ORGANIC PRODUCTION OF TOMATO UNDER DIFFERENT MULTIPURPOSE TREE BASED AGROFORESTRY PRACTICES AS INFLUENCED BY MULCHING

A THESIS

BY

SUDHIR CHANRDA BORMAN
Registration No. 1605444
Session: 2016

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MASTER OF SCIENCE (M.S.)
IN
AGROFORESTRY AND ENVIRONMENT

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HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY
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DECEMBER 2017

DEDICATED

TO

MY BELOVED PARENTS

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ORGANIC PRODUCTION OF TOMATO UNDER DIFFERENT MULTIPURPOSE TREE BASED AGROFORESTRY PRACTICES AS INFLUENCED BY MULCHING

ABSTRACT

An experiment was carried out at the Agroforestry and Environment Research Farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during October 2016 to April 2017 to evaluate the performance of tomato under kalo koroi, gora neem and ipil-ipil based agroforestry systems as influenced by different organic mulching. The experiment was conducted in 9 years old established woodlot of multipurpose tree species namely *Albizia lebbeck* (kalo koroi), *Melia azedarach* (ghora neem) and *Leucaena leucocephala*) (ipil-ipil) and the tree spacing were 3m × 3m. A popular tomato variety ratan as the test crop. The treatments of the experiment were factor A: T_0 = Tomato sole cropping (Control), T_1= Tomato + Kalo Koroi, T_2= Tomato + Gora Neem and T_3= Tomato + Ipil-ipil while the factor B: M_0= No mulch, M_1= Ash mulch, M_2= Saw dust mulch, and M_3= Water hyacinth mulch. All the organic mulching materials were applied in 15 days after transplanting in the experimental plots. Seeds were sown on 10th October 2016 in the seed bed. Twenty one days old seedlings were transplanted in the main plots on 31st October 2016. The results of the research were showed that the effect of production systems were significant in respect of plant height (cm), number of fruits plant^{-1}, fruit weight plant^{-1} and fruit yield of tomato, respectively. The highest yield (57.92 t ha^{-1}) was found in sole cropping of tomato which was identical to (57.52 t ha^{-1}) found in ipil-ipil + tomato based agroforestry system and also (54.17 t ha^{-1}) in ghora neem + tomato

based agroforestry system and the lowest yield (50.50 t ha^{-1}) was observed in kalo koroi + tomata based agroforestry system. In case of organic mulching, the highest yield (63.42 t ha^{-1}) was found in ash mulch which was identical to (61.25 t ha^{-1}) found in water hyacinth mulch while the lowest yield (41.33 t ha^{-1}) was observed in control (without mulch), respectively. The yield of tomato was also significantly varied due to interaction effect. Significantly the highest fruit yield (68.00 tha^{-1}) was recorded in ipil-ipil + tomato under organic ash mulch treatment combination. On the other hand, the lowest fruit yield (36.67 tha^{-1}) was recorded in kalo koroi + no mulch treatment combinations. The result revealed that the production of tomato will be ranked as open field > ipil-ipil > ghora neem > kalo koroi. Therefore, it should be mentioned that most of the organic mulch materials suitable for tomato in shade condition along with open field; but their degree of suitability will be as ash mulch > water hyacinth mulch > saw dust mulch. From the results and foregoing discussion, it is clear that open field is so good for the production of tomato in association of organic mulch but in MPT_s based agroforestry system it could be grown well. Based on the finding it can be concluded that tomato (var. Ratan) cultivation under the ipil-ipil tree appears as the best than other trees with association of ash organic mulching.

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CHAPTER 1
INTRODUCTION

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 person^{-1}, 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 recognise 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 nutritionally- 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 marginalised 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 the minimum daily requirement of 200 gm, the national production of vegetables should be over 10 million tons.

Tomato (*Lycopersicon esculentum* L.) is very popular vegetable grown successfully throughout the Bangladesh. It ranks next to potato and sweet potato in respect of vegetable production in the world (FAO, 2003). It has good production potential in our climate. Miah (2001) observed that tomato (single variety) could be grown successfully without yield loss up to 25% shade level. The growing management of tomatoes, however, is highly influenced by pulverization of pesticides, so, there is the requirement for improving tomato production, and give consumers superior flavor and quality to reach their expectations (Stolz, 2011). To produce organic food, it is necessary to use inputs and methods that improve the ecological equilibrium of natural systems. This happens because organic vegetable is grown without pesticides, herbicides, highly soluble fertilizers and genetically modified organisms.

The value of the organic product is not only in the product itself, but also in its production process. Mulching helps in better utilization of all the nutrients in the soil, meeting up the need of irrigation and thus increases yield. In the production of crops, soil always serves as the basic ingredient to be exploited fully to produce more. Mulching stimulates microbial activity in soil (Sayren, 1971) through the improvement of soil agro-physical properties (Geneve, 1981) so that organic matter content is increased (Stirzaker *et al.,* 1989). So, to combat these alarming situations, efficient management of natural resources is the call for of the hour. The existing land use systems with separate allocation to agriculture and forest are insufficient to meet the demands for food, fuel, fodder, timber and other minor products in the 21st century. One should follow effective and compatible cultivation approaches where forest tree and vegetables can be grown combined in the limited land. In this link, the agroforestry system may be the best substitute cultivation approach. The present experiment will be exploited to study the organic tomato production under different agroforestry as influenced by mulching for safe food tenure under the following objectives.

Objectives-

- To find out the growth and yield potential of tomato under kalo koroi, ghora neem and ipil-ipil based agroforestry systems.
- To determine the effect of different mulches on growth and yield of tomato.
- To measure the interaction effect of agroforestry practices and different mulches on growth and yield of tomato.

CHAPTER 2
REVIEW OF LITERATURE

This research has been undertaken to observe the performance of okra under litchi 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

Chapter 2

Review of Literature

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 circumstance 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,1997) 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, diversifies 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).

Agroforesty 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 *et al.,* 2006; Yamada and Osaqui, 2006).

Chapter 2

Review of Literature

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, diversifies 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 farming 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.

Penafiedl (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 *et 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.

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Review of Literature

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 bole 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.

Chapter 2

Review of Literature

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) abilit y 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%).

Chapter 2
Review of Literature

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.

Chapter 2

Review of Literature

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 and 3.38) 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-You 5) plants grafted on rootstocks of *Cucurbita ficifolia*, Zaoqing pumpkin, Jingli 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-1, no. of fruit plant-1, 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 Horitoki - Lemon - Vegetable based 11 Agroforestry system.

Chapter 2

Review of Literature

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.

Chapter 2

Review of Literature

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.

Bari 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 (29.87t ha-1in 2005 and 29.24t 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 characteristic 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 socioeconomic 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 socioeconomic 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.

Chapter 2

Review of Literature

Babu (2012) conducted an experiment to study the growth and yield of two vegetables i.e. chilli 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 chilli & sweetgourd.

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 plant^{-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, 2,5 plants/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/m^2 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 100 J/cm^2/plant and in addition per cluster 100 J/cm^2 with 240 W/m^2 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 agrofrestry system (T_1), Horitaki + Lemon based agroforestry system (T_2) and Bohera + lemon based agroforestry system (T_3) 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 field 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. After 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 14 and BARI Tomato 8, respectively.

2.6 Effect of light on plant growth in understoried 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 mungbean yield decreased linearly with the reduced percent light incidence, rice yields decreased by 47 kg/ha but mungbean yields decreased 10 kg/ha. In pruning regimes mungbean 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 tree 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 a IW/CPE ratio 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 14300/ha compared with the unmatched control.

Pertierra and Melin (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 fruits per plant (142) and the highest fruit yield per plant (691.1 g). Harvesting began 69 and 71 days after sowing for NN Claudia and Dwarf Green Long Pod, respectively.

According to Li-Xuezhi *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.

Chapter 2

Review of Literature

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 or 3 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 biofertilizers 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 at 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 (October, 2016 to January, 2017) are presented in the Appendix-II.

3.4 Experimental period

The experiment was conducted during October, 2016 to April, 2017

3.5 Experimental materials

1st layer: Three Multipurpose Trees

The tree species were -

- Kala koroi (*Albizia lebbeck*)
- GhoraNeem (*Melia azedarach*)
- Ipil- Ipil (*Leucaena leucocephala*)

The spacing for all the tree species were 3 m x 3 m. and the age were 8 years. The present status of the tree species in the research field are-

Table 3.1. Status of the existing tree species in the research field

Trees	Plant height (m)	Clean bole height	Base Girth (cm)	Bole Girth (cm)	Diameter at Breast Height
Kala koroi	15.5	5.5	100.0	80.0	75.0
Ghoraneem	13.0	5.0	110.0	85.0	80.0
Ipil-Ipil	16.5	6.5	95.0	70.00	70.0

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

A) Kala Koroi (*Albiza lebbeck*) - *Albizia lebbeck* is a tropical hardwood species. It is a large deciduous tree with spreading crown. It has blackish or dark grey, irregularly cracked bark. Leaf rachis 17-35 cm long (sometimes up to 20 cm) usually with an oval gland at the base, pinnae usually 2-5 pairs 5-20cm long often with glands between the leaflets. leaflets 3-10 pairs/pinna 2.5-3.0x1.5-2.0cm oblong Flowers greenish white in pedunculate heads calyx funnel shapped corolla te twice the length of the calyx Fruit a pod 15-30x3-4cm pale shiny yellowish-brown alterrately depressed on either side over the seed (Singh and Srivastra, 1989) The rootsystem is largely superficial leaflets during cold season Flowering time May jun freiting time:December-February

Functional uses:

Young leaves are used as cattle fodder. Albizia forage has about 20% protein.The wood of this tree burns well Its calarfic value is 5200k cal/kg of dry fuel.*Albizia* is a strong wood being about the same weight and hardness as teaj the wood is excellent for high cous furriture interior decoration and panelling. It is also used for making agricultural implements transport bodies etc (Trotter, 1982).

Services:

The foliage may be used as green manure or mulches in Agroforestry system the mulch reduces airdrop impact and prevent deterioration of the land the chopped leaves when used as green manure improves soil fertility status of soil.*Albizia lebbeck* is good soil binder.Its flower is a good source for honey production.

B) Ghora neem (*Melia azedarach*)- A handsome deciduous tree up to 45 m tall with wide spreading branches. The bark is smooth greenish brown. Leaves are bipinnate, sometimes tripinnate, 20-50 cm long. Pinnae usually opposite, 3-7 leaflets are found in each pinnae. Flowers are small liliac blue, Inflorescences long, auxillary panicle upto 20 cm long. Fruit a small, yellow drupe round about 1.5 cm in diameter, seed oblonged, 3.5 mm x 1.6 mm (Nagveni*et al.* 1987). Flowering time: March to May. Fruiting time: December to January.

Functional uses

Leaves and young shoots are lopped for fodder and are highly nutritious. The fruits are consumed by goat, sheep and birds. Fuel wood is a major use of it. It has calorific value of 5100 kcal/ kg. The wood is extensively used for toys, small box, house building, different furnitures etc. Aqueous and alcoholic extracts of leaves and seed reportedly control many insects, mite nematode pest. The fruits of *M. azedarach* is highly toxic to warm blooded (Attri, 1982). It is well known for its medicinal uses. Its various parts have antihelmintic, antinalarial and emmenegogic properties and are also used to treat skin disease.

Services:

Widely planted as a shade tree in coffee plantation. As an avenue tree, fruit, scented flowers and shady crown. *M. azedarach* is useful flowers shady for growing with crops like wheat. It has been successfully planted with sugarcane. The foliage can be used as green manure and mulch. The seed cakes can be proceeded to produce biofertilizer (Tiwari, 1983).This is mainly used against attacks of insects on dry fruit.

C) Ipil- ipil (*Leucaena leucocephala*)- *Leucaena leucocephala* is a fast growing deciduous tree with a short clear bole to 5 m upright, angular branching and open crown, maximum height 20 m. Bole diameter 10-15 cm, bark on young branches smooth, grey-brown, rustly orange-brown vertical tissues and deep red inner bark on older branches and bole. The deep- rooted plant often has a combination of flowers, immature and mature pods, all presents on the tree at the same time. Flowering time: March-April and August-October; Fruiting time: December-February.

Functional uses:

Pods, seeds and leaf tips have been used as food. although Mimosine toxicity makes this practice risky. Seeds can also be prepared as a coffee substitute.*Leucaena leucocephala* is one of the highest quality and most plantable fodder trees of the tropics. But livestock feed should not contain more than 20% of *L. leucocephala* as the mimosine can cause hair loss and stomach problems.It is an excellent firewood species with a specific gravity of 0.45-0.55 and a high colorific value of 4600 k cal/kg. The tree makes excellent charcoal with a heating value of 29 mj/kg and good recovery value (25-30%). Its pulping properties are suitatle for both paper and rayon production.*L. leucocephala* has hard heavy wood (about 800 kg/m) with a pale yellow sap wood and light reddish- brown hard wood. The wood is known to be of medium density and to dry without splitting or cheeking. It is strong medium textured, close grained and easily workable for a wide variety of carpentry purposes.

Services: Different services like erosion control, shade reclamation, it forms symbiotic relationship with *Rhizobium loti* (Halliday and Somasegaran, 1983), soil improvement by the addition of organic matter (Pathak and Gupta, 1987), decoration and boundary, barrier or suppor can get from this tree

A popular local Tomato variety Ratan was used for the study. This is a high yielding indeterminate type. The seeds of the variety were collected from Bangladesh Agricultural Development Corporation, Dinajpur. The variety was marketed by Bangladesh Agricultural Development Corporation.

3.6 Experimental design

The experiment was laid out following two factors RCBD with three (3) replications. Total no of experimental plots were 48. The unit plot size is 2.5m × 2.5m = 6.25 m^2. The treatments of the experiment are as follows-

Factor A: Four production systems

T_0= Open field + Tomato

T_1= Kalo Koroi + Tomato

T_2= Gora Neem + Tomato

T_3= Ipil-ipil + Tomato

Factor B: Four organic mulches

M_0 = No mulch

M_1 = Ash mulch

M_2 = Saw dust mulch

M_3 = Water hyacinth mulch

So, there were 16 treatment combinations. There are as follows-

T_0M_0, T_0M_1, T_0M_2, T_0M_3, T_1M_0, T_1M_1, T_1M_2, T_1M_3, T_2M_0, T_2M_1, T_2M_2, T_2M_3, T_3M_0, T_3M_1, T_3M_2 and T_3M_3

Mulch application

All the organic mulching materials were applied in 15 days after transplanting seedling in the plot i.e. 16 November 2016.

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3.7 Raising of seedlings

Tomato seedlings were raised in a seed bed situated on a relatively high land adjacent to the Agroforestry and Environment Research field. Five gram of seeds was sown in a seedbed on October 10th, 2016. Sown seeds were covered with light soil. Complete germination of the seeds took place within 7 days after sowing. Weeding, mulching and irrigation were done from time to time as and when needed.

3.8 Land preparation

The land of experimental plot was opened in the 2nd week of October 2016 with spade and it was made ready for transplanting on 31th October 2016. The corners of the land were spaded and visible larger clods were hammered to break into small pieces. All weeds and stubbles were removed from the field. The layout was done as per experimental design. All basal dosages of fertilizer 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_2O_5/ha and 187 kg K_2O/ha and cowdung 14000 kg/ha.

3.10 Transplanting of seedlings

Twenty one days old healthy and disease free seedlings were uprooted from the seedbed and transplanted in to the main field on 31th october 2016 maintain spacing 15 cm plant to plant and line to line 10cm.

3.11 Intercultural Operations

Weeding and Mulching

Manual weeding was done as and when necessary to keep the plots completely free from all weeds. 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 10 days after transplanting. Subsequently irrigations were given at 15 days interval.

Plant protection

Rovral 50 WP was sprayed (0.2%) at 10 days interval after 15 days of transplanting up to 75 DAP to control purple blotch caused by *Alternaria porri.*

3.12 Harvesting

The crop was harvested on 12 February, 2017. 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 fruits per plant
- Individual fruit weight
- Fruit yield per plant
- Yield

Plant height (cm)

The height of the selected plants were recorded at 15, 30, 45 and final 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.

Land preparation open field

Land preparation gora neem field

Land preparation kalo koroi field

Land preparation ipil-ipil field

Plate 3.1. Land preparation of different tree based agroforestry for tomato production

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Materials And Methods

Number of branch per plant

The number of active branch per plant at 15, 30, 45 and 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.

Number of fruits plant^{-1}

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

Individual fruit weight

Total numbers of harvested fruits during the harvesting periods were recorded and measured individual fruit weight through divided by the total number of fruits to total weight.

Fruit yield plant^{-1}

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}

3.14 Data analysis

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 experiment was carried out to investigate the growth and yield performance of tomato under *Albizia lebbeck, Melia azedarach and Leucaena leucocephala* based agroforestry production system as influenced by different organic mulching. The results and related discussion was 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 than grown in sole cropping i.e. in full sun light conditions (Table 1). It exhibited considerably higher plant height under tree based agroforestry system. At 15 days after transplanting (DAT) the highest plant height (32.67 cm) was observed in kalo koroi + tomato based agroforestry system (T_1) where as the lowest plant height (26.58 cm) was observed in sole cropping of tomato (T_0). Again at 30 DAT, the highest plant height (82.33cm) was observed in ghora neem + tomato based agroforestry system (T_2) on the other hand the lowest plant height (76.13 cm) was observed in sole cropping of tomato (T_0). At 45 DAT, the highest plant height (129.8 cm) was observed in kalo koroi + tomato based agroforestry system (T_1) on the other hand the lowest plant height (115.7 cm) was observed in sole cropping of tomato (T_0). Significantly at final harvesting time, the highest plant height (134.5 cm) was observed in kalo koroi + tomato based agroforestry system (T_1) on the other hand the lowest plant height (119.8 cm) was observed in sole cropping of tomato (T_0). 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 4.1. Effect of production system on plant height (cm) of tomato

Treatments	Plant height (cm)			
	15 DAT	30 DAT	45 DAT	Final harvest
T_0	26.58 b	76.13 a	115.7 b	119.8 b
T_1	32.67 a	81.71 a	129.8 a	134.5 a
T_2	27.75 ab	82.33 a	114.8 b	122.0 b
T_3	29.50 ab	78.54 a	118.0 b	123.8 ab
CV%	5.69	8.25	3.45	6.79

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

4.1.2 Number of branches plant^{-1}

Number of branches plant^{-1} of tomato was observed significantly varied in different production system (Table 2). At 15 DAT the highest number of branches plant^{-1} (3.17) was recorded in ghora neem + tomato based agroforestry system (T_2), where as the lowest number of branches plant^{-1} (2.33) was recorded in both sole cropping of tomato (T_0) and kalo koroi + tomato based agroforestry system (T_1). Again at middle stage (30 DAT) the highest number of branches plant^{-}

^{1} (7.33) was observed in ghora neem + tomato based agroforestry system (T_2), where as the lowest number of branches plant^{-1} (5.42) was recorded in sole cropping of tomato (T_0). At 45 DAT, the highest number of branches plant^{-1} (10.17) was observed in ghora neem + tomato based agroforestry system (T_2), where as the lowest number of branches plant^{-1} (8.83) was recorded in ipil-ipil + tomato based agroforestry system (T_3), respectively. Finally at harvesting time, the highest number of branches plant^{-1} (11.92) was observed in ghora neem + tomato based agroforestry system (T_2), where as the lowest number of branches plant^{-1} (10.67) was recorded in ipil-ipil + tomato based agroforestry system (T_3).

Table 4.2. Effect of production system on number of branches plant^{-1} of tomato

Treatments	Number of branches plant^{-1}			
	15 DAT	30 DAT	45 DAT	Final harvest
T_0	2.33 a	5.42 a	10.42 a	11.83 a
T_1	2.33 a	5.67 a	9.25 a	11.42 a
T_2	3.17 a	7.33 a	10.17 a	11.92 a
T_3	2.75 a	6.83 a	8.83 a	10.67 a
CV%	3.90	5.34	6.89	10.12

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

4.1.3 Number of fruits plant^{-1}

Number of fruits plant^{-1} was found statistically significant by the effect of different production systems (Table 3). Significantly the highest number of fruits plant^{-1} (11.00) was recorded in ipil-ipil + tomato based agroforestry system (T_3) which was similar to (9.42) found in ghora neem + tomato based agroforestry system (T_2). On the other hand, the lowest number of fruits plant^{-1}(7.41) was found in kalo koroi + tomato based agroforestry system (T_2) which was statistically similar to (7.67) found in sole cropping of tomato (T_0), respectively.

4.1.4 Individual fruit weight

Fruits weight was found statistically insignificant by the effect of different production systems (Table 3). Numerically the highest fruits weight (220.8 g) was recorded in ghora neem + tomato based agroforestry system (T_2). On the other hand, the lowest fruits weight (204.2 g) was found in kalo koroi + tomato based agroforestry system (T_2), respectively.

4.1.5 Fruit yield plant^{-1}

Fruits yield plant^{-1} was found statistically significant by the effect of different production systems (Table 3). Significantly the highest fruits plant^{-1} (2321 g) was recorded in ipil-ipil + tomato based agroforestry system (T_3). On the other hand, the lowest fruits plant^{-1}(14.63 g) was found in kalo koroi + tomato based agroforestry system (T_2) which was statistically similar to (1632 g) found in sole cropping of tomato (T_0), respectively.

4.1.6 Yield (tha^{-1})

Chapter 4

Results and Discussion

Tomato yield was differed significantly by the four production systems (Table 3). The highest yield (57.92 t ha^{-1}) was found in sole cropping of tomato (T_0) which was identical to (57.52 t ha^{-1}) found in ipil-ipil + tomato based agroforestry system (T_3) and also (54.17 t ha^{-1}) in ghora neem + tomato based agroforestry system (T_2). On the other hand the lowest yield (50.50 t ha^{-1}) was observed in kalo koroi + tomato based agroforestry system (T_1).

Table 4.3. Effect of production system on number of fruits $plant^{-1}$, individual fruit weight, fruit yieldplant^{-1} and yield (t ha^{-1}) of tomato

Treatments	Number of fruits $plant^{-1}$	Individual fruit weight	Fruit yield $plant^{-1}$ (g)	Yield (t ha^{-1})
T_0	7.67 b	215.0 a	1632 c	57.92 a
T_1	7.42 b	204.2 a	1463 c	50.50 b
T_2	9.42 ab	220.8 a	2054 b	54.17 ab
T_3	11.00 a	216.7 a	2321 a	57.25 a
CV%	6.43	9.87	10.48	4.49

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

4.2 Effect of organic mulching on growth and yield of tomato

4.2.1Plant Height

Effect of different organic mulches on the plant height was presented in the table 4. The plant height from the soil surface to the last opened leaves of the apex were recorded from 15 days after transplanting (DAT) and continued until harvesting. The results revealed that different mulching and non-mulching (control) treatments had significant variations over control. The highest plant height (30.00 cm) was recorded for plants grown under ash mulch while control had the lowest plant height (20.67cm) at 15 DAT. At 30 DAT the highest plant height of 82.25 cm was found in M_1 (ash mulch) which was followed by 80.13 cm in M_3 (water hyacinth mulch) and the lowest plant highest was 70.88 cm was found in control (M_0). At 45 DAT, the highest plant height was recorded in M_1 (128.40 cm) and the lowest was found in control treatment of 115.4 cm. The plant height was observed (133.50 cm) in tomato at final harvest from ash mulch (M_1) and the lowest was recorded in control (121.5 cm). Hossain (1996) recorded that plant height of garlic were significantly higher for mulched than unmatched plants. In a trail with organic mulches or polythene mulch on tomato a minimum effect had been observed on plant height by (Srivastara *et al.,* 1981). A similar result was also reported by Buitelaar (1989) in his studies.

Table 4.4. Effect of organic mulch on plant height (cm) of tomato

Treatments (Mulching)	Plant height (cm)			
	15 DAT	30 DAT	45 DAT	Final harvest
M_0	20.67 c	70.88 c	115.4 c	121.5 c
M_1	30.00 a	82.25 a	128.4 a	133.5 a
M_2	25.83 b	75.46 b	123.3 b	129.3 b
M_3	29.00 ab	80.13 ab	121.1 b	125.8 c
CV%	5.69	8.25	3.45	6.79

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at P ≤ 1% level.

4.2.2 Number of branches plant^{-1}

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Effect of different organic mulches on the number of branch plant^{-1} was presented in the table 5. The results revealed that different mulching treatments had no significant variations in number of branch plant^{-1} in the early stage of plant growth but with the advancement of the plant growth i.e. at 45 DAT and at final harvest the branch number vary significantly. The highest number of branch plant^{-1} (20.58) was recorded in plants grown under ash mulch while control had the lowest branch plant^{-1} (10.42) at 45 DAT. At final harvest the highest number of branch plant^{-1}(35.50) was found in M_1 (ash mulch) which was followed by M_2 (saw dust mulch) and the lowest number of branch plant^{-1}(20.75) was found in control (M_0). Olasautan (1985) was found significantly higher number of branch/plant in tomato from mulched plants than unmulched plants. A similar finding was reported by Wojtaszek *et al.* (1977).

Table 4.5. Effect of organic mulch on number of branches plant^{-1} of tomato

Treatments (Mulching)	Number of branches plant^{-1}			
	15 DAT	30 DAT	45 DAT	Final harvest
M_0	2.33 a	6.25 a	10.42 c	20.75 c
M_1	3.08 a	7.33 a	20.58 a	35.50 a
M_2	2.67 a	6.08 a	19.50 ab	30.42 ab
M_3	2.50 a	5.58 a	16.17 b	25.17 b
CV%	3.90	5.34	6.89	10.12

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

4.2.3 Number of fruits plant^{-1}

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Effect of different mulches on the number of fruits plant^{-1} was presented in the table 6. Significantly the highest number of fruit plant^{-1} (15.75) was recorded in M_1 (ash mulch) On the other hand, the lowest number of fruit plant^{-1} (8.08) was recorded in M_0 control (unmulched treatment). Total number of fruit plant^{-1} is an important yield contributing character. Mateusz *et al.* (2009) also found cultivar specific difference in fruit number.

4.2.4 Individual fruit weight

Among all mulching treatments, the highest individual fruit weight (233.3 g) was recorded in M_1 (ash mulch) followed by M_3 (Water hyacinth). The lowest fruit weight (191.7 g) was recorded in M_0 control (without mulch). Medina *et al.* (2011) reported that all mulch treatment give higher yield compared with the control.

4.2.5 Fruit yield plant^{-1}

Fruits yield plant^{-1} was found statistically significant by the effect of different organic mulching (Table 6). Significantly the highest fruits plant^{-1} (2123 g) was recorded in M_1 (ash mulch) followed by M_2 (saw dust mulch) and M_3 (Water hyacinth). On the other hand, the lowest fruits plant^{-1}(1513 g) was found in M_0 control (without mulch), respectively. Medina *et al.* (2011) reported that all mulch treatment give higher yield compared with the control.

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4.2.6 Yield (tha^{-1})

Tomato yield was differed significantly by the four organic mulching (Table 6). The highest yield (63.42 t ha^{-1}) was found in M_1 (ash mulch) which was identical to (61.25 t ha^{-1}) found in M_3 (Water hyacinth). On the other hand the lowest yield (41.33 t ha^{-1}) was observed in M_0 control (without mulch), respectively. Medina *et al.* (2011) reported that all mulch treatment give higher yield compared with the control.

Table 4.6. Effect of organic mulch on number of fruits $plant^{-1}$, individual fruit weight, fruit yieldplant^{-1} and yield (t ha^{-1}) of tomato

Treatments (Mulching)	Number of fruits plant-	Individual fruit weight	Fruit yiel plant^{-1} (g	Yield (t ha^{-1})
M_0	8.08 c	191.7 c	1513. b	41.33 c
M_1	15.75 a	233.3 a	2123. a	63.42 a
M_2	12.67 b	216.7 b	1896. a	53.83 b
M_3	10.00 b	225.0 ab	1938. a	61.25 a
CV%	6.43	9.87	10.48	4.49

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

4.3 Interaction effects of production system and organic mulching on growth and yield of tomato

4.3.1 Plant height

The interaction effect of production system and organic mulches had brought about significant differences in plant height among the treatments (table 7). From the interaction effect, the plant height of tomato at different DAT was shown significantly different except 30 DAT. At 15, highest plant height (34.33 cm) was found in T_1M_1 treatment combination which was followed by other treatment combination except T_3M_2. At 30 DAT the plant height was found statistically insignificant. At 40 DAT the highest plant height (89.83 cm) was recorded in T_1M_1 treatment combination and the lowest plant height (101.70 cm) was found in T_2M_0 treatment combination. Finally at final harvest the highest plant (140.0 cm) was observed in T_1M_1 treatment combination and the lowest plant height (106.7 cm) was found in T_2M_0 treatment combination, respectively.

Table 4.7. Interaction effect of production system and organic mulch on plant height (cm) of tomato

Interaction		Plant height (cm)			
		15 DAT	30 DAT	45 DAT	Final harvest
T_0	M_0	26.33 ab	76.67 a	113.3 abc	120.0 fg
	M_1	31.33 ab	76.33 a	118.3 abc	120.7 ef
	M_2	31.00 ab	75.67 a	128.7 ab	135.7 b
	M_3	29.33 ab	75.83 a	111.7 abc	118.7 fg
T_1	M_0	32.67 ab	76.17 a	130.0 ab	134.3 b
	M_1	34.33 a	89.83 a	135.0 a	140.0 a
	M_2	32.67 ab	83.67 a	127.7 abc	133.7 b
	M_3	31.00 ab	77.17 a	126.7 abc	130.0 c
T_2	M_0	28.33 ab	77.33 a	101.7 c	106.7 i
	M_1	25.67 ab	83.67 a	111.7 abc	118.3 g
	M_2	28.33 ab	81.50 a	119.7 abc	125.3 d
	M_3	28.67 ab	86.83 a	126.0 abc	129.0 c
T_3	M_0	27.33 ab	77.33 a	106.7 bc	113.3 h
	M_1	28.67 ab	79.17 a	118.7 abc	126.7 d
	M_2	23.33 b	77.00 a	117.3 abc	122.3 e
	M_3	27.00 ab	80.67 a	120.0 abc	125.7 d
CV%		5.69	8.25	3.45	6.79

4.3.2 Number of branches plant^{-1}

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The interaction effect of production system and organic mulches had significant effect on number of branch plant^{-1} at the later stage of plant growth (Table 8). At 15, 30 DAT there was no significant variation among the treatment combinations but, at 45 DAT and at the time of final harvest, the branch plant^{-1} showed significant variation among the treatment combinations. At 45 DAT significantly the highest branch plant^{-1} (11.33) was found in both T_0M_1 and T_0M_2 treatment combinations and the lowest number of branch plant^{-1} (6.67) was in T_1M_2 treatment combination. At final harvest, significantly the highest branch plant^{-1} (13.00) was found in T_2M_2 treatment combination and the lowest number of branch plant^{-1} (9.67) was in both T_1M_2 and T_3M_3 treatment combinations, respectively.

Table 4.8. Interaction effect of production system and organic mulch on number of branches plant^{-1} of tomato

Interaction		Number of branches plant^{-1}			
		15 DAT	30 DAT	45 DAT	Final harvest
T_0	M_0	1.667 a	4.667 a	9.00 b	10.33 b
	M_1	2.000 a	5.333 a	11.33 a	12.67 ab
	M_2	3.333 a	6.000 a	11.33 a	12.67 ab
	M_3	2.333 a	5.667 a	10.00 ab	11.67 ab
T_1	M_0	2.333 a	5.667 a	10.67 ab	11.67 ab
	M_1	3.000 a	7.667 a	10.33 ab	12.67 ab
	M_2	1.667 a	4.333 a	6.67 d	9.67 c
	M_3	2.333 a	5.000 a	9.33 c	11.67 ab
T_2	M_0	3.000 a	7.000 a	9.33 c	10.67 b
	M_1	4.333 a	9.000 a	10.67	12.33 ab

				ab	
	M_2	3.000 a	7.000 a	11.00 ab	13.00 a
	M_3	2.333 a	6.333 a	9.67 b	11.67 ab
T_3	M_0	2.333 a	7.667 a	8.67 c	10.33 b
	M_1	3.000 a	7.333 a	10.00 b	12.33 ab
	M_2	2.667 a	7.000 a	9.00 b	10.33 b
	M_3	3.000 a	5.333 a	7.67 cd	9.67 c
CV%		3.90	5.34	6.89	10.12

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

4.3.3 Number of fruits plant^{-1}

Number of fruit plant^{-1} was found significantly different due to interaction effect of production system and organic mulching presented in table 9. Significantly the highest number of fruit plant^{-1} (15.0) was found in T_3M_1 treatment combination which was followed by T_1M_2, T_3M_2 and T_3M_3 treatment combinations. On the other hand, the lowest number of fruit plant^{1} (5.33) was recorded in T_1M_0 treatment combination that was statistically similar to T_0M_0 treatment combination, respectively.

4.3.4 Individual fruit weight

Individual fruit weight was found significantly different due to interaction effect of production system and organic mulching presented in table 9. Significantly the highest individual fruit weight (266.7 g) was found in T_3M_1 treatment combination which was followed by all other treatment combinations except T_1M_3 and T_2M_3 treatment combinations. On the other hand, the lowest individual fruit weight (166.7

g) was recorded in both T_1M_3 and T_2M_3 treatment combinations.

4.3.5 Fruit yield plant^{-1}

Fruit yield plant^{-1} was found significantly varied due to interaction effect of production system and organic mulching presented in table 9. Significantly the highest fruit yield plant^{-1} (3167 g) was observed in T_3M_1 treatment combination which was followed by (3050 g) was found in T_3M_2 treatment combination. On the other hand, the lowest fruit yield plant^{-1} (1000 g) was recorded in T_1M_3 treatment combinations, respectively.

4.3.6 Yield (tha^{-1})

Yield (tha^{-1}) was found significantly diverse due to interaction effect of production system and organic mulching presented in table 9. Significantly the highest fruit yield (68.00tha^{-1}) was recorded in T_3M_1 treatment combination. On the other hand, the lowest fruit yield (36.67 tha^{-1}) was recorded in T_1M_0 treatment combinations, respectively.

Table 4.9. Effect of organic mulch on number of fruits plant^{-1}, individual fruit weight, fruit yieldplant^{-1} and yield (t ha^{-1}) of tomato

Treatment combination		Number of fruits plant^{-1}	Individual fruit weight	Fruit yield plant^{-1} (g)	Yield (t ha^{-1})
T_0	M_0	6.33 c	216.7 ab	2400 b	45.67 cde
	M_1	8.00 b	210.0 ab	1460 def	59.00 ab
	M_2	7.00 bc	200.0 ab	1333 ef	63.67 ab
	M_3	9.00 b	233.3 ab	1333 ef	63.33 ab
T_1	M_0	5.33 c	233.3 ab	1967 bcd	36.67 e
	M_1	7.00 bc	216.7 ab	1617 de	54.33 bc

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	M_2	10.33 ab	200.0 ab	1267 ef	62.67 ab
	M_3	7.33 bc	166.7 b	1000 f	47.67 cd
T_2	M_0	9.67 b	233.3 ab	2200 bc	39.00 de
	M_1	9.00 b	233.3 ab	2250 bc	54.33 bc
	M_2	9.67 b	216.7 ab	1933 bcd	61.33 ab
	M_3	9.33 b	166.7 b	1833 cd	62.00 ab
T_3	M_0	7.33 bc	183.3 ab	1183 ef	44.00 de
	M_1	15.00 a	266.7 a	3167 a	68.00 a
	M_2	11.67 ab	250.0 ab	3050. a	57.33 b
	M_3	10.00 ab	200.0 ab	1883 cd	60.33 ab
CV%		6.43	9.87	10.48	4.49

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

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1. (a) Final plot preparation for transplanting of tomato

1. (b) Tomato seedlings were transplanted in the main plot

1. (c) Organic mulching application in the experimental field

1. (d) Vegetative stage of tomato production in experimental

Plate 4.1. Plates showing different activities were dune throughout the experimental period

CHAPTER 5
SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

A field experiment was carried out at the Agroforestry and Environment Research Farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during October, 2016 to April, 2017 to evaluate the production of tomato under *Albizia lebbeck, Melia azedarach a*nd *Leucaena leucocephala* based agroforestry systems along with sole cropping of tomato i.e. open field condition as influenced by different organic mulching. The experiment was conducted in newly established orchard of multipurpose tree species namely *Albizia lebbeck* (Kalo koroi), *Melia azedarach* (Ghora neem) and *Leucaena leucocephala*) (Ipil-ipil) the tree saplings were planted at the spacing (3 m×3 m) and the orchard was 10 years old.

A popular tomato variety Ratan 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 Factor A: T_0= Tomato sole cropping (Control), T_1= Tomato + Kalo Koroi, T_2= Tomato + Gora Neem and T_3= Tomato + Ipil-ipil. On the other hand, Factor B: M_0 = No mulch, M_1 = Ash mulch, M_2 = Saw dust mulch and M_3 = Water hyacinth mulch. Total no of experimental plots were 48. The unit plot size is 2.5m x 2.5m. The land was opened on 20 September 2016 by ploughing through power tiller. 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. The entire quantity of cow dung (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 P_2O_5 and 50 kg K_2O in each experimental plot. The Tomato seeds were sown on 10th October 2016 in seed bed. Finally, twenty one days old seedlings were transplanted in the main plots on 31th October 2016. 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 15, 30, 45, and 60 days after sowing (DAS) for plant height and number of branch plant^{-1}. The harvesting stage data were taken in the harvesting stage viz. number of fruits per plant, individual fruit weight, fruit yield per plant and yield of tomato. 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}, number of fruit plant^{-1}, fruit weight plant^{-1} , single fruit weight and fruit yield, respectively.

In case of production system, plant height was found almost highest in kalo koroi + tomato based agroforestry system at different days after transplanting, while the lowest plant height was calculated from sole cropping of tomato (control treatment). At 15, 30, 45 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 ghora neem + tomato based agroforestry system where as the lowest number of branches plant^{-1} was recorded in both sole cropping of tomato. Number of fruits plant^{-1} was found statistically significant by the effect of different production systems. Significantly the highest number of fruits plant^{-1} was recorded in ipil ipil + tomato based agroforestry system which was similar to found in ghora neem + tomato based agroforestry system and the lowest number of fruits plant^{-1} was found in kalo koroi + tomato based agroforestry system which was statistically similar to found in sole cropping of tomato, respectively. Significantly the highest fruits plant^{-1} was recorded in ipil-ipil + tomato based agroforestry system. On the other hand, the lowest fruits plant^{-1} was found in kalo koroi + tomato based agroforestry system. The highest yield was found in sole cropping of tomato which was identical to ipil-ipil + tomato based agroforestry system and the lowest yield was observed in kalo koroi + tomato based agroforestry system.

Effect of different organic mulches on the plant height was found positive at different days after transplanting. Mainly organic ash mulch enhanced the plant more vigorously than other organic mulch as well as control treatment. The highest number of branch plant^{-1} was recorded in plants grown under ash mulch while control had the lowest branch plant^{-1} at different days after transplanting. Significantly the highest number of fruit plant^{-1} was recorded in ash mulch and the lowest number of fruit plant^{-1} was recorded in control (unmulched treatment). Significantly the highest fruits plant^{-1} was recorded in ash mulch followed by saw dust mulch and Water hyacinth. On the other hand, the lowest fruits plant^{-1} was found in control (without mulch). The highest yield was found in ash mulch which was identical to Water hyacinth. On the other hand the lowest yield was observed in control (without mulch).

Finally, interaction effects of production system and different organic mulch had diverse variation significantly. Among the 16 treatment combinations, ipil-ipil + tomato with ash much had the best performance in response of growth and yield of tomato.

5.2 Conclusion

The present study indicates tomato can be grown more effective in the vacant space of kalo koroi, ghora neem and ipil-ipil multipurpose tree species based agroforestry system as an organic basis that brings health hygiene for fresh consume as well as cooking food. The result revealed that the production of tomato was ranked as open field > ipil-ipil > ghora neem > kalo koroi. Therefore, it should be mentioned that most of the organic mulch materials suitable for tomato in shade condition along with open field; but their degree of suitability will be as ash mulch > water hyacinth mulch > saw dust mulch. Finally it would be concluded that the ipil ipil tree based tomato production is more profitable in association of ash organic mulch.

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 tree + tomato with organic and inorganic mulch.
- 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.

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 October, 2016 to April, 2017

Month	** Air Temperature (ºC)					
	Maximum	Minimum	Average	**Relative Humidity (%)	*Rainfall (mm)	*Sunshine (hrs.)
October	21.8	18.0	19.9	83.0	1.0	269.7
November	32.8	21.1	26.9	85.0	5.0	280.4
December	32.9	22.7	27.8	90.0	10.0	250.1
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
April	38.5	30.0	34.25	84.5	200	240.0

* Monthly Total

** Monthly average

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

Appendix III. Land Preparation seeding transplanting and growth stage of the tomato in the experimental field (a, b, c, d, e, f)

a

b

c

d

e

f

Appendix IV. Organic Mulching application and Date collecting in the experimental field (a, b, c, d, e, f)

a

b

APPENDIX

c

e

d

f

Appendix V. Harvesting activities was done in the experimental plot
(a, b, c, d, e)

a

b

c

d

f

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