AGRO-ECONOMIC PERFORMANCE OF GIMA KALMI UNDER GHORA NEEM AND IPIL-IPIL BASED AGROFORESTRY SYSTEMS

A THESIS
BY

MD. NURUL ISLAM
Student No. 0905040
Session: 2009-10

MASTER OF SCIENCE (M.S.)
IN
AGROFORESTRY

DEPARTMENT OF AGROFORESTRY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY
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Submitted to the Department of Agroforestry, 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

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The Author

Abstract

An experiment was conducted at the Agroforestry Research Farm of the Hajee Mohammad Danesh Science and Technology University, Dinajpur during the period from 5th April to 20th May, 2009 to investigate the canopy shade effect of ghora neem and ipil-ipil trees, different levels of fertilizer and plant densities on the growth and yield of Gima Kalmi (*Ipomoea reptans*). There were three canopy orientations viz., no canopy, ghora neem canopy (*Melia azedarach*) and ipil-ipil canopy (*Leucaena leucocephala*), four levels of fertilizer viz. no fertilizer, recommended fertilizer, 20% and 40% less than the recommended fertilizer, three levels of plant density viz., 30 cm x 15 cm, 30 cm x 25 cm and 30 cm x 30 cm as treatments of the experiment. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Performance of Gima Kalmi grown under no canopy, ghora neem canopy and ipil-ipil canopy were evaluated. The plant height, number of leaves per plant, number of branches per plant, fresh weight of foliage per plant, yield per plot and yield per hectare grown under ghora neem and ipil-ipil canopy showed significantly reduction than those grown in no canopy. The ranked order of different canopy shade for better performance were no canopy > ghora neem canopy > ipil-ipil canopy. In combined effects of different canopies and different levels of fertilizer the highest plant height, number of leaves per plant, number of branches per plant, fresh weight foliage per plant, yield per plot were 28.89 cm, 78.79, 11.59, 87.79 g were found in no canopy with recommended fertilizers. The combined effects of different canopy and different plant densities on the growth and yield of Gima Kalmi did not show any remarkable variation among the parameters. The combined effects of different plant densities and different levels of fertilizer showed significant variation on the growth and yield of Gima Kalmi. The highest plant height (25.30 cm), number of leaves per plant (68.17), number of branches per plant (10.02), fresh weight foliage per plant (72.04 g) were recorded in 30 cm x 15 cm with recommended fertilizers. The combined effects of different canopy shade, plant densities and different levels of fertilizer resulted statistically significant on the growth and yield of Gima kalmi. The highest plant height (30.10 cm), number of leaves per plant (78.80), number of branches per plant (12.90) were found in recommended fertilizers, 30 cm x 30 cm plant density in open condition i.e. no canopy. The yield per plot and yield per hectare (1.26 kg and 12.60 t) were recorded in recommended fertilizers with 30 cm x 15 cm plant density in open condition i.e. no canopy, respectively. In terms of benefit-cost ratio, the highest benefit-cost ratio (4.28) was recorded from ghora neem + Gima Kalmi based agroforestry system followed by ipil-ipil + Gima Kalmi based agroforestry system than in sole cropping (no canopy, open field condition). So, Gima Kalmi can profitably be cultivated in ghora neem based agroforestry systems.

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CHAPTER 1

INTRODUCTION

Bangladesh is an agrarian country and agriculture is the driving force for her economic growth (Anon, 2007). Although the share of this sector to its GDP has been decreasing over the last few years due to the multifold expansion of the export oriented garment sector. Yet it dominates the economy accommodating lion share of the labor force living in rural areas. More than 84% of the population are living in the rural areas this or that way dependent on this profession for their livelihoods (MoA, 2007). The economy of the domain is burdened with her increasing population. Note that the present growth rate is 1.5% (BBS, 2006) in the realm. This territory is one of the largest deltas of the world with a total area of 147570 square kilometer. About 1045 persons live here per square kilometer (CIA, 2007) leading it the densest populated country of the planet. This expanding population is exerting immense pressure on the usable land and ultimately reducing per capita available land in an alarming rate. This availability has been declined from 0.19 in 1961 to 0.101 ha in 1992 (Iqbal *et al.,* 2002) and now the country is claimed to have the lowest per capita arable land of 0.06 hectares. Most of the area of the country is floodplain, covering about 80% of her total land, the rest 20% constitute hills and raised terraces (Abedin *et al.,* 1991). Floodplain and terraces are the major ecosystem of Bangladesh in terms of traditional farm land agroforestry systems (Miah *et al.,* 2002).

This limited land resource cannot make up cereal requirements for her people. On the other hand, adequate emphasis has not been given to timber and vegetable production, which are important sources of different fire wood, construction materials, vitamin and minerals. The minimum dietary recommendation of fruits per capita per day is 85 g where the availability is only 30-35 g. Again the average consumption of vegetables in Bangladesh is only 70 g per head per day. Except tuber crops, it is only 30 g as against the recommendation of 200 g. Hence, there has been a widespread malnutrition in the country (Miah, 2001).

A country needs 25% of forestland of its total area for ecological stability and sustainability. Unfortunately, Bangladesh is endowed with only 13.6% (BBS, 2008) of unevenly distributed forests. However, actual tree cover is less than 10% (Akter *et al.,* 1989). The central region where the population density is the highest has the least forest resources. Substantial depletion of forest resources has occurred in the last few decades, and now it is reduced to less than 0.02 ha per person, one of the lowest ratios in the world (BBS, 2008). Under these alarming situations, agricultural production as well as forest resources must be increased by using modern techniques.

Recently, some techniques have already been advocated to overcome the future challenges, agroforestry is one of them. Agroforestry, the integration of the tree, crop and vegetables on the same area of land is a promising production system for yield (Nair, 1990) and maintaining friendly environment. Growing of crops in association with trees is becoming popular day by day for its higher multipurpose use and environment consciousness among them.

Traditionally farmers grow different types of trees and vegetables simultaneously in their homesteads, where productivity of vegetables is low due to lack of appropriate combinations. From time immemorial, a large number of diversified tree species are grown in the homesteads and recently many exotic species are also grown. Besides the homesteads and adjacent land, one - eight of the land surface area of Bangladesh consists of hills and valleys that also offer potentials for year round vegetable production under agroforestry system.

But farmers used to face the problems of growing crops after 4-5 years of tree plantation and even sometimes failed to grow under storey crops under around trees. In agroforestry systems, therefore, there is an inevitable competition for growth resources such as light, water, nutrients which may reduce the productivity of under storey crops in particular. Among different resource limitations light availability is the most important one for the performance of the understorey crops/vegetable particularly, where an upperstorey perennial forms a continuous overstorey canopy (Miah *et al.,* 1995).

Though agroforestry is a time old practice in Bangladesh, further improvement may be brought for harvesting maximum benefit by identification of appropriate tree crop combination ipil-ipil (*Leucaena leucocephala*) is an important tree species, which is grown in most of the homesteads and orchard of the country (Mustafa, 1996 and Chowdhury & Sattar, 1993). It is a medium size fast growing tree and its products and services is one of the most popular in Bangladesh.
Gima Kalmi (*Ipomoea reptans*) is a leafy vegetable which belongs to the family Convolvulaceae. The crop is also known as kangkong, swamp cabbage, water convolvulus, water spinach etc. (Tindal, 1983). It is an excellent source of vitamin-A. 100 g of its edible portion contains 87.6 g water, 1.1 g minerals, 0.1 g fat. 9.4 g carbohydrates, 107 mg calcium, 3.9 mg iron, 10740 microgram carotene, 0.14 mg

vitamin B_1, 0.40 mg vitamin B_2, 42 mg vitamin C, 1.8 g protein and 46 kilocalories (Anon, 1983). Leafy vegetables such as Gima Kalmi, Spinach, Indian spinach and Amaranth are commonly close to "Spinach group" of vegetable (Shinohara, 1980).

Gima Kalmi is an important leafy vegetable of the South-East Asia and is widely grown throughout the South East Asian Countries, Australia and some parts of Africa (Hossain and Siddique, 1982). It is a popular vegetables in Bangladesh. It was developed from an introduced strain of Kangkong brought from Taiwan by the Citrus and Vegetables Seed Research Centre (CVSRC) of Bangladesh Agricultural Research Institute, Gazipur (Rashid *et al.,* 1993).

In Bangladesh most the of vegetable are produced in summer and winter seasons, while in between these two seasons, there is a lag period when scanty of vegetables exists. Introduction of Gima Kalmi is a positive achievement since it can be grown both in summer and rainy seasons (Shinohara, 1978). Aquatic type of local kalmi is naturally grown in ponds or marshy land of Bangladesh. Gima Kalmi is a special significance, because it grows on upland soil with an appreciable yield potential of foliage.

For proper crop production, application of fertilizer at optimum dose is one of the most important factors. Fertilizer increases the vegetables growth of plants and produces good quality foliage and promotes carbohydrate synthesis (Rai, 1981). For successful production, Gima Kalmi requires early growth which could be influenced by application of fertilizers. However, the application of optimum quantity of this fertilizer varies from place to place depending on agro-climate situation. Literature on the influence of different doses of fertilizers on the production of Gima Kalmi is limited. Moreover, information on this crop under Bangladesh conditions is also meager. The use of fertilizer for the production of Gima Kalmi is partcularly important when several harvests are done from a single plant. In Bangladesh fertilizer is mostly used as the source of NPK and split application N fertilizer is commonly practiced for leafy vegetable production (Hossain, 1990).

Plant spacing is another important aspect of crop production to maximize the yield. Optimum plant spacing ensures judicious use of natural resources, makes the intercultural operations easier, which help to be used in Gima Kalmi cultivation is scanty. The farmers cultivate this crop according to their own conception due to absence of standard production technique.

Gima Kalmi is usually recommended for enrichment of human diet but unfortunately this crop can not be successfully grown during the summer and rainy season in Bangladesh while serious scarcity of vegetables prevail that time. On the other hand, due to land scarcity, it is necessary to test the performance of this crop under agroforestry system.

Considering the above mentioned facts and potentiality a study was undertaken with broad objective to examine the compatibility of ghora neem and ipil-ipil trees in association with Gima Kalmi. The specific objectives of the study were:

i) To evaluate the comparative performance of Gima Kalmi grown under five years old ghora neem and ipil-ipil tree species.
ii) To examine the effect of different plant densities and fertilizer doses on the yield and yield components of Gima Kalmi under five years old ghora neem and ipil-ipil tree species.
iii) To identify the best combination of tree-Gima Kalmi based agroforestry practice.

CHAPTER 2
REVIEW OF LITERATURE

Gima kalmi is an important leafy vegetables in Bangladesh. Very little research has been done here on this crop. Experiments on the effect of fertilizer on the production of leafy vegetables like Gima kalmi, spinach, Indian spinach and amaranth have been conducted in various parts of the world, but research regarding the effect of canopy, fertilizer and plant density on the growth and yield of Gima kalmi under Bangladesh condition especially northern part is scanty. Studies on the effect of fertilizer on leafy vegetables production in different part of the world have revealed that the yield is directly related to the quantity of fertilizer application. An attempt has been made in this chapter to review all literature available at home and abroad pertaining to the present research work under the following heading:

2.1 Concept 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 from 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.

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 three 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 Tree-crop interaction

Khan and Aslam (1974) studied the effect of single sissoo (*Dalbergia sissoo*) tree on the yield of wheat crop. Yield was from plots within a quadrate of $1m^2$. The quadrates were taken at a distance of 3m, 4.5m and 6m from the base of tree. One quadrate was taken from the center of the field, that is, well away from the influence of trees involved. The grain yield showed a decrease of 30.88%, 23.6% and 12.7% at the distance of 3, 4.3 and 6m, respectively as compared to the open field. Both the tree and the crops were raised under irrigated condition.

Scott (1987) investigated the *Inga edulis* rows reduced rice yield 50% compared with those in rows farthest away. A follow up research was designed to observe the effect of *Inga edulis* on upland rice yield. It was known that *Inga edulis* has a pronounced effect reducing rice yields by 50% up to 2.5m away; beyond that, yield were similar to those in rows 6m away (Palm *et al.,* 1992).

Dhukia *et al.* (1988) observed that in the rabi season of 1984-87, four fodder crops (*Trifolium alexandrium*, oats, *Vicia faba* and *Trifolium foenum-graecum)* and two field crops (*Triticum aestivum* and *Cicer arietinum*) were grown under *Dalbergia sissoo* and *Albizia lebbeck.* Among the fodder crops the highest fresh fodder and dry matter yields under both plantations were given by *Trifolium alexandrium* follower by oats. The yields decreased less than 4 years old trees compared with those under 3 years old trees. Wheat gave higher yields than *Cicear arietinum* under both plantations. Yields of all crops under the *Dalbergia sissoo* plantation were higher than under the *Albizia lebbeck* plantation.

Hazra and Tripathi (1989) reported that four oat cultivars were grown under the canopy of different trees and in open plots of a suitable cultivar for cultivation under an Agroforestry system. Cv. OL- 189 and OL- 125 gave the highest fodder yields under different trees. The average yields were 95% under *Albizia lebbeck*, 90% under *Hardwickia* binarta, 88% under *Acacia nilotica*, and 74% under Melia azadiracht (*Azadirachta indica*), compared with the open plot yields. The PAR received under the 4 trees canopies was 90, 87, 80 and 63%, respectively of suitable for cultivation in Agroforestry system especially under *A. lebbeck.*

Basri *et al.* (1990) observed that hedgerow trees competed for nutrients and light with upland rice crops to a significant extent. Competition was most severe in the 2-3 rice rows closed in the hedgerows where yields were reduced by 50-70% compared with those in the center of the alley.

Garrity *et al*. (1992) observed that in an alley cropping system yield depression of upland rice was obtained in the zone near the hedgerows although plant height did not affected much. Results of three-year trial indicated that *Geliricida sepium* exhibited the lowest yield depression on upland rice in rows near the hedges.

Studies at ICRAF's research filed with *Leucaena lucocephala* and maize showed that total maize yields under improved trees were only 50% of the sole maize yield which increased to 80% due to pruning (Ong *et al.*, 1992) indicating the benefits of pruning in reducing tree-crop competition.

Puri and Bangarwa (1993) studied wheat yield in Agroforestry system. They collected data on crop yield from each tree species at different distances 1, 3, 5 and 7m) and in 4 directions (east, west, north and south) from the tree bases and control. The results indicated that *Azadirachta indica* and *Prosopis cineraria* did not make any significant difference to wheat yield. While *Acacia nilotica* reduced yield by 4-30%, but reduction was only up to a distance of 3m. In general, the effect of trees on wheat yield was observed up to 3m distances and there was little effect from 3 to 5m distances, and almost no effect at 7m distances. In all the tree species, the wheat yield was reduced to a maximum on the north side of trees and had almost no effect in the southern direction.

Khan and Ehrenreich (1994) determined the influence of boundary planting of *Acacia nilotica* on the growth and yield of associated rice (*Oryza sativa*) crops under irrigated condition. The results indicated that close proximity to trees adversely affected tillers m^{-2}, grains $panicle^{-1}$ or 1000-grain weight, but grain yield were slightly lowest near largest trees.

Shading effect can be minimized by proper orientation of rows, side or top pruning of trees in the outer of plots, having larger plots for crops

Hocking and Islam (1995) reported the growing of trees like *Acacia nilotica, Acacia catechu,* and *Borassus flabellifer* in rice paddy fields in Bangladesh. Viswanath *et al.* (1998) have documented the cultivation of *Acacia nilotica* trees on rice bunds (raised risers) in Tanjavur reports on the practice of maintaining *Acacia nilotica* trees in upland rice fields.

2.3 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 a result 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. 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 cause poor performance of understorey crops. The key to the development of compatible tree crop combination in agroforestry is greater light interception by understorey 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 (Howard *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 (Howard *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.*, 1995).

2.4 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 (regrowth following topping).
v) Effective nutrient recycling abilities especially dinitrogenfixation
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.

2.5 Forest tree based agroforestry systems

Mishra (1979) reported that the crop yield of maize and rice grown with *Dalbergia sissoo* was not significantly affected in comparison to the yield of control (no tree) plots. Singh *et al.* (1989), however, reported a marked increase in grain yield of pigeon pea, sesame, castor and jowar when cultivated with *Leucaena leucocephala.* Similarly, Dhukia *et al.* (1988) obtained higher green fodder yield of faba bean grown under five year old Poplar trees spaced at 6 x 6. Ranasinghe and Mayhead (1984) recorded decreased bean yield when grown under Poplar during the second year only, and there was no adverse effect of trees on the crop yield at the end of the first year.

In an experiment at the Forestry Research Station, Mettupalayam, Tamil Nadu, eleven agricultural crops like, sunflower (*Helianthus annuus)*; cotton (*Gossypium hirsutum)*; green gram (*Vigna radiata)*; sesame (*Sesamum indicum)*; sorghum (*Sorghum vulgare)*; cowpea (*Vigna unguiculata)*; soyabeans (*Glycine max)*; turmeric (*Curcuma longa)*; maize (*Zea mays)*; black gram (*Vigna mungo)* and groundnut (*Arachis hypogaea*) were planted at various spacings in the interspaces of 3 multipurpose tree species, viz. *Eucalyptus tereticornis*, *Casuarina equisetifolia* and *Leucaena leucocephala*, planted as 9 month old seedlings at a spacing of 4×1 m by Srinivasan *et al.* (1990). Six successive croppings of each crop were raised, by which time the trees were 32 month old. Considering the sixth cropping, and comparing with the monocrop as control, yield of all intercrops was severely inhibited, with the reduction greatest in *L. leucocephala* and least in *C. equisetifolia*. The yield reduction is attributed primarily to reduced light transmission. Light under the canopy was reduced to about a quarter during the morning and to less than half during the afternoon for the entire tree species. Tree root weight per unit soil volume was the highest in *L. leucocephala* and least in *C. equisetifolia*. Soil moisture deprivation was highest in *E. tereticornis*. Since the 3 tree species competed for light to an equal extent, the higher crop yield reduction in *L. leucocephala* is attributed to greater competition for water and nutrients by its extensive root system.

The effect of three tree species namely eucalyptus (*Eucalyptus teretcornis*), acacia (*Acacia nilotica*) and Poplar (*Populus deltiondes*) on the performance of turmeric (*C. longa*) was investigated in Karnal, Haryana, India by Singh *et al.* (2001). They observed that the mean germination of turmeric was maximum when grown in association with acacia and minimum in the control i. e. in open. The mean height attained by turmeric after 90 days was highest under eucalyptus and lowest under poplar. The yield of turmeric was in the order: eucalyptus>control>poplar>acacia.

Jaswral *et al.* (1993) studied on the performance of two rhizomatous crops namely ginger (*Zingiber officinale)* and turmeric (*Curcuma longa*) under rainfed conditions in pure stands and as intercrops with 5 year old poplars (*Populus* 'G-3') planted at three spacings (5×5, 5×4 and 5×3 m) at the experimental farm of the Dr. Y. S. Parmar University of Horticulture and Forestry at Solan, Himachal Pradesh, India. They reported that the average illumination below the canopies was 53, 46 and 38% of incident radiation, respectively. Both crops performed better as intercrops than as pure stands as measured by growth (height, tillers and leaves per plant, and leaf length and breadth), yield (rhizome length and breadth), yield per plant and hectare, and dry matter content, and survival. However, all parameters decreased as poplar spacing became closer, and in the case of turmeric, yield parameters were nearly all less at the closest poplar spacing than for the pure crop. For quality parameters, only oil content in ginger and oleoresin in turmeric showed significant differences. The cultivation of turmeric was more remunerative than that of ginger. Among the poplar spacings, 5 × 4 m for ginger and 5×5 m for turmeric were delineated as the best.

An experiment was conducted by Samsuzzaman *et al.* (2002) during April 1990 to March 1993 at the Agricultural Research Station in Pabna to investigate the effect of tree spacing (6m × 1m, 8m × 1m, 10m × 1m and 12m × 1m) and root pruning on tree-crop interaction. In this experiment they grown wheat, rice and one year old *Acacia nilotica* in an alley cropping system. The results of the experiment indicated that the wider the tree spacing, the lower will be the reduction in the yield of adjacent crops. Root and shoot pruning increased the grain yield of wheat by 22%. Shoot pruning also contributed to a additional fuelwood generation every season. Moreover, root and shoot pruning was found to reduce tree-crop competition, thereby enhancing crop yield. The highest increase in the yield of rice (27%) and radish (71%) were obtained due to pruning of *Acacia nilotica* two or three times a year, respectively.

Katiyar *et al.* (1999) conducted a field experiment during 1994-97 in Lucknow, India, to study the response of annual and biennial *Curcuma longa* to N and P application in an intercropping system with poplar on sodic soils. *C. longa* performed well under the partial shade of 6 to 9 year old poplar trees. The biennial crop yielded 2.5 times more than the annual crops (10.6 t/ha). Vegetative growth was promoted by increasing N doses. The highest yields were obtained following the application of 90 kg N and 60 kg P/ha.

An experiment was carried out by Neuman *et al.* (1989) in order to stydy the yield, morphology and specific leaf weight of the summer crops like maize (*Zea mays*), beans (*Phaseolus spp.*) and ginger (*Zingiber officinale*) in relation to tree proximity and PAR (photosynthetically active radiation) transmissivity in a 7-year-old plantation of *Paulownia elongata* grown at a spacing of 15×5 m. Trees had a mean height of 16 m, diameter at breast height 35 cm and canopy diameter 7 m. The yield of intercropped beans and maize was significantly reduced, compared with control monocrops, at all positions relative to the trees. This yield depression was particularly marked at positions closest to the trees. Beans grown at 2 m from the trees had reduced height and specific leaf weight. These crops would yield more at wider row spacing. Ginger gave higher yields when intercropped and is an ideal shade crop.

In West Bengal, Pal *et al.* (1993) conducted a field experiment, where turmeric (*Curcuma domestica*) was planted at 40 × 20 cm in the alleys between *Leucaena leucocephala* trees planted in rows 4 m apart with 0.5, 0.75 or 1.0 m between the trees in rows. Turmeric rhizomes were harvested after 270 days in each of 2 years. The effects of applying N at 60 or 120 kg/ha all as urea or half as urea and half as green *L. leucocephala* leaves and K at 60 or 120 kg K_2O/ha as muriate of potash were studied. Average turmeric yields ranged from 61.57 q/ha in control to 98.09 q/ha with 120 kg N (half as urea and half as leaves) + 120 kg K_2O. Biomass production of *L. leucocephala* was also highest (107.3 q/ha) in this treatment (compared with 72.3 q/ha in the control). Net profits from alley cropping were as high as Rs 2.01 per rupee invested compared with Rs 2.83 from sole cropped turmeric. Turmeric yields increased as *L. leucocephala* spacing increased but the biomass production of *L. leucocephala* decreased.

Cumba *et al.* (1992) made studies from 1981 to 1986 in coffee plantations in Cuba grown under two different species of shade tree, *Leucaena leucocephala* and *Albizzia procera*, each at spacings of 6 × 8m and 8 × 8m. Data were presented on coffee growth and yield. The results indicate that performance was the best under *L. leucocephala* shade trees at 8m × 8 m spacing. Again, Lahiri (1980) raised 2 lines of turmeric under 2-year old teak plantation at 3 m apart in rows both as annual and biennial crops and reported a yield of 17.5 and 25 q ha^{-1}, respectively. However, 40 q ha^{-1} yield was recorded when he raised 3 lines of turmeric as biennial crop in between rows of teak, 4 m apart. Subsequent inter-cropping under the teak resulted in decreased turmeric yields. In comparison to other agricultural crop species, turmeric appeared to be promising.

Newman (1997) specifically recommended the increase in spacing between rows with compensatory decrease within row distance in order to improve the performance of an understorey crop besides selection of more shade-tolerant species and varieties of agricultural crops. The investigation made by Malik and Sharma (1990) recorded reduced yield in mustard and wheat to the tune of 47 and 34 per cent, respectively up to 10m in distance from 3.5 year old *Eucalyptus tereticornis* probably owing to competition for soil moisture.

Thakur and Singh (2003, 2004) reported that different shade intensities created through tree crown management significantly affected growth, root characters and yield related parameters in *Phaseolus mungo* and *Pisum sativum* grown as understorey field crops with *Morus alba* under rainfed conditions. They observed that growth and yield was maximum in open (without tree); however, unmanaged canopy of *Morus* trees caused 42 % yield reduction beneath the canopy up to 3m distance from tree trunk

An investigation was conducted by Calstellani and Prevosta (1961) to observe the effect of poplar plantation on associated crops. They inferred that poplar planted in rows in any direction had no significant effect on yields of crops along side up to fourth year after plantation. Tiwari (1992) also reported that agricultural crops can be grown successful with poplars without *any* detrimental effects. Reduction in mung bean, soybean, groundnut and maize yield with increase in age of rubber tree was reported by Laosuwan *et al.* (1987), and this reduction was due to soil inconsistency. Neuman *et al* (1989) reported the reduction in yield of soybean as compared with the open control, when grown with *Grevellia robusta.* However, the yield of the maize, bean and sweet potato was high when integrated with trees. Ten thousand cobs of maize were obtained in 4x4 in teak spacing in first year of plantation, however, in the second year the yield was reduced to half under the same spacing (Lahiri, 1980).

Preliminary results under upland conditions at the IITA research farm at Ibadan showed that the intercropping of maize under *Leucaena was* promising. Under 1 year old *Leucaena,* the recorded maize yield was 2857 kg ha^{-1} whereas without *Leucaena* it was only 2512 kg ha^{-1}. Grain yield of 3400 kg/ha has been reported by Sheikh and Haq (1978) in a 1.2 ha plantation of 4-year old hybrid poplars of average height 15 m, diameter 19 cm, grown at a spacing of 5.5 x 5.5m under irrigated conditions.

Direction of planting the crop with respect to tree row plays an important role in growth and yield performance of field crop. North-South direction causes least negative influence on crop yield than East-West as was reported by Dhillon *et al.* (1982) for rice, wheat and potato grown with Eucalyptus. Similar results were obtained by them for wheat and rice grown with *Dalbergia sissoo* and *Acacia nilotica.* Comparing the performance of maize, soybean, wheat and lentil, sown in north and south direction to *Mortis* and *Grewia* tree rows, Kumar (1996) reported better growth and yield in south direction than in north.

Sheikh and Haq (1978) studied the effect of shade of *Acacia nilotica* and *Dalbergia sissoo* on wheat and reported that both the factors i.e. distance from tree base and the direction of the tree shade had significant effect on wheat yield. The yield was lowest up to a distance of 2 m from the base of the tree when the plots were on the northern, north -eastern, north -western side of the trek. Singh *et al.* (1989) in a study of alley cropping of cow pea, castor and sorghum in India concluded that yield of crops decreased as the distance from the hedgerow decreased from 5 to 0.3 m. There was some modification of microclimate in the alley but the changes were not great enough to influence crop yield significantly.

Khan and Better (1990) reported better wheat yield grown in association with poplar raised at 2.5 x 10 m spacing in blocks. On the other hand, Khan and Aslant (1974) recorded decreased grain yield of 30.8, 23.6 and 12.7 per cent in wheat sown at distances of 3, 4.5 arid 6 m, respectively from tree *(Dalbergia sissoo)* base in comparison to control plots. Moreover, Kohli (1990) observed negative effects of *Eucalyptus tereticornis* on the growth and yield of chickpea, lentil, wheat, cauliflower, toria and berseem up to 11 m distance from tree base, while Dhukia *et al.* (1988) reported decreased yield of agricultural crops with the increasing age of trees. Low yield of pulses and forage crops growing with *Eucalyptus* is attributed to the lowering of water table and depletion of soil nutrients by the tree. Rai (1981) reported a reduction in plant height and number of leaves of sorghum, sesame and cotton when grown under *Casuarina equisetifolia.*

The tree crop interactions under rainfed conditions in Dehra Dun valley was studied by Khybri *et al.* (1992). The experiment was conducted for 13 years (1977-90) involving *Grewia optiva, Morus alba,* and *Eucalyptus tereticornis* tree species with rice/wheat rotation. All the tree species had a depressing effect on crop yields. This effect on crop yield varied from 28 to 34 per cent depending on the tree crop combination. Distance of crop from tree line significantly affected the crop yield i.e. 39 per cent decrease in crop yield up to 1 m, 33 per cent from 1-2 m, 25 per cent from 2-3 in and 12 per cent from 3-5 in distance. Puri and Bhargawa (1992) observed little impact of trees on wheat yield up to 3 in distance from tree base, very little impact up to 5 m and no impact at and beyond 7 m.

Sharma and Singh (1992) investigated growth and yield of wheat crop as influenced by single row bund plantation of *Populus deltoides* grown on the southern aspect of the field in east- west direction. The results did not indicate significant differences in the sample plots laid out near tree line and plots laid out at the farthest distance (control). However, some improvement in crop yield (10.63 kg) was found up to 15 m zone from tree line. Ong *et al.* (1992) carried out an experiment to assess the importance of aboveground competition between single rows of *Leucaena leucocephala* and the adjacent maize crop, and showed that the influence of *Leucaena* extended-to about 5 m, beyond this distance, maize yield was close to the level achieved as obtained in sole maize plots.

Yamoah *et al.* (1986) reported beneficial effect of *Cassia siamea* hedgerows on maize crop probably due to the accumulation of more litter close to the hedgerows. Significant increase in grain yield of maize grown under *Leucaena leucocephala* was observed by Gichuru and Kang (1989). Grain yield in maize grown with alley cropping than sole cropping. Non-inhibitory effects of *Leucaena leucocephala* on maize crop were reported by Lal (1989).

Higher wheat yield grown with *Dalbergia sissoo* in comparison to the yield obtained under *Eucalyptus camaldulensis, Populus deltoides* and *Bombax ceiba* was recorded by Khattak *et al.* (1980). Similarly, Swaminathan (1987) reported increased grain yield of agriculture crops, and moisture availability due to *Leucaena leucocephala* plantation as a windbreak. The beneficial effects of *Acacia albida* and *Prosopis cineraria* on mung bean and cluster bean have been reported by Singh *et al.* (2001). Srinivasan and Caulfield (1989) reported beneficial cultivation of wheat and maize intercropped with poplar tree.

2.6 Bio-economic appraisal of agroforestry systems

Singh *et al.* (2001) analyzed the economic profitability of raising medicinal and aromatic plants as intercrops in four and five year-old poplar (*Populus deltoides*) based agroforestry system. All the crops namely *Mentha arvensis, M. gractlis, Zingiber officinale, Curcuma domestica, Pogostemon cablin, Artimisia annita, Ocimum basilicum* and *Piper longum,* except *Costus speciosus,* performed well in agroforestry system. Maximum net return was obtained in *C. domestica* (Rs. 64,700/ha and 68,300/ha) and net return was Rs. 25852/ha and Rs. 23437/ha in *Ocimum basilicum* in the first and second year, respectively.

An field experiments was conducted by Meerabai *et al.* (2001) during 1998/99 and 1999/2000 at Vellayani, Kerala, India to investigate the effects of N (50, 100, 150 and 200 kg/ha), P (0, 25, 50 and 75 kg/ha) and K (0, 50, 100 and 150 kg/ha), applied at different combinations, on the yield of ginger intercropped under partial shade of coconut. Yield increased with increasing rate of each fertilizer. Treatment with 15 kg N/ha+50 kg P/ha+150 kg K/ha resulted in the highest average fresh rhizome yield (18.4 t/ha), net return (Rs. 148000/ha), and benefit: cost ratio (2.35). Again, Isaac and Nair (2000) discussed about intercropping of tree and perennial agricultural crops within coconut gardens in Kerala, India. Agroforestry practices in coconut holdings have a 3 to 5 layered multi-storeyed cropping pattern, with palms occupying the uppermost canopy, multipurpose trees the intermediate layers, and herbaceous agricultural crops (e.g. vegetables and fodder crops) as the lower layer. It is suggested that agroforestry offers great scope for sustaining the productivity of coconut gardens for longer periods, without great reliance on chemical inputs. The total income per unit area will be greater than from the same area of pure plantation crop.

Chauhan (2000 a) observed average net returns of Rs. 25690/ha/yr from sole plantation of *Populus deltoides* and Rs 43590/ha/yr from lemongrass, Rs 39670/ha/yr from palma rosa, and Rs 36370/ha/yr from Japanese mint using Poplar based agroforestry system over a period of five years. In another study, Chauhan (2000 b) inferred that *Tagetes minuta* can be successfully grown at 50x75 cm spacing with 40 kg N/ha under eight year old Poplar, resulting in monetary gains (net profit) of about Rs. 52000/ha/year.

Potential productivity and financial returns from selected agroforestry systems and traditional monocrops located in the Phu Wiang watershed at Thailand were estimated from limited trials of cropping alternatives using cost-benefit analysis by Wannawong *et al.* (1991). The agroforestry systems studied consisted of combinations of eucalyptus (*Eucalyptus camaldulensis*), leucaena (*Leucaena leucocephala*), or acacia (*Acacia auriculiformis*) intercropped with cassava (*Manihot esculenta*) or mung bean (*Vigna radiata*). Parameters considered were tree growth, charcoal production and crop yield. Evidence from trials at short, 3 years rotations, demonstrates that early supplementary and complementary relations between some system components can imply synergistic financial gains. Although these biological interactions become competitive over time, in this case, the gains should be sufficient to make early adopters consider agroforestry (intercropping) systems financially preferable to traditional monocrops.

The experiment conducted by Rajput *et al.* (1989) at Lucknow, India for the profitable use of the space between plants in a young mango orchard through judicious intercropping. The intercrops like vegetables, pulses and wheat grown in a particular rotation did not significantly affect the growth and yield of Dashehari mango. Dashehari mango, planted in 1979, was grown with different intercrops in rotation, and the mango crop and cumulative yield of intercrops were recorded in 1983. In the first trial, using pairs of vegetables in rotation, highest mango yields were obtained with fallow/chillies (Capsicum) (3.28 q/ha), bittergourd (*Momordica charantia*)/brinjal (3.26 q/ha) and cowpea (*Vigna unguiculata*)/potato (3.01 q/ha), compared with the monocropped control (1.28 q/ha). In the second trial, intercropping legumes and wheat, pigeon pea (*Cajanus cajan*) gave the lowest mango yield (1.76 q/ha). Higher mango yields were obtained with black gram (*Vigna mungo*)/wheat (4.32 q/ha), fallow/wheat (4.08 q/ha) and control (4.86 q/ha). Highest total monetary returns were obtained with cowpea/potato (trial 1) and black gram/wheat (trial 2). Tree volumes varied, but differences were not significant.

In an experiment conducted by Bhuva *et al*. (1989), mango cv. Rajapuri was planted in 1979 at 6×6 m, and was interplanted from 1980 with (a) banana, (b) cassava, (c) tomato followed by cluster bean (*Cyamopsis tetragonoloba*), or (d) brinjal followed by cowpea (*Vigna unguiculata*). They reported that mango grown with tomato and cluster bean as intercrops gave the greatest financial return per hectare.

Marz (1992) stated that the introduction of alley cropping systems based on neem (*Azadirachta indica*) may have strong impacts on the traditional cropping pattern and economic performance of small farms in the Sudano-Sahelian Zone of West Africa. The analysis shows that the farm income and liquidity of farms in particular are increased significantly by integrating neem (for the production of wood and fruits) into the traditional cropping pattern. The potential benefits as a result of combining field crop with trees are so obvious from consideration of the waste of light resources experienced in orchard and tree crop orientation (Jackson, 1987).

Four land use options (annual cropping, 'agroforestry', 'agrihorticulture', and 'agrosilviculture' were compared by Das *et al*. (1993) on a degraded Alfisol under rainfed conditions in Andhra Pradesh, India. Annual cropping consisted of rotation of blackgram (*Vigna mungo*) with grain sorghum (*Sorghum bicolor*). In the agroforestry system, trees (*Acacia auriculiformis*) were planted in rows and blackgram, grain sorghum and horsegram (*Macrotyloma uniflorum*) were raised in the alleys. In the agrohorticultural system, guava (*Psidium guajava*) fruit trees were planted in a definite pattern and the interspaces were used to grow food grains. In the agrosilviculture system, saplings of leucaena (*Leucaena leucocephala*) were planted in hedgerows and grain crops were raised in the interspaces. They found that the agrohorticultural system required more cash input but gave a value:cost ratio of 2.16 compared with 1.95 with annual cropping, 1.69 with agroforestry and 1.52 with agrosilviculture. Runoff was 4.9% in the agrohorticultural system and 10.6% with agroforestry. Economic and soil considerations indicated that the agrihorticultural system was a sustainable options for the semiarid Alfisol.

Afzalur and Islam (1997) conducted research under the government-initiated Community Forestry Project at Madhyapara, Dinajpur. Under this project the participants were promised a 50% share from the sales proceeds of the final tree harvest in addition to 100% of all other benefits generated from agricultural crops, thinning materials and pruning. The plots were planted with mixed tree species (mainly

Eucalyptus camaldulensis and *Acacia mangium*) at 1.5×1.5 m spacing in double rows, with 9 m alleys between the rows, in which rice, sugarcane, maize, pulses, vegetables and sesame were grown as intercrops. Crop production was hampered by shade and root competition after the first 3 yr. While the system as a whole was highly financially feasible, the results also show that the benefits to both the participants and the Forest Department were encouraging. A sensitivity analysis allowing for probable variations in cost and benefits revealed no financial risk of the system under any criteria. Michon *et al*. (1986) stated that multistoried agroforestry system is characterized by an intensive integration of forest species and commercial crops forming a forest like system. Subsistence and commercial products supplement rice production. The agroforestry is a profitable production system and provides a buffer between villages and protected forest.

Blanc Parmad and Ruf (1992) in their report stated that when the farmers retain their coffee trees more as a component of multi-cropping of the prevailing Coffee Agroforestry systems, which combine rice, rainfed crops (cassava, bananas, sweet potatoes, maize, beans) and cash crops (coffee, bananas, litchi, clove, cinnamon, black pepper), brings out their remarkable aptitude to regulate the place of coffee in their farming systems, to satisfy their basic needs and ensure their survival. Food security and monetary concerns push farmers into maintaining coffee production, in such a way as to achieve complementarily rather than competition between coffee and subsistence crops. Coffee agroforestry provides an evolutionary model for agriculture in tropical humid zones.

Singh *et al.* (1988) reported that net return from 5 year old poplar was Rs. 44385/ha and as intercrop with *Mentha arvensis* it was Rs.

65857/ha for agroforestry option. Korikanthimath and Hedge (1994) reported that the total cost (per ha) of raising a new arecanut garden (13 years) is about Rs. 140000; gross income per year is Rs. 305000/ha with cardamom and arecanut as components.

Another study carried out with mixed cropping of arecanut *(Areca catechu)* + *Elettaria cardamonn an* on comparison with monoculture of *A. catechu,* Korikanthimath *et al.* (1997) indicated that the cost of cultivation was higher (Rs. 40683/ha) in mixed cropping than under monoculture (Rs. 27571/ha) and the net return (Rs. 161837/ha) realised in mixed cropping was 1.56 times higher than in monoculture (Rs. 103626/ha). The incremental net gain in mixed cropping was Rs. 58211/ha (56.2% over monoculture). Net Present Worth and Benefit Cost Ratio were higher by 1.48 and 1.01 times, respectively, under mixed cropping compared with monoculture. Again, Yadava and Singh (1996) reported that the combination of lemongrass 45 x 45 cm spacing and NPK (250 : 100 : 80) provided the highest net returns of Rs. 60237 and Rs. 100555 in 1993 and 1994, respectively when planted with Poplar tree

2.7 Performance of Crops 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.

Fifty per cent shading during ear formation and milking stage of rice decreased yield by 48% and 18%, respectively (Park and Kwon, 1975). Nayak and Murty (1980) reported that yield reduction of rice occur by 47, 57 and 74 per cent in 75, 50 and 25 per cent of normal light.

Nayak and Murty (1980) reported that yield reduction of rice by 47, 57 and 74 percent in 75, 50 and 25 percent of normal light, respectively. This was mosltly due to impaired dry matter production, panicle number and grains per panicle.

Yamoah *et al.* (1986) reported that maize heigh, stover and cob weights were reduced (though insignificantly) in maize rows close to the shrub hedgerows compared with those in the middle of the alley.

Jadhav (1987) reported that partial shading (45-50% of normal light) at 15 days after transplanting reduced grain yield of rice by 73 percent bedause of reduction in number of panicles per plant (51.5%), number of grain per panicle (16.7%) and increase in number of unfilled spiklets (42.1%) in 25 rice cultivars.

Chaturvedi and Singh (1987) mentioned that pre-flowering shade (50% shade) resulted in reduced leaf area, tiller number, spiklets per panicle, whereas post-flowering shade reduced filled spiklets fraction and grain weight in rice.

Akber *et al.* (1990) reported that wheat yield under different tree species (*E. camaldulensis*, Mulberry, Siris, Ipil-ipil) did not show any significant difference as compared to control yield.

The influence of *Acacia nilotica* on the growth and yield of associated wheat crop under irrigated condition in India was examined by Sharma and Tiware (1992). He reported that the tree line did negatively affect all crop parameters like yield in the vicinity of trees and established that as the distance from the tree line increased the growth and yield of wheat also increased.

Rabarimandimby (1992) observed that hedgerows significantly competed for nutrients and light with upland rice and mungbean in the alley. He found that competition was severe in the 2-3 rows closest to the hedgerows, while yields were reduced by 47-95 percent and 11-37 percent for rice and mungbean, respectively.

Nazir *et al.* (1993) conducted a trial in Pakistan, rice was sown parallel to *Dalbergia sissoo* trees at distance which gave 0.2, 3, 4, 5, 6, 7, and 8 hour to shade/ day. Increasing duration at shading decreased plant height, number of fertile tillers unit^{-1} area, number of grains/ spike, 1000-grain weight, grain protein concentration and percentage DM and grain yield. Yield was 2.99, 2.96, 2.11, 2.57, 2.4, 2.12, 164 and 1.32 t /ha with 0.2, 3, 4, 5, 6, 7 and 8 hr. shade /day respectively.

Jaing *et al.* (1994) reported that tree crown had no significant effect on the number of effective spikelets and grains of rice but it affected total grain yield and 1000-grain weight, with the size of the effect on crop, depending on the distance from the trees.

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

Solanki (1998) stated that fruit trees and crops are grown together in various ways. Depending on the pattern and configuration, these companion crops are known as intercrops, under planting, hedgerow planting or alley cropping. In an agroforestry system where agricultural crops are normally grown between rows of fruit trees, the agricultural crops provide seasonal revenue, whereas fruit trees managed for 30-35 years giving regular returns of fruit and in some cases fuel wood from pruned wood and fodder. Several kinds of crops are also under planted to take the advantage of shade provide by the canopy of fruit trees.

Nandal *et al.* (1999) had grown 5 rice cultivars under the *Sissoo* tree. In their experiment grain yield, dry matter yield, leaf area index, spiklets m^{-1}, grain $spike^{-1}$ and test weight were reduced under the tree canopy compared with crops growing in the open place.

Pandey *et al.* (1999) reported that rice yield was positively related to distance from the tree. Impact of the trees was maximum at 2m distance from the tree crop yield reduced by 44% and declined with increasing the distance (to 14% reduction at 8 m). There was an increase relationship between the percentage decrease in the parameters and the distance indicating that the greater the distance the smaller the effect of the tree.

Time tested, indigenous land use systems can provide valuable information for the design of ecologically sustainable and socially acceptable agro forestry systems. One such traditional system is the growing of *Acacia nilotica* (L.) Willd. Ex Delile trees, locally known as babul, in rice fields of smallholder farmers in Madhya Pradesh State of central India, an area with subhumid monsoon climate and hot summer. The functional characteristics of the system were collected through participatory rural appraisal involving intensive interactions with farmers in the region during six years, and through a structured-questionnaire survey in 25 villages, involving a total of 200 farm families. The farms had an average of 20 babul trees, ranging in age from <1 to 12 years, per hectare in upland rice fields, the tree-stand density being greater on smaller than of larger farms (>8 ha). Over a ten year rotation period, the trees provide a variety of products such as fuel wood (30 kg/tree), brushwood for fencing (4 kg/tree), small timber for farm implements and furniture (0.2 cu.m), and non-timber products such as gum and seeds. The babul + rice system was extimated to have a benefit/cost (B/C) ratio of 1.47 and an internal rate of return (IRR) of 33% at 12% annual discount rate during a ten-year period, though at a low level of income. Babul trees account for nearly 10% of the annual farm income of smallholder farmers (<2 ha). By practicing the agroforestry (rice+babul) system, farmers get higher cash returns on a short-term (10 year) harvest cycle of trees, and the labour input (both family-and hired) on farms was distributed more uniformly throughout the year than in rice monoculture.

Purchased inputs are seldom used in the system. The ease of management of the system, the self-generating and robust nature of the tree and the multiple products and services it provides, and easy marketability of the products are the major factors that encourage farmers to adopt the system. Furthermore, the farmers have secure ownership rights to their farms. In spite of its long history and tradition as a sustainable approach to land use, the system has not attracted the attention of development agencies. More detailed investigations on its social, economic, and cultural attributes are warranted to not only improve this system, but provide insights into farmer adoption of agrofeorestry innovations (Viswanath *et al.,* 2000).

Samsuzzaman *et al.* (2002) carried out three studies in Bangladesh to find out the effect of tree species on crops and alternative management practices for better system productivity. The first experiment revealed that the highest yield of mustard (0.788 t/ha) and rice (2.89 t /ha) was obtained under *Albizia lebbock* trees and *Acacia nilotica*, respectively. The result of the second experiment indicated that the lower reduction in yield of adjacent crop with wider the tree spacing the result of the third experiment showed that root and shoot pruning increased the grain yieldof wheat by 22%. The highest increase in the yield of rice (27%) and radish (72%) were obtained due to pruning of *Acacia nilotica* two and three times a year respectively. Pruning of *Albizia lebbeck* three times a year contributed to the highest increase in rice (50%) and radish (35%) yields.

2.8 Importance of studies summer vegetables (like kangkong)

In Bangladesh most the of vegetables are produced in summer and winter season. While in between these two seasons, there is a lag period when scanty of vegetables exists. Introduction of Gima Kalmi is a positive achievement since it can be grown both in summer and rainy season (Shinohara, 1980). Aquatic type of local kalmi is naturally grown in ponds or ponds or marshy land of Bangladesh. Gima Kalmi is a special significance, because on upland soil with an apprceiable yield potenial of foliage.

Kangkong is a rich vegetable from the nutritional point of view. Each hundred gram of its edible parts contain 3.6% protein, 0.4% fat, 1.1% carbohydrate, 5800 mili equivalent of vitamin A, 0.12 mg thiamine, 0.16 mg riboflavin, 0.8 mg niacin, 52 mg vitamin C, 107 mg calcium and 2.1 mg iron (S). The calcium of the Kangkong is stated to be mostly unavailable owing to the fact that is unites with exalic acid to form calcium oxalate. The ascorbic acid of the knagkong exists primary in the leaves and that the stalks are almost devoid of this vitamin (Tressler, 1936).

Gima Kalmi (*Ipomoea reptans*) is a leafy vegetable which belongs to the family Convolvulaceae. The crop is also known as knagkong, swamp cabbage, water convolvulus, water spinach etc. It is very important leafy vegetable from the nutritional point of view. It is an excellent source of vitamin-A. One hundred grams of it edible portion contains 87.6 g water, 1.1 g minerals, 0.1 g fat, 9.4 g carbohydrate, 107 mg calcium, 3.9 mg iron, 10740 microgram carotene, 0.14 mg vitamin B_1, 0.40 mg vitamin B_2 , mg vitamin C, 1.8 g protein and 46 kilocalories (Anon, 1983). Leafy vegetables such as Gima Kalmi. Spinach, Indian spinach and Amaranth are commonly close to "Spinach group" of vegetables (Shinohara, 1980).

2.9 Kangkong seeds success for Bangladesh disaster victims

The loss of life and property caused by the cyclone and tidal bore that lashed Chittagong and Cox's Bazar in Bangladesh 29 April 1991 was cataclysmic. Response to immediate relief needs poured from various countries.

Farmers lost not only standing crops, but seed stores and other vital agricultural inputs. Bangladesh agriculture researchers, extension specialists, and USAID supported agricultural development consultants were busy designing both immediate and long-term plant to aid farmers.

The specialists sought to initiate activities that would quickly provide farmers with vegetables tolerant to the prevailing waterlogged conditions. Ideally, vegetable chosen would be fast growing, nutritious, and require limited inputs. Horticulture specialists from the Bangladesh Agriculture Research Institute (BARI) and the Asian vegetable Research and Development Center (AVRDC) recommended kangkong, a fast growing, hardy, and nutritious green leafy vegetable.

AVRDC supplied 10 kg of Kangkong seed to BARI. The seed was divided into 900 packets and distributed, along with information on cultivation techniques, through the Department of Agricultural Extension to farmers in Chittagong and Cox's Bazar. Kangkong seems to and excellent vegetable for rehabilitation activities. It is high yielding, can be grown year-round, and is a rugged, disease-tolerant plant that is easy to propagate.

Now, less than a year after the cyclone, knagkong has sprouted everywhere. According to BARI and DAE staff, farmers were quick to sow the seeds in plots varying in size from 1×5 m to 5×25 m. Thirty to 40 days after sowing a first crop was ready for harvest. Thriving in the monsoon rains, bunches of kangkong were harvested every 15 days thereafter.

The spread of kangkong to neighboring fields had been exceeding all expectations according to BARI scientists. Specialists found that, in addition to the original 900 farmers, many neighboring farmers have planted knagkong. Kangkong has taken root beyond garden areas. In fact, any available space seems to be supporting lush stands of the vegetable. The demand for a fast-growing vegetable plus the fact that kangkong can be conveniently multiplied by cuttings, facilitates farmer-to farmer dissemination of the plant. Moreover, the fact that farmer like to eat kangkong ensured its adoption to kitchen gardens. Kangkong provides vitamins A and C as well as iron and calcium, nutritional requirements that are chronically deficient in Bangladesh diets. Cattle and poultry also benefit from the emerald green vegetable which is used as a feed supplement for livestock.

Kangkong can easily ber grown throughout the year, it is particularly abundant when other vegetable are scarce, during the monsoon monsoon months of June through September.

It has helped meet the demand for a nutritional food source, and supply much needed supplemental income to the rural poor. Researches are now rearing kangkong as an integral crop in everyday farming activities.

2.10 Effect of fertilizer on the growth and yield of Gima Kalmi

Urea enhances the vegetable growth and development which ultimately increase the yield. Use of urea at an optimum dose increases the yield, but excessive and under dose of urea affect the growth and yield of Gima Kalmi to a greater extent. Positive correlation between yields and urea application in Spinach for the entire growth period was observed. Increase of yield of Spinach was also obtained from application of urea up to 120 kg/ha (Sehunphan and Postel, 1958). In another field trial on the nutrient requirement of Spinach, Salmon and Jasa (1965) found a significant effect of urea on the yield and leaf size. They obtained maximum yield with 60 kg urea/ha.

Westgate *et al.,* (1958) conducted an experiment on improvement of the cultural practices for leafy vegetable crops. They reported that mixed fertilizer have enough effectiveness in increasing the yield of leafy vegetables.

Leafy vegetable crops required more urea, and higher urea levels increased the yield and dry matter content to the tops (Verma *et al.* 1969).

Results of four years experimental work conducted by Cervato (1969) revealed that yield of Spinach were closely related to the available urea and except in soils already rich in urea. It was also reported that the response of spinach to ammonium nitrate application of two or three during the growing season was very effective. He further noticed that there was no definite response of spinach to K, but the highest K rate (120 kg K_2O/ha) in combination within high urea increased the yield.

Singh *et al.* (2001) conducted an experiment on the effect of urea sources and levels on the yield some leafy vegetables in Malaysia and it was reported that in pot culture experiments with some Malaysian leafy vegetables, significant differences were observed between urea sources and rates. For Kangkong (*Ipomoea reptans*) yield significantly increased up to 120 kg urea/ha.

Like Spinach, Kangkong also responds to the application or urea. The general recommendation of urea for Kangkong under Bangladesh conditions is 150 kg urea per hectare (Anon, 1980). They suggested to apply 50% of urea during land preparation and the rest 50% should be applied in three equal installments as top dressing. 1^{st} after seven days of germination, 2^{nd} and 3^{rd} after 1^{st} and 2^{nd} harvest of the crop.

Rai (1981) also reported that urea increases the vegetative growth and produces good quality foliage and promotes carbohydrate synthesis.

Rashid *et al.*, (1993) studied on the acclimatization, adaptability and performance of kangkong (*Ipomoea reptans*) and reported that the yield was significantly increased by increasing the application of jurea leaves up to certain limit.

Tindal (1983) reported that Kangkong responded to urea fertilizers applied either before planting or as subsequent to dressing.

The experimental results obtained by Islam *et al.* (1984) at the Bangladesh Agriculture University, Maymensingh revealed that application of urea increased the yield and quallity of kangkong. The influence of urea was distinct at the second and third harvest.

Application of 160 kg urea/ha was found to be the best for seed propagated plants, while for the vegatatively propagated plants the use of urea fertilizer appeared to be economic only upto the level of 80 kg urea/ha. In addition to increased yield, the added urea also improves the edible quality of the vegetable, particularly at the later harvests.

Rahman *et al.* (1985) studied on Indian Spinach and reported that the highest yield of greens (62.89 t/ha) was obtained from the closest spacing when the highest dose of urea fertilizer was applied. Due to the application of N at different levels, all the characters differed significantly. However, the maximum number of shoots (88) was produced from the highest dose of N (82.8kg/ha).

Dhillon *et al.* (1987) conducted an experiment on effect of different levels of mixed fertilizer on yield and chemical compositon of spinach (Ipomoea reptans) and they reported that in field trials over 2 years with the cv. Punjab selection, N was applied as urea at 0-90 kg/ha at zero kg N to 41.2 t/ha at the highest N rate. Leaf N content rose with increasing N rate but leaf Fe, Mn content decreased, content of P,K,S and Zn were unaffected.

Park *et al.* (1993) conducted an experiment on the effect of fertilizer level on the growth of water Spinach (*Ipomoea reptans*) and reported that application of urea fertilizer at 30 kg per 10 acres increased yield more than lower rates.

A field experiment was carried out at IPSA, Salna, Gazipur during the kharif season of 1986 to study the effect of manuring doses on the growth and yield of Gima Kalmi. Plant height, number of branches per plant and weight of foliage per plant were significantly increased by increasing manual dose. Even increase in manual dose was associated with a significant increase in yield (Awal, 1989). For obtaining good yield and high quality Shak of Gima kalmi, 150 kg urea per hectare should be applied (Rashid, 1993).

For obtaining good yield and high quality shak in Gima kalmi 150 kg urea per hectare should be applied (Rashid, 1993).

A hydroponic study was conducted to determine the optimum fertilizer combination that will reduce the nitrate concentration of spinach (*lpomoea reptans*) and increase its yield. Nitrate reduces activity increased with increasing potassium and molybdenum rates and consequently reduced the nitrate content in the crop. The results showed that the optimum combination of nitrogen, potassium and molybdenum that will reduce the nitrate content in aquatic spinach and increase its yield is 354.9-382.2 mg/litre, respectively (Zhao, 2003).

Bunyeth and Preston (2004) found that a split plot design was used to study growth of spinach (kangkong) as affected by the type of planting material (seeds or stems) and by biodigester effluent (0, 50, 100, 150 and 200 kg urea/ha) used as fertilizer. The best level of fertilizer is 150 kg urea/ha for better performance of kangkong.

2.11 Effect of plant density on the growth and yield of Gima Kalmi

Plant density is an important factor which affects the growth and yield of Gima Kalmi. An experiment was conducted by Park *et al.* (1993) on water Spinach *(Ipomoea reptans)* they observed that planting at a spacing of 30cm x 30cm was better than 15cm x 15cm or 45cm x 45cm for the crop. Somes (1954) reported that wider spacing resulted in better growth and rapid development than closer spacing. Davey (1965) observed than maximum head size in cabbage was obtained with a spacing of 25-40 cm in row. However, closer spacing results in higher yields pre hectare with greater variability in head.

Crookston *et. al.,* 1975 carried out an experiment to study the effects of seeding method, spacing and fertilizer on Chinese kale (*Brassica alboglabra*) in Malaysia. Transplanting after two weeks of sowing resulted in more vigorous plant growth and higher yield than direct seedling. Decreasing plant spacing with in the row from 30 cm to 20 cm and resulted in a progressive increase in yield per hectare.

Neuvel (1978) carried out experiment to study the effect of plant density on Chinese cabbage (*Brassica parachinensis* Rupr.). From a two years trial with Chinese cabbage accommodating 30000-60000 plants per hectare, optimum production was obtained from the density of 50000-60000 plants per hectare. Mol (1979) showed from a cultural trial with Chinese cabbage spaced at 30 cm 40 cm within and between the rows that plant weights declined as plant density was increased.

Izaki *et al.* (1988) reported the effects of spacing on the yield and quality of Chinese cabbage. A spacing of 10 plants per square meter was found to give the highest yield. He also stated beneficial effects of high plant density on growth and development in Chinese cabbage under field conditions.

Isaac and Nair (2000) conducted and experiment to study the effect of appropriate planting method and density for economical production of

Pak-choi (*Brassica chinensis* L.) in Singapore. The treatments compared were direct seedling bare root transplanting or ball root transplanting in rows 30 cm apart with interplant spacing of 10 cm 20 cm and 30 cm. The highest yield (50 t/ha) was obtained from the transplanted plants with the closest spacing. He also studied the effects of plant densities on some leafy vegetables including Pak-chi. Four plant densities viz. 10 cm × 10 cm, 15 cm × 15 cm, 20 cm × 20 cm and 30 cm × 30 cm were included in the study. The highest yield was obtained in 15 cm × 15 cm spacing having no significant difference with 10 cm × 10 cm spacing.

Vogel and Paschold (1989) conducted an experiment in Germany on Pak-choi (*Brassica chinensis* L.) in relation to different spacing and date of planting. A Crop density of 160000 plants per hectare with a spacing of 25 cm × 25 cm gave the highest yield and a high proportion of plants weighting 200-600 g.

Rai (1981) recommended of 45 cm × 30 cm and a fertilizer dose of 300 kg urea (138 kg N), TSP and 220 kg MP for production of batisak in Bangladesh. He also studied the effects of spacing and different levels of nitrogen yield of batisak (*Brassica chinensis* L.) in Horticulture Fram. Bangladesh Agriculture University, Mymensingh. Maximum yield (47.4 t/ha) was obtained from in closest spacing of 40 cm × 20 cm.

From the above review it is clear that growth and yield of Gima Kalmi largely depend upon the rate of fertilizer application, plant spacing and canopy. These three factors both singly or combined influence the growth, quality and yield of the crop. But effect of fertilizer level, spacing and canopy on the growth and yield of Gima Kalmi have not yet been studied in details under Bangladesh conditions. Therefore, to ensure proper crop growth and to get the highest possible yield, such studies are needed.

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

3.2 Soil characteristics

The experimental plot was 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. 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 are presented in the Appendix-II.

3.4 Planting materials

In this research work, Gima kolmi (*Ipomoea reptans*) was used as the planting material. The seeds of Gima kolmi were collected from substation of BARI (Bangladesh Agricultural Research Institute) Thakurgaon.

3.5 Treatments

The present experiment comprised of three (3) factors where trees are main factor and level of fertilizer & plant density is sub factors.

Factor A: It included trees canopy with an control (open field).

i) Open field (no canopy) (C_0)

ii) Ghora neem (*Melia azedarach*) (C_1)

iii) Ipil- Ipil (*Leucaena leucocephala*) (C_2)

The spacing for all the tree species were 3 m x 3 m. and the age were 5 years. The present status of the tree species in the research field are-

Trees	Plant height (m)	Clean bole height (m)	Base Girth (cm)	Bole Girth (cm)	Diameter at Breast Height (cm)
Ghora neem	12.0	4.0	82.0	61.0	67.0
Ipil-Ipil	15.0	5.6	75.0	66.67	63.0

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. Flowering time: March to May. Fruiting time: December to January.

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. 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.

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 bio-fertilizer (Tiwari, 1992). This is mainly used against attacks of insects on dry fruit.

Leucaena leucocephala - It 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.

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.

Different services like erosion control, shade reclamation, it forms symbiotic relationship with *Rhizobium loti* can improvement soil by the addition of organic matter decoration and boundary, barrier or suppor can get from this tree

Factor B: It included four (4) doses of mixed fertilizer. The quantities of fertilizers are shown below-

Levels of fertilizers	Doses of fertilizer
T_0	No fertilizer
T_1	Recommended (optimum) dose
T_2	20% less than the recommended dose
T_3	40% less than the recommended dose

The following doses of manure and fertilizers were applied to grow the experimental crop as recommended by BARI (1983)

Manure and fertilizers	Doses per hectare	Doses per plot
Cowdung	10 ton	1 kg
Triple superphophate (TSP)	110 kg	11 g
Muriate of potash (MP)	110 kg	11 g
Urea (No top dressing)	150 kg	37 g

Factor C: It included three (3) plant densities.

i) $D_1 = 30$ cm x 15 cm

ii) $D_2 = 30$ cm x 25 cm

iii) $D_3 = 30$ cm x 30 cm

Thus the 36 treatments combinations of factorial experiment were $C_0T_0D_1$ $C_0T_0D_2$ $C_0T_0D_3$ $C_0T_1D_1$ $C_0T_1D_2$ $C_0T_1D_3$ $C_0T_2D_1$ $C_0T_2D_2$ $C_0T_2D_3$ $C_0T_3D_1$ $C_0T_3D_2$ $C_0T_3D_3$ $C_1T_0D_1$ $C_1T_0D_2$ $C_1T_0D_3$ $C_1T_1D_1$ $C_1T_1D_2$ $C_1T_1D_3$ $C_1T_2D_1$ $C_1T_2D_2$ $C_1T_2D_3$ $C_1T_3D_1$ $C_1T_3D_2$ $C_1T_3D_3$ $C_3T_0D_1$ $C_3T_0D_2$ $C_3T_0D_3$ $C_3T_1D_1$ $C_3T_1D_2$ $C_3T_1D_3$ $C_3T_2D_1$ $C_3T_2D_2$ $C_3T_2D_3$ $C_3T_3D_1$ $C_3T_3D_2$ and $C_3T_3D_3$.

3.6 Experimental design and layout

The well prepared land was laid out following Randomized Complete Block Design with three (3) replications. The entire experimental area was fierst divided into three (3) blocks and each block was then divided into 36 unit plots. The size of unit plot was 2.5 m x 2.5 m. The space between 2 plots in a block was 30 cm. The 36 combinations were distributed in the 36 unit plots of each block.

No canopy open field,		
R_1	R_2	R_3
$C_0T_0D_1$	$C_0T_2D_3$	$C_0T_1D_2$
$C_0T_0D_2$	$C_0T_3D_1$	$C_0T_1D_3$
$C_0T_0D_3$	$C_0T_3D_2$	$C_0T_2D_1$
$C_0T_1D_1$	$C_0T_3D_3$	$C_0T_2D_2$
$C_0T_1D_2$	$C_0T_0D_1$	$C_0T_2D_3$
$C_0T_1D_3$	$C_0T_0D_2$	$C_0T_3D_1$
$C_0T_2D_1$	$C_0T_0D_3$	$C_0T_3D_2$
$C_0T_2D_2$	$C_0T_1D_1$	$C_0T_3D_3$
$C_0T_2D_3$	$C_0T_1D_2$	$C_0T_0D_1$
$C_0T_3D_1$	$C_0T_1D_3$	$C_0T_0D_2$
$C_0T_3D_2$	$C_0T_2D_1$	$C_0T_0D_3$
$C_0T_3D_3$	$C_0T_2D_2$	$C_0T_1D_1$

Ghora neem		
R_1	R_2	R_3
$C_1T_0D_1$	$C_1T_2D_3$	$C_1T_1D_2$
$C_1T_0D_2$	$C_1T_3D_1$	$C_1T_1D_3$
$C_1T_0D_3$	$C_1T_3D_2$	$C_1T_2D_1$
$C_1T_1D_1$	$C_1T_3D_3$	$C_1T_2D_2$
$C_1T_1D_2$	$C_1T_0D_1$	$C_1T_2D_3$
$C_1T_1D_3$	$C_1T_0D_2$	$C_1T_3D_1$
$C_1T_2D_1$	$C_1T_0D_3$	$C_1T_3D_2$
$C_1T_2D_2$	$C_1T_1D_1$	$C_1T_3D_3$
$C_1T_2D_3$	$C_1T_1D_2$	$C_1T_0D_1$
$C_1T_3D_1$	$C_1T_1D_3$	$C_1T_0D_2$
$C_1T_3D_2$	$C_1T_2D_1$	$C_1T_0D_3$
$C_1T_3D_3$	$C_1T_2D_2$	$C_1T_1D_1$

Ipil-ipil		
R_1	R_2	R_3
$C_2T_0D_1$	$C_2T_2D_3$	$C_2T_1D_2$
$C_2T_0D_2$	$C_2T_3D_1$	$C_2T_1D_3$
$C_2T_0D_3$	$C_2T_3D_2$	$C_2T_2D_1$
$C_2T_1D_1$	$C_2T_3D_3$	$C_2T_2D_2$
$C_2T_1D_2$	$C_2T_0D_1$	$C_2T_2D_3$
$C_2T_1D_3$	$C_2T_0D_2$	$C_2T_3D_1$
$C_2T_2D_1$	$C_2T_0D_3$	$C_2T_3D_2$
$C_2T_2D_2$	$C_2T_1D_1$	$C_2T_3D_3$
$C_2T_2D_3$	$C_2T_1D_2$	$C_2T_0D_1$
$C_2T_3D_1$	$C_2T_1D_3$	$C_2T_0D_2$
$C_2T_3D_2$	$C_2T_2D_1$	$C_2T_0D_3$
$C_2T_3D_3$	$C_2T_2D_2$	$C_2T_1D_1$

Fig 1. Layout of treatments combinations in open field, and ipil-ipil with level of fertilizers and plant density.

3.7 Land preparation

The land was opened with spade on 3rd April 2009. The land was ploughed and also cross ploughed several times followed by laddering to obtain good tilth. The land was leveled and corners of the plots were trimmed and clods were broken into small pieces as far as possible. All weeds and stables were collected and removed. The land was finally prepared two days before sowing.

3.8 Seed sowing

Direct sowing method was followed in this experiment the and of Gima Kalmi seeds were sown on April 5, 2009. Two seeds were sown in each planting hole at one cm depth and covered with a thin layer of soil. Thinning was done seven days after emergence and only one seedling was allowed to grow in each hill. Seeds were also sown around the experimental area to check the border effect.

3.9 Intercultural operation

The plants were kept under careful observation. Weeding was done whenever necessary to keep the plot free from weeds and to pulverise the soil. The plots were irrigated by watercan for one time. At the time of irrigation, care was taken so that no water logging condition occurred at any place of the experimental plot. No insecticides or fungicides were applied since there was no problem of insect or disease infestation.

3.10 Harvesting

The harvest was done from all plots at 45 days after sowing (DAS). The border plants were not included in the harvest. The plants were cut at a length of 2 cm from the ground level and data were recorded on several characters.

3.11 Collection of data

Five plants were randomly selected from each unit plot for the collection of data.

Data were collected in respect of the following characters.

1. Plant height: Plant height was measured in centimetre (cm) from the ground level to the tip of the stem at harvest and the average was calculated from five samples plants,
2. Number of leaves per plant: The total number of leaves was counted from the sampled plants and their average was calculated as the number of leaves per plant.
3. Number of branches per plant: The total numbers of branches were counted from five randomly selected plants and their average was calculated as the number of branches per plant.
4. Yield per plant: Five randomly selected plants were harvested and weighted. The average was calculated to make the weight of individual plant. An analytical beam balance was used to take the weight of foliage,
5. Yield per plot: Foliage yield per plot was recorded by harvesting all plants in each plot and taking their weights by a simple balance and the weight was recorded in kilogram (kg).
6. Yield per hectare: per plot yield was converted into yield per hectare was express in metric ton (t)

3.12 Bio-economics of the Gima kalmi based agroforestry system

In order to work out the economic profitability of the agroforestry systems, the economic yield of Gima Kalmi 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 local market prices prevailing at the time of the termination of experiments.

Total cost of production

The cost of cultivation of the Gima Kalmi was worked out on the basis of per hectare. The initial plantation cost of the ghora neem and ipil-Ipil, saplings were included in this study. The management cost of ghora neem and ipil-Ipil were 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 Gima Kalmi 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 (Kundu, 2002).

Net return= Gross return (Tk. ha^{-1}) – 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).

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

3.13 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 adjudged by the Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

The present investigation was carried out to agro-economic performance as influenced by the effect of canopy shade, fertilizer and plant density on the growth and yield of Gima Kalmi. The analysis of (ANOVA) of the data on different yield contributing characters-and yield of Gima Kalmi are given in Table 1-5 and appendix IV. The results of the experiment as influenced by canopy shade, different levels of fertilizer and plant density and their different combinations have been presented and discussed in this chapter under the following sub-headings.

4.1 Plant height

The main effect of plant height of Gima Kalmi was found statistically highly significant due to different canopy shades. Significantly the maximum plant height (26.49 cm) was found under no canopy (C_0) i. e. open field, moderate (21.50 cm) under canopy and lowest (15.51 cm) under ipil-ipil canopy at 45 days after sowing (Table 1). This happened due to canopy affect the penetration of sun light that influenced photosynthetic activities.

The sub effects of fertilizer on the plant height of Gima Kalmi at 45 days after sowing (DAS) have been presented in Table 1. There was significant difference among different doses of fertilizer for plant height. During the period of plant growth the highest plant height was found when recommended dose of fertilizer was applied and the lowest was found when no fertilizer was used. At 45 DAS, the maximum plant

Table 1. Effect of canopy, level of fertilizer and plant density on growth and yield of Gima Kalmi at 45 DAS

Treatment	Plant height (cm)	Number of leaves per plan	Number o branches per plant	Fresh weigh of foliage per plant (g)	Yield per plot (kg)	Yield per hectare (t)
Canopy Orientation						
No canopy (Control)	26.49a	70.97a	9.36a	80.20a	0.80a	8.00a
canopy	21.50b	64.21b	7.16b	64.20b	0.64b	6.40b
Ipil-ipil canopy	15.51c	50.24c	5.77c	50.54c	0.48c	4.80c
(VC%)	0.06	0.10	0.04	0.09	0.01	0.10
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
Level of fertilizer						
No fertilizer	19.40d	58.01d	6.84c	60.91c	0.58c	5.79c
Recommended fertilizer	23.87a	66.51a	9.08a	70.51a	0.74a	7.39a
20% less fertilizer	21.56b	62.77b	7.36b	67.37b	0.65b	6.52b
40% less fertilizer	19.83c	59.93c	6.43d	61.13c	0.59c	5.89c
(VC%)	0.07	0.11	0.05	0.11	0.01	0.11
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
Plant density						
30 cm * 15 cm	19.92c	59.63c	6.66c	62.80c	0.89a	8.85a
30 cm x 25 cm	21.12b	61.88b	7.43b	65.14b	0.56b	5.58b
30 cm x 30 cm	22.45a	63.91a	8.20a	67.00a	0.48c	4.77c
(VC%)	0.06	0.10	0.04	0.09	0.01	0.10
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01

The figures in a column having the same letter(s) do not differ significantly.

** = Significant at 0.01 level

height (23.87 cm) was recorded against the application of recommended dose of fertilizer which was statistically different from the rest of treatments and the minimum (19.40 cm) was found from no fertilizer treatment. Such effect might be attributed to the usual role of fertilizer on vegetative growth. It was also found that plant height was gradually decreased at 20% and 40% less fertilizer. Similar results were reported by several authors (Anon, 1980 and Islam *et al,* 1984).

Plant height was significantly influenced by plant density at 45 DAS. In general, there was an increase in plant height due to increase in plant density. At 45 DAS, the widest density (30 cm x 30 cm) gave the tallest plant (22.45 cm) which was significantly different from the closest density (30 cm x 15 cm) with the lowest plant height of 19.92 cm (Table 1). It was also found that plant height was moderate (21.12 cm) at 30 cm x 25 cm density.

Plant height was found to be significantly different due to the combined effect of canopy shade, different levels of fertilizer and plant density at different Agroforestry system after sowing (Table 3). In case of all the treatment combinations, it was observed that plan height gradually increased with increasing fertilizer levels and plant density. At 45 DAS, the tallest plant (30.10 cm) was found in the treatment combination of recommended dose of fertilizer with 30 cm x 30 cm density at no canopy (open field), while the shortest plant (12.67 cm) was found in the treatment combination of no fertilizer with 30 cm x 15 cm density under ipil-ipil canopy. Plant height was gradually decreased at canopy and ipil-ipil canopy for partial and heavy shading (Table 5).

4.2 Number of leaves per plant

The main effects of canopy shade in number of leaves per plant were found statistically significant. Significantly the maximum number of leaves per plant (70.97) was found under no canopy (open field), moderate (64.21) under canopy and lowest (50.24) under ipil-ipil canopy at 45 DAS (Table 1).

Good foliage indicates higher growth, development and productivity of a plant. In the present study, number of leaves per plant was significantly influenced by different levels of fertilizer applied (Table 1). It was apparent that the number of leaves per plant increased with the increasing levels of fertilizer along with advancing time. At 45 DAS, the highest rate of fertilizer (recommended dose of fertilizer) gave the highest number of leaves per plant (66.51) and the lowest (58.01) was given by T_0 i.e., the treatment where no fertilizer was applied. Plants grown with higher doses of fertilizer received higher amount of fertilizer element from the soil and thus attained more height along with more number of leaves per plant and the reverse was with the plants growing with lower fertilizer levels. It was also found that number of leaves per plant was gradually decreased at 20% and 40% less fertilizer. This result is similar to the findings of Islam *et al.* (1984) and Hamid *et al.* (1986).

Significant variation in number of leaves per plant was observed due to the effect of plant density at the time of harvest. At 45 DAS, the widest density (30 cm x 30 cm) gave the highest number of leaves per plant (63.91) and the lowest number of leaves per plant (59.63) was obtained from the plant density of 30 cm x 15 cm. It was also found that number of leaves per plant was moderate (61.88) at 30 cm x 25 cm (Table 1).

The combined effect of canopy, fertilizer and plant density significantly influenced the number of leaves per plant at different agroforestry systems (AFS) and the results have been presented in Table 5. At 45 DAS, the highest number of leaves per plant (78.80) was given by the treatment combination of recommended dose of fertilizer with 30 cm x 30 cm density at no canopy and the lowest (44.93) was found in no fertilizer with 30 cm x 15 cm density under ipil-ipil canopy. Plant at widest density with highest fertilizer dose gave higher number of leaves per plant and density with no fertilizer application gave lower number of leaves per plant at 45 DAS. This was due to the better vegetative growth of the plant resulted from the application of higher dose of fertilizer along with lower inter plant competition in the wider-density. Number of leaves per plant was gradually decreased at canopy and ipil-ipil canopy for partial and heavy shading.

4.3 Number of branches per plant

The main effect of canopy shade was found highly significant. Significantly the maximum number of branches per plant (9.36) was found under no canopy, moderate (7.16) under canopy and lowest (5.77) under ipil-ipil canopy at 45 DAS (Table 1). This was happened due to lack of sunlight, temperature and rain fall that affect the plant physiology of Gima Kalmi.

The number of branches per plant increased significantly with the increase in different levels of fertilizer (Table 1). The highest number of branches per plant (9.08) was obtained at 45 DAS from the highest rate of fertilizer (recommended dose of fertilizer) and the lowest (6:43) was found in the 40% less fertilizer. It was generally noticed that number of branches per plant was enhanced by increasing levels of fertilizer. Islam *et al.* (1984) also stated that higher dose of fertilizer produced maximum number of branches per plant.

Number of branches per .plant was significantly influenced by plant density and it was observed that the number of branches per plant increased with increase in plant density (Table 1). At 45 DAS, the maximum number of branches per plant (8.20) was found with the density of 30 cm x 30 cm and the minimum (6.66) was obtained from 30 cm x 15 cm density. Also found that number of branches per plant was moderate (7.43) at 30 cm x 25 cm.

The combined effect of fertilizer levels, plant density and canopy had significant influence on the number of branches per plant at different agroforestry systems (Table 5). At 45 DAS, it was observed that number of branches per plant was increased gradually with increasing fertilizer level and plant density. The lowest number of branches per plant (5.07) was recorded in the treatment combination of with 30 cm x 15 cm density at ipil-ipil canopy. On the other hand, the highest number of branches per plant (12.90) was recorded in the treatment combination of recommended dose of fertilizer with 30 cm x 30 cm density at no canopy. It was also found that number of branches per plant was gradually decreased canopy and ipil-ipil canopy for partial and heavy shading.

4.4 Fresh weight of foliage per plant

The main effect of canopy shade was found highly significant. Significantly the maximum fresh weight of foliage per plant (80.20 g/plant) was found under no canopy, moderate (64.20 g/plant) under canopy and lowest (50.54 g/plant) under ipil-ipil canopy at 45 DAS

(Table 1). Fresh foliage accumulates per plant due to their carbohydrates function and these developed in plant by photosynthetic activity.

Fresh weight of foliage per plant was significantly influenced by different fertilizer level. At 45 DAS, the maximum fresh weight of foliage per plant (70.51 g/plant) was obtained from the application of recommended dose of fertilizer and the lowest (60.91 g/plant) was obtained from the application of no fertilizer. Fresh weight of foliage per plant was gradually decreased at 20% and 40% less fertilizer.

The effects of plant density on fresh weight of foliage per plant were significant and have been presented in (Table 1). The maximum fresh weight of foliage per plant (67.00 g/plant) was obtained from the widest density of 30 cm x 30 cm at 45 DAS. The fresh weight of foliage per plant gradually declined with the decrease in plant density and advancement of time. The minimum fresh weight of foliage per plant (62.80 g/plant) at the density of 30 cm x 15 cm. It was also found that fresh weight of foliage per plant was moderate (65.14 g/plant) at 30 cm x 25 cm.

The results on the fresh weight of foliage per plant as influenced by the combined effects of different levels of fertilizer, plant density and canopy at different agroforestry systems have been found to be significant and are presented in Table 5. The treatment combination of recommended dose of fertilizer applied at 30 cm x 30 cm density produced the highest fresh weight of foliage per plant (89.77 g/plant) at no canopy at 45 DAS. On the other hand, no fertilizer at close density (30 cm x 15 cm) gave the lowest fresh weight of foliage per plant

(45.17 g/plant) at guava canopy at 45 DAS. It was also found that fresh weight of foliage per plant was gradually decreased at canopy and ipil-ipil canopy for partial and heavy shading.

4.5 Yield of Gima Kalmi per plot

The main effect of canopy shade was found highly significant. Significantly the highest yield per plot (0.80 kg/plot) was found under no canopy (open field), moderate (0.64 kg/plot) under canopy and lowest (0.48 kg/plot) under ipil-ipil canopy at 45 DAS (Table 1). Yield depends on the leaf fresh weight and branches. It was found that the leaf fresh weight and branches more in open condition rather than partial and impartial shade.

The yields per plot as influenced by different fertilizer levels was significant and have been presented in Table 1. The highest yield per plot (0.74 kg/plot) was obtained from the plants which received fertilizer at the rate of recommended dose and the lowest (0.58 kg/plot) was found in the control treatment at 45 DAS. It appeared from the result that the yield of Gima Kalmi increased with increase in fertilizer. It might be due to the fact that fertilizer might be encouraged vegetative growth of Gima Kalmi plant and as a result photosynthesis occurred at higher rate in the leaves producing more yield.

The yield per plot was significantly influenced by different plant densities. The maximum yield per plot (0.89 kg/plot) was found from the (30 cm x 15 cm) while the minimum (0.48 kg/plot) was obtained from the widest density (30 cm x 30 cm) at 45 DAS. It was also found that yield per plot was moderate (0.56 kg/plot) at 30 cm x 25 cm. It was observed from the results that yield per plot decreased with the increase in plant density. This was happened due to accommodation of less number of plants in a small unit area which caused lower yield per plot. Whereas in closer density was accommodated which had a compensating effect resulting in higher yield per plot (Table 1).

The combined effect of canopy, different fertilizer levels and plant density significantly influenced the yield per plot and the results have been presented in Table 5. The highest yield per plot (1.26 kg/plot) was found in the treatment combination of recommended dose of fertilizer with 30 cm x 15 cm density at 45 DAS under no canopy. The lowest yield per plot (0.32 kg/plot) was obtained from the treatment combination of no fertilizer with 30 cm x 30 cm under ipil-ipil canopy.

4.6 Yield of Gima Kalmi (tha^{-1})

For canopy orientation, the highest yield per hectare (8.00 t/ha) was found under no canopy, moderate (6.40 t/ha) under canopy and lowest (4.80 t/ha) under ipil-ipil canopy at 45 DAS (Table 1).

The yield was significantly influenced by different doses of fertilize. The yield was increased with the increase in fertilizer levels. The highest yield (7.39 t/ha) was found by applying recommended dose of fertilizer and the lowest (5.79 t/ha) was found from the control treatment where no fertilizer applied. The yield was increased with the increasing levels of fertilize-as stated by different workers (Bruemmer and Roe, 1979; Rashid *et al,* 1993 and Islam, *et al.* 1984). It was also found that yield gradually decreased at 20% and 40% less fertilizer (Table 1).

The effects of plant density on the yield have been presented in Table 1. It was apparent that different plant densities had significant effect on yield. The highest yield of Gima Kalmi (8.85 t/ha) was obtained from the closes density (30 cm x 15 cm). The lowest yield was (4.77 t/ha) at wides plant density (30 cm x 30 cm). It was possibly due to lower number of plants per unit area at the widest density resulted in lower yield of Gima Kalmi. On the other hand, higher yield per unit area was obtained from the closest density although per plant yield was lower. This might be attributed to the increased number of plants per unit area which have compensated and resulted in higher yield.

The results on the yield as influenced by the combined effect of canopy, different fertilizer levels and plant density have been presented in Table 5. The highest yield of Gima Kalmi (12.60 t/ha) was produced by the treatment combination of recommended dose of fertilizer with 30 cm x 15 cm plant density under no canopy (open field) and the lowest yield (3.20 t/ha) was found in the treatment combination of no fertilizer and 30 cm x 30 cm plant density under ipil-ipil canopy. It was also found that the yield was gradually decreased at canopy and ipil-ipil canopy at 45 DAS.

4.7 Combined effect of canopy and level of fertilizer on the growth and yield of Gima Kalmi at 45 DAS

The combined effects of different canopies and different levels of fertilizer on the growth and yield of Gima Kalmi at 45 DAS have been presented in Table 2. The highest plant height, number of leaves per plant, number of branches per plant, fresh weight of foliage per plant and yield per plot were found 28.89 cm, 78.79, 11.59 and 87.79 g, respectively in C_0T_1 while yield per plot (0.92 kg) and yield (9.22 t). were not significant in C_0T_1. The lowest plant height, number of leaves per plant, number of branches per plant, fresh weight foliage per plant yield per plot and yield per hectare were recorded in C_2T_3 (13.42 cm, 46.79, 5.19, 47.88 g, (0.44 and 4.37 t), respectively.

Table 2. Combined effect of canopy and fertilizer on the growth and yield Gima Kalmi at 45 DAS

Treatment combinations	Plant height (cm)	Number of leaves per plant	Number of branches per plant	Fresh weight of foliage per plant (g)	Yield per plot (kg)	Yield per hectare (t)
C_0T_0	25.34c	66.23d	8.41d	74.44c	0.71	7.13
C_0T_1	28.89a	76.86a	11.59a	87.79a	0.92	9.22
C_0T_2	26.48b	71.04b	9.76b	84.19b	0.83	8.27
C_0T_3	25.23c	69.74c	7.68e	74.39c	0.74	7.38
C_1T_0	19.27g	61.00f	6.92f	60.40f	0.59	5.88
C_1T_1	23.49d	69.24c	8.73c	69.69d	0.74	7.41
C_1T_2	22.41e	65.43e	6.70f	65.79e	0.65	6.47
C_1T_3	20.82f	61.17f	6.28g	60.91f	0.58	5.83
C_2T_0	13.59i	48.89i	5.19i	47.88i	0.45	4.37
C_2T_1	19.23g	53.43g	6.91f	54.06g	0.55	5.55
C_2T_2	15.78h	51.83h	5.62h	52.13h	0.48	4.83
C_2T_3	13.42i	46.79J	5.34i	48.10i	0.44	4.47
Sx	0.12	0.20	0.08	0.19	0.02	0.20
Level of significance	0.01	0.01	0.01	0.01	NS	NS

C_0= No canopy (open field, control
C_1=Ghora neem canopy
C_2= Ipil-ipil canopy

T_0= No fertilizer
T_1=Recommended fertilizer
T_2= 20% less fertilizer
T_3= 40% less fertilizer

The figures in a column having the same letter(s) do not differ significantly. ** = Significant at 0.01 level; NS = Not significant

4.8 Combined effect of canopy and plant density on the growth and yield of Gima Kalmi at 45 DAS

The combined effects of different canopies and different plant densities on the growth and yield of Gima Kalmi at 45 DAS have been presented in Table 3. The plant height and fresh weight per plant were not significant. The highest number of leaves per plant and number of branches per plant were found in C_0D_3 (72.93 and 10.62). But the yield per plot (1.10 kg) and yield (11.03 t) were found in C_0D_1, respectively. The lowest number leaves per plant, number of branches per plant (48.29, 5.41) were recorded in C_2D_1, but the yield per plot and yield (0.36 kg and 3.59 t) were observed in C_2D_3, respectively.

Table 3. Combined effect of canopy and plant density on the growth and yield of Gima Kalmi at 45 DAS

Treatment	Plant height (cm)	Number of leaves per plant	Number of branches per plant	Fresh weight of foliage per plant (g)	Yield per plot (kg)	Yield per hectare (t)
C_0D_1	25.17	68.93c	7.96c	77.81	1.10a	11.03a
C_0D_2	26.46	71.04b	9.50b	80.53	0.70c	7.00c
C_0D_3	27.83	72.93a	10.62a	82.27	0.60d	5.97d
C_1D_1	20.21	61.67f	6.62e	62.03	0.88b	8.79b
C_1D_2	21.43	64.48e	7.07d	64.31	0.56d	5.64d
C_1D_3	22.85	66.47d	7.78c	66.26	0.48e	4.75e
C_2D_1	14.38	48.29i	5.41h	48.58	0.67c	6.73f
C_2D_2	15.47	50.10h	5.70g	50.57	0.41f	4.10f
C_2D_3	16.67	52.32g	6.19f	52.48	0.36g	3.59g
Sx	0.10	0.17	0.07	0.16	0.02	0.17
Level of significance	NS	0.01	0.01	NS	0.01	0.01

C_0= No canopy (open field, control
C_1=Ghora neem canopy
C_2= Ipil-ipil canopy

D_1= 30 cm x 15 cm
D_2= 30 cm x 25 cm
D_3= 30 cm x 30 cm

The figures in a column having the same letter(s) do not differ significantly. ** = Significant at 0.01 level; NS = Not significant

4.9 Combined effect of plant density and fertilizer on the growth and yield of Gima Kalmi at 45 DAS

The combined effects of different plant densities and different levels of fertilizer on the growth and yield of Gima Kalmi at 45 DAS have been presented in Table 4. The highest plant height, number of leaves per plant, number of branches per plant, fresh weight foliage per plant, (25.30 cm, 68.17, 10.02, 72.04 g) were recorded in D_3T_1. The yield per plot and yield per hectare were not significant. The lowest plant height, number leaves per plant, number of branches per plant, fresh weight foliage per plant, yield per plot and yield per hectare were (18.28 cm, 55.74, 6.04, 57.74 g) were found in D_1T_0 i.e. 30 cm x 15 cm plant density and no fertilizer, respectively.

Table 4. Combined effect of plant density and fertilizer on the growth and yield of Gima Kalmi at 45 DAS

Treatment Combination	Plant height (cm)	Number of leaves per plant	Number of branches per plant	Fresh weight of foliage per plant (g)	Yield per plot (kg)	Yield per hectare (t)
D_1T_0	18.28k	55.741	6.04h	57.74i	0.80	7.99
D_2T_0	19.4H	57.78h	6.96h	61.28g	0.50	5.05
D_3T_0	20.51g	60.50f	7.52e	63.70f	0.43	4.34
D_1T_1	22.69d	64.66c	8.10d	68.94c	1.01	10.05
D_2T_1	23.62b	66.71b	9.11b	70.54b	0.67	6.66
D_3T_1	25.30a	68.17a	10.02a	72.04a	0.55	5.46
D_1T_2	19.88h	60.24fg	6.33g	65.68e	0.91	9.13
D_2T_2	21.72e	63.11d	7.38e	67.44d	0.57	5.67
D_3T_2	23.07c	64.96c	8.37c	68.99c	0.48	4.76
D_1T_3	18.83J	57.89h	6.17gh	58.84h	0.82	8.23
D_2T_3	19.72hi	59.90g	6.26gh	61.28g	0.49	4.94
D_3T_3	20.92f	62.01k	6.88f	63.28f	0.45	4.51
Sx	0.12	0.20	0.08	0.19	0.02	0.20
Level of significance	0.01	0.01	0.01	0.01	NS	NS

D_1= 30 cm x 15 cm
D_2= 30 cm x 25 cm
D_3= 30 cm x 30 cm

T_0= No fertilizer
T_1=Recommended fertilizer
T_2= 20% less fertilizer
T_3= 40% less fertilizer

The figures in a column having the same letter(s) do not differ significantly. ** = Significant at 0.01 level; NS = Not significant

4.10 Combined effect of canopy, fertilizer and plant density on the growth and yield of Gima Kalmi at 45 DAS

The combined effects of different canopy orientations, plant densities and different levels of fertilizer on the growth and yield of Gima Kalmi at 45 DAS have been presented in Table 5. The highest plant height, number leaves per plant, number of branches per plant, (30.10 cm, 78.80, and 12.90), were found in $C_0T_1D_3$. The yield per plot and yield per hectare (1.26 kg and 12.60 t) were recorded in $C_0T_1D_1$, respectively. The lowest plant height, number leaves per plant, number of branches per plant, fresh weight foliage per plant, (12.67 cm, 44.93, 5.07, 45.17 g) were different treatment combination. The lowest yield per plot (0.32 kg) and yield (3.20 t) and were found in $C_2T_0D_3$ i.e. ipil-ipil canopy no fertilizers and 30 cm x 30 cm treatment combinations, respectively.

Table 5. Interaction effect of canopy, fertilizer and plant density on the growth and yield of Gima Kalmi at 45 DAS

Treatment combination	Plant height (cm)	Number of leaves per plant	Number of branches per plant	Fresh weight of foliage per plant(g)	Yield per plot (kg)	Yield per hectare (t)
$C_0T_0D_1$	23.73g	65.13jk	6.80kl	71.27	0.97cd	9.74cd
$C_0T_0D_2$	25.47de	65.97ij	8.60f	75.07	0.63ij	6.26jkl
$C_0T_0D_3$	26.83c	67.60h	9.83de	77.00	0.54j-m	5.391-o
$C_0T_1D_1$	28.13b	74.60c	10.03de	85.93	1.26a	12.60a
$C_0T_1D_2$	28.43b	77.17b	11.83b	87.67	0.82ef	8.18ef
$C_0T_1D_3$	30.10a	78.80a	12.90a	89.77	0.69ghi	6.88hij
$C_0T_2D_1$	24.07g	67.73h	7.87gh	81.87	1.15b	11.45b
$C_0T_2D_2$	26.90c	71.60d	10.10d	84.73	0.73fgh	7.34f-i
$C_0T_2D_3$	28.47b	73.80c	11.30c	85.97	0.60ijk	6.01j-m
$C_0T_3D_1$	24.73f	68.27gh	7.13ijk	72.17	1.03c	10.34c
$C_0T_3D_2$	25.03ef	69.43ef	7.47hij	74.67	0.62ij	6.21jkl
$C_0T_3D_3$	25.93d	71.53d	8.43f	76.33	0.56jkl	5.591m
$C_1T_0D_1$	18.37n	57.17p	6.27mn	56.80	0.81ef	8.14ef
$C_1T_0D_2$	19.20m	60.90n	7.10jk	60.93	0.51k-n	5.07m-p
$C_1T_0D_3$	20.23 1	64.93k	7.40ij	63.47	0.44m-p	4.44o-r
$C_1T_1D_1$	22.10i	68.13h	8.00g	68.53	1.00c	10.05c
$C_1T_1D_2$	23.10h	69.20fg	8.60f	69.73	0.67ghi	6.74h-k
$C_1T_1D_3$	25.27ef	70.401e	9.60e	70.80	0.54j-m	5.431-o
$C_1T_2D_1$	21.27J	62.331m	6.07n	64.33	0.90de	9.00de
$C_1T_2D_2$	22.50i	66.17i	6.471mn	65.50	0.57jkl	5.67k-n
$C_1T_2D_3$	23.47gh	67.80h	7.57ghi	67.53	0.471-o	4.72n-q
$C_1T_3D_1$	19.10m	59.07o	6.13mn	58.43	0.80f	7.98efg
$C_1T_3D_2$	20.93jk	61.671m	6.13mn	61.07	0.5lk-n	5.09m-p
$C_1T_3D_3$	22.43i	62.771	6.571m	63.23	0.44m-p	4.42o-r
$C_3T_0D_1$	12.73s	44.93w	5.07q	45.17	0.61ijk	6.08j-m
$C_3T_0D_2$	13.57r	46.47v	5.17pq	47.83	0.38opq	3.82qps
$C_3T_0D_3$	14.47q	48.97u	5.33opq	50.63	0.32q	3.20s
$C_3T_1D_1$	17.83no	51.23st	6.27mn	52.37	0.75fg	7.51fgh
$C_3T_1D_2$	19.33m	53.77r	6.90kl	54.23	0.51k-n	5.06m-p
$C_3T_1D_3$	20.53kl	55.30q	7.57ghi	55.57	0.41n-q	4.07p-s
$C_3T_2D_1$	14.30q	50.67t	5.07q	50.83	0.69ghi	6.95g-j
$C_3T_2D_2$	15.77p	51.57st	5.57op	52.10	0.40opq	3.99p-s
$C_3T_2D_3$	17.27o	53.27r	6.23 mn	53.47	0.36pq	3.56ps
$C_3T_3D_1$	12.67s	46.33v	5.23opq	45.93	0.64hij	6.38i-l
$C_3T_3D_2$	13.20rs	48.60u	5.17pq	48.10	0.35pq	3.52rs
$C_3T_3D_3$	14.40q	51.73s	5.63o	50.27	0.35pq	3.51rs
SX	0.20	0.34	0.15	0.32	0.03	0.34
Level of significance	0.01	0.01	0.01	NS	0.01	0.01

4.11 Economic analysis

Profitability of growing Gimà Kalmi as inter-crop in different tree (open field, ghora neem and ipil-ipil,) based agroforestry system was calculated based on local market prevailed during experimentation. The cost of production of Gima Kalmi and cost of production of tree plantation and management of trees have been summarized in appendix III. The return of produce and the profit per taka i.e. Benefit Cost Ratio (BCR) also have been presented in Table 6.

Total cost of production

The values in Appendix III indicate that the total cost of production was highest (82975 Tk./ha) under ipil-Ipil + Gima Kalmi based agroforestry system (C_2) followed by ghora Neem + Gima Kalmi based agroforestry system (81046 Tk./ha) (C_1). The lowest cost of production (32047 Tk./ha) was recorded from the sole cropping of Gima Kalmi (C_0). Higher cost of production was found in the ipil-Ipil + Gima Kalmi based agroforestry system due to higher plantation cost of the system.

Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. The highest value of gross return (355,200 Tk /ha) was obtained from ghora Neem + Gima Kalmi (C_1) based agroforestry system (Table 6). On the other hand, the lowest value of gross return (80000 Tk. /ha) was obtained from sole cropping of Gima Kalmi. The highest gross return was obtained due to higher yield of Gima Kalmi along with the value of trees.

Net return

Results presented in the Table 6 show that net return was comparatively higher in producing Gima Kalmi under ghora neem based agroforestry system than ipil-ipil based agroforestry system. It was observed that ghora Neem + Gima Kalmi based agroforestry system (C_1) gave the highest net return (272225 Tk. /ha) followed by (213354) in ipil-Ipil + Gima Kalmi (C_2) based agroforestry system over total cost of production. At the same time, the lowest net return (47953 Tk. /ha) was received from the sole cropping of Gima Kalmi (C_0). Higher net return was the result of higher gross return from the Gima Kalmi cultivation together with trees.

Table 6 Economics of Gima Kalmi production under different trees based agroforestry system (average of one year)

Treatments	Return (Tk./ha)			Gross Return (Tk./ha)	Total cost of Production (Tk./ha)	Net Return (Tk./ha)	BCR
	Gima kalmi	Ghora neem	Ipil-Ipil				
C_0	80000	------	-------	80000	32047	47953	2.50
C_1	48000	307200	-------	355200	82975	272225	4.28
C_2	64000	-------	230400	294400	81046	213354	3.63

Note: Gima kalmi @10 Tk./kg, Ghora Neem 225 Tk./Tree/Year, Ipil-Ipil @267 Tk./Tree/Year

Benefit-cost ratio

The highest benefit-cost ratio (4.28) was recorded from ghora Neem + Gima Kalmi (C_1) based AFS followed by ipil-Ipil + Gima Kalmi (C_2) based AFS. The lowest benefit-cost ratio of (2.50) was observed in C_0 i.e. in sole cropping of Gima Kalmi. So, Gima Kalmi can profitably be cultivated in ghora Neem based agroforestry systems. Thus, it may be advocated that such type of speculation will be beneficial to the farmer as because such project provides cash money to the farmer and gradually can enrich the soil nutritionally.

parameters decreased remarkably by tree canopy. Variation in plant height was observed in different orientation under tree canopy, where significantly the tallest plant (30.10 cm) was observed in no canopy orientation and the shortest (12.67 cm) plant was recorded in ipil-ipil canopy and moderate (21.27 cm) was under ghora Neem canopy. In case of number of leaves per plant (44.93), number of branches per plant (5.07), fresh weight of foliage per plant (45.17 g/plant) were always lower under ipil-ipil canopy compared to no canopy (78.80, 12.90 and 89.77 g). Plant growth was moderate under ghora neem canopy (64.93, 8.00 and 67.53 g/plant).

Levels of fertilizer significantly influenced all the parameters studied. The values of yield contributing characters increased with an increase in fertilizer level. The maximum plant height (30.10 cm), number of leaves per plant (78.80), number of branches per plant (12.90), fresh weight of foliage per plant (89.77 g/plant), yield per plot (1.26 kg) and yield (12.60 t/ha) were found with the application of recommended dose of fertilizer at 45 DAS under no canopy and the minimum plant height (12.67 cm), number of leaves per plant (44.93), number of branches per plant (5.07), fresh weight of foliage per plant (45.17 g/plant), yield per plot (032 kg) and yield (3.20 t/ha) were observed at 45 DAS under guava canopy at no fertilizer level.

Levels of plant density significantly influenced all the parameters studied. The values of yield contributing characters increased with the decrease in plant density. The maximum plant height (30.10 cm), number of leaves per plant (78.80), number of branches per plant (12.90) and fresh weight of foliage per plant (89.77 g/plant) were found at 45 DAS with 30 cm x 30 cm plant density. The highest yield per plot

(1.26 kg) and yield (12.60 t/ha) were found at 45 DAS with 30 cm x 15 cm plant density. The minimum plant height (12.67 cm), number of leaves per plant (44.93), number of branches per plant (5.07) and fresh weight of foliage per plant (45.17 g) were observed in 30 cm x 15 cm plant density at 45 DAS under guava canopy. The lowest yield per plot (0.32 kg) and yield (3.20 t/ha) were observed at 45 DAS under guava canopy at 30 cm x 30 cm plant density.

Regarding combined effect of fertilizer, plant density and canopy, the maximum plant height (30.10 cm), number of leaves per plant (78.80), number of branches per plant (12.90) and fresh weight of foliage per plant (89.77 g) were found at recommended dose of fertilizer with 30 cm x 30 cm plant density at 45 DAS under no canopy. The highest yield per plot (1.26 kg) and yield (12.60 t) were produced by recommended dose of fertilizer with 30 cm x 15 cm spacing under no canopy. The minimum plant height (12.67cm), number of leaves per plant (44.93), number of branches per plant (5.07) and fresh weight of foliage per plant (45.17 g) were produced by no fertilizer application with 30 cm x 15 cm spacing at 45 DAS under ghora Neem canopy. The lowest yield per plot (0.32 kg) and yield per hectare (3.20 t) were produced by no fertilizer application with 30 cm x 30 cm plant density at 45 DAS under ipil-ipil canopy.

The moderate plant height (23.47 cm), number of leaves per plant (67.80), number of branches per plant (7.57) and fresh weight of foliage per plant (67.53) were produced with 20% less fertilizer application and 30 cm x 30 cm plant density under ghora neem canopy. The moderate yield per plot (0.90 kg) and yield (9.00 t/ha) with 20% less fertilizer application and 30 cm x 15 cm plant density under ghora neem canopy.

Effect of fertilizer, plant density and canopy was observed in this experiment. The recommended dose of fertilizer in combination with the widest plant density (30 cm x 30 cm) was found suitable for higher growth and recommended dose of fertilizer in combination with 30 cm x 15 cm plant density for higher yield of Gima Kalmi under no canopy in the agro climate condition of Hajee Mohammad Danesh Science and Technology University, Dinajpur.

Among different canopy orientations Kangkong grown in no canopy orientation showed the best performance and ipil-ipil canopy orientation showed lowest performance, where ghora neem canopy orientation showed comparatively moderate performance. According to performance the ranked order of canopy orientation were open > ghora neem > ipil-ipil. According to the experimental results it may be concluded that two tree species can be used in agroforestry systems by different management practices. But degree of their suitability for agroforestry systems were open > ghora neem > ipil-ipil. In benefit cost ratio, it was found the highest benefit-cost ratio (4.28) was recorded from ghora neem + Gima Kalmi (C_1) based AFS followed by ipil-ipil + Gima Kalmi (C_2) based AFS. The lowest benefit-cost ratio of (2.50) was observed in C_0 i.e. in sole cropping of Gima Kalmi. So, Gima Kalmi can profitably be cultivated in ghora neem based agroforestry systems. Thus, it may be advocated that such type of speculation will be beneficial to the farmer as because such project provides cash money to the farmer and gradually can enrich the soil nutritionally.

From the present study it is concluded that Gima Kalmi (Kangkong) could be grown under ghora neem canopy and ipil-ipil canopy although 30-35% yield was reduced compared to no canopy. Comparatively better yield of Gima Kalmi was found under ghora neem canopy due to less crown diameter, crown depth, size of studied trees and less competition between Gima Kalmi and tree species for light, nutrient, water etc. Comparatively less fresh weight yield per plot was recorded under ipil-ipil which may be due to heavy competition for moisture, nutrient, light and other negative effect between tree species and Gima Kalmi.

However, to draw a conclusion the experiment should be tested at different locations in Bangladesh with further higher doses of fertilizer and closer density than the one that had been used in the present experiment. In this study, only performance was evaluated, there is a need to find out the interactions/competition for resource sharing and allelopathic effect between tree and crop species. Based on the present study, this agroforestry practice can be applied at the field levels to identify its possibility and constraints at farmers level.

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APPENDICES

Appendix-I: The physical and chemical properties of soil in Agroforestry Farm, HSTU, Dinajpur

Soil characters	Physical and chemical
Texture	
Sand (%)	65
Silt (%	30
Clay(%	5
Textural class	Sandy loam
CEC (meq/ 100g)	8.07
pH	5.35
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 (2010)

Appendix II: Every day air temperature and relative humidity (%) of experimental site in April to May 2009

Date	Average air temperature (^{O}C)	Relative Humidity (%)
5 April 2009	18	76
6April 2009	17	74
7 April 2009	22	74
8 April 2009	18	74
9 April 2009	20	66
10 April 2009	20	68
11April 2009	20	86
12April 2009	16	70
13April 2009	18	76
14April 2009	20	76
15April 2009	19	65
16April 2009	17	70
17April 2009	16	64
18April 2009	16	70
19April 2009	15	74
20April 2009	18	74
21April 2009	15	74
22April 2009	16	74
23April 2009	16	74
24April 2009	15	70
25April 2009	16	73
26 April 2009	18	75
27April 2009	17	74
27April 2009	16	70
28April 2009	17	70
29April 2009	16	70
30April 2009	14	70
1 May 2009	16	76
2 May 2009	18	74
3 May 2009	16	76
4 May 2009	16	76
6 May 2009	18	76
7 May 2009	17	75
8 May 2009	15	76
9 May 2009	16	75
10 May 2009	18	76
11May 2009	16	78
12May 2009	17	77
13May 2009	20	76
14May 2009	20	78
15May 2009	19	76
16May 2009	18	72
17May 2009	19	76
18May 2009	18	77
19May 2009	20	75
20 May 2009	20	75

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

APPENDICES

Appendix III. Cost of production for Gima Kalmi based agroforestry system

Treatment	Input cost											Total input cost (Tk/ha)	Over head cost			Total cost of production (Tk/ha)
	Non material cost (Tk/ha)			Material cost (Tk/ha)												
	Trees	Gima kalmi production	Total non material cost	Seed	Fertilizer	Pesticide	Irrigation	Maintenance cost of trees	Initial plantation cost of trees	Total 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)	
C_0	------	3550	3550	6700	7500	2500	2800	------	------	19500		23050	1844	6000	1153	32047
C_1	14575	4200	18775	4800	5500	2000	2000	5120	12288	31708		50483	4039	24000	2524	81046
C_2	15570	4200	19770	4800	5500	2000	2000	5120	13000	32400		52190	4175	24000	2610	82975

Note: Urea 12 Tk./kg, TSP 22 Tk./kg; MP 24 Tk./kg, Labour 120 Tk./day, Plantation cost for ipil-ipil, ghora neem were 20, 15 Tk./tree, respectively (rotation year for ipil-ipil and ghora neem were 12 and 8 years, respectively).

Appendix 1V. Analysis of variance of the characters studied in Gima Kalmi

Source of variation	Degrees of freedom	Mean squares values					
		Plant height	Number of leaf per plant	Number of branch per plant	Fresh weight of foliage per plant	Yield per plot	Yield per hectare
Replication	2	2.560	7.706	1.288	7.472	0.001	0.058
Canopy (A)	2	1088.170**	4025.081**	118.061**	7934.601**	0.919**	91.889**
Fertilizer (B)	3	111.419**	369.03	36.547**	609.209**	0.146**	14.585**
Canopy×Fertilizer (A×B)	6	5.586**	12.676**	3.056**	34.764**	0.005 NS	0.455NS
Density (C)	2	57.685**	164.611**	21.237**	159.413**	1.682**	168.173**
Canopy×Density (A×C)	4	0.141NS	0.996*	3.085**	0.453NS	0.030**	3.017**
Fertilizer×Density (B×C)	6	0.751**	1.200**	0.914**	4.005**	0.006 NS	0.574NS
Canopy×Fertilizer× Density (A×B×C)	12	.947**	3.406**	0.190**	0.453NS	0.001 NS	0.072NS
Error	70	0.125	0.355	0.064	0.313	0.003	0.345
CV (%)	107	1.67	1.96	3.40	1.86	9.17	9.17

* = Signigicant at 0.05 level
** = Significant at 0.01 level
NS = Not significan