COMPONENT INTERACTIONS IN MANGO BASED AGROFORESTRY SYSTEM IN THE SUB-TROPICS OF JAMMU AND KASHMIR

By

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IN

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CERTIFICATE – I

This is to certify that the thesis entitled **"Component Interactions in Mango Based Agroforestry System in the Sub-tropics of Jammu and Kashmir"** submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Agroforestry** to the Faculty of Post Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu is a record of bonafide research, carried out by **Ms. Meenakshi Gupta**, Registration Number **J-13-D-193-A** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that help and assistance received during the course of investigation have been duly acknowledged.

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ABSTRACT

The present investigation, "**Component interactions in mango based agroforestry system in the sub-tropics of Jammu and Kashmir**" was conducted at Udheywalla Farm of SKUAST-Jammu, during the years 2015 and 2016. The study was aimed to explore the possibilities of successfully integrating intercrops namely Ginger (*Zingiber officinalis*),Turmeric (*Curcuma longa*), Stevia (*Stevia rebaudiana*) and Kalmegh (*Andrographis paniculata*) under the canopy of 29 years old mango orchard. The effect of light intensity and spacing on growth, physiology and yield of intercrops and effect of tree-crop interaction on soil physico-chemical properties, soil carbon and microbial count has been studied to work out the optimum tree-crop combination with respect to growth and yield.

The findings indicated that the mango orchard selected for the study had a very dense canopy and the interception of light was only upto the extent of 30-40 percent than that in the open. The shade had profound influence on the survival percentage and growth parameters like plant height, number of leaves per plant, number of branches/tillers per plant and leaf area per plant of ginger, turmeric, stevia and kalmegh. Among the four crops, stevia had a very low survival percentage under mango as compared to that in the open. Likewise ginger had a poor survival percentage in the open compared to that under the mango canopy. The height of the intercrop was significantly affected due to overhead shade of the trees and different spacing of the intercrops. Maximum height increment was observed in the treatments with closer spacing. Under shade, the higher values for number of leaves, number of tillers and leaf area per plant were recorded in ginger and turmeric as compared to stevia and kalmegh. A marked increase was seen in the growth parameters at wider spacing of 30cm x 30cm and 30cm x 40cm in all the crops. The economic yield of the four crops varied as per the crop habit. Fresh rhizome weight was taken for ginger and turmeric, dry leaves for stevia and dry above ground biomass for kalmegh. It was found that (1) the yield, in general, decreased under mango trees as compared to the open for all the crops under study, (2) ginger performed very poor under open conditions and (3) stevia was not suitable for intercropping under intense overhead shade. The yield was higher at closer spacing of 30cm x 20cm in all the crops except stevia under mango and ginger in open.

Amongst the physiological parameters like Relative Growth Rate (RGR), Net Assimilation Rate (NAR), total chlorophyll content, carotenoid content and the average leaf area, the crop under open had high RGR and NAR values than as intercrop. Crops planted at close spacing (S_1- 30cm x 20cm) had a lower RGR and NAR both in the open and in the intercropping. The total chlorophyll (at vegetative and reproductive stage) and carotenoid content was more under mango than in open. Crops allocated maximum assimilates towards leaf and branch both in open and under shade and the distribution was 1.5 to 2.0 times higher towards above ground biomass in intercrops compared to sole crop. Regarding the root characteristics, turmeric, stevia and kalmegh had higher number of roots and subsequently higher root dry weight in the open/ sole crops compared to under shade. Number and dry weight of roots/rhizomes increased with spacing. Root growth potential had negative values for all crops except ginger.

Irrespective of the crop and spacing, improvement in the physico-chemical properties of soil was observed. The microbial population was low under mango compared to that in the open for all the crops and at both the depths (0-15cm and 15-30cm). Amongst the fungal species isolated from the soil at two depths under mango and in sole cropping, *Alternaria* sp., *Paecilomyces* sp., *Fusarium* sp., *Penicillium* sp., *Cladosporium* sp. *and Aspergillus* sp. were found to be the most prominent out of the nine species isolated. The cost of cultivation, gross returns and net return of the system (with and without mango) decreased with the increase in spacing for the intercrops. The value of Benefit Cost Ratio (B:C ratio) of mango+intercrops varied in 2015 and 2016 due to the alternate bearing character of mango. In general, ginger, turmeric and kalmegh under mango had higher BC ratio in both the years. In stevia, gross returns were higher on account of yield of mango which inflated the B:C ratio of stevia+mango treatment combination. The value of Land Equivalent Ratio (LER) was highest in mango+ginger and minimum in mango+stevia. In case of ginger, the yield was very poor under open conditions which inflated the value of LER and the crop stevia was almost a failure under mango leading to the low LER values. The findings of the present investigation indicated that ginger, turmeric and kalmegh can be grown successfully as intercrops in the old mango orchards under the subtropical conditions of Jammu. Though the growth was more at wider spacing but the yield was maximum at closer spacing. Thus it can be deduced that all the crops except stevia can be integrated in mango orchards (>20 years of age) which can improve livelihood, and can add monetary value to the farming business.

Keywords: Mango, ginger, turmeric, stevia, kalmegh, growth, yield, physiology, BC ratio and LER

Signature of the student

Signature of Major Advisor

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LIST OF SYMBOLS AND ABBREVIATIONS

m^2	:	meter square	FYM	:	Farm Yard Manure
ha	:	hectare	NS	:	Non- significant
c.mol.P^+	:	centimoles of positive charge per kilogram of exchanger	PAR	:	Photosynthetically active radiation
mm	:	millimeter	$\pm$SE(m)	:	Standard error of mean
cm	:	centimeter	t ha^{-1}	:	Tonnes per hectare
g	:	gram	*viz.,*	:	Namely
Kg ha^{-1}	:	Kilogram per hectare	VC	:	Vermicompost
g cm^{-3}	:	gram per cubic centimeter	g kg^{-1}	:	gram per kilogram
%	:	per cent	S	:	Sulphur
m	:	meter	@	:	at the rate of
dSm^{-1}	:	Deci Siemens per meter	g/l	:	gram per litre
°C	:	Degree Celsius	q ha^{-1}	:	quintals per hectare
AF	:	Agroforestry	mg gm^{-1}	:	milligram per gram
BD	:	Bulk density	LER	:	Land equivalent ratio
CD	:	Critical difference	MPTs	:	Multipurpose tree species
masl	:	Meter above sea level	$gg^{-1}day^{-1}$	:	gram per gram per day
N	:	Nitrogen	SOC	:	Soil organic carbon
OC	:	Organic carbon	B: C	:	Benefit cost ratio
P	:	Phosphorus	EC	:	Electrical conductivity
pH	:	Negative logarithm of hydrogen ion	*et al.*	:	and others people
q	:	Quintal	Fig.	:	Figure
RBD	:	Randomized block design	K	:	Potassium
₹	:	Rupees	cfu g^{-1}	:	colony forming units per gram

Introduction

CHAPTER I

INTRODUCTION

India is the world's largest producer of milk, pulses, and spices, and has the largest cattle herd (buffaloes), as well as the largest area under wheat, rice and cotton. Agriculture plays a vital role in India's economy. Over 58 per cent of the rural households depend on agriculture as their principal means of livelihood. Agriculture, along with fisheries and forestry, is one of the largest contributors to the Gross Domestic Product (GDP). Notwithstanding such a remarkable progress, still large scale poverty exists. The only difference is that poverty now exists with food grain surplus as compared to poverty with food grain scarcity in 1950's. The average land holding of Indian farmers has been consistently declining over the last two decades, down by 20 per cent to 1.15 ha (Puri, 2015). Farm crisis in India is deepening, mainly due to back-to-back monsoon failures and descending prices of crop in addition to the problems of natural resource degradation, erosion of biodiversity, regional and class inequity and deceleration in growth rate of production which has eclipsed the net profitability from the agriculture sector.

Against the backdrop of these facts, the requirement is of a new paradigm of agricultural development, particularly to liberate small and marginal farmers from poverty trap. The diversification with agriculture and allied sector can be seen as a process of shift at two levels.

- From crop to non-crop sectors (such as horticulture, animal husbandry, fishery, forestry, aquaculture, sericulture etc.)
- Within the crop sector from food grain to non-food grains (such as pulses, cotton, sugarcane, spices, oilseeds, medicinal and aromatic plants etc.)

The diversification would mean that small farmers would not only undertake seasonal crop farming, but also animal husbandry, fishing, agroforestry, horticulture etc. and would participate in industrial and other non-farm economic activities as either self-employed or wage earners, for supplementing their incomes. A more mixed farming/diversified system/agroforestry land use exploiting crop-tree-livestock synergies will increase livelihood options and promise stability of farm income, the risks due to fluctuating production and market prices would be minimum, as all crops/enterprises on the same farm would not face adverse weather condition, insect/pest attack or price uncertainties.

According to the United Nations Convention to Combat Desertification (UNCCD, 2000), drylands are defined as: 'areas where the potential amount of water that is transferred from the land to the atmosphere is at least 1.5 times greater than the mean precipitation: a calculation known as the aridity index. They are defined by water scarcity and characterized by seasonal climatic extremes and unpredictable rainfall patterns'. Dryland are fragile and less productive, resulting in low and uneconomic yields. Such areas have high soil and climatic variability, land degradation, and resource poor farmers. The sole agriculture in dryland tract is not sustainable due to erratic rainfall. The people thus practise agroforestry and has been the rural way of life since time immemorial. Though the integration of multipurpose tree species is specific to topography and soil properties of an area, it accrues enhanced productivity per unit area on sustainable basis. Fruit tree based agroforestry systems are readily picked up by the farmers due to cash benefits derived from these systems. Fruit growing also provides scope for ancillary industries like fruit processing, canning, preservation, dehydration, essential oils, package transport and refrigeration.

In recent years, there has been an increasing trend toward the adoption of fruit tree-based systems particularly mango in view of the growing demand for fruits, higher returns, support from developmental programmes like National Horticulture Mission (NHM), micro-irrigation and setting up of National Horticulture Board. On farm experimentation have shown that introduction of pasture component has substantially improved the profitability of mango-based systems even in low rainfall regions (CRIDA, 2005). Mango orchard provides an opportunity for utilizing the space to its maximum in the initial years (up to 8-10 years) of establishment. Due to wider spacing and developing root patterns, the large unutilized inter-space of about 60 to 70 per cent can be exploited for growing inter and mixed crops successfully. Selection of intercrops depends on agro-climatic region, marketing facilities, levels of inputs and other local considerations. The partial shade loving crops like pineapple, ginger, turmeric, medicinal plants etc. can be grown in these orchards.

Mango has wide adaptability to varied agro-climatic conditions, has excellent dessert quality of the fruits and has immense potential for export. Jammu division of Jammu and Kashmir State has 12,754 hectares of area under mango cultivation producing 23,736.80 metric tons of fruit (J&K Department of Horticulture, 2016). The mango trees are planted at wider spacing (8x8 m^2 or 10x10 m^2) leaving a considerable area for intercrop. The life span of mango orchards is about 20-30 years and monoculture of mango has become risky as productivity and returns are fast diminishing. It becomes imperative on the part of the orchardist to use the vacant space between the trees to ensure a quick and sustainable return on investment done. Intercropping with suitable and synergistic crop (vegetables/medicinal plants) improves the fertility and protects the orchard soil and gives additional income.

The livelihood of farmers in dryland areas depend on the success or failure of crops, hence, the sole dependence on traditional crops is becoming uneconomical. The farmers are looking for better alternative to diversify from traditional agriculture. Thus medicinal plants could be included as a high value cash crop in the existing farming system. Majority of medicinal plants are shade loving and can be successfully grown under fruit trees. A variety of medicinal and aromatic plants can be intercropped with a given tree species depending on the size and intensity of its shade, spacing and management, especially pruning of branches. Shade-tolerant and rhizomatic plants can be grown on a long-term basis in widely spaced plantations. Short stature and short duration medicinal and aromatic plants and culinary herbs are particularly suited for short-term intercropping during the juvenile phase of trees. Ashwagandha – *Withania somnifera*, Kalmegh - *Andrographis paniculata*, Senna - *Cassia angustifolia*, Makoi - *Solanum nigrum*, Tulsi - *Ocimum sanctum*, Sarpagandha - *Rauvolfia serpentina*, Guduchi - *Tinospora cordifolia*, Gudmar - *Gymnema sylvestre*, Shatavari - *Asparagus racemosus*, Kalihari - *Gloriosa superba* are suitable for cultivation under dryland conditions (Kalaichelvi and Swaminathan, 2009). But, cultivating medicinal and aromatic plants (MAP's) faces certain constraints; most important being the availability of land which is becoming scarce. Therefore, putting the vacant spaces on the farms (agroforestry/ agricultural/horticultural) under cultivation with such crops will not only lead to land utilization but also conserve the species and provide adequate assurance in the event of crop failure.

Ginger (*Zingiber officinale* Roscoe), a rhizomatous crop belonging to the family Zingiberaceae is one of the important and widely used spice worldwide and is believed to have originated in Southeast Asia. Though the plant is an herbaceous perennial, it is usually grown as an annual for its pungent aromatic rhizomes. India is the leading producer of ginger in the world and during 2014–2015 the country produced 703.53,000 tons of the spice from an area of 137.506 ha. Ginger is cultivated in most of the states in India (Thankamani *et al*., 2016). Ginger contains gingerol, an oleo-resin that accounts for the characteristic aroma and therapeutic properties. Components of gingerol possess beneficial properties for the treatment of poor digestion, heart burn, vomiting and preventing motion sickness.

Turmeric (*Curcuma longa* L.) is a perennial herb, native to tropical South-East Asia, belonging to the family Zingiberaceae. It is cultivated for its underground rhizomes which are used as spice and condiment, dye stuff and in cosmetic and drug industry, particularly in the preparation of anti-cancerous medicines. It forms an important adjuvant in Indian culinary as it imparts colour and aromatic flavour to various dishes. Turmeric is widely used as a condiment in the preparation of pickles and curries and as a colouring agent in textile, food and confectionary industries (Pujari *et al*., 2015). India is the largest producer, consumer and exporter of turmeric in the world. Indian turmeric is considered to be the best in the world market because of its high curcumin content. India accounts for about 80 per cent of world turmeric production and 60 per cent of world exports (Srinivasan *et al*., 2016).

S*tevia rebaudiana* (Bert.) is a perennial sweet herb of Paraguay, known for its sweet compounds. The importance of this plant was re-discovered by M.S. Bertoni in the 18th century. The herb produces a high potency, zero calorie sweetener in its leaf tissues with the steviol glycosides, stevioside and rebaudioside A, reported to be 200-300 times sweeter than cane sugar (Ramesh *et al*., 2006). Stevia can be used to replace the high calorie sugar sources in food products.

Andrographis paniculata (Burm. f.) Wall. ex Nees belonging to the family Acanthaceae known as kalmegh, is an important medicinal plant and widely used around the world. It is native to Taiwan, Mainland China, and India. It is also found in the tropical and sub- tropical Asia, Southeast Asia, and some other countries including Cambodia, Caribbean Islands, Indonesia, Laos, Malaysia, Myanmar, Sri Lanka, Thailand, and Vietnam (Niranjan *et al*., 2010; Hossain *et al.*, 2014). Generally, the plant is known as "King of Bitters" for its extremely bitter taste. Andrographolide (the diterpenoid lactones) is the main bitter principle found in high concentrations in the leaves of kalmegh (Tang and Eisenbrandt, 1992). Due to its "cold property", it is recommended to get rid of the body heat in fevers and to dispel toxins from the body. The plants are also recommended for leprosy, gonorrhea, scabies, boils, skin eruptions, and chronic and seasonal fever due to its high "blood purifying" properties (Akbar, 2011).

Although conventional agricultural crops have been tried as intercrops under mango, but the literature on possibility of growing medicinal and aromatic plants as intercrop in the subtropics of Jammu and Kashmir is scarce. This study is an attempt to explore the prospects of growing four important crops *viz*., ginger, turmeric, kalmegh and stevia as intercrop under mango orchard with the following objectives:

1. To study the effect of light intensity and spacing on growth, physiology and yield of intercrop.
2. To assess the effect of tree-crop interaction on physico-chemical properties of soil and soil carbon.
3. To work out the optimum tree-crop combination with respect to growth and yield.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Agroforestry practices actively manipulate and utilize the interactions among components (trees, crops and /or livestock) to yield multiple harvestable products, while concurrently providing numerous conservation and ecological benefits as well as new market opportunity to the land owner. The intercropping concept holds remarkable application in conditions where land remains locked under orchards. This allows utilization of inter-space between trees and providing income when fruit plants are not in bearing. However, the quantum of profit depends on the choice of crop to be added to the system. In this context, the literature relevant to the study "**Component Interactions in Mango Based Agroforestry System in the Sub-tropics of Jammu and Kashmir**" is reviewed under the following heads:

2.1 Effect of trees on growth and yield of intercrops

2.2 Component interactions

2.2.1 Physiological attributes of intercrops

2.2.2 Effect of crops on soil physico-chemical properties

2.2.3 Soil microbial load

2.3 Economic evaluation of fruit tree based agroforestry system

2.1 Effect of trees on growth and yield of intercrops

Stevia grows naturally on infertile, sandy soils with shallow water tables (Lester, 1999). The natural climate is semi humid and subtropical with temperature extremes from 21-42^{0}C, averaging 24^{0}C with an annual rainfall of 1375 mm (Brandle *et al*., 1998). The plant has an extensive tap root system with brittle stems producing sessile, oppositely branched, lanceolate to oblanceolate leaves. The leaves are bright green in colour, having distinct characteristic odour and sweet taste. It is a short day plant with a critical day length of 13 h (Zaidan *et al.,* 1980) and remain vegetative in the spring through early summer and flower in late summer (Shock, 1982). Long day conditions increase internode length, leaf area and stevioside content (Metivier and Viana, 1979) whereas, shade reduce total growth, delay flowering and reduces the rate of flowering (Slamet and Tahardi, 1988). The plant can initiate flowering after a minimum of four true leaves have been produced (Carneiro, 1990).

Manna and Singh (2001) conducted an experiment at two sites having 38 and10 years old orchard cropping systems (coconut intercropped with guava) to evaluate changes in organic carbon accumulation and chemical and microbiological properties of the soils. The average level of soil microbial biomass carbon was 1158 kg ha^{-1} (0-0.15m depth) and the organic carbon turnover rate was 8.5 yr^{-1} after 38 years of intercropped fruit trees, which resulted in a lower ratio (1.81) of carbon inputs to soil microbial biomass carbon.

Kalmegh is an annual, branched, erect, and herbaceous plant which grows well in tropical and subtropical regions under hot and humid conditions. Plants grow luxuriantly with the onset of monsoon and starts flowering within 90-120 days in the month of September. The optimum mean temperature for kalmegh is between 30-40^0C during the major period of the crop. It can be cultivated on number of soils from loam to laterite with moderate fertility and normal pH range. It cannot tolerate waterlogged condition and high soil sodicity. Its cultivation can also be carried out on shady wastelands. It can be taken as an intercrop under fruit trees (Papaya, Mango, Guava, Aonla) and multipurpose trees like Poplar and Arjuna. Intercropping of kalmegh under various medicinally important tree species can significantly enhance the net returns per unit area, apart from utilizing natural resources very effectively. In case of intercropping, dried herb yield of 1.5-2.0 t/ha (single harvest); dried herb yield upto 4.0 t/ha can be obtained in case of two harvests of the crop (Patra *et al*., 2004).

Megeji *et al*. (2005) took two accessions of *Stevia rebaudiana* to conduct a cultivation trial at Palampur (H.P.) and inferred that overall, fresh and dry leaf yields were higher in regenerated (ratoon) crop irrespective of the month of harvest (156.99 and 32.22 q/ha) compared to those from the crops in the first year of growth (74.00 and 16.28 q/ha). Total fresh herb yield was 140.84 q/ha in the first year of the crop and 263.09 q/ha in case of the regenerated crops whereas, dry herb yield was 35.33 and 62.54 q/ha respectively. They outlined the growing pattern and stevioside yield of stevia from the North Indian region and three cuts could be obtained during the two-year growing period of the crop.

Pawar and Sarwade (2006) while evaluating the performance of intercrops in mango orchards observed that the higher benefit:cost ratio (2.56) was recorded when soybean sequenced with mustard was intercropped in mango plants followed by cowpea sequenced with gram. The lowest benefit: cost ratio of 1.99 was recorded in mango alone. They inferred that intercropping was beneficial over sole cropping.

In a comprehensive review, Ramesh *et al*. (2006) has opined that Stevia has given a new direction to the farming community, businessmen and also the researchers. In association with most plants, the growth and flowering of stevia are affected by radiation, day length, temperature, soil water and by wind in exposed places.

During the early phase of the growth of arecanut (non bearing period), cultivation of medicinal plants in the arecanut plantations could act as a supplementary source of income to the farmer opined Channabasappa *et al*. (2007). They inferred that *Catharanthus roseus, Andrographis paniculata* and *Stevia rebaudiana* can be recommended for cultivation in the arecanut gardens.

Pujar *et al*. (2007) worked out the performance of medicinal and aromatic plants as intercrops with teak. They found that out of the eight treatment combinations viz., Aloe (*Aloe vera*), kalmegh (*Andrographis peniculata*), Coleus (*Coleus forskohlii*), Stevia (*Stevia rebaudiana*), citronella (*Cymbopogon winterianus*), lemongrass (*Cymbopogon flexuosus*), palmarosa (*Cymbopogon martinii*) and patchouli (*Pogostemon patchouli*) grown under teak (*Tectona grandis*), aloe, lemongrass and coleus had higher herbage yield compared to others. However, compared to the respective sole crops, there was reduction in fresh weight and in dry weight per plant of all crops (except coleus) indicating competitive effect of teak and availability of sub-optimum growth resources like light, moisture and nutrients.

Ramesh *et al*. (2007) studied the production potential of *Stevia rebaudiana* (Bert.) Bertoni. under intercropping systems. Wheat, barley, lentil and gobhi sarson were intercropped with stevia at two spacing 45cm x 45cm and 60cm x 45cm. They found that intercropping reduced the production of *S. rebaudiana* up to 50 per cent when compared to sole cropping. However, a row spacing of 60cm x 45cm resulted in less competition than the former, although, single cropping of *S. rebaudiana* produced the maximum stevioside. Intercropping with wheat increased the stevioside content when compared to other intercrops. The introduction of wheat resulted in higher monetary benefits at 60cm x 45cm spacing. Results indicated that reduction in stevia biomass was mainly due to overlapping of the emergence period of the main crop with rapid growth and development of the intercrops. They concluded that competitive effects can be lowered by choosing the intercrop which has early maturity.

Rao *et al*. (2006) attempted to analyse the growth pattern and curcumin content of long, medium and short duration turmeric (*Curcuma longa* L.) genotypes. They concluded that long duration genotypes accumulated more dry matter and maintained leaf area index, chlorophyll content and cumulative growth rate for longer period up to 210 days, resulting in higher yield and curing percentage over medium and short duration genotypes. Curcumin content was higher in short duration genotypes over medium and long duration genotypes.

Gill *et al.* (2008) studied the intercropping of medicinal, aromatic and spice crops in poplar plantation. The results revealed that an increase in the age of poplar decreased the yield of crops. During 2005-06, in the second year of plantation, the reduction in the yield of lemongrass, *Tagetes minuta, Mentha arvensis* and *M. spicata*; and yield of turmeric rhizome, seed of coriander, fennel, dillseed, fenugreek, sarson and wheat was 6.55, 7.50, 60.5,50.0, 40.6, 28.1, 43.9, 27.6, 37.4 and 34.4 and 32.7%, respectively in compact poplar plantation compared with that in sole or pure cultivation of these crops; and in 2006-07 it was 25.4, 39.3, 78.6, 77.0, 56.3, 70.4, 88.5, 79.6, 65.6, 85.9 and 67.2%, respectively.

Saravanan *et al*. (2008) contemplated the influence of light intensity on gas exchange, herbage yield and andrographolide content in *Andrographis paniculata*. They observed significant differences in growth characters between plants grown in open and shade conditions. Leaf photosynthesis was noticed to increase from 11.56 to 19.70 mmol $m^{-2}s^{-1}$ as photon flux density increased from 25 to 100 per cent and herbage yield increased from 226.70 to 379.45 g in open. Thus it was concluded that *A. paniculata* is suitable for cultivation in open light condition.

Padmapriya and Chezhiyan (2009) laid out a field experiment to study the effect of partial shade, inorganic, organic and biofertilizers on morphological parameters, yield and quality of turmeric cv. CL 147. They noticed significant variation among the treatments for the quality characters *viz.,* curcumin, oleoresin and essential oil content. The quality parameters were found to be higher under shade compared to open condition. The highest curcumin (5.420 %), oleoresin (10.150 %) and essential oil (5.60 %) content were registered in the treatment M_2S_{18} (shade + 50 % FYM + coir compost + *Azospirillum* (10 kg ha^{-1}) + phosphobacteria (10 kg ha^{-1}) + 3 % *Panchakavya*). The lowest curcumin (3.86 %), oleoresin (7.53 %) and essential oil (4.83 %) content was documented in the treatment M_1S_{20} (open + absolute control).

In a prepensed experiment on effect of plant population and soil moisture stress on herbage yield and andrographolide content in *Andrographis paniculata*, Saravanan *et al*. (2009) noticed that spacing and irrigation levels influenced dry weight of leaves and fresh and dry weight of stems significantly. Plant spacing of 15 x 15 cm produced higher herbage yields of 707.8, 742.3 and 690.6 gm^{-2} in well-watered control, mild and severe water stress treatments, respectively. Andrographolide content in the leaves was highest in severely water stressed plants. Dry matter yield was lower under mild and severe water stress conditions even under closer spacing, but the loss of andrographolide yield was partly compensated by its higher content.

Abouziena *et al.* (2010) studied the efficacy of intercropping mango, mandarin or egyptian clover plants with date palm on soil properties, rhizospere microflora and quality and quantity of date fruits. The results indicated that the intercropping with mango gave the highest net profit (\$8213 ha^{-1} yr^{-1}), followed by the same area intercropped with mandarin (\$3992 ha^{-1} yr^{-1}). Evaluation of growing mango, mandarin or egyptian clover with date palm indicated that growing mango with date palm could be used for combating desertification in sandy soil in arid regions and gave the highest net return per unit area.

Amin *et al.* (2010) evaluated the performance of ginger under agroforestry system. Ginger was grown under 2.5 years old multipurpose tree species viz. siris, mango and guava. The study revealed that ginger was a scicophytic crop and it performs well under partial shade (50$\pm$5 per cent) than the open field. The finding further pointed that the best combination among the three tree species was of mango+ginger as the yield of ginger was highest (12.42 t/ha) under mango followed by guava (7.79 t/ha) and the least under black siris (5.07t/ha).

An experiment was conducted by Bari and Rahim (2010a) to evaluate the performance of medicinal plants in mango based multistoried agroforestry system. Three medicinal plants viz. aloevera (*Aloe indica*), asparagus (*Asparagus racemosus*) and misridana (*Kaempferia angustifolia*) were grown under the canopy of guava in the middle storey and mango at the top layer. The growth and yield of medicinal plants were compared with their growth and yield in open conditions as control. In the open conditions, the crops received 100% sunlight; while multi-storied agroforestry systems allowed 19 to 23% sunlight for the growth of the ground layered medicinal crops. They revealed that though the economic yield of crops was more in control but the highest gross returns were registered under mango based multi-storied agroforestry systems They suggested that the combination of high value medicinal crops viz. aloevera, asparagus and misridana with commercial fruit tree species on the same land ensures diversified products and greater profit to the farmers. They further ranked the degree of their profitability as misridana>*Aloe vera*>asparagus.

Bari and Rahim (2010b) evaluated the growth and productivity of ginger under sissoo based Multi-strata Agroforestry System (MAF). The three layered woodlot consisted of sissoo at the top layer, guava and lemon at the middle layer and ginger at the ground layer. The results revealed that the rhizome yield of ginger was considerably reduced under closer spacing of tree species compared to that in wider spacing. Among the different treatments, it was found that the highest benefit-cost ratio of 3.73 was recorded from the wider spacing of sissoo+guava based MAF and the lowest benefit-cost ratio of 1.43 was observed in sole cropping of ginger. It was concluded that ginger can be cultivated profitably in multistrata sissoo woodlot.

Goel (2010) analyzed the changes in morphometric and biochemical characteristics of S*tevia rebaudiana* under the effect of distillery spent wash in Muzaffarnagar, UP. Propagules of stevia variety SRB 128 were treated with 5.0 per cent, 10.0 per cent, 15.8 per cent, 25.1 per cent, 36.6 per cent and 39.8 per cent spent wash. The results depicted that at low concentration of distillery spent wash i.e. 5.0 per cent and 10.0 per cent, seed germination percentage increased from 3 to 9 days of germination but high concentration of spent wash inhibited/delayed the seed germination percentage. The leaf area and the total chlorophyll content decreased steeply with increase in concentration of spent wash which suggested nitrogen and phosphorus deficiency in the plant due to mineral absorption.

Suresh *et al.* (2010) conducted an experiment to see the effect of teak on *Coleus forskohlii*. In this study, plant spacing showed significant variation in growth and yield of *Coleus forskohlii* under teak plantation. Among three spacing viz. 60 x 20 cm, 60 x 30 cm and 60 x 45 cm, the spacing (60 cm x 45 cm) recorded higher dry weight (30.80 g/plant) of root biomass. However, the maximum tuber yield was recorded in closer spacing of 60 x 20 cm and it was due to more number of plants per unit area.

In an experiment on impact of spacing and inorganic fertilizer on growth characteristics of sarpagandha (*Rauvolfia serpentina*), Ali *et al.*(2011) found that the best spacing for growing sarpagandha under the shade of poplar and teak was 45cm x 45cm, and the results were best when trees were planted at distance of 9m x 3m.

In an intercropping trial, *Das et al*. (2011) raised turmeric, ginger and arbi beneath 6-year-old aonla (*Emblica officinalis* Gaertn.;cv. NA-7) orchard. The results indicated that the production of aonla fruits significantly increased due to intercrops and it was maximum in association with turmeric (13.30 tons/ha) followed by arbi (11.71 tons/ha). On the other hand, there was reduction in yield of intercrops (7.5–12.0% for turmeric, 12.2–19.3% for ginger and 15.7–25.3% for arbi) compared to the yield in open area without trees. In terms of benefits : cost ratio, ‘aonla + turmeric’ gave a higher value (6.29) followed by ‘aonla + ginger’ (3.44) and ‘aonla + arbi’ (3.20).

Kafle (2011) studied the physiology of *Stevia rebaudiana* (Bertoni) using three varieties of stevia 99-8, Fengtian 4 and Shoutain-2. The results indicated that irrespective of the varieties that commencement of flowering under 12 hours day length was early and also the number of flowering plants (100%) was significantly higher as compared to those grown under longer photoperiods (24, 16 and 14 hours), it confirmed that stevia was a short day species. Biomass yield of stevia was also related to the availability of soil water. Plants resulted in low yields both under low and very high moisture content. High leaf yield was obtained on plants grown under field capacity (FC) and 80 per cent of FC. Plant growth and leaf yield of stevia was maximum at pH ranging from 4-6. High pH levels from neutral to alkali reduced plant growth and leaf yield.

Kumar (2011) investigated the effect of vermicompost application on growth and yield of *Andrographis paniculata* and *Stevia rebaudiana* under plum based agroforestry system in mid hill zone of Himachal Pradesh and found that the above said medicinal plants thrived well under plum trees. The production potential and economic returns were higher inside the agroforestry system than mono cropping.

Parashar *et al*. (2011) conducted an experiment on morpho-physiological parameters of *Andrographis paniculata* at different growth stages. The results were evaluated on the basis of growth analytical parameters (Leaf area, Leaf area index, Crop growth rate, Relative crop growth rate, Leaf area duration, Biomass duration and Specific leaf area) as well as morpho-physiological (Plant height, No. of leaves, No. of branches, plant fresh weight, plant dry weight, leaves fresh and dry weights and herbage yield) parameters. The result revealed that all the selected parameters go on increasing with crop growth stages. However, the specific leaf area increased up to 90 DAS and there after it gradually declined up to 120 DAS indicating the maturity of crop.

Purwanto *et al*. (2011) studied the effect of shading levels and nutrition sources on growth, yield and andrographolide content of Sambiloto (*Andrographis paniculata* Ness) in Indonesia. The result indicated that 25 per cent shade level in combination with straw compost fertilizer increased the growth characteristics (number of leaves, number of branches, plant height, dry weight and simplisia weight) whereas, andrographolide content was recorded maximum in case of treatment combination of 50 per cent shade level and straw compost fertilizer.

Turmeric as intercrop in mango has been found not only to assist in suppressing the population of trunk borers, termites and gummosis causing pathogens in the soil, but also provided additional income from the harvest of the rhizomes, 9 months after planting. The orchard was also found to be free from termite attack after planting turmeric as intercrop in mango. Turmeric plantation as intercrop can find application in organic farming systems, to control various soil borne pests and diseases in several fruit orchards (Usha, 2011).

Bhuiyan *et al*. (2012) evaluated the growth and development of turmeric and ginger under five different light levels. The spices were grown beneath different combinations of tree species- sissoo, guava, lemon and coconut. The results showed that maximum vegetative growth of both the spices occurred under coconut+ lemon (severe shade conditions) but the highest yield was recorded under coconut + guava (partial shade conditions). Similar results were obtained by Jayachandran and Nair (1998) in a field trial on the performance of mango-ginger (*Curcuma amada* Roxb.) under different levels of shade. They also concluded that the rhizome yield was maximum in 25 per cent shade and was at par under open conditions. The crop was shade tolerant and was suitable for intercropping situations.

In a study on the structure, composition and diversity of horticulture trees and agricultural crops productivity under traditional agri-horticulture system in mid hill situation of Garhwal Himalaya, Bijalwan (2012), found that agroforestry was a common practice in the mid hill situation of Garhwal Himalaya. Farmers were inclined toward retention of fruit trees on their agricultural fields for additional monitory gain from the fruits and therefore agri-horticultural practice was the priority of large farmers as the climatic and geographical situation also permitted such practices. He further concluded that the average annual productivity of grain recorded under agri-horticulture system was 1106 kg ha^{-1} $year^{-1}$ on northern aspect and 1122 kg ha^{-1} $year^{-1}$ on southern with a reduction of 34.56 per cent and 38.29 per cent compared to the sole agriculture crops, but this reduction was supplemented by fruit production which supported and sustained the rural community of the hilly region.

In another study on intercropping tree plantation with medicinal and aromatic crops Hazarika *et al*. (2012) evaluated the growth and yield performance of Stevia (*Stevia rebaudiana*), Brahmi (*Bacopa monnieri*) and Patchouli (*Pogostemon cablin*) as intercrops with Som (*Persea bombycina*), a host plant of muga silkworm (*Antheraea assamensis*). All three crops showed relatively higher values in case of survival percentage under shade of *Persea bombycina* than open condition. Plant height, plant spread, leaf area index (LAI), fresh and dry herb yield, net return and benefit : cost ratio (BCR) of *P. cablin* and *B. monnieri* were also higher in shade than open condition which indicated that *P. cablin* and *B. monnieri* preferred partial shade for better growth and yield indicating their possibility as intercrops in matured *P. bombycina* plantations. In case of stevia, there was significant reduction in growth, yield, net return and BCR in shade compared to open condition.

In an experiment conducted to study the impact of integrated nutrients on growth and yield of kalmegh, Hemalatha and Suresh (2012) concluded that the highest plant height (56.54 cm $plant^{-1}$), number of branches (22.65 $plant^{-1}$), number of leaves (41.40 $plant^{-1}$), leaf area (128.34 cm^2 $plant^{-1}$), dry biomass (2.639 t ha^{-1}), fresh herbage (1392.22 kg ha^{-1}) and alkaloid yield (0.739 %) of *Andrographis paniculata* were recorded in the treatment containing 15 t FYM ha^{-1} + 45:25:25 kg NPK ha^{-1} +1 kg *Azospirillum* ha^{-1}.

Kumar *et al*. (2012a) conducted two separate field experiments to study the effect of agro-techniques on the performance of natural sweetener plant–stevia (*Stevia rebaudiana*) under western Himalayan conditions. In the first experiment, two doses of farm yard manure (FYM) and seven inorganic fertilizers were compared with untreated plot (control). Application of 50:60:50 kg NPK/ha recorded significantly higher plant height, stem, flower and total weight/plant (dry) and consequently recorded higher dry leaf yield as compared to other treatments. However, stevioside and rebaudioside contents were found to reduce due to the application of manures/fertilizers. FYM application recorded higher marker compounds than inorganic fertilizers. Owing to higher dry leaf yield, 50:60:50 kg NPK/ha recorded highest steviol glycoside (stevioside and rebaudioside A) yield/ha than other treatments. In second experiment, effect of land configuration and harvesting time on growth, yield and steviol glycosides of stevia was evaluated. Planting stevia in broad bed and furrow (BBF) recorded 31 and 23 per cent higher leaf biomass over flat and camber bed methods, respectively. Steviol glycosides (stevioside and rebaudioside-A) concentration was higher when stevia was planted in camber bed as compared to flat and BBF. Significantly higher leaf biomass and rebaudioside -A content was obtained when harvested once at 50 per cent flower bud stage compared with those harvested once at the 60 and 90 days after transplanting (DAT). Owing to higher dry leaf yield, stevia planted in BBF and harvested at 50 per cent flower bud stage recorded highest net return and B:C ratio than other treatments.

Kumar *et al*. (2012b) investigated the effects of shade regimes and planting geometry on growth, yield and quality of the natural sweetener plant stevia in north-western Himalaya. It was concluded that intensive shade in stevia production should be avoided. 25 per cent shade level remained at par with controls (0% shade) and recorded significantly higher leaf dry biomass compared with 50 and 75 per cent shade. An increase in shade levels resulted in an increase in the time taken to reach different phenological stages of stevia. Planting stevia with a wide row spacing of 45x10 cm in a N–S direction yielded higher dry leaf weight than in narrow row spacing. Stevia can tolerate slight shade up to 25% so it should be intercropped with other plants to increase cropping intensity.The farming community may obtain additional benefit by adopting stevia in intercropping with cereals, oilseed, or pulses.

Madhavi Lata *et al*. (2012) investigated two agroforestry models i.e., aswagandha and andrographis, each inter-cropped with four year old amla and terminalia plantations. They reported that growth and yield of both the crops was higher in sole cropping compared to intercropping. Physiological maturity was delayed by 9-10 days in aswagandha and by 3-4 days in andrographis when intercropped with both the trees. Terminalia+aswagandha and Terminalia+andrographis, both the systems had higher gross and net returns compared to sole crops.

Singh *et al.* (2012a) while studying the dynamics of tree-crop interface in relation to their influence on microclimatic changes, revealed that compared to an open environment, the modified microclimate under trees have reduced solar radiation, a lowered red: far-red light ratio, a more moderate temperature regime, higher humidity, lower rates of evapo-transpiration and higher soil moisture levels. All of these factors change as a function of tree development and tree management practices. The spacing chosen for trees determine how rapidly the changes come into play. During the establishment phase, tree shade remains minimal and have little significant effect on the understory companion crops. However, as the trees grow, the changes in the microclimate become more pronounced, which strongly affect the growth and compatibility of the understory crop.

Singh *et al.* (2012b) studied the effect of different intercrops on yield, quality and shelf- life in mango cv. Himsagar (*Mangifera indica* L). They found that maximum number of fruits tree^{-1} (192.41) and yield tree^{-1} (46.09 Kg) was found in mango+cowpea whereas, maximum fruit weight (254.16 g) was found in mango+lentil crop combination. They inferred that under the new alluvial zone of West Bengal, the performance of different intercrops in young mango orchard appeared to be economical without affecting the yield of the mango cv. Himsagar and hence, recommended that among different leguminous intercrops, cowpea intercrop was the best for the region.

In a study conducted in Gulian province of Iran, Taleie *et al*. (2012) reported that transplanting date and spacing significantly ($P < 0.05$) affected plant height, herbage (leaf and stem) fresh and dry weight and also stevioside, phenol and flavonoid yield in stevia. Maximum plant height (80 cm), total fresh (2017.21 g/m^2) and dry (588.69 g/m^2) herbage weight, and the highest stevioside (34.51 g/m^2), phenol (1.5 g/m^2) and flavonoid (1.97 g/m^2) yield were obtained in the 50×20 cm spacing when transplanted on the 15th March.

Tripathi (2012) investigated the effect of organic manures on yield and biomass production of MAPs under peach based agroforestry system. The results revealed that MAPs *viz. Andrographis paniculata*, *Withania somnifera* and *Ocimum sanctum* could successfully be cultivated as intercrop under peach without any adverse impact on the performance and production ability of intercrops. The performance of *Andrographis paniculata*, *Withania somnifera* and *Ocimum sanctum* were found better under peach than control. The intercropping of MAPs with peach also improved fruit quality and fruit yield.

In an experiment to assess the phytochemical content of some medicinal plants under different agroforestry systems Ali *et al.* (2013) planted medicinal plants (ginger, turmeric and asparagus) under the trees of mango and litchi. They found that the yield of the three medicinal crops was maximum in sole cropping compared to that under the trees, but maximum oil content was recorded under litchi based agroforestry system and total organic matter percent was highest (8.70 and 11.10%) in mango based agroforestry system in case of ginger and turmeric.

Chauhan *et al.* (2013) inferred from their study on physiological behaviour and yield evaluation of agronomic crops under agri-horti-silviculture system that the transpiration (E) rate of crops was lowest under shade conditions irrespective of the crop used in the experiment leading to more water use efficiency in the shade conditions than in open. There was gradual reduction in crop yield with advancement of age due to increased shade, but the economic benefits of intercropping were two to three times higher than traditional crop rotation. It is suggested that to minimize resource competition and improve physiological processes of crops, canopy management (pruning of canopy and roots) is essential to ensure better yield under Poplar-based agri-horti-silvicultural system.

Shading reduces yield of ginger, it was confirmed through the study done by Kratky *et al.* (2013). Shaded ginger foliage was darker green in color and exhibited less wilting than non-shaded plants. However, ginger rhizome yield production was reduced by 30-60 per cent under shade compared to open. They opined that covering the crop with a permanent shade screen reduces light throughout the day, including those periods (early to mid-morning and later afternoon) when light intensity is less than optimal for the maximum photosynthetic rate, and this negative effect appears to predominate over any positive effects of shading.

Kumar and Kumar (2013) probed the influence of harvesting time and spacing on growth, dry herbage biomass, seed yield and quality traits of *Andrographis paniculata.* The maximum dry herbage biomass yield (5.14 t ha^{-1}), net returns (760.00 EUR ha^{-1}), B:C ratio (2.59), andrographolide content (2.63%) and total yield (135.00 kg ha^{-1}) were marked 135 days after planting with a spacing of 30× 15 cm. However, the maximum iron content was estimated 120 days after planting. The highest dry herbage (4.58 t ha^{-1}) and maximum seed yield (19.7 kg ha^{-1}) were registered at plants that were lined out with a distance of 20× 10 cm.

The results of an experiment carried out in Nigeria on the growth and yield of maize (*Zea mays* l.) in maize-ginger intercrop showed that the over shading of the ginger crop with increasing maize density reduced the rhizome yield of ginger. It also revealed that Land

Equivalent Ratio (LER) ranged from 23-79 per cent over the sole cropping implying that 23 -79 per cent more land would be required to produce the same amount of maize and ginger in sole culture (Lyocks *et al.*, 2013).

Rashid *et al*. (2013) reported the effect of different levels of farmyard manure and nitrogen on the yield and nitrogen uptake by stevia (*Stevia rebaudiana* Bertoni). The experiments consisted of four levels of farmyard manure (0, 15, 30 and 45 t/ha) and four levels of nitrogen (0, 20, 40 and 60 kg/ha). The outcome of the study was that plants grown at 40 and 60 kg N ha^{-1} produced significantly higher number of branches, number of leaves per plant, and showed higher leaf area index and nitrogen uptake compared to lower nitrogen levels. Leaf biomass yield (kg /ha) and other yield parameters (dry leaf yield, number of leaves per plant, leaf area index and dry matter accumulation per plant) were maximum in plants grown at the highest level of farmyard manure (45 t FYM ha^{-1}). Dry leaf yield and dry matter accumulation per plant was highest at 60 kg N ha^{-1}.

Rathore *et al.* (2013) while evaluating the performance of mango based agri-horticultural models under rainfed situation of Western Himalayas inferred that on degraded lands, leguminous and oilseed crops can be grown economically with mango upto 7 years and thereafter shade tolerant crop like ginger, turmeric, colocasia etc. can be grown for judicial use of resources. They further recommended that the mango based agri-horticultural model with intercropping of 15 years can add more monetary value to the farming business as compared to those having 10 years of intercropping or no intercropping with reduced pay back period.

Kashyap *et al*. (2014) in a review on intercropping for efficient resource utilization in Indian agriculture has stated that the most common advantage of intercropping is to produce a greater yield on a given piece of land by achieving more efficient use of the available growth resources that would otherwise not be utilized by each single crop grown alone. Cereals, oil seeds, legumes, cash crops like sugarcane and horticultural crops; all can be efficiently used in intercropping for taking advantage of ecological balance, more utilization of resources, increasing the quantity and quality of harvest and reducing damage by pests, diseases and weeds simultaneously. It also helped in conservation of the soil resource, improvement of soil health and protection of the environment by minimizing nitrate leaching, besides improving nutrient and water-use efficiencies.

Kumar *et al*. (2014) studied the effect of plant spacing and organic mulch on growth, yield and quality of natural sweetener and soil fertility in Western Himalayas. They studied the effect of plant spacing (30 × 30 cm and 45 × 30 cm) and four mulches {pine needles

(*Pinus roxburghii*), poplar leaf (*Populus deltoides*), silver oak (*Grevillea robusta*) tree leaf mulch and un-mulched control} on growth, yield, quality of stevia and soil fertility. They found that weed count and dry weed weight was not affected by spacing levels during August and at the time of harvest, whereas, in un-mulched plots it was significantly higher. Dry leaf yield, total dry biomass and leaf area index (LAI) were significantly higher in 30 cm × 30 cm spacing level and poplar leaf mulch. All the mulched plots significantly increased organic carbon (OC), available nitrogen (N), phosphorus (P) and potassium (K), bacterial and fungal population compared to un-mulched plots. Rebaudioside-A content was higher in plots mulched with poplar leaves. Steviol glycosides were not significantly affected by different treatments. Soil biological activities were also enhanced by tree leaf mulches. Leaf mulch enhanced microbial biomass, relative to non-mulched soils, likely via improving C and water availability for soil microbes.

Lulie and Bogale (2014) analysed the prospects of intercropping of Haricot Bean (*Phaseolus vulgaris* L.) with stevia (*Stevia rebaudiana* L.) as supplementary income generating system at Wondo Genet Agricultural Research Center, South Ethiopia. Their results showed that the yields of haricot bean were not significantly decreased with the increase of stevia population. Sole planting of stevia was superior to other intercropped treatments and produced 20035.3 kg ha^{-1}, 41859 $kgha^{-1}$ and 30947 $kgha^{-1}$ above ground biomass yield (total of three harvesting cycle), 12439.47 $kgha^{-1}$, 26296.2$kgha^{-1}$ and 19367.8 $kgha^{-1}$ leaf fresh weight (total of the three harvesting cycle) and 3450.71$kgha^{-1}$, 7570.3$kgha^{-1}$ and 5510.5$kgha^{-1}$ leaf dry weight (total of the three harvesting cycle) in the consecutive two cropping season and the pooled mean respectively. The LER and MAI indicating the practice of intercropping of haricot bean with stevia was more advantageous than the conventional monoculture crop. Even if significant yield difference was not observed for haricot bean among the treatments, haricot bean intercrop with 80% stevia mix proportion with LER of 1.43 and MAI of 88278 followed by 60 per cent stevia mix proportion with LER of 1.34 and MAI of 62027 proved to be best than planted as sole indicating that the practice of haricot bean–stevia intercropping was more advantageous and profitable than the conventional monoculture crop.

The integrated use of biofertilizers, chemical fertilizers and vermicompost significantly increased the growth parameters (plant height, number of branches, number of leaves, leaf length and breadth, leaf area, land area occupied per plant and leaf area index, number of flowers and fruits) of *Andrographis paniculata* (Mishra and Jain, 2014).

Nayak *et al*. (2014) valuated the economics and yield performance of some short duration fruit and medicinal crops under agri-silvicultural system in rainfed uplands of Odisha. They took two tree species *Acacia mangium* (mangium) and *Gmelina arborea* (gamhar) and four agricultural crops viz. *Ananas comosus* (pineapple), *Aloe vera* (aloevera), *Andrographis paniculata* (kalmegh) and *Curcuma amada* (mango ginger). They established that the trend of crop yield under both the trees and open condition was: Pineapple>Aloe vera>Mango ginger>Kalmegh.

Nedunchezhiyan (2014) conducted an experiment to study the production potential of intercropping spices (ginger and turmeric) in elephant foot yam (*Amorphophallus paeoniifolius*). The intercropping systems showed higher total productivity and starch content, and reduced calcium oxalate content. The highest corm equivalent yield (39.6 t/ha), gross (Rs.3,96,000.00) and net returns (Rs.2,33,000.00) and benefit: cost ratio (2.43) were noticed in elephant foot yam + ginger combination.

Rathore *et al.* (2014) when studying litchi based intercropping models concluded that cultivation of cowpea–toria, okra–toria and pigeon pea as intercrops was successful up to the first 10 years among different fruit-based models, beyond which it was no longer economical. After 10 years, shade-tolerant intercrops (turmeric and colocasia) performed well with litchi. All the agri-horticultural models registered higher BCR in 15 years of intercropping than sole litchi plantation. Among all the models litchi+cowpea+toria and litchi+turmeric recorded maximum net present value (USD 23,983 ha^{-1}) compared to sole litchi model (USD 19,872 ha^{-1}). The study inferred that the space in litchi orchard can be efficiently utilized to grow intercrops and helps in reducing the time of getting returns from the orchard.

Solanki *et al.* (2014) conducted an experiment to find out performance of tuberous medicinal crops (kalihari, kali musli and safed musli) under sapota-jatropha based three-tier agroforestry system. The maximum economic yield was recorded in sole cropping as compared to intercropping of all tuber crops grown under sapota-jatropha. The per cent yield reduction was minimum in kalihari (58.21 %) followed by safed musli (59.95 %) and kali musli (63.54 %) as compared to sole crops. The reason ascribed for this trend was greater availability of solar energy for photosynthesis coupled with lack of competition by tree component.

Swain (2014) in rainfed uplands of Odisha revealed that the mango + guava +cowpea intercropping system exhibited better performance in terms of plant height, girth, canopy area, fruit weight and fruit yield of mango closely followed by mango + guava +

french bean system. The mango plants, under study, however, did not exhibit any kind of variation in quality parameters in fruits. The leguminous intercrops, cowpea and french bean, were the most effective crop because of their desirable impact on improvement of nutrient status of soil and plant of mango orchard. Highest Land Equivalent Ratio (LER) was obtained with mango + guava +cowpea intercropping system (4.17) followed by mango + guava + french bean. The highest benefit cost ratio (2.02) was recorded in the mango + guava + cowpea intercropping systems, which was almost similar to that of mango + guava + turmeric, mango + guava + french bean and mango + guava + tomato.

In a field investigation on performance of turmeric in cashew plantation as intercrop compared to sole cropping, Vikram and Hegde (2014), reported significantly higher fresh weight of rhizome per clump (353.52g), number of secondary rhizome (27.97) and clump size (201.24cm^2) under sole cropping compared to cashew based intercropping (271.83g/clump, 25.53 and 157.88cm^2, respectively) with turmeric. They also observed that turmeric had significantly higher leaf area index (20.28) compared to sole cropping (17.63) at 150 DAP. This revealed that turmeric was a shade loving plant and its yield was found to be significantly higher under sole cropping (224.58q/ha) when compared to intercropping (203.12q/ha) in cashew plantation.

Yadav *et al.* (2014) carried out a trial to study the ideal date of planting and spacing to obtain better growth, yield and quality of ginger crop var. 'IISR Mahima'. They observed that dates of planting had significant effect on all the characters studied but spacing had no significant effect on quality attributes viz., oil and crude fibre content. The closer spacing of 15 cm × 25 cm recorded higher harvest index.

Choudhary *et al*. (2015) studied the effect of multipurpose trees (MPTs) on growth and yield of ginger and turmeric grown as intercrops with MPTs. They found that turmeric and ginger did not perform well under as many as 18 and 5 MPTs, respectively. Turmeric did not significantly reduce its productivity under trees but reduction in yield of ginger ranged from 11.3 to 31.3%. In terms of economic returns, the cost of production was highest in sole crops as it involved two additional weedings. In turmeric, highest net return and B:C ratio was obtained with trees whereas in ginger net returns and B:C ratio were highest in sole cropping. Yield of ginger reduced significantly to the tune of 2.1 t ha^{-1} to 5.84 t ha^{-1} due to the MPTs.

Gebru (2015) in a review on comparative advantages of intercropping to mono-cropping system has summarized some of the important aspects of intercropping system comparative to mono-cropping system. He has concluded that through intercropping, farmers can achieve the full production of the main crop and also an additional yield (bonus) associated with an increased plant population of the second component. Hence, intercropping can increase incomes obtained by smallholder farmers in areas where labour is not scarce, like in the sub Saharan Africa for the small farms where surplus family labour is found; through reduction of economic risk and market fluctuation resulting from growing of a single crop which is more prone to natural hazards and helping the farmers in better utilization of land by having more than one crop produced per unit area. Though all intercrops produced higher productivity, the farmers could better use the appropriate population of component crops in intercropping systems in order to maximize yield of both crops as well as total productivity.

Haque (2015) had reported that mango intercropping with various cereal crops especially paddy had been gaining momentum in Rajshahi region of Bangladesh. It had been found that systematic intercropping of paddy, onion, lentil, mug bean, garlic and some other winter crops, vegetables and spices helped in increasing mango yield compared to sole-cropping. He further revealed that intercropping not only increased total crop production but also helped in improving soil health and fertility with little or no negative effect on mango yield and quality. Furthermore, intercropping created additional job opportunity needed for intensive crop production.

Jarma *et al*. (2015) recorded the effect of flooding on growth parameters of stevia at the University of Cordoba, Colombia. The plants were subjected to flooding before, during and after flowering by periods of 6, 12, 24, 48 and 72 hours. The results indicated that in all evaluated physiological states, the plants died after 24 hours of flooding, with significant reductions in leaf area (80%) and number of leaves (30%) at blooming, as well as the overall biomass per plant which was reduced by 21 per cent. At the post-flowering stage physiological stress induced hypoxia leading to preferential distribution of biomass to the root at the expense of the stem. The results of study indicate that stevia is a plant, highly susceptible to water stress conditions.

Ginger grows well in warm and humid climate. Moderate rainfall at sowing time till the rhizomes sprout, fairly heavy and well distributed showers during the growing period and dry weather for about a month before harvesting are necessary. It thrives best in well drained soils like sandy loam, clay loam, red loam or lateritic loam. A friable loam with a pH of 6.0 to 6.5 rich in humus is ideal. However, being an exhausting crop it is not desirable to grow ginger in the same soil year after year. The crop performs well in a temperature range of 19°C- 28°C and a humidity of 70-90% (Jayashree *et al.*, 2015).

Kittur *et al*. (2015) examined the performance of turmeric (*Curcuma longa* L.) in the subcanopy of differentially spaced seven year-old bamboo stand. The study revealed that growth of turmeric is inversely related with LAI of bamboo. Due to higher light interception in close spacing bamboo, turmeric yield was significantly decreased. They concluded that turmeric, although a shade tolerant crop, may perform better if light transmittance was between 66 and 86 % and for optimal performance of the under-storey turmeric in mixed species systems, wider bamboo spacing beyond 8 x 8 m were recommended.

Kunhamu *et al.* (2015) worked out the performance of understorey herbaceous medicinal crops viz. *Zingiber officinale*, *Curcuma longa* and *Kaempferia galangal* under mature plantations of coconut, cashew, rubber and homegarden. It was found that except turmeric all other crops showed reduction in yield under tree component as compared to treeless open. The rhizome yield of ginger followed the order treeless open (3.45 Mg ha^{-1}), coconut (2.86 Mg ha^{-1}), cashew (2.63 Mg ha^{-1}), rubber (2.60 Mg ha^{-1}) and homegarden (1.49 Mg ha^{-1}). Turmeric rhizome production showed considerable variation with highest rhizome yield from mature cashew plantation (7.63 Mg ha^{-1}) followed by open area (7.01 Mg ha^{-1}) and the lowest from homegarden (1.77 Mg ha^{-1}). It was inferred that under storey photo-synthetically active radiation (PAR) transmittance had a cardinal influence on intercrop growth which was highest under cashew (75%), followed by rubber (58%), coconut (17%) and lowest under homegarden (7%). The experiment thus revealed that ginger growth was better under coconut while understorey turmeric and galangal yield were better under cashew and rubber.

In an attempt to determine the effect of shade level and method of pruning to optimize high dry herbage yield per hectare of *Andrographis paniculata*, Nur Faezah *et al*. (2015) conducted a factorial experiment taking 4 levels of shade and method of pruning. They reported that the root fresh weight and dry weight were not influenced by both the factors. Shoot fresh weight and shoot dry weight showed significant increase with the increase in shade levels. Meanwhile the lowest shoot dry weight was recorded from plants grown under full sunlight. Method of pruning significantly produced higher shoot fresh weight by 18.6% and shoot dry weight by 15.4% compared to unpruned plant. *A .paniculata* grown under shade and undergone one time pruning would help in higher biomass production.

Oyedele *et al*. (2015) assessed the response of three spices and one vegetable crop (pepper, turmeric, ginger and basil) as intercrops with juvenile citrus at different spacing regimes. It was revealed that pepper, turmeric and basil were suitable for intercropping than ginger.

Pal and Tarai (2015) in an experiment to find out the viable vegetable based intercropping system in Sweet orange cv. Mosambi in semi arid zone of West Bengal inferred that out of vegetable crops, leafy radish (*Raphanus sativus* L.), guwar (*Cyamopsis tetragonoloba* L.), groundnut (*Arachis hypogea*), guwar gave the highest economic returns followed by leafy radish and groundnut. In addition to monetary gains, the system controlled weed population, checked soil erosion, conserved soil moisture and organic matter and protected the soil from leaching of nutrients. The experiment led to the conclusion that for short term intercropping system, leafy radish was best in citrus orchard. On the other hand, guwar gave maximum returns as an intercrop though it remained for a longer duration in the field than radish.

Pal *et al*. (2015) studied the interactive effects of crop ecology and plant nutrition on yield and secondary metabolites of *Stevia rebaudiana*. The investigation was carried out at three experimental locations CSIR-IHBT, Palampur; Regional Horticultural Research Station (RHRS), Jachh and Punjab Agricultural University, Ludhiana. The experiment comprised of three levels of nitrogen, two levels of phosphorus and three levels of potassium. The results confirmed that the growth and dry matter accumulation of stevia are markedly governed by the prevailing environmental conditions at planting time and vegetative growth phases. The plants, grown under CSIR-IHBT conditions, produced maximum dry leaf and stem yield, while least performance was found under PAU condition. These results could be due to the fact that environmental conditions, particularly temperature was not favourable during planting and vegetative growth phases at PAU. The maximum temperature at PAU reached more than 42°C during plant establishment and vegetative growth stages which caused reduction in the yield. Extremely high temperature and corresponding lower RH could have reduced photosynthetic activities.

Pordel *et al*. (2015) studied the effect of waterlogging level and duration, nitrogen fertilizer and terminal drought stress on root and shoot growth of stevia. Treatments included four waterlogging levels; (0, -5, -10 cm from soil surface and with normal irrigation as control), in periods of 2 and 4 days of waterlogging, two levels of nitrogen (6% and 0) from source of urea and two levels of terminal drought stress. They concluded that increase of waterlogging either level or duration decreased the amount of root and shoot characteristics. Low nitrogen supply and drought stress both reduced stevia growth and increased dry matter allocation to roots as differences between shoot traits which received nitrogen or did not, were smaller in comparison with root ones. Drought stress increased root length. The amount of this increase was more when nitrogen was applied. Generally, these interactions showed that application of nitrogen fertilizer was reducing the negative effects of waterlogging or drought stress. Nitrogen also favored root growth over shoot growth under stress thereby increasing the root/shoot ratio.

Prakash and Pant (2015) while investigating the effect of tree spacing and organic manures on growth parameters of *Dianthus barbatus* under *Grewia optiva* based agroforestry system revealed that maximum plant height, maximum plant spread and number of side stems in the flower were recorded in open condition as compared to agroforestry system. Organic manures like FYM, vermicompost, enhanced the growth parameters both in open condition and within agroforestry system. The study further revealed that with increase in the tree spacing, growth parameters like plant height, plant spread and number of side stems also increased. Intercropping of flower crop with *Grewia optiva* provides an excellent agroforestry system to enhance the socioeconomic status of the farmers.

In another review on intercropping of medicinal plants, Singh *et al.* (2015) have advocated to adopt intercropping of medicinal plants for obtaining additional remuneration for the farmers. Medicinal plants like *Lavendula officinalis, Atropa belladonna* and *Echinacea purpurea* are important source of alkaloids and essential oils, which have huge demand in pharmaceutical industries can be grown successfully in the wide spacing available in the tree plantations. Intercropping of compatible plants also encourages biodiversity, by providing a habitat for a variety of insects and soil organisms that would not be present in a single-crop environment. This in turn can help limit outbreaks of crop pests by increasing predator biodiversity. Additionally, reducing the homogeneity of the crop increases the barriers against biological dispersal of pest organisms through the crop.

Bammanahalli *et al.* (2016) in a review on fruit based agroforestry systems for food security and higher profitability has opined that these system comprises of a combination of perennial (fruit trees) and annual plant species as different components in the same piece of land arranged in a geometry that facilitates maximum utilization of space in four dimensions (length, width, height and depth) leading to maximum economic productivity of the system. This agroforestry system contributes products as well as services some of which have economic potential as cash crops and are also highly adaptable and applicable to a wide area and range of physical and social conditions worldwide. Because of the relatively short juvenile (pre-production) phase of fruit trees, fruits have high market value and the contribution of fruits to household dietary and nutrition, this system enjoys high popularity among resource limited producers worldwide and provides the subsistence to farmers and appreciable amount of economic returns even under unfavourable agro-ecological situations.

Islam *et al.* (2016), in an experiment on productivity and profitability of intercropping sesame with turmeric at marginal farmers level of Bangladesh found that rhizome yield of turmeric was significantly higher in intercropping (22.85-23.77 t ha^{-1}) with sesame than in sole turmeric (18.80 t ha^{-1}). The maximum yield (23.77 t ha^{-1}) was in treatment turmeric (100%) + 3 row sesame (100%) in between turmeric lines intercropping system. It might be due to poor growth and development of sole turmeric in open sunlight than in intercropped condition, turmeric being a shade loving crop. It was also recorded that the emergence of turmeric plants was faster in sesame-turmeric combination than in sole turmeric only.

Jakhar *et al.* (2016) while assessing multitier agroforestry system for integrated resource conservation on uplands of Eastern Ghats region in India found that integration of suitable fruit trees within the cropping system can reduce risk allied with rainfed farming. Their results revealed that multitier plantation of drumstick (*Moringa oleifera*) with *Gliricidia sepium* hedgerow and ginger *(Zingiber officinale*): pigeonpea (*Cajanus cajan*) (8:2) intercropping enumerated minimum mean runoff (8.26 %) and soil loss (3.45 Mg ha^{-1}). This treatment saved 74 per cent more soil organic carbon, 64 per cent more phosphorus and 66 per cent more potassium, respectively than broadcasted finger millet cultivation (traditional farmers' practice). An increase of 24–27 per cent drumstick fruit yield was observed in Gliricidia hedgerow based multitier agroforestry system over non-Gliricidia system.

In an economic appraisal of growing ginger and turmeric as intercrops with tree species (Sapota-Jatropha) Pandey *et al.*, 2016 reported that growing of ginger crop in South Gujarat had higher cost of production but lesser economic returns both as a sole crop or under Sapota-Jatropha based agro-forestry systems as compared to growing turmeric, which had lower cost of production and higher net income and benefit cost ratio.

Priyadharshini *et al*. (2016) investigated the effect of bio-fertilizer on *Andrographis paniculata.* The experiment was conducted in earthern pots. It was found that the maximum yield in growth parameters such as in shoot length, root length, plant height, leaf length, leaf width, leaf area, number of leaves, number of hairy roots, shoot girth and number of branches were obtained in bio-fertilizer applied pot than the untreated pots. They reported that the use of bio-fertilizers, chemical fertilizers along with vermicompost in integrated manner was beneficial in improving the growth of *Andrographis paniculata.*

Turmeric can be grown under diverse tropical conditions with altitudes ranging from sea level to 1500 meters above sea level. It requires a well drained sandy or clay loam soil with a pH range of 4.3-7.5 and temperature ranging from 20^{o}C -30^{o}C with annual rainfall of 640 to 4290 mm. The crop is raised as rainfed where rainfall is high and distributed for 5-7 months and as irrigated crop where rainfall is low. Average yield is 200-225 q/ha (Samnotra *et al*., 2016). It is a partial shade tolerant plant that could be cultivated at around 59−73% Relative Light Intensity (RLI) for higher yield and curcumin content. However, the degree of RLI required for better turmeric cultivation vary with the place, year and irradiance level (Hossain *et al*., 2009).

In a field study on influence of crop geometry on yield, yield attributes and glycoside yield of *Stevia rebaudiana*, Rashid *et al*. (2015) revealed that in case of row to row spacing, highest number of leaves per plant (533.0, 447.6), leaf area (8113.1, 6322.6 cm^2/plant), leaf area index (5.1, 8.7) and dry matter accumulation per plant (86.0, 76.9 g/plant) during 2006 and 2007, respectively were found under wider row spacing of 75 cm. Whereas, the fresh biomass yield (9861 and 11801 kg/ha), dry biomass (2080 and 2550 kg/ha), leaf yield (6129 and 4414 kg/ha) and stem yields (7611 and 5447 kg/ha) during 2006 and 2007, respectively and glycoside yield were registered higher under closer row spacing of 45 cm than the wider row spacing of 60 cm and 75 cm. In plant to plant spacing, the maximum number of leaves (5681.3 cm^2/plant) was recorded under plant spacing of 45 cm which was statistically at par with plants spaced at 37.5 cm and 30.0 cm. The increase in dry biomass yield under plant spacing of 15.0 cm was 16.22, 33.46, 48.70 and 51.28 per cent higher over plant spacing of 22.5 cm, 30.0 cm, 37.5 cm and 45.0 cm.

Sanwal *et al*. (2016) considered the integration of *Andrographis paniculata* as potential medicinal plant in Chir Pine (*Pinus roxburghii* Sarg.) plantation of North-Western Himalaya. They revealed that the growth parameters, namely, plant height and number of branches per plant, were significantly higher on western aspect and lowest on northern aspect except for leaf area index which was non-significant. They divulged that net returns can be enhanced by integrating *Andrographis paniculata* with pine and this silvi-medicinal system can be suggested which will help in utilizing an unutilized part of land and increase total productivity from such lands besides *in-situ* conservation of the *A. paniculata*.

In a field experiment on influence of planting geometries and weed control practices on growth and herbage yield of kalmegh, Semwal *et al*. (2016) The findings of the study indicated that growth related parameters of kalmegh like number of branches, plant spread and leaf area index were significantly influenced by the wider planting geometry over that of close spacing. However, plant height, dry matter accumulation by crop/m^2 and dry herbage yield/ha were significantly higher under the closely spaced plants compared to widely spaced plants. It was deduced that an integrated approach of pre and post-emergence applied herbicides followed by mechanical weeding along with close planting geometry produced the best result in achieving more dry herbage yield of kalmegh.

Sharma *et al*. (2016) in another comprehensive review on agro-technologies of stevia stated that it is a crop of recent domestication in the world. An extension of intercropping in stevia can lead to increased stevia productivity, along with food grain production. A yield advantage in intercropping is achieved only when component crops do not compete for the same resources over time and space. To reduce competition for stevia with wheat cropping, maturing along with the emergence of stevia needs to be explored to increase stevioside productivity.

Shriver (2016) has reported that intercropping of turmeric and ginger with coffee in dry areas of Central America was putting cash in the hands of farmers at a very critical moment of increasing poverty, decreasing food security and degrading natural resources due to changing climatic conditions. The farmers were adopting the system enthusiastically due to (i) Short production cycle of both ginger and turmeric (ii) Both rhizomes can be grown in a wide range of altitudes, making both crops highly suitable alternatives in a changing climate (iii) Both turmeric and ginger were shade tolerant and could be intercropped with coffee between rows in an agro-forestry system or in full-sun compact systems.

In an investigation on evaluating the efficiency and economic potential of vegetable crops as intercrop for orchard floor management in guava and Indian goose berry plantation, Singh *et al*. (2016), found that tuber crops like aroids, turmeric and ginger were most remunerative in terms of high benefit: cost ratio when grown under Guava and Amla. They have further reported ginger to be a suitable intercrop among different tuber crops under perennial tree plantations. It is shade loving and has high biological efficiency to transfer intercepted solar energy to highest rate of dry matter production per unit area per day. But the rhizome yield increased only upto 25 per cent shade and thereafter it declines. At shade levels above this, the leaf area was found to increase, which further resulted in mutual shading (Girija Devi *et al.*, 2011).

While evaluating the performance of root vegetables and spices in association with Banana (*Musa spp.*) under coastal plain zone of Odisha, Swain *et al*. (2016) revealed that arrow root intercropped with banana gave the highest yield of 16.4 t ha^{-1} followed by elephant foot yam (13.5 t ha^{-1}) and the minimum yield was with ginger (6.2 t ha^{-1}). Banana and arrow root intercropping yielded a net profit of Rs. 3, 98,750/- as compared to a net profit of Rs. 3, 66,450/- with banana + turmeric and a net profit of Rs. 1, 95,750/- under control. Maximum B: C ratio of 2.38 was obtained in banana + arrow root intercropping as compared to 2.29 with banana+ turmeric and minimum under control.

In an experiment conducted by Tadesse *et al*. (2016) on influence of plant population density on growth and yield of stevia at Wondo Genet South Ethiopia, stevia was planted in five intra-row spacing (20cm, 25cm, 30cm, 35cm, and 40cm) and three inter-row spacing (40cm, 50cm and 60cm) with fifteen treatment combinations. The study showed that the highest stevia herbage yield per unit area was recorded from the combined spacing of 20cm intra-row and 40cm inter-row spacing. However, due to difficulty in performing intercultural operations at this spacing, 25cm x 40cm was the best combination for stevia to attain maximum yield under appropriate management conditions at Wondo Genet and similar locations.

Liphan and Detpiratmongkol (2017) studied the effect of 5 shading levels (0%, 20%, 40%, 50% and 80% of shading) on four local Kalmegh varieties (Phisanulok 5-4, Prachinburi, Ratchaburi and Phichit 4-4) and they consummated that Prachinburi was the best among the four varieties. 20 per cent shade level was optimum for getting highest growth and leaf dry weight and increased shading above 20 per cent reduced stem growth and dry weight yield.

2.2 Component interactions

2.2.1 Physiological attributes of intercrops

Growth is directly related to the amount of radiation intercepted by a canopy (Monteith *et al*., 1991; Terashima and Hikosaka, 1995). High irradiances induce depression of photosynthetic productivity in many crops (Barth *et al*., 2001). It has been reported that intercropping enhances growth as a result of reduced high temperature stress or light induced inhibition of photosynthesis (Rodrigo *et al*., 2001). A severe reduction in incident radiation reduces photosynthetic productivity and growth. Plants adapt to shade by increasing leaf area, manifested by changes in specific leaf area (SLA), leaf weight ratio (LWR) and leaf area ratio (LAR) (Valio 2001). Shade leaves also have a higher chlorophyll concentration per unit of fresh mass and a lower chlorophyll a/b ratio than sun leaves, because a greater quantity of chlorophyll is associated with antennae molecules in shade leaves (Evans and Poorter, 2001).

Goncalves *et al*. (2001) carried out a study to assess environmental light effects on leaf pigment concentrations and chlorophyll *a* fluorescence in mahogany (*Swietenia macrophylla*

King) and tonka bean (*Dipteryx odorata* Aubl. Willd). Chlorophyll concentrations (Chl *a*, Chl *b* and Chl *tot*) on a fresh mass basis were greater in shade leaves than in sun acclimated leaves in both species. Carotenoid concentrations were higher for sun-acclimated leaves of mahogany, both on a per unit area and on a fresh mass basis. In tonka bean, higher carotenoid concentrations were observed in shade leaves on a fresh weight basis. It was concluded that species use different strategies of utilizing photosynthetic pigments in order to adapt the changing environment. Plants increase light capture in shade environment, and protection against photo-inhibition in bright environments.

Senevirathna *et al*. (2003) compared growth, photosynthetic performance and shade adaptation of rubber (*Hevea brasiliensis* Muell. Arg.) plants growing in natural shade (33, 55 and 77% reduction in incoming radiation) to control plants growing in full sunlight. They concluded that plants had a low photosynthetic capacity under shade conditions which coincided with a decrease in total dry matter production with increasing shade and low biomass accumulation of rubber under shade conditions was associated with a decline in RGR.

In a review on the impact of long-term changes in temperature on plant growth and its underlying components, Atkin *et al*. (2006), surmised that adaptation of crops to stressful, unfavourable habitats was associated with increased plasticity of biomass allocation between leaves and roots in response to differences in temperature during growth. The increased mass of roots or increased allocation of biomass to root help in the increased uptake of nutrients under stressful environments.

Net assimilation rate (NAR), one of the most important growth parameters describes the net production efficiency of the assimilatory apparatus. Rapid increase in the net assimilation rate led to rapid decrease in the vegetative growth in the later stages of crop growth. The highest NAR was obtained at high light intensity and low temperatures conditions and vice versa. At high temperature, increasing light integrally increased relative growth rate linearly. Caliskan *et al*. (2009) regressed the relation among the temperature and light intensity of growth in *Ocimum basilicum* and concluded that the highest relative growth rate was found at high light intensity and high temperatures. It was found that 28°C was the optimum temperature for the relative growth rate. Maximum crop growth rate ranged from 15 to 30 g $m^{-2}d^{-1}$, which increased with increasing light density.

Abou-Arab *et al*. (2010) assessed the physico-chemical characters of natural sweeteners steviosides produced from *Stevia rebaudiana* plant. Their study showed that the content of chlorophylls in fresh leaves was 161.7 mg 100 g^{-1} and the content of carotenoids was 39.8 mg100 g^{-1}.

Bukhsh *et al.* (2010) studied the effect of different plant density levels on agro-physiological traits of different maize hybrids under site specific conditions of Pakistan. Out of the three hybrids (pioneer 30 DSS, pioneer 3012 and pioneer 3062) Pioneer-30D55 significantly produced more NAR (4.51 g m^{-2} day^{-1}). Crop planted at plant density 40816 plants ha^{-1}, produced significantly more NAR (4.81 g m^{-2} day^{-1}) against 4.53 g m^{-2} day^{-1} and 3.79 g m^{-2} day^{-1} at plant density 57142 plants $ha^{-1}$and at plant density 95238 plants ha^{-1}, respectively, with significant variation between them. Low NAR at high plant density was ascribed to proportionally less increase in dry matter accumulation per unit area as compared to increase in leaf area duration and leaf area index.

The ecological advantage of high RGR in plant indicated a rapid increase in size and was able to occupy a large space, both below and above ground and had the opportunity to acquire a large share of limiting resources like nutrient or water than a slow growing species. A high RGR also facilitated rapid completion of life cycle of a plant opined Gulshan *et al.* (2012).

Sangwan (2014) studied agri-horti-silviculture model involving fruit trees, poplar as timber tree and colocasia as root crop. Colocasia performed better under partial shade in terms of yield and yield contributing factors. The yield decreased with increasing shade level. Yield showed inverse relationship with canopy age. The transpiration rate of colocasia was lowest under shade conditions irrespective of the crop used in the experiment leading to more water use efficiency in the shade conditions than in open. It was suggested that to minimize resource competition and improve physiological processes of crops, canopy management is essential to ensure better yield under pear-based agri-horti-silvicultural system.

Dry matter distribution/ partitioning at different developmental stages of the crop is useful to improve quantification of various parameters in crop growth simulation studies. Banerjee and Krishnan (2015) conducted field experiments to characterize changes in biomass of each aerial component at different crop growth stages in wheat (*Triticum aestivum* L.) var. HD 2967 under the ambient and high temperature stress (ambient +3^{o}C) conditions. Under ambient condition the proportion of allocation of biomass was high (0.298) towards leaves compared to the high temperature where higher proportion (0.86) was observed in stems and low in leaves. This showed that the high temperature shunt the growth of leaf organs.

Thirumdasu *et al*. (2015) investigated the effect of intercropping spice crops (ginger and turmeric) on growth, physiological aspects and yield of elephant foot yam. Highest LAI (1.88) was recorded in elephant foot yam (EFY) with single row of turmeric. Irrespective of the treatment effect, net assimilation rate and relative growth rate of the EFY were continuously reduced with the duration of the crop but the crop growth rate increased with advancing of days. The higher rate of net assimilation and relative growth at initial 60-90 days after planting was due to rapid increase of dry matter in the plant and corm of the EFY.

2.2.2 Effect of intercrops on soil physico-chemical properties

Soil moisture plays major control on many hydrological processes, especially runoff generation, soil evaporation and plant transpiration. Soil moisture is one of the most difficult variables to estimate because of its interaction with vegetation, soil types, topography and climate variability. Hydraulic soil properties differ at depths, because of a vertical soil heterogeneity and soil type's effect. Deeper soil moisture profile, where evapo-transpiration losses are smaller has less variation in moisture content with initially high water followed by smooth depletion. Overall the soil moisture is affected by the precipitation fluctuation (Longobardi, 2008).

Mubarak *et al*. (2008) monitored dry-matter weight loss and macro- and micronutrient changes during decomposition of litters from three forest trees (Eucalyptus, Ficus, and Leucaena) and litters from two horticultural trees (mango and guava). It was concluded that nitrogen was continuously immobilized in mango during the decomposition period. The release rate of phosphorous from guava was about 2.7-fold that from mango. Concentration of K in the decomposing guava residue was only one third of the initial content compared to one half of mango residues. Finally, they inferred that rate of mass loss of guava (9.8% week 21) was faster than that of mango (4% week 21) by about 145%. Guendehou *et al.* (2014) supplemented the above results through a study, "Decomposition and changes in chemical composition of leaf litter of five dominant tree species in a West African tropical forest." They reported that the chemical fractions decomposed according to species, the higher the N content in fresh litter the higher the mass loss at early stages of decomposition. Mass loss at an early stage might be related to the concentrations of the major nutrients, such as N, P and sulphur (S), not only within a single species but also over several species. After 8 weeks, litter chemistry was dominated by acid-hydrolysable compounds, lignin and N, thus driving the decomposition process in subsequent stages.

Rodrıguez Pleguezuelo *et al*. (2009) assessed the decomposition rates and N-release in various types of litter. The work revealed that amongst the sub tropical crops chosen for the study, cherimoya (*Annona cherimola*) had the highest decomposition rate and mango had the lowest 1.30 and 0.64 year^{1}, respectively. The mean residence time for mango was 2.03-fold higher than for cherimoya. Mango had the highest C:N ratio at the beginning of the experiment and it had the most persistent leaves, whereas the opposite trend was found for cherimoya. The remaining biomass (RB) values for cherimoya, loquat, avocado, and mango were 13.4, 26.9, 23.2, and 38.7%, respectively. Cherimoya had average daily decomposition rates of 1.8- and 1.4-fold higher than mango for the first and second period, respectively. The experimental set up provided a general decreasing trend for the C content in the litter of four plants, more marked in avocado and mango, which had only 60 and 67% of the remaining C at the end of the experiment. Loquat and mango showed the highest accumulation of N, and thus they could be used for long-term soil fertilization. On the other hand, cherimoya accumulated higher amounts of C than the rest of the subtropical leaves studied.

Singh *et al*. (2012c) conducted an experiment on effect of spacing and biofertilizers on growth and nutrients of stevia (*Stevia rebaudiana*) taking four spacing levels (30 cm × 20 cm, 30 cm × 30 cm, 45 cm × 20 cm and 45 cm × 30 cm) and six bio-fertilizer based nutritional trials (100% NPK (recommended dose: 60:30:45 kg/ha) 75% N + PK + *Azotobacter* (Azoto), 100% N + PK + Azoto, 75% N + PK + *Azospirillum* (Azosp), 100% N + PK + Azosp; and control (no fertilizers). They reported that the spacing of 30 cm × 30 cm recorded significantly higher number of leaves, than other spacing levels, at 30, 60 and 90 DAP. Higher plant height, plant spread (24.06 cm^2/plant), number of leaves and number of branches were recorded in the treatment that received 100% N + PK + *Azotobacter* and 100% N + PK + *Azospirillum* at all the growth stages Significantly, higher N content of 1.64% and K content of 1.49% was recorded in the treatment combination 30 cm × 20 cm with 100% N + PK + *Azotobacter* than other treatment combinations.

Orchard soils need special attention on micronutrient management opined Kumar *et al*. (2015) while studying the micronutrient status of mango orchards of Uttar Pradesh and identifying the limiting micronutrients in mango. The study revealed that the soils of mango orchard had low soil organic carbon due to (1) the increased microbial activity and rapid organic matter decomposition under high temperature of subtropical region which restricted carbon build up in soils (2) farmers adopted conventional system of orchard management (clean cultivation) without adding organic supplements.

In a study conducted to assess the effect of various intercrops on the performance of mango in the rainfed uplands of Odisha, Swain (2014) reported an increase in the content of nitrogen, phosphorus and potassium in the top soil but the rate decreased with depth. The increase in availability of nutrient contents in the soil was due to increase in humus content of soil after decomposition of biomass of intercrops that builds up total population of beneficial microbes in the orchard soil.

The results of comprehensive investigations done by Ganeshamurthy *et al*. (2016) on soil chemical, physical, biochemical and biological properties of soils under conventional and conservation horticulture practices over a long period in dryland mango orchards revealed that long-term soil conservation management in mango orchards improved the quality of soils through enhancing the organic carbon fraction and biological status, especially near the surface. Addition of litter and other crop residues lowered the soil bulk density and enhanced the infiltration rate. Soil aggregates and water stability improved under conservation treatments. Soil microbial diversity and extra cellular enzymes level improved over conventional management. Clean cultivation in mango orchards lead to crust formation, decreased porosity, increased bulk density and low infiltration rates. The situation was reversed by adopting conservation practices (incorporating vegetables and/or legume cover crop and intercropping with sweet potato and cowpeas). Conservation horticulture practices led to increased microbial diversity. Proportionately higher fungi in conservation plots than in conventional plots indicated higher importance of fungi to decomposition of residues and nutrient mineralization in those systems.

Selvaraj *et al*. (2016) focused on the estimation of carbon sequestration potential, physicochemical and microbiological properties in *Mangifera indica* L. (Mango), *Manilkara zapota* L. (Sapotta), *Cocos nucifera* L. (Coconut) and *Tectona grandis* L. (Teak) maintained under different years viz., 5, 10, 15 and 20 years, respectively. The microbial colonies and humus content was high in mango and teak compared to sapotta and coconut orchards. The highest total organic carbon and carbon stock was recorded in teak followed by sapotta, mango and coconut. The highest nitrogen content was recorded in soils with teak plantation which was due to the high litter fall and high rate of decomposition.

2.2.3. **Effect of intercrops on soil microbial load**

Soil microbial communities are arguably the most diverse communities ranging from myriad of invisible microbes to the more familiar macro-fauna that plays a critical role in the maintenance of ecosystem sustainability. Microorganisms are found in abundance with great species diversity in the soil of the earth (Ishaq and Khan, 2011). Nonetheless, agricultural landscapes exhibit a high degree of spatial variability, including variation in soil physicochemical characteristics and agro-ecosystem management (Vasseur *et al*., 2013).

The vertical distribution of specific microbial groups depends solely on the basis of decline in carbon availability with soil depth. Higher concentration of C in soil raise the proportions of fungi and gram-negative bacteria in the microbial community and lower the proportions of actinomycetes and gram-positive bacteria. Thus actinomycetes and gram positive bacteria count increased with soil depth while the abundances of fungi and gram-negative bacteria decreased (Fierer *et al*., 2003).

Acosta-Martınez *et al*. (2008) evaluated the microbial communities and enzyme activities of C, N, P and S cycling in representative soils (0–5 and 5–15 cm) of the semiarid region of Puerto Rico as affected by management and land use. They found that the fungal FAMEs (18:1v9c, 16:1v5c, 18:2v6c and 18:3v6c) were higher under pasture soils and mango and quenepa (*Melicoccus bijugatus*) trees compared to vegetable production but no significant differences in soil organic carbon content. It was attributed to a slower degradation of quenepa and mango leaves due to higher lignin content and lower nutrient (i.e., Fe, Mn) contents in quenepa and mango leaves.

Soil pH was the best predictor of bacterial community composition across the landscape while fungal community composition was most closely associated with changes in soil nutrient status (Lauber *et al*., 2008).

Abouziena *et al.* (2010) studied the effect of intercropping on occurrence and enumeration of microorganisms in the rhizosphere of trees. The results indicated that the colony count of fungi and bacteria in date palm rhizosphere fluctuated according to plantation method. Intercropping date palm with mandarin decreased the total fungal count from 21.17 cfu x 10^3g^{-1} to 16.00 cfu x 10^3g^{-1} (24.4% decrease).While, intercropping date palm with mango and clover increased the total fungal count to 118.32 cfu x 10^3g^{-1} and 52.00 x10^3g^{-1} in date palm root, respectively. The reason for the dynamic increase of the microorganisms in the rhizosphere of date palm intercropped with other cultivations was postulated to be the favorable quantitative and qualitative composition of organic compounds added to soil in the form of root exudates and crop residues.

Krishna *et al.* (2012) measured the depth wise profile of microbial load in relation with important soil physicochemical characteristics (soil temperature, soil pH, moisture content, organic carbon and available NPK) of the soil samples collected from Mahatma Gandhi University Campus, Kottayam (midland region of Kerala). The study unbosomed that except pH all other physico-chemical properties showed a decreasing trend with increasing depth. The microbial load (bacteria, fungi and actinomycetes) also decreased with increasing depth. It was inferred that the microbial load was highest at the soil surface where organics and nutrients were highest.

Wemedo and Onolleka (2012) evaluated the rhizospheric bacteria of mango and almond. The study revealed that the mean microbial counts and values of physicochemical parameters were lowest in rhizosphere of mango plant, increased in almond plant and peaked in control soil. They noted that the presence of certain antibacterial compounds such as glycosides, triterpenes, alkaloids, and saponins inhibited microbial growth leading to reduced microbial numbers.

The dynamics of fungal species was greatly influenced by the changes in canopy cover and soil nutrient status. Similar results have been reported by Bhattarai *et al*. (2015) who deduced that tilled soil was well aerated and favored micro-organismic growth. The microbial population was found to be more in O_2 rich soil compared to CO_2. Soil compaction increased with increase in depth and it altered the physical properties of the soil viz. decreased total pore space, decreased soil oxygen content, reduced water infiltration and percolation rate hence, reduced microbial population.

Munaganti *et al*. (2015) isolated and enumerated actinobacteria from mango orchards and they inferred that 13 strains out of the 30 isolated strains of actinobacteria showed antimicrobial activity. Antimicrobial activity of the secondary metabolites produced by two predominant actinobacterial strains (VL-RK_05 and VL-RK_09) among the 13 strains was high against *Bacillus megaterium* and *Xanthomonas campestris*.

Sinha and Raghuvanshi (2015) assessed bacterial, fungal and actinomycetes count in irrigated (daily) and water stress conditions (3 days) in two different medicinal plants (*Eclipta prostrata* and *Andrographis paniculata*) after six microbial treatments. The overall rhizospheric bacterial populations was 2.28 x $10^5 g^{-1}$ in *A. paniculata* followed by *E. prostrata* 2.19 x $10^5 g^{-1}$. The fungal population was 0.96 x 10^5 g^{-1} in *A. paniculata* and 0.89 x $10^5 g^{-1}$ in *E. prostrata*. The actinomycetes population was 1.54 x $10^5 g^{-1}$ in *A. paniculata* and 1.16 x $10^5 g^{-1}$ in *E. prostrata*. The study revealed that the overall microbial load (x10^5cfu/g soil) in rhizospheric soil of two medicinal plant declined in the order bacteria> actinomycetes> fungi both under irrigated and draught conditions.

Tangjang *et al*. (2015) observed higher microbial counts in the surface soil (0-10 cm) which was due to the presence of high organic matter content and adequate moisture supply. The microorganisms in this layer readily decomposed the complex organic residues into simpler forms, hence their large number. In the lower depths there was reduction in microbial population which was attributed to lower amounts of minerals, low oxygen content and increased carbon-dioxide concentration. On the other hand, higher CFUs layer during rainy season corroborates those of Mishra (1965) who pointed out that during rainy months, this layer occasionally harbours more fungal populations caused by temperature and moisture regimes than the topsoil layer. They also reported that in the subsurface soil (10-20 cm) there was more fungal population during rainy season and it was due to percolation and leaching of the organic matter to this layer.

2.3 Economic evaluation of fruit tree based agroforestry system

Ram *et al.* (1999) reported that in patchouli (*Pogostemon patchouli*), its major constituent patchouli alcohol was considerably increased by shade in the intercropped situation of patchouli with papaya than in sole patchouli crop. In case of understory species, Gangadharan and Menon (2003) also found significant effect of shade, with lesser amount of shade promoting higher yield, thus following an inverse relationship.

Singh *et al.* (2001) studied the economic profitability of raising medicinal and aromatic plants as intercrops in four and five year old poplar (*Populus deltoides*) based agroforestry system. All the crops namely *Mentha arvensis*, *M. gracilis*, *Zingiber officinale*, *Curcuma domestica, Pogostemon cablin*, *Artimisia annua*, *Ocimum basilicum* and *Piper longum*, except *Costus speciosus*, performed well in the system. The maximum net return was obtained in *Curcuma domestica* Val. (64,700 and 68,300), followed by *Zingiber officinale* Rosc. (59,750 and 61,700) in the first and second year, respectively. The intercropping of *Costus speciosus* Koen. gave least net returns (1710 and 550) in the respective years. However, the net returns per rupee invested, was highest in *Artemisia annua* L. (4.83 and 5.14) followed by *Pogostemon cablin* Benth. (4.81 and 3.98). Investigation carried by Kumar (2001), revealed that net return of Rs. 29039 (morus, maize and soybean), Rs. 31942 (peach, maize and soybean), Rs. 31554 (peach, morus, maize and soybean), Rs. 25140 (morus, maize and lentil), Rs. 30195 (peach, maize and lentil) and Rs. 28810 (peach, morus, maize and lentil) from rainy and winter season cropping patterns were recorded.

Dutt and Thakur (2004) calculated the monetary status of cropping systems for two consecutive years under Shivalik Ranges of outer Himalayas, combining medicinal and aromatic herbs with commercial timber species. Four herbal crops namely *Ocimum sanctum*, *Spilanthes acmella*, *Tagetes minuta* and *Withania somnifera* were intercropped with 6 year old plantation of Poplar hybrid (G-48) having 8 m × 3 m, 6 m × 4 m, 5 m × 5 m and 4 m × 6 m spacing. Net returns were comparatively more under agroforestry systems combining *Ocimum sanctum* and *Tagetes minuta* with poplar at different spacing in comparison to mono-cropping. However, in *Spilanthes acmella*, the net returns were higher from sole cropping and in *Withania somnifera* due to high cost of cultivation, the net returns became negative. Among different spacing 8 m × 3 m and 6 m × 4 m excelled over 5 m × 5 m and 4 m × 6 m spacing, which ensured significantly higher net returns from the combination.

Tomar and Bhatt (2004) conducted a field experiment in a six year old plantation of guava (*Psidium guajava* cv. Allahabad safeda), Assam lemon (*Citrus lemon*) and peach (*Prunus persica* cv. TA 170) during 2002 and 2003, on acid alfisol under rainfed condition in Umiam, Meghalaya, India to study the performance of upland rice cultivars as intercrops in the existing fruit plantation and to study the overall productivity of agri-horticulture systems. The result showed that on an average, the maximum net monetary benefit per hectare was recorded from peach intercropped with rice (Rs. 48,044), followed by guava (Rs. 27,887) and Assam lemon (Rs. 20,991), irrespective of rice cultivars. Peach, guava and Assam lemon exhibited 5.09, 2.95 and 2.22 fold higher net returns, respectively compared to the control. Peach based agroforestry system was found promising for rain fed agricultural conditions in the north-eastern region of India in general and Meghalaya in particular.

In an intercropping study carried out by Ratha and Swain (2006) in mango orchard in Orissa, mango+ginger combination proved to be the best in terms of monetary benefits (Rs. 63,940 ha^{-1}) followed by mango+cowpea (Rs. 30,210 ha^{-1}). It was inferred that intercropping increased the yield of base mango crop which in turn provided extra income to the farmers and restricted the temporary migration of labour/farmer. The biomass produced by the intercrops as well as the yield obtained from the intercrop augmented the net returns per unit area leading to better utilization of land, light and water. The tree-crop combination also helped in checking the soil and water erosion from the sloppy upland besides generating employment.

Pujar *et al.* (2007) studied suitable medicinal and aromatic plants as intercrops with teak. Eight treatment combinations of four medicinal and four aromatic plants viz., aloe (*Aloe vera*), kalmegh (*Andrographis peniculata*), Coleus (*Coleus forskohli*), Stevia (*Stevia rebaudiana*), citronella (*Cymbopogon wintereanus*), lemongrass (*Cymbopogon flexuosus*), palmarosa (*Cymbopogon martinii*) and patchouli (*Pogostemon patchouli*) were grown under teak (*Tectona grandis*). The spacing of teak was maintained at 2.4 m × 2.4 m. The significantly higher herbage yield was obtained in aloe (24.50 t ha^{-1}) than in other crops. The next best crop in terms of herbage yield was lemongrass (21.01 t ha^{-1}) which was significantly superior to remaining crops. Herbage yield ranged from 0.98 to 10.07 t ha^{-1} in remaining crops. Compared to their respective sole crops there was marginal reduction (-2.39 to -14.02%) in herbage yield of all the medicinal and aromatic crops (except coleus) when they were grown with teak. Whereas, herbage yield of coleus was increased by 12.93 per cent when grown with teak. This can also be evidenced from significantly higher relative crop yield (112.93%) in case of coleus. In other crops, relative crop yield was less than 100 per cent indicating that herbage yield in association with teak was lesser than their sole crops.

In another study, Channabasappa *et al.* (2009) examined the effect of arecanut on MAP's. The experiment was laid out in split plot design with twelve MAP's (*Andrographis paniculata*, *Ocimum sanctum*, *Stevia rebaudiana*, *Coleus forskohlii*, *Mentha arvensis*, *Catharanthus roseus*, *Pogostemon patchouli*, *Withania somnifera*, *Centella asiatica*, *Hemigraphis colorata*, *Eclipta alba* and *Tinospora cordifolia*) and were tried under arecanut plantation as well as in open field. The economic yield in open conditions was higher than that obtained from crop grown under the shade of arecanut. Among different MAP's Bhringaraj (*Eclipta alba*) recorded maximum yield (11005 kg ha^{-1}) followed by Menthol mint (*Mentha arvensis*) (6158 kg ha^{-1}) and Brahmi (*Centella asiatica*) (5178 kg ha^{-1}). Lowest economic yield (682 kg ha^{-1}) was recorded by Ashwagandha (*Withania somnifera*).

In an investigation on livelihood security to urban and peri-urban farm families through two tier horticultural based cropping system in Farrukhabad district of Uttar Pradesh, Singh *et al.* (2010) have found that the mango based cropping system add synergistic effect on the fruit yield of mango and yield of companion crops (potato, brinjal, pumpkin, vegetable pea, garlic and onion) due to positive effect of root secretion of mango on associated crops and *vice versa*. They also recorded that potato, brinjal, green fruits of pumpkin, green pods of vegetable pea, garlic and onion yielded 225, 218, 278, 92, 73 and 255 q ha^{-1}, respectively, in addition to the 20-25 q ha^{-1} mango fruit. It was concluded that mango based cropping system maintained the cash flow system and improved the economic status of farming community and created eco-friendly environment.

Das *et al.* (2011) reported that the interspaces of the aonla orchard in calcareous belt of Eastern India could be utilized for growing intercrops (turmeric, ginger and arbi) to generate substantial additional income without adverse effect on the soil fertility and productivity of the main crop. Economic analysis of different systems showed that turmeric with aonla earned maximum net returns (Rs 463,665 ha^{-1}), followed by aonla + ginger (Rs

333,993 ha^{-1}) and aonla + arbi (Rs 167,721 ha^{-1}). The three intercropping systems estimated an additional income of Rs. 399,033, Rs.269, 361 and Rs. 103,089 ha^{-1}, respectively over sole orcharding. It was confirmed that aonla based agri-horticultural systems were effective in bringing about improvement in the soil properties as reflected by the significant increase in organic carbon, available nitrogen and phosphorus.

Ghosh and Hore (2011) worked out the economics of a coconut-based inter-cropping system as influenced by spacing and seed rhizome size of ginger. Amongst the five different spacing (20 × 15 cm, 20 × 20 cm, 25 × 20 cm, 25 × 25 cm and 30 × 25 cm) and two rhizome size (15-20 and 25-30 g), the close spacing (20 × 15 cm) in combination with bigger rhizome (25-30 g) produced highest yield (15.39 kg/3 m^2). The high yield recorded in closest spacing was due to increased plant population per unit area, though growth and yield was superior under medium and wider spacing.

Tripathi (2012) evaluated bio-economic appraisal of peach based agroforestry system. Results revealed that peach based agroforestry system exhibited better cost-benefit ratio over sole crop system. Out of three medicinal herbs, *Withania somnifera* provided better returns in comparison to *Ocimum sanctum* and *Andrographis paniculata*.

Material and Methods

CHAPTER III

MATERIAL AND METHODS

Studies on **"Component Interactions in Mango Based Agroforestry System in the Sub-Tropics of Jammu and Kashmir"** were carried out in the year 2015 and 2016. The details of the experimental site, material and research methodology adopted are as under:

3.1 EXPERIMENTAL SITE

3.1.1. Location

The present investigation was carried out at Experimental Farm of **Advance Centre for Horticulture Research (ACHR), Sher-e-Kashmir University of Agricultural Sciences and Technology, Udheywalla, Jammu,** which is located at an altitude of 327m above mean sea level, between $32^{0}73'$ N latitude and $74^{0}87'$ E longitude.

3.1.2. Climate

The experimental site falls under sub-tropical zone of Jammu division of Jammu and Kashmir, with hot dry summers, hot humid rainy and cold winter months. The average annual rainfall of the experimental location is about 1000-1200 mm, of which 75-80 per cent is received during July to September and rest 20-25 per cent during winter months in December to February. The maximum temperature rises upto 45^{0}C during May to June and minimum falls to 1^{0}C during December- January. The meteorological data for the years 2015 and 2016 is illustrated in Figs. 1 & 2 and appended in Appendix I.

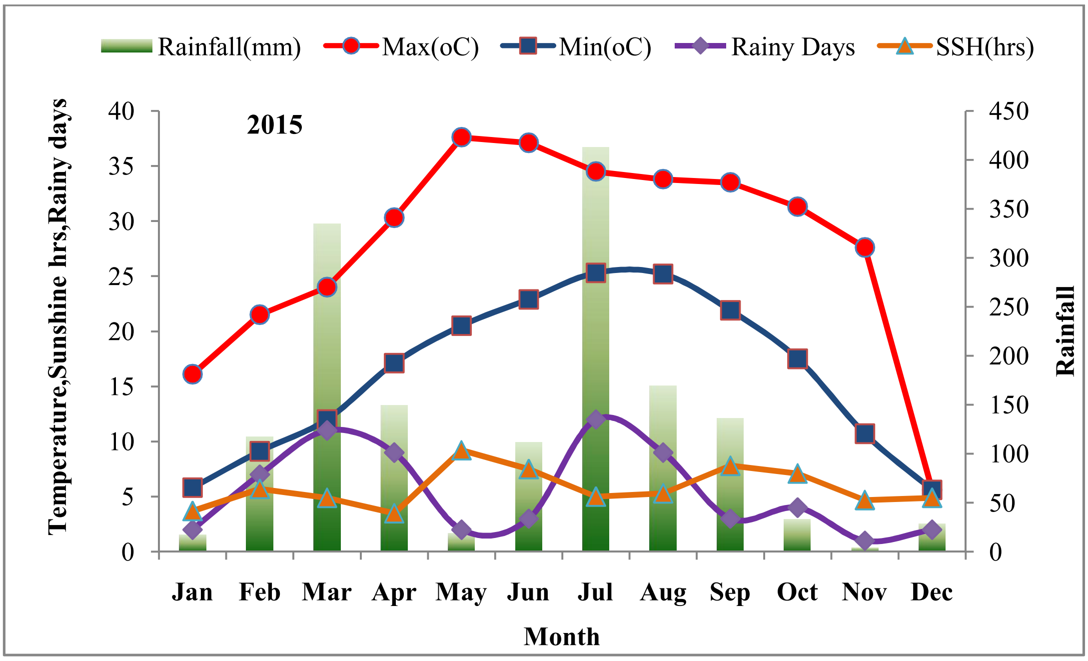


Fig. 1: Meteorological data for the year 2015

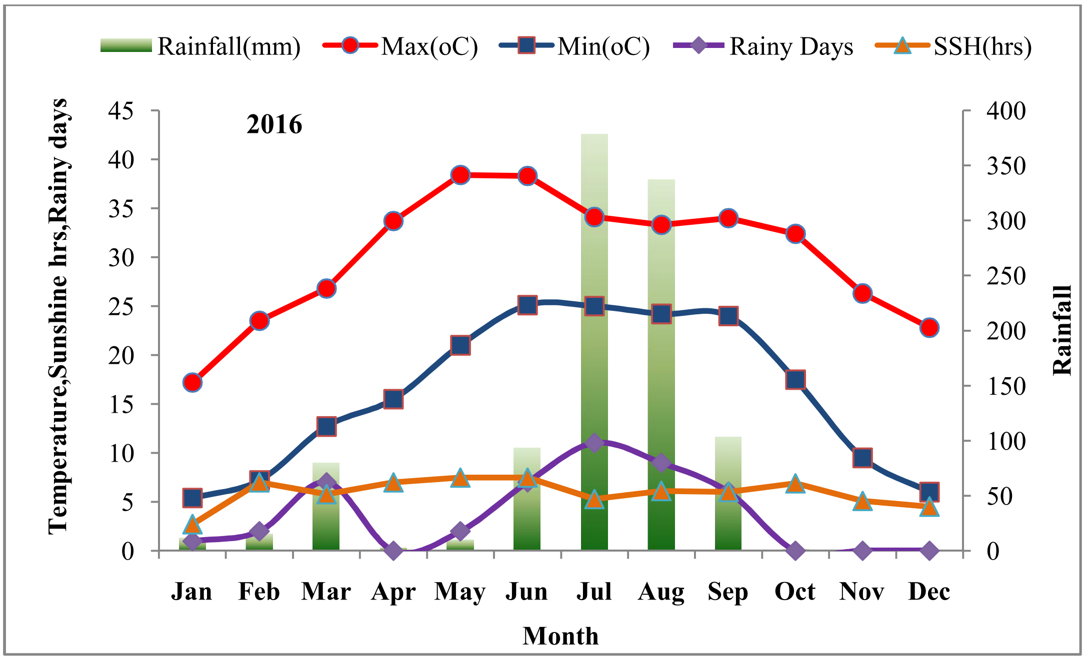


Fig. 2: Meteorological data for the year 2016

3.1.3. Soil characteristics

For physico-chemical analysis of the soil, five composite soil samples were collected through random sampling from the experimental site (under mango and under open condition) at different depths (0-30 cm, 30-60cm and 60-90 cm) before planting by core sampler (Peterson and Calvin, 1965). The collected samples were mixed thoroughly, air dried, ground, sieved and kept in cloth bags for subsequent analysis.

Table 1. Physico-chemical properties of study site

Parameters	Test values					
	Mango orchard			Open condition		
	0-30 cm	30-60cm	60-90cm	0-30 cm	30-60cm	60-90cm
Bulk density (g cm^{-3})	1.173	1.347	1.371	1.147	1.334	1.364
Soil moisture (%)	17.65	18.64	20.18	17.82	19.12	20.06
CEC (c.mol.P^{+})	13.26	12.28	10.58	11.80	11.10	10.50
pH (1:2.5 ::Soil: Water)	6.35	6.42	6.47	6.40	6.59	6.61
EC(dS m^{-1})	0.11	0.10	0.09	0.09	0.08	0.07
Soil organic carbon content (g kg^{-1} soil)	5.10	4.60	4.10	5.81	5.23	4.84
Available Nitrogen (kg ha^{-1})	200.07	186.42	178.27	201.32	150.86	135.12
Available Phosphorus (kg ha^{-1})	13.40	12.04	10.90	13.80	12.26	11.75
Available Potassium (kg ha^{-1})	120.40	115.00	110.38	125.12	110.07	112.34

3.1.3.1 Soil Microbial Count

For soil microbial count, five composite samples were collected (under mango and under open conditions) at two depths (0-15 cm and 15-30 cm) before planting using auger. The collected samples were homogenised and spread in trays to be cleaned of extraneous materials (pieces of root, leaves, small stems, etc.) followed by drying and storing in plastic containers. Microbial load was ascertained by standard serial dilution plate technique (Plate-I). 10 g of soil was transferred to 90 ml sterile distilled water and agitated vigorously. Different aqueous dilutions, 10^{-1} to 10^{-7} of the suspensions were prepared and plated on Soil extract agar and Potato malt agar for determining microbial load and fungal isolation respectively. For determining the load of microorganisms in the sample, colony forming units were determined by the formula:

No. of microorganisms per gram of sample = No. of colonies × dilution factor

Table 2. Soil Microbial count of the study site

Parameter	Open condition		Mango orchard	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Soil Microbial count (x 10^4 cfu g^{-1} soil)	295	178	242	101

3.2 EXPERIMENTAL METHODOLOGY

The study consisted of two structural and functional components viz. Mango (*Mangifera indica*) fruit tree as woody perennial and four medicinal plants as intercrop. In addition, the effect of three spacing of intercrops on their growth and yield was studied with and without mango. Thus, two experiments with same treatment combinations were laid out separately (i) under mango and (ii) in open (without mango).

3.2.1 Structural Components

A. **Tree species** : Mango (*Mangifera indica*)

Spacing : 9m × 9 m

Age of plantation : 29 years

B. **Medicinal plants** (intercrops)**:** Four **(Factor-1)**

i. Ginger (*Zingiber officinale*) - G
ii. Turmeric (*Curcuma longa*)- T
iii. Stevia *(Stevia rebaudiana*)-S
iv. Kalmegh (*Andrographis paniculata*)-K

Spacing (for intercrops): Three **(Factor-2)**

i. 30x20cm -S_1

ii. 30x30cm- S_2

iii. 30x40cm- S_3

3.2.2. Layout and Design

Design	:	Factorial RBD
Treatment combinations	:	12
Replications	:	3
Plot size	:	3.6 x 2.4m
Planting time	:	May, 2015 and May, 2016

Treatment combinations

Crops	**Spacing level**	**Treatment combinations**
Ginger (G)	S_1 (30x20cm)	G S_1
	S_2 (30x30 cm)	G S_2
	S_3 (30x40 cm)	G S_3
Turmeric (T)	S_1 (30x20cm)	T S_1
	S_2 (30x30 cm)	T S_2
	S_3 (30x40 cm)	T S_3
Stevia (S)	S_1 (30x20cm)	S S_1
	S_2 (30x30 cm)	S S_2
	S_3 (30x40 cm)	S S_3
Kalmegh (K)	S_1 (30x20cm)	K S_1
	S_2 (30x30 cm)	K S_2
	S_3 (30x40 cm)	K S_3

Recommended dose of fertilizer to different crops

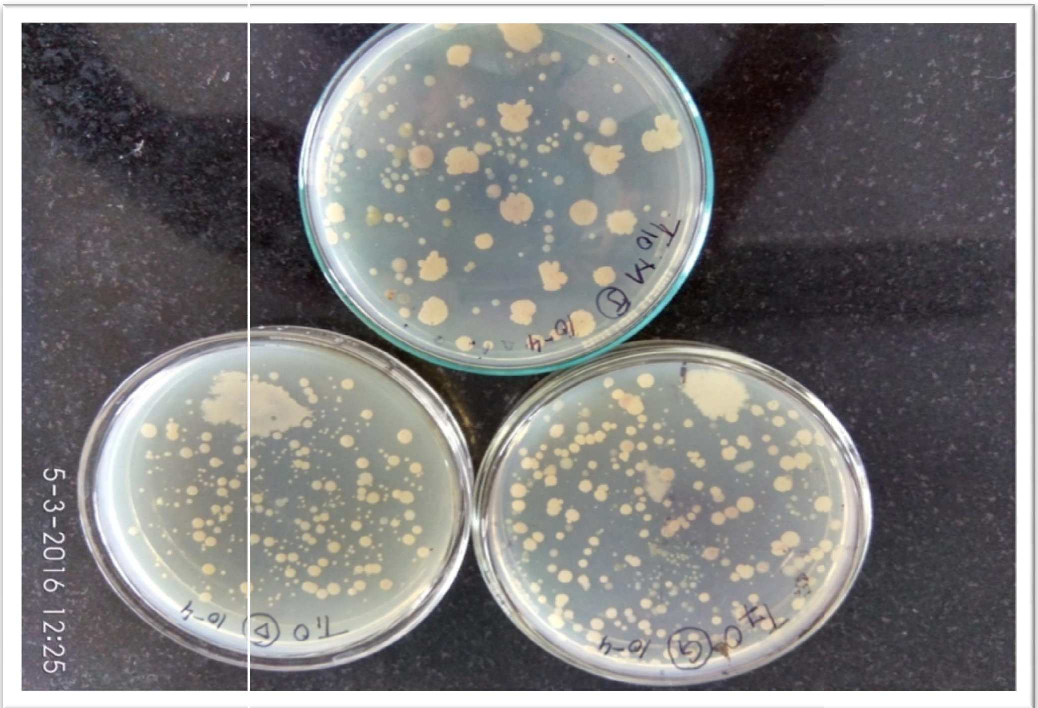
Crop	**N (kg ha^{-1})**	**P (kg ha^{-1})**	**K (kg ha^{-1})**
Ginger	75	50	75
Turmeric	60	30	90
Stevia	60	30	45
Kalmegh	75	75	50

Detailed lay-out plan of the treatment combinations has been appended in appendix II.

3.2.3. Field preparation

The field was prepared thoroughly by using disc plough, harrow and rotavator. All the stubbles and weeds were removed and FYM @25q ha^{-1} was incorporated in the soil. Thirty six raised plots of size 3.6 x 2.4m were prepared both in mango orchard and in open.

Serial dilution of soil sample



Microbial colonies

Plate- I : Plate count method for determining microbial load

Treatment combinations were allotted to the plot randomly under the canopy of mango as well as open conditions.

3.2.4. Planting/transplanting

Bits of size 25-30g were used for planting ginger and turmeric crops. Before planting, the bits were treated with carbendazim (1g/litre) and mencozeb (2.5g/litre) to protect them from seed born diseases. Healthy and uniform (10-15cm height) seedlings were used for transplanting of stevia and kalmegh. The recommended fertilizer dose of respective crop was applied at the time of planting. The crops were planted on 12th May in 2015 and 7th May in 2016. Light irrigation was given after transplanting/planting. Seedlings were regularly watered for about a month for proper establishment.

3.2.5. Intercultural operations

Regular hand weeding was done to keep the crop weed free. Each weeding was followed by hoeing. Earthing up was done in turmeric and ginger after 45 days of planting. Regular pinching was done in stevia after 55-60 days of transplanting to facilitate more vegetative growth.

3.3 Observations recorded

3.3.1. Growth parameters of tree crop

The following growth parameters of randomly selected five mango trees were recorded in the month of May, 2015 and 2016 and expressed as mean values:

3.3.1.1. Crown projection area (cm^2)

Crown projection area of mango tree was calculated using the following formula (Rédei and Veperdi, 2001):

$$CPA = \frac{d_{cr}^{2} \times \pi}{4}$$

Where,

d_{cr} = crown diameter

3.3.1.2. Basal diameter (m)

The collar diameter of mango tree was measured with the help of tree caliper at a height of 25 cm above the ground level and reported as mean.

3.3.1.3. Crown spread (m)

Crown spread (width) was measured from tree trunk in east-west and north-south direction with the help of properly graduated wooden stick and expressed in meters using following formula (Blozan, 2006):

$$\text{Crown spread} = \frac{D_1 + D_2}{2}$$

3.3.1.4. Canopy volume (m^3)

Canopy volume was calculated by using the formula given by Cauldwell (1998).

$$\text{Canopy volume} = 0.333\,\pi[2R^3-(X-H)^2(3R-X+H)]$$

Where,

2R = Greatest canopy diameter

X = Total tree height

H = Variable height used in data analysis not measured in field

3.3.2 Growth and yield parameters of intercrops

Observations were recorded on 15 randomly selected plants per treatment (5 plants per replication) in second week of October, 2015 and 2016 (stevia and kalmegh) and third week of December, 2015 and 2016 (ginger and turmeric). The observations were recorded for the following parameters in both the experiments:

3.3.2.1. Survival per cent

Number of plants survived in each replication was counted after 60 days of planting and expressed as mean in per cent.

3.3.2.2. Plant height (cm)

Plant height of intercrops was recorded in centimetres from base to tip of the main leading shoot using meter scale and reported as mean.

3.3.2.3. Number of leaves per plant

The number of leaves was counted at the end of growing season when no new leaf was formed and reported as mean number of leaves per plant.

3.3.2.4. Number of branches or tillers per plant

Total number of branches or tillers were counted and reported as mean number of branches per plant.

3.3.2.5. Number of roots per plant

Number of rhizomes was counted in turmeric and ginger, whereas number of roots was counted in stevia and kalmegh and reported as mean.

3.3.2.6. Dry weight of roots/ rhizomes per plant (g)

After uprooting the plants, the roots/ rhizomes were chopped off into small pieces with sharp razor and then dried in oven at 50^0C for 2-3 days. Sample was weighed and values were reported as mean.

3.3.2.7. Root growth potential (%)

Root growth potential for all the intercrops was calculated using formula (Ritchie, 1985) as under:

$$RGP = \frac{\text{Crop root number under treatments} - \text{Root number in sole crop}}{\text{Crop root number in sole crop}} \times 100$$

Value was reported as the mean and expressed in per cent.

3.3.2.8. Fresh weight of plant (g)

After uprooting the plant, the fresh weight of whole of the plant was weighed in gram and reported as mean.

3.3.2.9. Dry weight of plant (g)

After recording the fresh weight of the plant, the individual plant was cut into small pieces to facilitate early drying. Thereafter, the samples were dried in oven at 50^0C for 2-3 days, weighed and recorded dry weight till constancy and reported as mean value in grams per plant.

3.3.2.10. Herbage yield (q ha^{-1})

The fresh leaves of stevia were removed from each sampled plant and weighed in grams using electronic balance separately for each seedling and average value was calculated as fresh leaf yield per plant. In case of kalmegh, the whole above ground biomass was weighed and recorded as mean value per plant.

3.3.2.11. Rhizome yield (q ha^{-1})

In ginger and turmeric, the rhizomes were uprooted (January), weighed and recorded as mean. In each treatment combination, the fresh yield was calculated by multiplying the yield per plant with number of plants per hectare and expressed in quintals per hectare. After drying the economic part of each crop in oven at 50^0C for 2-3 days, weighed and multiplied by their corresponding number of plants per hectare, reported as dry yield per hectare in quintals.

3.3.3 Physiological parameters of intercrops

3.3.3.1 Leaf area per plant (cm^2)

Fully expanded leaves of intercrops were taken to laboratory and leaf area of leaves was measured with the help of leaf area meter and mean values were expressed in cm^2.

3.3.3.2 Chlorophyll content (mg gm^{-1})

Chlorophyll content of leaves of intercrops was estimated as per method described by Arnon (1949). The total chlorophyll content was estimated at both vegetative and reproductive stage as per below mentioned formula and expressed as mg/gm.

$$\text{Chlorophyll content} = (20.2 \times OD_{645nm}) + (8.02 \times OD_{663\,nm}) \times \frac{V}{1000} \times W$$

Where,

V = Final volume of supernatant in ml
W = Fresh weight of leaf
OD = Optical density measured at specific wavelength

3.3.3.3 Carotenoid content (mg gm^{-1})

Carotenoid content of leaves of intercrops was estimated as per method described by Price and Hendry (1991). Carotenoid content was calculated as per below mentioned formula and expressed as mg/gm.

$$\text{Total carotenoides} = [OD_{480nm} + (0.114 \times OD_{663nm}) - (0.638 - OD_{645\,nm})] \times \frac{V}{1000} \times W$$

Where,

V = Final volume of supernatant in ml
W = Fresh weight of leaf
OD = Optical density measured at specific wavelength

3.3.3.4. Relative growth rate (RGR) and Net assimilation rate (NAR)

RGR and NAR of intercrops were calculated by formulae (Williams (1946) and expressed in g $g^{-1}day^{-1}$:

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

$$NAR = \frac{W_2 - W_1}{L_2 - L_1} \times \frac{\log_e L_2 - \log_e L_1}{t_2 - t_1}$$

Where,

W_1 = Value of total plant dry weight at time t_1

W_2 = Value of total plant dry weight at time t_2

L_1 = Value of dry weight of leaves at time t_1

L_2 = Value of dry weight of leaves at time t_2

$t_2 - t_1$ = Sampling intervals in days

3.3.3.5. Partitioning coefficient (dry weight basis)

Partitioning coefficient of different plant parts viz. leaves, branches, roots and inflorescence was determined on dry weight basis using following formula (Keulen and Wolf, 1986**).**

$$\text{Partitioning coefficient (part)} = \frac{\text{Dry weight of plant part}}{\text{Dry weight of whole plant}} \times 100$$

3.3.4 Soil parameters

The physico-chemical properties of the soil both under mango orchard and in open were determined before laying out the experiment (Table-3) and at the end of the experiments in 2015 and 2016. Five composite soil samples were taken at three depths viz. 0-30 cm, 30-60 cm and 60-90 cm per replication per treatment with the help of core sampler. After taking them to laboratory, the samples were air dried under shade and crushed using wooden mortar and pestle, sieved through 2 mm plastic sieve.

Table 3. The details of soil parameters recorded and methods employed

S.No.	Soil parameters	Method employed
1	Bulk density (g cm^{-3})	Core tube method (Johnson, 1962)
2	Soil moisture (%)	Gravimetric method (Reynolds, 1970)
3	CEC (c.mol.P^{+})	Sodium acetate method (Chapman, 1965)
4	pH (1:2.5 ::Soil: Water)	1:2.5 Soil: water suspension (Jackson, 1973)
5	EC(dS m^{-1})	1:2.5 Soil: water suspension (Jackson, 1973)
6	Soil organic carbon (g kg^{-1} soil)	Rapid titration method (Walkley and Black, 1934)
7	Available Nitrogen (kg ha^{-1})	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
8	Available Phosphorus (kg ha^{-1})	Olsen *et al*. (1954)
9	Available Potassium (kg ha^{-1})	Neutral 1 N ammonium acetate solution method (Mervin and Peech, 1951)
10	Soil Microbial count (x 10^4 cfu g^{-1} soil)	Standard serial dilution and pour plate method (Johnson and Curl, 1972)

3.4 Bio-economics of the system

Bio economics of system was analyzed by calculating the cost of cultivation, gross and net returns per hectare. In mango+intercrop system, fixed cost towards maintenance of mango was included with all twelve treatment combinations having the four crops. Gross returns from mango was added to the gross returns from the treatment combinations of the intercrops for calculating the total return and B:C ratio from the system as a whole.All these parameters were calculated on the basis of prevailing market price at the time of termination of experiment.

3.4.1 Cost of cultivation

The cost of cultivation of the different intercrops and the tree component was worked out on per hectare basis. The requirement of labour and expenses on different operations such as ploughing harrowing, weeding and harvesting were calculated on the basis of prevalent rates. Cost of inputs like seeds, manures were calculated for each crop based on the actual amounts applied to land use system.

3.4.2 Gross returns

The prevailing local market prices were used to convert the yield of all the medicinal crops as well as mango fruit yield into gross return in rupees per hectare.

3.4.3 Net returns

The net return in rupees per hectare was calculated by subtracting cost of cultivation in per hectare from gross returns per hectare.

3.4.4 Benefit: Cost ratio

Benefit cost ratio was calculated by dividing gross return/income by cost of cultivation.

3.4.5 Land equivalent ratio (LER)

The land equivalent ratio was calculated by the following formula (Willey, 1979):

$$\text{LER of crop} = \frac{\text{Yield obtained in intercropping}}{\text{Yield obtained in sole crop}}$$

3.5 Statistical analysis

In both the experiments, the statistical analysis for each character was carried out on mean values. The data was analysed using OPSTAT programme.

Experimental Results

Experimental Results

CHAPTER IV

EXPERIMENTAL RESULTS

The present investigation entitled “**Component interactions in mango based agroforestry system in the sub-tropics of Jammu and Kashmir**” was conducted at Research Farm Udheywalla of SKUAST-Jammu during 2015 and 2016. Efforts were made to estipulate the impact of different spacing on performance of four crops namely Ginger (*Zingiber officinalis*), Turmeric (*Curcuma longa*), Stevia (*Stevia rebaudiana*) and Kalmegh (*Andrographis paniculata*) both in the open and as intercrop under mango orchard. The results obtained during the course of investigation are presented in this chapter under the following heads:

4.1 Growth parameters of mango trees

4.2 Effect of spacing on growth performance of intercrops under mango orchard

- 4.2.1 Growth parameters
- 4.2.2 Yield parameters
- 4.2.3 Physiological attributes
- 4.2.4 Root characteristics

4.3 Effect of spacing on growth performance of intercrops under open conditions

- 4.3.1 Growth parameters
- 4.3.2 Yield parameters
- 4.3.3 Physiological attributes
- 4.3.4 Root characteristics

4.4 Effect of spacing and crops on the physico-chemical properties of soil under mango orchard

4.5 Effect of spacing and crops on the physico-chemical properties of soil under open conditions

4.6 Effect of intercrop and spacing on the soil total microbial count

4.7 Bio-economic appraisal

- 4.7.1 Sole crop under open conditions
- 4.7.2 Intercrops under mango orchard

4.1 Growth parameters of mango trees

Average growth statistics of mango trees grown in the orchard are described below:

Table 4. Description of average tree growth statistics of mango orchard (29 years old)

Trees	Height (m)	Basal Diameter (m)	Crown spread (m)	Crown projection area (m^2)	Canopy volume (m^3)
1.	4.5	0.39	9.52	65.01	656.67
2.	5.0	0.40	10.05	76.16	963.86
3.	6.0	0.41	8.15	49.61	970.43
4.	6.2	0.46	7.75	45.94	985.97
5.	5.5	0.39	7.12	35.77	630.97

The perusal of the data in table 4 show that in the mango orchard under experimentation the average height of the trees varied from 4.5m to 6.2m, average diameter of the trees ranged from 0.39 to 0.46 m, crown spread ranged from 7.12 m to 10.05 m, crown projection area varied from 35.77 to 76.16 m^2 and canopy volume ranged from 630.97 to 985.97 m^3.

4.2 Effect of spacing on growth performance of intercrops under mango orchard

4.2.1. Growth parameters

Data recorded on growth parameters of four intercrops as influenced by mango trees have been described below.

4.2.1.1. Survival per cent

Mango trees had a notable effect on intercrops under the tree canopy. The continuous shade of the tree canopy significantly influenced the survival of crops. The data related to the effect of spacing of intercrop on the survival percent of plant for two successive years given in Table 5 clearly indicate that amongst the crops, stevia had lowest survival (11.31%) whereas ginger (90.28%), turmeric (90.12%) and kalmegh (90.50%) had least mortality in the year 2015. The critical difference was significant. Plant spacing did not significantly affect the survival and the results were statistically at par with maximum value (71.44%) in S_3 (30cm x 40cm) and minimum (69.46%) in S_1 (30cm x20cm). In 2016, the maximum survival was again found in ginger (91.59%), kalmegh (91.58%) and turmeric (90.93%) and the least in stevia (12.67%). Spacing had no significant effect on survival percentage of all the crops in the second year too. The pooled data also showed that kalmegh

Field preparation **General view of the experimental area**

Ginger **Turmeric**

Kalmegh **Stevia**

Plate-II: Performance of different intercrops under mango orchard

(91.04%), ginger (90.93%) and turmeric (90.52%) had maximum survival and were statistically at par to each other whereas, stevia had least (11.99%) survival percentage.

The interaction (crops x spacing) was found to be non- significant during the two years as well as in the pooled results.

4.2.1.2. Plant height (cm)

Amongst the four crops, maximum plant height was obtained in turmeric (134.35 cm in 2015, 143.46 cm in 2016 and 138.90 cm in pooled) followed by ginger (99.25 cm in 2015, 109.08 cm in 2016 and 104.16 cm in pooled). Minimum plant height was recorded for stevia (65.57 cm, 61.22 cm and 63.39 cm) in the two years and pooled data respectively. The height of crops did not vary significantly with the change in spacing. The critical difference was found to be non-significant for both the years as well as pooled. The interaction effect between crops and spacing was also found to be statistically non-significant.

4.2.1.3. Number of leaves per plant

The average number of leaves per plant varied significantly among the crops as evident from the data presented in Table 5. Turmeric recorded minimum number of leaves (10.38) and kalmegh had the highest number (101.20) in 2015. Similar results were obtained in 2016 with maximum number of leaves in kalmegh (107.27) and minimum in turmeric (11.25). In pooled analysis, kalmegh recorded the highest (104.24) number of leaves and turmeric recorded the lowest number (10.81).

Spacing had a significant effect on the leaf number but the values were at par in S_2 (57.95) and S_3 (57.03). The lowest number was observed in S_1 (43.81) in 2015. In 2016, similar trends were obtained (62.63 in S_2, 63.61 in S_3 and 50.23 in S_1). The pooled analysis of years also gave the same trend.

Though, the interaction effect was non-significant, the highest leaf number was recorded in kalmegh at all the spacing (91.54, 107.13 and 114.05) in the pooled data. The lowest number was recorded in turmeric at all spacing combinations.

4.2.1.4. Number of branches/tillers per plant

The observations with regard to the number of tillers/branches in crops grown under mango are presented in Table 5.

The perusal of data show that out of the four crops, kalmegh had the highest number of branches per plant (5.66) and stevia had the lowest (1.11) in 2015. Similarly in 2016,

Table 5. Crop performance and effect of spacing on the growth of intercrops under mango orchard

Treatment combination	Survival per cent			Plant height (cm)			Number of leaves plant^{-1}			Number of tillers /branches plant $^{-1}$		
Crops	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Ginger (G)	90.28 (72.19)	91.59 (73.60)	90.93 (72.85)	99.25	109.08	104.16	76.81	85.51	81.16	4.58	4.82	4.70
Turmeric (T)	90.12 (72.03)	90.93 (72.83)	90.52 (72.42)	134.35	143.46	138.90	10.38	11.25	10.81	3.14	3.33	3.23
Stevia (S)	11.31 (19.27)	12.67 (20.65)	11.99 (19.98)	65.57	61.22	63.39	23.32	31.25	27.28	1.11	1.11	1.11
Kalmegh (K)	90.50 (72.43)	91.58 (73.66)	91.04 (73.01)	86.41	94.11	90.26	101.20	107.27	104.24	5.66	8.11	6.89
±SE(m)	**1.27**	**1.36**	**1.28**	**2.95**	**3.95**	**2.67**	**4.20**	**4.05**	**3.15**	**0.22**	**0.24**	**0.23**
$CD_{0.05}$	**3.71**	**3.99**	**3.74**	**8.63**	**11.61**	**7.85**	**12.33**	**11.89**	**9.25**	**0.66**	**0.70**	**0.64**
Spacing												
20x30cm (S_1)	69.46 (57.98)	70.25 (58.93)	69.86 (58.44)	97.46	104.71	101.09	43.81	50.23	47.01	3.15	3.89	3.52
30x30cm (S_2)	70.76 (59.13)	71.98 (60.34)	71.37 (59.72)	98.13	99.85	98.99	57.95	62.63	60.29	3.80	4.41	4.10
30x40cm (S_3)	71.44 (59.82)	72.84 (61.29)	72.14 (60.53)	93.59	101.34	97.46	57.03	63.61	60.31	3.92	4.72	4.32
±SE(m)	**1.09**	**1.18**	**1.10**	**2.55**	**3.42**	**2.31**	**3.63**	**3.51**	**2.73**	**0.19**	**0.21**	**0.19**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**10.68**	**10.30**	**8.01**	**0.57**	**0.61**	**0.56**
Crops x spacing												
G S_1	89.66 (71.73)	90.36 (72.91)	90.01 (72.27)	101.11	108.71	104.91	63.88	68.61	66.24	3.73	4.07	3.90
G S_2	91.16 (73.04)	92.55 (74.42)	91.85 (73.71)	106.72	115.24	110.98	91.32	98.79	95.05	5.62	5.56	5.59
G S_3	90.01 (71.79)	91.86 (73.47)	90.93 (72.58)	89.93	103.28	96.60	75.22	89.14	82.18	4.39	4.84	4.62
T S_1	88.74 (70.74)	89.20 (71.10)	88.97 (70.92)	133.90	144.93	139.42	8.50	9.04	8.77	2.77	2.95	2.86
T S_2	90.19 (72.10)	91.24 (73.06)	90.72 (72.57)	134.22	132.61	133.41	11.35	12.06	11.70	2.96	3.13	3.04
T S_3	91.42 (73.24)	92.34 (74.33)	91.88 (73.76)	134.94	152.83	143.88	11.29	12.67	11.97	3.68	3.91	3.80
S S_1	10.48 (18.37)	11.56 (19.55)	11.02 (18.97)	61.17	65.46	63.31	17.26	25.76	21.51	1.00	1.00	1.00
S S_2	11.48 (19.44)	12.55 (20.58)	12.02 (20.03)	64.70	57.48	61.09	23.33	31.22	27.27	1.00	1.00	1.00
S S_3	11.98 (20.01)	13.90 (21.82)	12.93 (20.95)	70.83	60.71	65.78	29.37	36.76	33.07	1.33	1.33	1.33
K S_1	88.97 (71.10)	89.89 (72.16)	89.43 (71.61)	93.67	99.75	96.71	85.57	97.50	91.54	5.11	7.57	6.34
KS_2	90.19 (71.93)	91.58 (73.29)	90.89 (72.57)	86.88	94. 06	90.47	105.80	108.46	107.13	5.62	7.97	6.79
K S_3	92.35 (74.25)	93.27 (75.53)	92.81 (74.84)	78.66	88.53	83.60	112.23	115.86	114.05	6.26	8.80	7.53
±SE(m)	**2.19**	**2.36**	**2.21**	**5.09**	**6.85**	**4.63**	**7.27**	**7.02**	**5.46**	**0.38**	**0.42**	**0.38**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS- Non-significant *Figures in parenthesis are square root transformed values for survival percent kalmegh had the highest value (8.11) and stevia had the lowest (1.11). The trend was similar in pooled averages. Spacing had a statistically significant impact on the number of tillers/branches. Plants which were widely spaced as in S_2 and S_3 showed more branch number (3.80 and 3.92 in 2015, 4.41 and 4.72 in 2016, 4.10 and 4.32 in pooled data) than closely spaced (3.15 in 2015, 3.89 in 2016 and 3.52), respectively. The critical difference was significant for crops and spacing during both the years individually and with pooled averages.

The interaction effect of crop and spacing for both the years as well as the pooled was nonsignificant on the number of tillers / branches plant^{-1}.

4.2.2. Yield Parameters

The impact of plant spacing on the yield of the four crops was recorded for two consecutive years (Table 6). The data was collected on the fresh weight and dry weight basis and expressed in grams per plant and was then converted to q ha^{-1}. The findings have been described as under:

4.2.2.1. Fresh weight plant^{-1} (g)

The data presented in table 6 indicate that in 2015, there was a significant difference in the mean fresh weight per plant. Turmeric recorded the highest mean fresh weight (241.81g) out of all the crops and stevia had the lowest 13.08g. Similar results were obtained in the second year (2016) too. The critical difference was significant for both the years. The pooling of results also showed the same trend. Spacing significantly influenced the mean fresh weight per plant in 2015 whereas in the 2nd year and the pooled data, the differences were non-significant. The plants at closer spacing (S_1) produced lower mean fresh weight (89.91g) as compared to higher fresh weight in wider spacings S_2 (100.27g) and S_3 (109.23g) in 2015. Almost analogous results were obtained in the year 2016 also.

The interaction effect of crop and spacing was found to be non-significant in the individual years as well as the pooled data.

4.2.2.2. Dry weight plant^{-1} (g)

The dry weight of a plant depends on the moisture percentage in a plant and the fresh weight of the plant. Like fresh weight, the mean dry weight of the plants followed the same trend; turmeric recorded the highest (83.56g) dry weight followed by ginger (24.0g), kalmegh (18.97g) and stevia (6.11g) in 2015. In 2016, similar trend of turmeric (107.33g) followed by ginger (25.07g), kalmegh (23.93g) and stevia (7.87g) was obtained.

Table 6. Crop performance and effect of spacing on the yield of crops under mango orchard

Treatment combination	Fresh weight plant $^{-1}$ (g)			Dry weight plant $^{-1}$ (g)			Yield (Fresh) ha^{-1} (q)			Yield (Dry) ha^{-1} (q)		
Crops	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Ginger (G)	100.01	106.75	103.38	24.00	25.07	24.53	55.77	59.91	57.84	8.23	8.82	8.52
Turmeric (T)	241.81	269.46	255.63	83.56	107.33	95.44	91.03	81.82	86.42	13.99	12.51	13.25
Stevia (S)	13.08	16.73	14.90	6.11	7.87	6.99	0.30	0.37	0.33	0.10	0.11	0.10
Kalmegh (K)	44.31	54.60	49.45	18.97	23.93	21.45	41.81	52.71	47.26	17.29	22.10	19.69
±SE(m)	**4.95**	**8.91**	**5.75**	**1.66**	**2.11**	**1.57**	**4.14**	**8.30**	**4.07**	**0.68**	**1.36**	**0.71**
$CD_{0.05}$	**14.53**	**26.31**	**16.96**	**4.87**	**6.23**	**4.65**	**12.14**	**24.50**	**11.84**	**1.99**	**4.03**	**2.07**
Spacing												
20x30cm (S_1)	89.91	102.04	95.98	29.27	37.62	33.44	59.71	63.19	61.45	12.51	14.06	13.26
30x30cm (S_2)	100.27	114.61	107.44	32.17	42.45	37.31	45.47	48.61	47.04	9.57	11.17	10.37
30x40cm (S_3)	109.23	119.01	114.12	38.04	43.09	40.57	36.49	34.31	35.40	7.62	7.48	7.55
±SE(m)	**4.29**	**7.72**	**4.98**	**1.44**	**1.83**	**1.37**	**3.59**	**7.18**	**3.51**	**0.59**	**1.18**	**0.61**
$CD_{0.05}$	**12.58**	**NS**	**NS**	**4.22**	**NS**	**4.03**	**10.51**	**21.21**	**10.25**	**1.72**	**3.49**	**1.79**
Crops x spacing												
G S_1	86.18	92.92	89.55	20.14	21.71	20.92	72.57	78.98	75.78	10.85	11.79	11.32
G S_2	107.67	114.36	111.01	26.76	28.82	27.78	53.86	59.09	56.47	7.99	8.72	8.36
G S_3	106.20	112.97	109.58	25.10	24.70	24.90	40.87	41.68	41.27	5.84	5.95	5.89
T S_1	223.11	250.12	236.61	75.36	100.84	88.10	112.49	103.58	108.03	17.04	16.22	16.63
T S_2	235.26	272.97	254.11	76.37	108.30	92.33	85.72	83.71	84.71	12.85	13.20	13.03
T S_3	267.06	285.29	276.17	98.96	112.84	105.90	74.87	58.18	66.53	12.07	8.11	10.09
S S_1	11.14	15.04	13.09	4.91	6.87	5.90	0.37	0.44	0.40	0.12	0.14	0.13
S S_2	12.73	16.52	14.63	6.12	7.81	6.97	0.30	0.32	0.31	0.10	0.10	0.10
S S_3	15.35	18.62	16.99	7.30	8.91	8.11	0.24	0.30	0.27	0.08	0.10	0.08
K S_1	39.20	50.08	44.64	16.68	21.03	18.85	53.43	69.77	61.59	22.01	27.88	24.94
KS_2	45.43	54.58	50.00	19.44	24.89	22.16	42.02	51.32	46.67	17.36	22.63	19.99
K S_3	48.30	59.16	53.73	20.81	25.89	23.35	29.97	37.06	33.51	12.50	15.78	14.14
±SE(m)	**8.58**	**15.44**	**9.95**	**2.87**	**3.66**	**2.73**	**7.17**	**14.38**	**6.97**	**1.78**	**2.36**	**1.21**
$CD_{0.05}$	**NS**	**NS**	**NS**	**8.44**	**NS**	**NS**	**NS**	**NS**	**NS**	**3.45**	**NS**	**3.58**

NS- Non-significant

Of the three spacing, highest dry weight was recorded in S_3 (38.04g) and the least in S_1 (29.27g) in 2015. The interaction (crop x spacing) was also significant. Within the crops, the differences were insignificant except in turmeric at wider spacing TS_3 (98.96g) showed significant increase in mean dry weight over TS_1 (75.36g) and TS_2 (76.37g).

In 2016 as well as in the pooled data, spacing had no significant effect on mean dry weight. The critical difference was statistically non-significant for the spacing as well as for interaction (Table 6).

4.2.2.3. Yield (Fresh) (q ha^{-1})

The economic yield refers to the yield of leaves and above ground biomass in case of herbs stevia and kalmegh, respectively, whereas the rhizome yield in turmeric and ginger.

Data on the fresh yield per hectare of the four intercrops during the study period are presented in table 6. Of the four crops, stevia had the lowest yield (0.30 q ha^{-1} in 2015 and 0.37 q ha^{-1} in 2016) whereas, turmeric recorded the highest yield of 91.03 q ha^{-1} in 2015 and 81.82 q ha^{-1} in 2016. The pooled data also revealed the similar results. The critical difference was found to be significant for the crops.

The data indicated that fresh yield per hectare decreased with increased spacing as it was recorded in 2015, 2016 and in the pooled. The fresh yield was maximum in S_1 (59.71 q ha^{-1} in 2015; 63.19 q ha^{-1} in 2016 and 61.45 q ha^{-1} in pooled) and significantly at par in S_2 and S_3 in both years. The interaction effect of crops and spacing was non-significant during 2015, 2016 and the pooled data.

4.2.2.4. Yield (Dry) (q ha^{-1})

From the data presented in Table 6 on the dry yield of the crops on per hectare basis, it was deduced that kalmegh had the significantly highest dry yield (17.29 q ha^{-1}) followed by turmeric (13.99 q ha^{-1}) in 2015. The minimum recorded yield was of stevia (0.10 q ha^{-1}). Similar trend was observed in 2016 and in the pooled data.With regard to the effect of spacing on the dry yield of the crops in the two years, in all the crops yield was maximum (12.51 q ha^{-1} in 2015, 14.06 q ha^{-1} in 2016 and 13.26 q ha^{-1} in the pooled) at the spacing S_1 (30x20cm) followed by the wider spacing. However, in the interaction, the order of yield was (22.01)KS_1>(17.36)KS_2>(17.04)TS_1 in 2015. Similar results were recorded in the pooled. The critical difference was not significant in 2016.

4.2.3. Physiological attributes

The growth and yield of the crop depends on the physiological behaviour of the crop in varying situations. The data recorded with regard to the impact of spacing on physiological attributes of the four crops is presented in Tables 7-8.

4.2.3.1. Relative growth rate (RGR) ($gg^{-1}day^{-1}$)

The data depicts that turmeric had the highest RGR (0.013 in 2015, 0.014 in 2016 and 0.013 in the pooled) followed by stevia (0.012 in 2015), ginger (0.009 in 2016) and stevia (0.009 in the pooled). The growth rate was maximum in S_2 (0.010 in 2015, 0.012 in 2016 and 0.010 in pooled). The critical difference for the spacing was non-significant in both years and significant in the pooled data. In all the treatment combinations the interaction effect (crops x spacing) was also non-significant (Table 7).

4.2.3.2. Net assimilation rate (NAR) ($gg^{-1}day^{-1}$)

RGR values depend on the NAR values. Higher RGR values correlate to higher NAR values (Table 7). Among the crops, in 2015, turmeric and ginger had the highest and statistically at par values (0.043 and 0.046) and the lowest in ginger (0.026). In 2016, turmeric had highest value (0.042) and ginger had the least (0.025). The critical difference was found to be significant for the study period. The pooling of results showed the same trend. The critical difference was non- significant for effect of spacing on NAR values in the two years. Like RGR, higher NAR values (0.040, 0.036 and 0.038) were recorded in spacing S_2 in the two consecutive years and their pooled analysis.

The interaction of crops and spacing was found to be non-significant in 2015, 2016 and the pooled data.

4.2.3.3. Total chlorophyll content (vegetative phase) (mg g^{-1})

Chlorophyll content carries a unique role in the physiology, productivity and economy of green plants. Quantity of chlorophyll per unit area is an indicator of photosynthetic capacity of the plant. Amount of chlorophyll in leaf tissues is influenced by nutrient availability and environmental stresses such as draught, salinity, heat, cold etc. Therefore, it is of special interest to quantify chlorophyll content in leaves.

The data related to the amount of chlorophyll content at vegetative stage is presented in Table 7. In 2015, significantly highest chlorophyll content was of kalmegh (2.81) followed by ginger (1.98), turmeric (1.61) and stevia (0.93). In 2016 similar trend was observed kalmegh (2.85) > turmeric (2.04) > turmeric (1.73) > stevia (1.16). The pooled data also showed that maximum chlorophyll content was recorded in kalmegh (2.83 mg/g) and minimum in stevia (1.04). The critical difference was significant for crops in both the years.

Regarding effect of spacing on chlorophyll content, different spacings had significant influence on total chlorophyll content of crops, maximum content (2.06 in 2015, 2.23 in 2016 and 2.14 in pooled) was found in S_1 (30cm x 20cm) spacing whereas spacing S_2 (30cm x 30cm) and S_3 (30cm x 40cm) were statistically at par with each other.

The interaction effect (crop x spacing) was statistically significant in 2015, 2016 as well as in the pooled data. In 2015, the maximum content was in kalmegh at spacing S_3 (3.08) followed by kalmegh at spacing S_1 (2.72) which was statistically at par with ginger at spacing S_1 (2.70) and kalmegh at spacing S_2 (2.63). Minimum chlorophyll content was recorded in stevia with spacing S_1 (0.79) and spacing S_2 (0.96). Similar pattern was found in 2016 and in the pooled data.

4.2.3.4. Total chlorophyll content (reproductive phase) (mg g^{-1})

The observations on the impact of spacing on the chlorophyll content of leaves at reproductive stage are tabulated in table 7. The perusal of data shows that values of chlorophyll content at reproductive phase differed significantly among the crops. Stevia (2.76 mg/g) gave the highest content followed by other crops, turmeric (2.14), kalmegh (2.02) and ginger (1.35) in 2015. In 2016, the findings were again similar as well as in the ensembled data. Different spacing did not show significant influence on the total chlorophyll content.

The interaction amidst crops and spacing was significant in 2015 only and non-significant in 2016. In 2015, maximum chlorophyll content was recorded in stevia in all three spacing with values statistically at par to each other and followed by kalmegh at spacing S_3 (2.27) statistically equal to turmeric at spacing S_1 (2.25). The results were statistically significant in pooled data.

4.2.3.5. Carotenoid content (mg g^{-1})

The data related to the quantity of carotenoid in the leaves was given in table 7. A glance at the table show that the crops recorded significant variations in the carotenoid content. Minimum value recorded was of turmeric (0.26 mg/g) in 2015 and maximum was of kalmegh (2.24) in the same year. Similar outcomes were obtained in 2016 and in the pooled

Table 7. Crop performance and effect of spacing on the physiological parameters of crops under mango orchard

Treatment combination	Relative growth rate (RGR) ($gg^{-1}day^{-1}$)			Net assimilation rate (NAR) ($gg^{-1}day^{-1}$)			Total chlorophyll content (vegetative phase) ($mg\ g^{-1}$)			Total chlorophyll content (reproductive phase) ($mg\ g^{-1}$)			Carotenoid content ($mg\ g^{-1}$)		
Crops	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Ginger (G)	0.0070	0.0090	0.006	0.0260	0.025	0.026	1.98	2.04	2.01	1.35	1.11	1.23	0.77	0.76	0.77
Turmeric (T)	0.0130	0.0140	0.013	0.0430	0.042	0.042	1.61	1.73	1.67	2.14	2.54	2.34	0.26	0.28	0.27
Stevia (S)	0.0120	0.0080	0.009	0.0460	0.034	0.040	0.93	1.16	1.04	2.76	2.85	2.81	0.37	0.41	0.39
Kalmegh (K)	0.0060	0.0060	0.006	0.0300	0.026	0.028	2.81	2.85	2.83	2.02	2.11	2.06	2.24	2.37	2.30
±SE(m)	**0.0007**	**0.0016**	**0.001**	**0.0034**	**0.003**	**0.003**	**0.03**	**0.03**	**0.03**	**0.04**	**0.08**	**0.04**	**0.01**	**0.01**	**0.01**
$CD_{0.05}$	**0.0022**	**0.0050**	**0.002**	**0.0100**	**0.008**	**0.008**	**0.07**	**0.09**	**0.07**	**0.12**	**0.23**	**0.15**	**0.05**	**0.05**	**0.04**
Spacing															
20x30cm (S_1)	0.0080	0.0070	0.008	0.0320	0.028	0.030	2.06	2.23	2.14	2.07	2.15	2.11	0.88	0.92	0.89
30x30cm (S_2)	0.0100	0.0120	0.010	0.0400	0.036	0.038	1.73	1.82	1.77	2.01	2.12	2.06	0.92	0.98	0.94
30x40cm (S_3)	0.0090	0.0080	0.008	0.0370	0.032	0.034	1.71	1.78	1.75	2.12	2.19	2.15	0.94	0.97	0.95
±SE(m)	**0.0006**	**0.0014**	**0.001**	**0.0030**	**0.002**	**0.002**	**0.02**	**0.02**	**0.02**	**0.03**	**0.07**	**0.03**	**0.01**	**0.01**	**0.01**
$CD_{0.05}$	**NS**	**NS**	**0.002**	**NS**	**NS**	**NS**	**0.06**	**0.08**	**0.06**	**NS**	**NS**	**NS**	**0.04**	**0.04**	**0.04**
Crops x spacing															
G S_1	0.0050	0.0050	0.005	0.0210	0.020	0.021	2.70	2.76	2.72	1.46	1.20	1.33	0.77	0.75	0.76
G S_2	0.0080	0.0170	0.008	0.0310	0.030	0.031	1.60	1.63	1.61	1.18	1.03	1.10	0.80	0.85	0.82
G S_3	0.0070	0.0060	0.006	0.0260	0.025	0.025	1.66	1.73	1.69	1.41	1.11	1.25	0.74	0.71	0.72
T S_1	0.0120	0.0140	0.013	0.0400	0.041	0.041	2.04	2.20	2.12	2.25	2.68	2.46	0.22	0.23	0.22
T S_2	0.0130	0.0140	0.013	0.0450	0.044	0.045	1.72	1.84	1.78	2.19	2.59	2.38	0.28	0.29	0.28
T S_3	0.0130	0.0130	0.013	0.0440	0.040	0.042	1.07	1.15	1.11	1.98	2.35	2.16	0.29	0.31	0.30
S S_1	0.0100	0.0060	0.008	0.0370	0.027	0.032	0.79	1.16	0.97	2.70	2.77	2.73	0.29	0.32	0.30
S S_2	0.0120	0.0090	0.011	0.0470	0.039	0.043	0.96	1.17	1.07	2.75	2.87	2.81	0.35	0.40	0.37
S S_3	0.0130	0.0080	0.009	0.0530	0.037	0.045	1.03	1.14	1.08	2.84	2.92	2.88	0.48	0.51	0.49
K S_1	0.0060	0.0050	0.006	0.0310	0.024	0.027	2.72	2.80	2.76	1.87	1.95	1.91	2.23	2.36	2.29
KS_2	0.0080	0.0070	0.007	0.0340	0.029	0.032	2.63	2.64	2.63	1.92	2.01	1.96	2.24	2.37	2.30
K S_3	0.0050	0.0050	0.005	0.0250	0.026	0.025	3.08	3.12	3.10	2.27	2.38	2.32	2.24	2.38	2.31
±SE(m)	**0.0013**	**0.0027**	**0.001**	**0.0059**	**0.004**	**0.005**	**0.04**	**0.05**	**0.05**	**0.07**	**0.14**	**0.07**	**0.03**	**0.03**	**0.03**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.13**	**0.16**	**0.13**	**0.22**	**NS**	**0.27**	**0.09**	**0.09**	**0.08**

NS- Non-significant

data. In 2015, the maximum ad-measurement was for spacing S_3 (0.94mg g^{-1}). However, in 2016 maximity was for S_2 (0.98mg g^{-1}) which was repeated in the pooled data too. The critical difference was significant.

The interaction effect between crop and spacing showed significant results during the two years of study (Table 7). In 2015, among all crop-spacing combinations, maximum interaction was recorded in KS_2 (2.24) and KS_3 (2.24) which was statistically alike in both the spacing S_2 and S_3 followed by KS_1 (2.23) (kalmegh with spacing S_1) and minimum interaction (0.22) was recorded in (TS_1) turmeric with spacing S_1. Similar results were obtained in 2016 and the pooled data.

4.2.3.6. Partitioning co-efficient

Distribution of photo-assimilates within the plant is called partitioning. As the sum of the fractions of the portioning coeffecients of all the organs is 100, a cumulative presentation is depicted in the table 8.

It is clear from the data with regard to partitioning of assimilates to leaves and branches that maximum assimilates were allocated to the leaves of turmeric (51.32 %), branches of kalmegh (56.36%) in 2015. Similar results were recorded in 2016 and in pooled analysis. In case of roots/rhizomes, maximum allocation was in rhizomes of ginger (34.07%) followed by stevia (18.05 %) in 2015. Similarly in 2016 maximum allocation was in rhizomes of ginger (33.98 %) followed by stevia roots (17.80 %) and similar trend was observed after pooling the data. In case of inflorescence, maximum allocation was in kalmegh (44.36 %) in 2015. Similar results were obtained in 2016 as well as pooled data. Since no flowering was observed in ginger and turmeric there was no allocation of assimilates in them. The effect of spacing was non-significant for partitioning to leaves, roots/rhizomes and inflorescence; however, there was significant effect of spacing on partitioning coefficient to branches in 2015 and in the pooled values. The highest branch dry weight partitioned to was in S_1 (35.10) followed by S_2 (33.22) and S_3 (30.78) in 2015 and similar assessment was in 2016 and in the pooled values. The interaction was statistically non-significant for all parts except branches in 2016 and in the pooled data.

4.2.4. Root characteristics

4.2.4.1. Number of roots/rhizomes per plant

The number of roots/rhizomes was counted immediately before the initiation of flowering in all the crops and the observations were recorded in table 9.

Table 8. Crop performance and effect of spacing on the partitioning coefficient of crops under mango orchard

Treatment combination	Partitioning coefficient (per cent)											
	Leaf			Branch			Root			Inflorescence		
Crops	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Ginger (G)	46.55	46.50	46.52	19.39	19.51	19.44	34.07	33.98	34.02	-	-	-
Turmeric (T)	51.32	62.05	56.68	31.95	28.61	30.27	16.74	9.33	13.03	-	-	-
Stevia (S)	13.16	10.04	11.60	24.44	31.75	28.10	18.05	17.80	17.92	44.36	40.41	42.38
Kalmegh (K)	32.10	33.90	33.00	56.36	54.55	55.46	5.38	5.56	5.47	6.16	5.98	6.06
±SE(m)	**1.36**	**1.82**	**1.05**	**0.92**	**1.03**	**0.82**	**1.10**	**1.76**	**1.04**	**4.47**	**4.80**	**1.44**
$CD_{0.05}$	**3.99**	**5.38**	**3.10**	**2.71**	**3.01**	**2.43**	**3.24**	**5.20**	**3.06**	**1.40**	**1.50**	**4.60**
Spacing												
20x30cm (S_1)	35.26	37.20	36.23	35.10	35.44	35.27	17.49	16.87	17.18	24.32	20.98	22.64
30x30cm (S_2)	36.38	39.46	37.92	33.22	32.35	32.78	18.31	16.76	17.54	24.17	22.86	23.51
30x40cm (S_3)	35.70	37.72	36.71	30.78	33.04	31.91	19.87	16.37	18.13	27.29	25.74	26.51
±SE(m)	**1.17**	**1.57**	**0.91**	**0.79**	**0.88**	**0.71**	**0.95**	**1.53**	**0.89**	**1.72**	**1.84**	**1.77**
$CD_{0.05}$	**NS**	**NS**	**NS**	**2.34**	**NS**	**2.11**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Crops X spacing												
G S_1	43.41	43.31	43.36	20.32	20.60	20.46	36.27	36.08	36.17	-	-	-
G S_2	50.15	51.84	50.99	19.45	17.52	18.48	30.40	30.63	30.51	-	-	-
G S_3	46.08	44.35	45.22	18.39	20.40	19.40	35.52	35.23	35.38	-	-	-
T S_1	51.62	61.52	56.57	32.93	27.91	30.42	15.45	10.56	13.00	-	-	-
T S_2	49.07	61.56	55.31	34.04	26.87	30.45	16.89	11.56	14.23	-	-	-
T S_3	53.26	63.08	58.17	28.87	31.04	29.95	17.87	5.87	11.87	-	-	-
S S_1	14.63	10.45	12.54	29.29	38.02	33.66	13.50	15.65	14.57	42.60	35.88	39.23
S S_2	13.15	9.70	11.43	23.42	30.36	26.89	20.96	19.70	20.33	42.47	40.23	41.35
S S_3	11.69	9.97	10.83	20.60	26.87	23.73	19.70	18.03	18.87	48.01	45.12	46.56
K S_1	31.38	33.52	32.45	57.85	55.21	56.53	4.74	5.17	4.95	6.04	6.09	6.06
KS_2	33.15	34.72	33.94	55.97	54.64	55.30	5.00	5.15	5.08	5.88	5.48	5.68
K S_3	31.77	33.46	32.61	55.27	53.81	54.54	6.40	6.36	6.38	6.56	6.36	6.46
±SE(m)	**2.35**	**3.16**	**1.82**	**1.59**	**1.78**	**1.43**	**1.91**	**3.05**	**1.79**	**2.43**	**2.60**	**2.50**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**5.24**	**4.22**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS- Non-significant

The data recorded in the table 9 reveal that the number of roots/rhizomes differed significantly among the crops. Maximum number was recorded in stevia (13.82) followed by kalmegh (11.67) and ginger (4.98) in 2015. Similarly in 2016 maximum value was observed in stevia (14.33) which was statistically alike to kalmegh (13.73) and the minimum value was again recorded for ginger (4.99). The results of the pooled analysis exhibited the trends similar to the year 2016. The planting distance had a prominent effect with maximum number of roots/rhizome (11.44) in S_3 and minimum (7.72) in S_1 in 2015. However in 2016 maximum number of roots/rhizomes (12.06) were recorded in S_3 and minimum (8.54) in S_1. Similar results were observed in the pooled data.

Regarding the interaction between crop and spacing, minimum value was recorded for ginger (GS_1, GS_2 and GS_3) at all the three spacing in 2015. Similarly in 2016 and the pooled data, minimum value was recorded in ginger in all the three spacing. Interaction effect of crop and spacing was recorded maximum (17.24) in SS_3 (Stevia with spacing S_3) in 2015. In 2016, maximum value (17.26) was again recorded in SS_3. The interaction between crop and spacing was significant in 2015 and non-significant in 2016 and in the pooled data.

4.2.4.2. Dry weight of roots/rhizomes per plant (g)

Dry weight of roots/rhizomes differed significantly amongst the crops (Table 9) with turmeric recording the highest weight (14.08 g) followed by kalmegh registering the lowest weight (1.03 g) in 2015. In 2016 and in the pooled data same results were observed. Values of root dry weight recorded for stevia and kalmegh were statistically at par in 2015, 2016 and the pooled data. A significant effect of spacing on root/rhizome weight of crops was observed. Higher root dry weight was observed in plants grown at wider spacing of 30x40 cm (7.33g, 6.02g) in 2015 and 2016, respectively.

The interaction effect of crop and spacing was statistically non-significant for 2015, 2016 as well as for the pooled data.

4.2.4.3. Root growth potential (%)

Root growth potential gives an insight about the root characteristics of the intercrops. It is a predictor of survival/growth performance of a species. From the data recorded in table 9 for root growth potential, it was clear from negative values for all the crops that, all the species performed better as sole crops in open conditions compared to underneath of tree cover. Ginger showed positive values due to its poor performance in open. Among the other three crops in 2015, minimum growth was recorded for stevia (-78.05%). Turmeric, ginger and kalmegh performed well (-5.84%, 26.22% and -25.66%).

Table 9. **Crop performance and effect of spacing on the root characteristics of crops under mango orchard**

Treatment combination	Number of roots plant $^{-1}$			Dry weight of roots/ rhizomes plant $^{-1}$ (g)			Root Growth Potential (%) under mango orchard		
Crops	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Ginger (G)	4.98	4.99	4.98	7.98	8.43	8.20	26.22	35.79	31.01
Turmeric (T)	8.24	9.10	8.67	14.08	11.86	12.93	-5.84	-4.59	-5.21
Stevia (S)	13.82	14.33	14.07	1.12	1.40	1.26	-78.05	-77.83	-77.94
Kalmegh (K)	11.67	13.73	12.70	1.03	1.33	1.18	-25.66	-26.03	-25.85
±SE(m)	**0.47**	**0.59**	**0.52**	**0.53**	**1.17**	**0.59**	**2.97**	**6.11**	**3.93**
$CD_{0.05}$	**1.39**	**1.73**	**1.52**	**1.56**	**3.43**	**1.72**	**8.71**	**17.95**	**11.54**
Spacing									
20x30cm (S_1)	7.72	8.54	8.13	5.02	5.22	5.12	-18.66	-15.29	-16.98
30x30cm (S_2)	9.87	11.01	10.44	5.75	6.02	5.88	-26.15	-16.41	-21.28
30x40cm (S_3)	11.44	12.06	11.75	7.33	6.02	6.67	-17.68	-22.78	-20.23
±SE(m)	**0.41**	**0.51**	**0.45**	**0.46**	**1.02**	**0.51**	**2.57**	**5.29**	**3.41**
$CD_{0.05}$	**1.20**	**1.49**	**1.32**	**1.35**	**NS**	**NS**	**NS**	**NS**	**NS**
Crops x spacing									
G S_1	4.48	4.82	4.65	7.24	7.77	7.50	43.02	55.24	49.12
G S_2	4.79	4.94	4.87	7.88	8.51	8.19	8.96	43.04	26.00
G S_3	5.66	5.22	5.44	8.81	9.01	8.91	26.69	9.11	17.90
T S_1	6.78	7.34	7.06	11.43	11.00	11.21	-4.01	-2.75	-3.38
T S_2	8.33	9.52	8.93	12.88	12.77	12.82	-8.53	-4.22	-6.37
T S_3	9.61	10.44	10.02	17.72	11.82	14.77	-4.98	-6.80	-5.89
S S_1	9.71	10.22	9.97	0.65	1.05	0.85	-80.68	-81.00	-80.83
S S_2	14.49	15.51	15.00	1.28	1.54	1.41	-76.00	-74.78	-75.39
S S_3	17.24	17.26	17.25	1.44	1.60	1.52	-77.49	-77.72	-77.60
K S_1	9.92	11.80	10.86	0.78	1.07	0.92	-32.98	-32.67	-32.83
KS_2	11.84	14.07	12.96	0.97	1.28	1.12	-29.06	-29.71	-29.38
K S_3	13.24	15.32	14.28	1.33	1.64	1.49	-14.95	-15.71	-15.33
±SE(m)	**0.82**	**0.02**	**0.90**	**0.92**	**2.03**	**0.02**	**5.14**	**10.59**	**6.81**
$CD_{0.05}$	**2.40**	**NS**	**NS**	**NS**	**NS**	**NS**	**15.10**	**NS**	**NS**

NS- Non-significant

The critical difference was significant. Similar results were obtained in 2016 and in the pooled data. The effect of spacing was non-significant.

The interaction (crop x spacing) was found to be non-significant for the second year and in the ensemble data (Table 9). However, in the first year considerable variation was visible within the crops and in between the crops. Minimum value was for stevia with spacing S_1(-80.68%) and maximum was for ginger with spacing S_1 (43.02%).

4.3 Effect of spacing on growth performance of intercrops under open conditions

The performance of crops and influence of different spacing viz S_1(30cm x20 cm), S_2(30cm x30cm) and S_3(30cm x40cm) on the growth and physiological parameters of intercrops, Ginger (*Zingiber officinalis*), Turmeric (*Curcuma longa*), Stevia (*Stevia rebaudiana*) and Kalmegh (*Andrographis paniculata*) was studied for two successive years. The results so obtained are presented in tables 10-14 and are described below (Plate III):

4.3.1 Growth parameters

Data on survival and growth performance of different crops in open conditions are presented in table 10.

4.3.1.1. Survival per cent

The survival per cent of the four crops differed significantly in both the years. Maximum survival was of turmeric (88.38%) followed by kalmegh (84.33%) and stevia (74.64 %) and the minimum survival was in ginger (13.68%) in the year 2015. Similar trend was followed in 2016 with maximum plant population in turmeric (89.96%) and minimum in ginger (12.75%). The pooling of data ensued the same results with turmeric at maximity and ginger at the minimal. Different spacing had a profound influence on the survival of the crops. In both the years, S_2 was at par with S_3 showing the percent survival of 67%-70% and the least was in S_1 (58%).

The interaction effect (crops x spacing) of crops and spacing was found to be non-significant in the both the years.

4.3.1.2. Plant height (cm)

Data presented in table 10 indicate that the plant height significantly differed in all the four crops for both the years. Turmeric plants were the tallest with a mean height of 120.73cm followed by stevia (69.01cm) and kalmegh (58.96 cm) in 2015. However, in 2016, turmeric recorded highest plant height (127.59 cm) followed by kalmegh (70.32 cm) and stevia (69.92 cm) and ginger (36.05 cm). Ginger had the lowest height growth in both the years under open conditions. The pooling of data revealed that overall maximum (124.16 cm) height was observed in turmeric while the minimum (36.40 cm) was observed in ginger. The critical differences for plant height within the crops were statistically significant during both the experimental years.

Spacing had no significant effect on height growth of crops in the first year but significant in the second year. The maximum plant height was recorded in S_2 (83.31cm) significantly followed by S_1 (77.07cm) and S_3 (67.53 cm). The pooled data showed the same trend so far as the effect of spacing on plant height is concerned.

The interaction effect (crop x spacing) was statistically significant in the year 2015 and in the pooled data, however, it was non-significant for the year 2016. Among the four crops, spacing had influenced the height of turmeric plants notably and the rest had statistically at par values within the individual crop.

4.3.1.3. Number of leaves per plant

The number of leaves were counted immediately before the initiation of flowering. The data so obtained are presented in table 10.

Amongst the four crops, maximum number of leaves were found in kalmegh (451.68, 463.62) in the two successive years respectively. Similar trend was noticed in stevia (184.18, 198.89) in both the years, whereas, turmeric and ginger showed statistically at par values to each other. Same sequence was recorded in the pooled data in both the years. The critical difference for plant height within the crops were statistically significant during both years.

Leaf number was not significantly affected by the spacing in the two years as well as in the pooled data. Similarly, the interaction effect of both the treatment combinations was non-significant in the individual years as well as the pooled data.

4.3.1.4. Number of tillers/branches per plant

Number of tillers /branches was counted before the initiation of flowering. A perusal of the data presented in table 10 indicate that in the four crops, the branch count was highest in kalmegh (16.76) and the lowest in ginger (2.67) in the year 2015. The same trend appeared in 2016 except in crops ginger and turmeric which had the values statistically at par to each other. Spacing had a significant impact on the number of branches/tillers of all the four crops in both the years. Wider spacing (S_3) had the maximum (8.52) number of

Field preparation in open conditions **General view of experimental area**

Ginger **Turmeric**

Kalmegh **Stevia**

Plate-III: Performance of different crops under open conditions

Table 10. Crop performance and effect of spacing on the growth of sole crops in open condition

Treatment combination	Survival per cent			Plant height (cm)			Number of leaves plant^{-1}			Number of tillers /branches plant $^{-1}$		
Crops	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Ginger (G)	13.68 (21.62)	12.75 (20.82)	13.22 (21.22)	36.74	36.05	36.40	29.88	13.91	21.90	2.67	2.70	2.68
Turmeric (T)	88.38 (70.34)	89.96 (72.13)	89.17 (71.17)	120.73	127.59	124.16	15.36	16.35	15.85	3.94	2.28	3.11
Stevia (S)	74.64 (60.28)	75.95 (61.26)	75.29 (60.74)	69.01	69.92	69.47	184.18	198.89	191.53	6.47	7.29	6.88
Kalmegh (K)	84.33 (67.21)	84.40 (67.37)	84.36 (67.28)	58.96	70.32	64.64	451.48	463.62	457.55	16.76	26.40	21.58
±SE (m)	**1.26**	**1.45**	**1.31**	**3.01**	**2.98**	**2.79**	**9.46**	**8.36**	**8.81**	**0.25**	**0.33**	**0.27**
$CD_{0.05}$	**3.72**	**4.24**	**3.85**	**8.82**	**8.76**	**8.18**	**27.77**	**24.54**	**25.87**	**0.75**	**0.96**	**0.80**
Spacing												
20x30cm (S_1)	58.73 (50.14)	58.95 (50.34)	58.84 (50.23)	73.30	77.07	75.19	159.57	162.58	161.08	6.64	8.92	7.77
30x30cm (S_2)	67.27 (56.26)	67.70 (56.67)	67.48 (56.46)	72.63	83.31	77.97	171.00	173.59	172.30	7.24	9.00	8.12
30x40cm (S_3)	69.79 (58.18)	70.65 (59.18)	70.22 (58.62)	68.15	67.53	67.84	180.10	183.41	181.75	8.52	11.07	9.79
±SE (m)	**1.09**	**1.25**	**1.13**	**2.60**	**2.59**	**2.42**	**8.19**	**7.25**	**7.64**	**0.22**	**0.28**	**0.24**
$CD_{0.05}$	**3.22**	**3.67**	**3.33**	**NS**	**7.59**	**7.09**	**NS**	**NS**	**NS**	**0.65**	**0.83**	**0.69**
Crops x spacing												
G S_1	11.71 (19.95)	10.67 (19.00)	11.19 (19.48)	43.78	34.91	39.34	30.67	11.52	21.09	2.92	2.92	2.92
G S_2	13.88 (21.83)	12.83 (20.92)	13.35 (21.38)	31.94	42.16	37.05	26.40	11.28	18.84	2.50	2.59	2.54
G S_3	15.46 (23.06)	14.76 (22.54)	15.11 (22.81)	34.52	31.09	32.80	32.59	18.95	25.77	2.60	2.60	2.60
T S_1	86.42 (68.53)	88.27 (70.35)	87.35 (69.41)	120.89	128.53	124.71	14.25	14.73	14.49	3.50	2.06	2.78
T S_2	89.16 (71.13)	90.19 (72.15)	89.67 (71.63)	136.55	145.37	140.96	16.51	17.32	16.92	3.85	2.20	3.03
T S_3	89.57 (71.36)	91.42 (73.89)	90.49 (72.48)	104.74	108.88	106.81	15.32	17.00	16.16	4.48	2.57	3.52
S S_1	60.07 (50.81)	61.23 (51.50)	60.65 (51.15)	63.70	72.64	68.17	167.13	187.70	177.42	4.22	6.78	5.50
S S_2	79.31 (63.08)	80.69 (64.20)	80.00 (63.62)	70.38	73.04	71.71	184.08	197.55	190.82	5.87	5.51	5.69
S S_3	84.54 (66.95)	85.93 (68.09)	85.23 (67.44)	72.95	64.09	68.52	201.32	211.43	206.37	9.32	9.58	9.45
K S_1	76.70 (61.27)	75.63 (60.51)	76.17 (60.88)	64.84	72.21	68.53	426.25	436.38	431.31	15.90	23.91	19.90
KS_2	86.72 (69.00)	87.07 (69.42)	86.89 (69.20)	51.64	72.66	62.15	457.03	468.21	462.62	16.73	25.73	21.23
K S_3	89.57 (71.36)	90.49 (72.18)	90.03 (71.76)	60.41	66.08	63.25	471.16	486.26	478.71	17.67	29.55	23.61
±SE (m)	**2.19**	**2.50**	**2.27**	**5.21**	**5.18**	**4.83**	**16.39**	**14.49**	**15.27**	**0.44**	**0.57**	**0.47**
$CD_{0.05}$	**NS**	**NS**	**NS**	**15.28**	**NS**	**14.18**	**NS**	**NS**	**NS**	**1.29**	**1.67**	**1.38**

NS- Non-significant *Figures in parenthesis are square root transformed values for survival percent branches/tillers and the lowest with closer spacing S_1 (6.64) in 2015. In 2016, highest number of tillers/branches (11.07) were recorded in S_3 and the lowest in S_1 and S_2 which were statistically at per to each other. The critical difference for the trait within the crops and spacing was significant in both the years.

The interaction between the crop and spacing was found to be significant in the two years of study. Spacing profoundly affected the branch count in stevia and kalmegh. In 2015, maximum number of branches were recorded in kalmegh with spacing S_3 (17.67) followed by KS_2 (16.73), KS_1 (15.90), stevia with spacing S_3 (9.32), S_2 (5.87) and turmeric TS_3 (4.48). The minimum number was counted for ginger with spacing S_2 (2.50). In 2016, highest number of branches were recorded in KS_3 (29.55), KS_2 (25.73), KS_1 (23.91) and the least number was recorded in TS_1 (2.06). In the pooled data, minimum number was observed in GS_2 (2.54).

4.3.1.5. Average leaf area per plant (cm^2)

The average leaf area per plant varied significantly among the crops and at varying spacing levels both under the canopy of mango trees as well as in open conditions (Table 11).

The highest average leaf area recorded in 2015 was in kalmegh (8936.60 cm^2) followed by turmeric (5326.94 cm^2), stevia (2082.77 cm^2) and ginger (302.35 cm^2). Similarly in 2016, kalmegh recorded the highest value (9900.29 cm^2) and ginger gave the lowest (136.49 cm^2). The same trend was obtained in the pooled data. The leaf area was significantly affected by the spacing. Maximum leaf area was at spacing S_3 followed by S_2 and S_1 (4938.08 cm^2, 4297.46 cm^2 and 3250.96 cm^2, respectively) in the first year. Similar results were obtained in second year and in the pooled analysis of the two years with highest average leaf area in S_3 (5274.70 cm^2) and minimum in spacing S_1 (3450.55 cm^2).

Though the interaction (crop x spacing) was found to be non-significant in the individual years as well as the pooled analysis, the leaf area increased with increasing spacing in all the crops.

Among the different crops, the leaf area differed significantly under the canopy of mango with maximum leaf area recorded for turmeric (5665.43 in 2015 and 6450.55 cm^2 in 2016) and the lowest for stevia (254.53 cm^2 in 2015 and 343.64 cm^2 in 2016). The inter crop under mango revealed a distinct effect of spacing on the average leaf area per plant. The plants grown at close spacing (30 cm x 20 cm) exhibited lower values for leaf area. However, at wider spacing considerable increase in leaf area was observed. It was

Table 11. Crop performance and effect of spacing on leaf area of crops under mango and in open

Treatment combination	Av. Leaf area plant $^{-1}$(cm^2)						% increase/decrease in leaf area		
	Sole crops			Intercrops					
Crops	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Ginger (G)	302.35	136.49	219.42	1379.27	1630.82	1505.04	-356.18	-1094.83	-585.92
Turmeric (T)	5326.94	6105.03	5715.99	5665.43	6450.55	6057.99	-5.97	-5.66	-5.98
Stevia (S)	2082.77	2403.89	2243.33	254.53	343.64	299.08	718.28	85.70	86.67
Kalmegh (K)	8936.6	9900.29	9418.45	1626.52	2154.98	1890.75	449.43	78.23	79.93
±SE(m)	**352.44**	**420.31**	**375.37**	**131.13**	**140.55**	**120.29**			
$CD_{0.05}$	**1033.93**	**1233.04**	**1101.22**	**384.68**	**412.32**	**352.87**			
Spacing									
20x30cm (S_1)	3250.96	3650.14	3450.55	1710.57	2037.61	1874.08	90.05	44.18	45.69
30x30cm (S_2)	4297.46	4647.81	4472.64	2391.3	2836.2	2613.75	79.71	38.98	41.56
30x40cm (S_3)	4938.08	5611.32	5274.7	2592.44	3061.19	2826.81	90.48	45.45	46.41
±SE(m)	**305.22**	**363.99**	**325.08**	**113.56**	**121.72**	**104.17**			
$CD_{0.05}$	**895.41**	**1067.84**	**953.68**	**333.14**	**357.07**	**305.59**			
Crops x spacing									
G S_1	307.11	111.81	209.46	1141.62	1312.95	1227.29	-73.10	-1074.27	-485.93
G S_2	257.9	105.85	181.88	1479.59	1736.99	1608.29	-82.57	-1540.99	-784.26
G S_3	342.03	191.81	266.92	1516.6	1842.51	1679.55	-77.45	-860.59	-529.23
T S_1	3565.55	3941.33	3753.44	4168.45	4800.76	4484.6	-14.46	-21.81	-19.48
T S_2	5605.91	6289.44	5947.68	6128.82	7069.33	6599.08	-8.53	-12.40	-10.95
T S_3	6809.37	8084.33	7446.85	6699.01	7481.56	7090.28	1.65	7.46	4.79
S S_1	1861.2	2194.25	2027.73	187.29	283.73	235.51	893.75	87.07	88.39
S S_2	2061.81	2456.35	2259.08	254.04	342.91	298.47	711.61	86.04	86.79
S S_3	2325.32	2561.08	2443.2	322.27	404.29	363.28	621.54	84.21	85.13
K S_1	7270	8353.19	7811.6	1344.9	1752.99	1548.94	440.56	79.01	80.17
KS_2	9264.21	9739.61	9501.91	1702.76	2195.55	1949.16	444.07	77.46	79.49
K S_3	10275.6	11608.07	10941.83	1831.89	2516.4	2174.14	460.93	78.32	80.13
±SE(m)	**610.44**	**727.99**	**650.17**	**227.12**	**243.44**	**208.34**			
$CD_{0.05}$	**NS**	**NS**	**NS**	**666.28**	**714.15**	**611.19**			

NS- Non-significant

observed that higher leaf area was observed in S_3 during both the years, the corresponding value being 2592.44 cm^2 in 2015 and 3061.19 cm^2 in 2016. The minimum leaf area (1710.57 cm^2 and 2037.61 cm^2) was recorded in S_1 in the two years, respectively. The pooling of data also revealed the same trend.

The interaction (crop x spacing) was significant during both the years as well as in the pooled analysis. In 2015, maximum leaf area was found in turmeric TS_3 (6,699.01 cm^2) and minimum was recorded in stevia SS_1 (187.29 cm^2). In 2016, again, maximum value was for turmeric (7,481.56 cm^2) at a spacing 30cm x 40 cm while the minimum was for stevia (283.73 cm^2) at a spacing 30 cm x 20 cm. The similar trend was observed in the pooled.

The comparison of leaf area under two contrasting conditions revealed that in both the years as compared to sole conditions (standard), ginger and turmeric recorded considerable increase in leaf area under mango canopy. Negative values signify the increasing leaf area of ginger and turmeric under mango. However, in stevia and kalmegh, decrease in leaf area was observed under mango. Irrespective of spacing, a decrease in leaf area was observed under shade and the maximum decrease was recorded in S_3 (30 cm x 40 cm).

4.3.2. Yield parameters

4.3.2.1. Fresh weight per plant (g)

Among the four crops turmeric had highest (334.99g) fresh weight of plant followed by kalmegh (164.22 g) and ginger gave the lowest weight of 58.07 g in 2015. In 2016 and pooled data, similar results were obtained. The fresh weight of plant was significantly influenced by the spacing. Plants at narrow spacing i.e. S_1 (30cm x 20cm) recorded lower plant weight (56.37g, 167.98g and 162.17g) in 2015, 2016 and in pooled data, respectively (Table 12). Widely spaced plants recorded maximum weight of plants in the two years as well as in the pooled data. The critical difference was found to be significant for the crops and the spacing in both the years and their pooling.

The interaction (crop x spacing) was observed to be significant for the first year and in pooled data but was non-significant in the second year. Maximum fresh weight was recorded in turmeric at all the three spacing (S_3-399.17g, S_2-292.37g and S_1-295.16g). The minimum weight was with ginger in all the three spacing (S_1- 58.07g, S_3- 55.60g and S_2-51.11g) in the pooled results of both the years.

4.3.2.2. Dry weight per plant (g)

The dry weight of plant emulated the trend similar to that of fresh weight of plant. Out of the four crops turmeric had the significantly highest dry weight (114.62g) followed by kalmegh (76.07g), stevia (51.34g) and ginger (10.89g) in 2015. The crops recorded the similar order in 2016 and in the pooled analysis. Spacing significantly influenced the dry weight of plants. The dry weight at close spacing (30 cm x 20 cm and 30 cm x 30 cm) was significantly low (54.38g and 58.94g) in 2015. The crops had the same pattern of weight with spacing in 2016 also. The results of the pooled data also followed the same trend. The critical difference was significant for both the factors as well as for the interaction. The interaction (crop x spacing) effect of spacing on plant weight was significant and found maximum in turmeric TS_3 (142.26g) and minimum in ginger GS_2 (10.43g) in 2015. Similar trend was observed in 2016 and in the pooled data as well (Table 12).

4.3.2.3. Yield (Fresh) (q ha^{-1})

The perusal of the data from table 12 clearly shows that among the crops, significantly maximum average fresh yield was recorded in turmeric (175.40 qha^{-1} in 2015, 166.01 qha^{-1} in 2016 and 170.70 qha^{-1} in the pooled) and the minimum in ginger (5.61 qha^{-1} in 2015, 4.89 qha^{-1} in 2016 and 5.25 qha^{-1} in pooled). The table also explained the effect of spacing on the fresh yield of the crops. The fresh yield was highest {90.94 qha^{-1} (2015) and 95.71 qha^{-1} (2016)} at lowest spacing S_1 (30 cm x 20 cm) and the yield was statistically at par at the increased spacing S_2 and S_3.The critical difference was statistically significant for the crops and spacing in both the years. The pooling of data also observed the same trend with regard to effect of spacing on fresh yield.

The interaction of the two factors (crop x spacing) was found to be significant for 2015 and the pooled data, however, it was non-significant in the year 2016.Within the crops, all the crops had high yield {212.74 qha^{-1} (T), 121.94 qha^{-1} (K), 7.89 qha^{-1} (G)} in narrow spacing (30x20cm) as compared to wider spacing in 2015 except Stevia where the yield was (23.74 qha^{-1}) at spacing S_2 (30 x 30cm) in 2015. The pooling of interaction values also gave the same pattern.

4.3.2.4. Yield (Dry) (q ha^{-1})

The data pertaining to dry yield are presented in table 12. The results indicated that amongst the crops, significantly highest dry yield was recorded in kalmegh (44.97 qha^{-1})

Table 12. Crop performance and effect of spacing on the yield of sole crops under open condition

Treatment combination	Fresh weight plant $^{-1}$ (g)			Dry weight plant $^{-1}$ (g)			Yield (Fresh)ha^{-1} (q)			Yield (Dry)ha^{-1} (q)		
Crops	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Ginger (G)	58.07	51.78	54.93	10.89	9.09	9.99	5.61	4.89	5.25	0.83	0.72	0.77
Turmeric (T)	334.99	323.11	329.05	114.62	118.96	116.79	175.40	166.01	170.70	26.22	26.49	26.36
Stevia (S)	158.89	173.26	166.07	51.34	53.49	52.42	22.31	23.51	22.91	7.83	7.94	7.88
Kalmegh (K)	164.22	202.05	183.13	76.07	97.60	86.83	108.82	119.73	114.28	44.97	49.50	47.24
±SE (m)	**4.40**	**8.78**	**5.77**	**1.27**	**2.26**	**1.66**	**4.82**	**9.41**	**5.96**	**1.22**	**1.92**	**1.47**
$CD_{0.05}$	**12.91**	**25.94**	**17.03**	**3.73**	**6.68**	**4.90**	**14.13**	**27.76**	**17.59**	**3.56**	**5.66**	**4.34**
Spacing												
20x30cm (S_1)	56.37	167.98	162.17	54.38	60.20	57.29	90.94	95.71	93.32	22.61	24.09	23.36
30x30cm (S_2)	163.84	179.43	171.64	58.94	67.22	63.08	68.85	74.26	71.55	18.42	20.82	19.62
30x40cm (S_3)	216.92	215.24	216.08	76.37	81.94	79.15	74.32	65.62	69.97	18.86	18.57	18.71
±SE (m)	**3.81**	**7.61**	**4.99**	**1.09**	**1.96**	**1.44**	**4.17**	**8.15**	**5.16**	**1.05**	**1.66**	**1.27**
$CD_{0.05}$	**11.18**	**22.46**	**14.75**	**3.23**	**5.78**	**4.24**	**12.24**	**24.04**	**15.23**	**3.08**	**NS**	**3.75**
Crops x spacing												
G S_1	63.11	53.04	58.07	11.35	9.16	10.25	7.89	6.41	7.15	1.15	0.93	1.04
G S_2	55.18	47.05	51.11	10.43	8.25	9.34	5.81	4.91	5.36	0.84	0.71	0.78
G S_3	55.93	55.27	55.60	10.90	9.87	10.39	3.15	3.34	3.24	0.48	0.51	0.50
T S_1	290.04	301.16	295.61	102.14	110.76	106.45	212.74	223.17	217.95	31.81	35.65	33.73
T S_2	285.01	299.73	292.37	99.47	110.98	105.23	139.18	148.25	143.71	20.83	24.48	22.66
T S_3	429.93	368.42	399.17	142.26	135.13	138.70	174.27	126.60	150.43	26.02	19.34	22.68
S S_1	142.08	161.08	151.58	44.89	48.38	46.63	21.18	23.14	22.16	7.25	7.33	7.29
S S_2	157.10	174.02	165.56	53.10	54.07	53.58	23.74	25.24	24.48	8.36	8.89	8.63
S S_3	177.48	184.69	181.08	56.05	58.04	57.04	22.01	22.14	22.08	7.88	7.59	7.73
K S_1	130.24	156.63	143.44	59.15	72.48	65.81	121.94	130.13	126.04	50.25	52.47	51.36
K S_2	158.09	196.92	177.50	72.79	95.59	84.19	106.67	118.66	112.67	43.64	49.21	46.42
K S_3	204.32	252.61	228.46	96.26	124.72	110.50	97.86	110.41	104.13	41.04	46.83	43.93
±SE (m)	**7.62**	**15.22**	**9.99**	**2.19**	**3.92**	**2.87**	**8.35**	**16.29**	**10.33**	**2.11**	**3.33**	**2.54**
$CD_{0.05}$	**22.37**	**NS**	**29.51**	**6.45**	**11.57**	**8.48**	**24.48**	**NS**	**30.47**	**NS**	**NS**	**NS**

NS- Non-significant

followed by turmeric (26.22 qha^{-1}), stevia (7.83 qha^{-1}) and ginger (0.83 qha^{-1}) in 2015. In 2016 and the pooled data similar results were obtained. Closer spacing S_1 (30 x 20 cm) recorded the highest yield (22.61 qha^{-1}) and than wider spacing viz. S_2 and S_3 was statistically at par to each other. The critical difference was significant in the year 2015 both for crops and spacing but it was non-significant for spacing in the year 2016. However, it was again significant in the pooled values.

The interaction between crop and spacing on dry yield was statistically non-significant during 2015, 2016 and the pooled data.

4.3.3. Physiological attributes

4.3.3.1. Relative growth rate (RGR) ($gg^{-1}day^{-1}$)

Relative growth rate is a measure of the growth efficiency of the plant. RGR as affected by the crops as well as by the planting distance/spacing is shown in table 13. Statistically maximum RGR was observed in stevia (0.024 $gg^{-1}day^{-1}$) and followed by kalmegh (0.021)>turmeric (0.016)> ginger (0.007) in 2015 and similar outcomes were obtained in the 2016 viz. maximum in stevia (0.024), minimum in ginger (0.005) and in pooled data. The critical difference among various crops was statistically significant. Plant spacing changed the RGR value marginally with statistically higher and at par value (0.017) in widely spaced plants and lowest (0.016) in closely spaced plants in 2015. Similar results were obtained in 2016 and in the pooled averages.

The interaction between crop and spacing on relative growth rate was statistically significant in 2015, 2016 and pooled data. In 2015, maximum RGR value was recorded in stevia with spacing S_3 (SS_3- 0.025) which was statistically at par with SS_2, SS_1 and KS_3 (kalmegh+S_3). Minimum interaction was observed in ginger with spacing S_3 (GS_3- 0.005). In 2016 similar results were obtained with maximum RGR value (0.025) of stevia (SS_3) and minimum (0.004) of ginger (GS_3). Similar results were obtained in the pooled analysis.

4.3.3.2. Net assimilation rate (NAR) ($gg^{-1}day^{-1}$)

The data on net assimilation rate of crops presented in table 13 indicate that the highest NAR (0.097 $gg^{-1}day^{-1}$) was recorded in stevia and lowest (0.039 $gg^{-1}day^{-1}$) with ginger in 2015. In 2016 and the pooled data similar results were obtained. The critical difference was significant in 2015, 2016 and the pooled averages.

With regard to effect of spacing on NAR, the value increased with increase in spacing ($S_1<S_2<S_3$). Minimum NAR (0.068 $gg^{-1}day^{-1}$) was recorded in S_1 and maximum

(0.079 $gg^{-1}day^{-1}$) was obtained in S_3 in 2015. The results were nearly similar in 2016 and the pooled data. The critical difference was significant during 2015, 2016 and in the pooled data. The interaction between crop and spacing was statistically significant in 2015, 2016 and in the pooled analysis. Minimum (0.028) NAR value was observed in ginger with spacing S_3 (GS_3) in 2015 and in the same treatment (GS_3-0.023) in 2016 also. However, maximum (0.103, 0.115) value was recorded in treatment KS_3 in 2015 and 2016, respectively. Ginger and stevia had higher NAR values (0.043, 0.100) at spacing S_2 in the pooled data. In rest of the interactions, the value of NAR increased with increase in spacing.

4.3.3.3. Total chlorophyll content (vegetative phase) (mgg^{-1})

This parameter reflects the general status of the growth of the plants. The data related to the chlorophyll content of the crops in the vegetative phase under open conditions and given in table 13. The figures pertaining to the average chlorophyll content in crops showed that kalmegh had the highest content (1.74, 1.77 and 1.75mg g^{-1}) in 2015, 2016 and the pooled data, respectively. The other three crops had values statistically at par to each other. The content increased with the increase in plant spacing and was recorded in the order of S_1 (0.97) < S_2 (1.18) < S_3 (1.58) in 2015. Similar values were recorded in 2016 (S_1 (1.03) < S_2 (1.21) < S_3 (1.58) and the pooled data.

With regard to the interaction between the treatments, it was observed that in all the combinations, the chlorophyll content increased with the increase in spacing. Maximum interaction effect was recorded in kalmegh with spacing S_2 and S_3 (KS_2 – 1.79 and KS_3 – 1.78) and the two were statistically at par to each other in 2015. Similarly, in 2016 and in the pooled analysis statistically at par values were observed for kalmegh in the two spacing S_2 and S_3.

4.3.3.4. Total chlorophyll content (reproductive phase) (mgg^{-1})

The observations in context of impact of spacing on the chlorophyll content in leaves of the crops at reproductive stage were recorded for two consecutive years and the data obtained are presented in table 13.

Among the four crops, stevia had the maximum chlorophyll content (2.77, 2.84 and 2.80 mgg^{-1}) and ginger had the minimum (0.99, 0.98, 0.98 mgg^{-1}) in the two years and in the pooled result, respectively. The critical difference was statistically significant for all the crops. No significant effect of spacing on the chlorophyll content was visible during

Table 13. Crop performance and effect of spacing on the physiological parameters of sole crops under open condition

Treatment combination	Relative growth rate (RGR) ($gg^{-1}day^{-1}$)			Net assimilation rate (NAR) ($gg^{-1}day^{-1}$)			Total chlorophyll content (vegetative phase) (mg g^{-1})			Total chlorophyll content (reproductive phase) (mg g^{-1})			Carotenoid content (mg g^{-1})		
Crops	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Ginger (G)	0.0070	0.005	0.0060	0.0390	0.0330	0.0360	1.08	1.10	1.09	0.99	0.98	0.98	0.71	0.70	0.70
Turmeric (T)	0.0160	0.016	0.0160	0.0750	0.0760	0.0730	1.05	1.13	1.09	2.01	2.35	2.18	0.21	0.24	0.22
Stevia (S)	0.0240	0.024	0.0240	0.0970	0.0990	0.0980	1.11	1.09	1.09	2.77	2.84	2.80	0.31	0.32	0.31
Kalmegh (K)	0.0210	0.020	0.0210	0.0840	0.0900	0.0870	1.74	1.77	1.75	1.55	1.55	1.56	2.23	2.25	2.24
±SE (m)	**0.0004**	**0.000**	**0.0004**	**0.0032**	**0.0031**	**0.0031**	**0.02**	**0.01**	**0.01**	**0.06**	**0.11**	**0.08**	**0.05**	**0.05**	**0.05**
$CD_{0.05}$	**0.0013**	**0.001**	**0.0011**	**0.0095**	**0.0092**	**0.0091**	**0.07**	**0.05**	**0.04**	**0.20**	**0.31**	**0.23**	**0.15**	**0.13**	**0.14**
Spacing															
20x30cm (S_1)	0.0160	0.015	0.0160	0.0680	0.0680	0.0680	0.97	1.03	0.99	1.88	1.94	1.91	0.87	0.87	0.87
30x30cm (S_2)	0.0170	0.016	0.0170	0.0740	0.0780	0.0750	1.18	1.21	1.19	1.81	1.85	1.84	0.85	0.86	0.85
30x40cm (S_3)	0.0170	0.017	0.0170	0.0790	0.0780	0.0780	1.58	1.58	1.58	1.80	2.00	1.90	0.88	0.90	0.89
±SE (m)	**0.0004**	**0.000**	**0.0003**	**0.0028**	**0.0027**	**0.0027**	**0.02**	**0.01**	**0.01**	**0.06**	**0.09**	**0.07**	**0.04**	**0.04**	**0.04**
$CD_{0.05}$	**NS**	**0.001**	**NS**	**0.0082**	**0.0080**	**0.0079**	**0.06**	**0.04**	**0.04**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Crops x spacing															
G S_1	0.0080	0.005	0.0070	0.0430	0.0360	0.0400	0.70	0.72	0.71	1.04	1.03	1.03	0.71	0.70	0.70
G S_2	0.0080	0.005	0.0070	0.0470	0.0400	0.0430	0.90	0.92	0.91	0.85	0.85	0.85	0.73	0.73	0.73
G S_3	0.0050	0.004	0.0040	0.0280	0.0230	0.0250	1.63	1.67	1.65	1.07	1.07	1.07	0.68	0.68	0.68
T S_1	0.0150	0.015	0.0150	0.0670	0.0670	0.0670	0.58	0.63	0.60	2.04	2.21	2.13	0.17	0.18	0.17
T S_2	0.0150	0.016	0.0160	0.0700	0.0860	0.0720	0.94	1.01	0.97	2.10	2.28	2.19	0.22	0.23	0.22
T S_3	0.0170	0.016	0.0160	0.0880	0.0750	0.0820	1.63	1.76	1.69	1.87	2.55	2.21	0.25	0.31	0.28
S S_1	0.0230	0.023	0.0230	0.0960	0.1000	0.0980	0.96	1.10	1.00	2.93	2.98	2.95	0.21	0.22	0.22
S S_2	0.0240	0.024	0.0240	0.0990	0.1000	0.1000	1.10	1.10	1.10	2.66	2.74	2.69	0.30	0.31	0.30
S S_3	0.0240	0.025	0.0240	0.0980	0.0970	0.0970	1.27	1.08	1.17	2.72	2.81	2.76	0.42	0.43	0.42
K S_1	0.0190	0.018	0.0190	0.0680	0.0690	0.0680	1.64	1.67	1.65	1.49	1.54	1.51	2.39	2.39	2.38
K S_2	0.0210	0.020	0.0200	0.0820	0.0850	0.0840	1.79	1.82	1.80	1.61	1.54	1.62	2.15	2.18	2.16
K S_3	0.0230	0.023	0.0230	0.1030	0.1150	0.1090	1.78	1.82	1.80	1.54	1.58	1.55	2.16	2.18	2.17
±SE (m)	**0.0008**	**0.001**	**0.0006**	**0.0056**	**0.0055**	**0.0054**	**0.04**	**0.03**	**0.03**	**0.12**	**0.18**	**0.14**	**0.09**	**0.08**	**0.09**
$CD_{0.05}$	**0.0020**	**0.002**	**0.0020**	**0.0160**	**0.0160**	**0.0160**	**0.12**	**0.08**	**0.08**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS- Non-significant

both the years, the critical difference was also found to be non-significant.

The interaction effect of spacing and crop was found to be statistically non-significant during 2015, 2016 and the pooled data.

4.3.3.5. Carotenoid content (mgg^{-1})

Carotenoid provides a channel to dispose of excess energy absorbed by chlorophyll. The data pertaining to the carotenoid content recorded for the two consecutive years is displayed in table 13.

Among the four crops, the average carotenoid content was maximum in kalmegh (2.23 mg/g) followed by ginger (0.71), stevia (0.31) and turmeric (0.21 mgg^{-1}) in the year 2015. Statistically similar readings were obtained in the year 2016 (K-2.25 > G-0.70 > S-0.32 > T-0.24) and in the pooled data as well. The critical difference was significant for both the years and for the combined data. The spatial arrangement of the crops did not alter the content significantly.

It was evinced from the data that the carotenoid content of the four crops was not significantly affected by the varied spacing. The interaction of crop and spacing was found to be non-significant in all the treatment combinations, however, the maximum effect was seen in kalmegh {KS_1 (2.39), KS_3 (2.16), KS_2 (2.15)} in 2015. In 2016 and in the pooled analysis similar results were recorded.

4.3.3.6. Partitioning co-efficient (%)

It is clear from the data (Table 14) that with regard to partitioning of assimilates to leaves and branches, maximum assimilates were allocated to the leaves of turmeric (36.42 %), branches of turmeric (41.28%) in 2015. Similar results were recorded in 2016 and in pooled data. In case of roots/rhizomes maximum allocation was in rhizomes of ginger (50.43%) followed by turmeric (28.47 %) in 2015 whereas, in 2016 maximum allocation was in rhizomes of ginger (56.70 %) followed by stevia roots (27.77 %). In pooled data, the trend was similar to 2015. In case of inflorescence maximum allocation was in kalmegh (32.75 %). Similar results were obtained in 2016 and in pooled. No flowering was observed in ginger and turmeric, hence no allocation of assimilates. Spacing had no effect on the distribution of dry matter accumulates to different part of plant body in any of the crops. The critical difference was found to be insignificant for all parts except inflorescence in both the years and the pooled data. The distribution of dry matter content to inflorescence was maximum in S_3 (31.91%) followed by S_2 (30.33%) and minimum in S_1 (27.59%) in 2015. Similar observations were recorded in 2016 and in assemblage of data.

Table 14. Crop performance and effect of spacing on the partitioning coefficient of sole crops under open condition

Treatment combination	Partitioning coefficient (%)											
	Leaf			Branch			Root			Inflorescence		
Crops	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Ginger (G)	32.10	21.90	27.00	17.46	21.38	19.42	50.43	56.70	53.56	-	-	-
Turmeric (T)	36.42	33.19	35.55	41.28	41.80	41.54	28.47	24.99	25.12	-	-	-
Stevia (S)	21.50	22.04	21.76	39.97	38.97	39.47	11.39	27.77	19.58	27.13	27.78	27.46
Kalmegh (K)	29.77	24.16	26.96	34.42	31.31	32.87	3.04	3.01	3.02	32.75	41.51	37.13
±SE (m)	**1.56**	**1.22**	**1.35**	**1.08**	**1.47**	**1.23**	**1.98**	**1.75**	**1.79**	**0.90**	**0.97**	**0.91**
$CD_{0.05}$	**4.60**	**3.58**	**3.98**	**3.17**	**4.32**	**3.62**	**5.80**	**5.16**	**5.26**	**2.88**	**3.10**	**2.92**
Spacing												
20x30cm (S_1)	31.36	26.48	28.92	32.55	33.50	33.02	23.14	27.48	25.31	27.59	32.07	29.83
30x30cm (S_2)	31.00	24.74	28.43	32.95	32.01	33.12	26.10	29.51	27.80	30.33	35.79	33.06
30x40cm (S_3)	27.49	24.75	26.12	34.35	34.60	34.48	20.75	27.36	24.06	31.91	36.07	33.99
±SE (m)	**1.35**	**1.05**	**1.17**	**0.94**	**1.27**	**1.06**	**1.71**	**1.51**	**1.55**	**1.10**	**1.19**	**1.12**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Crops X spacing												
G S_1	30.82	20.95	25.89	16.54	20.55	18.55	52.63	58.48	55.55	-	-	-
G S_2	32.71	21.05	26.88	17.55	23.09	20.32	49.73	55.85	52.79	-	-	-
G S_3	32.77	23.71	28.24	18.30	20.50	19.41	48.92	55.77	52.35	-	-	-
T S_1	37.57	34.72	36.14	42.06	43.66	42.86	23.78	21.60	22.69	-	-	-
T S_2	39.78	31.11	37.69	40.26	37.17	41.29	40.84	31.71	36.28	-	-	-
T S_3	31.91	33.76	32.83	41.52	44.58	43.05	20.79	21.65	21.22	-	-	-
S S_1	21.68	21.39	21.53	40.23	40.94	40.58	12.29	25.85	19.07	25.79	25.86	25.82
S S_2	21.37	22.51	21.94	41.91	38.68	40.29	10.83	27.72	19.28	25.88	27.72	26.80
S S_3	21.44	22.21	21.82	37.78	37.30	37.54	11.05	29.75	20.40	29.73	29.75	29.74
K S_1	35.36	28.87	32.11	31.38	28.83	30.11	3.87	4.01	3.94	29.39	38.28	33.83
KS_2	30.14	24.29	27.21	32.08	29.10	30.58	3.01	2.74	2.87	34.77	43.86	39.32
K S_3	23.83	19.32	21.57	39.81	36.01	37.91	2.25	2.28	2.26	34.10	42.38	38.24
±SE (m)	**2.71**	**2.11**	**2.34**	**1.87**	**2.54**	**2.13**	**3.43**	**3.03**	**3.11**	**1.56**	**2.68**	**1.58**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**10.05**	**NS**	**NS**	**NS**	**NS**	**NS**

NS- Non-significant

The interaction of crops and spacing was found to be statistically non-significant in all the treatment combinations except for roots/rhizomes and inflorescence in the year 2015. In 2015, in case of root/rhizome maximum interaction was observed in treatment combination GS_1- 52.63 which was statistically at par with GS_2 and GS_3. In case of inflorescence, maximum interaction effect was recorded KS_2 (34.77) which was statistically at par with KS_3 followed by SS_3 (29.73) which was statistically similar to KS_1.

4.3.4. Root characteristics

4.3.4.1. Number of roots/rhizomes per plant

The data on number of roots/rhizomes for various crops and treatment combinations are presented in table 15. The data revealed that maximum number of roots/rhizomes were found in stevia (61.15) and the minimum in ginger (4.06) in 2015. Similar results were recorded in 2016 (S-62.65 and G- 3.88) and in the pooled data (S-61.90 and G-3.97). Three different plant spacing significantly affected the number of roots/rhizomes during both the experimental years. Statistically significant highest (26.33) number of roots were recorded in spacing S_3 (30x40) and the lowest (18.96) in S_1 (30x20) in 2015. In 2016, maximum number of roots (27.54) were recorded in S_3 followed by S_2 (23.36) and S_1 (20.31). Similar results were also obtained in the pooled analysis.

The interaction of crops and spacing was significant for both the years as well as for the pooled data. Stevia (SS_3) recorded statistically higher (74.67) interaction effect followed by SS_2 (58.73) and SS_1 (50.06) in 2015. Similar results were obtained in 2016 and in the pooled data.

4.3.4.2. Dry weight of roots/rhizomes per plant (g)

Root/ rhizome dry weight differed significantly amongst the crops in the year 2015, 2016 and the pooled data (Table 15) Among the four crops., maximum dry weight of roots/rhizomes was recorded in turmeric (27.58 g in 2015, 26.12g in 2016 and 26.85 g in pooled)) and minimum in kalmegh (2.21g in 2015, 2.79 g in 2016 and 2.50g in pooled). A significant effect of spacing on root/rhizome weight was observed. Higher root dry weight was observed in plants grown at wider spacing of 30 cm x 40 cm (13.37 g, 11.10 g) in 2015, 2016, respectively. The critical difference was significant for the factors in the year 2015 and the pooled data but the effect of spacing was non-significant in 2016.

The interaction between crop and spacing was statistically significant for the first year of experiment as well as for the pooled data. However, the interaction effect for the 2^{nd} year was non-significant.

Table 15. Crop performance and effect of spacing on the root characteristics of sole crops under open condition

Treatment combination	Number of roots plant $^{-1}$			Dry weight of roots/ rhizomes plant $^{-1}$ (g)		
Crops	**2015**	**2016**	**Pooled**	**2015**	**2016**	**Pooled**
Ginger (G)	4.06	3.88	3.97	5.58	5.21	5.39
Turmeric (T)	8.77	9.58	9.17	27.58	26.12	26.85
Stevia (S)	61.15	62.65	61.90	6.03	6.27	6.16
Kalmegh (K)	15.90	18.86	17.38	2.21	2.79	2.50
$\pm$SE (m)	**1.54**	**1.25**	**1.36**	**0.74**	**1.22**	**0.85**
$CD_{0.05}$	**4.51**	**3.67**	**4.00**	**2.18**	**3.59**	**2.51**
Spacing						
20x30cm (S_1)	18.96	20.31	19.64	9.08	9.68	9.38
30x30cm (S_2)	22.11	23.36	22.74	8.61	9.51	9.06
30x40cm (S_3)	26.33	27.54	26.94	13.37	11.10	12.23
$\pm$SE (m)	**1.33**	**1.08**	**1.18**	**0.64**	**1.05**	**0.74**
$CD_{0.05}$	**3.91**	**3.18**	**3.46**	**1.89**	**NS**	**2.18**
Crops x spacing						
G S_1	3.39	3.13	3.25	6.08	5.38	5.73
G S_2	4.06	3.75	3.90	5.31	4.73	5.02
G S_3	4.74	4.75	4.75	5.37	5.51	5.44
T S_1	7.07	7.57	7.32	22.07	24.25	23.17
T S_2	9.11	9.94	9.52	20.94	24.45	22.69
T S_3	10.12	11.22	10.67	39.73	29.67	34.70
S S_1	50.06	52.34	51.20	5.89	6.18	6.03
S S_2	58.73	59.77	59.25	6.02	6.29	6.15
S S_3	74.67	75.85	75.26	6.21	6.36	6.28
K S_1	15.33	18.23	16.78	2.29	2.92	2.60
KS_2	16.56	19.99	18.28	2.17	2.59	2.38
K S_3	15.80	18.35	17.08	2.18	2.86	2.52
$\pm$SE (m)	**2.67**	**2.17**	**2.36**	**1.28**	**2.11**	**1.48**
$CD_{0.05}$	**7.82**	**6.36**	**6.93**	**3.78**	**NS**	**4.36**

NS- Non-significant

The maximum rhizome weight was recorded in TS_3 (39.73 g) followed by root weight in TS_1 (22.07g) and TS_2 (20.94g) in 2015. The minimum root weight was in KS_2 (2.17g) in 2015. Similar results were obtained in 2016 and in the pooled data.

4.4 Effect of spacing and crops on the physico-chemical properties of soil under mango orchard

The soil samples at different depths for various physico-chemical parameters were collected and analysed after the crop harvesting in both the years. The data recorded for the first year of experimentation is given in Appendix III and the results of the second year data (end of the experiment) are described here.

4.4.1. Soil pH (1:2.5 :: Soil :Water)

The data presented in table 16 reveal that there was no significant response in soil pH due to different crops and spacing in all the three depths. The data related to the effect of crops on soil pH showed that pH did not vary with depth. It was recorded high in depth 30-60 cm in all crops. Maximum pH (6.75 in 0-30cm, 6.78 in 30-60cm and 6.68 in 60-90 cm) was marked in kalmegh and minimum (6.37 in 0-30 cm, 6.41 in 30-60cm and 6.30 in 60-90 cm) in turmeric. As regards spacing, maximum pH was registered in S_2 (30 cm x 30 cm) in all the three depths (6.58 in 0-30 cm, 6.67 in 30-60 cm and 6.53 in 60-90 cm) but the differences were statistically non-significant for all the depths.

The interaction effect of crop and spacing was non- significant for all treatment combinations at all the depths.

4.4.2 Electrical conductivity (EC) (dS m^{-1})

The data on electrical conductivity presented in table 16 clearly indicate that EC decreased with increasing depth. The highest value of EC (0.149 dS m^{-1})was recorded for ginger and minimum 0.108 dS m^{-1} for kalmegh at 0-30cm. At depth 30-60, the value ranged from 0.107 dS m^{-1} (kalmegh) to 0.144 dS m^{-1} (ginger) and in 60-90 cm depth the value ranged between 0.101 dS m^{-1} (turmeric) to 0.126 dS m^{-1} (ginger). The difference was non-significant in all the treatments. Among the spacing S_1, S_2, S_3, maximum electrical conductivity (0.126 dS m^{-1}) was noted in S_1 and minimum (0.118 dS m^{-1}) in S_3 at 0-30 cm depth. Similar results were obtained at 60-90 cm depth. But at depth 30-60 cm, maximum EC (0.123 dS m^{-1}) was recorded in S_2 and minimum (0.106 dS m^{-1}) in S_3.

The interaction between crop and spacing was found to be non-significant at all depths.

4.4.3. Soil moisture (%)

It is evident from the data given in table 16 that soil moisture content increased with increase in soil depth in all the crops and at all spacings. The minimum moisture content (17.63%) was observed in stevia and the maximum was in ginger (18.66%) at the depth of 0-30cm, although the differences among the crops were statistically non-significant. At 30-60cm, the maximum content (21.05%) was under turmeric followed by ginger (19.64%). As regards spacing, the highest moisture was recorded in S_1 (18.56%) and minimum in S_2 (17.54%) in 0-30 cm. The maximum content (19.48%) at 30-60 cm was again in S_1. In the deepest depth of 60-90cm, the maximum moisture (22.15%) was noted in spacing S_3. However, the values were at par in all the spacings and at all depths.

The interaction (crop x spacing) was found to be non-significant in all the depths.

4.4.4. Bulk density (BD) (g cm^{-3})

With regard to bulk density, it is clear from the table 16 that bulk density did not differ significantly among the crops but in general, the values increased with increasing depth. Among the crops, maximum BD was found in kalmegh (1.166 g cm^{-3}) at depth 0-30cm and (1.347 g cm^{-3}) at 30-60 cm depth which were statistically at par in Stevia and Kalmegh (1.368 g cm^{-3} each) in depth of 60-90 cm. Though the bulk density was recorded to be maximum in S_3 (1.208 at 0-30 cm, 1.344 at 30-60 cm and 1.361 at 60-90 cm), the critical difference was non- significant.

At all the depths, the effect of crop-spacing interaction was found to be non-significant.

4.4.5. Cation Exchange Capacity (CEC) (c.mol.P^+)

The data recorded at the end of the experiment with regard to CEC is tabulated in the table 16.

The perusal of the data depict that there was a marginal improvement in the CEC of the soil at all depths as compared to the values obtained at the start of the experiment (Appendix III) but the differences were non-significant. Minimum CEC (13.15 c.mol.P^+) value was found in kalmegh (K) and the maximum (13.88 c.mol.P^+) was recorded in turmeric (T) at 0-30 cm. At 30-60 cm depth, maximum value (12.57 c.mol.P^+) was recorded for stevia and in the third depth 60-90 cm, maximum CEC content (11.43 c.mol.P^+) was noticed in ginger (G) and minimum (10.66 c.mol.P^+ in stevia (S). At depth (0-30 cm), spacing S_1 had maximity of CEC value i.e. 13.52 c.mol.P^+, at depth 30-60 cm, maximum value (13.48) was recorded in S_3.

Table 16. Soil physico-chemical properties as affected by intercrops and different spacing under mango orchard after 2 years (2016)

Treatment combination	pH (1:2.5 ::Soil: Water)			EC (dS m^{-1})			Soil Moisture (%)			Bulk density (g cm^{-3})			CEC (c.mol.P^{+})		
Depths(cm) / Crops	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**
Ginger (G)	6.61	6.68	6.65	0.149	0.144	0.126	18.66	19.64	21.98	1.120	1.320	1.362	13.47	12.53	11.43
Turmeric (T)	6.37	6.41	6.30	0.130	0.114	0.101	18.01	21.05	23.58	1.147	1.327	1.346	13.88	12.42	10.98
Stevia (S)	6.47	6.56	6.54	0.122	0.109	0.102	17.63	18.76	22.09	1.124	1.331	1.368	13.29	12.57	10.66
Kalmegh (K)	6.75	6.78	6.68	0.108	0.107	0.104	18.31	19.27	21.08	1.166	1.347	1.368	13.15	12.24	11.07
±SE(m)	**0.02**	**0.04**	**0.06**	**0.01**	**0.01**	**0.01**	**0.56**	**0.59**	**0.29**	**0.04**	**0.01**	**0.01**	**0.47**	**0.39**	**0.48**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.74**	**0.88**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Spacing															
20x30cm (S_1)	6.56	6.59	6.42	0.126	0.122	0.111	18.56	19.48	21.89	1.138	1.338	1.348	13.52	12.55	10.48
30x30cm (S_2)	6.58	6.67	6.53	0.123	0.123	0.105	17.54	19.45	21.76	1.148	1.336	1.374	12.91	12.57	11.34
30x40cm (S_3)	6.51	6.53	6.49	0.118	0.106	0.106	18.37	18.61	22.15	1.208	1.344	1.361	13.42	13.48	11.28
±SE(m)	**0.01**	**0.04**	**0.05**	**0.01**	**0.01**	**0.01**	**0.48**	**0.51**	**0.25**	**0.04**	**0.01**	**0.01**	**0.41**	**0.34**	**0.42**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Crops x spacing															
G S_1	6.64	6.73	6.87	0.143	0.127	0.110	18.69	20.18	21.37	1.133	1.347	1.330	11.99	10.39	10.02
G S_2	6.73	6.83	7.04	0.170	0.180	0.140	18.38	17.54	19.99	1.133	1.350	1.400	13.30	12.45	11.69
G S_3	6.45	6.47	6.51	0.133	0.127	0.127	18.92	18.21	21.59	1.393	1.360	1.357	13.11	13.86	12.58
T S_1	6.51	5.59	5.60	0.143	0.123	0.103	17.71	21.00	23.04	1.180	1.357	1.360	14.26	13.80	11.41
T S_2	6.63	6.61	7.17	0.123	0.107	0.087	17.43	22.06	23.69	1.133	1.313	1.323	13.70	13.09	10.94
T S_3	5.97	6.12	6.14	0.123	0.113	0.113	18.88	20.10	24.01	1.127	1.310	1.353	13.68	13.36	10.60
S S_1	6.36	6.63	6.64	0.123	0.097	0.170	17.97	18.34	22.14	1.110	1.313	1.343	11.63	12.00	9.68
S S_2	6.33	6.42	6.48	0.090	0.097	0.087	16.77	19.37	21.93	1.133	1.313	1.380	12.22	12.69	11.81
S S_3	6.73	6.63	6.50	0.113	0.113	0.110	18.16	18.58	22.20	1.130	1.367	1.380	13.03	13.03	10.50
K S_1	6.72	6.62	6.59	0.093	0.060	0.060	19.86	18.40	21.00	1.127	1.333	1.357	13.18	14.01	10.81
K S_2	6.62	6.82	6.63	0.107	0.107	0.067	17.57	18.84	21.43	1.190	1.367	1.393	12.40	12.04	10.93
K S_3	6.89	6.91	6.81	0.063	0.070	0.073	17.51	17.57	20.81	1.180	1.340	1.353	13.86	13.66	11.45
±SE(m)	**0.03**	**0.07**	**0.11**	**0.01**	**0.01**	**0.01**	**0.97**	**1.02**	**0.52**	**0.07**	**0.02**	**0.02**	**0.81**	**0.67**	**0.83**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Initial value	**6.35**	**6.42**	**6.47**	**0.11**	**0.10**	**0.09**	**17.65**	**18.64**	**20.18**	**1.173**	**1.327**	**1.371**	**13.26**	**12.28**	**10.58**

NS- Non significant

The maximum value (11.34) was obtained in S_2 at 60-90 cm but these values were statistically alike.The critical difference however came to be non-significant both for crops and for the spacing.

The interaction (crop x spacing) was found to be insignificant for the entire soil profile.

4.4.6. Soil organic carbon (g kg^{-1}soil)

The organic carbon content of the soil did not change drastically despite addition of organic matter into the soil when compared to the initial values. The observations regarding soil organic carbon content are given in the table 17.

The data clearly depicted that though the differences were non-significant, organic carbon content decreased with increasing depth in all crops and spacing. Maximum content (5.99 g kg^{-1}) was recorded in kalmegh (K) at 0-30 cm, 4.72 g kg^{-1} in turmeric at depth 30-60 cm and 4.28 g kg^{-1} was observed in kalmegh at depth 60-90cm.

Amongst the spacing, highest content (5.99 g kg^{-1}) was noted in spacing S_1 and minimum (5.01) in spacing S_3 in the depth 0-30 cm. In 30-60 cm depth, the highest organic carbon (4.65 g kg^{-1}) was recorded in S_3 and statistically alike value (4.47 g kg^{-1}) was recorded in S_1 and S_2. In 60-90 cm depth, maximum carbon content (4.30 g kg^{-1}) was noted in S_2.The critical difference was non-significant for all treatments and their combinations and interactions.

4.4.7. Available nitrogen (kg ha^{-1})

The rate of plant growth is proportional to the rate of nitrogen supply. It is responsible for increased yield and quality, and as nitrogen rates increase, so does the yield. The data on available nitrogen content in the soil after two years of experimentation are given in the table 17.

The aggregation presented in table 17 showed that the orchard soils had a low available N content and there was no marked improvement in the content even after two years of intercropping. Highest nitrogen (235.09 kg ha^{-1}) was found under ginger crop and the lowest content (221.79 kg ha^{-1}) was recorded under stevia at 0-30cm. At the depth 30-60 cm, maximum content (206.44 kg ha^{-1}) was found under turmeric and the differences were statistically significant at this depth. At 60-90 cm depth, the values were statistically non-significant but the lowest nitrogen (161.55 kg ha^{-1}) was recorded in ginger. Similarly among the three spacing the values of available N were significantly influenced. The maximum value was noted in S_1 (238.39 kg ha^{-1}) followed by S_3 (227.55 kg ha^{-1}) at 0-30cm. However, at depth 30-60 cm, highest N content was in S_3 (204.18 kg ha^{-1}) and also at 60-90 cm depth, highest N content (173.89 kg ha^{-1}) was recorded in S_3.

The interaction between crop and spacing was non-significant at depth 0-30cm and significant for the depths 30-60cm and 60-90cm. At 30-60cm, maximum effect of crop and spacing on soil N was visible in turmeric with spacing S_1 (TS_1-221.99 kg ha^{-1}) and minimum in ginger with spacing S_2 (GS_2-168.08 kg ha^{-1}) whereas at 60-90cm, highest effect (194.89 kg ha^{-1}) was in GS_3 (ginger + S_3) and lowest (138.42 kg ha^{-1}) was in GS_2 (ginger+S_2).

4.4.8. Available phosphorus (kg ha^{-1})

Phosphorus is the critical nutrient element in root development, crop maturity and seed production. The data regarding the amount of available phosphorus at the end of the experiment is given in table17.

The perusal of the data showed that P content did not vary amongst the crops at 0-30 cm and 30-60 cm depths but in general, the value decreased with increasing depth and it varied from 14.76 kg ha^{-1} in surface soil to 9.17 kg ha^{-1} at 60-90 cm. Maximum phosphorus (14.76 kg ha^{-1}) was in ginger soil and minimum in kalmegh (13.29 kg ha^{-1}) in surface soils. At the lower depth of 30-60 cm, soil beneath stevia had highest (13.94 kg ha^{-1}) value and ginger and kalmegh had at par values. At the lowest depth, kalmegh recorded minimum (9.17 kg ha^{-1}) P content and the maximum (11.98 kg ha^{-1}) was noted in turmeric (T). With regard to spacing, the differences were significant, S_2 showed highest phosphorus content (14.88 kg ha^{-1}) and the other two spacings had at par values at 0-30 cm. For 30-60 cm, spacing S_1 registered the highest content of 12.94 kg phosphorus per hectare and at 60-90 cm depth, S_2 recorded the highest P value of 11.56 kg ha^{-1}.

The interaction between crop and spacing was non- significant at 0-30 cm depth. At 30-60 cm, maximum interaction effect of crop and spacing (16.15 kg ha^{-1}) was recorded in SS_1 (stevia+spacing S_1) followed by SS_2 (stevia +S_2- 14.91) and TS_1 (turmeric + S_1- 14.65). At the lowest depth, maximum available P (13.54 kg ha^{-1}) was recorded in TS_2 (turmeric + S_2) and the minimum (8.07) was observed in (GS_1) ginger with spacing S_1.

4.4.9. Available potassium (kg ha^{-1})

Fruit size, appearance, colour, soluble solids, acidity, vitamin content, taste, as well as shelf-life are significantly influenced by adequate supply of potassium (K). The assemblage of figures regarding potassium content in the soil after the end of the experiment is shown in the table 17.

Table 17. Soil chemical properties as affected by intercrops and different spacing under mango orchard after 2 years (2016)

Treatment combination	Soil organic carbon (g kg^{-1} soil)			Available N ($kg\ ha^{-1}$)			Available P ($kg\ ha^{-1}$)			Available K ($kg\ ha^{-1}$)		
Depths(cm) / Crops	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
Ginger (G)	5.90	4.70	4.23	235.09	186.21	161.55	14.76	11.29	10.77	127.27	132.64	121.48
Turmeric (T)	5.96	4.72	3.95	230.54	206.44	168.68	14.32	12.18	11.98	144.57	135.69	127.49
Stevia (S)	5.86	4.49	4.03	221.79	204.55	167.24	14.65	13.94	10.29	136.58	113.06	112.35
Kalmegh (K)	5.99	4.20	4.28	224.19	196.78	162.64	13.29	11.04	9.17	124.82	115.40	105.25
+SE(m)	**0.11**	**0.15**	**0.39**	**3.92**	**3.87**	**2.12**	**0.93**	**0.48**	**0.42**	**5.66**	**2.51**	**4.37**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**11.43**	**NS**	**NS**	**NS**	**1.24**	**NS**	**7.41**	**12.92**
Spacing												
20x30cm (S_1)	5.99	4.47	4.07	238.39	199.25	161.04	14.45	12.94	9.80	132.05	126.86	119.13
30x30cm (S_2)	5.28	4.47	4.30	217.77	192.06	160.15	14.88	12.01	11.56	133.34	122.63	109.22
30x40cm (S_3)	5.01	4.65	4.01	227.55	204.18	173.89	13.44	11.39	10.29	134.55	123.11	121.58
+SE(m)	**0.09**	**0.13**	**0.34**	**3.39**	**3.35**	**1.83**	**0.80**	**0.42**	**0.36**	**4.90**	**2.17**	**3.79**
$CD_{0.05}$	**NS**	**NS**	**NS**	**10.01**	**NS**	**5.41**	**NS**	**1.23**	**1.07**	**NS**	**NS**	**NS**
Crops x spacing												
G S_1	5.57	4.37	4.10	251.70	177.01	151.35	14.38	10.22	8.07	116.29	143.11	122.52
G S_2	5.83	4.43	4.47	214.61	168.08	138.42	14.99	11.35	11.93	139.92	137.94	120.39
G S_3	5.27	5.30	4.13	238.96	213.54	194.89	14.90	12.31	12.30	125.62	116.88	121.52
T S_1	5.17	5.00	4.23	249.13	221.99	170.84	14.94	14.65	12.55	151.27	141.42	138.70
T S_2	5.47	4.70	4.10	218.69	196.96	164.48	14.59	10.61	13.54	137.24	127.11	105.97
T S_3	5.50	4.46	3.53	223.79	200.36	170.71	13.43	11.27	9.85	145.21	138.55	137.80
S S_1	5.70	4.47	3.96	226.32	206.76	161.30	15.47	16.15	9.28	151.27	112.68	108.75
S S_2	5.67	4.47	4.16	217.70	207.80	168.86	15.24	14.91	11.99	137.24	109.29	112.86
S S_3	5.43	4.53	3.96	221.33	199.08	171.56	13.24	10.77	9.61	145.21	117.21	115.43
K S_1	5.53	4.03	4.00	226.38	191.23	160.68	13.00	10.75	9.31	129.02	110.24	106.54
K S_2	5.17	4.27	4.46	220.08	195.38	168.85	14.70	11.16	8.77	120.19	116.16	97.65
K S_3	5.83	4.30	4.40	226.12	203.72	158.39	12.17	11.21	9.41	125.26	119.79	111.57
+SE(m)	**0.19**	**0.25**	**0.67**	**6.78**	**6.71**	**3.67**	**1.60**	**0.84**	**0.73**	**9.80**	**4.35**	**7.58**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**19.80**	**10.82**	**NS**	**2.47**	**2.15**	**NS**	**12.84**	**NS**
Initial Value	**5.10**	**4.60**	**4.10**	**200.07**	**186.42**	**178.27**	**13.40**	**12.04**	**10.90**	**120.40**	**115.00**	**110.38**

NS- Non significant

The cursory glance through the data showed that the available potassium varied significantly amongst the crops at depths 30-60 cm and 60-90 cm whereas the values at 0-30 cm were statistically non-significant. The maximum K content (144.57 kg ha^{-1}) was observed under turmeric crop and minimum (124.82 kg ha^{-1}) under kalmegh at surface soil (0-30 cm). At 30-60 cm, the K content was maximum (135.69) in turmeric which was statistically at par with ginger and the minimum content (113.06) was in stevia statistically at par with kalmegh. Highest K value (127.55 kg ha^{-1}) was obtained under turmeric at 60-90 cm depth and lowest (105.25 kg ha^{-1}) under kalmegh. The amount of available K was statistically at par in all the three spacings and at all the depths.

The critical difference for the interaction effect of crop and spacing was non-significant at 0-30 cm and 60-90 cm depths but was significant for the depth 30-60 cm. At 30-60 cm, maximum value was recorded in ginger with spacing S_1 (143.11 kg ha^{-1}) which was statistically at par with turmeric (TS_1-141.42, TS_3- 138.55 kg ha^{-1}) and ginger (GS_2-137.94 kg ha^{-1}).

4.5. Effect of spacing and crops on the physico-chemical properties of soil under open conditions

The data recorded for the first year of experimentation is given in Appendix IV and the results of the second year data (end of the experiment) are described here onwards.

4.5.1. Soil pH (1:2.5:: Soil:Water)

The observations related to the soil pH under sole cropping at the end of the experiment are tabulated in the table 18.

The peek through the data depicted that the crops and their planting distance had very insignificant effect on the soil pH in all the depths. Amongst the crops maximum pH (6.75) was recorded under turmeric at 0-30 cm depth.The value ranged from 6.40 to 6.75 at 0-30 cm, 6.49-6.91 at 30-60 cm and from 6.57 to 6.83 at 60-90 cm depth. Spacing had no significant effect on the value of pH in the lower depths however, at 0-30cm, maximum pH (6.73) was recorded in spacing S_3.

The interrelation between crop and spacing was found to be non-significant for all the depths.

4.5.2 Electrical conductivity (EC) (dS m^{-1})

The electrical conductivity value is a general measure of the soluble salt content or salinity of a soil. The data for the EC of the soil of experimental site after two years of experimentation is presented in table 18.

The sifting of the data showed that the value of EC did not differ significantly in the surface soils (0-30 cm) with maximum value (0.124 dS m^{-1}) under stevia and minimum (0.094 dS m^{-1}) under turmeric. At 30-60 cm, maximum EC (0.085 dS m^{-1}) was recorded under ginger and minimum (0.063 dS m^{-1}) under turmeric. In deeper profile 60-90 cm, EC ranged from 0.061 dS m^{-1} to 0.074 dS m^{-1} among the crops. With regards to spacing, EC decreased with increasing depth except in S_3. In $S_{3,}$ EC value ranged from 0.101 dS m^{-1} at 0-30 cm to 0.114 dS m^{-1} at 60-90 cm depth.

The interaction between crop and spacing was found to be non-significant at all the depths.

4.5.3. Soil moisture (%)

The data regarding soil moisture in the second year is tabulated in the table 18. The overview of the data showed that moisture content did not increase in the second year and the values were very near to the initial values (at the start of the experiment- Appendix IV).

The close inspection revealed that although the differences among the crops were statistically non-significant, the maximum soil moisture (19.04%) was recorded under stevia and and minimum (18.01%) under turmeric in the top layer of soil. At 30-60 cm, highest value (21.30%) was observed under kalmegh and minimum (19.19%) under ginger. At 60-90 cm depth, the moisture increased maximally (22.32%) under ginger and minimally (18.73%) under turmeric. The values were at par in all the spacings and at all depths.

In the interaction effect of crop and spacing, though the values were statistically at par in all the depths, maximum value (27.09%) was recorded in stevia + S_3 at 60-90 cm depth and minimum (14.73%) in ginger + S_1 at depth 0-30 cm.

4.5.4. Bulk density (BD) (g cm^{-3})

The aggregation of data with respect to bulk density at three depths is depicted in table 18. The figures so obtained for the four crops and the three spacing specified that bulk density increased with depth (increased compactness of soil).

At 0-30 cm, maximum BD (1.144 gcm^{-3}) was observed in kalmegh and minimum (1.097 gcm^{-3}) in stevia. For 30-60 cm, maximum BD (1.333 gcm^{-3}) was recorded under kalmegh and minimum (1.229 gcm^{-3}) under stevia. At 60-90 cm depth, maximum value (1.364 gcm^{-3}) was observed under kalmegh and minimum (1.335 gcm^{-3}) under ginger. Spacing of crops didn't affect the BD. The interaction between crop and spacing was found to be non-significant for all the treatments and their combination.

Table 18. Soil physico-chemical properties as affected by different crops and their spacing under open condition after 2 years (2016)

Treatment combination	pH (1:2.5 ::Soil: Water)			EC (dS m^{-1})			Soil Moisture (%)			Bulk density (g cm^{-3})			CEC (c.mol.P^{+})		
Depths(cm) / Crops	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
Ginger (G)	6.74	6.91	6.83	0.103	0.085	0.074	18.19	19.19	22.32	1.123	1.256	1.335	11.80	11.25	10.65
Turmeric (T)	6.75	6.81	6.71	0.094	0.063	0.062	18.01	19.78	18.73	1.117	1.318	1.338	12.46	11.98	9.98
Stevia (S)	6.63	6.65	6.64	0.124	0.077	0.061	19.04	19.60	22.05	1.097	1.229	1.338	12.16	11.53	10.33
Kalmegh (K)	6.40	6.49	6.57	0.099	0.080	0.137	18.26	21.30	20.76	1.144	1.333	1.364	11.95	11.35	10.73
+SE(m)	**0.02**	**0.02**	**0.02**	**0.002**	**0.003**	**0.030**	**0.41**	**1.11**	**1.31**	**0.020**	**0.020**	**0.010**	**0.29**	**0.28**	**0.31**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.054**	**NS**	**NS**	**NS**	**NS**
Spacing															
20x30cm (S_1)	6.66	6.69	6.67	0.107	0.077	0.069	17.26	19.83	20.43	1.11	1.291	1.355	11.60	11.42	10.15
30x30cm (S_2)	6.50	6.71	6.68	0.107	0.077	0.068	18.56	19.33	19.73	1.124	1.303	1.349	12.40	11.51	10.51
30x40cm (S_3)	6.73	6.75	6.71	0.101	0.074	0.114	19.29	20.73	22.73	1.128	1.257	1.345	12.26	11.64	10.62
+SE(m)	**0.02**	**0.02**	**0.03**	**0.002**	**0.003**	**0.030**	**0.35**	**0.96**	**1.13**	**0.010**	**0.020**	**0.010**	**0.25**	**0.24**	**0.27**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Crops x spacing															
G S_1	6.74	6.68	6.67	0.098	0.126	0.109	14.73	16.83	18.44	1.128	1.252	1.34	11.66	10.31	10.02
G S_2	6.87	6.79	6.77	0.09	0.071	0.043	18.20	17.77	22.75	1.131	1.267	1.37	12.30	11.58	11.03
G S_3	6.63	7.26	7.05	0.12	0.057	0.069	21.64	22.97	25.76	1.111	1.249	1.37	11.45	11.86	10.91
T S_1	6.84	6.68	6.62	0.112	0.068	0.066	16.91	23.25	21.06	1.08	1.329	1.38	12.21	12.47	10.41
T S_2	6.66	7.10	6.78	0.108	0.07	0.08	18.33	18.38	17.52	1.127	1.308	1.33	12.65	12.10	8.94
T S_3	6.74	6.66	6.73	0.064	0.052	0.04	18.78	17.69	17.62	1.145	1.317	1.30	12.51	11.36	10.60
S S_1	6.54	6.95	6.96	0.154	0.054	0.042	19.83	19.79	20.33	1.129	1.230	1.34	11.29	11.25	9.35
S S_2	6.54	6.45	6.42	0.102	0.056	0.034	18.59	18.57	18.72	1.045	1.278	1.31	12.52	11.66	11.14
S S_3	6.80	6.55	6.54	0.116	0.12	0.108	18.70	20.43	27.09	1.117	1.178	1.36	12.65	11.69	10.50
K S_1	6.52	6.44	6.42	0.154	0.061	0.059	17.59	19.46	21.87	1.101	1.352	1.36	11.25	11.68	10.81
K S_2	5.91	6.50	6.76	0.102	0.113	0.114	19.14	22.60	19.94	1.191	1.360	1.39	12.14	10.71	10.93
K S_3	6.77	6.52	6.52	0.116	0.067	0.239	18.05	21.84	20.46	1.139	1.285	1.35	12.46	11.66	10.46
+SE(m)	**0.04**	**0.04**	**0.05**	**0.002**	**0.005**	**0.050**	**0.71**	**1.93**	**2.27**	**0.030**	**0.030**	**0.020**	**0.50**	**0.48**	**0.54**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Initial value	**6.80**	**6.69**	**6.71**	**0.09**	**0.12**	**0.13**	**17.82**	**19.12**	**20.06**	**1.127**	**1.231**	**1.364**	**11.80**	**11.10**	**10.77**

NS- Non significant

4.5.5. Cation Exchange Capacity (CEC) (c.mol.P^+)

The assemblage of data pertaining to the CEC content in soil at various depths is given in the table 18.

The figures showed that CEC value does not change over a short span of time though the value decreased with increasing depth. The values were statistically non-significant for all the crops at all the depths but in general, value ranged from 12.46 c.mol.P^+ under turmeric in surface soil to 9.98 c.mol.P^+ under turmeric in the lowest depth. At depth (0-30 cm), spacing S_2 had maximity of CEC value i.e. 12.40 c.mol.P^+, at depth 30-60 cm, maximum value (11.64) was recorded in S_3. The maximum value (10.62) was obtained in S_3 at 60-90 cm. The critical difference however came to be non-significant for the spacings.

The interaction of crops and their spacing does not affect the CEC of the soil. The critical difference was found to be non-significant for all the treatments and at all the depths.

4.5.6. Soil organic carbon (g kg^{-1}soil)

The figures in relation to the soil organic carbon are presented in table 19. The assemblage reflected that though the differences were non-significant, organic carbon content decreased with increasing depth in all crops and at all spacing. Maximum content (6.08 g kg^{-1}) was recorded in turmeric (T) at 0-30 cm, 5.73 g kg^{-1} in ginger at depth 30-60 cm and 4.67 g kg^{-1} was observed in kalmegh at depth 60-90cm. Spacing however, had no impact on the carbon content. Amongst the spacing, highest content (5.92 g kg^{-1}) was noted in spacing S_2 and minimum (5.76) in spacing S_3 in the depth 0-30 cm. In 30-60 cm depth, the highest organic carbon (5.57 g kg^{-1}) was recorded in S_2 and statistically alike value (5.44 g kg^{-1}) was recorded in S_1 and S_3. In 60-90 cm depth, maximum carbon content (4.50 g kg^{-1}) was noted in S_1. The critical difference was non-significant for all treatments and their combinations and interactions.

4.5.7. Available nitrogen (kg ha^{-1})

The data regarding the available nitrogen content in soil at varying depths as affected by the different crops and their planting distance is given in the table 19.

The scanning of the data depicted that available nitrogen content was on the lower side in all the depths and there was no marked improvement in the content even after two years of intercropping. Highest nitrogen (221.93 kg ha^{-1}) was found under kalmegh crop and the lowest content (213.85 kg ha^{-1}) was recorded under stevia at 0-30cm. At 30-60 cm, maximum content (186.18 kg ha^{-1}) was found under ginger and the differences were statistically significant at this depth. At 60-90 cm depth, the values were statistically significant and the lowest nitrogen (131.23 kg ha^{-1}) was recorded in stevia. Similarly among the three spacing the values of available N were not significantly influenced. The maximum value was noted in S_2 (223.35 kg ha^{-1}) followed by S_3 (219.19 kg ha^{-1}) at 0-30cm. However, at depth 30-60 cm, highest N content was in S_1 (171.06 kg ha^{-1}) and also at 60-90 cm depth, highest N content (145.58 kg ha^{-1}) was recorded in S_1.

The interaction between crop and spacing was non-significant at all the depths.

4.5.8. Available phosphorus (kg ha^{-1})

The perusal of the data (Table 19) showed that P content did not vary amongst the crops at 30-60 cm and 60-90 cm depths but in general, the value decreased with increasing depth and amount varied from 16.99 kg ha^{-1} in surface soil to 10.23 kg ha^{-1} at 60-90 cm. Available P content varied significantly at 0-30 cm depth with maximum value (16.99 kg ha^{-1}) under ginger and minimum (11.84 kg ha^{-1}) under turmeric. At the lower depth of 30-60 cm, soil beneath ginger had highest (13.95 kg ha^{-1}) value and stevia, turmeric and kalmegh had at par values. At the lowest depth, ginger recorded minimum (10.23 kg ha^{-1}) P content and the maximum (13.20 kg ha^{-1}) was noted in kalmegh (K). With regard to spacing, the differences were non-significant, S_3 showed highest phosphorus content (14.52 kg ha^{-1}) and the other two spacings had at par values at 0-30 cm. For 30-60 cm, spacing S_1 registered the highest content of 12.84 kg phosphorus per hectare and at 60-90 cm depth, S_1 recorded the highest P value of 12.14 kg ha^{-1}.

The interaction between crop and spacing was non- significant at all the depths.

4.5.9. Available potassium (kg ha^{-1})

Potassium (K) content decreased with increasing depth. The observations regarding K content in the soil after the end of the experiment are shown in the table 19.

The glance through the data showed that the available potassium varied significantly amongst the crops at all depths. The maximum K content (134.17 kg ha^{-1}) was observed under turmeric crop and minimum (110.76 kg ha^{-1}) under kalmegh at surface soil (0-30 cm). At 30-60 cm, the K content was maximum (117.91) in ginger which was

Table 19. Soil chemical properties as affected by different crops and their spacing under open condition after 2 years (2016)

Treatment combination	Soil organic carbon (g kg^{-1} soil)			Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
Depths(cm) / Crops	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
Ginger (G)	6.06	5.73	4.48	219.13	186.18	148.67	16.99	13.95	10.23	133.03	117.91	103.99
Turmeric (T)	6.08	5.56	4.28	218.78	162.46	134.05	11.84	10.80	11.32	134.17	116.72	108.36
Stevia (S)	5.77	5.57	4.50	213.85	148.19	131.23	13.75	11.44	12.31	113.05	111.65	109.15
Kalmegh (K)	5.43	5.08	4.67	221.93	165.19	151.65	14.51	12.50	13.20	110.76	100.23	98.30
±SE(m)	**0.01**	**0.01**	**0.01**	**5.74**	**4.75**	**3.91**	**0.51**	**1.17**	**0.92**	**1.55**	**4.47**	**2.73**
$CD_{0.05}$	**0.22**	**0.38**	**NS**	**NS**	**14.03**	**11.54**	**1.49**	**NS**	**NS**	**4.57**	**13.18**	**8.04**
Spacing												
20x30cm (S_1)	5.83	5.44	4.50	212.73	171.06	145.58	14.34	12.84	12.14	121.24	108.10	102.89
30x30cm (S_2)	5.92	5.57	4.47	223.35	161.43	141.42	13.96	11.12	11.41	129.12	119.35	112.01
30x40cm (S_3)	5.76	5.44	4.48	219.19	164.03	137.20	14.52	12.56	11.75	117.90	107.43	99.94
±SE(m)	**0.01**	**0.01**	**0.01**	**4.97**	**4.12**	**3.38**	**0.44**	**1.01**	**0.79**	**1.34**	**3.87**	**2.36**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**3.96**	**NS**	**6.96**
Crops x spacing												
G S_1	6.10	5.80	4.47	214.00	178.66	151.65	17.53	14.86	8.62	125.64	124.73	105.33
G S_2	6.17	5.87	4.60	223.64	189.81	152.52	16.05	13.47	10.39	137.87	119.08	99.82
G S_3	5.90	5.53	4.37	219.75	190.07	141.82	17.40	13.52	11.68	135.58	109.91	106.81
T S_1	6.03	5.27	4.37	212.85	179.66	136.02	12.19	10.32	12.50	145.24	114.77	110.10
T S_2	6.13	5.68	4.03	234.42	154.91	132.18	10.13	9.66	10.63	139.85	120.63	124.87
T S_3	6.07	5.73	4.43	209.06	152.82	133.95	13.21	12.42	10.83	117.44	114.74	90.11
S S_1	5.90	5.70	4.87	199.17	152.86	130.79	13.88	13.52	13.58	115.26	106.29	112.33
S S_2	5.90	5.71	4.43	218.61	150.09	139.92	14.20	9.09	10.87	104.73	115.26	104.82
S S_3	5.50	5.31	4.20	223.77	141.62	122.98	13.16	11.70	12.48	119.14	113.41	110.28
K S_1	5.27	5.00	4.30	224.89	173.05	163.86	13.77	12.64	13.85	98.81	86.60	83.81
K S_2	5.47	5.03	4.81	216.74	150.92	141.06	15.44	12.26	13.74	134.05	122.43	118.53
K S_3	5.57	5.20	4.90	224.16	171.61	150.03	14.32	12.59	12.01	99.43	91.65	92.56
±SE(m)	**0.01**	**0.02**	**0.02**	**9.94**	**8.24**	**6.77**	**0.88**	**2.02**	**1.59**	**2.68**	**7.74**	**4.72**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**7.92**	**NS**	**13.93**
Initial value	**5.81**	**5.23**	**4.84**	**201.32**	**150.86**	**135.12**	**13.80**	**12.26**	**11.75**	**125.12**	**110.07**	**112.34**

NS- Non significant

statistically at par with turmeric and the minimum content (100.23) was in kalmegh statistically at par with stevia. Highest K value (109.15 kg ha^{-1}) was obtained under stevia at 60-90 cm depth and lowest (98.30 kg ha^{-1}) under kalmegh. The amount of available K was statistically at par in all the three spacing at 30-60 cm but differed significantly in 0-30 and 60-90 cm depths. At 0-30 cm, maximum available K content (129.12 kg ha^{-1}) was recorded in S_2 and at 60-90 cm, maximum content (112.01 kg ha^{-1}) was again observed in S_2.

The critical difference for the interaction effect of crop and spacing was non-significant at 30-60 cm but was significant for the 0-30 cm and 60-90 cm depths. At 0-30 cm, maximum value was recorded in turmeric with spacing S_1 (145.24 kg ha^{-1}) which was statistically at par with turmeric (TS_2-139.85) and ginger (GS_2- 137.87 kg ha^{-1} and GS_3-135.58 kg ha^{-1}). At 60-90 cm, maximum value (124.87) was observed for turmeric (TS_2) and minimum (83.81) for kalmegh (KS_1).

A quick glance through the table 20-22 summarising the soil physico-chemical properties under sole cropping and under the mango canopy revealed that the soils had lower pH and soil moisture under canopy than in open. The organic carbon content was lower under trees than in open. Bulk density and CEC, available N, P and K were higher under the mango compared to open in all the depths.

4.6. Soil total microbial count ($x10^4$cfu/g soil)

Soil microorganisms exist in large numbers in the soil, about 8-15 tons of bacteria, fungi, protozoa, nematodes etc. The data relating to the microbial load in mango orchard soil and under sole crop at two depths 0-15cm and 15-30cm is given in the tables 23-24.

The data (Table 23) show that total number of microbes were more in the open/sole cropping as compared to mango+intercrops at both the soil depths. In the open conditions, maximum count ($320x10^4$cfu/g) was recorded under stevia (TS_1) and minimum ($258x10^4$cfu/g) under kalmegh (KS_3) in 0-15 cm depth. At the lower depth of 15-30 cm, highest number ($185x10^4$cfu/g) was observed under turmeric (TS_2) and the lowest ($127x10^4$cfu/g) in ginger (GS_3).

Regarding microbial population under mango orchard, the highest load ($280x10^4$cfu/g) was noted in the upper layer (0-15cm) underneath ginger (GS_1) and the least ($169x10^4$cfu/g) was under kalmegh (KS_3). In the deeper layer (15-30cm) least count ($84x10^4$cfu/g) was in treatment (TS_3) and the highest (149 $x10^4$cfu/g) in GS_1 (ginger).

Table 20. Soil physico-chemical properties as affected by sole cropping and intercropping at 0-30 cm depth after two years (2016)

Treatment combination	pH (1:2.5 ::Soil: Water)		EC (dS m^{-1})		Soil Moisture (%)		Bulk density (g cm^{-3})		CEC (c.mol.P^{+})		Soil organic carbon (g kg^{-1} soil)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
Crops	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**
Ginger (G)	6.74	6.61	0.103	0.149	18.19	18.66	1.123	1.120	11.80	13.47	6.06	5.90	219.13	235.09	16.99	14.76	133.03	127.27
Turmeric (T)	6.75	6.37	0.094	0.130	18.01	18.01	1.117	1.147	12.46	13.88	6.08	5.96	218.78	230.54	11.84	14.32	134.17	144.57
Stevia (S)	6.63	6.47	0.124	0.122	19.04	17.63	1.097	1.124	12.16	13.29	5.77	5.86	213.85	221.79	13.75	14.65	113.05	136.58
Kalmegh (K)	6.40	6.75	0.099	0.108	18.26	18.31	1.144	1.166	11.95	13.15	5.43	5.99	221.93	224.19	14.51	13.29	110.76	124.82
±SE(m)	**0.02**	**0.02**	**0.002**	**0.01**	**0.41**	**0.56**	**0.020**	**0.04**	**0.29**	**0.47**	**0.01**	**0.11**	**5.74**	**3.92**	**0.51**	**0.93**	**1.55**	**5.66**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.22**	**NS**	**NS**	**NS**	**1.49**	**NS**	**4.57**	**NS**
Spacing																		
20x30cm (S_1)	6.66	6.56	0.107	0.126	17.26	18.56	1.110	1.138	11.60	13.52	5.83	5.99	212.73	238.39	14.34	14.45	121.24	132.05
30x30cm (S_2)	6.50	6.58	0.107	0.123	18.56	17.54	1.124	1.148	12.40	12.91	5.92	5.28	223.35	217.77	13.96	14.88	129.12	133.34
30x40cm (S_3)	6.73	6.51	0.101	0.118	19.29	18.37	1.128	1.208	12.26	13.42	5.76	5.01	219.19	227.55	14.52	13.44	117.90	134.55
±SE(m)	**0.02**	**0.01**	**0.002**	**0.01**	**0.35**	**0.48**	**0.010**	**0.04**	**0.25**	**0.41**	**0.01**	**0.09**	**4.97**	**3.39**	**0.44**	**0.80**	**1.34**	**4.90**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**10.01**	**NS**	**NS**	**3.96**	**NS**
Crops x spacing																		
G S_1	6.74	6.64	0.098	0.143	14.73	18.69	1.128	1.133	11.66	11.99	6.10	5.57	214.00	251.70	17.53	14.38	125.64	116.29
G S_2	6.87	6.73	0.09	0.170	18.20	18.38	1.131	1.133	12.30	13.30	6.17	5.83	223.64	214.61	16.05	14.99	137.87	139.92
G S_3	6.63	6.45	0.12	0.133	21.64	18.92	1.111	1.393	11.45	13.11	5.90	5.27	219.75	238.96	17.40	14.90	135.58	125.62
T S_1	6.84	6.51	0.112	0.143	16.91	17.71	1.080	1.180	12.21	14.26	6.03	5.17	212.85	249.13	12.19	14.94	145.24	151.27
T S_2	6.66	6.63	0.108	0.123	18.33	17.43	1.127	1.133	12.65	13.70	6.13	5.47	234.42	218.69	10.13	14.59	139.85	137.24
T S_3	6.74	5.97	0.064	0.123	18.78	18.88	1.145	1.127	12.51	13.68	6.07	5.50	209.06	223.79	13.21	13.43	117.44	145.21
S S_1	6.54	6.36	0.154	0.123	19.83	17.97	1.129	1.110	11.29	11.63	5.90	5.70	199.17	226.32	13.88	15.47	115.26	151.27
S S_2	6.54	6.33	0.102	0.090	18.59	16.77	1.045	1.133	12.52	12.22	5.90	5.67	218.61	217.70	14.20	15.24	104.73	137.24
S S_3	6.80	6.73	0.116	0.113	18.70	18.16	1.117	1.130	12.65	13.03	5.50	5.43	223.77	221.33	13.16	13.24	119.14	145.21
K S_1	6.52	6.72	0.154	0.093	17.59	19.86	1.101	1.127	11.25	13.18	5.27	5.53	224.89	226.38	13.77	13.00	98.81	129.02
K S_2	5.91	6.62	0.102	0.107	19.14	17.57	1.191	1.190	12.14	12.40	5.47	5.17	216.74	220.08	15.44	14.70	134.05	120.19
K S_3	6.77	6.89	0.116	0.063	18.05	17.51	1.139	1.180	12.46	13.86	5.57	5.83	224.16	226.12	14.32	12.17	99.43	125.26
±SE(m)	**0.04**	**0.03**	**0.002**	**0.01**	**0.71**	**0.97**	**0.030**	**0.07**	**0.50**	**0.81**	**0.01**	**0.19**	**9.94**	**6.78**	**0.88**	**1.60**	**2.68**	**9.80**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**7.92**	**NS**
Initial value	**6.80**	**6.35**	**0.090**	**0.110**	**17.82**	**17.65**	**1.127**	**1.173**	**11.80**	**13.26**	**5.81**	**5.10**	**201.32**	**200.07**	**13.80**	**13.40**	**125.12**	**120.40**

NS- Non significant

Table 21. Soil physico-chemical properties as affected by sole cropping and intercropping at 30-60 cm depth after two years (2016)

Treatment combination	pH (1:2.5 ::Soil: Water)		EC (dS m^{-1})		Soil Moisture (%)		Bulk density (g cm^{-3})		CEC (c.mol.P^{+})		Soil organic carbon (g kg^{-1} soil)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
Crops	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**
Ginger (G)	6.91	6.68	0.085	0.144	19.19	19.64	1.256	1.320	11.25	12.53	5.73	4.70	186.18	186.21	13.95	11.29	117.91	132.64
Turmeric (T)	6.81	6.41	0.063	0.114	19.78	21.05	1.318	1.327	11.98	12.42	5.56	4.72	162.46	206.44	10.80	12.18	116.72	135.69
Stevia (S)	6.65	6.56	0.077	0.109	19.60	18.76	1.229	1.331	11.53	12.57	5.57	4.49	148.19	204.55	11.44	13.94	111.65	113.06
Kalmegh (K)	6.49	6.78	0.080	0.107	21.30	19.27	1.333	1.347	11.35	12.24	5.08	4.20	165.19	196.78	12.50	11.04	100.23	115.40
±SE(m)	**0.02**	**0.04**	**0.003**	**0.01**	**1.11**	**0.59**	**0.020**	**0.01**	**0.28**	**0.39**	**0.01**	**0.15**	**4.75**	**3.87**	**1.17**	**0.48**	**4.47**	**2.51**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**0.74**	**0.054**	**NS**	**NS**	**NS**	**0.38**	**NS**	**14.03**	**11.43**	**NS**	**NS**	**13.18**	**7.41**
Spacing																		
20x30cm (S_1)	6.69	6.59	0.077	0.122	19.83	19.48	1.291	1.338	11.42	12.55	5.44	4.47	171.06	199.25	12.84	12.94	108.10	126.86
30x30cm (S_2)	6.71	6.67	0.077	0.123	19.33	19.45	1.303	1.336	11.51	12.57	5.57	4.47	161.43	192.06	11.12	12.01	119.35	122.63
30x40cm (S_3)	6.75	6.53	0.074	0.106	20.73	18.61	1.257	1.344	11.64	13.48	5.44	4.65	164.03	204.18	12.56	11.39	107.43	123.11
±SE(m)	**0.02**	**0.04**	**0.003**	**0.01**	**0.96**	**0.51**	**0.020**	**0.01**	**0.24**	**0.34**	**0.01**	**0.13**	**4.12**	**3.35**	**1.01**	**0.42**	**3.87**	**2.17**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**1.23**	**NS**	**NS**
Crops x spacing																		
G S_1	6.68	6.73	0.126	0.127	16.83	20.18	1.252	1.347	10.31	10.39	5.80	4.37	178.66	177.01	14.86	10.22	124.73	143.11
G S_2	6.79	6.83	0.071	0.180	17.77	17.54	1.267	1.350	11.58	12.45	5.87	4.43	189.81	168.08	13.47	11.35	119.08	137.94
G S_3	7.26	6.47	0.057	0.127	22.97	18.21	1.249	1.360	11.86	13.86	5.53	5.30	190.07	213.54	13.52	12.31	109.91	116.88
T S_1	6.68	5.59	0.068	0.123	23.25	21.00	1.329	1.357	12.47	13.80	5.27	5.00	179.66	221.99	10.32	14.65	114.77	141.42
T S_2	7.10	6.61	0.07	0.107	18.38	22.06	1.308	1.313	12.10	13.09	5.68	4.70	154.91	196.96	9.66	10.61	120.63	127.11
T S_3	6.66	6.12	0.052	0.113	17.69	20.10	1.317	1.310	11.36	13.36	5.73	4.46	152.82	200.36	12.42	11.27	114.74	138.55
S S_1	6.95	6.63	0.054	0.097	19.79	18.34	1.230	1.313	11.25	12.00	5.70	4.47	152.86	206.76	13.52	16.15	106.29	112.68
S S_2	6.45	6.42	0.056	0.097	18.57	19.37	1.278	1.313	11.66	12.69	5.71	4.47	150.09	207.80	9.09	14.91	115.26	109.29
S S_3	6.55	6.63	0.12	0.113	20.43	18.58	1.178	1.367	11.69	13.03	5.31	4.53	141.62	199.08	11.70	10.77	113.41	117.21
K S_1	6.44	6.62	0.061	0.060	19.46	18.40	1.352	1.333	11.68	14.01	5.00	4.03	173.05	191.23	12.64	10.75	86.60	110.24
K S_2	6.50	6.82	0.113	0.107	22.60	18.84	1.360	1.367	10.71	12.04	5.03	4.27	150.92	195.38	12.26	11.16	122.43	116.16
K S_3	6.52	6.91	0.067	0.070	21.84	17.57	1.285	1.340	11.66	13.66	5.20	4.30	171.61	203.72	12.59	11.21	91.65	119.79
±SE(m)	**0.04**	**0.07**	**0.005**	**0.01**	**1.93**	**1.02**	**0.030**	**0.02**	**0.48**	**0.67**	**0.02**	**0.25**	**8.24**	**6.71**	**2.02**	**0.84**	**7.74**	**4.35**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**19.80**	**NS**	**2.47**	**NS**	**12.84**
Initial value	**6.69**	**6.42**	**0.12**	**0.10**	**19.12**	**18.64**	**1.231**	**1.327**	**11.10**	**12.28**	**5.23**	**4.60**	**150.86**	**186.42**	**12.26**	**12.04**	**110.07**	**115.00**

NS- Non significant

Table 22. Soil physico-chemical properties as affected by sole cropping and intercropping at 60-90 cm depth after two years (2016)

Treatment combination	pH (1:2.5 ::Soil: Water)		EC (dS m^{-1})		Soil Moisture (%)		Bulk density (g cm^{-3})		CEC (c.mol.P^{+})		Soil organic carbon (g kg^{-1} soil)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
Crops	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**	**Open**	**Mango**
Ginger (G)	6.83	6.65	0.074	0.126	22.32	21.98	1.335	1.362	10.65	11.43	4.48	4.23	148.67	161.55	10.23	10.77	103.99	121.48
Turmeric (T)	6.71	6.30	0.062	0.101	18.73	23.58	1.338	1.346	9.98	10.98	4.28	3.95	134.05	168.68	11.32	11.98	108.36	127.49
Stevia (S)	6.64	6.54	0.061	0.102	22.05	22.09	1.338	1.368	10.33	10.66	4.50	4.03	131.23	167.24	12.31	10.29	109.15	112.35
Kalmegh (K)	6.57	6.68	0.137	0.104	20.76	21.08	1.364	1.368	10.73	11.07	4.67	4.28	151.65	162.64	13.20	9.17	98.30	105.25
±SE(m)	**0.02**	**0.06**	**0.030**	**0.01**	**1.31**	**0.29**	**0.010**	**0.01**	**0.31**	**0.48**	**0.01**	**0.39**	**3.91**	**2.12**	**0.92**	**0.42**	**2.73**	**4.37**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**0.88**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**11.54**	**NS**	**NS**	**1.24**	**8.04**	**12.92**
Spacing																		
20x30cm (S_1)	6.67	6.42	0.069	0.111	20.43	21.89	1.355	1.348	10.15	10.48	4.50	4.07	145.58	161.04	12.14	9.80	102.89	119.13
30x30cm (S_2)	6.68	6.53	0.068	0.105	19.73	21.76	1.349	1.374	10.51	11.34	4.47	4.30	141.42	160.15	11.41	11.56	112.01	109.22
30x40cm (S_3)	6.71	6.49	0.114	0.106	22.73	22.15	1.345	1.361	10.62	11.28	4.48	4.01	137.20	173.89	11.75	10.29	99.94	121.58
±SE(m)	**0.03**	**0.05**	**0.030**	**0.01**	**1.13**	**0.25**	**0.010**	**0.01**	**0.27**	**0.42**	**0.01**	**0.34**	**3.38**	**1.83**	**0.79**	**0.36**	**2.36**	**3.79**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**5.41**	**NS**	**1.07**	**6.96**	**NS**
Crops x spacing																		
G S_1	6.67	6.87	0.109	0.110	18.44	21.37	1.34	1.330	10.02	10.02	4.47	4.10	151.65	151.35	8.62	8.07	105.33	122.52
G S_2	6.77	7.04	0.043	0.140	22.75	19.99	1.37	1.400	11.03	11.69	4.60	4.47	152.52	138.42	10.39	11.93	99.82	120.39
G S_3	7.05	6.51	0.069	0.127	25.76	21.59	1.37	1.357	10.91	12.58	4.37	4.13	141.82	194.89	11.68	12.30	106.81	121.52
T S_1	6.62	5.60	0.066	0.103	21.06	23.04	1.38	1.360	10.41	11.41	4.37	4.23	136.02	170.84	12.50	12.55	110.10	138.70
T S_2	6.78	7.17	0.08	0.087	17.52	23.69	1.33	1.323	8.94	10.94	4.03	4.10	132.18	164.48	10.63	13.54	124.87	105.97
T S_3	6.73	6.14	0.04	0.113	17.62	24.01	1.30	1.353	10.60	10.60	4.43	3.53	133.95	170.71	10.83	9.85	90.11	137.80
S S_1	6.96	6.64	0.042	0.170	20.33	22.14	1.34	1.343	9.35	9.68	4.87	3.96	130.79	161.30	13.58	9.28	112.33	108.75
S S_2	6.42	6.48	0.034	0.087	18.72	21.93	1.31	1.380	11.14	11.81	4.43	4.16	139.92	168.86	10.87	11.99	104.82	112.86
S S_3	6.54	6.50	0.108	0.110	27.09	22.20	1.36	1.380	10.50	10.50	4.20	3.96	122.98	171.56	12.48	9.61	110.28	115.43
K S_1	6.42	6.59	0.059	0.060	21.87	21.00	1.36	1.357	10.81	10.81	4.30	4.00	163.86	160.68	13.85	9.31	83.81	106.54
K S_2	6.76	6.63	0.114	0.067	19.94	21.43	1.39	1.393	10.93	10.93	4.81	4.46	141.06	168.85	13.74	8.77	118.53	97.65
K S_3	6.52	6.81	0.239	0.073	20.46	20.81	1.35	1.353	10.46	11.45	4.90	4.40	150.03	158.39	12.01	9.41	92.56	111.57
±SE(m)	**0.05**	**0.11**	**0.050**	**0.01**	**2.27**	**0.52**	**0.020**	**0.02**	**0.54**	**0.83**	**0.02**	**0.67**	**6.77**	**3.67**	**1.59**	**0.73**	**4.72**	**7.58**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**10.82**	**NS**	**2.15**	**13.93**	**NS**
Initial value	**6.71**	**6.47**	**0.13**	**0.09**	**20.06**	**20.18**	**1.364**	**1.371**	**10.77**	**10.58**	**4.84**	**4.10**	**135.12**	**178.27**	**11.75**	**10.90**	**112.34**	**110.38**

NS- Non significant

Table 23. Soil microbial count at varying depths affected by different crops under Mango orchard and open conditions

Treatment Combinations		Microbial count (x 10^4 cfu g^{-1} soil)			
		Open field		Mango orchard	
		0-15 cm	15-30-cm	0-15 cm	15-30-cm
Gingiber officinalis "G"	S_1 30x20cm	298	140	280	149
	S_2 30x30cm	283	134	271	131
	S_3 30x40cm	273	127	266	144
Curcuma longa "T"	S_1 30x20cm	315	174	185	93
	S_2 30x30cm	298	185	183	90
	S_3 30x40cm	281	151	174	84
Stevia rebaudiana "S"	S_1 30x20cm	320	163	209	108
	S_2 30x30cm	309	152	206	105
	S_3 30x40cm	294	145	199	102
Andrographis paniculata "K"	S_1 30x20cm	275	143	184	101
	S_2 30x30cm	261	138	175	98
	S_3 30x40cm	258	131	169	95
Initial status		295	178	242	101

Table 24. Frequency of different fungal genera in the orchard soil and in sole crop (open) soil

Fungal types	*Gingiber officinalis*				*Curcuma longa*				*Stevia rebaudiana*				*Andrographis paniculata*			
	Open		Mango		Open		Mango		Open		Mango		Open		Mango	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Fusarium sp.	+	+	-	+	+	+	-	+	+	+	-	-	+	+	-	-
Penicillium sp.	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+
Aspergillus sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Acremonium sp.	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-	+
Curvularia sp.	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-	+
Alternaria sp.	+	+	-	+	+	+	-	+	+	+	-	+	+	+	-	+
Paecilomyces sp.	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+
Cladosporium sp.	-	-	+	+	-	-	+	+	-	-	+	+	+	+	+	+
Epicoccum sp.	-	-	+	+	-	-	-	+	-	-	-	-	-	-	-	-
Rhizopus sp.	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Tricothecium sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+

+ : Present, - : Absent

The occurrence of fungal genera in various crops at two depths is tabulated in table 24. The glance through the list clearly divulge that in the rhizosphere of all the crops in both the situations, open as well as under mango,11 fungal genera were recorded. Out of these 8, *Aspergillus, Penicillium, Fusarium, Acremonium, Curvularia, Alternaria, Cladosporium* and *Paecilomyces* were present in open as well as in mango soils. The genera *Epicoccum* was present only in ginger and turmeric and *Rhizopus* was noted in stevia and *Tricothecium* was spotted in kalmegh at depth 15-30cm under mango only.

4.7.2. Bio-economics of crops under mango based agroforestry system

The data regarding B:C ratio and Land Equivalent Ratio (LER) under mango in two years of experimentation is given in tables 26-28.

In the tables 26-28 depicting the bio-economics of the mango+intercrop system fixed cost towards maintenance of mango was included with all twelve treatment combinations having the four crops. The maximum cost of cultivation was recorded where plants were grown under mango. Among the four intercrops, highest cost of cultivation was obtained for ginger in both years. Cost of cultivation was lowest in case of sole crops. Gross returns from mango crop were added with those from different treatment combinations of the intercrops for calculating the total returns and B:C ratio of the system as a whole. However, maximum gross and net returns were obtained in mango+turmeric in both the years. Lowest gross and net returns were obtained in mango + stevia. In open conditions, maximum net returns were recorded in turmeric and minimum in ginger in 2015 and 2016, respectively whereas, higher gross returns were recorded for turmeric and lowest in ginger in both the years. In the year 2015 (Table 26), maximum value of B:C ratio (1.80) recorded was of turmeric in treatment TS_3 followed by TS_1 and TS_2 (1.76 each). The minimum B:C ratio recorded was of stevia 0.62 in SS_1, 0.69 in SS_2 and 0.70 in SS_3. In the year 2016 (table 27), being an on year, there was a substantially high yield in mango which led to increase in B:C ratio and LER. Highest B:C ratio (3.13) recorded was of kalmegh with spacing S_1 and minimum (1.78) was of ginger with spacing S_1.

Regarding land equivalent ratio (LER) (Table 28), in 2015, highest figure (13.97) observed was for ginger in treatment GS_3 (spacing 30x40cm) and minimum (1.00) was observed in stevia (SS_2 and SS_3). In 2016, maximum LER (13.48) was recorded for ginger with spacing S_3 and minimum (1.01) was observed for stevia (SS_2 and SS_3). The figures so obtained signify the success and failure of respective crops in mango based agroforestry system.

Table 25. Bio-economics of sole crop (open condition)

Crops	Spacing	Yield (q ha^{-1})		Price (₹ kg^{-1})		Gross returns (₹ ha^{-1})		Cost of cultivation (₹ ha^{-1})		Net returns (₹ ha^{-1})		BC ratio	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Ginger	S_1	7.89	6.41	27	28	21303	17948	182545	180127	-161242	-162179	0.12	0.10
	S_2	5.81	4.91	27	28	15687	13748	139857	137253	-124170	-123505	0.11	0.10
	S_3	3.15	3.34	27	28	8505	9352	117697	115465	-109192	-106113	0.07	0.08
Turmeric	S_1	212.74	223.17	25	25	531850	557925	179188	177142	352662	380783	2.97	3.15
	S_2	139.18	148.25	25	25	347950	370625	141096	139050	206854	231575	2.47	2.67
	S_3	174.27	126.60	25	25	435675	316500	121876	120946	313799	195554	3.57	2.62
Stevia	S_1	7.25	7.33	135	140	97875	102620	83865	82563	14010	20057	1.17	1.24
	S_2	8.36	8.89	135	140	112860	124460	74889	73959	37971	50501	1.51	1.68
	S_3	7.88	7.59	135	140	106380	106260	71355	71169	35025	35091	1.49	1.49
Kalmegh	S_1	50.25	52.47	30	30	150750	157410	69991	68131	80759	89279	2.15	2.31
	S_2	43.64	49.21	30	30	130920	147630	67573	65899	63347	81731	1.94	2.24
	S_3	41.04	46.83	30	30	123120	140490	63969	63411	59151	77079	1.92	2.22

Cost of cultivation includes land rental value, land preparation/tractorisation, cost of planting material, man days, cost of fertilizers and pesticides (Appendix V & VI).

Table 26. Bio-economics of crops under mango based agroforestry system during 2015

Crops	Spacing	Mango			Intercrops			Mango + intercrops	Cost of cultivation (₹ ha^{-1})			Net returns (₹ ha^{-1})	BC ratio	Land equivalent ratio
		Yield* (q ha^{-1})	Price (₹ kg^{-1})	Avg Returns (₹ kg^{-1})	Yield (q ha^{-1})	Price (₹ kg^{-1})	Returns (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Mango	Intercrops	Total			
Ginger	S_1	17.84	22	39248	72.57	27	195939	235187	12910	189241	202151	33036	1.16	9.20
	S_2	17.84	22	39248	53.86	27	145422	184670	12910	145065	157975	26695	1.17	9.27
	S_3	17.84	22	39248	40.87	27	110349	149597	12910	121789	134699	14898	1.11	12.97
Turmeric	S_1	17.84	22	39248	112.49	25	281225	320473	12910	168772	181682	138791	1.76	0.53
	S_2	17.84	22	39248	85.72	25	214300	253548	12910	130866	143776	109772	1.76	0.62
	S_3	17.84	22	39248	74.87	25	187175	226423	12910	112948	125858	100565	1.80	0.43
Stevia	S_1	17.84	22	39248	0.12	135	1620	40868	12910	53247	66157	-25289	0.62	0.02
	S_2	17.84	22	39248	0.10	135	1350	40598	12910	45759	58669	-18071	0.69	0.01
	S_3	17.84	22	39248	0.08	135	1080	40328	12910	45015	57925	-17597	0.70	0.01
Kalmegh	S_1	17.84	22	39248	22.01	30	66030	105278	12910	58510	71420	33858	1.47	0.44
	S_2	17.84	22	39248	17.36	30	52080	91328	12910	54976	67886	23442	1.35	0.40
	S_3	17.84	22	39248	12.5	30	37500	76748	12910	53790	66700	10048	1.15	0.30

*Average fruit yield of mango

Table 27. Bio-economics of crops under mango based agroforestry system during 2016

Crops	Spacing	Mango			Intercrops			Mango + intercrops	Cost of cultivation (₹ ha^{-1})			Net returns (₹ ha^{-1})	BC ratio	Land equivalent ratio
		Yield* (q ha^{-1})	Price (₹ kg^{-1})	Avg Returns (₹ kg^{-1})	Yield (q ha^{-1})	Price (₹ kg^{-1})	Returns (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Mango	Intercrops	Total			
Ginger	S_1	54.74	25	136850	78.98	28	221144	357994	12910	188125	201035	156959	1.78	12.32
	S_2	54.74	25	136850	59.09	28	165452	302302	12910	143949	156859	145443	1.93	12.03
	S_3	54.74	25	136850	41.68	28	116704	253554	12910	120115	133025	120529	1.91	12.48
Turmeric	S_1	54.74	25	136850	103.58	25	258950	395800	12910	168028	180938	214862	2.19	0.46
	S_2	54.74	25	136850	83.71	25	209275	346125	12910	129564	142474	203651	2.43	0.51
	S_3	54.74	25	136850	58.18	25	145450	282300	12910	111832	124742	157558	2.26	0.46
Stevia	S_1	54.74	25	136850	0.14	140	1960	138810	12910	52689	65599	73211	2.12	0.02
	S_2	54.74	25	136850	0.10	140	1400	138250	12910	45201	58111	80139	2.38	0.01
	S_3	54.74	25	136850	0.10	140	1400	138250	12910	44643	57553	80697	2.40	0.01
Kalmegh	S_1	54.74	25	136850	27.88	30	83640	220490	12910	57580	70490	150000	3.13	0.53
	S_2	54.74	25	136850	22.63	30	67890	204740	12910	54418	67328	137412	3.04	0.46
	S_3	54.74	25	136850	15.78	30	47340	184190	12910	52116	65026	119164	2.83	0.34

*Average fruit yield of mango

Table 28. Land equivalent ratio (LER) for mango based intercropping system

Crops	Spacing	BC Ratio		Monoculture equivalent Mango		Monoculture equivalent Intercrops		Total LER of the system	
		2015	2016	2015	2016	2015	2016	2015	2016
Ginger	S_1	1.16	1.78	0.99	1.00	9.20	12.32	10.19	13.32
	S_2	1.17	1.93	0.99	1.00	9.27	12.03	10.26	13.04
	S_3	1.11	1.91	0.99	1.00	12.97	12.48	13.97	13.48
Turmeric	S_1	1.76	2.19	0.99	1.00	0.53	0.46	1.52	1.47
	S_2	1.76	2.43	0.99	1.00	0.62	0.51	1.61	1.57
	S_3	1.80	2.26	0.99	1.00	0.43	0.46	1.42	1.46
Stevia	S_1	0.62	2.12	0.99	1.00	0.02	0.02	1.01	1.02
	S_2	0.69	2.38	0.99	1.00	0.01	0.01	1.00	1.01
	S_3	0.70	2.40	0.99	1.00	0.01	0.01	1.00	1.01
Kalmegh	S_1	1.47	3.13	0.99	1.00	0.44	0.53	1.43	1.53
	S_2	1.35	3.04	0.99	1.00	0.40	0.46	1.39	1.46
	S_3	1.15	2.83	0.99	1.00	0.30	0.34	1.30	1.34

Discussion

CHAPTER V

DISCUSSION

The findings of the present investigation entitled "**Component interactions in mango based agroforestry system in the sub-tropics of Jammu and Kashmir**" are discussed with cause and effect relationship. Efforts were made during the present investigation to explore the possibility of successful integration of Ginger (*Zingiber officinalis*), Turmeric (*Curcuma longa*), Stevia (*Stevia rebaudiana*) and Kalmegh (*Andrographis paniculata*) important medicinal plant species, as intercrops between the mango trees of 29 years old mango orchard. In addition, the aim of the present study, which was conducted for two successive years, was to understand the influence of three plant spacing of intercrops on the growth performance and production of intercrop. This information was essential to prepare suitable tree-crop combinations in order to achieve diversification and obtain maximum benefit from the orchard land. The interacting behaviour of intercropped components, which vary in size, structure and nature but growing together on the farmland and their response to the presence of mango trees are discussed in the following pages.

5.1 Performance of intercrops grown with and without mango

- 5.1.1 Growth parameters
- 5.1.2 Yield parameters
- 5.1.3 Physiological attributes
- 5.1.4 Root characteristics

5.2 Physico-chemical properties of soil under intercrops grown with and without mango

5.3 Bio-economic appraisal of the system with and without mango

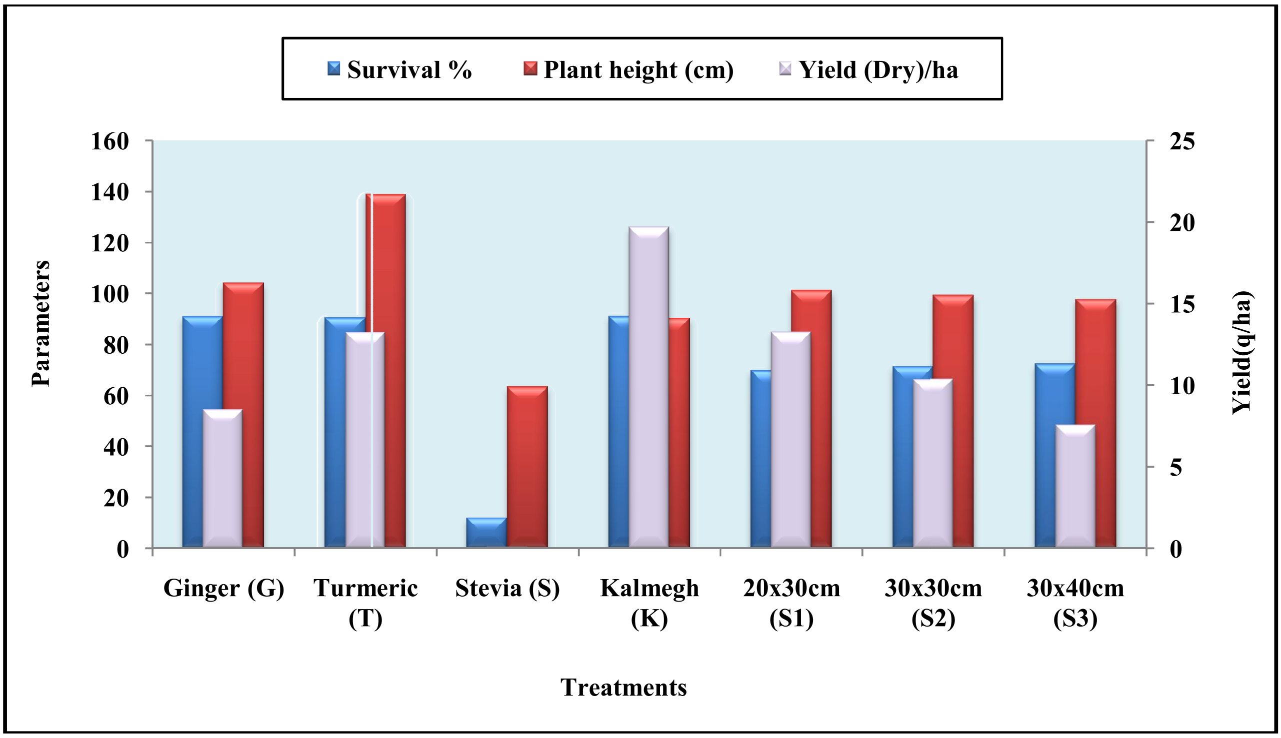
5.1 Performance of intercrops grown with and without mango

Fruit tree-based agroforestry involves intentional and simultaneous association of annual or perennial crops with perennial woody fruit trees on the same farm unit. The resource sharing, whether below ground and/or above ground depends upon fruit tree species, age and size of the tree and agricultural crops and availability of growth resources. Mango trees of >20 years age have large crown and dense canopy which allow only 30-40 per cent light transmission; hence, selective crops can be successfully grown (Shukla et al., 2016). The inclusion of intercrops in the present study was basically attributed to two reasons: i) increased demand globally of medicinal and herbal products and ii) to achieve diversification by combining high value cash crops in place of conventional food crops. Very few studies have been done to find suitable and economical fruit tree- crop combination. In this endeavour, four different crops (ginger, turmeric, stevia and kalmegh) were grown with three different spacing. The results indicated that stevia is not a suitable crop under mango orchards however, other three can be successfully cultivated. The results are discussed together for sole crop and mango+ intercrop under the following sub-heads.

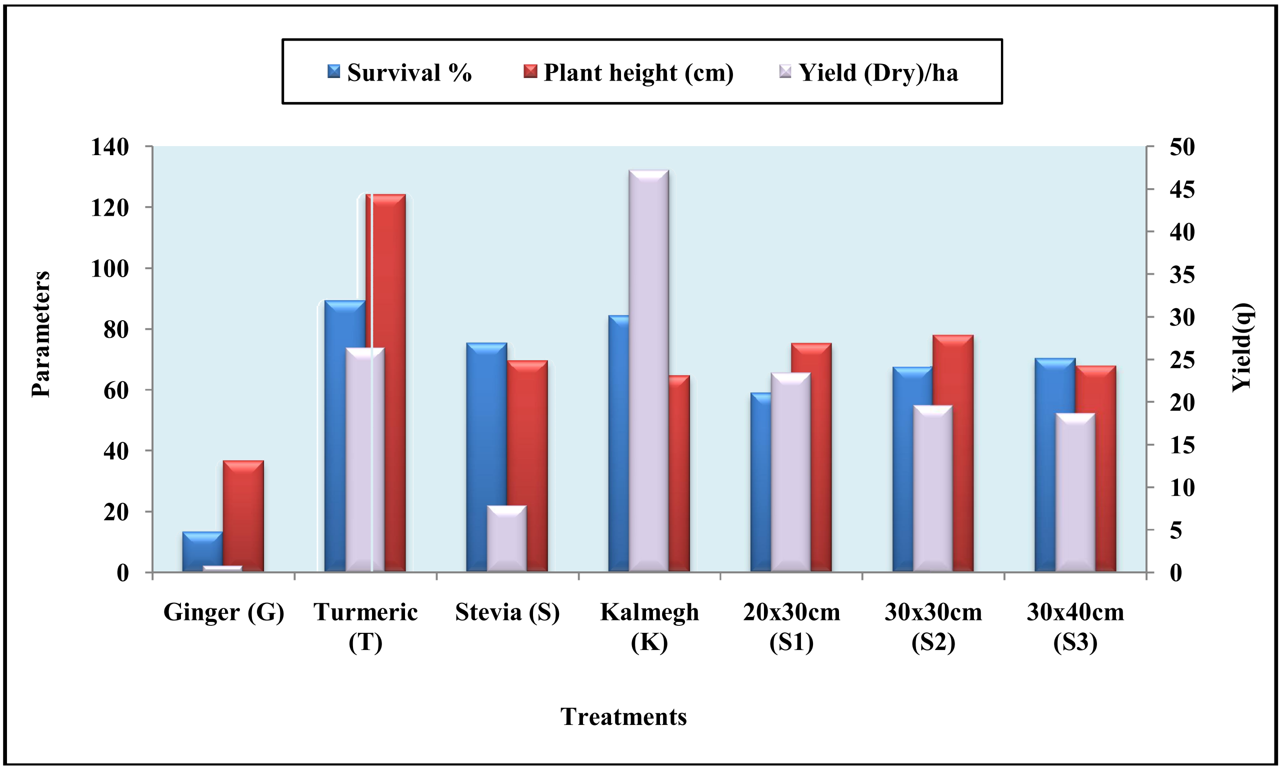
5.1.1 Growth parameters

Mango orchard selected for the study had a very dense canopy and thus the interception of light was only 30-40 percent than that in the open. The shade had profound influence on the survival percentage and growth parameters like plant height, number of leaves per plant, number of branches/tillers per plant and leaf area per plant of ginger, turmeric, stevia and kalmegh (Tables 1 and 6). Among the four crops, stevia had a very low survival percentage under mango as compared to that in the open (Fig. 3). The results are in agreement with that of Kumar *et al.* (2012b), where they concluded that intensive shade should be avoided for stevia cultivation due to increase in the time taken to reach different phenological stages. Likewise ginger had a low survival percentage in the open as compared to beneath the mango trees. The results are in conformity with Amin *et al.* (2010) and Garima *et al.* (2016) who revealed that ginger was a sciophyte and it performed well under partial shade (50±5 per cent) than the open field.

The height of the intercrop was significantly affected due to overhead shade of the trees and different spacing of the intercrops. The reason for height elongation in all the crops and in all the treatments except stevia under mango may be attributed to poor light intensity. Low light intensity might have reduced the rate of evaporation of water from the soil and thereby increasing the moisture availability to the intercrop. This probably increased the nitrogen supply to plants through water absorption which might have caused increase in the vegetative growth of the intercrop. Similar results were also recorded by Solanki *et al.* (2014), Chauhan *et al.* (2013) and Padmapriya and Chezhiyan (2009). Maximum height increment was found under the closer spacing. Possible reason for this could be that closer plant to plant spacing resulted in more competition for interception of light thereby causing increment in the height growth. The similar results were reported by Bhuiyan *et al*., (2012) and Semwal *et al*., (2016). The higher number of leaves, higher number of tillers and higher leaf area per plant recorded in ginger and turmeric under shade was credited to the shade



(a) Intercrops (Mango)



(b) Sole crops (open)

Fig. 3. Growth and yield of crops under (a) mango and (b) in open

loving nature of these crops. It was in sharp contrast to the growth pattern of these parameters in stevia and kalmegh which showed the close affinity of these crops to the high intensity of incident rays (Fig. 4). A marked increase was seen in the growth parameters at wider spacing of 30cm x 30cm and 30cm x 40cm in all the crops. It might be due to the decreased competition for the resources as the plant population reduced considerably with increasing plant to plant spacing. The increase in growth parameters in ginger and turmeric has been reported by Vikram and Hegde (2014), Girija Devi *et al.* (2011) and Sehgal, (2011). The reduction in growth parameters under shade in stevia and kalmegh has also been observed by Hazarika *et al*. (2012) and Sanwal *et al*. (2016).

5.1.2 Yield parameters

The economic yield of the four crops varied as per the crop habit. Fresh rhizome weight was taken for ginger and turmeric, dry leaves for stevia and dry above ground biomass for kalmegh. From the table 6 and table 12, it is clear that (1) the yield, in general, decreased under mango trees as compared to the open, (2) ginger performed very poor under open conditions and (3) stevia is not suitable for intercropping in old growth mango orchards. The possible reason could be intense shade under mango trees which does not favour reproductive growth of the crop thereby delaying their maturity and the yield. The optimum temperature requirement for ginger is ≤ 32^0C with high relative humidity throughout its growth period except at harvesting time, higher temperature and low humidity levels hamper the germination and further growth of the rhizomes. Stevia does not perform well under shade level of ≥25 percent. The reduction in yield has been reported by Prakash and Pant (2015), Rathore *et al.* (2014) and Bijalwan (2012). As discussed earlier, the wider spacing performed the best but the yield was higher under the closer spacing of 30cm x 20cm in all the crops except stevia under mango and ginger in open. It could be probably due to higher plant population in closer spacing than in the wider spacing. The results are in confirmity with Reddy *et al.*, (2016), Ghosh and Hore, (2011) and Suresh *et al.*, (2010). Stevia and ginger performed very poor in the respective conditions. The poor performance of ginger in open and of stevia under shade has also been proclaimed by Amin *et al.* (2010), Kunhamu *et al.* (2015), Kumar *et al*. (2012b) and Hazarika *et al*. (2012), respectively.

Comparatively no marked improvement in the yield of the four crops was recorded in the year 2016 as compared to the year 2015. The possible reason for this could be the decreased rainfall and increased temperature in the year 2016 than in 2015. The meagre increase could be attributed to the improvement in the soil quality as a result of intercultural operations and addition of fertilizers recommended for each crop in the previous and the current year.

The integration of crops with orchard trees resulted into a number of above and below ground biological interactions, where woody and non-woody components of the system compete with each other for the critical resources. During both the years, the growth and yield of the intercrops showed that shade was the key factor which was found to limit the productivity of crops in the system. The findings of this investigation are also in agreement with the findings of the researchers (Chauhan *et al.,* 2013, Gebru, 2015 and Islam *et al.*, 2016) who have reported greater production of dry matter in the open field than in intercropped field. The findings of the present investigation suggested that presence of trees in the system improve the microclimate by lowering the day temperature and increasing the night temperature, moderating the moisture content, reducing the transpiration losses and lowering the light intensity. The crop with greater intrinsic ability to undergo quick adjustments always has an added advantage. Kalmegh, ginger and turmeric performed comparatively better under mango in terms of growth though yield was less in contrast to the yield in open. It implied that these crops can be successfully introduced into mango based system (Fig. 3).

5.1.3 Physiological attributes

Productivity of crop is analyzed in terms of total incident solar radiation, the proportion of the incident solar radiation intercepted by the crop, the efficiency of conversion of intercepted radiation into plant dry matter and the partitioning of dry matter among various plant/crop components (Charles-Edwards, 1982). These are termed as the physiological determinants of crop growth. Total crop dry matter is the spatial and temporal integration of all plant processes and therefore, crop dry matter is the most relevant parameter in the study of crop canopies. Rate of dry matter accumulation varied across the life cycle of a crop. Dry matter and leaf area were recorded at intervals ranging from days to weeks to quantify effects of environmental influences or to analyze genotypic differences between crop cultivars. In growth analysis, two basic measurements were made, dry weight and leaf area and a large number of parameters were derived from these measurements viz. RGR (relative growth rate), NAR (net assimilation rate) and Partitioning coefficient (Anonymous, 2008). In the present study, four intercrops and three spacing had affected the physiological parameters differentially (Tables 7 & 8 and 13 & 14).

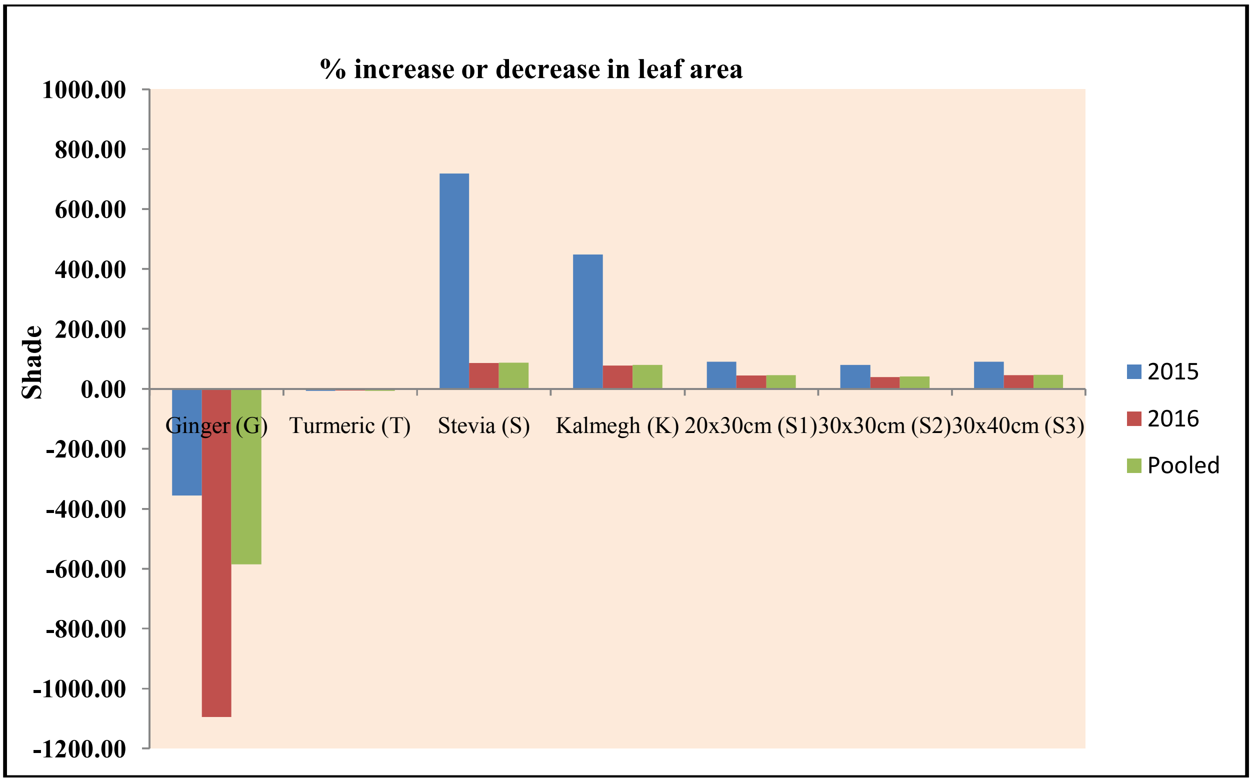


Fig. 4 Leaf area of crops in response to shade

During the present investigation, marked differences in the RGR and NAR values in open and under mango were observed. The sole crop of all species had high RGR and NAR values than as intercrop. It may be due to the fact that reduction in incident radiation reduces photosynthetic productivity and growth, hence the RGR and NAR. Similar results have also been reported by Monteith *et al*. (1991), Barth *et al*. (2001), Rodrigo *et al*. (2001) and Valio (2001) that reduction in incident light reduces RGR and NAR. With regards to the effect of spacing on the RGR and NAR values, it was observed that crops planted at closer spacing (S_1- 20cm x 30cm) had a lower RGR and NAR both in the open and in the intercropping arrangement. It may be due to proportionally less increase in dry matter accumulation per unit area as compared to increase in leaf area. Bukhsh *et al*. (2010) had also reported the similar results in maize hybrids while studying the agro-physiological trait of the hybrids influenced by varying plant density.

Chlorophyll and carotenoid both are pigments, or chromophores, that are involved in photosynthesis. Both chlorophyll and carotenoids are responsible for harvesting light, absorbing photons and transferring the excitation energy to the photosynthetic reaction centre. Only chlorophyll, however, functions within the reaction centre to reduce carbon dioxide (CO_2) to carbohydrates. Carotenoids have two main functions: harvesting light energy for photosynthesis and protecting chlorophyll from light damage (Starr, 2017). In the study presented here, the total chlorophyll (vegetative and reproductive stage) and carotenoid content was more under mango than in open. The increase in chlorophyll content under shaded condition is an adaptive mechanism commonly exhibited in plants to maintain the photosynthetic efficiency. Hence the increase in biomass production under shade could be substantiated by high level of chlorophyll content (Padmapriya *et al*., 2007). The chlorophyll content generally increased from vegetative stage to reproductive stage in stevia and turmeric under the different light conditions and these are in conformity with the findings of Padmapriya *et al*. (2007) and Rao *et al*. (2006). However, the results are contrary to these in case of ginger and kalmegh in both the stages which might be because of lower rate of leaf growth in later stages and visible leaf senescence (Rana and Rana, 2014). The results are in line with those of Kumar *et al*. (2009) who obtained the same trend in kalmegh as a result of light stress (Fig. 5).

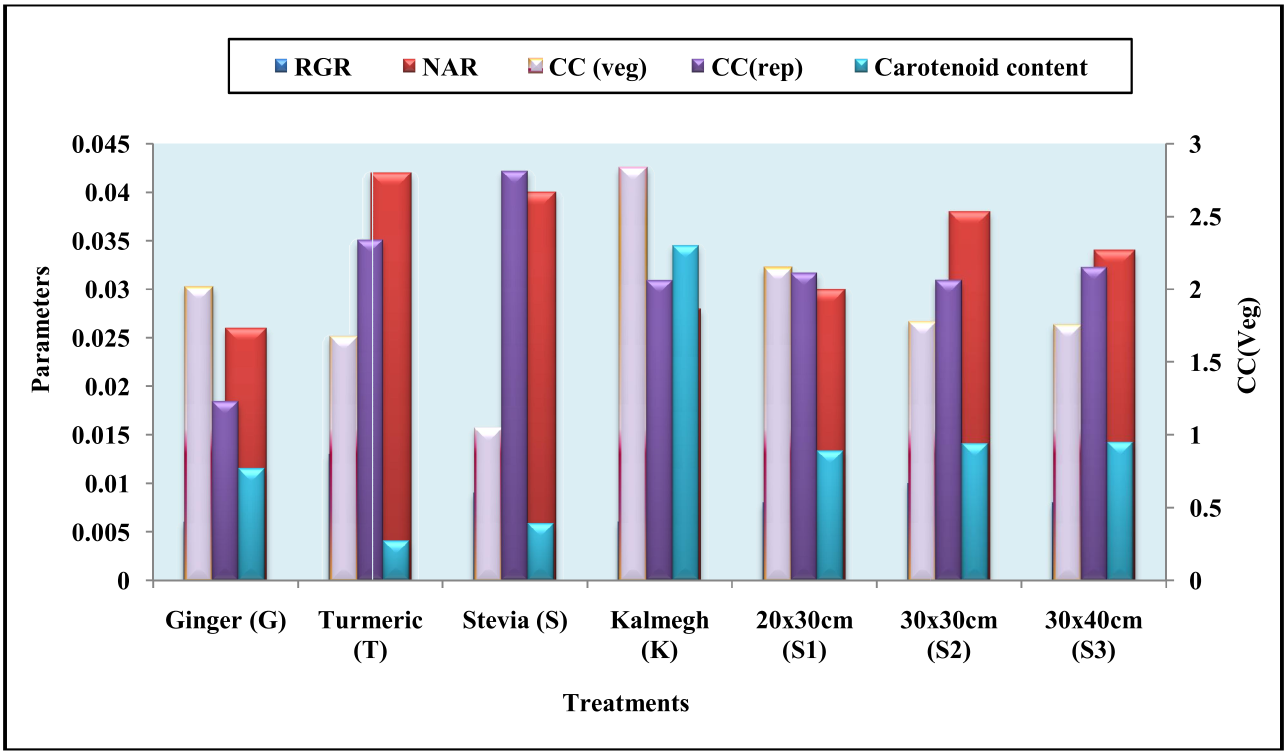
Biomass allocation at different developmental stages of the crop is useful to improve quantification of various parameters in crop growth simulation studies. It is not fixed but may vary over time, across environments and among species (Banerjee and Krishnan, 2015). The data presented in tables 8 and 14 show that crops allocated maximum assimilates towards leaf and branch growth both in open and under shade and the distribution was more pronounced under tree cover. There was almost 1.5 to 2 times higher distribution towards above ground biomass in case of intercrops as compared to sole crop. It shows that the plants actively alter their assimilate partitioning to adjust to a given environment of low light and low temperature compared to open.

In shade, plants have substantially low assimilatory capacity and they adapt to shade by increasing leaf area expansion and stem elongation (Poorter *et al*., 2012 and Senevirathna *et al*., 2003). In case of roots/rhizomes the partitioning decreased by almost 50 per cent in all the crops under mango as compared to open condition (Fig. 6). It may be due to the increased plasticity of biomass allocation between leaves and roots in response to differences in temperature during active growth period (Atkin *et al.*, 2006).

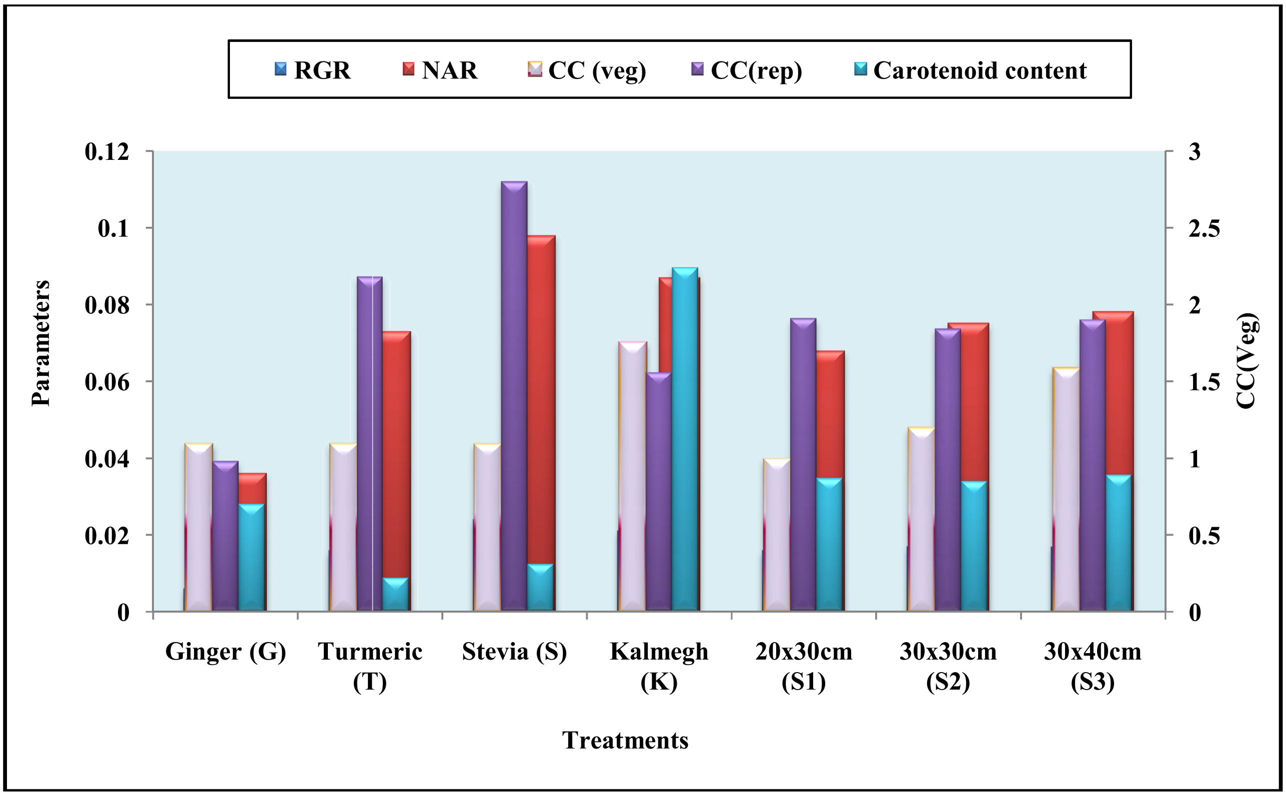
5.1.4 Root characteristics

The root parameters viz. number of roots, dry weight of roots/rhizomes and root growth potential varied under open and intercropping conditions (Tables 9 and 15). Turmeric (9.17), stevia (61.90) and kalmegh (17.38) had higher number of roots and subsequently higher root dry weight (26.85g, 6.16g and 2.50g), respectively in the open/sole codition compared to under shade. These species are shade intolerant and are adapted to low soil resource conditions, thus have more number of fine + coarse roots that maximise the surface for belowground resource capture. The finding is in confirmation with the functional equilibrium theory which indicate that plants respond to decrease in aboveground resources with increased allocation to shoots /leaves, whereas they respond to decrease in belowground resources with increased allocation to roots (Poorter and Nagel, 2000). In ginger, however, the trend is opposite which might be because of intolerance to high temperature and low moisture conditions prevailing in the site. Similar pattern of root growth and biomass allocation was found by Poorter and Remkes (1990), Modrzynski *et al*. (2015) where they studied the growth pattern of shade tolerant and intolerant plant species.

Root growth potential (RGP) is the method of root growth quantification (potential to grow roots) and indicator of field survival and growth ability of plants (Rietveld and Tinus, 1987). The negative values of RGP for all the crops except ginger showed that these crops have poor growth and yield under continuous intense shade under mango trees as compared to their growth and yield in open. RGP values decreased with increasing spacing. It might be due to the increasing light availablility and increasing shoot length with the

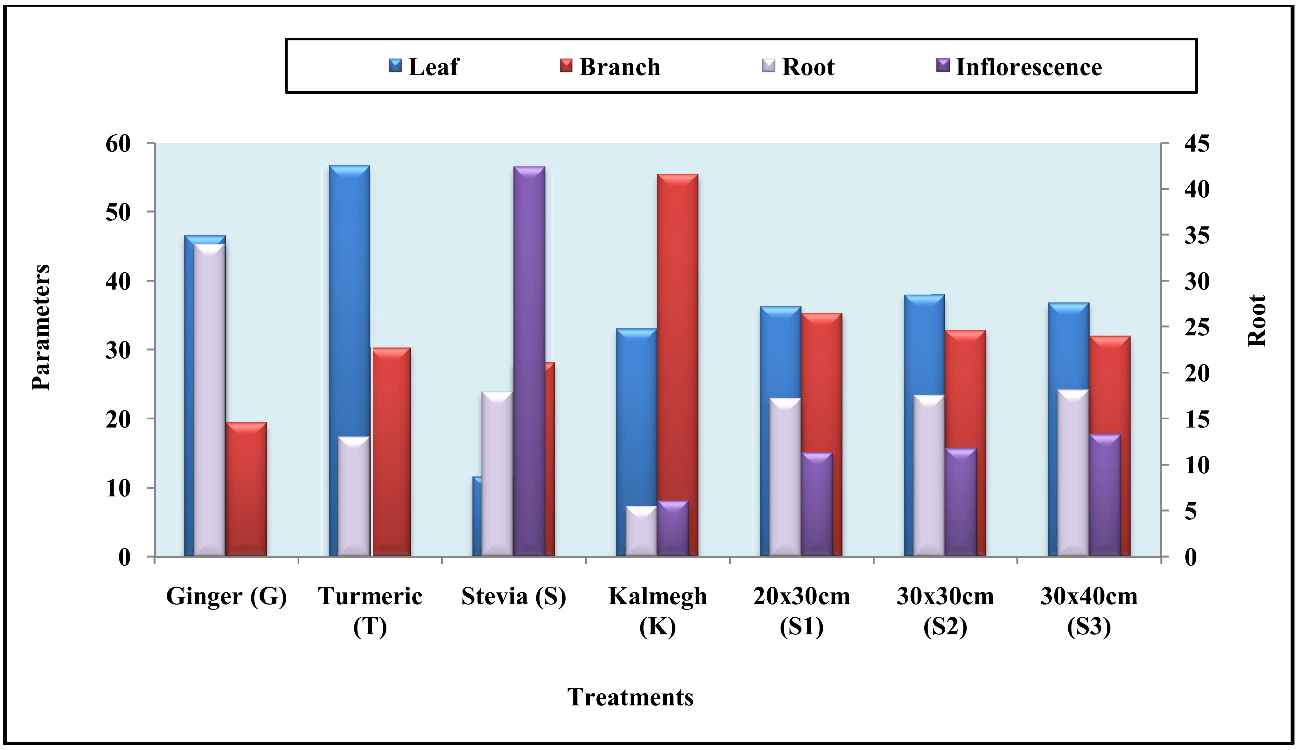


(a) Intercrops (Mango)

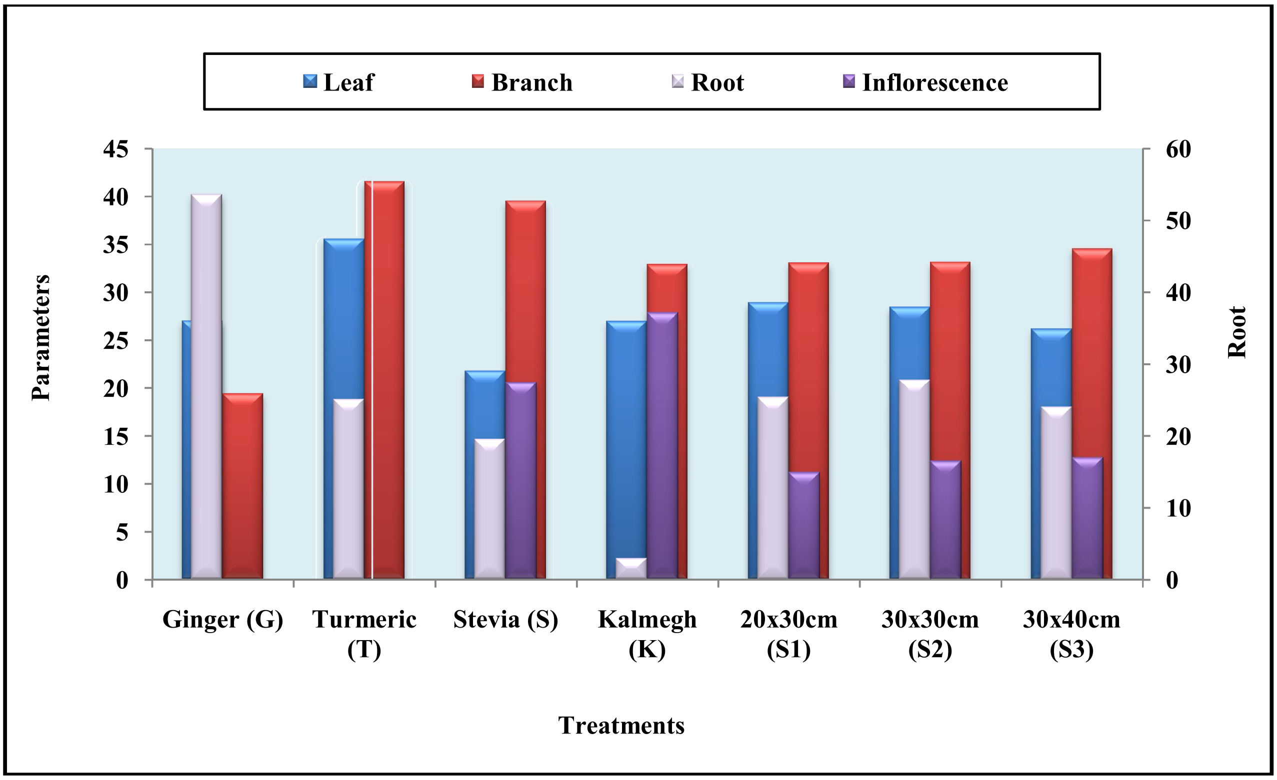


(b) Sole crops (open)

Fig. 5 Physiological response of crops under (a) mango and (b) in open



(a) Intercrops (Mango)



(b) Sole crops (open)

Fig. 6. Dry matter partitioning of crops under (a) mango and (b) in open

increase in spacing (Poorter *et al.*, 2012). The positive values for ginger are due to the poor performance of ginger as sole crop under the given environmental conditions prevailing at the site.

Number and dry weight of roots/rhizomes increased with increase in spacing. It might be due to the decrease in density of plants with increase in spacing. At low planting density, roots get enough space for better absorption of water and nutrient which help in extending and thickening of the root system. The results are in conformity with Semaw (2014) and Jiang *et al.* (2013).

5.2 Soil physico-chemical properties and microbial count under intercrops grown with and without mango

The data recorded on the physico-chemical properties of soil with and without mango canopy towards the end of the experiment (2015-2016) presented in tables 20-22 show the significant improvement in the bulk density, EC and moisture percentage of the soil in the open as well as under mango tree canopy. The improvement might be attributed to (1) increase in the soil organic matter content brought about by the incorporation of the biomass of the intercrops resulting in better aggregation properties of soil (2) the intercultural operations decreased the compactness of soil resulted in increased soil aeration under the trees. Similar positive effect of intercropping on the physical properties of soil has been reported by Swain and Patro (2007), Swain *et al*. (2012), Swain (2014) and Adak *et al*. (2016).

The increase in organic C content of soil, pH and CEC under the intercropping system and in the open could be due to the enhanced plant cover on the soil which helped in least crust formation below the sub-surface soil, increased porosity and reduced bulk density. The results are in conformity with Ganeshamurthy *et al*. (2016). There was improvement in the available N, P and K content in the soil at the end of the experiment which might be due to (1) increase in the humus content of soil after decomposition of biomass of tree leaves intercrops (2) addition of fertilizers to intercrops. Similar results of improvement in nutrient status of soil due to intercropping have been reported by Kumar *et al*. (2016), Swain *et al*. (2012), Tiwari and Baghel (2014) and Swain (2014).

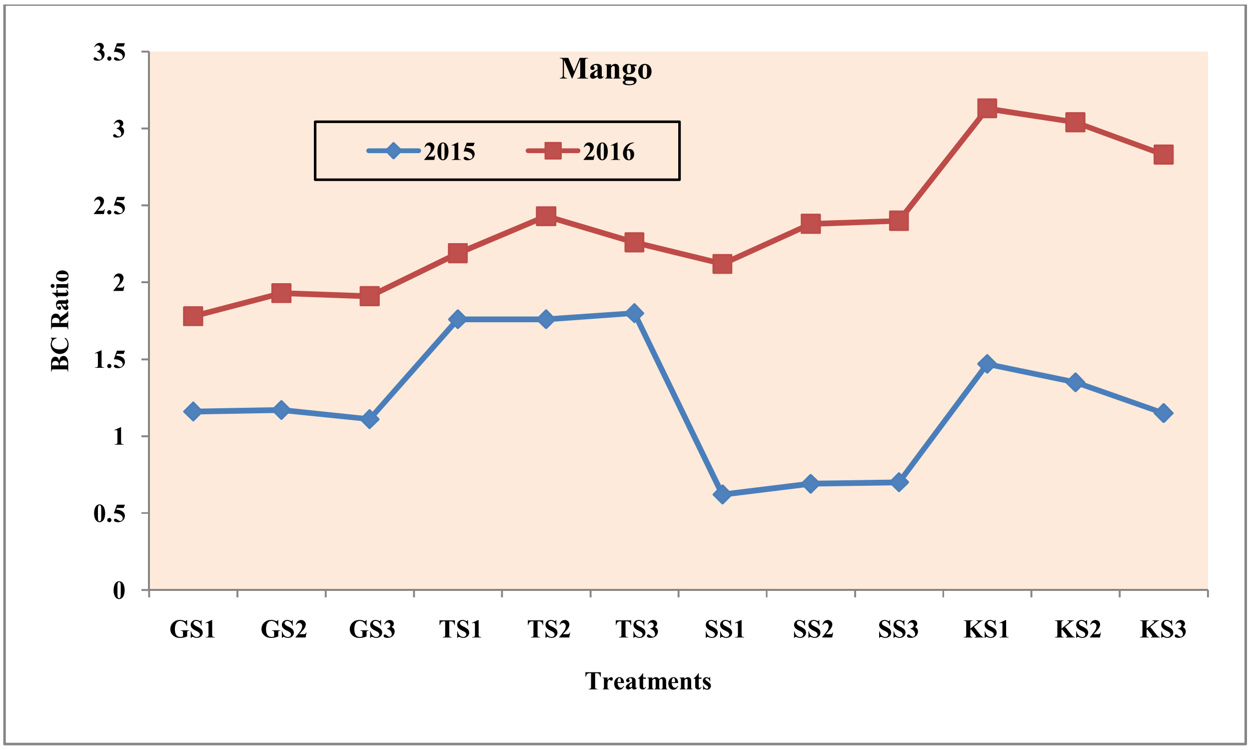
Higher microbial count in the surface soil (0-15 cm) might be because of higher organic matter and moisture content in this layer which favoured profuse microbial growth (Tangjang *et al*., 2015). The microbial population was low under mango orchard as compared to open condition in all the four crops and in both the depths (0-15cm and 15-30cm). It was perhaps due to the high bulk density, low organic matter content, more soil compaction and allelochemicals which might have inhibited the growth of microbial population under mango. The results are in conformity with Wemedo and Onolleka (2012), Munaganti *et al*. (2015) and Abouziena *et al*. (2010). Amongst the fungal species isolated from the soil at two depths under mango trees and in sole cropping, *Alternaria* sp., *Paecilomyces* sp., *Fusarium* sp., *Penicillium* sp., *Cladosporium* sp. and *Aspergillus* sp. were the most commonly found out of the nine identified isolated species. The possible reason for their occurrence could be (1) the presence of fresh organic matter of intercrops on which these cellulose–degrading fungi feed (2) higher growth temperatures favoured the growth of these species. Similar pattern of the prevalence of fungal species was observed by Swer *et al*. (2011), Istifanus *et al*. (2014) and Abouziena *et al*. (2010).

5.3 Bio-economics of the system

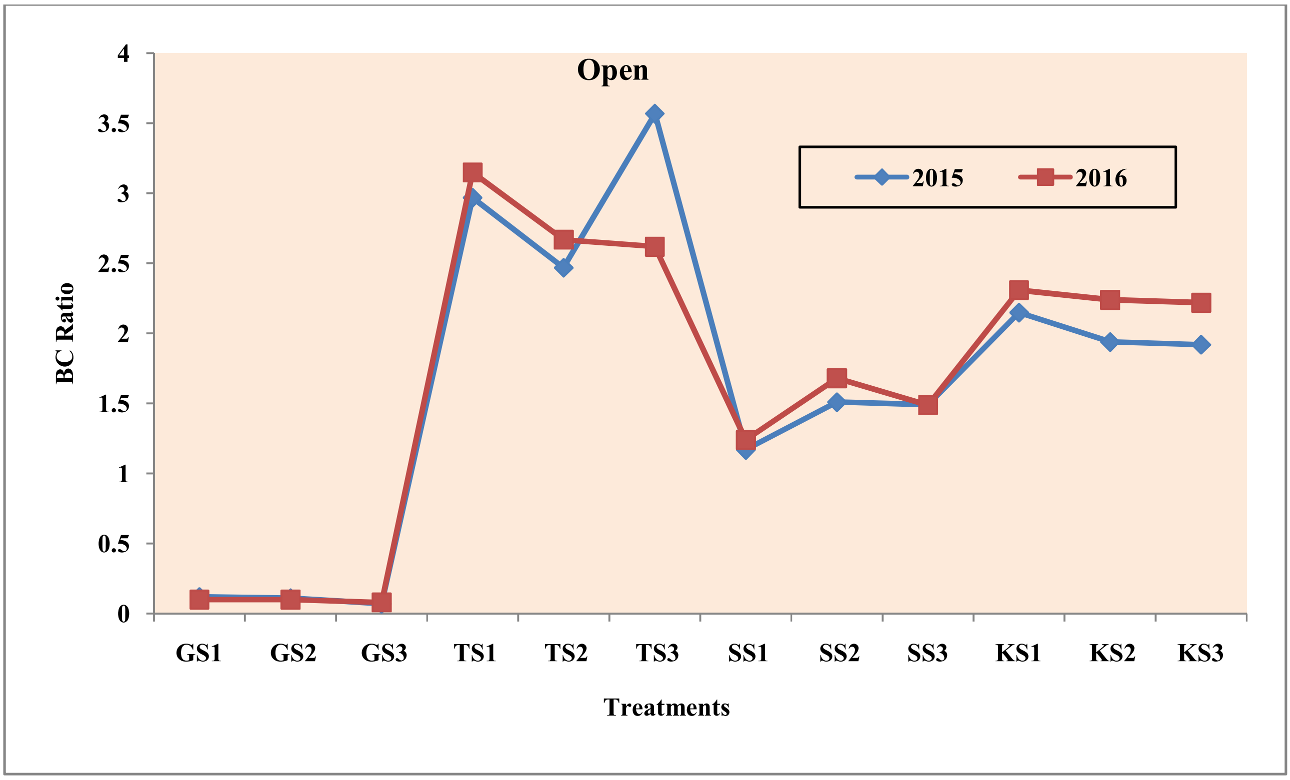
B:C ratio of the crops grown in association with mango and as sole crop varied significantly (Fig. 7). Marked variation was observed in yield of the crops (with and without mango) and it directly influenced the net returns per unit area. The tables 25-28 reveal that the cost of cultivation, gross return and net returns from the system (with and without mango) decreased with the increase in spacing of the intercrops. These findings are in agreement with Ghosh and Hore, 2011, Suresh *et al*., 2010.The cost of cultivation was highest in sole crops as it involved two additional weedings. Amongst the four crops, the highest B:C ratio was recorded in turmeric followed by kalmegh and stevia, the crops being sun loving and performed well in overhead sunlight. Ginger recorded the lowest yield. It might be due to the high temperature and very low humidity during active growth period June to October (Annexure I) which prevented sprouting of rhizomes.

In mango+intercrop system, fixed cost towards maintenance of mango was included with all twelve treatment combinations having the four crops. Gross returns from mango was added to the gross returns from the treatment combinations of the intercrops for calculating the total return and B:C ratio from the system as a whole. In the year 2015, turmeric recorded the highest B:C ratio followed by kalmegh and ginger. In 2016, being an on year for mango, there was a substantially high yield in mango which led to increase in B:C ratio and LER. The higher value of B:C ratio for stevia in the second year was due to the increased returns from mango.

As a measure of plant performance for yield, land equivalent ratios (LER) were calculated to evaluate the efficiency of the agri-horti system (Table 28). The monoculture equivalents were less than one for turmeric, stevia and kalmegh in all the treatments, indicating that production in such a system reduced the yield of each crop relative to what



(a) Intercrops (Mango)



(b) Sole crops (open)

Fig. 7. Comparative of bio-economics of crops under (a) mango and (b) open

had been produced in a similar sized monoculture plot i.e sole crop. It may be due to (1) less availability of transmitted light (20-30%) underneath the mango (2) intra- and/or interspecific competition for light, and/or nutrient resources. Similar trend was reported by Raut, 2006, Vikram *et al*., 2015, Swain, 2014 and Rivera and Quigley, 2004. Maximum yield reduction was reported in mango+stevia land-use because stevia is strong light demander and extremely sensitive to excessive moisture condition which induces senescence and death of the plant. Intercrop treatment combination had no significant effect on the mean yield of mango in both years. The value of LER was highest in mango+ginger and minimum in mango+stevia (Fig. 8). In case of ginger, the yield was very poor under open which inflated the value of LER and in case of stevia the crop was almost a failure under mango leading to the low LER values. Lower LER value indicated the unsuitability of intercropping with stevia in old orchards of mango under sub-tropical conditions of Jammu.

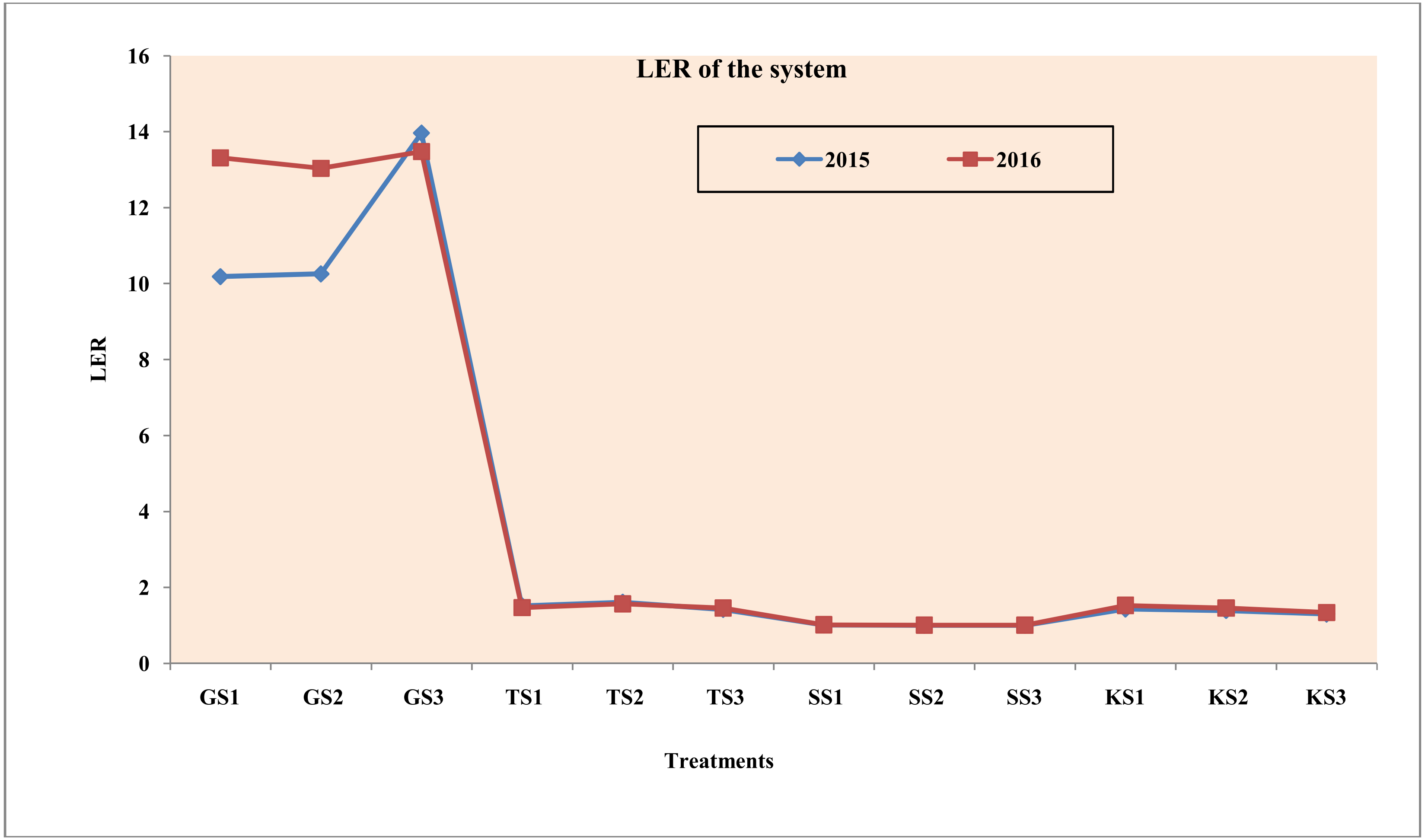


Fig. 8. Land equivalent ratio of the mango based intercropping system

Summary and Conclusions

Summary and Conclusions

CHAPTER VI

SUMMARY AND CONCLUSIONS

The present investigation, "**Component interactions in mango based agroforestry system in the sub-tropics of Jammu and Kashmir**" was conducted at Udheywalla Farm of SKUAST-Jammu, during the years 2015 and 2016. The study was aimed to explore the possibilities of successfully integrating intercrops namely; ginger (*Zingiber officinalis*), turmeric (*Curcuma longa*), *s*tevia (*Stevia rebaudiana*) and kalmegh (*Andrographis paniculata*) with mango trees existing in 29 years old orchard. The effect of light intensity and spacing on growth, physiology, yield of intercrops and effect of tree-crop interaction on soil physico-chemical properties, soil carbon and microbial count was studied to work out the optimum tree-crop combination with respect to growth and yield. Two experiments were laid out in Factorial Randomized Block Design with two factors (4 crops and 3 spacing) and three replications. The findings of the study are summarized under the following heads:

6.1 Performance of intercrops grown with and without mango

- 6.1.1 Growth parameters
- 6.1.2 Yield parameters
- 6.1.3 Physiological attributes
- 6.1.4 Root characteristics

6.2 Physico-chemical properties of soil in intercrops grown with and without mango

6.3 Bio-economics of the system

6.1 Performance of intercrops grown with and without mango

6.1.1 Growth parameters

The results obtained for various growth parameters indicated that the intense shade on the orchard floor significantly affected the survival percentage and the growth parameters like plant height, number of leaves per plant, number of branches/tillers per plant and leaf area per plant of ginger, turmeric, stevia and kalmegh. Among the four crops, stevia had a very poor survival percentage under mango as compared to the open. Likewise, ginger had a poor survival percentage in the open as compared to under the mango canopy. The plant height of the intercrop was significantly affected due to overhead shade of mango trees and different spacing of the intercrops. Maximum height increment was observed in the treatments with closer spacing. The higher values for number of leaves, number of tillers and leaf area per plant were recorded in ginger and turmeric under shade compared to stevia and kalmegh. A marked increase was seen in the growth parameters at wider spacing of 30 x 30cm in all the crops.

6.1.2 Yield parameters

All the yield and yield contributing parameters namely fresh weight per plant, dry weight per plant, fresh yield and dry yield (q ha^{-1}) were significantly influenced by the light intercepted and the plant spacing of the intercrops. The yield component recorded were the economic part used i.e. fresh rhizome weight for ginger and turmeric, dry leaves for stevia and dry above ground biomass for kalmegh. It was found that (1) the yield, in general, decreased under mango trees as compared to the open for all the crops under study, (2) ginger performed very poor with respect to rhizome yield under open conditions and (3) yield of stevia could not be realized and was found to be unsuitable for intercropping in intense overhead shade. The yield was higher at closer spacing of 30 x 20cm in all the crops except stevia under mango and ginger in open.

6.1.3 Physiological attributes

Physiological parameters like Relative Growth Rate (RGR), Net Assimilation Rate (NAR), total chlorophyll content, carotenoid content and the average leaf area also showed significant variation in different treatments. The sole crop of all species had high RGR and NAR values than as intercrop. Crops planted at closer spacing (S_1- 30 x 20cm) had a lower RGR and NAR both in the open and in the intercropping land-use. The total chlorophyll (at vegetative and reproductive stage) and carotenoid content was higher under mango than in open. All the crops selected in the present study allocated maximum assimilates towards leaf and branch growth both in open and under shade.

6.1.4 Root characteristics

The results obtained for the root characteristics viz. number of roots, root dry weight and root growth potential gave an insight of the below ground behavior of the crops in two contrasting situations. Turmeric, stevia and kalmegh had higher number of roots and subsequently higher root dry weight in the open/sole crops as compared to under shade. Number and dry weight of roots/rhizomes increased with spacing. Root growth potential (RGP) had negative values for all crops except ginger.

6.2 Physico-chemical properties of soil in intercrops grown with and without mango

Amongst the physico-chemical properties of soil, bulk density, EC and moisture percentage, organic C content of soil, pH and CEC, available N, P and K content showed improvement in all the depths regardless of the spacing of intercrops. The microbial population was low under mango orchard than in the open situation for all the crops. Amongst the fungal species isolated from the soil at two depths under mango and in sole cropping system, *Alternaria* sp., *Paecilomyces* sp., *Fusarium* sp., *Penicillium* sp., *Cladosporium* sp. *and Aspergillus* sp. were found to be the most prevalent out of the nine species isolated.

6.3 Bio-economics of the system with and without mango

The economic evaluation showed that the cost of cultivation, gross returns and net returns of the system (with and without mango) decreased with the increase in spacing for the intercrops. The value of Benefit Cost Ratio (B:C ratio) of mango+intercrops varied in 2015 and 2016 due to the alternate bearing character of mango. In general, ginger, turmeric and kalmegh recorded higher B:C ratio when grown under the shade of mango in both the years. In stevia, gross returns were higher on account of yield of mango (being on year which otherwise was off year in 2015) and this inflated the B:C ratio of stevia+mango treatment combination. The value of Land Equivalent Ratio (LER) was highest in mango+ginger and minimum in mango+stevia. In case of ginger, the yield was very poor under open conditions which inflated the value of LER and the crop stevia was almost a failure under mango leading to the low LER values.

CONCLUSION

The findings of the present investigation on the basis of growth and yield, physiological and soil parameters revealed that in the mango orchard (29 years of age) with spacing of 9 x 9 m under the subtropical conditions of Jammu region, ginger (*Zingiber officinalis*), turmeric (*Curcuma longa*) and kalmegh (*Andrographis paniculata*) can be grown successfully as intercrops, however, stevia (*Stevia rebaudiana*) cannot be integrated. The most remunerative crop among the four was turmeric followed by ginger and kalmegh. The yield was maximum at closer spacing (20 x 30 cm) of the intercrops. Based on the findings of the present investigation, it can be deduced that growing of shade tolerant intercrops in the mango orchard not only improves the soil fertility but also enhance monetary returns in farming business.

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Appendices

Appendix I

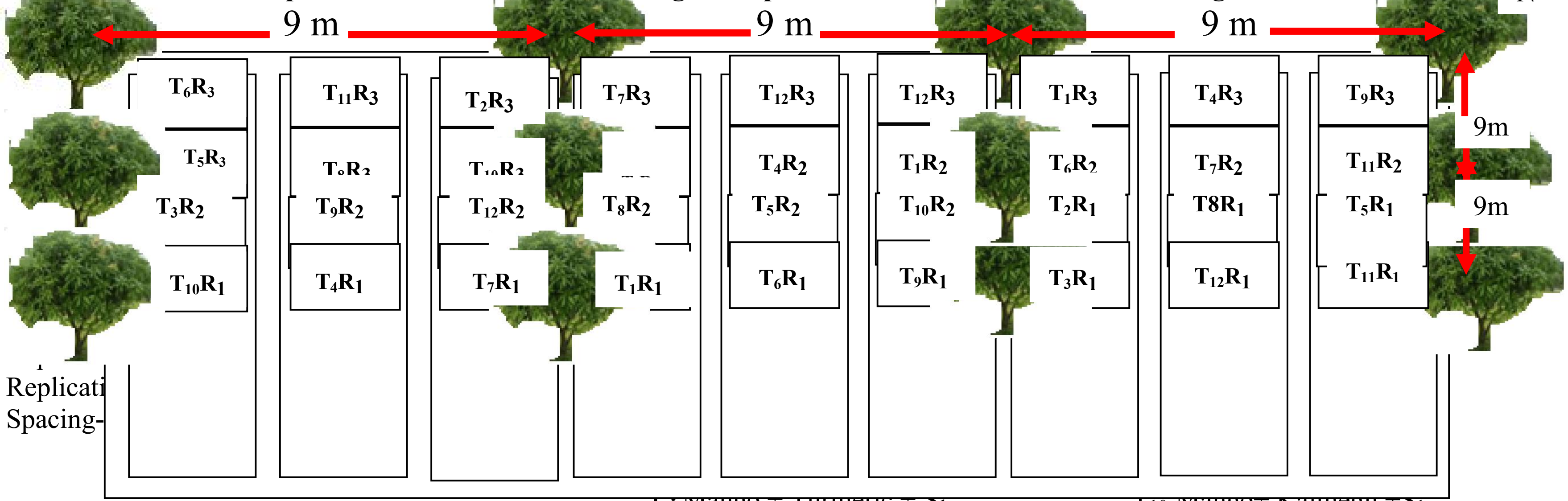
Monthly mean meteorological data for the year 2015 and 2016

Month	Rainfall (mm)		Rainy days		Temperature (^0C)				Sunshine hour(hrs)	
					Maximum		Minimum			
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
January	17.2	11.8	2	1	16.1	17.2	5.8	5.4	3.7	2.7
February	117.5	15.6	7	2	21.5	23.5	9.1	7.2	5.7	7.0
March	334.8	79.9	11	7	24.0	26.8	12.0	12.7	4.9	5.8
April	149.2	3.2	9	0	30.3	33.7	17.1	15.5	3.5	7.0
May	18.7	10.2	2	2	37.6	38.4	20.5	21.0	9.2	7.5
June	111.9	93.6	3	7	37.1	38.3	22.9	25.1	7.5	7.5
July	413.1	378.4	12	11	34.5	34.1	25.3	25.0	5.0	5.3
August	169.2	337.5	9	9	33.8	33.3	25.2	24.2	5.3	6.1
September	136.4	103.7	3	6	33.5	34.0	21.9	24.0	7.8	6.0
October	33.4	1.2	4	0	31.3	32.4	17.5	17.5	7.1	6.9
November	3.8	0.0	1	0	27.6	26.3	10.7	9.5	4.7	5.1
December	28.4	0.0	2	0	5.6	22.8	5.6	6.0	4.9	4.5

Appendix II A

LAYOUT PLAN

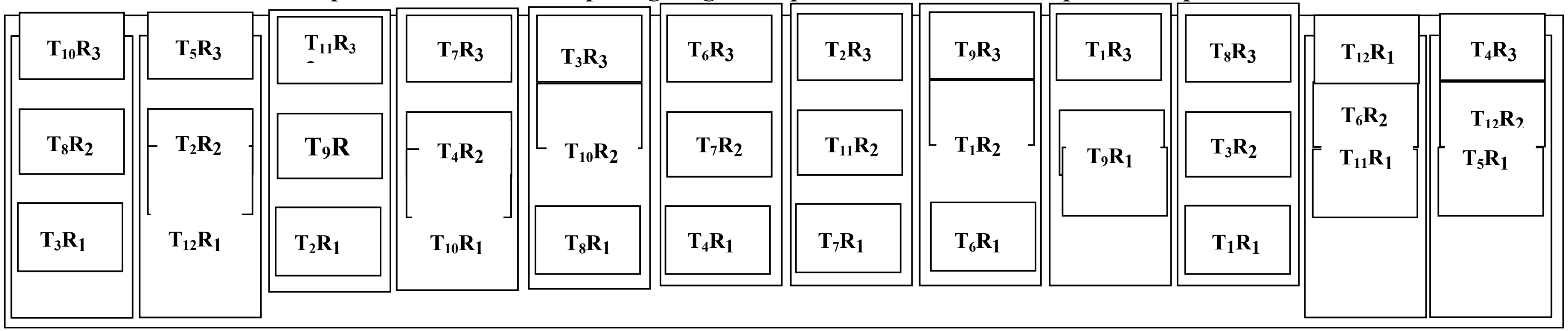
Experiment 1: Effec n growth performance (ınder mango orchard



T_4: Mango + Turmeric + S_1	T_{10}:Mango+ Kalmegh +S_1
T_5: Mango + Turmeric + S_2	T_{11}:Mango+ Kalmegh +S_2
T_6: Mango + Turmeric + S_3	T_{12}:Mango+ Kalmegh+S_3

LAYOUT PLAN

Experiment 2: Effect of spacing on growth performance of intercrops under open conditions



T_3: Ginger + S_3	T_9: **Stevia + S_3**
T_4: Turmeric + S_1	T_{10}: Kalmegh+S_1
T_5: Turmeric + S_2	T_{11}: Kalmegh + S_2
T_6: Turmeric + S_3	T_{12}: Kalmegh + S_3

Appendix III A

Soil physico-chemical properties as affected by intercrops and their spacing under mango orchard after 1 year (2015)

Treatment Combination	**pH (1:2.5::Soil: Water)**			**EC (dS m^{-1})**			**Soil Moisture (%)**			**Bulk density (g cm^{-3})**			**CEC (c.mol.P^{+})**		
Crops	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**
Ginger (G)	6.62	6.67	6.81	0.15	0.15	0.13	17.99	19.04	20.21	1.150	1.320	1.366	12.50	12.10	11.15
Turmeric (T)	6.37	6.30	6.44	0.13	0.12	0.10	17.86	20.74	22.70	1.147	1.340	1.349	13.75	13.33	10.98
Stevia (S)	6.47	6.57	6.55	0.11	0.10	0.12	18.30	18.80	21.86	1.124	1.343	1.370	12.21	12.45	10.66
Kalmegh (K)	6.75	6.77	6.68	0.09	0.06	0.06	18.51	18.88	20.90	1.168	1.367	1.379	12.97	13.20	11.06
±SE(m)	**0.05**	**0.05**	**0.06**	**0.01**	**0.01**	**0.01**	**0.62**	**0.53**	**0.26**	**0.016**	**0.012**	**0.012**	**0.44**	**0.39**	**0.49**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**1.56**	**0.75**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Spacing															
20x30cm (S_1)	6.56	6.38	6.44	0.13	0.10	0.11	18.40	19.52	21.28	1.138	1.343	1.362	12.40	12.37	10.27
30x30cm (S_2)	6.58	6.69	6.84	0.12	0.11	0.09	17.93	19.59	21.24	1.147	1.352	1.370	12.79	12.54	11.17
30x40cm (S_3)	6.52	6.52	6.51	0.11	0.11	0.11	18.18	18.53	21.73	1.157	1.345	1.367	13.39	13.39	11.44
±SE(m)	**0.04**	**0.04**	**0.07**	**0.01**	**0.01**	**0.02**	**0.53**	**0.46**	**0.22**	**0.014**	**0.011**	**0.010**	**0.38**	**0.35**	**0.42**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Crops x spacing															
G S_1	6.66	6.72	6.87	0.15	0.13	0.11	17.77	20.77	20.53	1.132	1.320	1.347	10.98	10.27	9.51
G S_2	6.74	6.84	7.05	0.17	0.18	0.14	17.63	17.92	19.47	1.134	1.373	1.413	13.23	12.26	11.35
G S_3	6.46	6.46	6.52	0.13	0.13	0.13	18.58	18.41	20.65	1.184	1.320	1.337	13.30	13.77	12.57
T S_1	6.49	6.55	6.68	0.14	0.12	0.10	18.03	20.81	22.48	1.181	1.340	1.365	14.08	13.34	11.07
T S_2	6.64	6.63	7.21	0.12	0.10	0.08	17.75	21.56	22.41	1.131	1.293	1.319	13.67	13.36	10.60
T S_3	6.78	6.12	6.14	0.13	0.12	0.11	17.80	19.86	23.22	1.129	1.343	1.364	13.48	13.29	11.26
S S_1	6.37	6.63	6.64	0.12	0.10	0.17	18.20	18.34	21.56	1.110	1.343	1.349	11.51	11.88	9.67
S S_2	6.32	6.44	6.49	0.09	0.10	0.08	18.08	19.54	21.52	1.130	1.373	1.379	12.10	12.60	11.80
S S_3	6.72	6.65	6.54	0.11	0.11	0.11	18.62	18.50	22.49	1.132	1.340	1.381	13.03	12.87	10.49
K S_1	6.73	6.60	6.59	0.10	0.06	0.06	19.60	18.18	20.55	1.130	1.367	1.386	13.03	14.00	10.81
K S_2	6.62	6.84	6.61	0.11	0.06	0.06	18.25	19.33	21.56	1.193	1.367	1.367	12.14	11.95	10.93
K S_3	6.90	6.87	6.85	0.08	0.07	0.07	17.70	17.33	20.58	1.182	1.377	1.385	13.72	13.64	11.43
±SE(m)	**0.08**	**0.09**	**0.10**	**0.01**	**0.01**	**0.01**	**1.07**	**0.92**	**0.44**	**0.028**	**0.022**	**0.021**	**0.76**	**0.69**	**0.84**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Initial value	**6.35**	**6.42**	**6.47**	**0.11**	**0.10**	**0.09**	**17.65**	**18.64**	**20.18**	**1.173**	**1.327**	**1.371**	**13.26**	**12.28**	**10.58**

NS Non significant

Appendix III B

Soil chemical properties as affected by intercrops and their spacing under mango orchard after 1 year (2015)

NS Non significant

Treatment combination	Soil organic carbon (g kg^{-1} soil)			Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
Crops	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**
Ginger (G)	5.92	4.56	4.23	235.70	187.05	162.62	14.42	11.74	11.00	126.86	133.31	120.84
Turmeric (T)	5.83	4.66	3.96	230.71	208.44	169.28	14.01	12.94	12.26	144.34	136.23	127.55
Stevia (S)	5.86	4.49	4.03	221.22	201.39	166.01	14.58	13.18	10.05	135.97	111.19	110.52
Kalmegh (K)	5.90	4.19	4.29	223.59	197.90	162.94	13.19	11.11	9.11	123.93	115.93	106.65
±SE(m)	**0.014**	**0.140**	**0.195**	**4.05**	**3.87**	**2.07**	**0.98**	**0.52**	**0.38**	**5.68**	**2.53**	**4.37**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**11.43**	**NS**	**NS**	**1.55**	**1.13**	**NS**	**7.46**	**12.90**
Spacing												
20x30cm (S_1)	5.95	4.42	4.08	238.79	200.02	161.54	14.27	13.06	9.93	131.79	126.97	119.44
30x30cm (S_2)	5.92	4.43	4.30	217.57	191.71	160.02	14.58	12.08	11.69	132.62	122.58	107.92
30x40cm (S_3)	5.92	4.58	4.01	227.06	204.35	174.07	13.30	11.59	10.21	133.92	122.95	121.81
±SE(m)	**0.012**	**0.121**	**0.169**	**3.51**	**3.35**	**1.79**	**0.85**	**0.45**	**0.33**	**4.92**	**2.19**	**3.78**
$CD_{0.05}$	**NS**	**NS**	**NS**	**10.37**	**9.90**	**5.30**	**NS**	**NS**	**0.98**	**NS**	**NS**	**11.17**
Crops x spacing												
G S_1	5.17	4.20	4.10	252.70	177.68	152.59	14.09	10.57	8.38	116.32	143.93	124.18
G S_2	5.03	4.27	4.47	215.07	168.90	139.23	14.80	11.65	12.15	139.21	138.40	116.67
G S_3	5.17	5.20	4.13	239.33	214.58	196.05	14.38	13.00	12.48	125.04	117.60	121.68
T S_1	5.83	4.90	4.23	250.00	224.78	171.39	14.68	15.42	12.81	151.13	141.96	138.79
T S_2	5.93	4.63	4.10	219.03	198.46	165.17	14.11	11.15	13.85	136.82	127.61	106.00
T S_3	5.73	4.43	3.53	223.10	202.08	171.28	13.24	12.23	10.12	145.08	139.14	137.87
S S_1	5.80	4.43	3.97	225.87	205.14	161.00	15.39	15.51	9.03	131.15	111.08	105.80
S S_2	5.90	4.53	4.17	217.18	203.12	167.41	14.81	13.94	11.92	135.06	107.81	111.25
S S_3	5.87	4.50	3.96	220.62	195.90	169.62	13.54	10.09	9.21	141.70	114.69	114.50
K S_1	6.00	4.13	4.00	226.59	192.50	161.19	12.91	10.72	9.49	128.57	110.90	109.00
K S_2	5.80	4.27	4.47	219.02	196.37	168.27	14.60	11.58	8.83	119.36	116.49	97.76
K S_3	5.90	4.17	4.40	225.17	204.84	159.35	12.06	11.04	9.01	123.87	120.38	113.18
±SE(m)	**0.024**	**0.242**	**0.338**	**7.02**	**6.70**	**3.59**	**1.71**	**0.91**	**0.66**	**9.83**	**4.38**	**7.57**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**19.80**	**10.61**	**NS**	**2.68**	**1.95**	**NS**	**12.92**	**NS**
Initial value	**5.10**	**4.60**	**4.10**	**200.07**	**186.42**	**178.27**	**13.40**	**12.04**	**10.90**	**120.40**	**115.00**	**110.38**

Appendix IV A

Soil physico-chemical properties as affected by crops and their spacing under open condition after 1 year (2015)

Treatment Combination	pH (1:2.5::Soil: Water)			EC (dS m^{-1})			Soil Moisture (%)			Bulk density (g cm^{-3})			CEC (c.mol.P^{+})		
Crops	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**
Ginger (G)	6.74	6.70	6.76	0.104	0.085	0.073	18.97	19.19	22.32	1.126	1.255	1.359	11.95	11.10	10.98
Turmeric (T)	6.75	6.69	6.71	0.095	0.063	0.063	17.88	19.78	18.74	1.119	1.320	1.338	12.34	11.88	10.86
Stevia (S)	6.63	6.67	6.52	0.124	0.077	0.064	19.12	19.60	22.05	1.098	1.231	1.338	12.11	11.43	10.66
Kalmegh (K)	6.40	6.51	6.57	0.099	0.080	0.079	17.79	21.30	20.76	1.146	1.334	1.364	11.97	11.20	11.06
±SE(m)	**0.03**	**0.07**	**0.03**	**0.002**	**0.002**	**0.002**	**0.58**	**1.11**	**1.31**	**0.018**	**0.019**	**0.011**	**0.28**	**0.27**	**0.31**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.055**	**NS**	**NS**	**NS**	**NS**
Spacing															
20x30cm (S_1)	6.66	6.70	6.58	0.107	0.077	0.069	17.46	19.83	20.43	1.111	1.292	1.355	11.67	11.25	10.56
30x30cm (S_2)	6.50	6.62	6.68	0.107	0.077	0.069	18.35	19.33	19.74	1.126	1.305	1.349	12.33	11.40	10.67
30x40cm (S_3)	6.74	6.61	6.66	0.102	0.074	0.071	19.51	20.73	22.73	1.130	1.258	1.345	12.26	11.56	11.44
±SE(m)	**0.02**	**0.06**	**0.03**	**0.002**	**0.002**	**0.002**	**0.59**	**0.96**	**1.13**	**0.015**	**0.016**	**0.010**	**0.25**	**0.23**	**0.27**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Crops x spacing															
G S_1	6.73	6.68	6.66	0.098	0.126	0.108	15.72	16.83	18.45	1.130	1.251	1.340	11.66	10.13	10.01
G S_2	6.90	6.78	6.77	0.092	0.071	0.042	19.35	17.77	22.75	1.134	1.267	1.370	12.24	11.40	11.35
G S_3	6.64	6.64	6.86	0.121	0.057	0.068	21.85	22.97	25.75	1.114	1.247	1.367	11.95	11.78	11.57
T S_1	6.84	6.69	6.63	0.113	0.068	0.066	17.16	23.25	21.07	1.081	1.332	1.377	12.07	12.33	12.07
T S_2	6.67	6.71	6.77	0.109	0.070	0.081	17.75	18.38	17.53	1.128	1.311	1.333	12.50	12.01	8.93
T S_3	6.74	6.67	6.73	0.064	0.052	0.041	18.74	17.69	17.62	1.149	1.316	1.303	12.45	11.29	11.59
S S_1	6.53	6.96	6.61	0.153	0.054	0.043	19.11	19.79	20.34	1.131	1.232	1.343	11.54	11.19	9.34
S S_2	6.54	6.47	6.42	0.101	0.056	0.035	18.66	18.57	18.72	1.048	1.279	1.307	12.43	11.57	11.47
S S_3	6.80	6.57	6.54	0.116	0.120	0.115	19.58	20.43	27.09	1.117	1.181	1.363	12.35	11.53	11.16
K S_1	6.52	6.46	6.43	0.064	0.061	0.060	17.83	19.46	21.88	1.103	1.352	1.360	11.43	11.33	10.81
K S_2	5.91	6.52	6.76	0.126	0.113	0.115	17.66	22.60	19.95	1.193	1.364	1.387	12.17	10.62	10.93
K S_3	6.76	6.54	6.51	0.106	0.067	0.060	17.87	21.84	20.46	1.142	1.285	1.347	12.30	11.64	11.43
±SE(m)	**0.05**	**0.13**	**0.06**	**0.004**	**0.004**	**0.003**	**1.41**	**1.92**	**2.26**	**0.030**	**0.032**	**0.028**	**0.49**	**0.47**	**0.54**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Initial value	**6.40**	**6.59**	**6.61**	**0.09**	**0.12**	**0.13**	**17.82**	**19.12**	**20.06**	**1.127**	**1.231**	**1.364**	**11.80**	**11.10**	**10.50**

NS Non significant

Appendix IV B

Soil chemical properties as affected by crops and their spacing under open condition after 1 year (2015)

NS- Non significant

Treatment combination	Soil organic carbon (g kg^{-1} soil)			Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
Crops	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**	**0-30**	**30-60**	**60-90**
Ginger (G)	6.06	5.68	4.31	216.78	184.72	148.31	16.54	13.98	9.57	131.34	115.82	100.87
Turmeric (T)	5.88	5.48	4.21	220.67	164.61	134.93	12.63	11.99	10.84	136.18	119.52	109.48
Stevia (S)	5.62	5.58	4.53	214.47	150.85	131.92	14.46	12.48	12.29	113.94	110.84	110.21
Kalmegh (K)	5.30	5.01	4.56	222.69	168.96	152.92	15.15	13.53	13.07	111.48	101.99	98.31
±SE(m)	**0.01**	**0.01**	**0.01**	**5.78**	**4.97**	**4.29**	**0.54**	**1.15**	**1.00**	**1.57**	**4.50**	**2.83**
$CD_{0.05}$	**0.01**	**0.03**	**NS**	**NS**	**14.66**	**12.65**	**1.58**	**NS**	**NS**	**4.63**	**NS**	**8.34**
Spacing												
20x30cm (S_1)	5.74	5.41	4.41	212.45	172.52	147.08	14.79	13.63	11.97	122.07	108.78	103.61
30x30cm (S_2)	5.79	5.51	4.38	223.77	163.35	142.43	14.31	11.77	10.91	129.59	119.79	111.68
30x40cm (S_3)	5.61	5.39	4.42	219.74	165.98	136.55	14.99	13.59	11.46	118.03	107.57	98.86
±SE(m)	**0.01**	**0.01**	**0.01**	**5.01**	**4.30**	**3.71**	**0.47**	**1.00**	**0.87**	**1.36**	**3.89**	**2.45**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**4.01**	**NS**	**7.22**
Crops x spacing												
G S_1	6.17	5.83	4.23	210.09	177.65	151.73	17.01	14.86	7.86	124.83	123.73	103.07
G S_2	6.17	5.70	4.43	222.03	188.64	154.35	15.68	13.59	9.60	135.76	116.72	96.88
G S_3	5.83	5.50	4.27	218.23	187.86	138.85	16.93	13.48	11.25	133.43	107.02	102.66
T S_1	5.83	5.07	4.23	214.54	181.23	138.01	12.70	11.77	12.51	147.15	118.88	112.88
T S_2	5.93	5.73	4.00	236.33	156.88	133.28	10.53	10.16	9.83	142.00	124.17	126.56
T S_3	5.87	5.63	4.40	211.13	155.71	133.49	14.66	14.05	10.18	119.39	115.51	88.99
S S_1	5.80	5.67	4.90	199.59	154.83	131.75	14.77	14.59	13.65	116.72	104.73	114.25
S S_2	5.70	5.70	4.47	219.68	153.51	142.14	14.98	9.70	10.70	105.42	113.03	105.33
S S_3	5.37	5.37	4.23	224.15	144.21	121.87	13.64	13.15	12.52	119.67	114.76	111.05
K S_1	5.17	5.07	4.27	225.58	176.38	166.82	14.68	13.30	13.86	99.59	87.78	84.24
K S_2	5.37	4.90	4.63	217.04	154.36	139.94	16.06	13.63	13.48	135.19	125.23	117.97
K S_3	5.37	5.07	4.77	225.46	176.14	151.99	14.72	13.67	11.87	99.66	92.97	92.73
±SE(m)	**0.02**	**0.02**	**0.02**	**10.02**	**8.60**	**7.42**	**0.93**	**1.99**	**1.74**	**2.72**	**7.79**	**4.89**
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**8.02**	**NS**	**14.45**
Initial value	**5.81**	**5.23**	**4.84**	**201.32**	**150.86**	**135.12**	**13.80**	**12.26**	**11.75**	**125.12**	**110.07**	**112.34**

Appendix V A

Cost of cultivation of sole crops during 2015 (₹ ha^{-1})

Crops	Spacing	Land rental value	Land preparation/ Tractorization	Planting material	Man days for different operations	Fertilizers	Pesticides	Gross expenditure
Ginger	S_1	5000	6000	120000	39432	9113.09	3000	182545
	S_2	5000	6000	80000	37944	9113.09	1800	139857
	S_3	5000	6000	60000	36084	9113.09	1500	117697
Turmeric	S_1	5000	6000	100000	56916	8272.18	3000	179188
	S_2	5000	6000	66000	53754	8272.18	2070	141096
	S_3	5000	6000	52000	49104	8272.18	1500	121876
Stevia	S_1	5000	6000	12000	53568	6997.18	300	83865
	S_2	5000	6000	6000	50592	6997.18	300	74889
	S_3	5000	6000	6000	47058	6997.18	300	71355
Kalmegh	S_1	5000	6000	3000	45942	9614.09	435	69991
	S_2	5000	6000	3000	43524	9614.09	435	67573
	S_3	5000	6000	2000	40920	9614.09	435	63969

Expenditure on labour component based on man-days engaged for different field operations during 2015 (sole crop)

Crops	Spacing	Man-days ha^{-1}									Rate (₹ manday^{-1})	Expen-diture (₹)
		Layout, preparation of beds, channels	Seed treat-ment	Nursery raising	Planting of seed material	Inter-culture operations*	Irri-gation	Plant protection measures	Harv-esting	Total		
Ginger	S_1	34	5	-	36	115	10	3	9	212	186	39432
	S_2	34	5	-	30	115	10	3	7	204	186	37944
	S_3	34	5	-	22	115	10	3	5	194	186	36084
Turmeric	S_1	34	5	-	36	172	10	3	46	306	186	56916
	S_2	34	5	-	30	166	10	3	41	289	186	53754
	S_3	34	5	-	22	156	10	3	34	264	186	49104
Stevia	S_1	34	-	6	43	151	15	3	36	288	186	53568
	S_2	34	-	6	38	146	15	3	30	272	186	50592
	S_3	34	-	6	30	138	15	3	27	253	186	47058
Kalmegh	S_1	34	-	5	43	122	10	3	30	247	186	45942
	S_2	34	-	5	38	118	10	3	26	234	186	43524
	S_3	34	-	5	30	115	10	3	23	220	186	40920

*Includes cost of hoeing, weeding/ pinching & earthing up operations

Appendix V B

Expenditure on planting material and pesticides during 2015 (sole crop)

Crops	Spacing	Planting material ha^{-1}			Pesticides ha^{-1}						
					Mencozeb			Carbendazim			
		Qty (kg)	Rate (₹ kg^{-1})	Exp. (`₹)	Qty (kg)	Rate (₹ kg^{-1})	Exp. (`₹)	Qty (kg)	Rate (₹ kg^{-1})	Exp. (`₹)	Total (`₹)
Ginger	S_1	2400	50	120000	5.0	300	1500	2.5	600	1500	3000
	S_2	1600	50	80000	3.0	300	900	1.5	600	900	1800
	S_3	1200	50	60000	2.5	300	750	1.25	600	750	1500
Turmeric	S_1	2500	40	100000	5.0	300	1500	2.5	600	1500	3000
	S_2	1650	40	66000	3.5	300	1050	1.7	600	1020	2070
	S_3	1300	40	52000	2.5	300	750	1.25	600	750	1500
Stevia	S_1	1.0	12000	12000	0.5	300	150	0.25	600	150	300
	S_2	0.5	12000	6000	0.5	300	150	0.25	600	150	300
	S_3	0.5	12000	6000	0.5	300	150	0.25	600	150	300
Kalmegh	S_1	1.5	2000	3000	0.75	300	225	0.35	600	210	435
	S_2	1.5	2000	3000	0.75	300	225	0.35	600	210	435
	S_3	1.0	2000	2000	0.75	300	225	0.35	600	210	435

Expenditure on Manures and fertilizers during 2015 (sole crop)

Crops	Spacing	Fertilizers ha^{-1}											
		Urea (N)			DAP (P)			MOP (K)			FYM		
		Qty (kg)	Rate (₹ kg^{-1})	Exp. (₹)	Qty (kg)	Rate (₹ kg^{-1})	Exp. (₹)	Qty (kg)	Rate (₹ kg^{-1})	Exp. (₹)	Qty (kg)	Rate (₹ kg^{-1})	Exp. (₹)
Ginger	S_1	99	5.41	535.59	109	22.5	2452.5	125	17	2125	20	200	4000
	S_2	99	5.41	535.59	109	22.5	2452.5	125	17	2125	20	200	4000
	S_3	99	5.41	535.59	109	22.5	2452.5	125	17	2125	20	200	4000
Turmeric	S_1	48	5.41	259.68	65	22.5	1462.5	150	17	2550	20	200	4000
	S_2	48	5.41	259.68	65	22.5	1462.5	150	17	2550	20	200	4000
	S_3	48	5.41	259.68	65	22.5	1462.5	150	17	2550	20	200	4000
Stevia	S_1	48	5.41	259.68	65	22.5	1462.5	75	17	1275	20	200	4000
	S_2	48	5.41	259.68	65	22.5	1462.5	75	17	1275	20	200	4000
	S_3	48	5.41	259.68	65	22.5	1462.5	75	17	1275	20	200	4000
Kalmegh	S_1	99	5.41	535.59	163	22.5	3667.5	83	17	1411	20	200	4000
	S_2	99	5.41	535.59	163	22.5	3667.5	83	17	1411	20	200	4000
	S_3	99	5.41	535.59	163	22.5	3667.5	83	17	1411	20	200	4000

Cost of cultivation of sole crops during 2016 (₹ ha^{-1})

Crops	Spacing	Land rental value	Land preparation/ Tractorization	Planting material*	Man days for different operations	Fertilizers*	Pesticides*	Gross expenditure
Ginger	S_1	5000	6000	120000	37014	9113.09	3000	180127
	S_2	5000	6000	80000	35340	9113.09	1800	137253
	S_3	5000	6000	60000	33852	9113.09	1500	115465
Turmeric	S_1	5000	6000	100000	54870	8272.18	3000	177142
	S_2	5000	6000	66000	51708	8272.18	2070	139050
	S_3	5000	6000	52000	48174	8272.18	1500	120946
Stevia	S_1	5000	6000	12000	52266	6997.18	300	82563
	S_2	5000	6000	6000	49662	6997.18	300	73959
	S_3	5000	6000	6000	46872	6997.18	300	71169
Kalmegh	S_1	5000	6000	3000	44082	9614.09	435	68131
	S_2	5000	6000	3000	41850	9614.09	435	65899
	S_3	5000	6000	2000	40362	9614.09	435	63411

* Details of expenditure same as in 2015

Expenditure on labour component based on man-days engaged for different field operations during 2016 (sole crop)

Crops	Spacing	Man-days ha^{-1}									Rate (₹ manday^{-1})	Expen-diture (₹)
		Layout, preparation of beds, channels	Seed treat-ment	Nursery raising	Planting of seed material	Inter-culture operations*	Irrig-ation	Plant protection measures	Harv-esting	Total		
Ginger	S_1	31	5	-	35	107	10	3	8	199	186	37014
	S_2	31	5	-	28	106	10	3	7	190	186	35340
	S_3	31	5	-	22	106	10	3	5	182	186	33852
Turmeric	S_1	31	5	-	35	166	10	3	45	295	186	54870
	S_2	31	5	-	28	162	10	3	39	278	186	51708
	S_3	31	5	-	22	156	10	3	32	259	186	48174
Stevia	S_1	31	-	6	40	152	15	3	34	281	186	52266
	S_2	31	-	6	36	146	15	3	30	267	186	49662
	S_3	31	-	6	30	140	15	3	27	252	186	46872
Kalmegh	S_1	31	-	5	40	120	10	3	28	237	186	44082
	S_2	31	-	5	35	115	10	3	26	225	186	41850
	S_3	31	-	5	30	115	10	3	23	217	186	40362

*Includes cost of hoeing, weeding/ pinching & earthing up operations

Appendix VI A

Cost of cultivation of intercrops under mango during 2015 (₹ ha^{-1})

Crops	Spacing	Land rental value	Land preparation/ Tractorization	Planting material	Man days for different operations	Fertilizers	Pesticides	Gross expenditure
Ginger	S_1	5000	6000	120000	46128	9113.09	3000	189241
	S_2	5000	6000	80000	43152	9113.09	1800	145065
	S_3	5000	6000	60000	40176	9113.09	1500	121789
Turmeric	S_1	5000	6000	100000	46500	8272.18	3000	168772
	S_2	5000	6000	66000	43524	8272.18	2070	130866
	S_3	5000	6000	52000	40176	8272.18	1500	112948
Stevia	S_1	5000	6000	12000	23250	6997.18	-	53247
	S_2	5000	6000	6000	21762	6997.18	-	45759
	S_3	5000	6000	6000	21018	6997.18	-	45015
Kalmegh	S_1	5000	6000	3000	34596	9614.09	300	58510
	S_2	5000	6000	3000	31062	9614.09	300	54976
	S_3	5000	6000	2000	30876	9614.09	300	53790

Expenditure on labour component based on man-days engaged for different field operations during 2015 (intercrops)

Crops	Spacing	Man-days ha^{-1}									Rate (₹ manday^{-1})	Expenditure (₹)
		Layout, preparation of beds, channels	Seed treatment	Nursery raising	Planting of seed material	Inter-culture operations*	Irrigation	Plant protection measures	Harvesting	Total		
Ginger	S_1	32	5	-	31	123	7	3	47	248	186	46128
	S_2	32	5	-	25	116	7	3	44	232	186	43152
	S_3	32	5	-	20	114	7	3	35	216	186	40176
Turmeric	S_1	32	5	-	31	126	7	3	46	250	186	46500
	S_2	32	5	-	25	119	7	3	43	234	186	43524
	S_3	32	5	-	20	115	7	3	34	216	186	40176
Stevia	S_1	32	-	6	38	38	6	-	5	125	186	23250
	S_2	32	-	6	33	35	6	-	5	117	186	21762
	S_3	32	-	6	29	35	6	-	5	113	186	21018
Kalmegh	S_1	32	-	5	38	76	7	3	25	186	186	34596
	S_2	32	-	5	33	69	7	3	18	167	186	31062
	S_3	32	-	5	29	67	7	3	23	166	186	30876

*Includes cost of hoeing, weeding/ pinching & earthing up operations

Appendix VI B

Expenditure on planting material and pesticides during 2015 (intercrops)

Crops	Spacing	Planting material ha^{-1}			Pesticides ha^{-1}						
					Mencozeb			Carbendazim			
		Qty (kg)	Rate (₹ kg^{-1})	Exp. (`₹)	Qty (kg)	Rate (₹ kg^{-1})	Exp. (`₹)	Qty (kg)	Rate (₹ kg^{-1})	Exp. (`₹)	Total (`₹)
Ginger	S_1	2400	50	120000	5	300	1500	2.5	600	1500	3000
	S_2	1600	50	80000	3	300	900	1.5	600	900	1800
	S_3	1200	50	60000	2.5	300	750	1.25	600	750	1500
Turmeric	S_1	2500	40	100000	5	300	1500	2.5	600	1500	3000
	S_2	1650	40	66000	3.5	300	1050	1.7	600	1020	2070
	S_3	1300	40	52000	2.5	300	750	1.25	600	750	1500
Stevia	S_1	1.0	12000	12000	-	300	-	-	600	-	-
	S_2	0.5	12000	6000	-	300	-	-	600	-	-
	S_3	0.5	12000	6000	-	300	-	-	600	-	-
Kalmegh	S_1	1.5	2000	3000	0.5	300	150	0.25	600	150	300
	S_2	1.5	2000	3000	5	300	1500	2.5	600	1500	3000
	S_3	1.0	2000	2000	3	300	900	1.5	600	900	1800

Expenditure on Manures and fertilizers during 2015 (intercrops)

Crops	Spacing	Fertilizers ha^{-1}											
		Urea (N)			DAP (P)			MOP (K)			FYM		
		Qty (kg)	Rate (₹ kg^{-1})	Exp. (₹)	Qty (kg)	Rate (₹ kg^{-1})	Exp. (₹)	Qty (kg)	Rate (₹ kg^{-1})	Exp. (₹)	Qty (kg)	Rate (₹ kg^{-1})	Exp. (₹)
Ginger	S_1	99	5.41	535.59	109	22.5	2452.5	125	17	2125	20	200	4000
	S_2	99	5.41	535.59	109	22.5	2452.5	125	17	2125	20	200	4000
	S_3	99	5.41	535.59	109	22.5	2452.5	125	17	2125	20	200	4000
Turmeric	S_1	48	5.41	259.68	65	22.5	1462.5	150	17	2550	20	200	4000
	S_2	48	5.41	259.68	65	22.5	1462.5	150	17	2550	20	200	4000
	S_3	48	5.41	259.68	65	22.5	1462.5	150	17	2550	20	200	4000
Stevia	S_1	48	5.41	259.68	65	22.5	1462.5	75	17	1275	20	200	4000
	S_2	48	5.41	259.68	65	22.5	1462.5	75	17	1275	20	200	4000
	S_3	48	5.41	259.68	65	22.5	1462.5	75	17	1275	20	200	4000
Kalmegh	S_1	99	5.41	535.59	163	22.5	3667.5	83	17	1411	20	200	4000
	S_2	99	5.41	535.59	163	22.5	3667.5	83	17	1411	20	200	4000
	S_3	99	5.41	535.59	163	22.5	3667.5	83	17	1411	20	200	4000

Appendix VI C

Cost of cultivation of intercrops under mango during 2016 (₹ ha^{-1})

Crops	Spacing	Land rental value	Land preparation/ Tractorization	Planting material	Man days for different operations	Fertilizers	Pesticides	Gross expenditure
Ginger	S_1	5000	6000	120000	45012	9113.09	3000	188125
	S_2	5000	6000	80000	42036	9113.09	1800	143949
	S_3	5000	6000	60000	38502	9113.09	1500	120115
Turmeric	S_1	5000	6000	100000	45756	8272.18	3000	168028
	S_2	5000	6000	66000	42222	8272.18	2070	129564
	S_3	5000	6000	52000	39060	8272.18	1500	111832
Stevia	S_1	5000	6000	12000	22692	6997.18	-	52689
	S_2	5000	6000	6000	21204	6997.18	-	45201
	S_3	5000	6000	6000	20646	6997.18	-	44643
Kalmegh	S_1	5000	6000	3000	33666	9614.09	300	57580
	S_2	5000	6000	3000	30504	9614.09	300	54418
	S_3	5000	6000	2000	29202	9614.09	300	52116

* Details of expenditure same as in 2015

Expenditure on labour component based on man-days engaged for different field operations during 2016 (intercrops)

Crops	Spacing	Man-days ha^{-1}									Rate (₹ manday^{-1})	Expen-diture (₹)
		Layout, preparation of beds, channels	Seed treat-ment	Nursery raising	Planting of seed material	Inter-culture operations*	Irri-gation	Plant protection measures	Harv-esting	Total		
Ginger	S_1	31	5	-	30	121	6	3	46	242	186	45012
	S_2	31	5	-	24	113	6	3	44	226	186	42036
	S_3	31	5	-	19	110	6	3	33	207	186	38502
Turmeric	S_1	31	5	-	31	125	6	3	45	246	186	45756
	S_2	31	5	-	24	117	6	3	41	227	186	42222
	S_3	31	5	-	20	112	6	3	33	210	186	39060
Stevia	S_1	31	-	6	37	37	6	-	5	122	186	22692
	S_2	31	-	6	31	35	6	-	5	114	186	21204
	S_3	31	-	6	28	35	6	-	5	111	186	20646
Kalmegh	S_1	31	-	5	37	74	6	3	25	181	186	33666
	S_2	31	-	5	32	67	6	3	20	164	186	30504
	S_3	31	-	5	27	67	6	3	18	157	186	29202

*Includes cost of hoeing, weeding/ pinching & earthing up operation

CURRICULUM VITAE

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M.Sc. (Forestry)	Dr. Y. S. Parmar University of Horticulture & Forestry, Nauni-Solan (HP)	2001	8.08
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(Meenakshi Gupta)

CERTIFICATE - IV

Certified that all the necessary corrections as suggested by the external examiner and the Advisory committee have been duly incorporated in the thesis entitled **"Component Interactions in Mango Based Agroforestry System in the Sub-tropics of Jammu and Kashmir"** submitted by **Ms. Meenakshi Gupta**, Registration Number **J-13-D-193-A.**

Dr. Sushil Kumar Gupta
Major Advisor and Chairman
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Date: 30-1-18

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