ECONOMIC POTENTIALITY OF TARO CV. LATIRAJ UNDER DIFFERENT MULTIPURPOSE TREE BASED AGROFORESTRY SYSTEM

A THESIS

BY

UMME. SUMAIA SUMI
Registration No. 1805100

Session: 2018

Thesis Semester: July-December, 2019

MASTER OF SCIENCE (M.S.)

IN

AGROFORESTRY AND ENVIRONMENT

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY,
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Submitted to the Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur in Partial fulfillment of the requirements for the degree of

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**DEDICATED TO MY
BELOVED PARENTS, HUSBAND
AND SON**

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The Authoress

ABSTRACT

A field experiment was carried out at the Agroforestry and Environment Research Farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during February to May2018 to evaluate the economic potentiality of taro latiraj under different multipurpose tree based agroforestry production system with control. The experiment was conducted in established MPTs woodlot. The experiment was laid out in single factor Randomized Complete Block Design (RCBD) with three replications. The modern popular variety of taro was used in this experiment namely latiraj. The treatments were T_1 (sole cropping of latiraj), T_2 (latiraj + gora neem), T_3 (latiraj + kalo koroi) and T_4 (latiraj + mango). Seedlings of latiraj were sown in in 27th February 2018 maintaining the distance line to line 50 cm and plant to plant distance 50 cm. From growth and yield parameters, at 90 DAP the highest (87.88 cm) plant height was recorded in latiraj + gora neem based agroforestry production system and the lowest plant height (81.84 cm) was recorded in control treatment. Significantly the highest Stolon number (29.50) was noted in sole cropping of latiraj production system followed by (25.67) was collected from latiraj + kalo koroi based agroforestry production system and the lowest number of Stolon (19.17) was recorded in latiraj + mango based agroforestry production system, respectively. Significantly the highest Stolon yield (10.08 tha^{-1}) was weighted in sole cropping of latiraj production system which was identical to (9.85 tha^{-1}) found in latiraj + kalo koroi based agroforestry production system. On the other hand, the lowest Stolon yield (3.49 tha^{-1}) was measured in latiraj + mango based agroforestry production system. From economic point of view, the maximum net return (425365 tk/ha) was recorded in latiraj + kalo koroi based agroforestry production system and the minimum net return (180965 tk/ha) was calculated from latiraj + mango based agroforestry production system. Finally, the highest benefit-cost ratio 4.72 was recorded from latiraj + kalo koroi based agroforestry production system followed by BCR 3.73 found in latiraj sole cropping production and the lowest benefit-cost ratio 1.74 was observed in latiraj + mango based agroforestry production system. The results indicated that latiraj in association with kalo koroi returned 4.72 taka in investment of 1 taka in a hectare of land for one year. Finally, this finding may help to progress the latiraj production in the vacant space of multipurpose partial shaded trees specially in *Albizia lebbeck.*

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CHAPTER 1

INTRODUCTION

Bangladesh is the 8th most densely populated country in the world having a population of 152.25 million in the area of 147570 sq. Km and growth rate is 1.37% per annum (BBS, 2018). Currently, about 65% of the population lives in rural areas and their livelihood largely depends on agricultural activities (World Bank 2016). Due to rapid urbanization and industrialization, the land area for agriculture has decreased sharply. The cultivable land has decreased 0.14% from 1976 to 2000 and 0.73% from 2000 to 2010; this trend is anticipated to worsen in the future (Hasan *et al.* 2013). Moreover, the present land use system with separate allocation to agriculture and forestry will not be sufficient to satisfy the demands of the people living in the rural communities (Hanif and Bari 2013). Critical situation, increasing demand for food, fodder and timber can be met through traditional and nontraditional agroforestry. It is well known fact (Bargali *et al.,* 2004; Bargali *et al.,* 2009; Pandey *et al.,* 2011; Padalia *et al.,* 2015 and Parihaar *et al.,* 2015) away out to practice agriculture without deteriorating agro-ecosystem services while maintaining or improving productivity, stability or in other words sustainability.

Agroforestry has the potential to help offset the loss of agricultural and forest land. It also focuses on the growing of annual crops sequentially or alongside perennial trees (Chowdhury 1997; Miah *et al.* 2002) and is a system that can be sustainable and eco-friendly (Hanif *et al.,* 2015a) and satisfies the socio-economic needs of the people (Sharmin and Rabbi 2016; Chakraborty *et al.* 2015). The products (food crops and tree resources) harvested from the agroforestry practices fulfil the multidimensional needs of rural people (Rahman *et al.* 2012). Agroforestry practices have the potential to improve soil fertility; control soil erosion; improve water quality and enhance biodiversity (Garrity 2004). It also alleviates poverty by increasing income and engage women's in production activities (Rahman *et al.* 2017).

Agroforestry involves the simultaneous production of perennial trees and annual crops in cropland (Yasmin *et al.* 2010). Even though agroforestry is a relatively new practice, Bangladeshi farmers have been growing trees within agricultural systems for a long time to obtain products and improve their livelihoods. In a composite plantation system, both fruit and woody species are planted to generate more income. Fast-growing, deciduous, nitrogen-fixing, small crowned trees are often chose for planting (Miah *et al.,* 2002). Horticultural-tree based agroforestry is more common than forest-tree (timber-yielding trees) based agroforestry in Bangladesh (Hasanuzzaman and Hossain 2015).

Panikachu (*Colocasia esculenta* L.) is one of the most common aroids. It is grown in low lying and swampy areas of the different countries of the world as well as in Bangladesh (Rana & Adhikary, 2005). Panikachu (cv Latiraj) is famous for the production of good quality stolon. It is highly nutritious and palatable. Stolon contains 1.12 g iron, 38 mg calcium, 500 IU vitamin A, 38 mg vitamin C and 35 Kilocalorie food energy under 100 g edible portion (Bhuiyan *et al.,* 2008). It is also a promising crop for exporting to the foreign countries. In Bangladesh, stolon producing Panikachu occupies an area of about 6,886 ha, with a total production of 38,502 tonnes of stolon, and an average yield of 5.6 tonnes per hectare in 2009-10 (BBS, 2010). It can grow easily with less care and input. Moreover, disease and insect infestations are less in case of Latiraj. Thus, there is a great opportunity to improve its production and quality through agroforestry system that maintain the nutrient release of the soil and also ensure the appropriate light demand of the vegetables.

A country needs 25% of forest land of its total area for ecological stability and sustainability. Sadly, Bangladesh is endowed with only 17.08% of unevenly distributed forests (BBS, 2017). Conversely, actual tree coverage is less than 10% (Akter *et al.,* 1989). 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, 2018). 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, 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”. Keeping on the mind all the aforementioned issues the research was done on the bases of the following objectives.

Objectives

1. To evaluate the growth and yield potentiality of the latiraj under *Melia azedarach, Albizia lebbeck* and *mangifera indica* based agroforestry system along with sole cropping.
2. To compare the economic performance of latiraj under four production system viz latiraj + *Melia azedarach,* latiraj + *Albizia lebbeck,* latiraj + *mangifera indica* and latiraj sole cropping.

CHAPTER 2
REVIEW OF LITERATURE

The research was carried out to evaluate the economic potentiality of latiraj taro under different multipurpose tree based agroforestry production system with control. In Bangladesh, the modern practices of agroforestry are extended in the crop field. The farmers are growing multipurpose trees in the crop field to get maximum benefit. But tree directly influence crop's yield. Literatures directly related to this aspect are meager. Therefore, literatures some way linking to the subject of interest from home and abroad are reviewed and outlined below under the following sub heads.

2.1 Concepts of Agroforestry
2.2 Importance of Light in Agroforestry
2.3 Characteristics of Tree Species in Agroforestry Systems
2.4 Performance of Crop in Agroforestry Systems
2.5 Effect of shade on plant growth of agroforestry system
2.6 Benefits of taro intercropping in agroforestry system
2.7 Economic performance of agroforestry system

2.1 Concepts of Agroforestry

Agroforestry is an age-old and ancient practice. It is an integral part of the traditional farming systems of Bangladesh. The concept of agroforestry probably originate from the realization that trees play an important role in protecting the long range interests of agriculture and in making agriculture economically viable. The emergence of agroforestry was mainly influenced by the need to maximize the utilization of soil resources through the "marriage of forestry and agriculture" (PCARRD, 1983). Agriculture and forestry were considered before as two distinct areas but these practices are now considered as complementary. This was brought about by the increasing realization that agroforestry can become an important component of ecological, social and economic development efforts.

Agroforestry is the idea of combining forestry and agriculture on the same piece of land. The basic concept of intercropping has been extended to agroforestry system. Many authors have defined agroforestry in different ways. A widely used definition given by the International Council for Research in Agroforestry (Nair, 1983) is that agroforestry is a collective name for all land use systems and practices where woody perennials are deliberately grown on the same land management unit as agricultural crop of animal in some form of spatial arrangement or temporal sequence.

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

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

From a business point of view 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 mixed canopy intercepts more solar energy.

MacDicken and Vergara (1990) state that agroforestry in a means of managing or using land (i.e., a land use system) that combines trees or shrubs with agricultureal/ horticultural crops and/or livestock.

In traditional agroforestry systems of Bangladesh, Farmers consider trees as saving and insurance against risk of crop failure or compensate low yields of crops (Akter *et al.,* 1989). Homestead gardens are common in Bangladesh where the farmers take up combination of 10-15 species of fruit, ornamental and multipurpose trees along with vegetables to meet their own or aesthetic own or aesthetic value (Rang *et al.,* 1990).

Trees are grown in the crop land, homestead, orchard not only produce food, fruits, fodder, fuel wood or to generate cash for various purpose (Chowdhury and Satter, 1993) but also gives better living environment (Haque, 1996).

The other potential benefit of agroforestry is that of the diversification of species grown on farm. Through this, and the domestication of an increasing number of tree species, it should be possible to make small-holder farming both more biologically diverse and more rewarding economically. Through the incorporation of a range of domesticated trees into different agroforestry practices within the same landscape, agroforestry can become, as recently defined (Leakey 1996).

According to Solanki (1998), Agroforestry can significantly contribute in increasing demand of fuel wood, fodder, cash and infrastructure in many developing countries. He also stated that Agroforestry has high potential to simultaneously satisfy 3 important objectives: (i) protecting and stabilizing the ecosystems (ii) producing a high level output of economic goods (fuel, fodder, small timber, organic fertilizer etc) (ii) providing stable employment, improved income and basic material to rural populations.

2.2 Importance of Light in Agroforestry

Okigbo and Geenland (1976) and Okigbo (1980) identified more efficient use of light resource by plants of different heights and canopy structures as one of the advantage to be gained by growing crops in mixed stands.

The potential benefits as results of combining field crops with trees are so obvious from consideration to the waste of light resources experienced in orchard and tree crop orientations (Jackson, 1987).

One of the major constraints of microclimate and growth in agroforestry practice is solar radiation. Interaction among the trees and solar geometry produce the particular solar climate of a tree/corm system. These interaction and effects include interception of radiation by tree stands of various densities, effect of canopy structure, effect spacing, effect of latitude and time of year on solar paths, shade from single crowns and spectral quality of sunlight under partial shade (Reifsnyder, 1987).

The yield advantage of conventional intercropping has been explained in terms of improved capture of utilization of growth resources (Willy *et al.*, 1986). The resource capture by agroforestry systems will probably be greater than in sole crops (Ong *et al.,* 1991).

Limiting light (Shade) is obviously the most important factor that causes poor performance of under-storey crops. The key to the development of compatible tree crop combination in agroforestry is greater light interception by understory crops. In India, it is widely believed that shading by trees is responsible for poor yields of associated crops (Ong *et al*., 1992).

The severity of competition in agroforestry system, ultimately crop yield is dependent upon the partitioning of resources, primarily of light and water between tress and crops (Howord *et al.,* 1995).

Essentially the underlying processes involved in the partitioning of resources (e.g. light water and nutrients) are not well understood. A better mechanistic understanding of resource capture and utilization in agroforestry system is required to facilitate the development of improved systems in terms of species combinations, planting arrangement and management (Howord *et al.,* 1995).

Agroforestry system that incorporate a range of tree and crop species offer much more scope for useful management of light interception and distribution than do monoculture forests and agricultural crops (Miah *et al.,* 1996).

2.3 Characteristics of Tree Species in Agroforestry Systems

Selection of Suitable tree species is vital factor in an agroforestry system. Nair (1980) considered the most choice of suitable plants species that can grown together as important factor in ensuring the sources of agroforestry. The most appropriate species for this system remains an open question for research. King (1979) listed the characteristics at tree species that should be grown with agricultural crops:

a) They should tolerate relatively high incidence of pruning.
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 of the ground.
f) Their phenology, particularly with reference to leaf flushing and leaf fall, should be advantageous to growth of the annual crop in conjunction with which their being raised.

g) The rate 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 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) pointed out the following factors to be considered during the selection of woody legumes for intercropping with annuals in the low land tropics:

i. Ease of establishment from seeds or seedlings.
ii. Rapid growth and high productivity of foliage and wood.
iii. Limited maximum size (may be optimum in small trees).
iv. Good coppicing ability (re-growth following topping).
v. Effective nutrient recycling abilities especially di-nitrogenfixation.
vi. Multiple uses: food, feed, fire wood, construction materials and other products and service (shade, shelter etc.).
vii. Minimum competition with shallow rooted annual crops.
viii. Small leaflets readily detached when dried and quickly decomposed when used as fertilizer.
ix. A high proportion of leaves to secondary branches.
x. Free from pests and diseases and
xi. Ease of control of eventual elimination.

Purohit (1984) suggested to selecting those species which would (i) not compete for moisture, space and air (ii) supply nitrogen in the soil (iii) provide food, fodder, fuel and timber (iv) maintain proper ecosystems (v) have no toxic effects to the crops; and (vi) have thin and erect leaves. Singh *et al.* (1984) 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: (i) Non-Interference with arable crops. (ii) Easy establishment (iii)

Fast growth and short gestation period (iv) Non-Allelopathic effects on arable crops, (v) Ability to Atmospheric nitrogen (vi) Easy decomposition of litter (Ability to litter, (vii) Ability to withstand frequent lopping (viii) Multiple uses and high returns, and (ix) 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 Performance of Crop in Agroforestry Systems

The response of different crops to the agroforestry systems was different. The performance of field crops in agroforestry systems is influenced by the tree and crop species and their compatibility, spacing between tree lines, management practices, soil and climatic factors.

It has been reported that shading reduced leaf number, leaf area and thickness of dry bean (Crookston *et. al.,* 1975). They also reported 38 percent decrease in photosynthesis per unit area of shaded leaves.

Taro was until recently the main crop throughout the whole country, not only as an important food but also as a major cash crop in all villages. In several locations, taro was cultivated from the coastal lowlands up to the rainforest. According to the agricultural census carried out by the Agriculture Department in 1989, the total land area under taro was about 15,000 ha, of which 76.3 percent was grown as a monocrop, 22.6 percent mixed with other crops, and 1 percent as scattered plants. Up to 80 percent of taro produced in the country was used for local consumption, including ceremonial function, and the rest was exported to overseas (Government of Western Samoa, 1989). Taro was one of the major commodities exported overseas, to serve the needs of the migrant Samoan community, where New Zealand was the biggest market, followed Australia and United State. However, since the outbreak of Taro Leaf Blight in 1993 destroyed taro production, people have started to diversify their cropping systems. Banana is now becoming important as a cash and food crop, together with *Alocasia macrorrhiza,* yams, *Xanthosoma spp* and cassava mixed cropping systems.

In the Solomon Islands, alley cropping experiments have been conducted since 1985, testing various multipurpose tree species for their potential in improving or maintaining crop yields. Results have shown that yield of cassava and sweet potato were generally low in alley cropped plots (Hancock, 1989). Research in Tonga has shown that yield of yams *(Dioscorea alata)* and taro *(Colocasiae escutenla)* were lower in 2m and 3m alley plots of *L leucocephala* compared to a control with no trees (Manu & Halavatau, 1994).

In Vanuatu, alley cropping research has been carried out to evaluate four legume trees in combination with yams, maize/cowpea intercrop, sweet potato and taro. The legume trees tested were *Cajanus cajan, G. sepium, Flemingia macrophytta* and *L leucocephala,* Early observations showed that *F. macrophylla* is slow to establish compared to other legumes, and sweet potato is difficult to manage in crop rotation and also in placing of pruning in the growing crop (Rogers, 1992).

In Fiji, on-farm research was carried out in the Lornaivuna area testing C, *calothyrsus* alley cropped with taro, ginger *(Zingiber officinalis)* and cassava grown in rotation. Results showed that taro yield per corm was reduced by 20% in alley treatments compared to the control, though taro spacing in alleys was more dense than the normal spacing. Yield of ginger dropped by 33% in agroforestry plots, while cassava showed a small positive response with a yield increase of around 3% in alley treatments (Singh & Kunzel, 1994).

Limited work on alley cropping has been reported from Western Samoa. In the early 1980's an experiment was carried out by the Community forest and the FAO Root Crop Development Project, aiming at the assessment of available multipurpose tree species as potential soil amenders. One trial involved taro (*C. esculenta)* with six different legume trees species, *C. calothyrsus, G. septum, L. leucocephala, Sesbania grandiflora, Albizia saman* (synonym *Samanea saman),* and *Erythrina sp.* (Kid and Taogaga, 1985). Results indicate that *C. calothyrsus, L. leucocephala* and *G. sepium,* all produce large quantities of foliage biomass, but there appeared no relationship between taro yield and the amount of tree biomass applied as mulch to the plot. However, there was no attempt made by these workers to assess the long term crop yield sustainability in the alley cropping system.

The first alley cropping experiment initiated at the University of the South Pacific, Alafua campus was in 1987. The trial was designed to evaluate two legume tree species, *C. calothyrsus,* and *G. sepium,* planted in three different alley widths, in combination with a taro crop (Rosecrance *et al.,* 1992), reported that after four consecutive years, hedge biomass yields ranged from 5.1 to 16t ha^{-1} yr^{-1} dry weight, with *C. calliandra* and *G. sepium* performing equally well. The tree biomass yields decreased by 2t ha-1 with increasing alley width from 4 to 6m. Weed populations were significantly lower in the 4m alleys compared to the 5m, 6m and control plots. Soils from the alley plots held significantly more water in the 0.3 to 1 bar range than soils from the controls. After four years of mulch application soil water holding capacity and bulk density were measurably improved, but no significant improvement was found in the chemical nutrient status of the soils. Despite reduced weed growth and improved soil physical properties there was no positive effect of alley cropping on taro yields over the first four years of the trial.

A cut and carry experiment in Western Samoa showed that the use of green leaf manure from *Erythrina variegata* trees as mulch increased taro yield by 40% (Weeraratna and Asghar, 1992). But the main disadvantage of cut and carried mulch is the transportation of a substantial amount of mulching material from where it is produced to the crop area. Such systems would require high labour inputs, and are therefore not appropriate for small farmers in Western Samoa.

An extensive survey of taro patches mainly in inland plantation lots, found out that the average weed cover in farmers taro plots was 60%. And it was estimated that up to 70% of total labour input in taro production is spent on weed control activities alone. Whilst data on work activities from an on farm agroforestry trial in Western Samoa, showed that it takes six hired labourers two days to clean a 44 x 37m plot, using a cultural method of land clearing with a bush knife and hooked sticks called lafo. The plot had previously been in fallow for several years and was dominated by the grass species *Brachiaria mutica* (Rogers 1992).

In Western Samoa, an economic analysis using the computer programme MULBUD, was carried out to investigate the potential net production benefit for the adoption of spacial agroforestry, as an alternative land use to taro production in traditional bush fallow rotation. Five years of data from an alley crop plot of taro intercropped with leguminous trees *G. sepium* and G *calothyrsus* from the Community Forestry Programme was used as the basis for the projection. Conclusions were that adoption by farmers of agroforestry would result in a benefit over the traditional bush fallow system of $1729 per acre for the five years, stated in net present value terms (Singh & Kunzel, 1994).

Earlier work (Weeraratna and Asghar, 1992) indicated that applying tree mulch improved taro yield in open plots. However (Rosecrance *et al.* 1992) showed that in 4m tree alleys yield reduced despite the large amount of mulch applied. This suggests that the tree competition at the tree/crop interface in the narrow alleys offset any advantages that might have been achieved from adding the tree primings as mulch to the crop. A possible way to reduce tree competition and maintain the high level of tree biomass to apply as prunings is by reducing the number of tree /crop interfaces per unit area of cropped land. This could be achieved by planting wider alleys and increasing the number of consecutive tree rows. This hypothesis is tested in this research project.

2.5 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.

Gondim *et al.,* 2018 reported that Taro (*Colocasia esculenta*) is a plant with a long crop cycle, what hinders its cultivation in properties with area limitations. The association of crops is an option for this kind of situation. However, in order to plan the cultivation using the intercropping system, it is important to define the tolerance levels of the taro plants and the period of highest sensibility to shading. This study aimed to evaluate the behavior of the 'Japanese' taro crop, regarding growth, cultivated under levels and periods of artificial shading. A split-plot randomized block design, with 13 treatments and four replications, was used. The plots consisted of four shading levels (control = full sun, 18 %, 30 % and 50 % of shade), maintained throughout the cycle or during three months, in three periods (initial = 0-3 months; intermediate = 3-6 months; final = 6-9 months). The subplot was composed of eight plant samples (60, 90, 120, 150, 180, 210, 240 and 270 days after planting). The shading levels increased the total and specific leaf area, leaf area and mass ratios and dry mass partition. Thus, the taro plants showed the capacity to make leaf adjustments to suit changes in light intensity. The shading intensity of 18 %, during the whole cycle or in any of the periods studied, provides a high expansion of the leaf area.

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).

Gondim *et al.,* 2007 reported that intercropping systems between different crops is considered an alternative for farms with limited area. But, for the establishment of these systems, it is fundamental to know the tolerance of the species to light restriction. The growth of the aerial portion and corm yield of 'Japanese' taro cultivated under different levels and periods of shading were determined in this study. The experiment was arranged in four random replicates, with 13 treatments. The experiment was composed of 13 treatments constituted of four levels of shading(control = full sunlight; 18; 30 and 50% of shading, maintained during the whole cycle), and the 18; 30 and 50% of shading in three periods(initial = 0 - 3 months; middle cycle = 3 - 6 months; and final = 6 - 9months). Plants under light restriction during the whole cycle had, in particular for the higher light restriction, a higher growth of aerial portion and yield of corm (mother rhizome) and small cormels, smaller number of commercial cormels per plant, yield of commercial cormels, and large and medium cormels. The 18% light restriction for the whole cycle and for the initial and middle cycle affected less the total and commercial yield.

Gondim *et al.,* 2008 stated that the intercropping system can cause shading of one associated crop, leading to morphological, anatomical and yield changes in the shaded crop. The taro [*Colocasia esculenta* (L.) Schott] crop, is a long cicle *Araceae* species, that is difficult for cultivated in small properties. The association of taro plants with other crops is an option in these situations. However defining the tolerance level of taro plants to shading is an important point to design the associated system. The aim of this work was to evaluate quantitative anatomical characteristics in taro 'Japonês' leaves and rhizomes. In order to understand the yield decrease in intercropping with other taller species taro plants were grown under 0%, 18%, 30%and 50% of shading. The increase on shadding induced changes in cells and tissues proportion, such as are reduction on leaf thickness, palisade parenchyma and are enchain thickness and on stomata density. It is concluded that taro plants show leaf anatomical plasticity under different shade levels, what probably changes the photosynthetic capacity and photosynthetic distribution in vegetative organs.

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.

Oliveira *et al.,* 2011 found that the growth and nutrient accumulation of taro plants (*Colacasia esculenta*) under artificial shading levels. The experiment consisted of four levels of shading (0, 25, 50 and 75% restriction of light) and nine monthly samples in a split-plot randomized block design with four replications. Shading levels were obtained through cubic metal frames covered with nylon nets. The restriction of light did not change the total biomass of plants, but root:shoot ratio was lower under 50 and 75% light restriction. Under these conditions taro plants showed greater height, number of leaves and leaf area, but lower net assimilation rate. The 75% light restriction delayed cormels formation by 30 days and reduced the final cormels production. The light restriction did not affect the accumulation of macronutrients, and the maximal accumulation was observed at 102 days after planting for N, P and K, and 123 days for Ca and Mg. Intense light restriction induced an initial investment of taro plants in the shoot rather than roots, with subsequent delay in the formation of reserve organs leading to reduced cormels production.

Pereira *et al.,* 2006 reported that the biomass accumulation (cormels and total plant dry weight), yield (fresh weight and number of cormels) and “Metsubure” incidence in taro cormels was evaluated on plants submitted to distinct potassium (K) fertilizer rates, with and without calcium (Ca) application. The experiment was conduced in a glasshouse from 10/19/2002 to 07/20/2003, with the taro ‘Chinês’ (BGH 5928). Five K levels (0; 150; 300; 600 and 1,200 mg K_2O kg^{-1} of soil), and absence or presence of Ca (0 and 232 mg Ca dm-3 of soil), were evaluated in a 5 x 2 factorial scheme, disposed in completely randomized design, with four replicates. The biomass accumulation and taro yield presented the same behavior in response to K rates, with and withoutCa application. Biomass accumulation and yield maximum values were obtained at K_2O rates of 794 and 760 mg kg-1 with Ca addition, respectively. Under low K supply, corms dry weight, total plant dry weight, cormels fresh weight and cormels number were higher in the absence of Ca application; this trend was inverted when K_2O rate reached 85; 46; 202, and 578 mg kg^{-1} of soil, respectively. Without Ca application, increased K rates led to increasing in cormels Ca contents; on the other hand, independently of Ca application, cormels K contents increased with the increasing in the K rates. Only without Ca application and K_2O rates of 600 and 1,200 mg kg^{-1} of soil were observed 6.56 and 9.84% of "Metsubure" incidence in taro cormels, respectively.

2.6 Benefits of taro intercropping in agroforestry system

Taro is mostly produced and consumed on a subsistence basis, and surpluses are sold as cash crops, which plays a huge role in combating poverty (Onwueme, 1999). Taro corms have been reported to have a high economic value in urban markets in Uganda, and its production provides employment to many people while the crop maintains ground cover in the fields. However, there is very limited local research on Taro in Uganda and its actual contribution to food security and economy is underestimated (Tumuhimbise *et al*., 2009). Taro has attained considerable economic importance as a fresh crop in many large islands in the region such as Fiji and others (Deo *et al.,* 2009). It has now become one of the major export commodities providing substantial foreign exchange to some of the Pacific Island countries.

Yield traits include total weight of cormels $plant^{-1}$, number of cormels $plant^{-1}$ and mass of individual corms (Mare, 2009). Taro is a staple root crop for many countries in the Pacific and in Africa (Goenaga and Chardon, 1995). Current yields level of taro production are relatively low. Yield fluctuates because of difference in cultivar, planting density, fertilizer application levels, natural factors and cultivar (Manner and Taylor, 2010). Worldwide, the crop yields about 6000kg/ha compared to 15000 kg/ha of potato and 14000 kg/ha of sweet potatoes. In most countries, taro is grown under rainfed conditions which can lead to radical yield declines because of transient drought periods. Furthermore, yield potential of taro is seldom realized due to lack knowledge of diseases, poor management practices, and physiological determinants that may limit growth and development (Goenaga and Chardon, 1995).

Noor *et al.,* (2014) reported that the yield attributes and yield of aquatic taro were significantly increased by the application of NPKS fertilizers. The highest stolon yields (25.60 and 28.16 t ha-1 for 2008-09 and 2010-11, respectively) were found in N100P45K100S20 kg ha-1 combination. From the regression analysis, it could be concluded that around 110- 50-105-24 kg ha-1 N-P-K-S was the optimum dose for the production of aquatic taro in Grey Terrace Soil of Gazipur.

Prasad and Singh (1992) stated that taro grown under artificial shade of 50% canopy were reported to have high plant height and leaf area compared to full sunlight, total plant biomass is also increased by shade; corm yields are not affected by the shade but the number and weight of plant suckers are increased. The highest yields for taro are obtained under full light intensity; this also means that good yields can be obtained even in shade conditions where other crops might fail completely. This is the other important characteristic which enables taro to fit into unique intercropping systems with tree crops and other crops (Lebot, 2009).

2.7 Economic performance of agroforestry system

Economic gain has been identified as the primary motivating factor in the adoption of agroforestry in the US (AFTA, 2006). Agroforestry practices must offer at least as much income potential without increasing risk, compared to current farming practices, and better scenarios for solving conservation problems than the current farming practice for adoption to take place (AFTA, 2006). Incentives for agroforestry can be implemented to provide economic or ecological benefits to the landowner and entice them to adopt practices that may have been too risky or foreign to them prior to the incentives.

Godsey (2005) and the National Agroforestry Center (2003) investigated the funding incentives available through the federal, state and non-governmental organizations (NGO) for the five agroforestry practices. Cost sharing was found to be the most commonly used incentive. Other incentives such as producer grants, land rental payments, financial incentive payments and technical assistance were also identified. Most federal funding available for agroforestry practices are distributed through the United States Department of Agriculture (USDA), while the state of Missouri funding is available through the Missouri Department of Agriculture (MDA).

(Dorr, 2006) said adoption of agroforestry by a higher number of landowners. Despite the advancement of government programs to encourage landowners to adopt conservation practices like agroforestry, research has shown that adoption rates by landowners compared to the agricultural related programs are still low and many challenges remain to develop and adopt of agroforestry as a viable land management strategy in the United States.

Rietveld and Francis (2000) stated that the competition of innovative agroforestry practices with conventional agriculture is one of the major challenges because farmers are reluctant to change or try new ideas. Participation in conservation efforts depends on a lot of factors like land values, rental rates and crop prices at any given time. For example in the US where currently the prices of corn have risen sharply in response to its demand as feedstock for fuel ethanol, the significant increase in income from production of corn is a disincentive for complying with the requirements by government incentive programs which includes putting land under trees. The effect of high corn prices on non-participation in incentive programs is supposed to have a greater impact on farm operators compared to non-operators who have other sources of income.

Amin *et al.,* 2017 reported that effect of trees were significant in respect of plant height at 30,45,60 and 75 DAT, number of leaf/plant at 30,45 and 75 DAT except 60 DAT, bulb diameter, bulb fresh and dry weight and bulb yield (t/ha). In initial stage 30 DAT the tallest plant (24.27 cm) was recorded in *Leucaena leucocephala* + taro based AFS. Consequently, the shortest plant was observed (20.07 cm) in sole cropping of taro (T0). In final stage at 75 DAT the tallest plant height 51.01 cm was found under *Leucaena leucocephala* + taro based AFS followed by *Melia azedarach* + taro based AFS (49.83 cm). On the other hand the shortest plant height 44.83 cm was recorded in sole cropping of taro. At 30 DAT, the maximum number of leaves palnt-1(4.80) was recorded under *Leucaena leucocephala* + taro based agroforestry production system. Apparently, the minimum number of leaves plant-1 (3.77 at 30 DAT) was observed in taro sole cropping production. The highest bulb diameter (4.40 cm) was measured in sole cropping of taro production and the lowest bulb diameter (3.85 cm) was measured under *Leucaena leucocephala* based agroforestry production system which was similar to that of T2 (3.87 cm) and T1 (3.92 cm), respectively. The highest fresh weight of bulb plant-1 (27.04 g) was found in sole cropping of taro followed by (25.33 g) *Albizia lebbeck* + taro based agroforestry production system, respectively. The highest benefit-cost ratio of 3.58 was recorded from *Albizia lebbeck* + taro based agroforestry production system followed by *Leucaena leucocephala* + taro based agroforestry production system and *Melia azedarach* + taro based agroforestry production system. The lowest benefit-cost ratio of 2.56 was observed in sole cropping of taro. Finally, it may be concluded that taro can be cultivated profitably in *Albizia lebbeck* based agroforestry production systems.

CHAPTER 3

MATERIALS AND METHODS

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

3.1 Location of the study

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

3.2 Soil characteristics

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

3.3 Climate and weather

The experimental site was situated under the tropical climate characterized by heavy rainfall from July to August and scanty rainfall in the rest period of the year. Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (February to May 2018) are presented in the Appendix-II.

3.4 Experimental period

The experiment was conducted during February to May, 2018.

3.5 Experimental materials

1st layer: Three Multipurpose Trees

The tree species were -

- Ghora Neem (*Melia azedarach*)
- Kalo koroi (*Albizia lebbeck*)

- Mango (*Mangifera indica*)

The spacing for all the tree species were 2.5 m x 2.5 m. and the age were 12 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

Name of the tree	Plant height (m)	Clean bole height (m)	Base Girth (cm)	Bole Girth (cm)	Diameter at Breast Height (cm)
Ghora neem	18.8	13.5	105.0	84.6	32.0
Kalo koroi	15.6	10.5	93.0	72.6	25.0
Mango	6.5	2.5	65.0	56.4	18.5

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

A) 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* are 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.

B) Kalo 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.

C) Mango (*Mangifera indica*)- Mango are long-lived evergreen trees that can reach heights of 15-30 m(50-100ft).Most cultivated mango trees are between 3and 10 m (10-33)tall when fully mature depending on the variety and the amount of pruning .Wild non-cultivated seedling trees often reach 15 m (50) when found in favorable climates , and they can live for over 100years and develop trunk girths of over 4m (13ft). Mango trees typically branch 0.6-2 m (2-6.5 ft) above the ground and develop evergreen, dome-shaped Mango grown in heavily forested areas branch much higher than solitary trees and have an umbrella-like form.

Functional uses

Mango, like citrus fruits, is an excellent source of vitamin C; 100 g fresh fruits provide 71.5 mg or 119% of daily-recommended value. Studies suggest that consumption of fruits rich in vitamin C helps the human body develop resistance against infectious agents and scavenge harmful, pro-inflammatory. Mango fruit contains 70 calories per 100 g, comparable to that in the table-grapes. It has no saturated fats or cholesterol, but composes of good amounts of dietary fiber, vitamins, and antioxidants etc.

Services

Research studies suggest that oligonol, a low molecular weight polyphenol, is found abundantly in litchi fruit. Oligonol is thought to have anti-oxidant and anti-influenza virus actions. In addition, it helps improve blood flow in organs, reduce weight, and protect skin from harmful UV rays. Compatible with other similarly vigorous species, as well as animal grazing.

Ground layer: Taro cv. latiraj

The modern popular variety of taro was used in this experiment namely latiraj.

3.6 Experimental design

The experiment was laid out single factor Randomized Complete Block Design (RCBD) with three replications. The four treatments were three multipurpose tree based agroforestry production system and one control open field. Total no of experimental plots were 12. The unit plot size was 2.5m x 2.5m = 6.25 m^2. The treatments of the experiment were as follows-

T_1 = Sole cropping of latiraj (open field control)
T_2 = latiraj + gora neem
T_3 = latiraj + kalo koroi
T_4 = latiraj + mango

3.7 Land preparation

The land which was selected conducting for the experiments was opened on 21st February 2018 by ploughing. After opening the land, the plots were cross-ploughed followed by laddering to break up the soil clods to obtain good tilth and level land. After final land preparation the experimental plots were laid out, and the edge around each unit plot was raised to check run out of the nutrients.

3.8 Manuring and fertilizer application

The entire quantity of cow dung (8 ton/ha) was applied just after opening the land (Rashid, 1993). Urea, TSP and MP were applied as the source of nitrogen, phosphorus and potassium respectively as recommended dose in each experimental plot. TSP was applied at the rate of 120 kg/ha (Rashid, 1993). The entire amount of Urea, TSP and MP in the experiment was applied at the time of final land preparation.

3.9 Seedling planting

The seedlings of latiraj was planted in the main plot randomly in 27th February 2018 maintaining the distance line to line 50 cm and plant to plant distance 50 cm.

3.10 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 15 days after planting. 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 planting.

3.11 Harvesting

Green stolon were harvested at 2-3 times per 15days interval when they attained edible stage.

3.12 Data collection

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

Morpho-physiological parameters

- Plant height (cm)
- Number of leaf plant^{-1}
- Leaf length
- Leaf breadth

Yield and yield contributing characters

- Number of stolon
- Stolon length
- Stolon girth
- Stolon yield plot^{-1}
- Stolon yield t ha^{-1}

Plant height (cm)

Plant height was measured in centimeter (cm) by a meter scale at 30, 60 and 90 days after planting (DAP) from the point of attachment of the leaf to the ground level up to the leaf.

Number of leaves plant^{-1}

Number of leaves plant^{-1} of randomly selected plans was counted at 30, 60 and 90 days after planting (DAP). All the leaves of selected plants were counted separately.

Leaves length & breadth

Leaves of randomly selected plants were made detached and measured in centimeter (cm) by a meter scale at 30, 60 and 90 days after planting (DAP).

Number of stolon

Mean number of stolon of selected plants from each plot was recorded.

Stolon length

The randomly selected stolon from each plot were taken and length was recorded by a meter scale in cm and finally mean was calculated.

Stolon girth

The randomly selected stolon from each plot were taken and girth were measured in cm with the help of slide calipers and finally mean was calculated.

Stolon yield (kg plot^{-1})

After harvesting, the total yield for each treatment was counted and stolon yield per plot was calculated in kilogram by converting the mean green stolon yield per plot.

Stolon yield (t ha^{-1})

After harvesting, the total yield for each treatment was counted and stolon yield per hectare was calculated in metric ton by converting the mean green stolon yield per plot.

3.13 Economic potentiality of the latiraj

In order to evaluate the economic return of the agroforestry production systems along with sole cropping, the yield price of stolon of latiraj and trees was subjected to economic analysis by calculating the cost of cultivation, gross and net returns per hectare and benefit-cost ratio. All these parameters were calculated on the basis of market prices prevailing at the time of the termination of experiments.

Total cost of production

The cost of cultivation of the taro latiraj was worked out on the basis of per hectare. The initial plantation cost of the ghora neem, kalo koroi and mango saplings were integrated in this study. The management cost of ghora neem, kalo koroi and mango, was also included. The total cost included the cost items like human labour and mechanical power costs, material cost (including cost of seed, fertilizers and manures, pesticide, bamboos, ropes etc.), land use cost and interest on operating capital.

Gross return

Gross return is the monetary value of total product and by-product. Per hectare gross returns from latiraj stolon was calculated by multiplying the total amount of production by their respective market prices.

Net return

Net return usually means the profit of the enterprises. Net return was calculated by deducting the total cost of production from the gross return (Kalita *et al.,* 2018).

$$\text{Net return} = \text{Gross return (Tk. ha}^{-1}) - \text{Total cost of production (Tk. ha}^{-1})$$

Benefit-cost ratio (BCR)

Benefit-cost ratio is the ratio of gross return with total cost of production. It was calculated by using the following formula (Islam *et al.,* 2004).

$$\text{Benefit-cost ratio} = \frac{\text{Gross return (Tk. ha}^{-1})}{\text{Total cost of production (Tk. ha}^{-1})}$$

3.14 Data analysis

ANOVA were done 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).

Latiraj in open field Latiraj + gora neem

Latiraj + kalo koroi Latiraj + Mango

Plate 3.1. Taro latiraj under gora neem, kalo koroi and mango agroforestry production system with control treatment

CHAPTER 4

RESULTS AND DISCUSSION

The present research work was conducted for the assessment of economic feasibility of taro cv. latiraj under three different MPTs in agroforestry system along with sole cropping i.e. open field condition. The results of the experiment were described in the 2 sub heads viz. main effect of different agroforestry production system and economic performance under the following sub-headings.

4.1 Main effect of different agroforestry production system on the growth, yield contributing characters and yield of taro cv. latiraj

4.1.1 Plant height

Plant height of taro cv latiraj was found significantly different due to the different multipurpose tree based agroforestry production systems along with sole cropping (Table 4.1). At the very early stage, 30 days after planting (DAP), plant height of taro cv latiraj was found statistically not significant, numerically the highest plant height (25.50 cm) was observed in (T_1) treatment latiraj growing in sole cropping and the lowest plant height (20.02 cm) was detected in (T_2) treatment latiraj + gora neem based agroforestry production system. Next at 60 DAP, the plant height was found little bit changes among the treatments. The highest plant height (60.54 cm) was recorded in (T_2) treatment latiraj + gora neem based agroforestry production system followed by (56.13 cm) was taken from (T_3) treatment latiraj + kalo koroi based agroforestry production system. On the other hand, the lowest plant height (50.33 cm) was noted in (T_1) treatment latiraj growing in sole cropping which was statistically identical to (50.93 cm) was found in (T_4) treatment latiraj + mango based agroforestry production system. The trend of growing plant height was change dramatically in 90 DAP. Finally, at 90 DAP the highest plant height (87.88 cm) was recorded in (T_2) treatment latiraj + gora neem based agroforestry production system that was identical to (87.20 cm) taken from (T_3) treatment latiraj + kalo koroi based agroforestry production system and also from (85.57 cm) in (T_4) treatment latiraj + mango based agroforestry production system. Conversely, the lowest plant height (81.84 cm) was noted in (T_1) treatment latiraj growing in sole cropping production system. 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. Plant growth reflects the adaptation to radiation conditions in the environment. Growth characteristics are generally used to infer about the tolerance of species to light availability (Teixeira, 2015). Luminosity is one of the most important determinants of the photosynthetic plant productivity (Cavatte *et al.,* 2009), and a low light intensity results in alterations of morphology, foliar anatomy, chloroplast ultrastructure, total exportation of assimilates and distribution patterns of assimilates (Bezerra *et al.,* 2009)

Table 4.1 Effect of production system on plant height of taro cv. latiraj

Treatments	**Plant height (cm)**		
	30 DAP	**60 DAP**	**90 DAP**
T_1	25.50 a	50.33 c	81.84 b
T_2	20.02 a	60.54 a	87.88 a
T_3	24.36 a	56.13 b	87.20 a
T_4	25.15 a	50.93 c	85.57 ab
CV%	27.04	1.81	1.97

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

4.1.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} of latiraj was observed significantly varied at 60 and 90 DAP due to the effects of different multipurpose tree based agroforestry production system (Table 4.2). Initially at 30 and DAP the results was found statistically not significant. Numerically, the maximum number of leaves plant^{-1} (1.67) was observed in (T_1) treatment latiraj growing in sole cropping production system and the minimum number of leaves plant^{-1} (1.53) was counted in all other treatments. Afterwards, at 60 DAP the maximum number of leaves plant^{-1} (5.80) was recorded in (T_3) treatment latiraj + kalo koroi based agroforestry production system that was statistically identical to (5.67) and (5.60) was taken in both T_1 and T_2 treatments, respectively. Besides, the minimum number of leaves plant^{-1} (4.50) was calculated in (T_4) treatment latiraj + mango based agroforestry production system. Finally, at 90 DAP the maximum number of leaves plant^{-1} (6.17) was observed in (T_1) treatment latiraj growing in sole cropping production system and the minimum number of leaves plant^{-1} (5.27) was observed in (T_4) treatment latiraj + mango based agroforestry production system. The vegetative growth of taro (*Colocasia esculenta*) is initially very slow, reaching a peak between four and six months of the cycle, with a subsequent decline, characterized by a reduction in the number of leaves, leaf area, petiole length and plant height (Gondim *et al.,* 2007). Similar results were found by Pereira *et al.* (2006) and Santos *et al.* (2015).

Table 4.2 Effect of production system on leaves plant^{-1} of taro cv. latiraj

Treatments	Number of leaves plant^{-1}		
	30 DAP	**60 DAP**	**90 DAP**
T_1	1.67 a	5.67 a	6.17 a
T_2	1.53 a	5.60 a	5.80 b
T_3	1.53 a	5.80 a	5.87 b
T_4	1.53 a	4.50 b	5.27 c
CV%	8.44	4.32	1.66

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

4.1.3 Leaf length

The effect of different multipurpose based agroforestry production system on leaf length was found statistically significant at 30, 60 and 90 DAP (Table 4.3). Firstly, at 30 DAP, the highest leave length (30.50 cm) was recorder in (T_4) treatment latiraj + mango based agroforestry production system which was identical to (28.97 cm) in (T_2) treatment latiraj + gora neem based agroforestry production system and the lowest leaf length (21.17 cm) was recorded in (T_1) treatment latiraj in sole cropping production system. In the middle stage, at 60 DAP, the highest leave length (45.43 cm) was observed in (T_4) treatment latiraj + mango based agroforestry production system followed by (41.50 cm) in (T_2) treatment latiraj + gora neem based agroforestry production system and the lowest leaf length (30.38 cm) was recorded in (T_1) treatment latiraj in sole cropping production system. Lastly, at 90 DAP, the highest leave length (65.80 cm) was found in (T_4) treatment latiraj + mango based agroforestry production system followed by (61.83 cm) in (T_2) treatment latiraj + gora neem based agroforestry production system and the lowest leaf length (50.45 cm) was recorded in (T_1) treatment latiraj in sole cropping production system. According to Vieira *et al.* (2014), the leaf area growth shows a gradual increase from 30 to 120 days, followed by a steady decline up to 150 days. Shading promotes changes in the microclimate, thus reducing the air temperature and favoring leaf growth (Gondim *et al.,* 2007).

Table 4.3 Effect of production system on leaves length of taro cv. latiraj

Treatments	Leaves length (cm)		
	30 DAP	60 DAP	90 DAP
T_1	21.17 c	30.83 d	50.45 d
T_2	28.97 a	41.50 b	61.83 b
T_3	24.60 b	35.60 c	55.93 c
T_4	30.50 a	45.43 a	65.80 a
CV%	2.80	0.81	0.95

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

4.1.4 Leaf breadth

The effect of different multipurpose tree based agroforestry production system on leaf breadth was initiated statistically significant at 30, 60 and 90 DAP (Table 4.4). At the early stage 30 DAP the highest leave breadth (11.60 cm) was recorder in (T_2) treatment latiraj + gora neem based agroforestry production system which was identical to (11.33 cm) in (T_4) treatment latiraj + mango based agroforestry production system and the lowest leaf breadth (8.83 cm) was recorded in (T_1) treatment latiraj in sole cropping production system alike to (8.83 cm) in (T_3) treatment latiraj + kalo koroi based agroforestry production system, respectively. In the middle stage, at 60 DAP, the highest leave breadth (26.83 cm) was observed in (T_4) treatment latiraj + mango based agroforestry production system followed by (25.83 cm) in (T_2) treatment latiraj + gora neem based agroforestry production system and the lowest leaf breadth (18.67 cm) was recorded in (T_1) treatment latiraj in sole cropping production system. Finally, at 90 DAP, the highest leave breadth (35.83 cm) was found in (T_4) treatment latiraj + mango based agroforestry production system followed by (32.83 cm) in (T_2) treatment latiraj + gora neem based agroforestry production system and the lowest leaf breadth (25.50 cm) was recorded in (T_1) treatment latiraj in sole cropping production system. Oliveira *et al.* (2011) observed that conditions of marked light restriction (50 % and 75 % of light restriction) induced an initial investment of 'Chinese' taro plants in shoot growth and in the expansion of the leaf area, in detriment of the root production, causing a delay in the formation of reserve structures and a reduction in the rhizomes productivity. Lenhard *et al.* (2013) also verified that plants grown under 70 % of shading presented higher levels of total chlorophyll and leaf area and weight ratios. A similar behavior of increase in specific leaf area with the increase in shading was found by Barrella *et al.* (2011) and Mota *et al.* (2008), for carrot and grape crops, respectively.

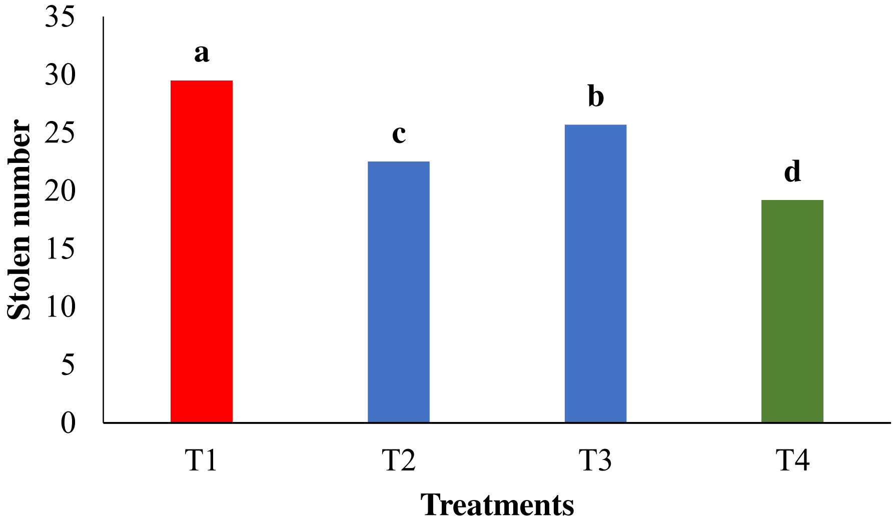
Table 4.4 Effect of production system on leaves breadth of taro cv. latiraj

Treatments	**Leaves breadth (cm)**		
	30 DAP	**60 DAP**	**90 DAP**
T_1	8.23 b	18.67 d	25.50 d
T_2	11.60 a	25.83 b	32.83 b
T_3	8.83 b	24.63 c	30.50 c
T_4	11.33 a	26.83 a	35.83 a
CV%	6.36	0.86	1.93

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

4.1.5 Stolon number

The effect of different multipurpose tree based agroforestry production system on stolon number of latiraj was found statistically significant (Fig 4.1). Significantly the highest stolon number (29.50) was noted in (T_1) sole cropping of latiraj production system followed by (25.67) was collected from T_3 treatment latiraj + kalo koroi based agroforestry production system. On the other hand, the lowest number of stolon (19.17) was recorded in (T_4) latiraj + mango based agroforestry production system, respectively.



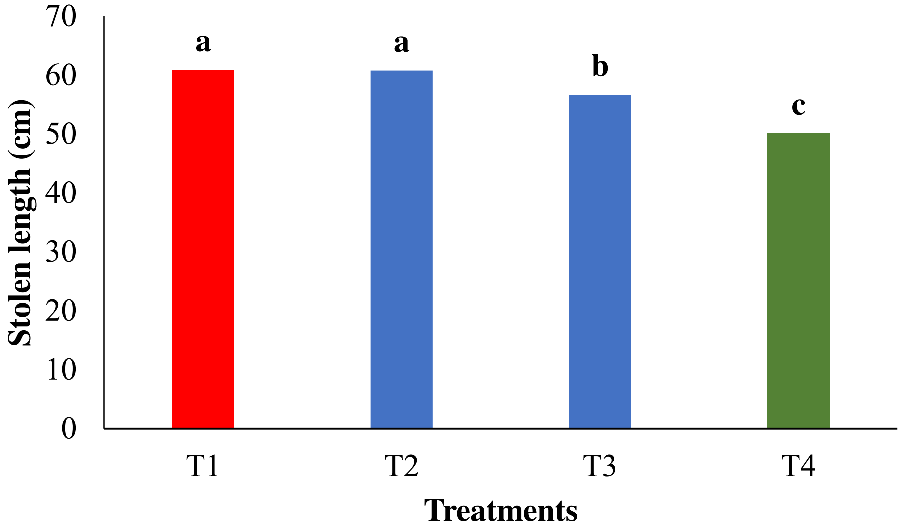
T_1 = Sole cropping of latiraj (open field control)
T_2 = latiraj + gora neem
T_3 = latiraj + kalo koroi
T_4 = latiraj + mango

In the figure, bars having similar letters mean treatments do not differ significantly and dissimilar letters mean treatments significantly differ by (DMRT) Duncan's Multiple Range Test.

Figure 4.1 Effect of different multipurpose tree based agroforestry production system on stolon number of latiraj

4.1.6 Stolon length

The effect of different multipurpose tree based agroforestry production system on stolon length of latiraj was originated statistically significant (Fig 4.2). Significantly the tallest stolon length (60.85 cm) was recorded in (T_1) sole cropping of latiraj production system which was statistically identical to (60.75 cm) observed in (T_2) latiraj + gora neem based agroforestry production system. Conversely, the shortest stolon length (50.08 cm) was observed in latiraj + mango based agroforestry production system (T_4), respectively. A similar result was also observed by Sen *et al.* (1998) in swamp taro and Alam *et al.* (2010).



T_1 = Sole cropping of latiraj (open field control)

T_2 = latiraj + gora neem

T_3 = latiraj + kalo koroi

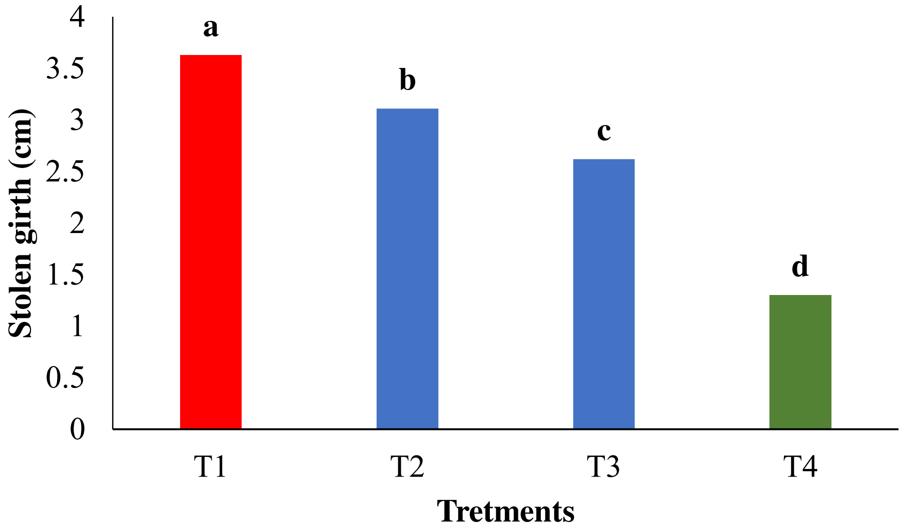
T_4 = latiraj + mango

In the figure, bars having similar letters mean treatments do not differ significantly and dissimilar letters mean treatments significantly differ by (DMRT) Duncan's Multiple Range Test.

Figure 4.2 Effect of different multipurpose tree based agroforestry production system on stolon length of latiraj

4.1.7 Stolon girth

The effect of different multipurpose tree based agroforestry production system on stolon girth of latiraj was coined statistically significant (Fig 4.3). Significantly the maximum stolon girth (3.63 cm) was recorded in (T_1) treatment sole cropping of latiraj production system followed by (3.11 cm) was observed from (T_2) treatment latiraj + gora neem based agroforestry production system. On the other hand, the minimum stolon girth (1.30 cm) was note down in (T_4) treatment latiraj + mango based agroforestry production system, respectively.



T_1 = Sole cropping of latiraj (open field control)

T_2 = latiraj + gora neem

T_3 = latiraj + kalo koroi

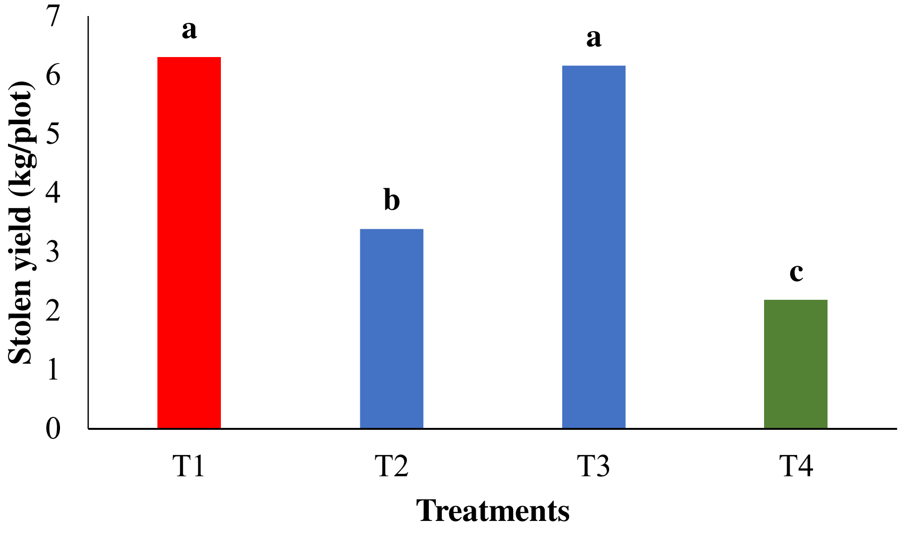
T_4 = latiraj + mango

In the figure, bars having similar letters mean treatments do not differ significantly and dissimilar letters mean treatments significantly differ by (DMRT) Duncan's Multiple Range Test.

Figure 4.3 Effect of different multipurpose tree based agroforestry production system on stolon girth of latiraj

4.1.8 Stolon yield kg/plot

The effect of different multipurpose tree based agroforestry production system on stolon yield kg/plot of latiraj was found statistically significant (Fig 4.4). Significantly the highest stolon yield plot^{-1} (6.30 kg) was found in (T_1) sole cropping of latiraj production system was statistically identical to (6.16 kg) observed in (T_3) latiraj + kalo koroi based agroforestry production system. However, the lowest stolon yield plot^{-1} (2.18 kg) was detected in (T_4) latiraj + mango based agroforestry production system followed by (3.39 kg) latiraj + ghora neem based agroforestry production system (T_2), respectively. Similar result was found Prajapati *et al.* (2003).



T_1 = Sole cropping of latiraj (open field control)

T_2 = latiraj + gora neem

T_3 = latiraj + kalo koroi

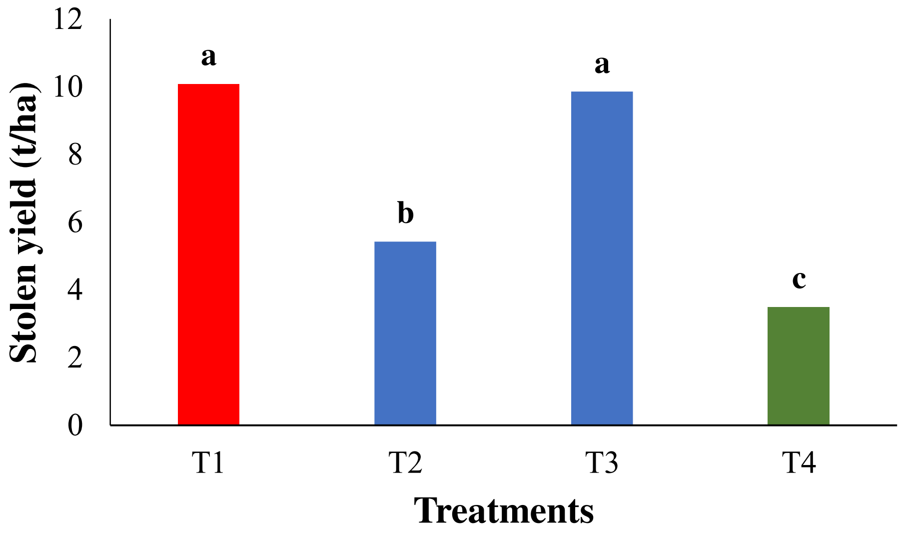
T_4 = latiraj + mango

In the figure, bars having similar letters mean treatments do not differ significantly and dissimilar letters mean treatments significantly differ by (DMRT) Duncan's Multiple Range Test.

Figure 4.4 Effect of different multipurpose tree based agroforestry production system on stolon yield (kg/plot) of latiraj

4.1.9 Stolon yield (t/ha)

The effect of different multipurpose tree based agroforestry production system on stolon yield ton/ha of latiraj was found statistically significant (Fig 4.5). Significantly the highest stolon yield (10.08 tha^{-1}) was weighted in (T_1) treatment sole cropping of latiraj production system which was identical to that means statistically no difference (9.85 tha^{-1}) found in (T_3) treatment latiraj + kalo koroi based agroforestry production system. On the other hand, the lowest stolon yield (3.49 tha^{-1}) was measured in (T_4) treatment latiraj + mango based agroforestry production system followed by (5.42 tha^{-1}) in (T_2) treatment latiraj + gora neem agroforestry production system, respectively.



T_1 = Sole cropping of latiraj (open field control)

T_2 = latiraj + gora neem

T_3 = latiraj + kalo koroi

T_4 = latiraj + mango

In the figure, bars having similar letters mean treatments do not differ significantly and dissimilar letters mean treatments significantly differ by (DMRT) Duncan's Multiple Range Test.

Figure 4.5 Effect of different multipurpose tree based agroforestry production system on stolon yield (ton/ha) of latiraj

4.2 Economic performance of taro latiraj under different multipurpose tree based agroforestry system

Economic potentiality of latiraj under different multipurpose tree (*Melia azedarach, Albizia lebbeck* and *Mangifera indica*) based agroforestry production system along with sole cropping was calculated based on local market rate prevailed during experimentation.

4.2.1 Total cost of production

The total cost of production has been presented in table 4.6. The highest cost of production (180965 Tk./ha) was recorded in (T_4) treatment latiraj + mango based agroforestry production system followed by (94335 Tk./ha) in (T_2) treatment latiraj + gora neem based agroforestry production system and (90135 Tk./ha) in (T_3) treatment latiraj + kalo koroi based agroforestry production system. On the other hand, the lowest cost of production (63935 Tk./ha) was recorded in (T_1) treatment latiraj sole cropping production.

4.2.2 Gross return

The highest value of gross return (515500 Tk./ha) was obtained from (T_3) treatment latiraj + kalo koroi based agroforestry production system. However, the lowest value of gross return (284700 tk./ha) was found from (T_4) treatment latiraj + mango based agroforestry production system. The highest gross return was obtained due to higher wood vale of kalo koroi trees along with the latiraj value.

4.2.3 Net return

The maximum net return (425365 tk/ha) was recorded in (T_3) treatment latiraj + kalo koroi based agroforestry production system and the minimum net return (180965 tk/ha) was calculated from (T_4) treatment latiraj + mango based agroforestry production system. Higher net return was the result of higher gross return from the latiraj production together with kalo koroi tree based agroforestry production system.

4.2.4 Benefit-cost ratio

The highest benefit-cost ratio of (4.72) was recorded from (T_3) treatment latiraj + kalo koroi based agroforestry production system followed by (3.73) found in (T_1) treatment latiraj sole cropping production and the lowest benefit-cost ratio of (1.74) was observed in T_4) treatment latiraj + mango based agroforestry production system. Thus, it may be promoted that latiraj + kalo koroi based agroforestry production system will be beneficial to the farmer as because of production system not only provides cash money to the farmer but also effective use of natural resources (land, nutrient, water, sun light). Amin *et al.,* 2017 was found the similar result in case of onion production under *Albizia lebbeck* based agroforestry production system.

Table 4.5 Economic returns of latiraj taro production under gora neem, kalo koroi and mango based agroforestry system with sole cropping

Treatment	Return (Tk./ha)				Gross Return (Tk./ha)	Total cost of Production (Tk./ha)	Net Return (Tk./ha)	BCR
	Latiraj production	Gora neem	Kalo koroi	Mango				
T_1	302400	----	----	----	302400	63935	238465	3.73
T_2	162600	150000	----	----	312600	94335	218265	2.3
T_3	295500	----	220000	----	515500	90135	425365	4.72
T_4	104700	----	----	180000	284700	103735	180965	1.74

Note: Latiraj market price 30 Tk./kg, ghora neem 300 tk./tree/year, kalo koroi 500 tk./tree/year and mango 350 tk./tree/year.

Table 4.6 Cost of production of latiraj taro under different multipurpose tree-based agroforestry system

Treatment	Input cost									Total input cost (Tk/ha)	Overhead cost			Total cost of production (Tk/ha)
	Non-material cost (Tk/ha)			Material cost (Tk/ha)							Interest of input cost @ 8% for the crop season (Tk/ha)	Interest of the value of land (Tk. 300000/ha /ha) @ 8% for the crop season (Tk/ha)	Miscellaneous cost @ 5% of the input cost (Tk/ha)	
	Trees	Taro latiraj production	Total non-material cost	Seedling	Fertilizer	Pesticide	Maintenance cost of trees	Initial plantation cost of trees	Total material cost (Tk/ha)					
T_1	………	15000	15000	12375	6660	1200	………	………	20235	35235	3000	24000	1700	63935
T_2	9600	15000	24600	12375	6660	1200	5000	12500	37735	62335	5000	24000	3000	94335
T_3	8000	15000	23000	12375	6660	1200	5000	10500	35735	58735	4500	24000	2900	90135
T_4	16000	15000	31000	12375	6660	1200	5000	14500	39735	70735	5500	24000	3500	103735

Note: Urea 14 Tk./kg, TSP 25 Tk./kg; MP 30 Tk./kg, labour 400 Tk./day, plantation cost for ghora neem, kalo koroi and mango were 30, 25 and 50 Tk./tree, respectively (rotation year for ghora neem, Kalo koroi and mango were 15, 20 and 12 years, respectively).

Plate 4.1. Taro latiraj production under different multipurpose tree based agroforestry production system with control treatment.

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 February to May 2018 to evaluate the economic potentiality of taro latiraj under different multipurpose tree based agroforestry production system with control. The experiment was conducted in established MPTs woodlot. The experiment was laid out in single factor Randomized Complete Block Design (RCBD) with three replications. The modern popular variety of taro was used in this experiment namely latiraj. The treatments were T_1 (sole cropping of latiraj), T_2 (latiraj + gora neem), T_3 (latiraj + kalo koroi) and T_4 (latiraj + mango). Seedlings of latiraj were sown in in 27th February 2018 maintaining the distance line to line 50 cm and plant to plant distance 50 cm. Necessary intercultural operations were done effectively.

The data were taken at 30, 60 and 90 days after planting (DAP) for plant height, number of leaves plant^{-1}, leaf length, leaf breadth. The data of the number of stolon plant^{-1}, stolon length, stolon girth, stolon and yield was taken in the harvesting stage. 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 different multipurpose tree based agroforestry production system with control were significant in respect of plant height, number of leaves plant^{-1}, leaf length, leaf breadth, the number of stolon plant^{-1}, stolon length, stolon girth, stolon and yield, respectively.

From growth and yield parameters, plant height at 90 DAP highest (87.88 cm) was recorded in latiraj + gora neem based agroforestry production system due to its canopy shade more than kalo koroi and mango tree and the lowest plant height (81.84 cm) was noted in control treatment because of full sunlight condition. In case of number of leaf per plant latiraj in sole cropping was perform the highest results at 30, 60 90 DAP (1.67, 5.67 and 6.17). On the other hand leaf length and breadth was found totally different results. The leaf length and breadth was gradually increasing and the highest vale was taken all DAP from latiraj + mango based agroforestry production system. Significantly the highest stolon number (29.50) was noted in sole cropping of latiraj production system followed by

(25.67) was collected from latiraj + kalo koroi based agroforestry production system and the lowest number of stolon (19.17) was recorded in latiraj + mango based agroforestry production system, respectively. The tallest stolon length (60.85 cm) was recorded in sole cropping of latiraj production system and the shortest stolon length (50.08 cm) was observed in latiraj + mango based agroforestry production system. Significantly the highest stolon yield (10.08 tha^{-1}) was weighted in sole cropping of latiraj production system which was identical to that means statistically no difference (9.85 tha^{-1}) found in latiraj + kalo koroi based agroforestry production system. On the other hand, the lowest stolon yield (3.49 tha^{-1}) was measured in latiraj + mango based agroforestry production system followed by (5.42 tha^{-1}) in latiraj + gora neem agroforestry production system, respectively.

From economic point of view, the highest cost of production (180965 Tk./ha) was recorded in (T_4) treatment latiraj + mango based agroforestry production system followed by (94335 Tk./ha) in latiraj + gora neem based agroforestry production system and the lowest cost of production (63935 Tk./ha) was recorded in latiraj sole cropping production. The highest value of gross return (515500 Tk./ha) was obtained from latiraj + kalo koroi based agroforestry production system. However, the lowest value of gross return (284700 tk./ha) was found from latiraj + mango based agroforestry production system. The maximum net return (425365 tk/ha) was recorded in latiraj + kalo koroi based agroforestry production system and the minimum net return (180965 tk/ha) was calculated from (T_4) treatment latiraj + mango based agroforestry production system. Finally, the highest benefit-cost ratio of (4.72) was recorded from latiraj + kalo koroi based agroforestry production system followed by (3.73) found in latiraj sole cropping production and the lowest benefit-cost ratio of (1.74) was observed in latiraj + mango based agroforestry production system.

5.2 Conclusion

Latiraj is a very delicious vegetables used for the cooking various curry as a supplement of vitamins and mineral. But unfortunately this famous vegetables are not produce commercially due to shortage of arable land in Bangladesh. The present research investigation has been showed that latiraj can possible to grow in different multipurpose tree based agroforestry production system. Initially production may be decrease but in case of economic benefits it will be much higher than mono cropping cultivation. Moreover latiraj under multipurpose tree based agroforestry practice can be fulfill the production deficit of the fabulous latiraj vegetables. The results indicated that latiraj in association of kalo koroi is return 4.72 taka in investment of 1 taka in a hectare of land for 1 year. This finding may help to progress the latiraj production in the vacant space of multipurpose partial shaded trees specially in *Albizia lebbeck.* Finally, in conclusion the findings of the research work may help the latiraj growing growers for earning a good amount of money and also it creates an opportunity to minimize the demand of the vegetables in the country.

5.3 Recommendation

However, to get good result the developed model should be applied in another multipurpose tree species like ipil-ipil, mahogany, sada koroi of the northern side of Bangladesh. It may be also recommendation this study should be repeated in different location of the country with different aged MPTs woodlots.

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APPENDICES

Appendix I. The physical and chemical properties of soil in experimental field situated in Mohabolipur Chahalgazi union sadar Dinajpur

Soil characters	Physical and chemical properties
Texture	
Sand (%)	65
Silt (%	30
Clay(%	5
Textural class	Sandy loam
CEC (meq/ 100g)	8.07
p^H	5.1
Organic matter (%)	1.06
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)	24.0
Sulphur (µg/g)	3.2
Boron (µg/g)	0.27
Iron (µg/g)	5.30
Zinc (µg/g)	0.90

Source: Soil Resources Development Institute, Dinajpur (2018).

Appendix II. Weather data of the experimental site during the period from February to May 2018

Months	* Air Temperature (C)			* Minimum Rainfall (mm)	* Relative Humidity (%)
	Maximum	Minimum	Average		
February	26.95	15.78	21.37	00	82.20
March	29.61	20.57	25.09	18.50	80.61
April	30.25	21.46	25.85	20.21	81.85
May	36.5	28.5	32.5	22.8	82.4

Note * Monthly average

Source: Meteorological Station, Wheat Research Center, Noshipur, Dinajpur.

Appendix III. Summary of analysis of variance (mean square) of plant height, and number of leaf per plant at different days after planting (DAP) of latiraj

Source of variation	Degrees of freedom	Mean Square Values					
		Plant height (cm)			Number of leaves plant^{-1}		
		30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
Replication	2	31.25	0.14	3.74	0.03	0.10	0.01
Factor A	3	19.32	69.23	21.88	0.01	1.08	0.42
Error	6	41.26	0.97	2.84	0.02	0.05	0.01

Appendix IV. Summary of analysis of variance (mean square) of plant leaf length, and leaf breadth at different days after planting (DAP) of latiraj

Source of variation	Degrees of freedom	Mean Square Values					
		Leaf length			Leaf breadth		
		30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
Replication	2	0.99	1.01	4.55	2.05	1.93	0.58
Factor A	3	53.99	124.16	135.74	8.82	40.23	57.11
Error	6	0.54	0.10	0.306	0.41	0.04	0.36

Appendix V. Summary of analysis of variance (mean square) of yield and yield contributing characters of latiraj

Source of variation	Degrees of freedom	Mean Square Values				
		Stolon Number	Stolon length (cm)	Stolon girth (cm)	Yield (kg/plot)	Yield (t/ha)
Replication	2	1.02	0.68	0.08	0.33	0.85
Factor A	3	58.47	76.87	3.00	12.61	32.29
Error	6	0.47	0.97	0.08	0.12	0.30