45	70000	5625	49500	125125	68198.55	1:2.20	1.30
T ₃ - (Mint Intercrop)	70	2.25	4.41	240000	13073.90	22000	275073.90	70000	5625	485100	560725	285651.10	1:2.04	1.34
T ₄ - (Basil Sole)	-	-	8.33	27777	13500.90	29080	70357.90	-	-	166600	166600	96242.10	1:2.37	-
T ₅ - (Kalmegh Sole)	-	-	5.52	55555	10926.45	29080	95561.45	-	-	138000	138000	42438.55	1:1.44	-
T ₆ - (Mint Sole)	-	-	10.99	555555	13073.90	29080	597708.90	-	-	1208900	1208900	611191.10	1:2.02	-

1. Rate of kalihari : 1 Rs /2 plant
2. Rate of kali musli : 1 Rs /2 plant
3. Rate of safed musli : 5 Rs / plant
4. Whole sale price of kalihari : 200 Rs/kg
5. Whole sale price of kali musli : 250 Rs/kg
6. Whole sale price of safed musli : 1100 Rs/kg
- Conti.....

7. Sapota : 10 Rs/kg
8. Jatropha : 25 Rs/kg
9. Labour charge : 120 Rs/day
10. Price of Nitrogen : 9.75 Rs/kg
11. Price of Phosphorus : 32.10 Rs/kg
12. Price of Potassium : 20.12 Rs/kg

Table – 4.42 Economics of growing tuber crops (Kalihari, Kali musli and Safed musli) under Sapota-Jatropha based three-tier agroforestry system (Second year, 2012)

Treatments	Yield (q/ha)			Cost of various products (₹ /ha)			Total cost of production (₹ /ha)	Gross income (₹ /ha)			Grand total (₹ /ha)	Net income (₹ /ha)	BCR	LER
	Sapota	Jatropha	Tuber	Planting material	NPK	Cost of cultivation		Sapota	Jatropha	Tuber				
T ₁ - (Basil Intercrop)	75	2.25	3.60	12000	15004.50	24100	51104.50	75000	5625	75600	156225	105120.50	1:3.06	1.34
T ₂ - (Kalmegh Intercrop)	75	2.25	2.05	24000	11304.75	24100	59404.75	75000	5625	53300	133925	74520.25	1:2.25	1.29
T ₃ - (Mint Intercrop)	75	2.25	4.45	240000	14355.05	24100	278455.05	75000	5625	534000	614625	336169.95	1:2.21	1.32
T ₄ - (Basil Sole)	-	-	8.61	27777	15004.50	33250	76031.50	-	-	180810	180810	104778.50	1:2.38	-
T ₅ - (Kalmegh Sole)	-	-	5.56	55555	11304.75	33250	100109.75	-	-	144560	144560	44450.25	1:1.45	-
T ₆ - (Mint Sole)	-	-	11.12	555555	14355.05	33250	603160.05	-	-	1334400	1334400	731239.95	1:2.20	-

1. Rate of kalihari : 1 Rs /2 plant
2. Rate of kali musli : 1 Rs /2 plant
3. Rate of safed musli : 5 Rs / plant
4. Whole sale price of kalihari : 210 Rs/kg
5. Whole sale price of kali musli : 260 Rs/kg
6. Whole sale price of safed musli : 1200 Rs/kg

7. Sapota : 10 Rs/kg
8. Jatropha : 25 Rs/kg
9. Labour charge : 150 Rs/day
10. Price of Nitrogen : 12.68 Rs/kg
11. Price of Phosphorus : 46.25 Rs/kg
12. Price of Potassium : 29.40 Rs/kg

Discussion



V. DISCUSSION

Crop performance under given environmental conditions is dependent on nature and composition of cropping system in vogue. For instance imposition of intercropping not only alters the conditions available for the pure crop by competition but also influences complementarity of one species over the other. Results of field experiments “The horticultural, silvicultural and medicinal crops in three-tier agroforestry system” conducted at the Agronomy Farm (Bock-E), ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat) during rainy season of 2011 and 2012 are discussed in this chapter along with earlier findings.

5.1 Growth status of Sapota

At the harvesting stage of observations, Sapota recorded more plant height, stem girth, number of primary branches and crown spread East-West and North-South when compared to initial stage of observation for the year 2011. During the second year (2012) it showed the same trend as per the results of first year (Table - 4.1). This may be due to the effect of application of fertilizer to the crop grown as an intercrops of herbal and tuber medicinal crops. This might also be due to suitable climatic condition of south Gujarat.

5.2 Growth status of Jatropha

The results presented in Table - 4.2 clearly showed that at the harvesting stage, Jatropha recorded more plant height, stem girth, number of primary branches and crown spread East-West and North-South when compared at the initial stage for the year 2011. During the second year (2012) it showed the same trend as per the results of first year. This may be due to the effect of application of fertilizer to crop grown as an

intercrops of herbal and tuber medicinal crops. It is also due to its genetic make-up and better compatibility of trees with regard to the prevailing edapho-climatic condition.

5.3 Experiment-I Performance of herbal crops (Basil, Kalmegh and Mint) under three-tier agroforestry system

5.3.1 Growth and yield parameter

It has been observed that when two or more crops are grown as intercrops, their yields are generally reduced in intercropping system as compared to their yields obtained under sole cropping systems, although combined yield may be higher than either of the sole crops.

5.3.1.1. Plant height (cm)

Significantly higher plant height was observed under Sapota-Jatropha in all the herbal medicinal crops basil, kalmegh and mint than open condition for the year 2011, 2012 and in pooled analysis also (Table - 4.3). This might be due to their ability to retain more soil moisture and better microclimate. Secondly it might be due to less light intensity under intercropping as compared to open condition. These results are in conformity with the findings of Arya *et al.* (2011), Kumar (2010 b) in safed musli, Vanlalhluna and Sahoo (2010) in ginger, turmeric, maize, Venugopal *et al.* (2008) in patchouli, Saroj *et al.* (2003) in groundnut, wheat, cluster bean, mustard, Singh *et al.* (1997) in turmeric and Nair *et al.* (1991).

5.3.1.2. Number of branches per plant

All the herbal medicinal crops basil, kalmegh and mint produced significantly more number of branches under open condition as compared to under

Sapota-Jatropha based cropping for the year 2011, 2012 and in pooled analysis also (Table - 4.4). The possible reason can be attributed to this phenomenon is that the available light, space, water or nutrients in a pure cropping system result in production of more number of branches. As light passes through the tree canopy in plantations, changes perceived by the plants through the phytochemical system may induce marked morphogenetic changes in plant and inhibit branching. Similar results were corroborated by Rathod *et al.* (2010), Nanda and Reghunath (2008), Venugopal *et al.* (2008) and Shinde (2001).

5.3.1.3. Fresh weight per plant (g)

The significantly maximum values of fresh weight per plant was recorded in the sole basil, kalmegh and mint herbal medicinal crops as compared to intercropped basil, kalmegh and mint herbal medicinal crops under Sapota-Jatropha for the year 2011, 2012 and in pooled analysis also (Table - 4.5). This was due to the uninterrupted and adequate amount of incident sunlight besides, zero tree-crop competition. Similar result were found by Vanlalhluna and Sahoo (2010), Venugopal *et al.* (2008), Parekh *et al.* (2005), Thakur and Dutt (2003), Shinde (2001), Nair *et al.* (1991) and George and Nair (1987).

5.3.1.4. Dry weight per plant (g)

Significantly maximum values of dry weight per plant was recorded in the sole basil, kalmegh and mint herbal medicinal crops as compared to grown under Sapota-Jatropha for the year 2011, 2012 and in pooled analysis also (Table - 4.6). This may be due to less competition for light, nutrient and moisture in open condition for synthesizing food material. Similar results were found by Vanlalhluna and Sahoo (2010), Venugopal

et al. (2008), Shinde (2001), Singh *et al.* (1997), Nair *et al.* (1991) and George and Nair (1987).

5.3.1.5. Fresh weight of plant per plot (kg)

The fresh weight of plant per plot was observed significantly maximum in open condition in all the herbal medicinal crops than under Sapota-Jatropha for the year 2011, 2012 and in pooled analysis also (Table - 4.7). This might be due to more light availability under open field condition and no competition for nutrients by the trees. The probable reason for minimum dry weight beneath the tree reflects the poor resources for growth such as moisture, nutrients and radiant energy. Similar result was found by Parekh *et al.* (2005), Thakur and Dutt (2003) and Shinde (2001).

5.3.1.6. Dry weight of plant per plot (kg)

Dry weight of plant per plot was observed significantly maximum in open condition in all the herbal medicinal crops than under shade condition for the year 2011, 2012 and in pooled analysis also (Table - 4.8). This account for the greater exposed photosynthetic area, ensuring greater interception of solar radiation, must have immensely helped the crop plants to maintain greater photosynthesis farther away from the trees. Similar result was found by Shinde (2001) and Singh *et al.* (1997).

5.3.1.7. Crown spread (E-W & N-S) (cm)

Crown spread of East-West and North-South in basil, kalmegh and mint were found to be significantly higher in open condition as compared to intercropped under Sapota-Jatropha of basil, kalmegh and mint while, crown spread of North-South in basil was significantly higher under Sapota-Jatropha as compared to open during 2011, 2012 and pooled data (Table - 4.9 and 4.10). This may be due to more branching and

sidewise growth of plants resulting from their profuse growth under open conditions. The primary reason for the decrease in the spread of plants under shade may be the reduction in the number of branches under Sapota-Jatropha shaded conditions. Similar results were corroborated by Rathod *et al.* (2010), Nanda and Reghunath (2008) and Venugopal *et al.* (2008).

5.3.1.8. Economic yield (q/ha)

In case of economic yield, the mean yield of basil, kalmegh and mint in open conditions which was significantly higher as compared to that obtained from intercrop under Sapota-Jatropha (Table - 4.11). It might be due to reduction in light intensity as a result of shading the photosynthetic ability of the secondary canopy for reducing the total photosynthate output from the plants. These results are in line with Rathod *et al.* (2010), Kumar *et al.* (2008), Sehgal and Thakur (2008), Venugopal *et al.* (2008), Thakur and Dutt (2007), Thakur and Kumar (2006), Mohsin (2005) in mint, Parekh *et al.* (2005), Saroj *et al.* (2003), Shinde (2001), Singh (2000), Singh *et al.* (1997) and George and Nair (1987).

5.3.1.9 Survival percent

The survival percent of basil, kalmegh and mint all herbal medicinal plant grown under Sapota-Jatropha and sole stand was found non-significant in their respective intercropping systems during 2011, 2012 and in their mean data (Table - 4.12). This may be due to their capability in establishing root system. It may also be due to the possibility of their beneficial compatibility, interaction and greater biological efficiency of crop grown in association.

5.3.2 Light and nutrients

5.3.2.1 Light intensity

In the present investigation, the light intensity in the system showed significant differences due to intercropping systems. The sole crop of basil, kalmegh and mint recorded significantly higher light intensity as compared to the intercropped under Sapota-Jatropha in both the years (Table – 4.13). This may be due to higher crown spread and dense canopy of Sapota and Jatropha. These results are in conformity with the results of Rathod *et al.* (2010) in senna crop, Kumar *et al.* (2008), Thakur and Dutt (2007) and Basavaraju *et al.* (2001).

5.3.2.2 Nutrient status in soil

5.3.2.2.1 Organic carbon

Content of organic carbon in soil was higher under intercrop of basil, kalmegh and mint under Sapota-Jatropha as compared to sole cropping of basil, kalmegh and mint (Table - 4.14). This may be due to more litterfall from trees and it may also be due to decomposition of litter. This is supported by Jaimini *et al.* (2006).

5.3.2.2.2 Major nutrients

Content of major nutrients such as N, P, K in soil were higher under intercropping of basil, kalmegh and mint under Sapota-Jatropha as compared to sole cropping of basil, kalmegh and mint (Table - 4.15). This may be due to higher microbial activities coupled with recycling of nutrients through leaf litter and more favorable physical condition viz., soil moisture, temperature under trees than sole. This is supported by Vanlalhluna and Sahoo (2010), Qaisar *et al.* (2007), Jaimini *et al.* (2006), Kaur *et al.* (2002) and Menezes *et al.* (2002) and Shinde (2001).

5.3.2.2.3 Secondary nutrients

Content of secondary nutrients like Ca and Mg in soil under intercropping of basil, kalmegh and mint under Sapota-Jatropha as compared to sole cropping of basil, kalmegh and mint were found non-significant difference (Table - 4.16). This may be due to all these nutrients are not added in significant quantity via process of recycling by leaf litter added by Sapota-Jatropha.

5.3.2.2.4 Micro nutrients

The data presented in Table - 4.17 clearly revealed that content of micro nutrients such as Fe, Mn, Zn, Cu in soil under intercropping of basil, kalmegh and mint with Sapota-Jatropha as compared to sole cropping of basil, kalmegh and mint were found non-significant. Sapota-Jatropha as tree component have failed in altering the status of micronutrients through addition of leaf litter.

5.3.2.3 Nutrient content in herbal crops

5.3.2.3.1 Organic carbon

It is evident from results presented in Table - 4.18 that organic carbon content was found non - significant in basil, kalmegh and mint under Sapota-Jatropha as compared to sole crop of basil, kalmegh and mint. Organic carbon content being the basic building blocks are ought to be the same, however, in term of total biomass the organic carbon will differ greatly.

5.3.2.3.2 Major nutrients

Looking to the data presented in Table - 4.19 it is seen that higher content of major nutrients N, P, K were found under intercropping of basil, kalmegh and mint

under Sapota-Jatropha as compared to sole crop of basil, kalmegh and mint. The content of all these nutrients increased with increased shade. Higher nutrient in intercropping which might be due to lesser weed competition there by higher absorption and utilization. Similar result was reported by Mohsin (2005) in mint and Rao *et al.* (2000) in nutrient removal in palmarosa and blackgram intercropping system.

5.3.2.3.3 Secondary nutrients

The content of secondary nutrients Ca was found significant and Mg was found non - significant under Sapota-Jatropha of basil, kalmegh and mint as compared to sole crop of basil, kalmegh and mint (Table - 4.20). The content of all these nutrients increased with increase in shade. Higher nutrient in intercropping which might be due to lesser weed competition there by higher absorption and utilization.

5.3.2.3.4 Micro nutrients

Higher content of micro nutrient viz., Fe, Mn, Zn, Cu were found under intercropping of basil, kalmegh and mint under Sapota-Jatropha as compared to sole crop of basil, kalmegh and mint (Table - 4.21). All these nutrients are increased with increase in shade probably due to their accumulation under shaded condition. It also may be due to a possible synergistic effect caused by relative shading and due to more contribution of organic matter to the soil by Sapota and Jatropha.

5.3.2.4 Economics

The economic returns measure the profitability of a system. The farmers adopt only such practices that are more profitable and viable over longer period.

The intercropping of herbal medicinal crops basil, kalmegh and mint recorded higher benefit cost ratio as compared to sole basil, kalmegh and mint. Compared to all treatments studied, treatment T₁ basil under Sapota-Jatropha recorded higher B:C as compared to all other treatments in both the years 2011 and 2012 (Table – 4.22). The reason may attributed to the compatibility of these crops under investigation with regard to their growth habit, nutrient requirement as well as light and moisture conditions and ultimately reflected in terms of better productivity and higher economic yields and returns. Similar results were observed by Kumar *et al.* (2010) in safed musli, Kumar *et al.* (2008), Ram *et al.* (1999), Singh *et al.* (1998a), Singh *et al.* (1998b) in *E. citriodora* with geranium, Maheshwari *et al.* (1997), RajeswaraRao *et al.* (1993), Kothari *et al.* (1987) in sugarcane and mint and Maheshwari *et al.* (1985) in *Rauvolfia serpentine* with soybean and garlic or onion.

5.4 Experiment-II Performance of tuber crops (Kalihari, Kali musli and Safed musli) under three-tier agroforestry system.

5.4.1 Growth and yield parameters

It is known that when two or more crops are grown as intercrops, their yields are generally reduced in intercropping system as compared to their yields obtained under sole cropping systems, although combined yield may be higher than either of the sole crops.

5.4.1.1. Plant height (cm)

Significantly higher plant height was observed under Sapota-Jatropha in all the tuber medicinal crops kalihari, kali musli and safed musli than open condition for the 2011, 2012 and in pooled analysis also (Table - 4.23). This might be due to their

ability to retain more soil moisture due to shade and better microclimate under better soil moisture retention and this may also be the reason for better plant height performance of the trees in cropped than the un-cropped plots. These results are in conformity with the findings of Arya *et al.* (2011), Vanlalhluna and Sahoo (2010), Kumar (2010) in safed musli, Venugopal *et al.* (2008), Saroj *et al.* (2003), Singh *et al.* (1997) and Nair *et al.* (1991). Mainly due to tree crop competition for light.

5.4.1.2. Number of tubers per plant

All the tuber medicinal crops kalihari, kali musli and safed musli produced significantly more number of tubers under open condition as compared to Sapota-Jatropha based cropping for the year 2011, 2012 and in pooled analysis also (Table - 4.24). The possible reason can be attributed to this phenomenon is that the available light, space, water or nutrients in a pure cropping system result in production of more number of tubers. As light passes through the tree canopy in plantations the plants through the phytochemical system may induce marked morphogenetic changes in plant and inhibit branching. Similar results were corroborated by Thakur and Dutt (2003).

5.4.1.3. Length of tuber (cm)

It is obvious from result presented in Table – 4.25 that length of tubers was found to be significantly higher in sole crop of kalihari and kali musli as compared to intercropped of kalihari and kali musli under Sapota-Jatropha. This may be due to more light availability under open condition and absence of competition from trees and more photosynthesis. Similar result was observed by Thakur and Dutt (2003). Maximum length of tuber in safed musli was found under Sapota-Jatropha intercrop compared to sole crop of safedmusli. Similar results were corroborated by Kumar *et al.* (2010).

5.4.1.4. Girth of tuber (cm)

From the results presented in Table – 4.26 it is evident that girth of tuber was observed to be maximum in sole crop of kalihari, kali musli and safed musli as compared to intercropped under Sapota-Jatropha. This might be due to the fact that plants grown in open condition have better opportunities to reap the solar energy requirement for photosynthetic activity for the production of photosynthates and increased carbohydrate synthesis which is ultimately reflected as better growth and production of biomass.

5.4.1.5. Fresh weight of tuber per plant (g)

The significantly maximum values of fresh weight of tuber per plant was recorded in the sole kalihari, kali musli and safed musli tuber medicinal crops as compared to intercropped under Sapota-Jatropha for the year 2011, 2012 and in pooled analysis also (Table - 4.27). This was due to the uninterrupted and adequate amount of incident sunlight besides, zero tree-crop competition ultimately leading to higher growth and biomass. Similar result was found by Vanlalhluna and Sahoo (2010), Venugopal *et al.* (2008), Parekh *et al.* (2005), Thakur and Dutt (2003), Shinde (2001), Nair *et al.* (1991) and George and Nair (1987).

5.4.1.6. Dry weight of tuber per plant (g)

The dry weight of tuber per plant was recorded significantly maximum in the sole kalihari, kali musli and safed musli tuber medicinal crops as compared to intercropped under Sapota-Jatropha for the year 2011, 2012 and in pooled analysis also (Table - 4.28). This may be due to less competition for light, nutrient and moisture in open condition for synthesizing food material. This result is in close proximity with the

earlier findings of Vanlalhluna and Sahoo (2010), Venugopal *et al.* (2008), Shinde (2001), Singh *et al.* (1997), Nair *et al.* (1991) and George and Nair (1987).

5.4.1.7. Fresh weight of tuber per plot (kg)

It is evident from results presented in Table – 4.29 that significantly higher fresh weight of tuber per plot was observed in open condition in all the tuber medicinal crops kalihari, kali musli and safed musli than under Sapota-Jatropha for the year 2011, 2012 and in pooled analysis. This might be due to more light availability under open field condition and no competition for nutrients by the trees. The reason for minimum dry weight beneath the tree reflects the poor resources for growth such as moisture, nutrients and radiant energy. This result is in close line with earlier findings of Parekh *et al.* (2005), Thakur and Dutt (2003) and Shinde (2001). Also the reduced light intensity in the present investigation supports this hypothesis.

5.4.1.8. Dry weight of tuber per plot (kg)

Significantly higher dry weight of tuber per plot was observed in open condition in all the tuber medicinal crops kalihari, kali musli and safed musli than under Sapota-Jatropha shade condition for the year 2011, 2012 and in pooled analysis also (Table - 4.30). This might be due to more light availability under open field condition and no competition for nutrients by the trees. The reason for minimum dry weight beneath the tree reflects the poor resources for growth such as moisture, nutrients and radiant energy. This result is analogous with earlier findings of Shinde (2001) and Singh *et al.* (1997).

5.4.1.9. Economic yield (q/ha)

In case of economic yield, the mean yield of kalihari, kali musli and safed musli in open conditions was significantly higher as compared to that obtained from the crop grown under the shade of Sapota-Jatropha (Table - 4.31). It may be due to greater availability of solar energy for photosynthesis coupled with lack of competition by tree component. Similar results were recorded by Rathod *et al.* (2010), Kumar *et al.* (2008), Sehgal and Thakur (2008), Venugopal *et al.* (2008), Thakur and Dutt (2007), Thakur and Kumar (2006), Mohsin (2005) in mint, Saroj *et al.* (2003), Shinde (2001), Singh (2000), Singh *et al.* (1997) and George and Nair (1987).

5.4.1.10. Survival percent

The survival percent of sole tuber medicinal crops of kalihari, kali musli and safed musli has higher as compared to intercrop under Sapota-Jatropha respectively (Table - 4.32). This may due to their capability in establishing root system. It may also due to the possibility of their beneficial compatibility, interaction and greater biological efficiency of crop grown in association.

5.4.2 Light and nutrients

5.4.2.1 Light intensity

In the present investigation, the light intensity reaching the system showed significant differences due to intercropping systems. The sole crop of kalihari, kali musli and safed musli recorded significantly higher light intensity as compared to the intercropped under Sapota-Jatropha in both the years (Table - 4.33). This may be due to higher crown spread and dense canopy of trees. Similar result was observed by Rathod

et al. (2010) in senna crop, Kumar *et al.* (2008), Thakur and Dutt (2007) and Basavaraju *et al.* (2001).

5.4.2.2 Nutrient status in soil

5.4.2.2.1 Organic carbon

The organic carbon content in soil was higher under intercropping of kalihari, kali musli and safed musli under Sapota-Jatropha as compared to sole cropping of kalihari, kali musli and safed musli (Table - 4.34). This may be due to more litterfall from trees and it also due to decomposition of litter over the years. This is supported by Jaimini *et al.* (2006).

5.3.2.2.2 Major nutrients

The major nutrients such as N, P, K in soil were higher under intercropping of kalihari, kali musli and safed musli with Sapota-Jatropha as compared to sole cropping of kalihari, kali musli and safed musli (Table - 4.35). This may be due to higher microbial activities and more favorable physical condition viz., soil moisture, temperature under trees than sole. This is supported by Vanlalhluna and Sahoo (2010), Qaisar *et al.* (2007), Jaimini *et al.* (2006), Kaur *et al.* (2002) and Menezes *et al.* (2002) and Shinde (2001). May be due to less growth and yield where absorption is less.

5.3.2.2.3 Secondary nutrients

The results presented in Table - 4.36 clearly revealed that content of secondary nutrients Ca and Mg in soil under Sapota-Jatropha kalihari, kali musli and safed musli as compared to sole cropping of kalihari, kali musli and safed musli were

found non-significant. The result suggests inability of Sapota-Jatropha to alter the availability of these nutrients via leaf litter.

5.3.2.2.4 Micro nutrients

Looking to the results presented in Table - 4.37 it is revealed that content of micro nutrients such as Fe, Mn, Zn, Cu in soil under Sapota-Jatropha intercrop of kalihari, kali musli and safed musli as compared to sole cropping of kalihari, kali musli and safed musli were found non-significant. Sapota-Jatropha being tree component in the present investigation could not alter the status of micronutrients by the process of recycling through leaf litter.

5.3.2.3 Nutrient content in tuber crops

5.3.2.3.1 Organic carbon

The organic carbon content was found non – significant under Sapota-Jatropha intercropping of kalihari, kali musli and safed musli as compared to sole crop of kalihari, kali musli and safed musli (Table - 4.38). Being the basic building block of plants the content is bound to show no variation.

5.3.2.3.2 Major nutrients

The data presented in Table - 4.39 clearly reveals that higher content of major nutrients N, P, K were found under Sapota-Jatropha intercropping of kalihari, kali musli and safed musli as compared to sole crop of kalihari, kali musli and safed musli. The content of all these nutrients increased with increased shade. Higher nutrient in intercropping which might be due to lesser weed competition there by higher absorption

and utilization. Similar result was reported by Mohsin (2005) in mint and Rao *et al.* (2000) in nutrient removal in palmarosa and blackgram intercropping system.

5.3.2.3.3 Secondary nutrients

Content of secondary nutrients Ca and Mg under intercropping of kalihari, kali musli and safed musli under Sapota-Jatropha as compared to sole crop of kalihari, kali musli and safed musli were found non-significant (Table - 4.40). The nutrients in soil are also unaffected by tree components under present investigation and this has led to non-significant differences observed.

5.3.2.3.4 Micro nutrients

Significantly higher content of micro nutrient such as Fe, Mn, Zn, Cu were found under Sapota-Jatropha intercropping of kalihari, kali musli and safed musli as compared to sole crop of kalihari, kali musli and safed musli (Table - 4.41). All these nutrients are increased with increase in shade probably due to their accumulation under shaded condition. It also may be due to a possible synergistic effect caused by relative shading and due to more contribution of organic matter to the soil by Sapota and Jatropha leading to improved physico-chemical properties of soil, thereby leading to higher uptake under intercrop.

5.4.2.4 Economics

It is evident from results of Table – 4.42 that the intercropping of tuber medicinal crops kalihari, kali musli and safed musli recorded higher benefit cost ratio as compared to sole kalihari, kali musli and safed musli. The reason may be attributed to the compatibility of these crops under investigation with regard to their growth habit, nutrient requirement as well as light and moisture conditions and ultimately reflected in

terms of better productivity and higher economic yields and returns. Similar results were also observed by Kumar *et al.* (2010) in safed musli, Kumar *et al.* (2008), Ram *et al.* (1999), Singh *et al.* (1998a), Singh *et al.* (1998b) in *E. citriodora* with geranium, Maheshwari *et al.* (1997), Rao *et al.* (1993), Kothari *et al.* (1987) in sugarcane and mint and Maheshwari *et al.* (1985) in *Rauvolfia serpentine* with soybean and garlic or onion.

Summary and Conclusion



VI. SUMMARY AND CONCLUSION

Two field experiments were conducted at Agronomy Farm (Bock-E), ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat) during rainy seasons of 2011 and 2012 to study “The horticultural, silvicultural and medicinal crops in three-tier agroforestry system”. Two experiments were replicated four times in a randomized block design. The salient findings of the study are summarized below.

Experiment-I Performance of herbal crops (Basil, Kalmegh and Mint) under three-tier agroforestry system

- Intercropping of basil, kalmegh and mint under Sapota-Jatropha recorded higher plant height as compared to their sole cropping during both the years and pooled analysis.
- The sole crop of basil, kalmegh and mint recorded maximum number of branches per plant, crown spread East-West, crown spread North-South and survival percent as compared to intercrop under Sapota-Jatropha in both the years and pooled analysis.
- Significantly maximum fresh and dry weight per plant, fresh and dry weight per plot and economic yield were recorded in sole crop of basil, kalmegh and mint as compared to intercrop under Sapota-Jatropha. The trend was same in both the years as well as in pooled analysis.
- The light intensity under sole crop of basil, kalmegh and mint was significantly higher as compared to intercrop under Sapota-Jatropha during both the years and pooled analysis.

- Organic carbon in soil was noted significantly higher under Sapota-Jatropha as compared to sole crops of basil, kalmegh and mint. The trend was observed same in individual year and as well as in pooled analysis.
- Major nutrients (N, P, K) available in soil was recorded significantly higher under Sapota-Jatropha as compared to sole crops of basil, kalmegh and mint. The trend was same in both the years as well as in pooled analysis.
- Secondary nutrients (Ca, Mg) available in soil were registered higher under Sapota-Jatropha as compared to sole crops of basil, kalmegh and mint. The trend was same in both the years 2011 and 2012 as well as in pooled analysis.
- Micronutrients (Fe, Mn, Zn, Cu) available in soil were recorded higher under Sapota-Jatropha as compared to sole crops of basil, kalmegh and mint. The trend was observed same in individual year and as well as in pooled analysis.
- Higher organic carbon content in plant was recorded under Sapota-Jatropha as compared to sole crop of basil, kalmegh and mint. The trend was observed same in individual year and as well as in pooled analysis.
- Major nutrients content in plant (N, P, K) were recorded significantly higher under Sapota-Jatropha as compared to sole crop of basil, kalmegh and mint. The trend was observed same in individual year and as well as in pooled analysis.
- Secondary nutrients content in plant (Ca, Mg) were noted higher under Sapota-Jatropha as compared to sole crop of basil, kalmegh and mint during both the years and pooled analysis.
- Higher micronutrients content (Fe, Mn, Zn, Cu) in plant were recorded under Sapota-Jatropha as compared to sole crop of basil, kalmegh and mint during both the years and pooled analysis.

- Intercropping of basil, kalmegh and mint recorded significantly higher B:C ratio as compared to sole crops during both the year and pooled analysis.

Experiment-II Performance of tuber crops (Kalihari, Kali musli and Safed musli) under three-tier agroforestry system

- Higher plant height of kalihari, kali musli and safed musli was registered under Sapota-Jatropha as compared to their sole cropping during both the years and pooled analysis.
- Number of tubers per plant, length of tubers, girth of tubers and survival percent of kalihari, kali musli and safed musli were noted maximum when grown as sole crop as compared to intercrop under Sapota-Jatropha in both the years and pooled analysis.
- Significantly maximum fresh and dry weight of tuber per plant, fresh and dry weight of tuber per plot and economic yield were recorded in sole crop of kalihari, kali musli and safed musli as compared to intercrop under Sapota-Jatropha. The trend was same in both the years as well as in pooled analysis.
- The sole crop of kalihari, kali musli and safed musli reported significantly higher light intensity as compared to intercropping of kalihari, kali musli and safed musli under Sapota-Jatropha during both the years and pooled analysis.
- The organic carbon in soil was significantly higher under intercropping of kalihari, kali musli and safed musli under Sapota-Jatropha as compared to sole cropping of kalihari, kali musli and safed musli. The trend was observed same in individual year and as well as in pooled analysis.

- Major nutrients (N, P, K) available in soil was recorded significantly higher under Sapota-Jatropha as compared to sole crops of kalihari, kali musli and safed musli. The trend was same in both the years as well as in pooled analysis.
- Secondary nutrients (Ca, Mg) available in soil were registered higher under Sapota-Jatropha as compared to sole crops of kalihari, kali musli and safed musli. The trend was same in both the years 2011 and 2012 as well as in pooled analysis.
- Micronutrients (Fe, Mn, Zn, Cu) available in soil were recorded higher under Sapota-Jatropha as compared to sole crops of kalihari, kali musli and safed musli. The trend was observed same in individual year and as well as in pooled analysis.
- Higher organic carbon content in plant was recorded under Sapota-Jatropha as compared to sole crop of kalihari, kali musli and safed musli. The trend was observed same in individual year and as well as in pooled analysis.
- Major nutrients content in plant (N, P, K) were recorded significantly higher under Sapota-Jatropha as compared to sole crop of kalihari, kali musli and safed musli. The trend was observed same in individual year and as well as in pooled analysis.
- Among secondary nutrients content in plant i.e. Ca, Mg, were noted higher under Sapota-Jatropha as compared to sole crop of kalihari, kali musli and safed musli during both the years and pooled analysis.
- Higher micronutrients content (Fe, Mn, Zn, Cu) in plant were recorded under Sapota-Jatropha as compared to sole crop of kalihari, kali musli and safed musli during both the years and pooled analysis.

- Significantly higher B:C ratio was noted in intercropping of Kalihari, kali musli and safed musli as compared to sole crops during both the years and pooled analysis.

CONCLUSION

On the basis of present investigation, it may be concluded that, growing of herbal medicinal crops in open condition resulted in significant increase in the growth as well as the economic return as compared to growing herbal medicinal crops (Basil, Kalmegh and Mint) under Sapota-Jatropha. Significantly maximum plant height was observed under Sapota-Jatropha intercrop as compared to sole crops. Significantly higher organic carbon (OC) and major nutrients (N, P, K) in soil and plants were observed under Sapota-Jatropha intercrop as compared to sole crops. Secondary nutrients (Ca, Mg) and micronutrients (Fe, Mn, Zn, Cu) in soil and plants were recorded higher under Sapota-Jatropha intercrop as compared to sole crops. Significantly higher economic returns were observed under Sapota-Jatropha intercrop as compared to sole crops. So far as trend of economics is concerned in sole crop it was Basil (1:2.28) > Kalmegh (1:2.02) > Mint (1:1.60); whereas the same herbal crops when grown as inter crop under Sapota-Jatropha, the trend was again Basil (1:3.01) > Kalmegh (1:2.86) > Mint (1:2.31).

Growing of tuber medicinal crops in sole cropping resulted in significant increase in the growth as well as the economic return as compared to growing tuber crops (Kalihari, Kali musli and Safed musli) under Sapota-Jatropha. Significantly maximum plant height of tuber crops was observed under Sapota-Jatropha intercrop as compared to sole crops. Significantly higher organic carbon (OC) and major nutrients (N, P, K) in soil and plants were observed under Sapota-Jatropha intercrop as compared to sole crops. Secondary nutrients (Ca, Mg) and micronutrients (Fe, Mn, Zn, Cu) in soil

and plants were recorded higher under Sapota-Jatropha intercrop as compared to sole crops. Significantly higher economic returns were observed under Sapota-Jatropha intercrop as compared to sole crops. So far as trend of economics is concerned in sole crop it was Kalihari (1:2.37) > safed musli (1:2.02) > kali musli (1:1.44); whereas the same tuber crops when grown as inter crop under Sapota-Jatropha, the trend was Kalihari (1:3.05) > kali musli (1:2.20) > safed musli (1:2.04).

On the basis of present investigation we recommended that both herbal (basil, kalmegh and mint) and tuber (kalihari, kali musli and safed musli) medicinal crops can be grown as intercrops under Sapota-Jatropha for good financial gain.

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Appendix



APPENDIX - I

Meteorological observations during the year 2011

Month	Temperature		Relative Humidity		Rainfall (mm)	Rainy Days	Sunshine Hours
	Max.	Min.	Morning	Evening			
January	30.1	12.0	73	33	0	0	9.2
February	32.2	14.4	76	33	0	0	9.4
March	35.5	17.5	75	30	0	0	9.3
April	35.6	22.6	83	51	0	0	9.7
May	34.3	26.5	80	57	005.2	1	9.4
June	33.8	27.2	89	72	067.1	6	4.9
July	30.3	25.5	93	84	482.0	19	2.0
August	29.1	25.3	94	88	718.0	23	1.1
September	30.3	24.4	94	78	323.7	16	4.1
October	35.6	22.3	84	45	001.0	0	8.0
November	35.2	19.0	70	34	0	0	8.8
December	32.4	14.9	80	32	0	0	8.1

APPENDIX – II

Meteorological observations during the year 2012

Month	Temperature		Relative Humidity		Rainfall (mm)	Rainy Days	Sunshine Hours
	Max.	Min.	Morning	Evening			
January	28.8	12.3	81	55	0	0	8.5
February	31.8	13.5	71	26	0	0	9.4
March	34.9	16.5	79	23	0	0	8.4
April	35.8	23.0	85	43	0	0	9.1
May	33.9	26.2	81	57	006.0	1	9.8
June	31.1	27.0	84	68	155.0	9	7.8
July	30.7	26.3	92	83	271.0	19	2.2
August	30.0	25.6	93	83	210.0	15	2.5
September	30.2	24.5	93	76	618.0	16	4.1
October	34.9	22.1	80	47	12.0	2	7.6
November	33.1	14.8	73	31	0	0	8.5
December	31.7	16.4	72	34	0	0	7.7

APPENDIX – III

Expenditure for economics of medicinal crops

Charges	1 st Year		2 nd Year	
	Intercropping	Sole cropping	Intercropping	Sole cropping
Total Labour	120	179	106	167
Planting	30	52	27	48
Weeding	25	35	23	33
Fertilizers	3	5	3	6
Irrigation	7	12	6	10
Harvesting	25	40	20	38
Threshing	20	25	17	22
Miscellaneous	10	10	10	10
Irrigation charges	1500 Rs		1700 Rs	
Ploughing charges	5500 Rs		6000 Rs	
Miscellaneous	600 Rs		500 Rs	
FYM	20t/ha = 10000 Rs			

CERTIFICATE

This is to certify that, I have no objection to supply one copy of any part of this thesis at a time to any scientist through reprographic process if necessary for rendering reference service in a library or documentation centre.

Place: Navsari

Date :

(Vishnu Kanwar Solanki)