EFFECT OF CHEMICAL FERTILIZER AND ORGANIC MANURING ON CARROT PRODUCTION UNDER LITCHI BASED AGROFORESTRY SYSTEM

A THESIS

BY

MD. MOSTAFIJUR RAHMAN

Student No. 1505251

Session: 2015

Thesis Semester: July- December, 2017

MASTER OF SCIENCE (M.S.)

IN

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DEDICATED TO MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are gone to the almighty ALLAH, the supreme ruler of the universe give me the chance to complete this present research work and to prepare the thesis.

The author takes the opportunity to express his sincere gratitude, heartfelt respect, immense indebtedness and the deepest appreciation to his reverend scientist and research supervisor ***Prof. Dr. Md. Shafiqul Bari,*** *Professor, Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur, for his ingenious suggestions, encouragement, guidance to complete this study and also for his constructive criticism and meticulous review of the manuscript.*

The author is honored to express his heartfelt appreciation and gratitude to his co-supervisor ***Md. Hafiz All Amin****, Associate Professor, Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur, for his co-operation and helpful suggestions to conduct the research work and in the preparation of this manuscript.*

The author would like to express his sincere respect to ***Prof. Dr. Md. Shoaibur Rahman****, Chairman, Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his encouragement, advice and constructive criticism during research work.*

The author is also grateful to Md. Iman Uddin, Senior Lab. Technician, Mintu Chandra Roy, lab attendant, field worker Md. Abdul Quddus and Nawshad Ali, M.L.S.S. for their cordial co-operation.

Finally, the author would like to take the opportunity to express his boundless gratitude and profound respect to his parents, brothers, sister, friends, well-wishers, roommates and relatives for their blessings, inspiration and co-operation throughout the period of the study.

The Author

Effect of chemical fertilizer and organic manuring on carrot production under litchi based agroforestry system

ABSTRACT

A field experiment was conducted at the Agroforestry and Environment Research Farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during December 2015 to March 2016 to evaluate the growth and yield performance of carrot cv. New kuroda influenced by the applications of different chemical fertilizer and organic manuring under litchi based agroforestry systems along with sole cropping i.e. open field condition. The experiment was laid out in two factors randomized complete block design (RCBD) with three replications. The treatments were factor A: Four chemical and organic fertilizer applications viz. F_1 = Control (no fertilizer), F_2 = Full chemical, F_3 = Cowdung + Poultry and F_4 = Cowdung. On the other hand factor B was Two Production system viz. S_1 = Sole cropping of carrot and S_2 = Carrot cultivation at the floor of Litchi orchard i.e. Litchi + carrot. So the treatment combinations were: $F_1 S_1$, $F_1 S_2$, $F_2 S_1$, $F_2 S_2$, F_3S_1, F_3S_2, F_4S_1 and F_4S_2. The main effect of chemical and organic fertilizer applications on growth, yield contributing characters and yield of carrot was found significant in response of plant height, number of leaves plant^{-1}, fresh leaves weight plant^{-1}, fresh root weight, dry root weight, root diameter and yield. The plant height was measured at 30, 45, 60 and 75 days after sowing (DAS) and the tallest plant height (34.37, 38.92, 42.21 and 44.54 cm) was found in the treatment where full chemical fertilizer was applied. On the other hand the shortest plant height (27.33, 30.57, 33.04 and 33.89 cm) were found in the treatment where no fertilizer was applied (control treatment). The highest carrot yield (11.86 t ha^{-1}) was found in full chemical fertilizer application and the lowest carrot yield (6.93 t ha^{-1}) was also found in no fertilizer treatment. Litchi based production system was sensational on growth and yield of carrot. The highest carrot yield (11.21 t ha^{-1}) was found in sole cropping of carrot production system and the lowest carrot yield (7.89 t ha^{-1}) was found in litchi + carrot based agroforestry production system. Significantly the highest root diameter (2.61 cm) was recorded in treatment combination of carrot sole cropping + full chemical fertilizer and the lowest root diameter (1.82 cm) was observed in treatment combination of carrot under litchi + no fertilizer. Similarly the highest carrot yield (13.14 t ha^{-1}) was found in treatment combination of carrot sole cropping + full chemical fertilizer and the lowest carrot yield (5.60 t ha^{-1}) was found in carrot cultivation under litchi tree + no fertilizer application treatment combination. Among the different chemical and organic fertilizer applications, full chemical fertilizer gave the highest yield at open condition as well as it performed well under litchi based agroforestry system. However, as compare to chemical fertilization, the organic manuring i.e. only cowdung application gave 15.07% yield reduction in case of open condition and 30.52% yield reduction in case of litchi + carrot based agroforestry production system. Again if we compare the yield reduction of cowdung + poultry manure as compare to chemical fertilization, then the yield reduction was 6.62% in case of sole cropping and 24.29% in case of litchi + carrot based agroforestry production system. So, in the context of chemical free safe carrot production with the benefit of environment as well as soil health then carrot may be cultivated using cowdung + poultry manure at the both floor of litchi orchard or sole cropping.

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CHAPTER 1
INTRODUCTION

Carrot (*Daucus carota* L.) belongs to the Umbelliferae family and is one of the major root vegetable used as salad and cooked vegetable, which is a rich source of beta carotene (Chadha, 2003). Carrots are becoming more popular as they contain a high amount of beta carotene; a precursor to vitamin A which prevents infection, some forms of cancer and improves vision. They also contain vitamin C, thiamin B_1 and riboflavin B_2 (Fritz, 2013). Fruits and vegetables are the major source of vitamins and minerals of the people of the country. The minimum dietary requirement of fruits and vegetables per day per capita is 85g and 220g/head/day whereas the availability is only 60g and 80g, respectively (Roy, 2011). However, due to high price of fruits and vegetables the majority of people cannot afford to buy them. Trees and tree products play an important role in household food security, the most important being in meeting seasonal food needs. In Bangladesh, it occupied an area of 4155 acres with annual production of 14145 metric tons and averageyields 20-25 tha^{-1} (BBS, 2015).

Carrot production in Bangladesh is quite low as our farmers are not interested in its cultivation, due to lower yields. Many factors are responsible for its low production, but the non-availability of nutrients in the soil is one of the basic constraints. Our soils are low in fertility and thus to get better production, it is the basic requirement to enrich our soils with the nutrients to fulfill the requirements of the crops for their better growth and yield. Balanced fertilization is one of the most important factors in maximizing the yield potential of various crops. The nutrients are either added to the soil by using chemical fertilizers or by incorporating natural organic manures. The use of mineral fertilizers is the quickest way of increasing crop production; almost 30 to 70% increase in yields of crops has been achieved through the use of optimum and balanced mineral fertilizers. High output from limited resources and intensive farming results in the accelerated use of chemical fertilizers, which pose certain threats to the environment and to humans (Zhu and Chen, 2002). Limitations in the food supply for an ever-increasing population is a major challenge for agricultural researchers (Saez *et al.*, 2012).

To get a high yield by limiting the use of chemical fertilizers and supplementing them with organic based fertilizers is a new concept for sustainable agriculture. Now, the growers are showing interest in utilizing organic manures, primarily due to the exorbitant price of imported chemical fertilizers and their freely availability. Organic wastes serve not only as a source of plant nutrients but also in restoring soil fertility and soil quality, thereby improving the chemical, physical and biological properties of soil (Tennakoon *et al.*,1995). A major component of organic production is providing organic sources of nutrients to promote plant growth as well as sustain soil quality (Dimitri and Greene, 2002).

Fruit-tree-based Agroforestry involves simultaneous association of annual or perennial crops with perennial fruit trees on the same farm unit. Because of the relatively short juvenile (preproduction) phase of fruit trees, high market value of their products and the contribution of fruits to household dietary needs, fruit-tree-based agroforestry enjoys high popularity among resources limited producers worldwide (Bellow *et al.*, 2008). Most example of fruit-tree-based Agroforestry has developed over long periods in response to interaction between agro ecological conditions, plant diversity and farmer resources and needs.

Agroforestry systems have been contributing to the livelihood systems of the rural household of Bangladesh for centuries through providing diversified products (Akter *et al*., 1990). It is also capable in providing higher economic return even under stress growing conditions prevailing under the upland situations than the other annual crops (Bikash *et al*., 2008). Moreover, tree plantations improve soil physical, chemical and biological properties through accretion and decomposition of organic matter through litter fall, and roots decay. Deep and extensive root systems of trees enable them to absorb substantial quantities of nutrients below the rooting zone of crops and transfer them to surface soil (Hartemink *et al*., 1996). Litchi is a high value fruit and rich source of vitamin and minerals. Establishment of litchi orchard is getting popularity in the central terrace ecosystem of Bangladesh but farmers are not managing litchi orchard scientifically to grow agricultural crops in the under storey of litchi plants.

There are many commercial and non commercial litchi orchards in Dinajpur region of Bangladesh, which is being used as monoculture practice (sole litchi). There is a great scope to bring these orchards under intensive cultivation like multilayered Agroforestry system. Moreover, no scientific research was done on litchi based production in this region. For this reason, a study was undertaken to investigate the yield and yield attributes of carrot in response to chemical and organic manure under litchi based Agroforestry production system. Keep in the mind of the aforementioned information the following objectives are taken for present investigation.

Objectives:

1. To compare the yield gap of area among different combination of chemical fertilizer and manure application
2. To evaluate the performance of carrot grown at the young litchi orchard

CHAPTER 2
REVIEW OF LITERATURE

This research has been undertaken to find out the performance of carrot under litchi based agroforestry system an emphasis on the chemical and organic fertilizers. Review is a required part of grant of research proposals and often a chapter in thesis. The reviews of literature of the past studies related to the present experiment collected through reviewing of journals, thesis, internet browsing, reports, newspapers, periodicals and other form of publications are presented and discussed in this chapter under the following sub heads.

2.1 Effect of trees on growth and yield of field crops
2.2 Effect of organic manures on growth and yield of field crops
2.3 Effect of trees and organic manures on soil physical and chemical properties
2.4 Benefits of agroforestry system
2.5 Fruit tree based agroforestry
2.6 Litchi based agroforestry
2.7 Carrot production under different shade level

2.1 Effect of trees on growth and yield of field crops

Hanada (1990) conducted an experiment with 8 levels of shading (0, 20, 37, 48, 50, 72, 87 and 98 percent) in radish, kangkong, cucumber and tomato cultivated under *Acacia auriculiformis* tree. He reported that shading decreased soil temperature, preserved soil moisture and prevented insect attack. It has been observed that yields of kangkong and cucumber increased with 20% and 37% of shading but yield decreased in radish and tomato with increasing amount of shade levels.

Ranasinghe and Mayhead (1990) carried out an experiment on dwarf French beans and broad beans grown at 0.25m×0.25m for 2 years with and without cuttings of Poplar tree at spacing of 2.0m × 0.5m and 3.0m × 0.5m. They reported that, the presence of bean lead to a greater height and diameter growth and greater total dry matter production per hectare of *Populus* at both spacing after 2 years. They indicated that there was no effect on the yield of bean at the end of the first year but yield was reduced at the end of the second year by the presence of *Populus*.

Kessler (1992) studied the effect of Karate (*Vitellaria paradoxa*) and Nere (*Parkia biglobosa*) trees on grain yield of sorghum. He reported Karate and Nere reduced the grain yield of sorghum about 50 and 70 per cent, respectively as compared to open field conditions.

Singh and Kohli (1992) conducted a field trial to study the economic yield of chick pea, lentil, wheat, cauliflower, barseem and toria, in 8 year old *Eucalyptus tereticornis* shelterbelts (three different locations). They reported that the economic yield of intercropped varieties under study was reduced by more than 50% as compared to control (open condition).

Dinssa (1993) reported that growth and yield of soybean, blackgram, horsegram and cowpea were higher under monoculture as compared to intercropping with *Morus alba*. Yield of wheat was found to be significantly reduced under *Paulownia* and it increased over 2 to 8 % away from the tree.

Pant (1993) studied the intercropping of wheat with *Eucalyptus* hybrid, *Populus deltoides, Syzygium cuminii* and *Trewia nudiflora* and found that the tree species showed a variable effect on growth and yield of wheat. The average wheat grain yield varied from 22.50 q ha-1 under Eucalyptus to 27.09 q ha-1 as sole crop. In comparison to sole crop, the average grain yield deceased by 7.1 per cent under jamun, to 16.5 per cent under eucalyptus. Straw yield also decreased by 5-6 per cent under jamun, to 25.4 per cent under poplar.

Crop yields under trees may be unaffected during the early years of tree growth but could increase or decrease when trees are large, depending on the tree species. Crop yield increases under open and well managed canopies of full grown trees. More than 50 % increase in maize yield in Malawi (Saka *et al*. 1994) and 76 % in Ethiopia (Poschen, 1986) were recorded under scattered *Faidherbia albida* trees while in sorghum yield increase was 36% in Ethiopia and 125% in Burkina Faso (Depommier *et al.* 1992) under the same species.

Mohsin *et al.* (1999) reported that *Populus deltoides* trees grown with various Mentha and Cymbopogon species attained better growth than their pure stands at juvenile (2 and 3 years) and advanced (6 and 7 years) age. Bolewood provided maximum contributed biomass among all the components in pure as well as intercropped stands at all the age group of trees. The total biomass was highest in plantation of *P. deltoides* of all ages intercropped with Mentha species. It decreased in Cymbopogon species but still remained higher than that of pure stands which showed lowest biomass production.

Nandal *et al.* (1999a) conducted an experiment to evaluate comparative performance of five wheat varieties grown under 12 years old *Dalbergia sissoo* planted at 5m × 5m and 10m × 10m spacing and two wheat varieties grown along 8 years old *Eucalyptus tereticorni*s and 7 years *old Populus deltoides* windbreaks. The result showed that the recent wheat variety WH-542 performed better both in *D. sissoo* block plantation and alongside the poplar windbreaks.

Nandal *et al*. (1999b) conducted field experiment during the winter season of 1994-95 and 1995-96 to find out the response of five wheat (*Triticum aestivum* L) varieties under *Dalbergia sissoo* Roxb. planted at two different spacing 5 × 5m spacing and 10×10m. The performance of wheat in terms of plant dry matter production, leaf area index, earheads/m and grains/earhead of intercropped wheat, resulting in 71% decrease in wheat yield under 5 × 5m spacing and 24% under 10 × 10m spacing as compared to control (without trees) field. Among the wheat varieties, WH 533 and WH 542 showed greater tolerance to shade and their yield did not differ significantly from control when intercropped with 10 × 10m spacing of *D. sissoo.*
Suresh and Rao (1999) studied the influence of three nitrogen fixing tree (NFT) species viz., *Faidherbia albida*, *Acacia ferruginea*, *Albizia lebbeck* and four nitrogen levels (0, 20, 40 and 60 kg N ha^{-1}) on intercropping of rainfed sorghum at Hyderabad, India. The trees were established in shallow alfisols during 1985 with a spacing of 4 m ×4 m. Intercropping was done in 1993 and 1994. The effect of trees on radiation interception, soil moisture, crop growth, yield components

and yield of sorghum was examined. Association of tree species reduced grain and dry fodder yields of sorghum to an extent of 12 to 40% compared to sole crop situation. The reduction was maximum under *A. lebbeck,* minimum in *F. albida* and moderate under *A. ferruginea*. Application of 40 kg N ha^{-1} resulted in increased grain and dry fodder yields over other levels. Crop growth in terms of LAI and dry matter had similar response. The receipt of photosynthetically active radiation (PAR) was low under NFTs compared to open situation. The relative PAR intercepted under the trees was in the order: *F. albida* > *A. ferruginea* > *A. lebbeck.* Soil moisture status was more favourable under *F. albida* than under the other tree species. Soil moisture at all stages of crop growth was more in sole crop situation.

Yadav (1999) conducted an experiment to investigate the effect of different spacings (30 × 45, 45 × 45, and 60 × 60 cm) and fertilizer (Urea, single superphosphate and muriate of potash) levels on lemon grass (*Cymbopogon flexuosus*) under poplar (*Populus deltoides* G-3) based agroforestry system. Spacing at 45 × 45 cm with highest fertility levels produced higher number of tillers, plant height, herbage and oil yield. The content and quality of oil remained the same in all treatments.

Bisht *et al.* (2000) studied the performance of ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) under 10-years-old fodder trees of *Grewia optiva, Celtis australis, Quercus leucotrichophora* and *Bauhinia variegata*. The results showed that yield of turmeric and ginger was significantly affected by different fodder trees. Both turmeric (12.04 t/ha) and 10 ginger (7.98 t/ha) gave the highest yield with *Q. leucotrichophora.* However, *Bauhinia variegata* resulted higher forage yield (7.7kg/tree). There was a negative correlation (r = -0.77) between light intercepted by the trees and yield of ginger and turmeric. Growing *Q. leucotrichophora* with ginger and turmeric was found to be the most suitable and remunerative intercropping.

Chauhan (2000) conducted an experiment to determine the performance of aromatic crops viz. lemon grass (*Cymbopogon flexuosus*), citronella java *(C. wintrianus*), palmarosa (*C. martini*) and Japaneses mint (*Mentha arvensis*) for five consecutive years in a poplar (*Populus deltiodes*) plantation. Intercropping of aromatic plants resulted into increased diameter at breast height (DBH) and height of the trees as compared to sole cropping. Growing aromatic species as intercrops with poplar has made it possible to produce a very high level of biomass with higher economic returns. Herb and oil yield from a sole crop was higher compared to the intercropped yields. Significant reduction in herb and oil yield started after the third year in *Cintronella java*, Palmarosa and Japanese mint, while that of lemon grass yield decreased slightly after the fourth year of the crop cycle. Lemon grass showed the best performance with respect to sustained herb and oil yield during entire growth period.

Sharma *et al.* (2000) studied variation in performance of wheat plants at an early growth stage when grown in association with boundary plantation of poplar. Wheat growth at 30 days after sowing showed that dry weight of shoot per plant increased significantly between 3-12 m and 3-15m distance from tree rows with 3 and 4 year old trees, respectively over their respective controls. However, significant reduction over control was recorded near the tree row (0-3m). Similarly, dry weight of root per plant reduced significantly over their respective controls between 3-12m and 3-15m distance from tree row with 3 and 4 year old trees, respectively. Other root characters (root length, number of roots and maximum root depth) were also influenced significantly by the tree plantation. Wheat grain yield was reduced significantly at 0-3m distance from tree row with 4 year old plantation only as compared to control.

Bhardwaj *et al.* (2001) reported that the poplar plantation harvested after 13 years, produced maximum biomass (218.08 t ha-1) in the closest spacing of 60cm×60cm.

Chaturvedi and Pandey (2001) studied the feasibility and economics of intercropping of maize – wheat – turmeric and pigeon pea – turmeric during first 10 years of poplar (*Populus deltoides*) plantation. They reported reduction in the yield of intercrops with the increase in plantation age.

Frieda *et al.* (2001) reported that the proportion of above-ground biomass found in stems declined with increasing spacing as the mass in foliage and branches increased. Stems accounted for 65% of aboveground biomass in block-planted trees but only 35% in isolated trees. The contributions of leaves and branches correspondingly increase from 19% to 35% and from 16% to 29%, respectively. Changes in biomass distribution were accompanied by increasing branch number, branch thickness, flatter branch angles and the longer retention of lower branches with greater spacing. These changes have implications for the economic importance of the timber.

Kaushik and Singh (2001) carried out field experiment on poplar with three plant geometries (5 × 4, 8 × 3 and 10 × 3 m) and three irrigation intervals (6, 12 and 18 day's interval) intercropped with pearl millet and wheat. For the first two years the growth performance of pearl millet and wheat cultivated in interspaces of poplar was evaluated in comparison to their sole cropping. Both basal diameter and diameter at breast height of 24 months old trees of poplar was at par in

8 × 3m and 10 × 3m plant geometries, which was significantly higher than that at 5 × 4m plant geometry. Irrigation intervals of 6 and 12 days were statistically at par in respect of survival and growth parameters of poplar but better than 18 days interval. Grain yield of pearl millet in first year and that of wheat in both the years under various plant geometries and irrigation intervals were statistically at par to their sole cropping. While in second year, the grain yield of pearl millet decreased significantly in closer spacing of 5 × 4 m in comparison to sole cropping.

Chauhan and Dhiman (2002) conducted a field experiment to evaluate relative performance of wheat cultivars HS 295, Sonalika, HD 2285 and HD 2380 under various tree spacing (8m × 3m, 6m × 4m, 5m × 5m and 4m × 6m) of poplar (*Populus deltoides*). The tree grown at 8m x 3m spacing gave highest growth and wheat grain yield. They found variation in tillers per plot between HS 295 and Sonalika and for effective tillers per plant between HS 295 and HD 2285.

Puri and Sharma (2002) assessed the performance of wheat intercropped with five different *Populus deltoides* clones (G3, 65/27, D121, G48 and S7C1) and recorded data on crop growth and yield at different distances (0.5m, 1.5m and 2.0m) and in four directions from the tree base and control (no trees). It is indicated that grain yield was found to be less near the tree and it increased with the increase of distance from the tree row. Wheat yield was maximum (12.3 q/ha) in the North of tree followed by West and South. Wheat productivity was affected by *P. deltoides* clones. A grain yield of 14.0 q/ha was obtained in the sole crop. It was maximum (13.8 1 q/ha) under D121 clone and the order of grain yield reduction due to clone was: S7C1> G48 > G3 > 65/27 > D121.

Chaudhry *et al*. (2003) conducted an experiment to assess physico-chemical characteristics of wheat variety under poplar based agroforestry system. Wheat variety cv. Inqalab-91 was intercropped with poplar (*Populus deltoides*) trees during the seventh and eighth year of its age, planted at spacing of 6.10 × 3.66m, 9.10 × 3.66m, 12.10 × 3.66m and reported that one-thousand- kernel weight, test weight and grain size was higher under monocropping of wheat compared to the intercropped wheat. Chemical analysis revealed that crude protein, crude fiber, ash and moisture percentage was higher under intercropping conditions while crude fat percentage was higher under wheat monocropping conditions. However, these contents were within the standard limits, indicating that the physicochemical characteristics of Inqalab-91 are not negatively affected by poplar tree intercropping under agroforestry system.

Chauhan and Dhiman (2003) conducted an experiment to assess the yield and quality of sugarcane cultivars. Sugarcane cultivars Co 88, Co 76, Co 64 and Co 7717 were cultivated in a poplar based agroforestry system, using *P. deltoides* clones PD 3294, PD G3, PD G48 and PD 1/56. Sugarcane cultivars Co 7717 and Co 64 were better in terms of crop yield (116.9 and 116.5 t/ha) and total soluble solids (20.8 and 19.6%, respectively) than the other cultivars. PD 3294 clone was inferior in terms of height (13.1m) and diameter at breast height (13.6 cm) compared to PD G3, PD G48 and PD 1/56 at 4 year of its age.
Rahman *et al*. (2004) reported that except plant height all others morphological characters viz. no. of branches/ plant, no. of fruits/ plant, fruit length, fruit diameter and fruit weight of three vegetables (Tomato, Brinjal, Chilli) were highest in open field condition. Among the different agroforestry system, highest yield was obtained in *Terminalia chebula* -Lemon - Vegetable based Agroforestry system.

Das and Chaturvedi (2005) reported that the biomass, floor litter mass, litter fall and net primary productivity (NPP) of plantations increased with an increase in age of trees whereas, crop biomass for any specific crop interplanted with poplar decreased with the age of the plantation. The total plantation biomass increased from 12.08 to 90.59 Mg ha-1 and NPP varied from 5.69 to 27.9 Mg ha-1 year^{-1}. The biomass accumulation ratio ranged from 2.1 to 3.2. Total annual litter fall was in between 1.95 and 10.00 Mg ha-1 year^{-1}, of which 92–94% was contributed by leaf litter helping to improve soil fertility.

Kaushal *et al*. (2006) studied the above and below ground interactions of *Grewia optiva* and wheat (*Triticum aestivum*) in a selected a single scattered tree on farmland. Growth and yield of wheat crop was negatively influenced below the tree crown while it increased with the increase in distance from the tree row. A reduction of 51.9% was recorded at 1m distance from the *Grewia optiva*. Light, soil moisture, soil nutrients, soil temperature and beneath canopy temperature were reduced considerably at 1m, 2m distance during all the growth stages of wheat. Thus, overall competition for moisture, nutrients and light were the major factors which contributed for the reduction of the growth and yield of wheat under tree canopy.

Mishra *et al.* (2006) conducted an experiment to evaluate the productivity of soybean and wheat under five promising clones (G3, G48, 65/27, D121 and S7C1) of *Populus deltoides* in agrisilviculture system. Soybean and wheat were intercropped in kharif and rabi seasons, respectively for two consecutive years 2000-2002. Both grain and straw yield of soybean and wheat were significantly reduced under poplar clones. Grain yield of soybean declined with an increase in age of the poplar clones. Between five and six years, the yield decreased by 1.3 to 14.2% under different clones compared to sole crop. Maximum reduction in yield with age of the clone was found in 65/27, while it was lowest in clone S7C1. Mean yield of soybean varied from 9 to 15.9 q ha^{-1}. It was highest in sole crop and reduced by 10.1 to 33.3% under different poplar clones.

Swamy *et al*. (2007a) reported that growth and yields of wheat were significantly higher in sole cropping and decreased under different spacing of *Gmelina arborea*. Shoot length of wheat reduced by 4.5%-1.7%, while root length by 29.8-35.9% at 60 days after sowing.

Swamy *et al.* (2007b) examined the variation in growth, yield and nutrient uptake (N, P, K) in wheat under different densities of *Gmelina arborea*. The result suggested that *G. arborea* should be planted either at a wider spacing or silvicultural practices (loping and pruning) and nutrient management practices under narrow tree spacing should be adopted to obtain higher yields of wheat in agrisilviculture system.

Chauhan *et al.* (2008) carried out an experiment in the summer season of 2002-2004 to evaluate comparative performance of maize under various tree spacing of *Populus deltoides* including control plot (no trees). They reported that increase in distance between tree rows resulted higher growth in height, diameter at breast height, crown diameter and crown length of tree and grain yield in maize crop.

Islam *et al.* (2008) conducted a field experiment to evaluate the performance of seven winter vegetables under coconut-lemon based multistrata system. Tomato, chilli, carrot, onion, garlic, turnip and french bean were the tested vegetables under two treatments namely multistrata system (Lemon + Coconut based, 35-50% reduced Photosynthetic Active Radiation (PAR)) and full sunlight condition (100% PAR). There were significant variations in respect of plant height of winter vegetables (except chilli and turnip) under shade condition. On the other hand, significantly highest yield per plot and yield per hectare were observed when plant grown under full sunlight condition. Moreover, the economic analysis showed that among the seven vegetables, carrot gave the highest economic return (108,937 Tk./ha) followed by chilli (95295 Tk./ha) under multristrata (Lemon + Coconut) Agroforestry system.

Swamy *et al.* (2008) studied the variation in tree growth, above and below ground biomass and nutrient storage (N, P and K) in *Gmelina arborea* planted at three densities (4m × 4m, 4m × 6m and 4m × 8m) and their effect on productivity of wheat, linseed and mustard crops under agrisilviculture system. The yields of all crops decreased under *Gmelina arborea* stand in comparison to their sole crops after five years of its planting.

Basak *et al.* (2009) reported that the yield contributing characters of the vegetables increased gradually with the increase of planting distance of *Zylia dolabiformis* tree and the growth characters of *Zylia dolabiformis* tree are higher in association with soybean than tomato and radish.

Milon (2009) conducted an experiment to show the performance of winter vegetables grown under Loquat (*Eriobotrya japonica*) tree saplings of different distance i.e. mustard, chilli and brinjal and the result showed that the growth characters of Loquat significantly influenced by the interaction of three winter vegetables such as mustard, brinjal, chili. Performance of winter vegetables in terms of morphological parameters was affected significantly by different distance from tree sapling. The highest tree growth was recorded in tree chilli combination while the lowest tree growth was found under tree brinjal combination.

Sayed *et al*. (2009) showed that highest production of vegetables was recorded in control condition (without tree) which was significantly similar with 3 and 4 feet distance from the tree base and the lowest was observed under one feet distance which was almost similar with 2 feet distance.

Chandra *et al.* (2010) reported that a marked improvement in biochemical characteristics of soil under tree plantation of 12 different species of 19 to 23 years age. The results showed that substantial improvement in water holding capacity, porosity and organic matter. Soil nitrogen was improved by 39.8%, phosphorus 42.19%, Potassium 37% and calcium 52% under tree plantations compared to the unplanted site. The Copper content was 83.7% greater, while Iron, Magnesium, and Zinc were about 52% to 58.5% greater due to tree plantations. It was found that *Eucalyptus citrodora*, *Dalbergia sissoo* and *Bambusa arundinacea* were more efficient than other tree species in rehabilitating the soil. Under these trees, the content of organic matter, nutritional properties and microbial populations were greater than under other plantations. Soil microbial activity was enhanced up to 2.9 fold due to accumulation of humus through organic matter. Mycorrhizal density also improved over 5 times in plantation than unplanted soil.

Dhillon *et al.* (2010) investigated the micro-environmental modification under poplar tree canopy and resultant effect on physiology and yield of turmeric grown under poplar canopy. Significant variations were observed in micro-environmental and physiological parameters of turmeric crop under one and two year old poplar plantations. The tree canopies had major influence on photosynthetic active radiation (PAR), humidity and air temperature. The light interception was higher in two year old poplar than one year old. The average air temperature under the canopy was lower than in open area, whereas, it was reverse for relative humidity. The physiological parameters of turmeric, the net photosynthesis, transpiration, water use efficiency and carboxylation efficiency were influenced significantly under poplar canopy than open conditions and higher values were recorded for all the physiological parameters in tree-less plot whereas, crops under two year old canopy recorded the least values. the yield reduction (14.65 %) was significantly more in the turmeric grown under two year old poplar and it was 11.33% under one year old plantation. The growth and development of turmeric under poplar canopy was strongly controlled by PAR.

Gandhi and Dhiman (2010) studied poplar plantation planted at spacing of 5 × 5m, 5 × 4m, 6 × 6m, 6 × 5m, 6 × 3m, 6 × 1.5m and 7 × 5m and their effect on productivity of wheat crop under poplar-wheat based agrisilviculture system. Poplar trees put significantly greater height and DBH growth at spacing of 7 × 5m in comparison to trees grown at a spacing of 5 × 5m, 6 × 3m and 6 × 1.5m. There were significant differences in mean values for grain yield, harvest index, length of spike, and number of sterile spikelets/spike, number of grains/spike and for weight of grains/spike of wheat crop as a result of tree spacing. Wheat crop grown under 6 × 6m tree spacing had produced maximum grain yield, harvest index, straw yield, number of spikes/m^2, length of spike, number of fertile spikelets/spike, number of grains/ spike, weight of grains/ spike and 1000 grain weight, whereas, wheat under 6 × 1.5m tree spacing produced maximum number of sterile spikelets/spike when compared with that of other spacing.

Hanif *et al.* (2010) studied the performance of three okra varieties viz. hybrid okra, BARI-1 and local okra variety under litchi based agroforestry system. There was also a control (sole cropping) treatment. The yield was highest (10.24 t/ha) in monocropping of hybrid okra and the lowest yield (4.24 t/ha) was found in Litchi + Local okra variety. But the litchi based agroforestry system ensures higher return and more sustainable than sole cropping.

Pant *et al*. (2010) investigated performance of Taro (*Colocasia esculenta*) under poplar (*Populus deltoides*) tree spacing (5m ×4m, 5m × 3m and open) and six nitrogen levels (0, 50, 75, 100, 125 and 150 kg/ha) in subtropical zone of Himachal Pradesh. The overall relative illumination below 5m × 4m and 5m ×3m poplar spacing was 48 and 40%, respectively. The nitrogen application induced improvement over control but failed to obtain significant difference in growth and yield parameters of the crop except number of leaves per plant. The nutrient content (N, P and K) in corm as well as leaf depicted an improvement with increase in nitrogen level. The shade of trees brought drastic reduction in growth and yield of crop compared to open. Among N, P and K contents in corms, only P and K were influenced significantly due to poplar spacing, both registered only significant influence on plant height and number of leaves per plant.

Prasad *et al*. (2010) carried out on-farm experiments for over 4 years to examine whether wide-row planting and grouping of certain tree rows will facilitate extended intercropping without sacrificing wood yield. *Eucalyptus* planted in five-spatial arrangements in agroforestry [3 × 2 m, 6 × 1 m, 7 × 1.5 m paired rows (7 ×1.5 PR), 11 × 1 m paired rows (11 × 1 PR) and 10 × 1.5 m triple rows (10 × 1.5 TR)] was compared with sole tree stands at a constant density of 1,666 trees ha-1. Cowpea (*Vigna unguiculata*) was intercropped during the post-rainy seasons from 2001 to 2004, and fodder grasses (*Panicum maximum* and *Brachiaria ruziziensis*) were intercropped during both the seasons of 2005. At 51 months after planting, different spatial arrangements did not significantly affect height and diameter at breast height (DBH). Total dry biomass of eucalyptus in different spatial arrangements ranged between 59.5 and 52 Mg ha^{-1}, the highest being with 6 × 1 m and the lowest with 10 × 1.5 triple rows, but treatment differences were not significant. The widely spaced paired row (11×1 PR) and triple row (10 × 1.5 TR) arrangements produced 62–73% of sole cowpea yield in 2003, 59–66% of sole cowpea yield in 2004, and 79–94% of sole fodder in 2005. In contrast, the 3 × 2 m spacing allowed only 17–45% of sole crop yields in these years. Intercropping of eucalyptus in these wider rows gave 14% greater net returns compared with intercropping in eucalyptus spaced at 3 × 2 m, 19% greater returns compared with that from sole tree woodlot and 263% greater returns compared with that from sole crops.

Tanni (2010) conducted an experiment to observe the growth and yield of tomato, radish, soybean and lettuce grown at different distance of Loquat tree (*Eriobotrya japonica*) and also under pruned and unpruned condition of the tree. The result of the experiment showed that the yield of crops increased gradually with increase of planting distance from the tree and crops under pruned condition of providing better yield performance compared to unpruned condition. The growth characters of Loquat tree are not satisfactory in association with tomato and radish but quite better in association with lettuce but found higher in association with soybean.

Kumar *et al.* (2011) conducted study to estimate the biomass production and nutrient removal by eight years old poplar plantation planted at different spacing of 5×4m, 10 × 2.5m and 15 × 2.5m. Biomass of all the plant parts decreased with increasing tree spacing except that the differences between 10 × 2.5m and 15 × 2.5m spacing. The total tree biomass including litter fall was higher in 5 × 4m (415 t/ha) followed by 10 × 2.5m (330 t/ha) and 15 × 2.5m (192 t/ha) spacing. Concentration of both primary and secondary nutrients in different plant parts differed significantly at different spacing. Maximum nutrient concentration was recorded in leaves at 15 × 2.5m spacing. However, poplar stem accounted for maximum uptake of all the nutrients. Among poplar spacing, closer tree spacing of 5 × 4m recorded maximum uptake of both primary and secondary nutrients except that K and Mg uptake was maximum at 10 × 2.5m spacing.

Manuel Bertomeu (2011) conducted on-farm experiments in Philippines to study the growth of two timber trees, Gmelina (*Gmelina arborea* R. Br.) and *Eucalyptus deglupta*, and their impact on the grain yield of intercropped maize. The experiment consisted of maize monocropping plots (control) and maize intercropped between trees planted in block (2 × 2.5 m), and hedgerow arrangement (1 × 10 m). Three maize crops were planted in the block plots before canopy closure, and seven maize crops were planted in the hedgerow and monocropping plots. Maize grain yield in the hedgerow and in the block arrangement with Gmelina were respectively 37% (16.58 tons ha^{-1}) and 68% (8.3 tons ha^{-1}) lower than in monocropping (26.21 tons ha^{-1}). In the plots with *Eucalyptus deglupta*, maize grain yield in hedgerow and in block arrangement were respectively 19% (24.8 tons ha^{-1}) and 66% (10.4 tons ha^{-1}) lower than in monocropping (30.6 tons ha^{-1}). For both tree species, the diameter at breast height (DBH) was greater in hedgerow than in block arrangement, with the difference being more pronounced with age. It was estimated that Gmelina planted in hedgerows would produce 6–8 m3 ha-1 of merchantable volume more than if planted in block. The study verifies the hypothesis that intercropping between widely-spaced trees rows (planted at 10 m or more) is more profitable and feasible to smallholders than either maize monocropping or woodlots.

Sanou *et al.* (2011) conducted an experiment in Burkina Faso to assess the effect of shade of two indigenous fruit trees, *Adansonia digitata* (Baobab) and *Parkia biglobosa* on a shade-tolerant crop called taro (*Colocasia esculenta*) in comparison with millet (*Pennisetum glaucum*) a shadeintolerant crop. Photosynthetically active radiation (PAR) and performance of crops under trees and in the open field were assessed during three cropping seasons. Millet performed better under baobab (806.1 ± 121.48 kg ha^{-1}) compared to the control plot (595.8 ± 83.43 kg ha^{-1}) and *Parkia biglobosa* (320.2 ± 59.91 kg ha^{-1}). In contrast, the yield of taro was higher under *Parkia biglobosa* (4124.0 ± 469.05 kg ha^{-1}) compared to the control plot (2336.9 ± 617.04 kg ha^{-1}) and baobab (2738.3 ± 595.61 kg ha^{-1}). There was a strong relationship between the amount of PAR intercepted by trees and crop yields under trees. As PAR decreased, the yield of millet decreased, whereas, the yield of taro increased.

Sehgal (2011) conducted field experiment to examine the effect of spacing and organic manures on *Ocimum basilicum* intercropped with *Leucaena leucocephala*. The results showed that closely spaced (0.50 m) *Leucaena* hedgerows negatively influenced various growth and yield attributes like plant height, number of inflorescence and economic yield of the associated herb as compared to its wider spacing (0.75 m and 1.50 m). Irrespective of the tree spacing the growth of *O. basilicum* was suppressed to a greater extent at a distance closer to the hedgerows in all the treatments.

Babu (2012) conducted an experiment to study the growth and yield of two winter vegetables i.e. chilli and sweet gourd under different spacing of Eucalyptus tree, and he found that all the parameters i.e. plant height, diameter, leaf length, leaf diameter, no. of fruits/plant, yield were increased gradually with increasing distance from Eucalyptus tree rows. It was concluded that boundary plantation of Eucalyptus has negative effect on the growth & yield of chilli & sweet gourd.

Patil *et al*. (2012) conducted an experiment on *Melia azedarach* based Agroforestry system consisted of four spacing *viz*, 5m × 1m, 5m × 2m, 5m × 3m and 5m × 4m. Soybean (JS- 335) crop was grown in the interspace of *Melia azedarach* rows during kharif every year.

Fertilizer dose of 100:50:100 NPK kg/ha was applied to *Melia azedarach* in the initial four years. At the end of 10th year the soybean yield were significantly decreased in 5m × 1m and 5m × 2 m spacing of *Melia azedarach* as compared to 5 × 4m spacing. The diameter at breast height was significantly higher in wider row spacing *viz.*, 5m × 4m as compared to 5m × 1m spacing. The net returns and B: C ratio were significantly higher in *Melia azedarach* at 5m × 4m soybean followed by at (5m × 3m) + soybean as compared to the other treatments.

Singh and Hymavathi (2012) conducted field experiment with three planting geometries (4 × 4m, 5 × 5m, and 6 × 6m) of *Dalbergia sissoo* and intercropped *zea maize* using two spacing (60cm and 120cm) of tree to crop line and evaluated soil properties and growth parameters of *Dalbergia sissoo* intercropped with *Zea mays*. The soil pH was found slightly alkaline and Electrical conductivity (E.C.) value showed noticeable increase. Organic carbon, available nutrients (N and K) and exchangeable cations (Mg and Ca) were found medium, whereas, available phosphorus found to be very low in all spacing. Growth parameter of *Dalbergia sissoo* showed a regular increase both in height and collar diameter along with maize crop in all the spacing. The maximum increase in height (22.56cm) and collar diameter (0.628cm) was observed in spacing of 6m × 6m and 60cm crop line spacing with regards to initial height and collar diameter. Tree spacing of 5m × 5m with 60cm crop line spacing produced maximum yield of maize crop in *Dalbergia sissoo-Zea mays* agrisilviculture system.

Hanif and Bari (2013) conducted an experiment to evaluate the potential of the Agrisilvicultural system which includes planting of potato on the floor of three different multipurpose tree species viz. *Leucaena leucocephala, Melia azedarach* and *Albizia lebbeck*. There was also a control treatment i.e. sole cropping of potato. The results showed that, potato production under *Melia azedarach* based agrisilvicultural system was highest (29.20 tha^{-1}) as compared to sole cropping of potato. On the other hand, lowest (8.76 $t\ ha^{-1}$) yield was recorded under *Albizia lebbeck* + Potato based agrisilvicultural system. But the Benefit cost Ratio (BCR) was highest (3.75) in agrisilvicultural system as compared to sole cropping of potato.

2.2 Effect of organic manures on growth and yield of crops

In an experiment conducted by Renuka and Ravishankar (2001), the application of biogas slurry + FYM, vermicompost + FYM, vermicompost alone have recorded maximum fruit size, more number of fruits per plant, while inorganic fertilizers (NPK) recorded the minimum fruit size. It is inferred that tomato crop would respond well to the application of organic manures either in combination with FYM or alone. Further, organic manures application helps to maintain good soil health.

Baig *et al.* (2004) studied the effect of organic manures (green manure and farm yard manure) on rice in saline- sodic soil. *Sesbania aculeata* was grown as a green manure crop for 2 months and then incorporated into the soil. FYM was applied at 0, 5, 10 and 20t/ha before sowing of *S.*

aculeata. Rice cv. Basmati 385 was used as indicator crop. Result showed that both grain and straw yield were significantly improved by the application of *S. aculeata* and FYM. Productive tillers were also increased by the application of FYM. The increase in grain yields with the application of 5t/ha, 10t/ha and 20t/ha FYM were 6.8%, 24.4% and 37.6% over the control, respectively. Nitrogen and phosphorus uptake was also improved by the application of green manures and different rates of FYM.

Bheemaiah and Subrahmanyan (2004) reported that alley cropping planted with *Dalbergia sissoo* and *Leucaena leucocephala* enhanced the pod yield of rainfed groundnut. They concluded that application of lopped foliage from the above nitrogen fixing trees as green manure further enhanced the productivity of groundnut and helped in reducing the required dosage of N-fertilizer. This technology was considered as economically viable option for the farmers growing groundnut under rainfed conditions in alfisols.

Panneer and Bheemaiah (2005) conducted field experiment to evaluate three intercropping systems (intercropping of sunflower with neem, intercropping of sunflower with *Melia* and sole cropping of sunflower) under different integrated nutrient management practices and reported that all integrated nutrient management practices significantly enhanced Nitrogen uptake, agronomic efficiency, apparent N recovery and seed yield of sunflower, bur net return and benefit cost ratio were higher with the recommended dose of fertilizers. Conjunctive use of N with green leaf manure was advantageous in enhancing crop yield and sustaining soil health.

Jat and Thakur (2010) carried out field experiment to assess the integration of medicinal herb (*Matricaria chamomilla*) with poplar trees by using organic manure as sources of soil nutrient to minimize competition for resources. The result revealed that *Matricaria chamomilla* can be grown successfully with poplar trees. The presence of trees had little suppressing effect on the yield and other growth parameter of herb even at distance close to tree trunk. The use of organic manures like vermicompost and FYM at appropriate doses was found beneficial for minimizing competition for critical resources.

Thakur *et al.* (2010) studied the compatibility of medicinal and aromatic herb species in association with poplar trees. Integration of medicinal and aromatic herbs namely, *Digitalis lanata*, *Matricaria chamomilla* and *Salvia sclaria* with *Populus deltoides*, planted at 4 × 4m spacing on farmland suggested better option for diversification of farming systems. It was indicated that no substantial adverse impact of the presence of tree canopies on growth, yield and physiological parameters of these medicinal and aromatic herbs. Application of fertilizers and farmyard manure was found to be very useful for enhancing growth and production ability as well as photosynthetic efficiency of all the herb species. Nitrogen @ 100 kg/ha and FYM @ 4 t/ha in the presence as well as absence of poplar trees proved most effective. Growth with respect to height, leaf number, spread, flower number, branch number and leaf area index, all index of better growth, was significantly higher in fertilizer and FYM treated plots in comparison to control plots. Production increased with the use of fertilizers and FYM even in the presence of tree canopies.

In an experiment carried out by Joshi and Vig (2010), cattle dung vermicompost (VC) was used to prepare different proportions of soil and vermicompost mixtures viz. Soil (control), VC15 (Soil+15% VC), VC30 (Soil+30% VC), VC45 (Soil+45% VC). Vermicompost was chemically analysed for various parameters like pH, Total Kjeldahl Nitrogen (TKN), Total Available Phosphorous (TAP), Total Sodium (TNa), Total Organic Carbon (TOC) and Electric Conductivity (EC). Germination percentage was noticed for each treatment. Various growth and yield parameters like mean stem diameter, mean plant height, yield/plant, marketable yield/plant, mean leaf number, total plant biomass were recorded for each treatment. Various quality parameters like ascorbic acid, titrable acidity, soluble solids, insoluble solids and pH were recorded for tomatoes from each treatment. Germination percentage was found the maximum at VC15 treatment that decreased in the subsequent treatments. Almost all the growth, yield and quality parameters increased significantly as compared to control, though the increase within the treatments was not found to be significant.

Sehgal (2011) conducted field experiment to examine the effect of spacing and organic manures on *Ocimum basilicum* intercropped with *Leucaena leucocephala.* The use of organic manures benefited the intercrop by improving the growth even in the presence of hedgerows as compared to control plots (without trees).

Chanda *et al.,* (2011) conducted field trials by using different fertilizers having equal concentration of nutrients to determine their impact on different growth parameters of tomato plants. Six types of experimental plots were prepared where T_1 was kept as control and five others were treated by different category of fertilizers (T_2 Chemical fertilizers, T_3 Farm yard manure (FYM), T_4 Vermicompost, T_5 and T_6 FYM supplemented with chemical fertilizers and vermicompost supplemented with chemical fertilizer respectively).The treatment plots (T_6) showed 73% better yield of fruits than control, Besides, vermicompost supplemented with

N.P.K treated plots (T_5) displayed better results with regard to fresh weight of leaves, dry weight of leaves, dry weight of fruits, number of branches and number of fruits per plant from other fertilizers treated plants.

Bahrampour and Ziveh (2013) conducted an experiment to determine the effect of vermicompost on growth, yield and fruit quality of tomato (*Lycopersicum esculentum*) var. Super Beta) in a field condition. The different rates of vermicompost (0, 5, 10 and 15 t ha^{-1}) were incorporated in to the top 15 cm of soil. The results revealed that addition of vermicompost at the rate of 15 t ha^{-1} significantly (at $p<0.05$) increased growth and yield compared to control. Vermicompost at the rate of 15 t ha^{-1} increased EC of fruit juice and percentage of fruit dry matter up to 30 and 24%, respectively. The content of K, P, Fe and Zn in the plant tissue increased 55, 73, 32 and 36% compared to untreated plots respectively. The result showed that addition of vermicompost had significant ($P<0.05$) positive effect on growth, yield and elemental content of plant as compared to control.

John and Prabha (2013) carried a study to understand the effect of vermicompost on the growth and yield of *Capsicum annum*. The results revealed that the total macronutrients and micronutrients showed elevated levels in vermicompost when compared to control. The enzyme activities amylase, cellulase, invertase, biochemical parameters namely protein; physiochemical parameters namely pH showed elevated levels after vermicomposting. The vermicompost applied plant *Capsicum annum* showed an increased shoot length and number of leaves when compared to the plants fertilized with inorganic fertilizer.

Najar and Khan (2013) conducted an experiment to investigate the effect of different rates of vermicompost on germination, growth and yield of *L. esculentum* under field conditions. The data revealed that different rates (2t/ha, 4t/ha and 6t/ha) of vermincompost produced varied and significant ($P < 0.05$) effect on the germination, vegetative growth parameters (shoot length, root length, leaf area, dry shoot weight, dry root weight and dry weight leaves) recorded at different intervals, yield parameters (number of clusters per plant, fruits per cluster, number of fruits per plant, mean fruit weight and total yield/plant) and marketable fruits. Dose of 6t/ha significantly ($P < 0.05$) increased germination (10.33%), mean fruit weight (41.64%), total yield (146.28%) and marketable fruits (7.19%) as compared to control.

Umrao *et al.* (2013) conducted experiment on effect of organic fertilizers on the growth and yield of garlic (*Allium sativum*) under *Tectona grandis* based Agroforestry System with seven treatments each in open and shade conditions. The treatment combinations used were control, FYM, vermicompost, neem cake, 50% FYM + 50% vermicompost, 50% FYM + 50% neem cake, 50% vermicompost + 50% neem cake. The results showed that different treatment of organic fertilizers had a positive effect on the growth and yield of plants under both open and shaded conditions but plants grown under shade conditions performed better in comparison to the ones grown in the open. Among all the treatment combination the application of FYM have better influence on growth and yield of garlic under open and shade conditions but more yield was obtained with the application of FYM under light shade of trees.

Kumar *et al.* (2014) conducted a study to investigate the influence of different organic manure doses on the herbage biomass and essential oil yield and oil quality of patchouli *Pogostemon cablin* (Blanco) benth under teak based agroforestry system. He concluded that, among seven treatment of different organic manure tested, the 100% vermicompost exhibited significantly high dry herbage yield, essential oil yield and oil content (%) in first second and third harvest per year from patchouli crop under teak based agroforestry system.

2.3 Effect of trees and organic manures on soil physical and
Chemical properties

Nair (1984) reported that the trees are not the only sources of addition of organic matter to the soil in an agroforestry system; but herbaceous components may also constitute a significant addition (e.g., cereal straws). It is therefore evident that management practices are the key to organic matter maintenance in agroforestry systems: if a major part of the tree and crop residues are returned to the soil, soil organic matter levels can not only be maintained, but can even be improved. Soil changes under trees may be species specific and also dependent on size and age of trees and site conditions. Soils under leguminous trees such as *Prosopis cineraria*, *Acacia tortilis and Parkia biglobosa* tends to be more acidic than soils under non-leguminous trees such as Baobab and Karite (Belsky *et al.*, 1993).

Several studies have reported that there is improved soil fertility in terms of soil organic matter, extractable P and exchangeable cations under trees compared with treeless areas (Campbell *et al.*, 1994). In Burkina Faso, soil under *Faidherbia albida* showed higher nutrient status than soils in open area: 14-100% more organic carbon, 13-117% more N, 18- 36% more extractable P, 2-67% more exchangeable Ca and 60-100% more exchangeable K (Depommier *et al.,* 1992). The fertility improvement was recorded mostly in the top soil (0- 20cm). Generally, there was a fertility gradient with fertility deceasing from a tree base to the edge of its crown or beyond.

Bhardwaj *et al.* (2001) reported that the nutrient accumulation in the biomass differed with tree density. The maximum nutrient content was present in the closest spacing. He also reported that organic carbon content in the soil decreased with the decrease in tree density. The nutrient return through litterfall was less in closer spacing as compared to the total uptake which created nutrient deficit in the soil.

Imayavaramban *et al*. (2001) reported that the soil under *Leucaena leucocephala* showed a trend of improvement in physico-chemical properties, viz., pH, EC and fertility enrichment of organic carbon and available nutrient status.

Lodhiyal *et al.*, (2002) reported that the total amount of nutrient return to the soil through litter increased with increase in plantation age because of higher litter accumulation. The nutrient use efficiency (NUE) ranged from 70 (1-yr) to 80 (4-yr) for N, 580 (1-yr) to 625 (4-yr) for P and 119 (3-yr) to 120 (4-yr) for K.

Anwer *et al*. (2005) reported that application of organic manure (FYM and vermicompost) and inorganic fertilizers nitrogen-phosphorus-potassium (NPK) increase soil organic carbon (C), available N, and P in soils. The soils received organic manure alone or in combination with inorganic fertilizers have higher available nutrients and soil organic carbon than control (no fertilizer or manure) and inorganic fertilizer treated soil. This study indicates that combined application of organic manure and fertilizer helps to increase crop productivity, quality and maintaining soil fertility.

Das and Chatrvedi (2005) studied nutrient concentrations in plant and soil and their rates of cycling in poplar (*Populus deltoides*) based agroforestry systems. The nutrient concentrations in the standing biomass of the crop were more than those in tree, whereas, the nutrient contents showed the reverse trend. Soil, litter and vegetation accounted for 80.3- 99.5%, 0.1-5.0% and 0.4-14.7%, respectively, of the total nutrients in the system. Considerable reduction (40-54%) in concentration of nutrients in leaves occurred during senescence. The uptakes of nutrients by vegetation, and also by different components with and without adjustment for internal recycling, were calculated separately. Annual transfer of litter nutrient to the soil by vegetation was 37.3-146.2 N, 5.6-17.9 P and 25.0-66.3 K kg ha^{-1} $year^{-1}$ in young (3-year-old) and mature 9-year-old plantations. Turnover rate and time for different nutrients ranged between 0.86-0.99 $year^{-1}$ and 1.01-1.16 years, respectively.

Isaac *et al.* (2005) studied carbon and nitrogen dynamics in a twenty-five year chronosequence of cacao (*Theobroma cacao* Linn.) plantations. Three treatments were selected as on-farm research sites: 2, 15 and 25-year-old plantations. Soil carbon (C, to a depth of 15 cm) varied between treatments (2 years: 22.6 Mg C ha^{-1}; 15 years: 17.6 Mg C ha-1; 25 years: 18.2 Mg C ha^{-1}) with a significant difference between the 2 and 15 and the 2 and 25-year-old treatments ($p < 0.05$). Total soil nitrogen in the top 15 cm varied between 1.09 and 1.25 Mg N ha^{-1} but no significant differences were noted between treatments. Soil nitrification rates and litter fall increased significantly with treatment age.

Mishra *et al.* (2006) reported that available N, P and K in the soil improved significantly after 6 years of poplar plantation. It was higher at 0-20cm and decreased with soil depth. At 0-20cm soil depth, N increased from 14.9 to 24.1%, P from 17.2 to 23.3% and K from 3.1 to 5.1% under different clones of poplar.

Mucheru *et al.* (2007) conducted an experiment to investigate the effects of different soil-incorporated organic manure, (*Tithonia diversifolia*, *Calliandra calothyrsus*, *Leucaena leucocephala*) and mineral fertilizer inputs on maize yield, and soil chemical properties over seven seasons. On average, *Tithonia* treatments (with or without half recommended rate of mineral fertilizer) gave the highest grain yield (5.5 and 5.4 Mg ha^{-1} respectively) while the control treatment gave the lowest yield (1.5 Mg ha^{-1}). After 2 years of trial implementation, total soil carbon and nitrogen contents were improved with the application of organic residues, and manure in particular improved soil calcium content.

Gupta *et al.* (2009) collect the surface and subsurface soil samples from Agroforestry and adjoining non-agroforestry sites with different years of poplar plantation (1, 3 and 6 years) and varying soil textures (loamy sand and sandy clay) and analyzed for soil organic carbon, its sequestration and aggregate size distribution. The average soil organic carbon increased from 0.36 in sole crop to 0.66% in agroforestry soils. The increase was higher in loamy sand than sandy clay soil.

Manivannan *et al.* (2009) conducted a field experiment to evaluate the efficacy of vermicompost, in comparison to inorganic fertilizers–NPK, on the physico-chemical and biological characteristics of the soils – clay loam soil (CLS) and sandy loam soil (SLS) and on the growth, yield and nutrient content of beans – *Phaseolus vulgaris*. Results showed that the application of vermicompost @ 5 tonnes ha-1 had enhanced significantly the pore space (1.09 and 1.02 times), water holding capacity (1.1 and 1.3 times), cation exchange capacity (1.2 and 1.2 times). It reduced particles (1.2 and 1.2 times), and bulk density (1.2 and 1.2 times), pH (1 and 1.02 times) and electrical conductivity (1.4 and 1.2 times) and increased organic carbon (37 and 47 times), micro (Ca 3.07 and 1.9 times, Mg 1.6 and 1.6 times, Na 2.4 and 3.8 times, Fe 7 and 7.6 times, Mn 8.2 and 10.6 times, Zn 50 and 52 times and Cu 14 and 22 times) and macro (N 1.6 and 1.7 times, P 1.5 and 1.7 times, K 1.5 and 1.4 times) nutrients and microbial activity (1.4 and 1.5 times) in both soil types, particularly more in CLS. The growth, yield (1.6 times) and quality protein (1.05 times) and sugar (1.01 times) content in seed) of bean were enhanced in CLS than SLS. On the other hand, the application of inorganic fertilizers @ 20:80:40 kg ha^{-1} has resulted in reduced porosity (1.03 and 1.01 times), organic carbon (1.04 and 9.5 times) and microbial activity (1.02 and 1.03 times) in both soil types.

Singh *et al*. (2010) conducted a study to evaluate the effect of pure stands of tree species and poplar-based agroforestry system for soil organic carbon (OC) and available N, P and K contents. Depth wise soil samples were taken from 13-year old *Eucalyptus tereticornis* (eucalyptus), *Azadirachta indica* (neem), *Melia azedarach* (dek), *Dalbergia sissoo* (shisham), *Albizia lebbeck* (siris), *Leucaena leucocephala* (subabul) and *Acacia nilotica* (kikar) spaced at 6 × 3 m and adjoining open area (control). Similarly, samples were taken from an agroforestry system having poplar planted at a spacing of 5 × 4 m and intercropped with pearlmillet-wheat rotation for six years and sole pearlmillet-wheat rotation at PAU Ludhiana. Soil OC and available nutrients were significantly higher in the surface soil depth (0-15 cm) than the lower depths irrespective of tree species. Organic carbon and available nutrients were significantly more under all the tree species compared to control in the surface layer. Organic carbon increased by 90.3 per cent under siris followed by kikar (84.5%), shisham (82.2%) and subabul (80.8%) over control (3.81 g/kg). The available N, P and K contents in surface layer were higher under subabul, siris, shisham and kikar than the other tree species. In poplar-based agroforestry system, the average contents of OC, N, P and K were higher by 22.2, 10.2, 33.6 and 4.5% respectively, than pure pearlmillet-wheat rotation. However, the interaction effects of soil depths and cropping systems were significant only for OC and available P.

2.4 Benefits of agroforestry system

Chauhan *et al.* (2010a) assessed carbon storage by poplar based agrisilvicultural system and change in soil organic carbon. After six years of poplar plantation total biomass in agrisilviculture system was found to be 25.2 tones/ha, which was 113.6% higher than sole wheat cultivation. Poplar tree stem alone contributed 21.99 tones/ha, which is very significant proportion and goes to the durable products. Net carbon storage (soil + tree/crop biomass) was 34.61 tones/ha in wheat-poplar interface compared to 18.74 tones/ha in sole wheat cultivation (soil + crop biomass). After six years of poplar planting organic carbon increased in soil (0-15cm) by 35.6% than pure wheat crop. There was substantial loss in yield of wheat crop under poplar but the decrease in wheat yield has been compensated by the poplar trees in terms of biomass, economic and carbon mitigation potential.

Chauhan *et al.* (2010b) quantified organic carbon in poplar-wheat based agrislviculture system and reported that at a rotation of seven years, timber carbon content was 23.57 t/ha and an equal amount was contributed by roots, leaves and tree bark. The contribution of branches was 24% of the total 62.8 tones poplar biomass (carbon storage) in seven years. Soil organic carbon increase was also substantial under tree-crop interface than sole wheat cultivation. The annual biomass in agroforestry intervention not only accumulated sixty per cent more carbon but a major portion of carbon is stored over a long period than sole crop.

Srinivasan *et al*. (2010) studied the effects of intercropping of three fast growing multipurpose trees viz. *Casuarina equisetifolia*, *Ailanthus triphysa* and *Leucaena leucocephala* planted in one year old coconut plantation, on soil physico-chemical and biological properties. The experiment was laid out during 1993 in one year old coconut plantation spaced at 7 × 7m. The MPTs were planted between rows of coconut at spacing of 2.33m. The observation on soil physico-chemical properties was made during 2004-2006 period. MPTs had tremendously increased the water holding capacity (77.80%) and infiltration capacity (18.5cm h-1) of the soil. Coconut plots interplanted with Casuarina showed lower soil pH (4.9) values compared to sole-coconut plot while highest pH was recorded in sole coconut plot. Agroforestry practices considerably increased the organic carbon content of the soil (were 1.52% instead of 0.65% in control). Leucaena interplanted plots shown higher concentration of available N (203.64 ppm) while, Casuarina interplanted plots showed higher available P (9.85 ppm), available K (66.18 ppm) and the surface layer had more concentration of available nutrients. As the soil depth increases the available nutrient concentration was found to decrease.

Mahmood *et al.* (2011) studied leaf litter decomposition of *Azadirachta indica*, *Dalbergia sissoo*, and *Melia azedarach.* Leaf litter decomposition experiment was conducted using litterbag technique to assess the nutrient return efficiency of these species. The decomposition rate of leaf litter was highest in *M. azedarach* and lowest in *D. sissoo*. The highest decay constant was observed in *M. azedarach* (6.67). Nitrogen and Phosphorus concentration in leaf litter showed a decreased trend sharply at the end of the first month, whereas rapid decrease of potassium concentration was reported within 10 days. Conversely, higher concentration of nutrient was observed at the later stages of decomposition. All three species showed a similar pattern of nutrient release (K > N > P) during the decomposition process of leaf litter. Among the studied species, *D. sissoo* was best in terms of N and P return and *A. indica* was best in terms of K return.

Kremer and Kussman (2011) carried out an experiment to assess the effects of a perennial legume, kura clover (*Trifolium ambiguum* M. Bieb.), on soil quality in a recently established pecan (*Carya illinoinensis Wangenh*) orchard. The pecan-kura clover Agroforestry practice was established on deep loss soils of the Missouri River hills landscape. These silt loams are on 2–20% slopes and can be highly erosive. Kura clover, introduced as the alley crop 5 years after pecan planting, was selected based on its perennial growth habit, nitrogenfixing ability, winter hardiness, high forage quality, and soil conservation properties. Kura clover was seeded in 2001 and harvested for hay annually beginning 2003. Soil quality indicators of total organic C, total N, water-stable aggregates, and selected soil enzymes were determined on surface soil samples collected annually after kura clover establishment. Soil organic C and activities of soil enzymes increased compared with cultivated and grass pasture control soils by the eighth year of establishment. Water-stable aggregation improved by 50% and surface soil shear strength improved significantly ($P<0.05$) in alleys compared with control sites. Results illustrate that kura clover as the alley-cropped component improved soil fertility and biological activity through increased organic matter and improved soil structure, and yielded high quality valuable forage for the cattle-feeding operation. Kura clover maintained or improved soil quality, reduced soil erosion potential, and benefited pecan growth by providing a source of soil nitrogen and improving soil structure for adequate water infiltration and aeration.

Wang and Cao (2011) carried out field experiment to examine the effects of different *Ginkgo biloba* tree species and crop species combinations on soil fertility. Two *Ginkgo biloba* and crop species systems were established: *Ginkgo biloba* + wheat + soybean (G + W + S), *Ginkgo biloba* + rape + soybean (G + R + S), and one *Ginkgo biloba* + mulberry (G + M) system, one pure mulberry plantation (M), and one crop systems of rape + soybean (R + S). Soil chemical properties and enzymes activities were measured 4 years after planting. These soil chemical properties and enzyme activities were used as soil fertility indicators (FI). The result showed that soil chemical properties (including pH, organic matter, total N, hydrolysable N, available P and K, total K) and soil enzyme activities (including catalase, sucrase, urease, dehydrogenase, phosphatase, polyphenol oxidase and protease) in the five planting systems were significantly different from each other (P = 0.0237). The concentration of total N, P, organic matter, available P and K of soil decreased significantly with soil depth (P = 0.0146), however, pH increased. The concentrations of organic matter, total N, hydrolysable N, available P and K of soil under rape + soybean (R + S) was lowest among the five planting systems. The integrated evaluation of soil fertility showed that soil fertility indicators (FI) were significantly different, and the FI values for the five systems followed order: G + M (0.847) > G + W + S (0.446) > M (0.399) > G + R + S (0.343) > R + S (0.211). These results indicated that adoption of *Ginkgo biloba*-crop combination could lead to increased long-term sustainability of soil fertility by improving levels of soil organic matter, pH, available nutrient and soil enzyme activity.

2.5 Fruit tree based agroforestry

Ghosh (1987) carried out field trials of 3 tier cropping systems during 1983-84 at the experimental farm of the Central Tuber Crops Research Institute, Kerala. The first tier comprised 4 perennial species: coconut, banana, Eucalyptus hybrid (*E. tereticornis*) and *Leucaena leucocephala*. The second tier contained cassava and the third tier groundnut and French bean. Pure stands of perennials and cassava were also maintained separately as controls and all the crop species received recommended doses of fertilizers. Significantly better vegetative growth of cassava plants was observed when grown in association with banana, while no significant differences were recorded in the growth of the plants raised in pure and mixed stands with the other perennial species. Similarly, maximum fresh tuber yield was obtained from the cassava plants under banana. Tuber yield of cassava under *E. tereticornis*, however, was minimum and significantly less than that of the pure stand. Yield differences among other treatment combinations were not significant. Growth of banana and *L. leucocephala* was adversely affected by cassava during the first 12 months, whereas in *E. tereticornis* intercropped with cassava small increases in growth occurred up to 18 months old. However, stem girths of *E. tereticornis* and *L. leucocephala* were greater in pure stands than in mixed stands with cassava. *L. leucocephala* gave better herbage yield in a pure stand. Banana fruiting at 18 months after planting was less in banana/cassava plots than in the pure stand. There were significant differences in leaf area index and nutrient uptake of cassava under different perennials. Again, Ghosh *et al*. (1989) reported the results of the trials on sloping ground at the Central Tuber Crops Research Institute in Kerala in 1983-86 when cassava was planted under the canopy of coconut, banana, Eucalyptus or *Leucaena spp*. Cassava stimulated the growth of Eucalyptus but reduced the growth of *Leucaena spp*., particularly during the first 6-12 months of establishment. Shading by Eucalyptus increased from 15.0 to 52.6% over a 3-year period whereas shading by other perennials was observed only in adjacent rows of cassava. Growth and tuber yield of cassava in each year was greater when grown under banana than under any other crop and averaged 28.4 t/ha compared with 26.3 t for cassava grown in pure stand and 11.3 t when grown under Eucalyptus with groundnuts. *Vigna unguiculata* grown between rows of cassava reduced tuber yields less than the groundnuts and gave a fresh pod yield of 4.81 t/ha. Although the presence of cassava increased groundnut pod yield (1.07 t/ha), the perennial tree species, especially Eucalyptus, significantly reduced yield (0.41 t).

An experiment was conducted by Kamal Sharma *et al*. (1993) with six irrigated litchi orchards consisting of plants of different age groups (15-50 yr) around Jandwal and Kandwal areas in Kangra District, Himachal Pradesh to study the effects of shelterbelts of 3 species (*Eucalyptus*, *Grevillea* and *Leucaena*) on growth and yield of litchi plants. The shelterbelts were planted either earlier or after the establishment of the litchi orchards. Five litchi plants were selected randomly in different farmers' fields and at different distances from the shelterbelts, and data on plant height, girth, spread, leaf area and yield of litchis recorded during 1989-90. The results indicate that Eucalyptus had an inhibitory effect on growth and yield of litchis, which decreased with increasing distance from the shelterbelt. Growth at all distances from *Grevillea* and *Leucaena* shelterbelts was better than that associated with Eucalyptus. Best litchi growth was near *Leucaena* shelterbelts.

In a field study in 1997/98 in Kerala, yield correlations of twenty five green gram (*Vigna radiata*) genotypes grown under the shade of coconut trees were examined by Rajeswari and Kamalam (1999). They reported that seed yield/plant was positively associated with all the characters except the days to flowering, days to first harvest and seeds/pod. Pods/plant and pod length were the prime characters for yield improvement in green gram under partially shaded conditions.

The coconut based mixed species systems in the tropics often aim at improved resource capture through incorporating several trees and field crops. Productivity of palms and the associated tree components in such mixed systems are, however, known to vary in response to the tree characteristics, planting pattern/geometry and shade tolerance of the components. The effects of three fast growing trees (*Vateria indica*, *Ailanthus triphysa* and *Grevillea robusta*) grown in association with coconut palms following two planting geometries (single row and double row), on the productivity of coconuts and growth of multipurpose trees were studied in Kerala, India, during 1992-96 by Kumar and Kumar (2002). *A. triphysa* demonstrated better growth than others with mean annual increments of 118 and 2.62 cm year^{-1} for height and basal stem diameter (at 50 months after planting), respectively, compared to 98 and 1.26 cm year^{-1} for *G. robusta*, which showed the next best height growth. Shade tolerance appears to be a major determinant of tree growth rates. It is concluded that integrating shade tolerant timber trees in the coconut based production systems could increase the overall productivity and profitability of coconut farms with no adverse effect on the main crop yield in the short term.

The effect of irrigation and 3 multiple crop systems: (A) + black pepper (Piper nigrum) + cocoa + elephant foot yam; (B) banana + black pepper + acidlime + arrowroot and (C) banana + betelvine + pineapple + elephant foot yam, on arecanut yield in a 16-year-old plantation was studied in Jalpaiguri and Coochbehar, West Bengal between 1983 and 1988 by Singh and Baranwal (1993). In general, irrigation increased the yield of all crops compared with rainfed crops. The cultivation of mixed intercrops did influence the yield of arecanut; in crop system A (irrigated), the yield of arecanut rose by 4.1%, but arecanut yields decreased in all other plots by 10.5-24.2%. This decrease in yield was not as great as that observed in the control plot.

Korikanthimath *et al*. (2000) conducted an experiment at Sirsi, Karnataka during 1992-95 to explore the possibility of cultivating cardamom (*Elettaria cardamomum* Maton) as a mixed crop with coconut. The average size of coconut holdings is as low as 0.22 ha and 98% of the holdings are below 2 ha. The results revealed that tall coconuts and short cardamom plants with varying rooting patterns and spacings intercepted solar energy at different vertical heights, and their roots (rhizosphere) absorbed nutrients and soil moisture at different depths and lateral distances. The coconut canopy provided adequate shade for shade-loving cardamom in this multi-storeyed cropping system. Intercropping with cardamom reduced coconut yield compared with coconuts in monoculture (mean values of 85.7 compared with 91.3 nuts/palm), but intercropping with high value cardamom increased overall profits (cardamom yields in 1993-94 and 1994-95 were 15.66 and 554.2 kg/ha, respectively).

Osei *et al*. (2002) have undertaken an experiment to compare the merits of four cacao-coconut intercropping systems with the traditional cultivation of cacao under *Gliricidia sepium* shade at the Cocoa Research Institute of Ghana. Cacao seedling girth was not affected when intercropped with coconut but was significantly (P=0.01) reduced when intercropped with *G. sepium*. High density cacao facilitated better early canopy formation. Yield of cacao spaced at 2.5 m triangular (1739 plants ha^{-1}) with coconut at 9.8 m triangular (105 plants ha^{-1}) was significantly higher (P=0.05) than from the other treatments during 1993/94 to 1995/96. Widely spaced coconuts intercropped with cacao spaced at 3 m × 3 m showed better flowering and gave higher coconut yields, but cacao spaced at 2.5 m triangular under coconuts spaced at 9.8 m triangular was more profitable than the other treatments. Moisture stress was the greatest in cacao system with *G. sepium* shade and this could be responsible for the low yield of cacao in that treatment. It is suggested that properly arranged high density cacao under widely spaced coconuts can be a profitable intercrop system for adoption by cacao farmers in Ghana.

To evaluate the possibility of coffee production in the non-traditional and tribal area of Madhya Pradesh, India, yield variation in Coffea robusta (*C. canephora*) cv. Sanramon under different canopy shades was carried out. The experiment was conducted on 5 year old plants grown without shade, or with shade provided by mango, mango + banana, guava, guava + banana or teak (*Tectona grandis*). Mango, guava and teak were aged 50, 10 and 45 years, respectively. The coffee yield was highest (mean for 5 years of 345 kg/ha) under mango + banana, followed by guava + banana (294 kg/ha), with lower yields in pure stands of mango, guava and teak. Yield was zero under control conditions (no shade).

2.6 Litchi based agroforestry

Hanif *et al.* (2010) reported that a field experiment was conducted at the Agroforestry Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur, during 08 January 2009 to 08 April 2009 to evaluate the performance of Okra plant under litchi based agroforestry system. The treatments were three okra variety viz. hybrid okra variety, BARI-1 and local okra variety, which were used as ground layer crop. There was also control (sole cropping) treatment. This experiment was laid out using two factors Randomized Complete Block Design (RCBD) with three replication. The aim of the experiments was to study the growth performance and selection of potential okra variety under litchi based agroforestry system. The yield contributing parameters were maximum in sole cropping of hybrid okra. The yield was highest (10.24 t ha^{-1}) in monocropping of hybrid okra and the lowest yield (4.24 t ha^{-1}) was found in T_6 (Litchi + Local okra variety). But the litchi based agroforestry system ensures higher return and more sustainable than sole cropping. The suitability of okra variety may be ranked as Okra hybrid variety > BARI-1 okra > Local okra variety.

Rahman *et al.* (2016) reported that the experiment revealed that there was a significant effect of different variety and production systems on the growth and yield contributing characters of potato. Significant effect of eight potato varieties and production system was found on the plant height, leaf length, leaf breath, no. of leaf per shoot, no. of shoot per hill and yield. The highest tuber yield (18.88 tha^{-1}) was recorded in Lady Rosetta potato variety whereas the lowest tuber yield (12.29 tha^{-1}) was recorded in Diamond.

Uddin and Chowhan (2016) mentioned that an investigation was conducted at Borjona village of Kapasia, Gazipur district during September 2011 to October 2012 to examine the biological performance of Indian spinach and papaya in litchi based agroforestry system. Papaya was planted between two litchi plants in each line and Indian spinach varieties were grown in the inter-space of two lines of litchi plant as well as control (farmers practice) in May 2012. Yield and yield contributing characters of Indian spinach varieties grown as litchi-papaya based agroforestry system and control did not vary. However, sprout $plant^{-1}$ and sprout weight of Indian spinach varieties grown in litchi-papaya based system were significantly influenced while the other parameters did not vary. Sprout $plant^{-1}$ of KS green (2.97) and local (2.89) variety were identical but higher over KS red variety (2.57). Sprout weight of KS red variety was the highest (85.80 g) while KS green and local variety gave lower and identical sprout weight. Though the yield did not vary among the varieties, KS red gave the highest yield (36.32 t ha^{-1}) followed by local (34.61 t ha^{-1}) and KS green (34.00 t ha^{-1}). In case of growth of litchi, plant height and stem diameter increment were 21.39 and 44.94 % over the eleven months observation period. The yield of papaya was quite satisfactory with an average 42 fruits per plant with 23.71 t ha^{-1}. Therefore, in the Litchi-Papaya-Indian spinach based system, Indian spinach varieties could be ranked as KS red > Local> KS green.

Zaman *et al.* (2016) stated that a field experiment was conducted at the Agroforestry and Environment Research Field, Hajee Mohammad Danesh Science and Technology University, Dinajpur during 2013 to investigate the potentiality of three napier fodder varieties under Litchi orchard. The experiment was consisted of 2 factors RCBD with 3 replications. Among the two factors, factor A was two production systems; S_1= Litchi + fodder and S_2 = Fodder (sole crop); another factor B was three napier varieties: V_1= BARI Napier -1 (Bazra), V_2= BARI Napier - 2

(Arusha) and V_3= BARI Napier -3 (Hybrid). The experimental results revealed that there were significant variation among the varieties in terms of leaf growth and yield. The maximum number of leaf plant $^{-1}$ was recorded in variety Bazra (V_1) whereas the minimum number was recorded in hybrid variety (V_3). Significantly the highest (13.75, 14.53 and14.84 tha^{-1} at 1st, 2nd and 3rd harvest, respectively) yield was also recorded in variety Bazra whereas the lowest (5.89, 6.36 and 9.11 tha^{-1} at 1st, 2$^{nd\ v}$ and 3rd harvest, respectively) yield was in hybrid variety. Again, in case of production systems, there were also significant differences between the two production systems were found. The maximum number of leaf plant $^{-1}$ was recorded under Litchi based agroforestry system (T_1) whereas the minimum was recorded in open condition (T_2). Similarly, significantly the highest (12.00, 12.35 and 13.31 tha^{-1} at 1st, 2nd and 3rd harvest, respectively) yield of napier was recorded under Litchi based agroforestry system where as the lowest (9.73, 10.47 and 11.66 tha^{-1} at 1st, 2nd and 3rd harvest, respectively) yield was recorded in open condition i.e. napier in sole cropping. Furthermore, the interaction effect of napier variety and production systems were also gave significant deviation result in terms of growth and yield. The maximum number of leaf plant^{-1} was recorded under Litchi based agroforestry systems with Bazra variety whereas the minimum was recorded in open condition with hybrid variety. The highest yield (14.42, 16.14 and 16.15 tha^{-1} at 1st, 2nd and 3rd harvest, respectively) of napier was found under Litchi based agroforestry systems with Bazra variety. Significantly the lowest (5.33, 5.79 and 8.48 tha^{-1} at 1st, 2nd and 3rd harvest, respectively) yield was found in open condition i.e. sole cropping with hybrid variety. In case of the quality perspective, the highest nutritive value (DM, ASH, CP, CF, EE, and NFE) was found in Bazra (V_1) and the lowest value was found in hybrid variety (V_3). Therefore, the suitability of napier production under Litchi based AGF system may be ranked as Bazra > Arusha > Hybrid variety. Finally, the economic analysis showed that maximum BCR (5.20) was found in the Litchi based agroforestry systems over sole cropping (BCR=4.38). From the findings of the taken investigation, it may be concluded that the cultivation of Bazra napier variety in the floor of Litchi orchard ensures higher revenue to the farmers compared to its sole cropping.

2.7 Carrot production under different shade level

Omar *et al.* (2007) reported that as sole cropping, variety NK gave better performance than that of variety SB. Again, both the varieties produced maximum yield in sole cropping. In multistoried cropping system, goraneem + lemon based multistoried agroforestry system, gave better performance (NK 23.83 and SB

17.03 t/ha). Then goraneem + guava based multistoried agroforestry system (NK 12.41 and SB 12.00 t/ha). Except plant height and length of leave all other parameters were significantly lower in multistoried agroforestry system than sole cropping. The economic analysis showed that multistoried cropping of variety NK with goraneem+lemon was beneficial in terms of total net return from a unit area and time.

Bari and Rahim (2010) carried out an experiment at the existing multistrata sissoo woodlot of the Horticulture Farm, Bangladesh Agricultural University, Mymensingh, to investigate the performance of carrot as intercrop in sissoo based multistrata Agroforestry system (MAF) and also to observe the effect of different spacing of upper and middle layer trees on carrot yield during the period of October 2005 to March 2007. The Experimental results revealed that multistrata agroforestry systems with different tree spacing were found to significantly influence on the root yield of carrot. The highest carrot root yield (29.87 t/ha in 2005 and 29.24 t/ha in 2006) was recorded under sole cropping, which was followed by the wider and intermediate spacing of sissoo+lemon based MAF. The reduction in yield of carrot compared to sole cropping was more at closer spacing of multistrata agroforestry systems. Significantly, the lowest yield (17.84 t/ha in 2005 and 18.65 t/ha in 2006) was recorded in narrower spacing of sissoo+guava based MAF. This yield reduction was 40.27 % in 2005 and 36.22 % in 2006 over the sole cropping. But, it was found that the highest benefit-cost ratio of 4.74 was recorded from intermediate spacing of sissoo+guava based MAF followed by T_4, T_5, T_1, T_2 and T_6 treatments. The lowest benefit-cost ratio of 3.48 was observed in sole cropping of carrot.

Mondal *et al.* (2012) reported that monoculture produced the highest yields of individual crops but in intercropping system the highest groundnut equivalent yield (10.63 t/h and 11.10 t/ha) was obtained from two rows of carrot in between two rows of groundnut. The maximum land equivalent ratio (1.67 and 1.74), the highest gross return (Tk.212600/ha and Tk. 248400/ha) and net return (Tk.184881/ha and Tk.211680) were also obtained from the intercropping treatment with two rows carrot in between two normal rows of groundnut. But due to higher cost in this treatment, maximum benefit cost ratio (7.09 and 7.01) was obtained from the intercropping treatment with one row carrot in between two normal rows of groundnut in both the years.

CHAPTER 3
MATERIALS AND METHODS

In this section the materials and methods have been presented which include brief description of location of the experimental site, soil, climate, materials used and methodology followed in the experiment. The details of these sections are described below.

3.1 Location of the study

The experiment was conducted in Agroforestry and Environment Research Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur. The site was between 25º 13´ latitude and 88º 23´ longitude, and about 37.5 m above the sea level.

3.2 Soil characteristics

The experimental plot was in a medium high land belonging to the old Himalayan Piedmont Plain Area (AEZ No. 01). Land was well-drained and drainage system was well developed. The soil texture was sandy loam in nature. The soil pH was 5.1 found in the field. The details soil properties are presented in Appendix-I.

3.3 Climate and weather

The experimental site was situated under the tropical climate characterized by heavy rainfall from July to August and scanty rainfall in the rest period of the year. Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (November 2016 to March 2017) are included in the Appendix-II.

3.4 Experimental period

Duration of the experiential period was from December 2015 to March 2016**.**

3.5 Experimental materials

Carrot variety New kuroda was used as experimental crop.

3.6 Experimental design

The experiment was laid out following two factors Randomized Complete Block Design (RCBD) with three replications. Total number of experimental plot was 24. The unit plot size was 2.0m × 2.0m i.e. 4.0 m^2. The treatments of the experiment were as follows-

Factor A:

Four Chemical and organic fertilizers

F_1 = Control (no fertilizer)

F_2 = Full chemical

F_3 = Cowdung + Poultry

Factor B:

Two Production systems

S_1 = Sole cropping of carrot

S_2 = Litchi + carrot

F_4 = Cowdung

The treatment combinations were $F_1 S_1$, $F_1 S_2$, $F_2 S_1$, $F_2 S_2$, F_3S_1, F_3S_2, F_4S_1 and F_4S_2.

3.7 Land preparation

The land which was selected to conduct for the experiments was opened on 2 December 2015 by ploughing. Opening the land the plots were cross-ploughed followed by laddering to break up the soil clods to obtain good tilth and level the land. After final land preparation the experimental plots were laid out, and the edge around each unit plot was raised to check run out of the nutrients.

3.8 Manuring and fertilizer application

The chemical and organic fertilizers were the treatments of the present research activities. So, first of all Urea (78 g) + TSP (52.8 g) + MOP (48 g) + Gypsum (36 g) was used in 3 plots in both sole cropping of carrot and carrot under litchi. On the other hand, cowdung manure (6 kg $plot^{-1}$) was used in 3 plots in both sole cropping of carrot and carrot under litchi. Similarly cowdung + poultry (5.4 kg $plot^{-1}$) was used in 3 plots in both sole cropping of carrot and carrot under litchi. The entire quantity of cow dung (15 ton/ha) was applied just after opening the land (Rashid, 1993). The entire amount of TSP, MOP and Gypsum in the experiment was applied at the time of final land preparation. Urea was applied in two equal (39 g) installments as top dressing.

3.9 Sowing of seeds

The carrot seeds of cv. New kuroda were sown on 17, December 2015 in lines of each plot at the rate 5 kg ha^{-1}. The line to line and plant-to-plant spacing were maintained 20 cm and 10 cm, respectively. Then, the seeds were covered with fine soil by hand.

3.10 Intercultural operations

Necessary intercultural operations were done through the cropping season for proper growth and development of the plant. After emergence, carrot plants were thinned out by maintaining 10 cm distance from plant to plant. Three weeding were done to keep the plots free from weeds. The field was irrigated at different times when ever needed during the whole period of plant growth. Light irrigation was given just after sowing the seeds. A week after sowing the requirement of irrigation was envisaged through visual estimation. Whenever the plants of a plot had shown the symptoms of wilting the plots were irrigated on the same day with a hosepipe until the entire plot was properly wet. Mole cricket, field cricket and cutworm attack were a serious problem for carrot cultivation. As a preventive measure against the insect pest, Dursban 20-EC was applied @0.2% at 15 days interval for three times starting from 20 days after sowing.

3.11 Harvesting

The crop was harvested after 90 days when the foliage turned pale yellow (Bose *et al.,* 1990). Carrot can be harvested after 75 days from the date of seed sowing. Hoque and Bhuyan (1983) suggested that carrots should be harvested in Bangladesh within 110-125 days after sowing for maximum yield and quality. Harvesting was done very carefully by spade. The soil and fibrous roots adhering to the tap roots were then removed.

3.12 Collection of data

Data were recorded on the following parameters from the sample plants during experiment. Ten (10) plants were randomly selected from each unit plot for the collection of per plant data. For this purpose, the outer two rows of plants and the plants in the extreme ends of the middle rows were not considered for selecting the sample plants.

Data were recorded on the following parameters from the sample plants during experimentation.

- Plant height (cm)
- Number of leaves plant^{-1}
- Fresh leaf weight (g)
- Fresh root weight (g)
- Dry root weight (g)
- Root length (cm)
- Root diameter (cm)
- Yield kg plot^{-1}
- Yield t ha^{-1}

Plant height (cm)

Plant height is measured in centimeter (cm) by a meter scale at 30, 45, 60 and 75 days after sowing (DAS) from the point of attachment of the leaf to the ground level up to the tip of the longest leaf.

Number of leaves per plant

Number of leaf per plant of ten randomly selected plans was counted at 30, 45, 60 and 75 days after sowing (DAS). All the leaves of selected plants were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from counting. Calculating the average number of leaves, the average number was recorded.

Fresh leaf weight

Leaves often randomly selected plants were made detached by a sharp knife and fresh weight of all leaves was taken by an electric balance at harvest and the mean weight recorded.

Fresh root weight

Underground modified carrot roots often selected plants were made detached by a knife from the attachment of the stem and after cleaning the soil and fibrous root, fresh weight was taken by the triple beam balance in g and then the average value was calculated.

Root length

The length of the conical roots was measured in cm with the help of a meter scale from the proximal end of the conical root to the last point of the tapered end of the root (distal end) in each treatment.

Root diameter

To measure the diameter of the root a slide calipers was used. The diameter of the roots was measured in cm after harvest at the thickened portion of the root.

Dry root weight

To measure the dry weight of the root the oven dried root was taken by the triple beam balance in g and then the average value was calculated.

Root yield

A balance was used to record the gross weight of the harvested roots. All leaves were removed from the plant by a sharp knife and weighted of the roots was taken in kilogram (kg) from each unit plot. The yield of roots per hectare was calculated in ton by converting the total yield of roots per plot.

3.13 Statistical analysis

The collected data were statistically analyzed using the (ANOVA) "Analysis of Variance" technique with the help of the computer package MSTAT. The mean differences were adjusted by the Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

CHAPTER 4
RESULTS AND DISCUSSION

The present investigation was carried out to evaluate the performance of carrot in connection with different chemical and organic fertilizers under litchi based agroforestry system along with sole cropping on the growth, yield and yield contributing characters. The results of the experiment was influenced by different chemical and organic fertilizers as well as two production systems have been presented and discussed in this chapter under the following sub-headings.

4.1 Main effect of chemical and organic fertilizers on growth, yield contributing characters and yield of carrot

4.1.1 Plant height

The plant height was measured at 30, 45, 60 and 75 days after sowing (DAS) and it was observed that there was a significant variation in plant height at different chemical and organic fertilizer application (Table 4.1). Plant height increased gradually with the advancement of time up to the maximum vegetative growth stage (75 DAS) in all the treatments. In initial stage 30 DAS the tallest plant (34.37 cm) was recorded in full chemical fertilizer (F_2) followed by cowdung + poultry (F_3) while, the shortest plant was observed (27.33 cm) in no fertilizer treatment F_1 (control treatment). Again, in the middle stage at 45 DAS the tallest plant (38.92 cm) was recorded in full chemical fertilizer (F_2), where as the shortest plant (30.57 cm) was found in no fertilizer treatment F_1 i.e. control treatment). In later stage at 60 DAS the tallest plant (42.21 cm) was observed in full chemical fertilizer (F_2) followed by cowdung + poultry

(F_3) and only cowdung (F_4), on the other hand, the shortest plant (33.04 cm) was recorded in no fertilizer treatment F_1 (control treatment). In final stage at 75 DAS the tallest plant height (44.54 cm) was found in full chemical fertilizer (F_2) followed by cowdung + poultry (F_3) and only cowdung (F_4) where as the shortest plant height (33.89 cm) was recorded in no fertilizer treatment (F_1) (control treatment). The present study revealed that the plant height increased with the chemical fertilizer. Plant height depends on a number of factors such as availability of required quality of essential plant nutrients, water, mineral nutrients, and area of growing space and genetic set-up of the plants. Chemical fertilizer is the booster of the plant height of carrot.

Table 4.1 Main effect of chemical and organic fertilizers on plant height (cm) of carrot

Treatments	Plant height (cm)			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
F_1	27.33 d	30.57 c	33.04 c	33.89 c
F_2	34.37 a	38.92 a	42.21 a	44.54 a
F_3	30.70 b	34.28 b	37.07 b	38.43 b
F_4	29.25 c	32.87 b	35.92 b	36.91 b
Level of sig.	**	*	*	**
CV%	3.22	3.69	3.70	3.80

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 5\%$ level.

F_1= No fertilizer
F_2 = Full chemical fertilizer
F_3 = Cowdung + Poultry
F_4 = Cowdung

4.1.2 Number of leaves plant^{-1}

Number of leaves per plant of carrot was highly significant disposed by the different chemical and organic fertilizers (Table 4.2). At 30 DAS, the maximum number of leaves palnt^{-1} (7.65) was recorded in full chemical fertilizer (F_2), which was statistically identical to cowdung + poultry (F_3), while the minimum number of leaves plant^{-1} (6.70) was found in no fertilizer treatment F_1 (control treatment). At 45 DAS, the maximum number of leaves palnt^{-1} (8.63) was recorded in full chemical fertilizer (F_2), followed by (7.90) in cowdung + poultry (F_3), on the other hand the minimum number of leaves plant^{-1} (7.08) was observed in no fertilizer treatment F_1 (control treatment). At 60 DAS the maximum number of leaves palnt^{-1} (9.47) was recorded in full chemical fertilizer (F_2), followed by (8.40) in cowdung + poultry (F_3), where as the minimum number of leaves plant^{-1} (7.40) was observed in no fertilizer treatment F_1 (control treatment). Finally, at 75 DAS, the maximum number of leaves palnt^{-1} (9.87) was found in full chemical fertilizer (F_2), followed by (8.73) in cowdung + poultry (F_3) and the minimum number of leaves plant^{-1} (7.57) was observed in no fertilizer treatment F_1 (control treatment), respectively.

Table 4.2 Main effect of chemical and organic fertilizers on number of leaves plant^{-1} of carrot

Treatments	Number of leaves plant^{-1}			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
F_1	6.70 c	7.08 d	7.40 d	7.57 d
F_2	7.65 a	8.63 a	9.47 a	9.87 a
F_3	7.50 a	7.90 b	8.40 b	8.73 b
F_4	7.13 b	7.57 c	8.00 c	8.38 c
Level of significance	*	**	**	**
CV%	3.38	2.83	2.52	2.32

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 5\%$ level.

F_1= No fertilizer
F_2 = Full chemical fertilizer
F_3 = Cowdung + Poultry
F_4 = Cowdung

4.1.3 Fresh leaves weight plant^{-1}

Fresh leaves weight plant^{-1} of carrot was highly significant varied by the different chemical and organic fertilizers (Fig. 4.1). The maximum fresh leaf weight plant^{-1} (296.7 g) was recorded in full chemical fertilizer (F_2), which was statistically identical to (246.7 g) cowdung + poultry (F_3). On the other hand, the minimum fresh leaves weight plant^{-1} (180.0 g) was found in no fertilizer treatment F_1 (control treatment) similar to that of (200.0 g) found in cowdung (F_4), respectively.

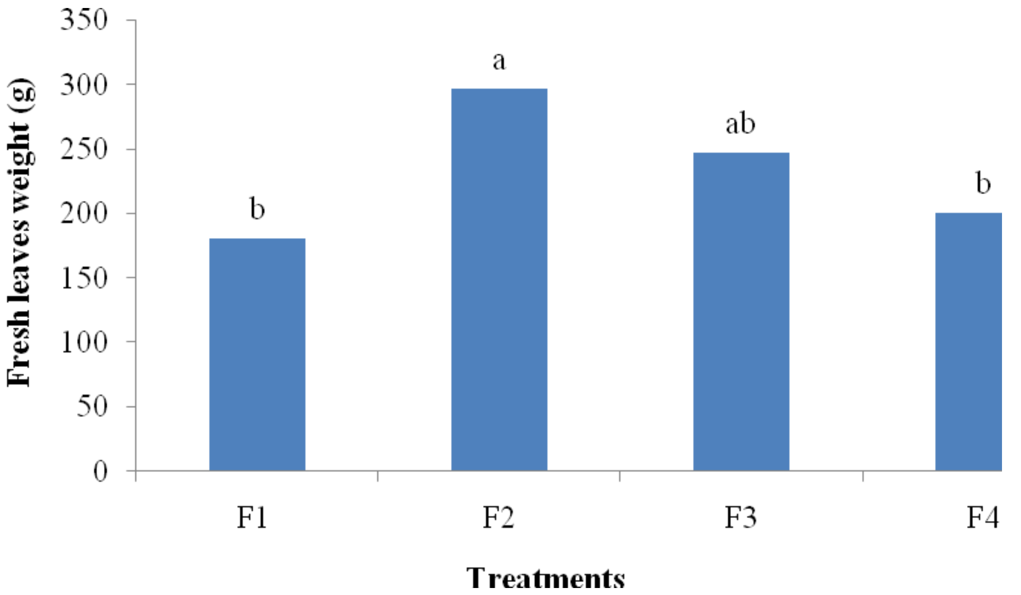

Fig. 4.1 Main effect of chemical and organic fertilizers on fresh leaves weight plant^{-1} (g) of carrot

4.1.4 Fresh root weight

Fresh root weight of carrot was highly significant differentiated by the different chemical and organic fertilizers (Fig. 4.2). The maximum fresh root weight (436.7 g) was recorded in full chemical fertilizer (F_2), which was statistically identical to (401.7 g) cowdung + poultry (F_3) and (351.7 g) cowdung (F_4). On the other hand, the minimum fresh root weight (265.7 g) was found in no fertilizer treatment F_1 (control treatment), respectively.

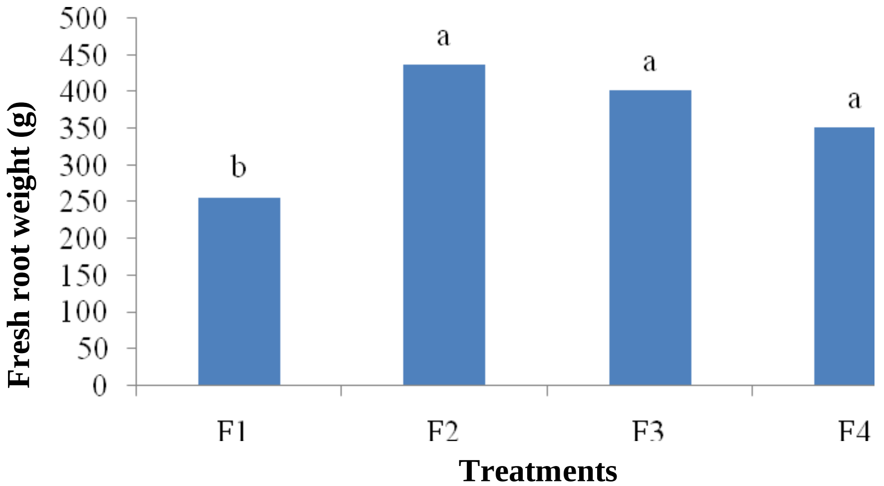

Fig. 4.2 Main effect of chemical and organic fertilizers on fresh root weight (g) of carrot

4.1.5 Dry root weight

Dry root weight of carrot was highly significant diverged by the different chemical and organic fertilizers (Fig. 4.3). The maximum dry root weight (12.50 g) was recorded in full chemical fertilizer (F_2), followed by (10.59 g) cowdung + poultry (F_3) and (10.30 g) cowdung (F_4). On the other hand, the minimum fresh root weight (9.38 g) was found in no fertilizer treatment F_1 (control treatment), respectively.

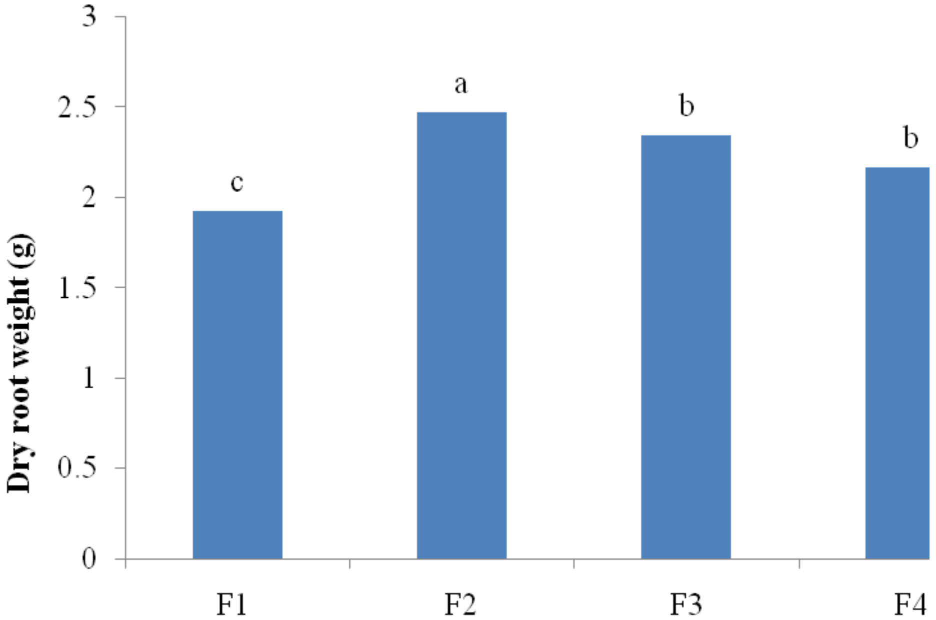

Fig. 4.3 Main effect of chemical and organic fertilizers on dry root weight (g) of carrot

4.1.6 Root length

Root length of carrot was found insignificant by the different chemical and organic fertilizers (Fig. 4.4). Numerically, the highest root length (13.97 cm) was recorded in full chemical fertilizer (F_2) and the lowest root length (12.55 cm) was found in no fertilizer treatment F_1 (control treatment), respectively.

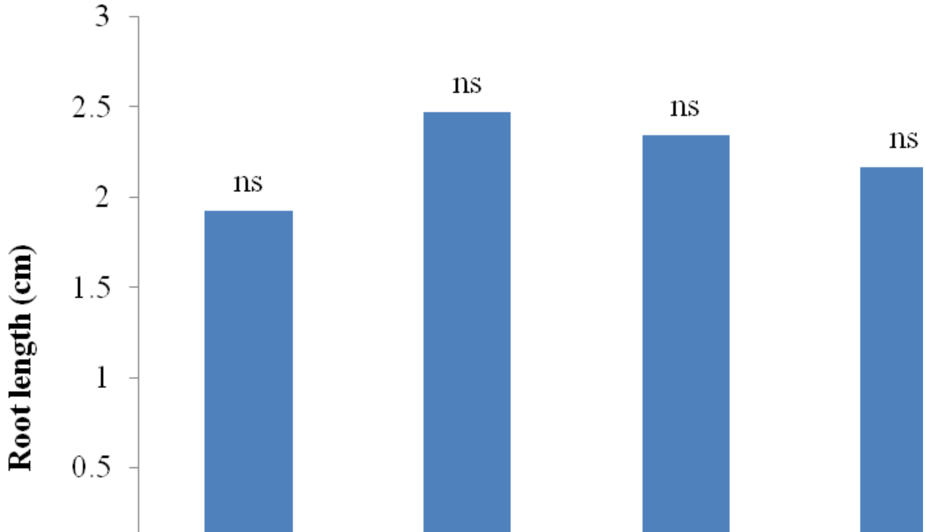

Fig. 4.4 Main effect of chemical and organic fertilizers on root length (cm) of carrot

4.1.7 Root diameter

Root diameter of carrot was highly significant differentiated by the different chemical and organic fertilizers (Fig. 4.5). The highest root diameter (2.47 cm) was recorded in full chemical fertilizer (F_2), which was statistically identical to (2.34 cm) cowdung + poultry (F_3) and (2.16 cm) cowdung (F_4). On the other hand, the minimum fresh root weight (1.92 cm) was found in no fertilizer treatment F_1 (control treatment), respectively.

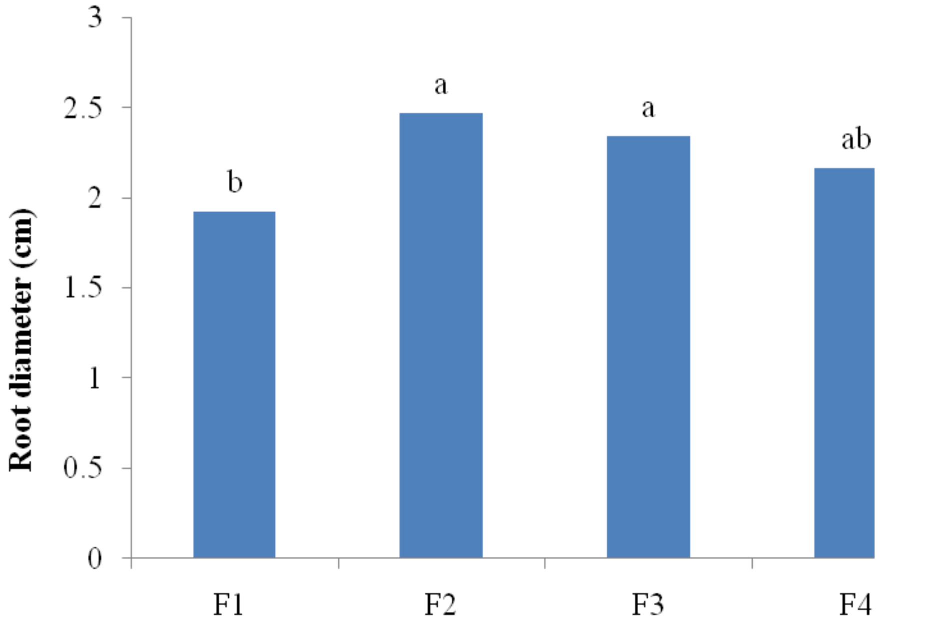

Fig. 4.5 Main effect of chemical and organic fertilizers on root diameter (cm) of carrot

4.1.8 Yield

Carrot yield was highly significant varied due to the different chemical and organic fertilizers application (Fig. 4.6 and 4.7). The highest carrot yield (4.74 kg plot^{-1}) was found in full chemical fertilizer (F_2), which was statistically identical to (4.05 kg plot^{-1}) cowdung + poultry (F_3) and followed by (3.70 kg plot^{-1}) cowdung (F_4). On the other hand, the lowest carrot yield (2.77 kg plot^{-1}) was found in no fertilizer treatment F_1 (control treatment). The carrot yield further converted into ton per hectare. The highest carrot yield (11.86 t ha^{-1}) was found in full chemical fertilizer (F_2), which was statistically identical to (10.14 t ha^{-1}) cowdung + poultry (F_3) and followed by (9.26 t ha^{-1}) cowdung (F_4). On the other hand, the lowest carrot yield (6.93 t ha^{-1}) was found in no fertilizer treatment F_1 (control treatment), respectively.

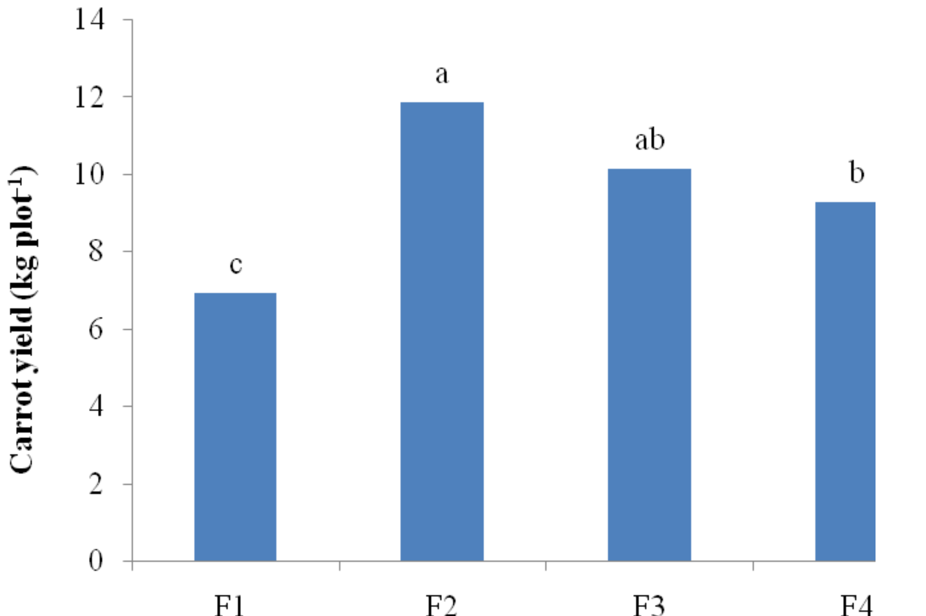

Fig.4.6 Main effect of chemical and organic fertilizers on carrot yield (kg plot^{-1})

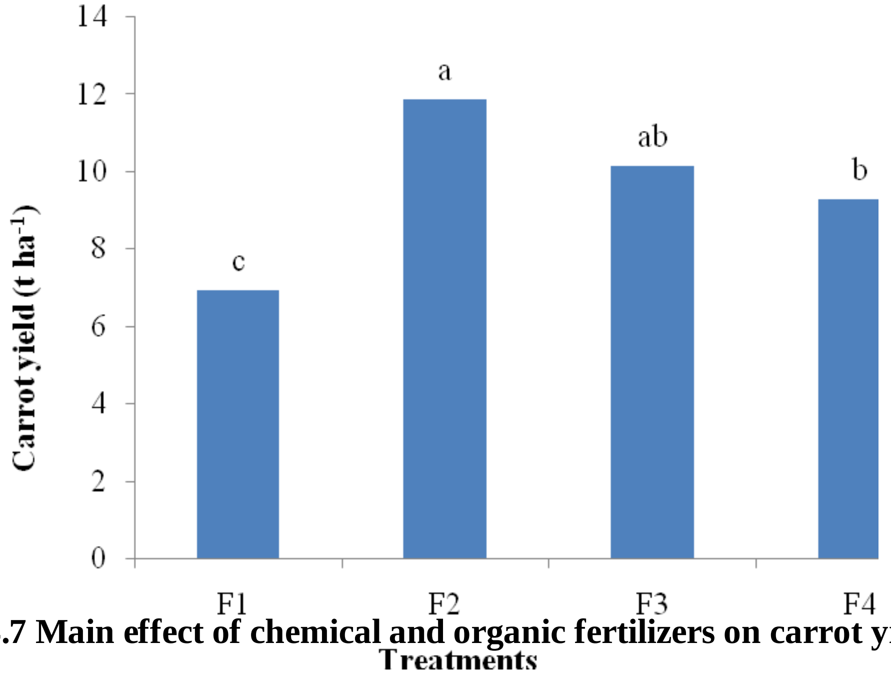

Fig. 4.7 Main effect of chemical and organic fertilizers on carrot yield (t ha^{-1})

4.2 Main effect of production system on growth, yield contributing characters and yield of carrot

4.2.1 Plant height

Plant height of carrot was found insignificant by two production systems (Table 4.3) at different Days after sowing (DAS). Numerically, the highest plant height (30.56, 34.29, 37.12 and 38.67 cm at 30, 45, 60 and 75 DAS) was found in sole cropping of carrot production system (S_1) i.e. control treatment. On the other hand, numerically, the lowest plant height (30.27, 34.03, 37.00 and 38.22 cm at 30, 45, 60 and 75 DAS) was recorded in carrot + litchi based Agroforestry production system (S_2). Plant height depends on a number of factors such as availability of required quality of water, mineral nutrients, quantity, quality and duration of light, temperature, area of growing space and genetic set-up of the plants. Hillman (1984) reported that, plant grown in low light levels was found to be more apical dominant than those grown in high light environment resulting in taller plants under shade.

Table 4.3 Main effect of production system on plant height (cm) of carrot

Treatments	Plant height (cm)			
	30 DAS	45 DAS	60 DAS	75 DAS
S_1	30.56	34.29	37.12	38.67
S_2	30.27	34.03	37.0	38.22
Level of sig.	ns	ns	ns	ns
CV%	3.22	3.69	3.70	3.80

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at P ≤ 5% level.

S_1= Sole cropping of carrot; S_2 = Carrot + Litchi

4.2.2 Number of leaves plant^{-1}

Number of leaves per plant of carrot was highly significant disposed by the two production system (Table 4.4). At 30 DAS, the maximum number of leaves palnt^{-1} (7.63) was recorded in sole cropping of carrot production system (S_1) and the minimum number of leaves palnt^{-1} (6.87) was found in carrot + litchi based agroforestry production system (S_2). In the middle stage, at 45 DAS, the maximum number of leaves palnt^{-1} (8.24) was observed in sole cropping of carrot production system (S_1) and the minimum number of leaves palnt^{-1} (7.35) was counted in carrot + litchi based agroforestry production system (S_2). Again at 60 DAS, the maximum number of leaves palnt^{-1} (8.71) was recorded in sole cropping of carrot production system (S_1) and the minimum number of leaves palnt^{-1} (7.93) was found in carrot + litchi based agroforestry production system (S_2). Finally, at 75 DAS, the maximum number of leaves palnt^{-1} (9.03) was measured in sole cropping of carrot production system (S_1) and the minimum number of leaves palnt^{-1} (8.24) was found in carrot + litchi based agroforestry production system (S_2), respectively.

Table 4.4 Main effect of production system on number of leaves plant^{-1} of carrot

Treatments	Number of leaves plant^{-1}			
	30 DAS	45 DAS	60 DAS	75 DAS
S_1	7.625 a	8.242 a	8.708 a	9.033 a
S_2	6.867 b	7.350 b	7.925 b	8.242 b
Level of sig.	*	*	*	*

CV%	3.38	2.83	2.52	2.32

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 5\%$ level.

S_1= Sole cropping of carrot; S_2 = Carrot + Litchi

4.2.3 Fresh leaves weight plant^{-1}

Fresh leaves weight plant^{-1} of carrot was insignificant due to the two production system (Fig. 4.8). Numerically, the maximum fresh leaf weight plant^{-1} (238.3 g) was recorded in carrot + litchi based agroforestry production system (S_2) and the minimum fresh leaves weight plant^{-1} (223.3 g) was found in sole cropping of carrot production system (S_1), respectively.

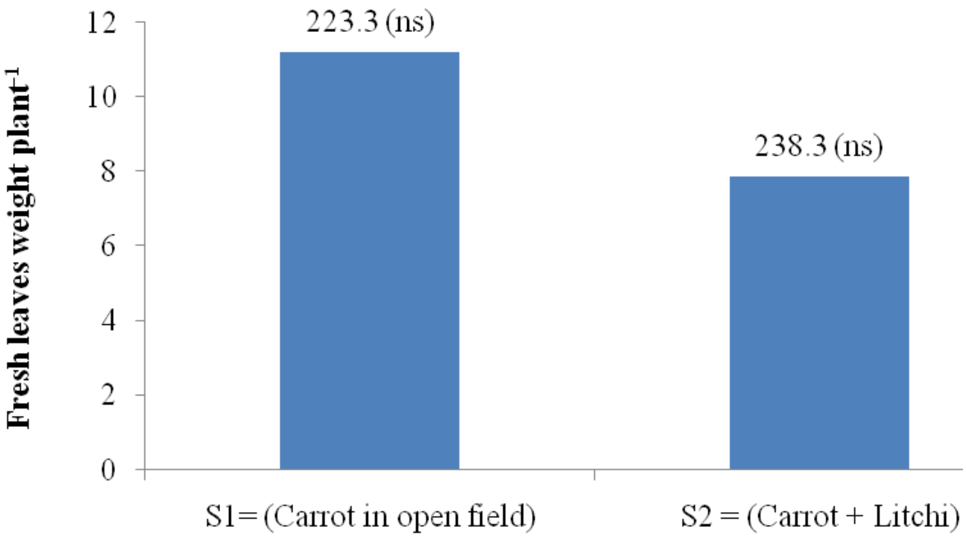

Fig. 4.8 Main effect of production system on fresh leaves weight plant^{-1} of carrot

4.1.4 Fresh root weight

Fresh root weight of carrot was highly significant differentiated by the two production systems (Fig. 4.9). The maximum fresh root weight (460.8 g) was recorded in sole cropping of carrot production system (S_1). On the other hand, the minimum fresh root weight (262.5 g) was found in carrot + litchi based agroforestry production system (S_2), respectively.

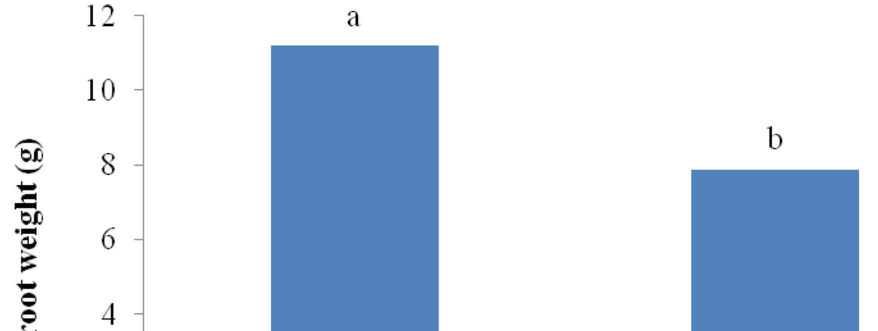

Fig. 4.9 Main effect of production system on fresh root weight (g) of carrot

4.2.5 Dry root weight

Dry root weight of carrot was highly significant varied due to the two production systems (Fig. 4.10). The maximum dry root weight (10.99 g) was recorded in sole cropping of carrot production system (S_1). On the other hand, the minimum fresh root weight (10.40 g) was found in carrot + litchi based agroforestry production system (S_2), respectively.

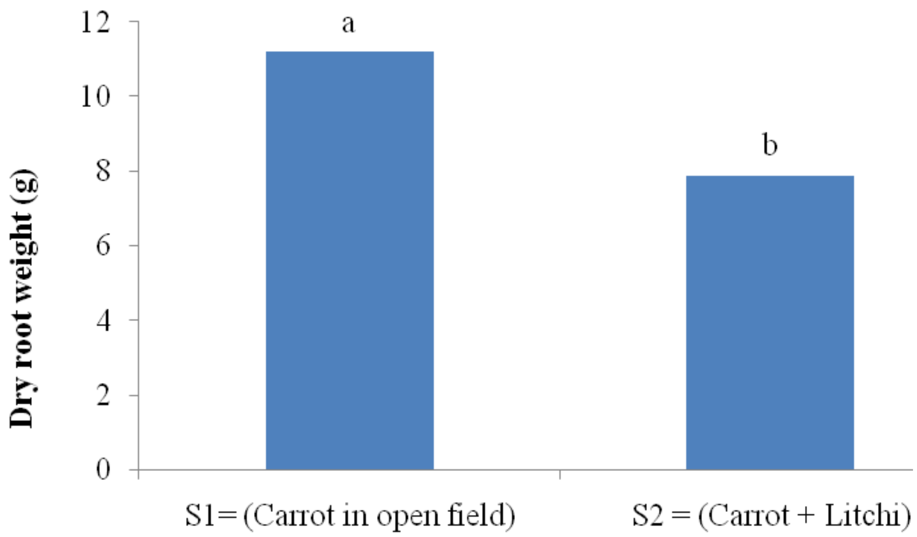

Fig. 4.10 Main effect of production system on dry root weight (g) of carrot

4.2.6 Root length

Root length of carrot was found insignificant due to the two production systems (Fig. 4.11). Numerically, the highest root length (13.60 cm) was recorded in sole cropping of carrot production system (S_1) and the lowest root length (12.31 cm) was found in carrot + litchi based agroforestry production system (S_2), respectively.

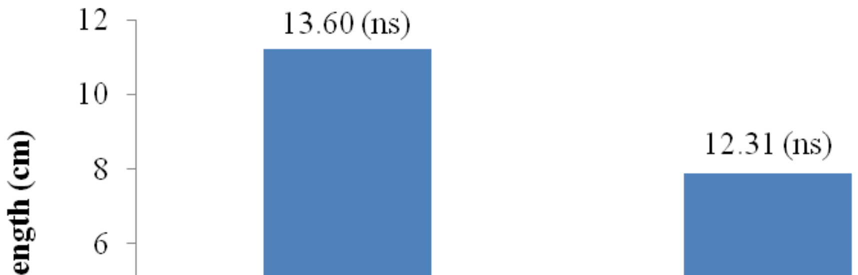

Fig. 4.11 Main effect of production system on root length (cm) of carrot

4.2.7 Root diameter

Root diameter of carrot was found insignificant due to the two production systems (Fig. 4.12). Numerically, the highest root diameter (2.35 cm) was recorded in sole cropping of carrot production system (S_1) and the lowest root diameter (2.10cm) was found in carrot + litchi based agroforestry production system (S_2), respectively.

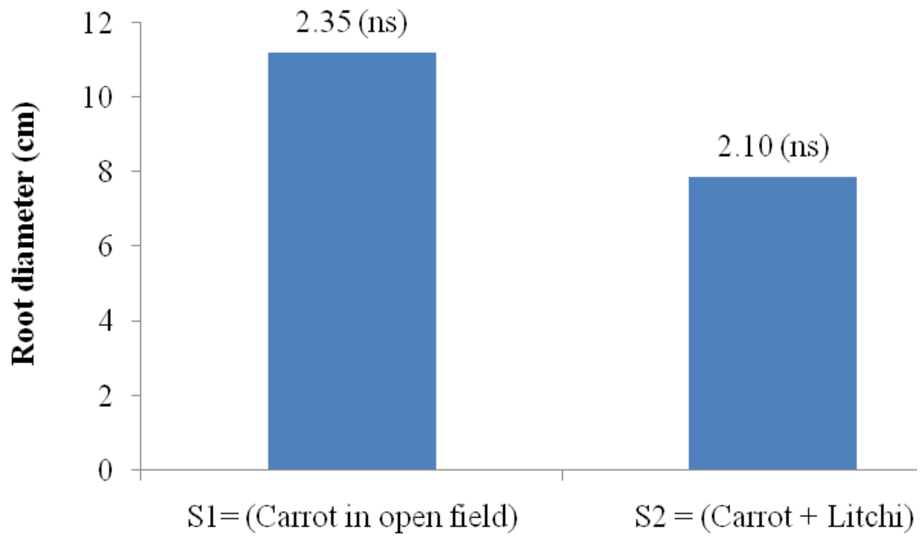

Fig. 4.12 Main effect of production system on root diameter (cm) of carrot

4.2.8 Yield

Carrot yield was highly significant varied due to the two production systems (Fig. 4.13 and 4.14). The highest carrot yield (4.48 kg plot^{-1}) was found in sole cropping of carrot production system (S_1) and the lowest carrot yield (3.15 kg plot^{-1}) was found in carrot + litchi based agroforestry production system (S_2). The carrot yield further converted into ton per hectare. The highest carrot yield (11.21 t ha^{-1}) was found in sole cropping of carrot production system (S_1) and the lowest carrot yield (7.89 t ha^{-1}) was found in carrot + litchi based agroforestry production system (S_2), respectively.

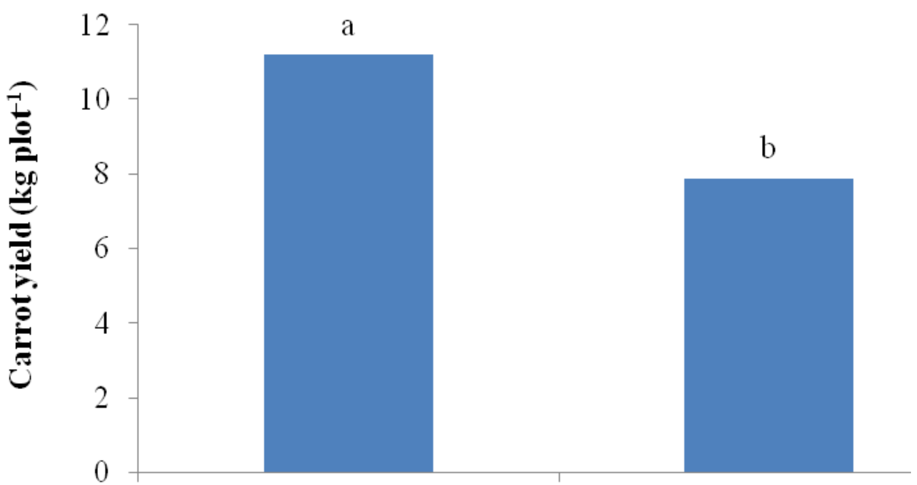

Fig. 4.13 Main effect of production system on carrot yield (kg plot^{-1})

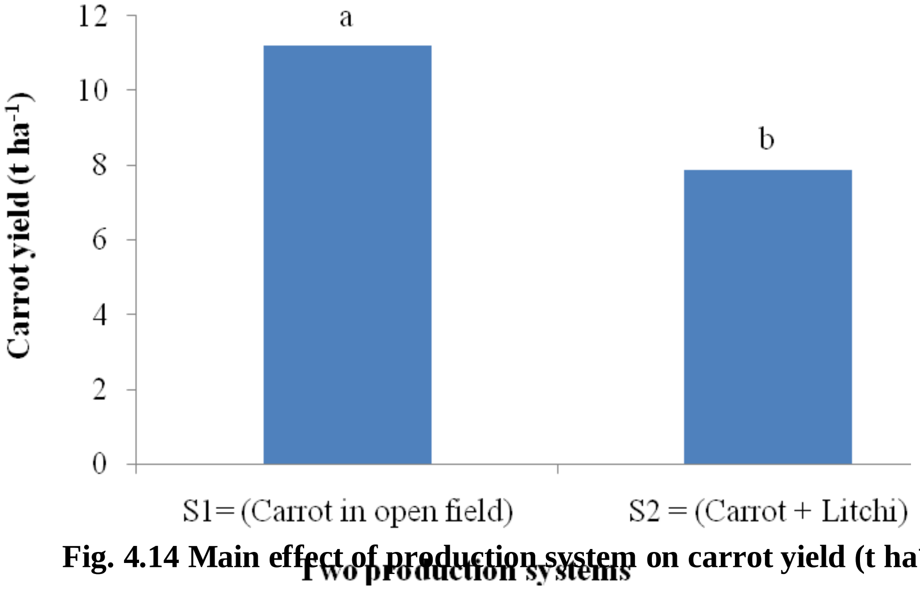

Fig. 4.14 Main effect of production system on carrot yield (t ha^{-1})

4.3 Interaction effect of different chemical & organic fertilizers with production system on growth, yield contributing characters and yield of carrot

4.3.1 Plant height

The interaction effect of fertilizers application and production system on plant height of carrot was found significantly different at 30, 45, 60 and 75 DAS (Table 4.5). At 30 DAS, the tallest plant height (35.19 cm) was recorded in S_2F_2 treatment combination which was statistically identical to S_1F_2 treatment combination and the shortest plant height (26.77 cm) was observed in S_2F_1 treatment combination. At 45 DAS, the similar trend of result was measured. Significantly the tallest plant height (39.60 cm) was found in S_2F_2 treatment combination which was statistically identical (38.23 cm) S_1F_2 treatment combination and the shortest plant height (30.38 cm) was observed in S_2F_1 treatment combination. In the middle stage at 60 DAS, the tallest plant height (42.92 cm) was found in S_2F_2 treatment combination which was statistically identical (41.51 cm) S_1F_2 treatment combination and the shortest plant height (32.95 cm) was observed in S_2F_1 treatment combination. Finally, at 75 DAS the tallest plant height (45.16 cm) was found in S_2F_2 treatment combination which was statistically identical (43.96 cm) S_1F_2 treatment combination and the shortest plant height (33.71 cm) was observed in S_2F_1 treatment combination, respectively. Plant height depends on a number of factors such as availability of required quality of water, mineral nutrients, duration of light, temperature, area of growing space. Plants were grown in low light levels with chemical fertilizers were found to be more apical dominant than those grown in high levels environment resulting in taller plants under shade (Hillman, 1984). Ali (1999) observed taller plant height of carrot under reduced PAR levels created by upper-storey trees. Similarly higher plant height under reduced light levels was also observed in eggplant (Miah, 2001; Ali, 1998; Islam, 1996) and in chickpea (Murshed, 1996). This may be attributed due to the estimulation of cellular expansion and cell division under shaded condition (Schoch, 1972).

Table 4.5 Interaction effect of different fertilizers and production system on plant height (cm) of carrot

Treatments	Plant height (cm)			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
S_1 F_1	27.89 de	30.77 d	33.12 c	34.07 d
S_1 F_2	33.55 a	38.23 a	41.51 a	43.93 a
S_1 F_3	31.03 b	34.97 b	37.77 b	39.57 b
S_1 F_4	29.77 bc	33.19 bc	36.09 b	37.10 bc
S_2 F_1	26.77 e	30.38 d	32.95 c	33.71 d
S_2 F_2	35.19 a	39.60 a	42.92 a	45.16 a
S_2 F_3	30.38 bc	33.60 bc	36.78 b	37.29 bc

S_2 F_4	28.73 cd	32.55 cd	35.76 b	36.72 c
Level of sig.	**	*	*	**
CV%	3.22	3.69	3.70	3.80

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 5\%$ level.

S_1F_1= Sole cropping of carrot + no fertilizer, S_1F_2= Sole cropping of carrot + full chemical fertilizer, S_1F_3= Sole cropping of carrot + cowdung and poultry; S_1F_4= Sole cropping of carrot cowdung, S_2F_1= Carrot under litchi + no fertilizer, S_2F_2= Carrot under litchi + full chemical fertilizer, S_2F_3= Carrot under litchi + cowdung and poultry; S_2F_4= Sole cropping of carrot cowdung

4.3.2 Number of leaves plant^{-1}

The interaction effect of fertilizers and production system on number of leaves plant^{-1} of carrot was found significantly different at 30, 45, 60 and 75 DAS (Table 4.6). At 30 DAS the maximum number of leaves plant^{-1} (8.03) was recorded in S_1F_2 treatment combination which was statistically identical both in (7.67) S_1F_3 and (7.70) S_1F_4 treatment combinations and the minimum number of leaves plant^{-1} (6.30) was observed in S_2F_1 treatment combination. At 45 DAS, significantly the maximum number of leaves plant^{-1} (9.23) was found in S_1F_2 treatment combination followed by S_1F_4, S_1F_3 and S_2F_2 and the minimum number of leaves plant^{-1} (6.63) was observed in S_1F_4 treatment combination. In the middle stage at 60 DAS, significantly the maximum number of leaves plant^{-1} (9.90) was found in S_1F_2 treatment combination followed by S_2F_2 and the minimum number of leaves plant^{-1} (6.90) was observed in S_2F_1 treatment combination. Finally, at 75 DAS the maximum number of leaves plant^{-1} (10.30) was found in S_1F_2 treatment combination followed by S_2F_2 treatment combination and the minimum number of leaves plant^{-1} (7.08) was observed in S_2F_1 treatment combination, respectively. The leaf-level photosynthetic rate also varies with temperature; air temperature at 23 ^{0}C and above increase the number of leaves and the leaf appearance and senescence rates (Manrique *et al.*,1989).

Table 4.6 Interaction effect of different fertilizers and production system on number of leaves plant^{-1}

Treatments	**Number of leaves plant^{-1}**			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
S_1 F_1	7.10 c	7.53 c	7.90 d	8.07 d
S_1 F_2	8.03 a	9.23 a	9.90 a	10.30 a
S_1 F_3	7.67 ab	8.07 b	8.53 c	8.90 c
S_1 F_4	7.70 ab	8.13 b	8.50 c	8.87 c
S_2 F_1	6.30 d	6.63 d	6.90 f	7.07 e
S_2 F_2	7.27 bc	8.03 b	9.03 b	9.43 b
S_2 F_3	7.33 bc	7.73 bc	8.27 c	8.57 c
S_2 F_4	6.57 d	7.00 d	7.50 e	7.90 d

Level of sig.	**	**	**	**
CV%	3.38	2.83	2.52	2.32

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at P ≤ 5% level.

S_1F_1= Sole cropping of carrot + no fertilizer, S_1F_2= Sole cropping of carrot + full chemical fertilizer, S_1F_3= Sole cropping of carrot + cowdung and poultry; S_1F_4= Sole cropping of carrot cowdung, S_2F_1= Carrot under litchi + no fertilizer, S_2F_2= Carrot under litchi + full chemical fertilizer, S_2F_3= Carrot under litchi + cowdung and poultry; S_2F_4= Sole cropping of carrot cowdung

4.3.3 Fresh leaves weight plant^{-1}

The interaction effect of fertilizers and production system on fresh leaves weight plant^{-1} of carrot was found significantly different (Table 4.7). Significantly the maximum fresh leaves weight plant^{-1} (306.7 g) was recorded in S_1F_2 treatment combination which was statistically identical (293.3 g) S_2F_3 treatment combination and the minimum fresh leaves weight plant^{-1} (166.7 g) was observed in S_2F_1 treatment combination.

4.3.4 Fresh root weight

The interaction effect of fertilizers and production system on fresh root weight of carrot was found significantly varied among the treatment combinations (Table 4.7). Significantly the maximum fresh root weight (540.0 g) was recorded in S_1F_2 treatment combination which was statistically identical in both (500.0 g) S_1F_3 and (463.3 g) S_1F_4 treatment combinations and the minimum fresh leaves weight (173.3 g) was observed in S_2F_1 treatment combination, respectively.

4.3.5 Dry root weight

The interaction effect of fertilizers and production system on dry root weight of carrot was found significantly different among the treatment combinations (Table 4.7). Significantly the maximum dry root weight (12.80 g) was recorded in S_1F_2 treatment combination and the minimum dry root weight (9.06 g) was observed in S_2F_1 treatment combination, respectively.

4.3.6 Root length

The interaction effect of fertilizers and production system on root length of carrot was found insignificantly among the treatment combinations (Table 4.7). Numerically, the highest root length (14.10 cm) was recorded in S_1F_2 treatment combination and the lowest root length (11.47 cm) was observed in S_2F_3 treatment combination, respectively.

4.3.7 Root diameter

The interaction effect of fertilizers and production system on root diameter of carrot was found significantly diverse among the treatment combinations (Table 4.7). Significantly the highest root diameter (2.61 cm) was recorded in S_1F_2 treatment combination and the lowest root diameter (1.82 cm) was observed in S_2F_1 treatment combination, respectively.

4.3.8 Yield

Carrot yield was highly extensively varied due to interaction effects of different fertilizers and production systems (Table 4.7). The highest carrot yield (5.25 kg plot^{-1}) was found in S_1F_2 treatment combination which was statistically identical in both (4.91 kg plot^{-1}) S_1F_3 and (4.46 kg plot^{-1}) S_1F_4 treatment combinations and the lowest carrot yield (2.24 kg plot^{-1}) was found in S_2F_1 treatment combination which was statistically identical to (2.94 kg plot^{-1}) S_2F_4, respectively. The carrot yield further converted into ton per hectare. The highest carrot yield (13.14tha^{-1}) was found in S_1F_2 treatment combination statistically identical in both (12.27 tha^{-1}) S_1F_3 and (11.16 tha^{-1}) S_1F_4 treatment combinations and the lowest carrot yield (5.60 tha^{-1}) was found in S_2F_1 treatment combination, respectively.

Table 4.7 Interaction effects of different fertilizers and production system on yield and yield contributing characters of carrot

Treatments	Fresh leaf weight (g)	Fresh root weight (g)	Dry root weight (g)	Root length (cm)	Root diameter (cm)	Yield kg/plot	Yield t/ha
S_1F_1	193.3 ab	340.0 b	9.70 e	13.28	2.02 bc	3.31 bc	8.27 bc
S_1F_2	306.7 a	540.0 a	12.80 a	14.10	2.61a	5.25 a	13.14 a
S_1F_3	200.0 ab	500.0 a	10.97 c	13.20	2.46 ab	4.91 a	12.27 a
S_1F_4	193.3 ab	463.3 a	10.48 d	13.83	2.32 ab	4.46 a	11.16 a
S_2F_1	166.7 b	173.3 c	9.07 f	11.82	1.82 c	2.24 c	5.60 c
S_2F_2	286.7 ab	333.3 b	12.20 b	13.83	2.35 ab	4.23 ab	10.58 ab
S_2F_3	293.3 a	303.3 b	10.22 d	11.47	2.22 abc	3.20 bc	8.01 bc
S_2F_4	206.7 ab	240.0 bc	10.12 de	12.12	2.01 bc	2.94 c	7.35 c
Level of sig	*	*	*	ns	*	*	*
CV%	14.06	18.17	7.77	11.04	11.06	15.71	15.70

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 5\%$ level.

S_1F_1= Sole cropping of carrot + no fertilizer, S_1F_2= Sole cropping of carrot + full chemical fertilizer, S_1F_3= Sole cropping of carrot + cowdung and poultry; S_1F_4= Sole cropping of carrot cowdung, S_2F_1= Carrot under litchi + no fertilizer, S_2F_2= Carrot under litchi + full chemical fertilizer, S_2F_3= Carrot under litchi + cowdung and poultry; S_2F_4= Sole cropping of carrot cowdung

CHAPTER 5
SUMMARY CONCLUSION AND RECOMMENDATION

5.1 Summary

The experiment was conducted in Agroforestry and Environment Research Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur to find out the suitable chemical fertilizer and organic fertilizer on growth and yield of carrot emphasis on litchi based agroforestry production system along with control sole cropping of carrot during December 2015 to March 2016. Carrot variety new kuroda was used as experimental crop. The experiment was laid out following two factors Randomized Complete Block Design (RCBD) with three replications. Total number of experimental plot was 24. The unit plot size is 2.0m x 2.0m = 4.0 m^2. The treatments were factor A: 4 Chemical and organic fertilizers viz. F_1 = Control (no fertilizer), F_2 = Full chemical, F_3 = Cowdung + Poultry and F_4 = Cowdung, while factor B: 2 production system viz. S_1 = Sole cropping of carrot and S_2 = Litchi + carrot. So the treatment combinations were F_1 S_1, F_1 S_2, F_2 S_1, F_2 S_2, F_3S_1, F_3S_2, F_4S_1 and F_4S_2.

The land which was selected to conduct for the experiments was opened on 2 December 2015 by ploughing. The carrot seeds were sown on 17, December 2015 in lines of each plot at the rate 5 kg ha^{-1}. The line to line and plant-to-plant spacing were maintained 20 cm and 10 cm, respectively. Necessary intercultural operations were done through the cropping season for proper growth and development of the plant. Data were recorded on the following parameters from the sample plants during experiment. Ten (10) plants were randomly selected from each unit plot for the collection of per plant data. The data were taken at 30, 45, 60 and 75 days after sowing (DAS) for plant height, number of leaves $plant^{-1}$. The data of the other variables were taken in the harvesting time. The data were analyzed statistically and means differences were adjusted by the Duncan’s Multiple Range Test (DMRT).

The main effect of chemical and organic fertilizers on growth, yield contributing characters and yield of carrot was found significant in response of plant height, number of leaves plant^{-1}, fresh leaves weight plant^{-1}, fresh root weight, dry root weight, root diameter and yield. The plant height was measured at 30, 45, 60 and 75 days after sowing (DAS) and was found the tallest plant height 34.37, 38.92, 42.21 and 44.54 cm from full chemical fertilizer application, while the shortest plant height 27.33, 30.57, 33.04 and 33.89 cm from no fertilizer (control treatment). Number of leaves per plant was measured at 30, 45, 60 and 75 days after sowing (DAS) and was found the maximum number of leaves per plant 7.65, 8.63, 9.47 and 9.87 cm from full chemical fertilizer application, while the minimum number of leaves per plant 6.70, 7.08, 7.40 and 7.51 cm from no fertilizer (control treatment). The maximum fresh leaf weight plant^{-1} (296.7 g) was recorded in full chemical fertilizer application and the minimum fresh leaves weight plant^{-1} (180.0 g) was found in no fertilizer (control treatment). The maximum fresh root weight (436.7 g) was recorded in full chemical fertilizer application and the minimum fresh root weight (265.7 g) was found in no fertilizer (control treatment). The maximum dry root weight (12.50 g) was recorded in full chemical fertilizer application and the minimum fresh root weight (9.38 g) was found in no fertilizer treatment (control treatment), respectively. The highest root diameter (2.47 cm) was recorded in full chemical fertilizer application and the minimum fresh root weight (1.92 cm) was found in no fertilizer (control treatment). The highest carrot yield (11.86 t ha^{-1}) was found in full chemical fertilizer application and the lowest carrot yield (6.93 t ha^{-1}) was found in no fertilizer (control treatment), respectively.

Main effect of production system was sensational on growth and yield of carrot. Significant results were found in case of number of leaves plant^{-1}, fresh root weight, dry root weight and yield of carrot. At 30, 45, 60 and 75 DAS, the maximum number of leaves palnt^{-1} (7.63, 8.24, 8.71 and 9.03 cm) was recorded in sole cropping of carrot production system and the minimum number of leaves palnt^{-1} (6.87, 7.35, 7.93 and 8.24 cm) was found in carrot + litchi based agroforestry production system. The maximum fresh root weight (460.8 g) was recorded in sole cropping of carrot production system and the minimum fresh root weight (262.5 g) was found in carrot + litchi based agroforestry production system. The maximum dry root weight (10.99 g) was recorded in sole cropping of carrot production system and the minimum fresh root weight (10.40 g) was found in carrot + litchi based agroforestry production system. The highest carrot yield (11.21tha^{-1}) was found in sole cropping of carrot production system and the lowest carrot yield (7.89 tha^{-1}) was found in carrot + litchi based agroforestry production system.

In case of interaction effect of different chemical & organic fertilizers with production system on growth and yield of carrot was found statistically significant in response of plant height, number of leaves plant^{-1}, fresh leaves weight, fresh root weight, dry root weight, root diameter and yield. At 30, 45, 60 and 75 DAS tallest plant height (35.19, 39.60, 42.92 and 45.16 cm) was recorded in treatment combination of carrot under litchi + full chemical fertilizer application and the shortest plant height (26.77, 30.38, 32.95 and 33.71 cm) was observed in treatment combination of carrot under litchi + no fertilizer. At 30, 45, 60 and 75 DAS the maximum number of leaves plant^{-1} (8.03, 9.23, 9.90 and 10.30) was recorded in treatment combination of carrot sole cropping + full chemical fertilizer application and the minimum number of leaves plant^{-1} (6.30, 6.63, 6.90 and 7.07) was observed in treatment combination of carrot under litchi + no fertilizer. Significantly the maximum fresh leaves weight plant^{-1} (306.7 g) was recorded in treatment combination of carrot sole cropping + full chemical fertilizer and the minimum fresh leaves weight plant^{-1} (166.7 g) was observed in treatment combination of carrot under litchi + no fertilizer. Significantly the maximum fresh root weight (540.0 g) was recorded in treatment combination of carrot sole cropping + full chemical fertilizer and the minimum fresh leaves weight (173.3 g) was observed in treatment combination of carrot under litchi + no fertilizer. Significantly the highest root diameter (2.61 cm) was recorded in treatment combination of carrot sole cropping + full chemical fertilizer and the lowest root diameter (1.82 cm) was observed in treatment combination of carrot under litchi + no fertilizer. The highest carrot yield (13.14 t ha^{-1}) was found in treatment combination of carrot sole cropping + full chemical fertilizer and the lowest carrot yield (5.60 t ha^{-1}) was found in S_2F_1 treatment combination, respectively.

5.2 Conclusion

From the results and foregoing discussion, it is clear that carrot is highly influenced by different chemical and organic fertilizer application under various production systems. Among the different chemical and organic fertilizer applications, full chemical fertilizer gave the highest yield in both open condition and litchi based agroforestry system. However, only cowdung application as organic manuring gave 15.07% yield reduction in case of open condition and 30.52% yield reduction in case of litchi + carrot based agroforsry production system as compare to chemical fertilization. Again, application of cowdung + poultry manure combination gave 6.62% yield reduction in case of sole cropping and 24.29% in case of litchi + carrot based agroforestry production system as compare to chemical fertilization. So, in the context of safe food consumption and keep sound environment, carrot may be cultivated at the floor of litchi of orchard using cowdung+ poultry manures.

5.3 Recommendation

1. Farmer can cultivate carrot at the floor of young litchi orchard using cowdung and poultry manuring in respect of sustainable application.
2. It may be also advocated that for a vital recommendation of the study, repeated trail should be needed in different location of the country with different aged litchi orchard for better achievement of carrot production in agroforestry system with different fertilizer and manure applications packages.

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APPENDIX

Appendix-I: The soil properties of Agroforestry and Environment farm HSTU, Dinajpur.

Soil characters	**Physical and chemical properties**
Texture	
Sand (%)	67
Silt (%)	33
Clay (%)	5
Textural class	Sandy loam
CEC (meq/ 100g)	8.00
pH	5.1
Organic matter (%)	1.25
Total nitrogen (%)	0.10
Sodium (meq/ 100g)	0.06
Calcium (meq/ 100g)	1.30
Magnesium (meq/ 100g)	0.40
Potassium (meq/ 100g)	0.26
Phosphorus (µg/g)	25.0
Sulphur (µg/g)	3.1
Boron (µg/g)	0.28
Iron (µg/g)	5.30
Zinc (µg/g)	0.90

Source: Soil Resources Development Institute, Dinajpur (2017).

Appendix II. Monthly records of different weather data at the period from December, 2015 to March, 2016

Month	** Air Temperature (ºC)			**Relative Humidity (%)	*Rainfall (mm)	*Sunshine (hrs.)
	Maximum	Minimum	Average			
December	32.9	22.7	27.8	90.0	8.0	225.1
January	35.5	27.6	31.5	92.0	13.0	220.1
February	36.5	28.6	32.55	90.0	8.0	230.1
March	37.5	29.6	33.55	88.5	00	235.4

* Monthly Total

** Monthly average

Source: Wheat Research Centre (WRC), Nashipur, Dinajpur

Appendix III: Plates of different activities done in the field and lab for data collection of the experiment

Plate 1. Data collection in field

Plate 2. Harvesting of carrot in experimental plot

Plate 3. Yield measurement of carrot

Plate 4. Activities done in laboratory