EFFECT OF DISTANCE ON THE GROWTH AND YIELD PERFORMANCE OF SUMMER TOMATO UNDER MANGO BASED AGROFORESTRY SYSTEM

A THESIS
BY

S.M. SHARIARE AKASH
Student No. 1805334
Session: 2018
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MASTER OF SCIENCE (M.S.)
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AGROFORESTRY AND ENVIRONMENT

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HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

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TO MY

FRIENDS AND FAMILY

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EFFECT OF DISTANCE ON THE GROWTH AND YIELD PERFORMANCE OF SUMMER TOMATO UNDER MANGO BASED AGROFORESTRY SYSTEM

ABSTRACT

An experiment was carried out at farmer's mango orchard in Sadar upazila of Dinajpur district under the supervision of Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during March to July 2019 to evaluate the performance of summer tomato influenced by different distances from the base of the Mango tree. The experiment was conducted at ten years aged of Mango orchard (*Mangifera indica*). A popular tomato variety BARI Tomato-4 was selected as the experimental crop. The treatments of the experiment were T_1= 45cm, T_2= 85cm, T_3= 125cm and T_4= 165cm distance from tree base. All the intercultural operations were done 10 days before transplanting as per needed. Twenty six days old tomato seedlings were transplanted in the plots on 24 March 2019. The experiment was conducted in a randomized complete block design (RCBD) with three replications. The results of the research showed that the effect of various distances from mango tree base was significant in respect of plant height (cm), fruit weight plant^{-1} and fruit yield of tomato, respectively, price of tomato, green weight and dry weight. The highest yield (26.95 t/h) was found in case of longer distances from the Mango tree base (165cm) and the lower yield (18.57 t/h) was found in case of shorter distances from Mango tree base (45 cm). however, the other two distanced tomato plants from mango tree base (85 cm and 125 cm) also grow a considerable amount of tomato yield but degree of suitability will be as Long distance (165 cm) > Medium distances (125 cm and 85 cm) > Short distances (45 cm). Based on the finding it can be concluded that tomato (var. BARI-4) cultivation under the younger aged Mango tree (10 years) with longer distances from tree base is a good option to get both tomato and mango fruit in the same piece of land.

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CHAPTER 1

INTRODUCTION

Bangladesh is an agro-based country where agriculture is considered as backbone of her economy. About 80 percent of its population lives in rural areas and 62 percent of total labor force are engaged in agriculture (BBS, 2005). Agriculture plays a vital role through employment generation, poverty alleviation, food security, enhance standard of living by increasing income level of rural population.

Many developing countries like Bangladesh benefited from the green revolution in cereal production in the past but were not able to substantially reduce poverty and malnutrition. Vegetable production can help farmers to generate income which eventually alleviate poverty. Among the vegetables tomato is one of the most important vegetables in terms of acreage, production, yield, commercial use and consumption. At present 6.10% (BBS, 2005) area is under tomato cultivation both in winter and summer. It is the most consumable vegetable crop after potato and sweet potato occupying the top of the list of canned vegetable (Chowdhury, 1979). It is cultivated all over the country due to its adaptability to wide range of soil and climate (Ahmed, 1976). However, the yield of the crop is very low compared to those obtained in some advanced country (Sharfuddin and Siddique, 1985). In Bangladesh congenial atmosphere remains for tomato production during low temperature winter season that is early November is the best time for tomato planting in our country (Hossain *et al*., 1986). It is a good source of vitamin C (31 mg per 100g), vitamin A, calcium, iron etc. (Matin *et al*., 1996). Although tomato plants can grow under a wide range of climatic conditions, they are extremely sensitive to hot and wet growing conditions, the weather which prevails in the summer to rainy season in Bangladesh. But limited efforts have been given so far to overcome the high temperature barrier preventing fruit set in summer-rainy (hot-humid) season. Its demand for both domestic and foreign markets has increased manifold due to its excellent nutritional and processing qualities (Hossain *et al*., 1999). Considering the growing demand and importance of tomato, Bangladesh Agricultural Research Institute (BARI) has taken initiative to develop off-season summer and rainy season tomatoes. So far BARI has developed and released 2 hybrid tomato varieties i.e. BARI hybrid tomato-3 and 4 which can be grown during summer and rainy season under poly tunnel. But very little information has been generated about the profitability and adoption of hybrid tomato cultivation technologies by the farmers in the country. Generalization from studies conducted by home and abroad (Mohiuddin *et al*., 2007; Zaman *et al*., 2006; Islam, 2005; Rahman *et al*., 1998; Ali and Gupta, 1978; Gupta and Rao, 1978) regarding the tomato production may not be always applicable due to considerable variation in attributes of the technologies and for various others factors. Fortunately, the farmers of Bagherpara thana under Jessore district started to adopt this technology as a pioneer farmer since 2005. It is recognized that in order to expand the area of this crop as well as to fit this crop in the farmers cropping system, studies are needed to ascertain its cost and return situation in relation to profitability, input use and farmer's resource use efficiency. Keeping all these factors in consideration the present study was undertaken to provide information through fulfillment of the following objectives.

Bangladesh is endowed with only 17.08% of unevenly distributed forests (BBS, 2015). Conversely, actual tree coverage is less than 10% (Akter *et al*., 1989). Due to rapid growth of population, there is a tremendous pressure on the forest lands. The northern part of the republic has got least forest resources. Substantial depletion of these possessions have occurred in the last few decades and now it is reduced to less than 0.02 ha per person, which is one of the lowly ratios in the globe (BBS, 2016).The loss and degradation of forests exacerbate the problem of food insecurity both directly and indirectly: directly, by affecting the availability of fruits and other forest and tree-based food products, and indirectly by modifying ecological factors relevant for crop and livestock and thereby affecting the availability of food (Van Noordwijk *et al*., 2014). According to the World Food Summit (1996), “Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life”. Food security encompasses many issues ranging from food production and distribution to food preferences and health status of individuals.

Despite impressive productivity increases, there is growing evidence that conventional agricultural strategies fall short of eliminating global hunger, result in unbalanced diets that lack nutritional diversity, enhance exposure of the most vulnerable groups to volatile food prices, and fail to recognize the long-term ecological consequences of intensified agricultural systems(FAO, 2013; FAO, 2014). In parallel, there is considerable evidence that suggests that forests and tree-based systems can play an important role in complementing agricultural production in providing better and more balanced diets

(Vinceti *et al.*, 2013); woodfuel for cooking; greater control over food consumption choices, particularly during lean seasons and periods of vulnerability (especially for marginalized groups); and deliver a broad set of *ecosystem services* which enhance and support crop production (FAO, 2011). The average consumption of vegetables in Bangladesh is only 70 gm per capita per day including potato and sweet potato. Except tuber crops, it is only 30 gm against the FAO recommendation of 200 gm. To supply them minimum daily requirement of 200 gm, the national production of vegetables should be over 10 million tons.

Tomato (*Solanum lycopersicum* L.) belongs to the family Solanaceae. It is one of the most popular and nutritious vegetable crop all over the world including Bangladesh. It ranks next to potato and sweet potato in respect of vegetable production in the world (FAO, 2010). But in Bangladesh, it ranks 2nd which is next to potato (BBS, 2009) and top the list of canned vegetables. It is a self-fertilized annual crop. Now, tomato is a universally known vegetable and is one of the highest grown vegetables in the world which leads all other vegetables in total volume of production (Ahmad *et al.*, 2012). Its food value is very rich because of higher contents of vitamin A, B and C including calcium, minerals, carotene and iron (Bose and Som, 1990). It is a nutritious and delicious vegetable used in salad, soups and processes into stable products like ketchup, sauce, pickles paste, chutney and juice. Lycopene in tomato is a powerful antioxidant and reduces the risk of prostate cancer (Hossain, 2001). In Bangladesh, tomato has great demand throughout the year especially in early winter and summer, but its production is mainly concentrated during the winter season. Recent statistics showed that tomato was grown in 30756 ha of land and the total production was approximately 414 thousand metric tons in 2015. Thus the average yield of tomato in Bangladesh was 5.47 t ha^{-1} (BBS, 2015), while it was 87.96 t ha-1 in USA, 49.87 t ha^{-1} in China and 20.12 t ha^{-1} in India (FAOSTAT, 2012). Cultivation of hybrid tomato varieties has increased considerably throughout the world and have many advantages compared to open pollinated ones. Production of hybrid tomato seed production is not so easy. Maintenance and seed production potentiality of inbred lines is very important in the hybrid seed production (Rashid *et al.*, 2010). Therefore, production of seeds from the single plant of the inbred line is also important. To meet nutritional demand of population, it is highly important to increase the yield of tomato per unit area of land. Increase of production depends on many factors, such as the use of improved varieties, proper management, quality of seed, awareness about improved production technologies and even conventional breeding methods may improve production level and quality under the existing environmental conditions. However, the horizontal expand of tomato production in Bangladesh is less possible due to land scarcity in our country. Therefore, we can use various agroforestry system to produce tomato during summer as like producing tomato in mango orchard, but there is no information about the appropriate distances from tree base to cultivate tomato. Considering this circumstances, the present experiment was exploited to study the performance of summer tomato (BARI Tomato-4) production as influenced by different distances from tree base using the following objectives.

Objectives-

- To find out the growth potential of summer tomato (BARI Tomato-4) under various distances from mango trees.
- To find out the yield potential of summer tomato (BARI Tomato-4) under various distances from mango trees.

CHAPTER 2

REVIEW OF LITERATURE

This research has been undertaken to observe the performance of summer tomato under mango based agroforestry system. 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.

2.1 Development and concept of agroforestry
2.2 Effect of tree-crop interaction in agroforestry system
2.3 Characteristics of tree species used in agroforestry systems
2.4 Response of crops in agroforestry systems
2.5 Effect of light on growth and yield of tomato
2.6 Effect of light on plant growth in understoried agroforestry system
2.7 Effect of shade on plant growth of agroforestry system
2.8 Benefits of tomato intercropping in agroforestry system

2.1 Development and Concept of Agroforestry

Agroforestry had been practiced earlier in temperate and sub-tropical countries, e.g., apple orchards with pastures and sheep or timber trees and nuts among cereals in Europe and North America, crops under fruit trees and olives in the Mediterranean, etc. However, the revival of interest in this subject in high-income countries of this region was delayed until promoted by economic circumstances of ever supply of agriculture produce, situation that has forced governments and farmers to think of alternate ways of imposing limits by setting aside land from agricultural production. Thus, the idea of reintroducing trees and tree crops in such circumstance has only recently re-emerged (Gordon and Newman, l997) and is still not fully accommodated within agricultural incentive schemes (sub sides).

"Agroforestry is a collective name for all land-use systems and technologies, where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components" (ICRAF, 1993).

"Agroforestry should be reconsidered as a dynamic, ecologically based, natural resource management system that, through the integration of trees in farm and rangeland, diversities and sustains production for increased social, economic and environmental benefits" (Leakey, 1996).

"The ecological integrity of an agroforestry is a state of system development in which the habitat structure, natural functions and species composition of the system are interacting in ways that ensure its sustainability in the face of changing environmental conditions as well as both internal and external stresses" (Wyant, 1996).

Agroforestry is an age-old practice but modern concept is now being developed. It is a sustainable management system for land that combines agricultural crops, trees, forest plants and/or animals simultaneously or sequentially, and applies management practices that are compatible with the cultural patterns of the local population (Raintree, 1997).

Homegardens represent intimate, multistory combinations of various trees and crops, sometimes in association with domestic animals, around the homestead. This concept has been developed around the rural settings and subsistence economy under which most homegardens exist (ed). The practice of homegardening is now being extended to urban settings (Drescher *et al*., 2006) as well as with a commercial orientation (Abdoellah *el al*., 2006; Yamada and Osaqui, 2006).

Alley cropping is one kind of agroforestry technology that is being explored as one of the land use options in the tropics. It is a land management practice in which food crops are grown in the interspaces between rows of planted woody shrubs or tree species, usually legumes and in which the woody species are periodically pruned during the cropping season to prevent shading and to reduce competition with the companion crops and the pruning provide the addition of organic matter from the hedgerow plants to improve soil physical, biological and chemical conditions; reduction in soil erosion; and harboring of beneficial predators in the hedgerows (Lal, 1991).

Though agroforestry is an age old practice in Bangladesh, further development may be brought for harvesting maximum benefit by identification of appropriate tree-crop combination. Recently International Centre for Research in Agroforestry (ICRAF) defined, “Agroforestry as a dynamic, ecologically based natural resources management system that through the integration of trees on farmland and in the agricultural landscape, diversities and sustains production or increased social, economic and environmental benefits for land users at all levels.”

“Agroforestry is a collective name for all land use systems and technologies where woody perennials (trees, shrubs, palms, bamboo etc.) are deliberately grown on the same land management unit as agricultural crops and/or animals either in spatial mixture or in temporal sequence. There must be significant ecological non-woody components,” (Lundgren and Raintree, 1982).

Vergara (1982) defined that agroforestry as a system of combining agricultural and tree crops of various longevity (ranging from annual through biennial and perennial plants), arranged either temporally (crop rotation) or spatially intercropping to maximize and sustain agricultural production.

Harou (1983) stated that agroforestry is a combined agriculture-tree crop fanning system which enables a farmer or land user to make more effective use of his land which may yield a higher net economic return on a sustainable basis.

Penafledl (1985) stated that agroforestry is an economic enterprise which aims to produce a combination of agricultural and forest crops simultaneously on the same land area.

Ong (1988) reported that by incorporating trees with arable crops, biomass production per unit area could be increased substantially when the roots of trees exploit water and nutrients below the shallow roots of crops and when a mixed canopy intercepts more solar energy.

MacDicken and Vergara (1990) stated that agroforestry is a means of managing or using land (i.e. a land use system) that combines trees or shrubs with agricultural / horticultural crops and / or livestock. From a business point of view, agroforestry is an economic enterprise which aims to produce a combination of agricultural and forest crops simultaneously in the same land area.

2.2 Effect of tree-crop interaction in agroforestry system

Saxena (1984) point out that agroforestry utilizes the inter space tree rows for intercropping with agricultural crops, this does not impair the growth and development of the trees but enables farmers to derive extra income in addition to benefits accrued from the use of fuel and timber from trees.

Akter *el al.* (1989) mentioned that farmers also considered tree as savings and insurance against risk of crop failure and low yield, as well as assets for their children. Some farmers stated that tree would contribute towards expenses for marriage of their daughters. In tree crop agroforestry system tree species are grown and managed in the farmland along with agricultural crops. The aim is to increase the overall yield of the land. This system is also based on the principle of sustained yield (Nair, 1990).

Agroforestry is the integration of tree and crop or vegetable on the same area of land is a promising production system for maximizing yield and maintaining friendly environment (Nair, 1990).

Agroforestry significantly contributes in increasing fuels wood, fodder, cash income and infrastructure in many developing countries. It was also stated that agroforestry has high potential to simultaneously satisfy three important objectives: (i) protecting and stabling the ecosystems, (ii) producing a high level of output of economic goods (fuel, fodder, small timber, organic fertilizer, etc.) and (iii) providing stable employment, improved income and material to rural populations (Solanki, 1998).

2.3 Characteristics of tree species used in agroforestry systems

Selection of suitable tree species is vital in an agroforestry system. Nair (1990) considered that most choice of suitable plant species that can grow together as important factor in ensuring the 7 success of agroforestry. The most appropriate species for this system remains an open question for research.

King (1979) listed that the characteristics of tree species that should be grown with agricultural crops:

(a) They should tolerate relatively high incidence of planning

(b) They should have a low crown diameter to whole diameter ratio

(c) They should be light branching in their habit

(d) They should be tolerant of side shade

(e) Their phylotaxie should permit penetration of the light to the ground

(f) Their phenology, particularly with reference to leaf flushing and leaf fall, should be advantageous to the growth of the annual crop in conjunction with which they are being raised

(g) The rate of litter fall and litter decomposition should have positive effect on the soil

(h) The above ground changes over time in structure and morphology should be such that they retain or improve those characteristics which reduce competition for solar energy, nutrient and water

(i) Their root systems and root growth characteristics should ideally result in exploration of soil layers that are different to those being tapped by agricultural crops.

Rachie (1983) point out that the following factors to be considered during the selection of woody legumes for intercropping with annuals in the low land tropics:

(1) Ease of establishment from seeds or seedlings
(2) Rapid growth and high productivity of foliage and wood,
(3) Limited maximum size (may be optimum in small trees)
(4) Good coppicing ability (re-growth following topping),
(5) Effective nutrient recycling abilities especially di-nitrogen fixation,
(6) Multiple uses: food, feed, firewood, construction materials and other products and services (shade. shelter etc.)
(7) Minimal competition with shallowly rotted annual crops
(8) Small leaflets readily detached when dried and quickly decomposed when used as fertilizer
(9) A high proportion of leaves to secondary branches, Good tolerance for drought, low fertility and others, Freedom from pests and diseases
(10) Ease of control of eventual elimination.

Purohit (1984) suggested that some criteria for selecting species which

(1) Do not compete for moisture, space and air,

(2) Supply nitrogen in the soil,
(3) Provide food, fodder, fuel and timber,
(4) Maintain proper ecosystems,
(5) Have no toxic effects to the crops, and
(6) Have thin and erect leaves.

He also opined that suitable species should be multipurpose, well adapted to different sites, easy to establish; have-nitrogen-fixing ability, rapid growth and ability to coppice.

Hegde and MacDicken (1990) pointed out some criteria for planting trees under the agroforestry system:

(1) Non-interference with arable crops.
(2) Easy establishment.
(3) Fast growth and short gestation period.
(4) Non allelopathic effects on arable crops.
(5) Ability to fix atmospheric nitrogen, easy decomposition of litter.
(6) Ability to withstand frequent lopping multiple uses
(7) Ability to generate employment.

However, it is not possible to select having all the above mentioned criteria. Therefore, researchers should select which have most of the points and which are adapted to local soil and environmental conditions.

2.4 Response of crops in agroforestry systems

Baevre (1990) reported that reducing incoming light by 30 and 60% resulted in significant reductions in the number of flowers, percent fruit set and yield. The reduction of yield was primarily caused by decreased of the number of fruit production.

Hanada (1990) conducted an experiment under 8 levels of shading (0, 20, 37, 48, 50, 72, 87 and 98 percent) cultivating radish, kangkong, cucumber and tomato and reported that shading decreased soil temperature, preserved soil moisture and prevented insect attack. Shading increased yields in kangkong and cucumber with 20 % and 37 % shading but decreased yields in radish and tomato with increasing amount of shade levels.

Leonardi (1996) suggested that shading (60% light reduction) reduce vegetative and fruits growth. Shading increased plant height. Shading also reduced chlorophyll content, stomata density, transpiration rate and photosynthetic rate. Yield of peppers decreased with increasing amount of shade levels.

Ali (1998) conducted an experiment during April to August in 1998, at BBSMRAU, Salna, Gazipur to study the performance of red amaranth and lady's finger grown at different orientations and distances under guava (*Psidium Guajava*) and drumstick *(Nloringa oleofera*) trees. The orientation was North, South, East, and West.21 and 28 days after emergence. The 30% level of shading did not reduce the size or weight of the roots.

Healey *et al.* (1998) reported that level of incident radiation reduced by 25% under shade-cloth decreased final yield and final leaf index, but increased canopy leaf, nitrogen concentration and radiation uses efficiency. A similar level of reduced incident radiation under solar weave shade cloth increased final yield and radiation use efficiency (46-50%).

Ong and Leakey (1999) reported that recent research findings on resource sharing between trees and crops in the semiarid tropics. In general, productivity of natural vegetation under savannah trees increases as rainfall decreases, while the opposite occurs in agroforestry. In agroforestry practices such as alley cropping where tree density is high, any beneficial effects of the trees on microclimate are negated by reductions in soil moisture due to increasing interception losses and tree transpiration. While investment in woody structure can improve the water economy beneath agroforestry trees, it inevitably reduces the growth rate of the trees and thus increases the time required for improved under storey productivity.

Souza *et al.* (1999) studied that the effect of 3 levels of shading (0, 30, and 50%) on the development and tuberous root yield of radish (*Raphanus sativus)* under field conditions and reported that 50% level of shading increased the plant height, life cycle, foliar area and reduce leaf chlorophyll content and the tuberous root yield where the plant were evaluated at 7, 14, 21 and 28 days after emergence. The 30% level of shading did no reduce the size or weight of the 10 root.

Reddy *et al.* (2002) observed that under the tree shade plant height was higher and root length, girth, dry weight and yield were lower.

Azad (2004) studied that the performance of three winter vegetable i.e. carrot, turnip and spinach were evaluated under three different orientations of guava tree and observed that plant height and leaf length increased gradually in treatments where light availability was meager in case of carrot and turnip. It concluded that the three winter vegetable grown in south side from the tree base showed better performance followed by north side in agroforestry system.

Nazrul *et al.* (2004) suggested that pineapples are being cultivated in the Hilly area in association with different kinds of trees and vegetables. Among all the vegetables, pumpkin has made the best association (i.e. 53%) with the pineapple and benefit cost ratio (BCR) was found the highest(5.11 and3.38) in the associated crop production.

Hasan (2006) studied that the performance of stem amaranth as under storied vegetable with akashmoni and eucalyptus in four orientations. The tree species were Among the different morphological characters of stem amaranth, plant height, stem girth, no. of leaves/plant, fresh leaf weight, dry leaf weight, fresh stem weight and dry stem weight were decreased consistently as the canopy density increased but the trend of orientation in respect of yield was south> East>West> North, where best result obtained in south and lowest was North orientation.

Chipungahelo *et al*. (2007) reported that light intensity strongly influenced on growth and development of sweet potato especially leaf morphological characteristics. Specific leaf area values in full light were smaller than those in under heavy shade.

Ding *et al.* (2007) observed the performance(growth, development, yield and Disease resistance) of alpine cucumber (cv. Jing-You5) plants grafted on Rootstocks of *Cucurbita ficifolia*, Zaoqing pumpkin, Jungli pumpkin and Hangzhou long bottle gourd to evaluate and compare with that of non-grafted plants. The survival rate was higher and the incidence of Fusarium wilt was lower in grafted seedlings than in non-grafted seedlings.

Rahman (2008) reported that except plant height all others morphological characters viz. no. of branches plant-l, no. of fruit plant-l, fruit length, fruit diameter and fruit weight of three vegetables (Tomato, Brinjal, Chili) were highest in open held condition. Among the different agroforestry system, highest yield was obtained in Horitoki - Lemon - Vegetable based 11 Agroforestry system.

Pulok (2008) identified that a total of five agroforestry practices viz. Palmyra palm - rice based agroforestry practices, pond size agroforestry practices, MPTs plantation the border of rice field, ailed based agroforestry practices and homestead agroforestry practices in the study area. He recommended that the selection and introduction of fast growing trees and multipurpose tree species are suitable for agroforestry practices for socioeconomic improvement of the farmers.

Nahidur (2009) stated that Agroforestry practice had significant role in improving the economic status of the people. It is implied that if people are encouraged to plant trees in their homestead, thereby, the people can live in a healthy environment at the same time if can ensure the supply of timber, fuel, fodder, nutrient and other products. Therefore, there is a great scope to improve the prevailing homestead agroforestry practices with modern agroforestry technologies for maximization of income of the farmers.

Partha (2009) has reported that CARE assisted Road side agroforestry program bring a change in the socioeconomic status of the participants through increasing income generating capacity and using the waste land of the road side. The program also improved the overall environmental condition and prevented the soil erosion.

Nahar (2009) observed that the average size of the homestead in the study area was 0.12 ha which increased with the increase of farm size. The homestead production system was found to be poor due to management practices. It was also observed that the major problem of planning new trees in the homestead was damaged by grazing animals (80.0%) followed by unavailability of space (61.0%), damaged by flood (55.0%), lack of good quality seeds(64.0%) and insect and pest infestation (56.0%). There is enough scope if improve productivity in the homestead by replacing the existing tree species with the improved and /or exotic ones, planting trees in planned ways and improving management practices.

Basak *et al.* (2009) found that the growth characteristics of *Xylia dolabiformis* tree are quite better in association with radish than tomato but found higher in association with soybean. The result of the experiment revealed that the yield contributing characters of vegetables gradually increased with the increase of planting distance of the tree.

Bad and Rahim (2009) found that multistrata agroforestry systems with different tree spacing were found to significant influence on the root yield of carrot. The highest carrot root yield (29.87 t ha^{-1} in 2005 and 29.24 t ha'1 in 2006) was recorded under sole cropping which were 12 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 MAF.

Islam *et al.* (2009) reported that morphological characteristics of winter vegetables, leaf length, leaf diameter, stem girth, fresh and dry weight decreased consistently with the decrease of distance from the tree. The growth characteristics of *Hopea oaiorata* was significantly influenced by all the three winter vegetables (red amaranth, stem amaranth and coriander).

Mamun (2009) studied that the performance of carrot, turnip and pea at different distances from the Boilam tree and found that the result of the experiment revealed that the yield contributing characters of the vegetables increased gradually with the increase of planting distance from the tree. The growth character of Boilam was not satisfactory in association with carrot and turnip but satisfactory in association with pea.

Moontasir (2009) studied that different Agroforestry practices for socio-economic improvement of the farmers. The findings revealed that majority (40.75%) of the farmers belong to medium category possessed medium (21-30 trees) number of diversified tree species. The majority 33.33% of the farmers had low attitude regarding contribution of diversified tree species for their socio-economic condition, where 25.92% was found to large category respectively. Within 40 different tree species, the high relative density of the study area was Mango (21.34%), Betelnut (12.89%) and Jackfruit (8.73%) respectively.

Tanni (2010) observed that the yield of crops increased gradually with increase of planting distance from the Lohakat tree and crops under pruned condition provide better yield performance compared to unpruned condition. The growth characters of Lohakat tree are not satisfactory in association with tomato and radish but quite better in association with lettuce but found higher in association with soybean.

Ding *et al*. (2007) reported that tree shading reduced the crop yield by 27 and 22% in western and eastern regions, respectively, and also, mean crop yield for western side was 23% lower the eastern side.

Ahmed (2012) found that the kankong and jute yield was gradually increased with increasing distance from akashmoni tree base. However, the vegetables yield had reduced remarkably at 5 feet distant from tree base. Both kankong and jute successfully cultivate along with 2 years old Akashmoni tree without significant yield loss.

Babu (2012) conducted an experiment to study the growth and yield of two vegetables i.e. chili and sweet gourd under different spacing from Eucalyptus tree, and he found that all the parameters i.e. plant height, diameter, leaf length, leaf diameter, no. of fruits plant-1, yield were increased gradually with increasing distance from Eucalyptus tree It concluded that boundary plantation of Eucalyptus has negative effect on the growth & yield of chili & sweet gourd.

Ummah (2012) reported that among the morphological parameters of bottle gourd such as vine length, no. of leaves, no. of fruits, weight of fruits, no. of branch and yield were decreased gradually when distance reduced in association of Mahogoni tree.

Habib *et al.* (2012) studied that the performance of summer vegetable in association with *Xylia dolabriformis* tree on summer vegetables. The results showed that the yield of the summer vegetables increased gradually with the increase of planting distance of the tree.

Bali (2012) conducted an experiment to study the growth and yield of okra under different spacing from lemon and guava tree, and he found that all the parameters i.e. plant height, , leaf length, leaf diameter, no. of fruits p1ant-^{1}, yield were increased gradually with increasing distance from lemon and guava tree. The result of the experiment revealed that the yield of Okra was increased gradually with the increase of planting distance from the tree.

2.5 Effect of light on growth and yield of tomato

Christina Stadler, 2012 reported that tomato (*Lycopersicon esculentum* Mill. cv. Encore, 2,5plants/m^{2}) was conducted from 13.09.2010 - 16.03.2011 in the experimental greenhouse of the Agricultural University of Iceland at Reykir. Plants in four replicates were grown under HPS lamps for top lighting with 300 W/m^{2} in one cabinet and with 240 W/m2 in three cabinets. Light was provided for max. 18 hours. During the time of high electrical costs for time dependent tariffs (November - February) one cabinet with the lower light intensity got supplemental light during the night as well during the whole weekend, whereas during the other months it was uniformly provided from 04-22 h as in the other cabinets, all the time. One cabinet received a daily integral of 100J/cm²/plant and in addition per cluster 100J/cm² with 240 W/m² supplemental light and natural light.

Rahman *et al.* (2010) investigated the performances of tomato under different multistoried agroforestry production system and open field condition. Different multistoried agroforestry system such as Amloki + Guava based agroforestry system (T1), Horitaki + Lemon based agroforestry system(T2) and Bohera 4 lemon based agroforestry system (T1) were investigated in the study. Tomato was grown following the RCBD design with three replications. The study showed that except plant height all others Morphological characters viz. Number of branches per plant, number of leaves per plant, number of fruits per plant, fruit length, fruit diameter and single fruit weight were highest in open field condition among the different Agroforestry systems (Multistoried vegetation), highest yield was obtained in Horitaki + lemon + tomato based agroforestry system, which was 16.67% lower than open held condition.

Hossain *et al.* (2014) reported that light availability in control plot (999.75 µ mol $m^{-2}s^{-1}$) was remarkably higher over fruit tree based agroforestry systems and it was 58.8, 43.9 and 31.5% of the control for guava, mango and olive based systems, respectively. The shortest tomato plant was observed in olive based system (54.91 cm), while the tallest plant was observed in mango based system (60.09 cm). The highest SPAD value and number of primary branches per plant was recorded in control plot. Fruit length, fruit girth was found lowest in olive based system. The highest yield (34.06 t ha^{-1}) was recorded in control plot while the lowest yield (10.26 t ha^{-1}) was recorded in olive based system. The economic performance of fruit tree based tomato production system showed that both the net return and BCR of mango and guava based system was higher over control and olive based system. The contents of organic carbon, nitrogen, available phosphorus, potassium and sulfur of before experimentation soil were slightly higher in fruit tree based agroforestry systems than the control. Alter experimentation, nutrient elements in soil were found increased slightly than initial soils. Fruit tree based agroforestry systems could be ranked based on the economic performance as mango> guava> control> olive based system with BARI Tomato 15, BARI Tomato 2, BARI Tomato l4 and BARI Tomato 8, respectively.

2.6 Effect of light on plant growth in under storied agroforestry system

Okigbo and Greenland (1976) identified ways of more efficient uses of light resources by plants of different heights and canopy structures as one of the advantages to be gained by growing crops in mixed stands.

Interaction among trees and solar geometry produce particular solar climate of tree/crop systems. These interactions and effects include interception of radiation by tree stands of various densities, effect of canopy structure, effect of latitude and time of year on solar paths, shade from single crowns and spectral quality of sun light under partial shade (Reifsnyder, 1987).

The yield advantage of conventional intercropping has been explained in terms of improved capture of utilization of growth resources. The resource capture by agroforestry systems will probably be greater than in sole crops (Ong *et al.*, 1991).

The higher amount of light transmitted through *Gliricidia sepium* species may be due to its small and thin leaflets as well as low branching habit (Miah, 1993).

2.7 Effect of shade on plant growth of agroforestry system

It has been reported that canopy shading reduced leaf number, leaf area and thickness of dry bean (Crookston *et al*., 1975). They also reported 38% decrease in short synthesis per unit area of shaded leaves. Alley cropping agroforestry systems have been emerged as a sound technology where tree leaves are periodically pruned to prevent shading the companion crops.

Chaturvedi and Ingram (1989) mention that pre-flowering shade (50% shade) resulted in reduced leaf area and tiller number spikelets per panicle, whereas post flowering shade reduced filled spikelet fraction and grain weight in rice.

The shading was responsible for suppression of maize yields in the second season, where rains ended abruptly; moisture competition was the main factor causing the drastically low yield (Singh *et al*., 1989).

Miah *et al.* (1995) reported that the mean light availability on crop rows decreased as they approached the tree rows across the alleys. The rate of decrease was greater in unpruned alleys than in pruned ones. Rice and mung bean yield decreased linearly with the reduced percent light incidence, rice yields decreased by 47 kg/ha but mung bean yields decreased 10kg/ha. In pruning regimes mung bean yield decreased more in pruned condition (13 kg/ha) than in unpruned condition (9 kg/ha).

Studies in New Zealand have indicated that the American ginseng can be successfully grown under *Pinus radiata* with best growth under a 11% stand of 130 stems/ha (Follett, 1997).

Rao and Mittra (1988) observed that shading by taller species usually reduced the photosynthetically active radiation. It also regulated photosynthesis, dry matter production and yield of crop.

2.8 Benefits of tomato intercropping in agroforestry system

Lourduraj *et al.* (1997) investigations were carried out on okra cv. Parbhani kranti to study the effect of different mulches (plastic mulch and organic mulch) and irrigation regimes (IW/CPE ratios of 0.4, 0.6 and 0.8) on yield. Mulching significantly increased yield. Particularly the plastic mulch irrigation at W/CPli who of 0.6 was the best irrigation regime to promote yield. The black plastic mulch was very effective at controlling weeds. Black plastic mulch increased net seasonal income by Rs l4300/ha compared with the unmatched control.

Pattern and Mclin (1998) conducted that okra seeds were direct-sown with 70 cm between rows and 30 cm between plants within the row. Cultivar NN Claudia had the tallest plants (63.1 cm), the most leaves in the central axis (15.7), the highest number of hits per plant (142) and the highest fruit yield per plant (691.1 g). Harvesting began 69 and 71 days after sowing for NN *C*laudia and Dwarf Green Long Pod, respectively.

According to Li-Xue *et al*. (2004) pod lengths, soluble protein contents, several nutrient contents and mucilage viscosity of okra cv. Green finger were determined at different stages after anthesis under protected cultivation. The eating quality of okra was best when the pods at 8 to 9 cm length were picked approximately five days after anthesis. John and Mini (2005) stated that okra planted at 60 cm × 45 cm spacing intercropped with cowpea produced the highest okra equivalent yield, low weed weight and the highest net and grows returns during both the seasons.

John *et al.* (2004) stated that intercropping improved the number and yield of pods of cowpea. The incidence of cowpea aphid was the lowest when intercropped in okra at lower spacing. The performance of amaranth and cucumber as intercrops in okra was not promising. However, the occurrence of fruit fly seemed reduced in cucumber when it was intercropped. Cowpea can be recommended as a suitable intercrop in okra.

Ribas *et al.* (2003) carried out an experiment, the effects of 2 population densities of *C.juncea* (400000 or 600000 plants/ha, with 2 or3 rows between rows of okra) as a green manure, and 2 rates of cattle manure (pre-plant applications of 10 or 20 t/ha, equivalent to 225 or 550 k N/ha)on okra (cv. Santa Cruz 47) were studied. Intercropping with *C. juncea* increased okra yield by approx.13%, with no significant difference between treatments. In addition, there was a marked reduction in the incidence of okra root galls due to *Meloidogyne spp.* In the presence of *C. juncea*. Cattle manure application had no effect on okra performance.

Singh *et al.* (2004) conducted field experiments to determine the effects of integrated nutrient management on crop nutrient uptake and yield under okra-pea-tomato cropping sequence. The integrated use of organic and inorganic sources of nutrients and bio-fertilizers increased the N, P and K concentrations in the plants (including fruits) of okra, pea and tomato. The integrated nutrient management also significantly increased shoot dry matter yield of tomato and fruit yields of okra and tomato.

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 a farmer’s mango orchard at Newtown 8 No., Sadar, Dinajpur. The site was between 25° 13´ latitude and 88° 23´ longitude, and about 37.5 m above the sea level.

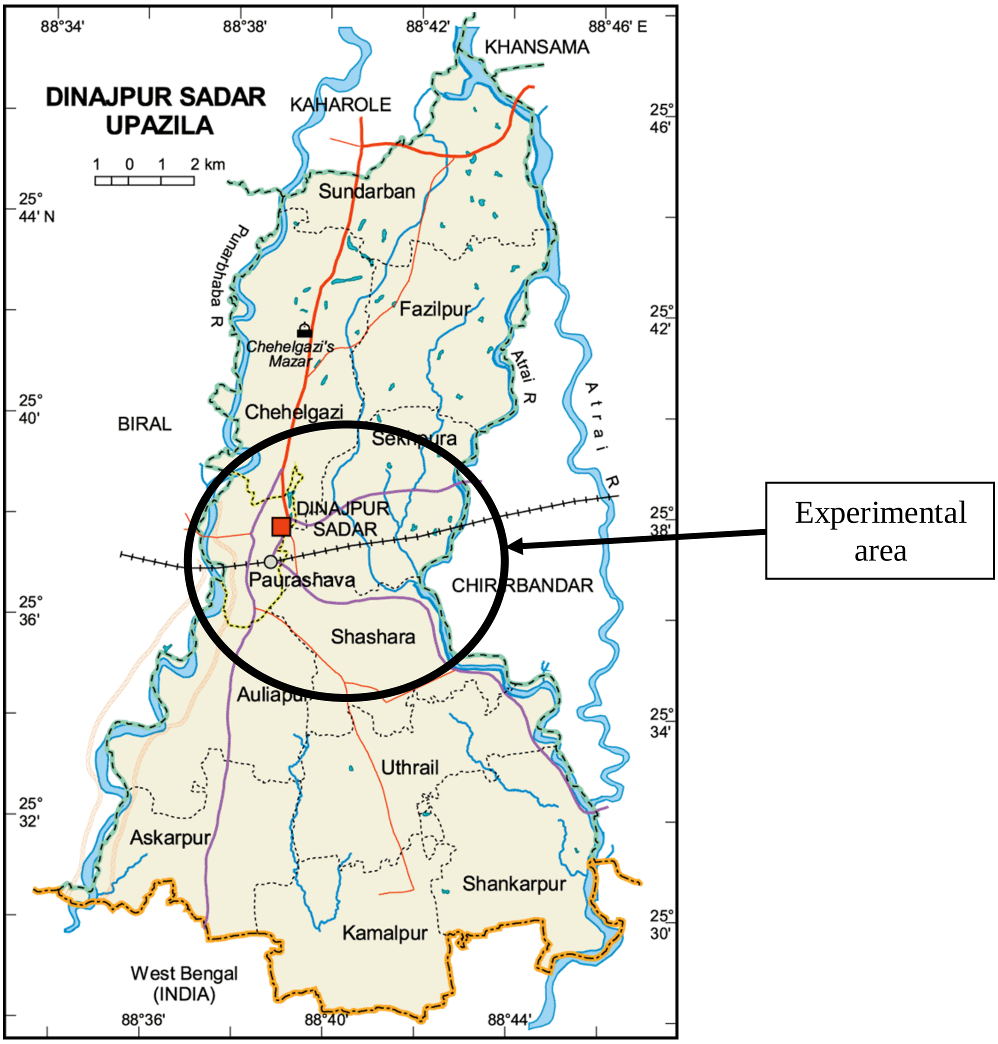

Fig. 3.1: Showing the map of experimental area in Dinajpur Sadar

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 and organic matter content is medium.

3.3 Climate and weather

The experimental site was situated under the tropical climatic zone characterized by heavy rainfall from June to August (Kharif Season) and scanty rainfall in the rest period of the year. The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February. Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (April, 2019 to July, 2019) are presented in the Appendix-I. As summer tomato was cultivated, special care was taken so that water don't logg off and damage the plants as there was a lot rainfall occurrence in this period of time.

3.4 Experimental period

The experiment was conducted during April, 2019 to July, 2019.

3.5 Experimental materials

Brief descriptions of the species and the reasons of their selection are given below:

Mango Tree (*Mangifera indica*) -The mango tree is erect, 30 to 100 ft (roughly 10-30 m) high, with a broad, rounded canopy which may, with age, attain 100 to 125 ft (30-38 m) in width, or a more upright, oval, relatively slender crown. In deep soil, the taproot descends to a depth of 20 ft (6 in), the profuse, wide-spreading, feeder root system also sends down many anchor roots which penetrate for several feet. The tree is long-lived, some specimens being known to be 300 years old and still fruiting.

Nearly evergreen, alternate leaves are borne mainly in rosettes at the tips of the branches and numerous twigs from which they droop like ribbons on slender petioles 1 to 4 in (2.5-10 cm) long. The new leaves, appearing periodically and irregularly on a few branches at a time, are yellowish, pink, deep-rose or wine-red, becoming dark-green and glossy above, lighter beneath. The midrib is pale and conspicuous and the many horizontal veins distinct. Full-grown leaves may be 4 to 12.5 in (10-32 cm) long and 3/4 to 2 1/8 in (2-5.4 cm) wide. Hundreds and even as many as 3,000 to 4,000 small, yellowish or reddish flowers, 25% to 98% male, the rest hermaphroditic, are borne in profuse, showy, erect, pyramidal, branched clusters 2 1/2 to 15 1/2 in (6-40 cm) high. There is great variation in the form, size, color and quality of the fruits. They may be nearly round, oval, ovoid-oblong, or somewhat kidney-shaped, often with a break at the apex, and are usually more or less lop-sided. They range from 2 1/2 to 10 in (6.25-25 cm) in length and from a few ounces to 4 to 5 lbs (1.8-2.26 kg). The skin is leathery, waxy, smooth, fairly thick, aromatic and ranges from light-or dark-green to clear yellow, yellow-orange, yellow and reddish-pink, or more or less blushed with bright-or dark-red or purple-red, with fine yellow, greenish or reddish dots, and thin or thick whitish, gray or purplish bloom, when fully ripe. Some have a "turpentine" odor and flavor, while others are richly and pleasantly fragrant. The flesh ranges from pale-yellow to deep-orange. It is essentially peach-like but much more fibrous (in some seedlings excessively so-actually "stringy"); is extremely juicy, with a flavor range from very sweet to sub acid to tart.

There is a single, longitudinally ribbed, pale yellowish-white, somewhat woody stone, flattened, oval or kidney-shaped, sometimes rather elongated. It may have along one side a beard of short or long fibers clinging to the flesh cavity, or it may be nearly fibreless and free. Within the stone is the starchy seed, monoembryonic (usually single-sprouting) or polyembryonic (usually producing more than one seedling).

Functional uses:

Young leaves are used as cattle fodder. The fruit are consumed by human and other domestic animals. Fuel wood is one of the major use of mango tree. Wood is also used for making various furniture. It has calorific value of 5100 kcal/kg. Wood is also used for making toys, small boxes, house buildings, different furniture etc. It is also used for making agricultural implements. The wood is kiln-dried or seasoned in saltwater. It is gray or greenish-brown, coarse-textured, medium-strong, hard, durable in water but not in the ground; easy to work and finishes well. In India, after preservative treatment, it is used for rafters and joists, window frames, agricultural implements, boats, plywood, shoe heels and boxes, including crates for shipping tins of cashew kernels. It makes excellent charcoal. The bark possesses 16% to 20% tannin and has been employed for tanning hides. It yields a yellow dye, or, with turmeric and lime, a bright rose-pink. A somewhat resinous, red-brown gum from the trunk is used for mending crockery in tropical Africa. In India, it is sold as a substitute for gum arabic. Dried mango flowers, containing 15% tannin, serve as astringents in cases of diarrhea, chronic dysentery, catarrh of the bladder and chronic urethritis resulting from gonorrhea. The bark contains mangiferine and is astringent and employed against rheumatism and diphtheria in India. The resinous gum from the trunk is applied on cracks in the skin of the feet and on scabies, and is believed helpful in cases of syphilis. Mango kernel decoction and powder (not tannin-free) are used as vermifuges and as astringents in diarrhea, hemorrhages and bleeding hemorrhoids. The fat is administered in cases of stomatitis. Extracts of unripe fruits and of bark, stems and leaves have shown antibiotic activity. In some of the islands of the Caribbean, the leaf decoction is taken as a remedy for diarrhea, fever, chest complaints, diabetes, hypertension and other ills. A combined decoction of mango and other leaves is taken after childbirth.

Summer Tomato (*Lycopersicum esculentum*) - Tomato plants are vines, initially decumbent, typically growing 180 cm (6 ft) or more above the ground if supported, although erect bush varieties have been bred, generally 100 cm (3 ft) tall or shorter. Indeterminate types are "tender" perennials, dying annually in temperate climates (they are originally native to tropical highlands), although they can live up to three years in a greenhouse in some cases. Determinate types are annual in all climates. Tomato plants are dicots, and grow as a series of branching stems, with a terminal bud at the tip that does the actual growing. When that tip eventually stops growing, whether because of pruning or flowering, lateral buds take over and grow into other, fully functional, vines. Tomato vines are typically pubescent, meaning covered with fine short hairs. These hairs facilitate the vining process, turning into roots wherever the plant is in contact with the ground and moisture, especially if the vine's connection to its original root has been damaged or severed.

Most tomato plants have compound leaves, and are called regular leaf plants, but some cultivars have simple leaves known as potato leaf style because of their resemblance to that particular relative. Of RL plants, there are variations, such as rugose leaves, which are deeply grooved, and vegetated, angora leaves, which have additional colors where a genetic mutation causes chlorophyll to be excluded from some portions of the leaves. The leaves are 10–25 cm (4–10 in) long, odd pinnate, with five to 9 leaflets on petioles, each leaflet up to 8 cm (3 in) long, with a serrated margin; both the stem and leaves are densely glandular-hairy. Their flowers, appearing on the apical meristem, have the anthers fused along the edges, forming a column surrounding the pistil's style. Flowers in domestic cultivars can be self-fertilizing. The flowers are 1–2 cm (0.4–0.8 in) across, yellow, with five pointed lobes on the corolla; they are borne in a cyme of three to 12 together.

Tomato fruit is classified as a berry. As a true fruit, it develops from the ovary of the plant after fertilization, its flesh comprising the pericarp walls. The fruit contains hollow spaces full of seeds and moisture, called ocular cavities. These vary, among cultivated species, according to type. Some smaller varieties have two cavities, globe-shaped varieties typically have three to five, beefsteak tomatoes have a great number of smaller cavities, while paste tomatoes have very few, very small cavities. For propagation, the seeds need to come from a mature fruit, and be dried or fermented before germination.

Functional uses:

Tomatoes are an intensely nutritious plant food. The benefits of consuming different types of fruit and vegetable are impressive, and tomatoes are no different. As the proportion of plant foods in the diet increases, the risk of developing heart disease, diabetes, and cancer decreases. There are different types and sizes of tomato, and they can be prepared in different ways. These include cherry tomatoes, stewed tomatoes, raw tomatoes, soups, juices, and purees. The health benefits can vary between types. For example, cherry tomatoes have higher beta-carotene content than regular tomatoes. High fruit and vegetable intake is also linked to healthy skin and hair, increased energy, and lower weight. Increasing the consumption of fruits and vegetables significantly decreases the risk of obesity and overall mortality.

3.6 Experimental Design

The experiment was laid out following factor RCBD with three (3) replications. Total no of experimental plots were 9. The unit plot size is 2m. × 2m. = 4 m^2. The treatment of the experiment are as follows-

Factor: Various distances from Mango tree

T_1= 45 cm from tree base

T_2= 85 cm from tree base

T_3= 125 cm from tree base

T_4= 165 cm from tree base

Fig. 3.2: Different distances from tree base

3.7 Tree management

The study was done under ten year's old Mango tree. At first soils at the base of tree were loosening very well and made friable. Weeds were removed from the surrounding area of the tree base; insect infected leaves of stems were also removed.

3.8 Land preparation

The land of experimental plot was opened in the 2nd week of March 2019 with spade and it was made ready for transplanting 23rd March, 2019. The land was properly cleared. The corners of the land were spaded and visible larger clods were hammered to breaking to small pieces. All weeds and stubbles were removed from the held. The layout was done as per experimental design and finally the land was prepared for transplanting the summer tomato seedlings. All basal dosages of fertilizers as per scheduled of the experiment was incorporated in the soil and finally the plots were made ready for planting.

3.9 Application of fertilizers and Manures

Cowdung and TSP were added to the soil at final land preparation. Half of urea and MP, were applied at the time of land preparation and remaining Urea and MP were top dressed in two equal installation at 25 and 50 days after transplanting. The doses were according to BARC rate i.e. 217 kg N/ha, 227 kg P_20_5/ha and 187 kg K_2O/ha and cowdung 14000 kg/ha.

3.10 Transplanting of seedlings

Twenty six days old and disease free seedlings were transplanted into the main field on 24th March, 2019 maintaining spacing 40 cm plant to plant and line to line 50 cm according to treatments.

3.11 Intercultural operation

Different management practices such as weeding, irrigation, earthen up, irrigation, plant protection, drainage system etc. were done for better growth of the plants. The management practices were done describe as follows:

Weeding and Mulching

Manual weeding was done as and when necessary to keep the plots completely free from all weeds by spades and khurpi by hands. The soil was mulched by breaking the crust for aeration and to conserve soil moisture after irrigation.

Irrigation

Irrigations were provided throughout the growing period. The first one was done at 1st day after transplanting. Irrigation was provided 2 times per day for next 10 days. After that irrigation was provided at 5 days interval 2 times per day.

Plant protection

Rovral 50 WP was sprayed (0.2%) at 10 days interval after 10 days of transplanting up to 75 DAP to control purple blotch caused by *Alternaria porri*. Tomato plants were provided support with bamboo sticks during 1st growing periods so that plants don't get injured due to rainfall and wind. During fruiting period thin ropes were used to make nets to provide support to the plants so that plants and fruits don't touch the soil and get infected.

Earthen up

Earthen up was done in every plants basal part to reduce the damage of water as rainfall occurs efficiently in this period of the year. Damage to the roots of tomato plants reduced due to earthen up and no plants were injured due to rainfall.

Drainage system

Good drainage system was made so that water don't stand and stagnation of water don't occur in the field and plants don't get damaged due to rainfall or excessive water.

3.12 Harvesting

The crop was harvested in 3 halves in whole time of fruiting depending on their maturity. Before 10 days of harvest, when the plants attained maturity by showing drying up of leaves and weakening of necks, the crop was bended at the soil level by hands and kept as such up to harvest to hasten maturity (Faruq, 2003). The Tomato was harvested with the help of hand. Care was taken so that no tomato was injured during harvesting. Then they were kept in a cool and dry place.

3.13 Data collection

Four plants were selected randomly from each plot and tagged properly for data collection. 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 branch per plant
- Number of leaves per plant
- Fruit yield of plants (t/h)
- Green weight of plants (gm)
- Dry weight of plants (gm)
- Yield

Plant height (cm)

The height of the selected plants were recorded at 30, 45 and 60 days after transplanting (DAT). Plant height was measured in centimeter from the neck to the tip of the longest leaf. Mean height of the individual plants were calculated from representative of 4 plants.

Number of branch per plant

The number of active branch per plant at final days after transplanting was counted and the average of selected 4 plants were taken as the number of branch per plant. Mean of total number of active leaves per plant was then recorded from the representative of 4 plants from every plots.

Number of leaves per plant

The number of active leaves per plant at final days after transplanting was counted and the average of selected 4 plants were taken as the number of branch per plant. Mean of total number of active leaves per plant was then recorded from the representative of 4 plants from every plots.

Fruit yield of plants

Fruits yield per plant was counted and the average of selected 4 plants was taken as the fruits yield per plant. Mean of total weight of fruits per plant was then recorded from the representative of 4 plants.

Yield

The fruits of selected plants weighed at each harvest and the summation is considered as fruit yield plot. Finally yield data was converted into t/ha^1.

Fresh weight of plants

The selected plants were uprooted and properly cleared the soil from the roots. Then plants were tagged with names. After that plants were taken to our Agroforestry and Environment Department laboratory in 3rd of July, 2019 and their fresh weight were taken.

Dry weight of plants

After fresh weight the plants were kept in oven for 72 hours for drying. After drying for almost 3 days the plants were taken out from the drying oven and their dry weight were taken carefully in our Agroforestry and Environment laboratory.

3.13 Data analysis

The data were collected from the experiment at different stages of various growths and then analyzed statistically by using PC STATISTIX 10 software package to find out the statistical significance of the experimental results. The analysis of variance (ANOVA) for each of the recorded character was done by F (variance ratio) test. The mean differences were evaluated by Least Significant Difference (LSD) test. The mean differences were evaluated by Tukey (HSD) test (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

Morphological characteristics of tomato were affected significantly by increasing distance from mango tree base. The data on various characteristics of morphological and yield traits viz. plant height, number of primary branches/plant, number of leaves/primary branch, number of leaves/plant, weight of fruits, fresh and dry weight of yield of fruits were discussed based on findings.The experiment was carried out to investigate the growth and yield performance of tomato under *Mangifera indica* based agroforestry production system as influenced by different spacing from Mango tree. The results and related discussion were presented in tables, figures and plates concurrently in this chapter under the following sub- headings.

4.1 Effect of production system on growth and yield of tomato

4.1.1 Plant Height

Tomato grown under multipurpose trees based agroforestry system was more vigorous i.e. in full sun light conditions (Table 4.1). It exhibited considerably higher plant height under tree based agroforestry system. At 30 days after transplanting (DAT) the lowest plant height (16 cm) was observed in $T_{4,}$ long distanced plants from tree where as the highest plant height (21 cm) was observed in T_1 short distance plants from tree. At first the growth of short distanced tomato plants were high but after a few days at 45 DAT, the lowest plant height (40 cm) was observed in $T_{1,}$ short distanced plants from tree, on the other hand the highest plant height (62 cm) long distanced plants from tree, where the long distanced plants became higher in T_4. At 60 DAT, the lowest plant height (102 cm) was observed in $T_{1,}$ short distanced plants from tree on the other hand the highest plant height (137 cm) was observed in $T_{4,}$ long distanced plants from tree. 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. The same results are evident in the study of Thangam and Thamburaj (2008) who stated that plants grown under shade exhibited better growth in term of plant height as compared to those in open field. Similarly Paez and Lopez (2000) observed that plant height and leaf area increased in the shade. Murakami *et al*. (1997) stated that red light interception caused low ratio of red and far red light which results in increase in plant height.

Table 4.1. Effect of production system on plant height (cm) of tomato

Treatment	Plant Height(cm)		
	30DAY	45DAY	60DAY
T_1 (45 cm from tree base)	19a	45.222c	110.67c
T_2 (85 cm from tree base)	18.667a	48.111bc	122.89b
T_3 (125 cm from tree base)	18.778a	51.222ab	124.11ab
T_4 (165 cm from tree base)	17.889a	54.222a	129.44a
CV%	7.86	8.42	3.6

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by (Tukey HSD test) at $P \leq 1\%$ level.

4.1.2 Number of branches plant^{-1}

Number of branches per plant of tomato was observed significantly varied in different production system (Table 4.2). At harvesting time, the highest number of branches per plant (2) was observed in T_1 and $T_{2,}$ short distanced tomato plants, where as the lowest number of branches per plant (4) was recorded in T_4 long distanced tomato plants. . Islam *et al*. (2009) reported that morphological characteristics of vegetables namely number of leaf, leaf length and diameter, stem girth, fresh and dry weight etc. decreased consistently with the decrease of distance from the tree base.

Table 4.2. Effect of production system on number of branches and leaves per plant of tomato

Treatment	Branch & Leaf Number	
	Branch	Leaf
T_1 (45 cm from tree base)	2.3333b	22.333b
T_2 (85 cm from tree base)	2.3333ab	24.889b
T_3 (125 cm from tree base)	2.6667a	27.111b
T_4 (165 cm from tree base)	3.3333a	28a
CV%	18.54	12.8

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by (Tukey HSD Test) at $P \leq 1\%$ level.

4.1.3 Number of leaves plant^{-1}

Number of leaves per plant of tomato was observed significantly varied in different production system (Table 4.2). At harvesting time, the highest number of leaves per plant (19) was observed in $T_{1,}$ short distanced tomato plants, where as the lowest number of leaves per plant (34) was recorded in $T_{3,}$ long distanced tomato plants. Islam *et al*. (2009) reported that morphological characteristics of vegetables namely number of leaf, leaf length and diameter, stem girth, fresh and dry weight etc. decreased consistently with the decrease of distance from the tree base.

4.1.4 Fruit yield plant^{-1}

Fruits yield per plant was found statistically significant by the effect of different production systems (Table 4.3). 25 days after flowering significantly the highest fruits per plant was (10.15 t/h) found in $T_{4,}$ long distanced tomato plants, on the other hand lowest fruits per plant was (5.55 t/h) found in T_1 short distanced tomato plants. 40 days after flowering significantly the highest fruits per plant was (11.375 t/h) found in $T_{4,}$ long distanced tomato plants, on the other hand lowest fruits per plant was (8.975 t/h) found in $T_{1,}$ short distanced tomato plants. Again 55 days after flowering significantly the highest fruits per plant was (6.15 t/h) found in $T_{4,}$ long distanced tomato plants, on the other hand lowest fruits per plant was (3.8 t/h) found in $T_{1,}$ short distanced tomato plants. Thangam and Thamburaj (2008) observed that the yield under shade was low as compared to open field. Abdel Mawgoud *et al*. (1996) reported that shade didn’t affect tomato fruit yield consistently and its use is not justified. Meanwhile shade can be used to improve fruit quality such as reducing sun burn.

Table 4.3. Effect of production system on yield of tomato

Treatment	Yield per plant(t/h)		
	25 DAF	37 DAF	49 DAF
T_1 (45 cm from tree base)	6.2889b	9.361c	4.3139d
T_2 (85 cm from tree base)	6.8222b	9.906b	4.7639c
T_3 (125 cm from tree base)	7.1333ab	10.244b	5.1083b
T_4 (165 cm from tree base)	8.1194a	10.864a	5.5639a
CV%	12.98	3.73	4.14

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by (Tukey HSD Test) at $P \leq 1\%$ level.

Similar findings was also observed by Basak *et al*. (2009) who found that the yield contributing characteristics of vegetables increased gradually with the increase of planting distance from the tree base. Similar result was also reported by Khatun *et al*. (2009) and Khan & Hasan (2015) for bitter gourd,tomato cultivation. Gent (2008) who stated that shading did not affect the rate of fruit production within three weeks of application, but after more then six weeks, it was 30% less under 0.5 shade density than under no shade. Paez and Lopez (2000) reported that shading contributed to ameliorate the effect on vegetative growth probably by causing a decrease in temperature but did not alter fruit establishment. Thangam and thamburaj (2008) stated that the number of fruits per plant was more in open field than under shade.

4.1.5 Total Yield

In case of total yield lowest yield was observed in T_1 the short distanced tomato plants from mango tree (18.575 ton/ha) and highest yield was recorded from the tomato plants (26.95 ton/ha) which were planted in T_4 long distances from mango tree. Similar findings was also observed by Basak *et al*. (2009) who found that the yield contributing characteristics of vegetables increased gradually with the increase of planting distance from the tree base. Similar result was also reported by Khatun *et al*. (2009) and Khan & Hasan (2015) for bitter gourd,tomato cultivation. Thangam and thamburaj (2008) stated that the number of fruits per plant was more in open field than under shade.

4.1.6 Fresh weight per tomato plant

After 5 days of final harvest, the sample plants were taken to laboratory for recording dry plants. Records showed various statistical data for various treatments of the tomato (Fig. 4.1). The lowest green weight data was (241 gm) found in $T_{2,}$ short distanced tomato plants, on the other hand the highest green weight data was (307 gm) found in $T_{4,}$ long distanced tomato plants.

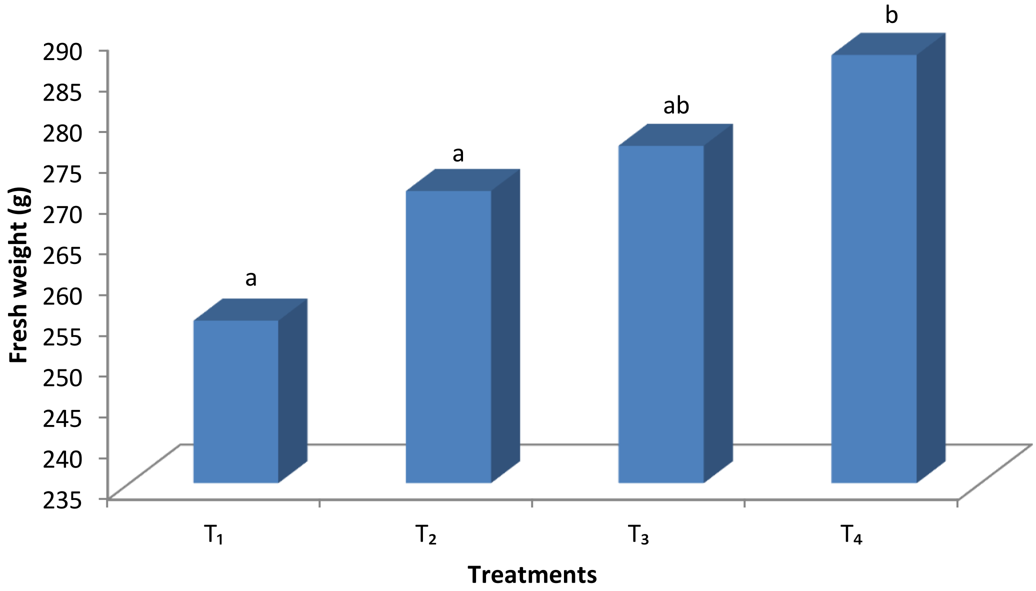

Fig. 4.1. Effect of production system on fresh weight of tomato plants

In a bar, figures having the similar letter (s) or without letter (s) do not differ significantly by (Tukey HSD Test) at $P \leq 1\%$ level.

Results are comparable with the findings of Basak *et al*. (2009) where they found that the yield contributing characters of the vegetables increased gradually with the increase of planting distance from the tree. Similarly Sayed *et al*. (2009) reported that the highest production of vegetables was recorded in control condition (without tree) and tomato, radish and soybean vegetable yield gradually increased with the increase of planting distance from the tree base.

4.1.7 Dry weight per tomato plant:

After 5 days of final harvest, the sample plants were taken to laboratory for recording dry plants. Records showed various statistical data for various treatments of the tomato (Fig. 4.2). The lowest green weight data was (34 gm) found in $T_{1,}$ short distanced tomato plants, on the other hand the highest green weight data was (94 gm) found in $T_{4,}$ long distanced tomato plants.

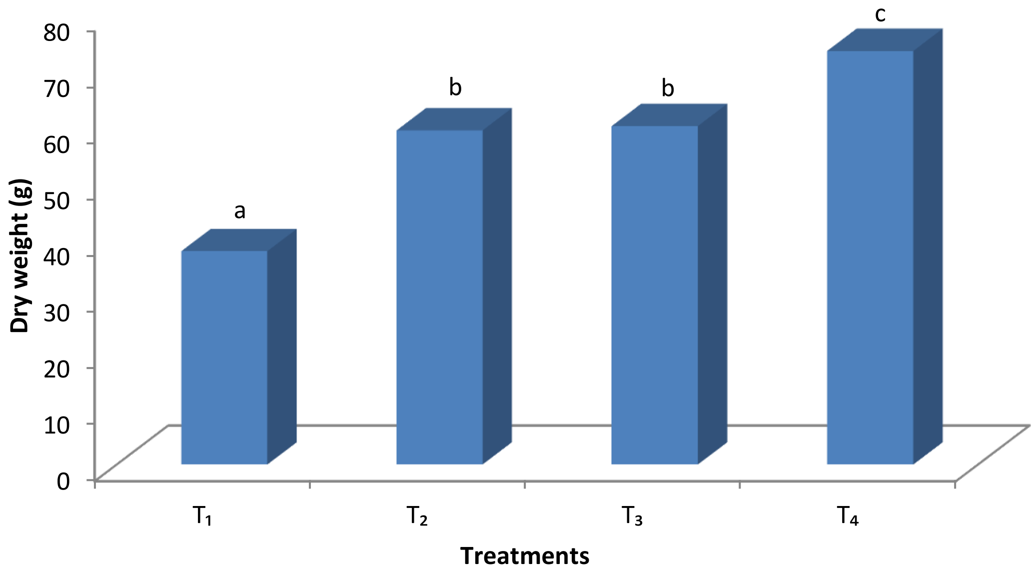

Fig. 4.2. Effect of production system on dry weight of tomato plants

In a bar, figures having the similar letter (s) or without letter (s) do not differ significantly by (Tukey HSD Test) at P ≤ 1% level.

Results are comparable with the findings of Masfikha (2013), Rahman (2013) and Khan & Hasan (2015) where they found the similar findings in case of dry weight of yield of bitter gourd. Mallick *et al*. (2013) and Rahman *et al*. (2013) also observed the consistent results of this present study.

4.1.8 Comparison among summer and winter tomato yield

In our country tomato in mainly cultivated as winter vegetables. Now a days both summer and winter tomato are grown with multiparous trees as inter crop following agroforestry system. We can say that it is profitable from the datas provided by various organizations and informations. But now it is to meet the need of people tomato is cultivated in summer season. Although it is tough to cultivate tomato in summer season because of heavy rainfall in rainy season and storms in summer season as like 'Kalbaishakhi'. So special care should be taken to have maximum yield of tomato during summer season. Because of this various types of special protection should be provided during production of summer tomato (BARI-4). Special care also should be taken towards irrigation and drainage system as standing water does a lot of damage to the roots of tomato plants. Another crucial factor is temperature. Excessive heat can also damage the growth and yield of the tomato plants. Though production of summer tomato is almost a new concept in our country but various steps are being taken to maximize the production of summer tomato. In our country production of summer tomato is increasing day by day by the help of various agricultural researches which is very helpful to meet our needs of vegetable during summer.

Table 4.4 Comparison among summer and winter tomato yield

Tomato	Yield t ha^{-1}		
	2015	2016	2017
Winter	13.51	13.46	14.04
Summer	7.21	6.98	8.03

(Source: BBS, 2017)

CHAPTER 5

SUMMERY, CONCLUSION AND RECOMMENDATION

5.1 Summery

The experiment was carried out to investigate the growth and yield performance of tomato under different ages of *Mangifera indica* based agroforestry production system as influenced by different spacing from Mango tree during March 2019 to July 2019. The experiment was conducted in newly established orchard of multipurpose tree species of *Mangifera indica* (Mango tree) the tree saplings were planted and the age of the tree were 8-10 years.

A popular tomato variety BARI-4 was used for the experiment. This is a high yielding indeterminate type. The experiment was laid out following two factors Randomized Completely Block Design (RCBD) with three (3) replications. The treatments of the experiment were T_1= 45cm, T_2= 85cm, T_3= 125cm and T_4= 165cm. Total no of experimental plots were 9. The unit plot size is 2 m × 2 m; The land was opened on 2^{nd} week of March 2019 by spades and khurpi. Opening the land, the plots were ploughed and cross-ploughed followed by laddering to break up the soil clods to obtain good tilth and level the land. The entire quantity of cowdung (10 ton/ha) was applied just after opening the land. Urea, TSP and MP were applied as the source of nitrogen, phosphorus and potassium respectively as recommended dose 100 kg N, 60 kg P205 and 50 kg K20 in each experiment plot. Finally, twenty six days old seedlings were transplanted in the main plots on 24 March 2019. After transplanting the seedlings necessary intercultural operations were done accordingly. Four plants were selected randomly from each plot and tagged properly for data collection. 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.

The data were recorded two broad heads, i) growth stage ii) harvesting stage, The growth stage data were taken at 30, 45, and 60 days after sowing (DAT) for plant height and number of branch plant^{-1}. The harvesting stage data were taken in the harvesting stage viz. fruit yield per plant, yield of tomato, branch number per plant, leaf number per plant, green weight and dry weight. The data were analyzed statistically and means were adjusted by DMRT (Duncan's Multiple Range Test). The results of the research were showed that the production systems of tomato, were significant in respect of plant height (cm), number of branch plant^{-1}, fruit weight plant^{-1} and fruit yield, respectively.

In case of production system, plant height was found almost highest in long distance based agroforestry system at different days after transplanting, while the lowest plant height was calculated from short distance from tree (control treatment). At 30, 45, 60 DAT and final harvesting time number of branches plant^{-1} of tomato was observed significantly varied in different production system. The highest number of branches plant^{-1} was recorded in long distance where as the lowest number of branches plant^{-1} was recorded in short distance from the tree. Number of fruits plant^{-1} was found statistically significant by the effect of different distances from Mango tree. Significantly the highest number of fruits plant^{-1} was recorded in long distance tomato plants from the Mango tree and the lowest number of fruits plant^{-1} was found in short distance tomato plants from Mango tree. The highest yield was found in the long distance tomato plants from Mango tree and lowest yield was found from the tomato plants which are near the mango tree. Finally, interaction effects of production system of tomato with various ages of mango tree and various distances had diverse variation significantly. Among the 12 treatment combinations, tomato plants which were long distanced from Mango tree and were cultivated association with younger mango trees had the best performance in response of growth and yield of tomato.

5.2 Conclusion

Significant influence of different distance from mango tree base on morphological characteristics as well as the yield of tomato was observed. Yield performance of tomato was better under open field condition compared to tree-crop base may be due to less competition for natural resources. Among the distances from the tree base, the long distance gave the best production of vegetable. The short distance showed less production due to competition for nutrient, water and other growth factors in agroforestry system. For this reason, growth and yield of summer tomato reduced beneath the tree canopy or near the tree base. But the agroforestry practice is profitable for farmer because same land produces vegetable and fruit at the same time. It may be concluded that tomato can successfully grow in cultivation with mango tree as silviagricultural system of Bangladesh perspective.

The present study indicates tomato can be grown more effective in the vacant space of various ages of Mango multipurpose tree species based agroforestry system as an organic basis that brings healthy hygiene for fresh consume as well as cooking food. The result revealed that most significant yield result can be found in long distance from tree which is suitable for summer tomato in shade condition; but their degree of suitability will be as long distance (165 cm) > medium distance (125 cm and 85 cm) > short distance (45 cm). Finally it would be concluded that the longer distance from tree base system with association of Mango tree based summer tomato production is more profitable in association of short distance from tree base system with association of Mango tree based agroforestry.

5.3 Recommendations

- This study should be repeated in the different locations of the country.
- The future research should be planned to work on several aspects of commercial trees of various ages + tomato with various distances from tree base.
- It appears that a package of technology could be formulated after completion of the research programme and it will be helpful for the poor people of the country to fulfill their nutritional needs of vegetables and at the same time, to make the tomato production a system based, cost effective and hence, profitable.

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APPENDICES

Appendix I: Weather report of few months experiments

Months	Air temperature (degree F)			Wind (km/h)	Relative Humidity	Rainfall (mm)	Sunshine (hrs)
	Maximum	Minimum	Average				
April	89	71	81	3.6	65%	27	312
May	88	72	82	3.75	76%	15	301
June	95	74	85	3	78%	21	329
July	90	74	83	4.2	82%	82	336
August	98	78	87	3.75	71%	92	322

Source: Bangladesh Meterological Station.

Appendix II: Some photographs of experimental site

(a) Fruit Harvesting Stage

(b) Growth Stage

(c) Fruiting Stage

(d) Earthen up

(e) Plant Protection

(f) Maturing Stage

(g) Pre-Maturing Stage

(h) Netting Plant protection

(i) Removal of weeds

(j) Taking data of tomato fruit

(k) Guide during data collection

(l) Initial fruiting stage

(m) Net Protection of Tomato plant

(n) Stick Protection of Tomato plant

(o) Irrigation

(p) Land Preparation

(q) Leaf curl of tomato

(r) Oven Dry Weight