

**PERFORMANCE OF INDIAN SPINACH AND PINEAPPLE
AT DIFFERENT ORIENTATIONS
OF LITCHI TREE**



A Thesis

By

MD. NASIR UDDIN

Student no. 0705014

Session: 2007-08

Thesis Semester: January-June, 2008



**MASTER OF SCIENCE (M.S.)
IN
AGROFORESTRY**

**DEPARTMENT OF AGROFORESTRY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY
DINAJPUR**

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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 AND
RESPECTED TEACHERS**

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ABSTRACT

A field experiment was conducted at the Agroforestry Farm, Hajee Mohammad Danesh Science and Technology University during February 2007 to January 2008 to examine the growth performance of Pineapple and Indian spinach grown at different orientations around litchi tree. There were five treatments viz. 4 different orientations (north, south, east and west) of litchi tree for production of Indian spinach in association with pineapple and one control plot. The treatments were as follows T_1 – North orientation (average 37.12 % shade), T_2 - South orientation (average 22.03 % shade), T_3 – East orientation (average shade 48.61 %), T_4 – West orientation (average 40.16 % shade) and T_5 – open field (No shade). The experiment was laid out in Randomized Complete Block Design (RCDB) with three replications. The aim of the study was to detect the orientational effect (Various shade % created by tree canopy) of litchi tree in multistoried agroforestry system. The longest plant of Indian spinach as well as pineapple were recorded in east orientation. The values of all other parameters were found highest in open field (full sun light). Significantly the highest yield (7.12 ton ha^{-1}) of Indian spinach was recorded in open field followed by south orientation (6.60 ton ha^{-1}) while the lowest yield (5.80 ton ha^{-1}) was found in the east orientation. On the other hand pineapple exhibited the highest value for all its growth parameters under litchi tree with the increase of shade level, (East>West>North>South>Open field). Moreover, the results indicate that, the litchi orchard of northern part of Bangladesh have the potentiality to produce pineapple as well as Indian spinach as multistoried production concept, although the yield performance of pineapple was not achieved in this study as it needs another year for its perennial life cycle.

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CHAPTER 1

INTRODUCTION

Bangladesh has the lowest per capita arable land due to its high population density. This limited land resource is engaged in producing minimum food requirements for the people. Therefore, much emphasis was not given on vegetable and fruit production, which are important sources of nutrition. The minimum dietary requirement of fruits per day per capita is 85 g, whereas the availability is only 30-35 g (Siddique, 1995). In view of the fact, that fruits are the important source of vitamins and minerals. However, the availability and consumption of fruits in Bangladesh are much less than it should be. Moreover, due to high price of fruits the majority of people cannot afford to buy them. As a result, many people especially children have been suffering from malnutrition in the country.

Vegetable crops excluding potato occupy only 1.97% of the total cropped area with a gross production of 1.89 million tons (BBS, 2007). Therefore, the availability of vegetable in Bangladesh is extremely lower when compared with other countries. In many of the developed countries, cereals and vegetable including roots and tubers are produced in the ratio of 1:2 (by weight). The ratio in many of the developing countries of Asia is some 2:1, but in Bangladesh it is 5:1 (Siddique and Aditya, 1992). This is because the status of vegetable consumption in our country is much lower and it is rather far below than the international standard. The per capita consumption of vegetable in Bangladesh is only 53 g, which is pretty below the recommended daily requirement of 200 g/head/day (Rashid, 1999). This figure is the lowest among the other Asian countries like India

(167 g), Pakistan (69 g), Sri Lanka (120 g), China (280 g) and Japan (248 g) (FAO, 1998). The low consumption of vegetables in Bangladesh creates a tremendous pressure over cereals and also causes malnutrition leading to several kinds of health hazards. To provide balance diet for the people of Bangladesh, there would be no alternative to produce vegetable, as this would also provide vitamins and minerals. Increasing the land area for vegetables production in Bangladesh seems to have little scope, because of decreasing trend in the land-man ratio. Thus in these circumstances in addition to using the conventional methods, the production of vegetable should also be trialed by adopting some unconventional methods.

On the other hand, Bangladesh is also constrained with insufficient forest recourses and these scarce resources are being destroyed at an alarming rate, widening the gap between the demand and supply of timber and fuelwood. In Bangladesh, the demand and supply of fuelwood are 310 and 125 million cft., respectively, and those for timber are 115 and 44 million cft. respectively (Hossain *et al.*, 1999). Thus, the shortages of timber and fuelwood are 61.91% and 59.67%, respectively. This large demand of wood has created a tremendous pressure on the reserved forests. For instance, reserve forests depleted by 61% between the year 1963 to 1983 (Chowdhury and Hossain, 1989). It is said that country needs at least 25% forest cover to maintain its ecological balance. But we have only 17% forest land and actual vegetation (tree) cover is only 6-7% (Hossain *et al.*, 1990). It is undoubtedly insufficient for ecological requirements.

Under these alarming conditions, it is necessary to find out a sustainable alternative to over come this situation. Since there is no scope for expanding forest area nor sole fruit and vegetable crop areas,

the country has to depend on the combined production of trees, vegetable and fruit crops, which is now being called agroforestry. Litchi-pineapple based agroforestry system can be more intensify with Indian spinach, which provides joint production of vegetable, fruits and woods.

The litchi (*Litchi chinensis*) is a delicious, juicy fruit of excellent quality. It is a popular fruit in our country. It is a perfect multipurpose tree. It grows well all over the country specially in the northern part of Bangladesh. On the other hand, pineapple (*Annanas comosus*) is also one of the major fruits of Bangladesh grown well in partial shade and acidic soil condition. The soil of Dinajpur district is slidely acidic (pH range 5.0-6.0) and most of it's litchi orchard is not used for understorey production. Therefore production of pineapple in association with litchi tree may be an ideal combination of two high value fruits. For more intensification Indian spinach can be introduce with pineapple. But it need scientific research for investigating interaction effects of these multistoried (Litchi-Pineapple-Indian spinach) production system. Without testing the performance of Indian spinach and pineapple under litchi tree with orientation and distance basis, it may not always profitable for large scale production.

Considering the above fact the present research has been taken to fulfill the following objectives:

1. To know the yield performance of Indian spinach under Litchi-Pineapple based multistoried agroforestry system.
2. To understand the growth performance of pineapple produced with Indian spinach under different orientation of litchi tree.
3. To find out the suitable lower storey practice of litchi tree.

CHAPTER 2

REVIEW OF LITERATURE

The research was carried out to observe the performance of Indian spinach and pineapple at different orientations of litchi tree. In recent times, the modern practices of agroforestry are extended in the crop field of Bangladesh. The farmers are growing tree in the vegetable field to get maximum benefit. But tree directly influences vegetable yield. Literatures directly related to this aspect are meager. Therefore, literatures some way linking to the subject of interest from home and abroad are reviewed and outlined below under the following sections.

2.1 Concepts of Agroforestry

Agroforestry is an age-old and ancient practice. It is an integral part of the traditional farming systems of Bangladesh. The concept of agroforestry probably originated 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 (ICRAF) 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 or animal in some form of spatial arrangement or temporal sequence (Nair, 1983).

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

From a bio-economic point of view, Harou (1983) stated that agroforestry is a combined agriculture-tree crop farming system which enables a farmer 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) stated that agroforestry is a means of managing or using land (i.e., a land use system) that combines trees or shrubs with agricultural/horticultural crops and/or livestock.

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) (iii) 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 quadrat of 1m^2 . The quadrats were taken at a distance of 3 m, 4.5 m and 6 m from the base of tree. One quadrat 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, 4.5 and 6 m, 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 2.5 m away; beyond that, yield were similar to those in rows 6 m 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* followed by oats. The yields decreased less than four years old trees compared with those under three years old trees. Wheat gave higher yields than *Cicer 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 azedarach* (*Azadirachta indica*), compared with the open plot yields. The PAR received under the four 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 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 7 m) and in four 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 3 m. In general, the effect of trees on wheat yield was observed up to 3m distances and there was little effect from 3 to 5 m distances, and almost no effect at 7 m 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 and isolating sole-crop plots from tree plot (Rao and Govindarajan, 1996).

Reports of trees that are deliberately maintained in upland rice (*Oryza sativa*) fields are rare. Hocking and Islam (1995) reported the growing of trees like *Acacia nilotica*, *Acacia catechu*, and *Borassus flabellifer* in rice paddy fields in Bangladesh. Jambulingam and Fernandes (1988) 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 in the Chhattisgarh region are also available (Jena, 1991; Puri *et al.*, 1994; Viswanath *et al.*, 1998).

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

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

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

Limiting light (Shade) is obviously the most important factor that 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 trees 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, 1996).

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 di-nitrogenfixation.
- vi) Multiple uses: food, feed, fire wood, construction materials and other products and service (shade, shelter etc.).
- vii) Minimum competition with shallow rooted annual crops.
- viii) Small leaflets readily detached when dried and quickly decomposed when used as fertilizer.
- ix) A high proportion of leaves to secondary branches.
- x) Free from pests and diseases and
- xi) Ease of control of eventual elimination.

Purohit (1984) suggested to select 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 (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 Performance of Crop in Agroforestry Systems

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

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

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 mostly due to impaired dry matter production, panicle number and grains per panicle.

Yamoah *et al.* (1986) reported that maize height, 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% because of reduction in number of panicles per plant (51.5%), number of grain

per panicle (16.7%) and increase in number of unfilled spikelets (42.1%) in 25 rice cultivars.

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

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). They 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% and 11-37% 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, 1.64 and 1.32 t ha⁻¹ with 0.2, 3, 4, 5, 6, 7 and 8 hr. shade per day, respectively.

Jiang *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 than in pruned alleys. Rice and mungbean yield decreased linearly with the reduced percent light incidence, rice yields decreased 47 and mungbean yields decreased 10 kg ha⁻¹. In pruning regimes, mungbean yields decreased more in pruned conditions (13 kg/ha) than in unpruned condition (9 kg ha⁻¹).

Growth of trees and seasonal yields of understorey crops were measured by Hicking *et al.* (1998) over a five year period for four crops grown under 17 tree species at 8 x 8 m spacing in wetland rice field. All tree species grew well in rice fields, at rates comparable to their growth in forest plantations. Top and root pruning reduced average tree girths by up to 19% and average tree volume by up to 41% depending on intensity of pruning. The crops monitored were *Oryza sativa*, *Triticum aestivum*, *Corchorus olerius*, and *lens culinaris*. Crop yields under the trees average 93% of the corresponding yield outside the tree canopy.

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 intercropping, 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, spikelets 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 estimated 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 years) 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 agroforestry 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 lebbeck* 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 yield of 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.

2.6 Characteristics and Importance of Litchi-Pineapple Agroforestry Systems

Litchi originated in china, where it has been cultivated for over 3000 years and was introduced to Burma and India by the end of the 17th century (Goto, 1960, Liang, 1981) and to the West Indies by the 18th century . It was introduce into Australia, South Africa and Hawaii by the end of 19th century (Menjel & Simpson,1986b). Other countries where it has spread are Thailand ,Madagascar, Mauritius , Reunion ,Hongkong etc

The food value of litchi mainly lies in its sugar and acid contents which vary due to cultivars and climate. The sugar content in different cultivars made from 6.74 to 18.86% in India (Singh and Singh, 1964); 12-15% in Florida and 11.8 to 20.6% Hawaii (Miller and Bajore,1945).Beside sugar litchi contains 0.7% protein, 0.3% fat, 0.7% mineral (partially calcium & phosphorus) and vitamin C (64mg/100g pulp) A, B1 & B2 . Pineapple is also a very popular fruit in Bangladesh and is particularly suitable for growing in partial shade due to its being an obligate crassulacean acid metabolism (CAM) plant. In this kind of plants, the stomata of the leaves are closed during

the day, open in late afternoon and remain fully open throughout night which help rapid absorption of water (Krauss, 1949).

Bonner and Bonner (1948) stated that CAM plants achieve their high water-use efficiency by opening their stomata during the cool, desert nights, and by closing them during the hot, dry day. This mechanism minimizes waterloss.

About soil requirements, Sen (1990) mentioned that sandy and loamy soils in the hilly areas are suitable for pineapple cultivation and the optimum pH range is 5.5 to 6.0. The Madhupur Tract largely fulfill such requirements of pineapple cultivation.

2.7 Response of Pineapple to Light and Shade

Bright sunshine and total shade both are harmful for pineapple (Sen, 1990). Chadha *et al.* (1974) reported that at Bangalore (India), dense planting of pineapple resulted in high yields without affecting the quality or size of fruits. He also stated that besides increased yield, high density planting of pineapple has some other advantages. Overlapping of the basal leaves provides shade and reduce evaporation loss as well as weed growth. Aside from crowding of the plants under high plant density, the vigorously growing leaves tend to twist and grow upright which provide the fruits a natural covering to prevent sun scald and result in uniformly coloured and lustrous fruits. When grown in Hawii in a garden in full sunlight, pineapple produced much smaller plants than in its native habitat in Brazil, but when grown in the shade of tall trees having a soil-much of dead plant debris, it produced larger plants (Collins, 1939).

Collins (1960) stated that the amount of sunshine which falls on the growing plants is an important climatic factor for both plant growth and fruit quality. A very low percentage of possible sunshine, such as that results from a high, percentage of cloudy days, retards growth and results in small fruits of poor quality, particularly lacking in sugars. On the other hand, too much sunshine may cause sunburning of nearly mature fruits.

Pineapple provides a ready source of many food nutrients and minerals. The fruit is nutritious and contains protein and calcium three times higher than apple and grapes and (Khan, 1987). Fresh pineapples contain proteolytic enzymes call Bromilin. Composition of the edible parts of the pineapple is also presented in the Appendix 4. Squah, syrup, jam, jally, vinegar, alcohol, citric acid, calcium, etc. are produced from pineapples. After collecting its juice, the leftover is used as livestock feed and also the tender leaves are used for the same purpose. Pineapple is also recommended as medical diet some diseased persons. Apart from these, the well-sliced pineapple is canned. In Philippines, a fine fabric known as 'pina-cloth' is produced from a kind of silky fibre collected from pineapple leaves (Moniruzzaman, 1988). Thailand is the largest pineapple producer country in the world which produce 17.27% of the world production while Bangladesh produces 1.28% of world production (FAO, 1998a).

Hossain (1999) observed that the yield of pineapple kept increasing up of jackfruit with 50 and 100 trees per hectare. He also suggested that the expected yield of pineapple would be the highest (64 t ha^{-1}) in 24 years old jackfruit orchard with 200 trees per hectare.

Excess light creates a less favorable micro environment for pineapple (Collins 1960, Sen 1990). A great crown and less light penetration also help minimize evapo-transpiration loss of water and suppress weed growth, which are favorable for pineapple (Chadha, 1974).

2.8 Performance of Indian Spinach in Agroforestry Systems

Indian (*Basella alba*) spinach is a popular summer leafy vegetable grown in all parts of Bangladesh. There are mainly two types, one with reddish leaves and stems and the other with green leaves, petioles and stems. Green cultivars belong to *Basella alba*. The plant has fleshy stem and leaves and of trailing habit. The nutritive value of the young shoots and leaves is very high in terms of minerals and particularly of vitamin A. According to Hossain (1995) the plant contains the following amount nutrients.

Nutrients composition	Content (per 100 g of edible portion)	Nutrients composition	Content (per 100 g of edible portion)
Calorie	27 K.Cal.	Carotin	12750 IU
Fat	0.2 g	Vitamin B ₁	0.02 mg
Starch	4.2 g	Vitamin B ₂	0.36 mg
Calcium	164 mg	Vitamin B ₃	64 mg
Iron	10.5 mg	Protein	2-2 g

CHAPTER 3

MATERIALS AND METHODS

This chapter deals with the materials and methodology used in conducting the experiment. The location of the experiment, materials used, and methods followed in different operations during the experiment as well as in data collection are described in the following sub heads:

3.1 Location of the Study

The experiment was conducted in the Agroforestry Farm, Hajee Mohammed Danesh Science and Technology University, Dinajpur. This site was located between 25°13' latitude and 88°23' longitude and about 37.5 m above sea level.

3.2 Soil Characteristics

The experimental site is situated in a medium high land belonging to the Old Himalayan Piedmont Plain area (AEZ 01). The rain water did not stay there. Irrigation facilities and drainage systems in the experimental fields were developed. The soil texture was sandy loam with sand 65%, slit 30%, clay 5%. The soil pH and CEC were 5.1 and 8.07 meq/100g soil, respectively. The structure of the soil was fine and the organic matter content was 1.06%. The soil possesses the following amount of other element i.e. Na 0.06 me/100g, Ca 1.30 me/100g, Mg 0.04 me/100g, K 0.26 me/100g, total N 0.103, P 24.0 µg/g soil, S 3.2 µg/ µg/g soil, Bo 0.27 µg/g soil, Cu 1.00 µg/g soil, Fe µg/g soil, Mn 0.07 µg/g soil, Zn 0.90 µg/g soil. CEC of the soil 8.0/100 g. (Source: SRDI, Noshipur, Dinajpur, 2007).

3.3 Climate and Weather

The climate of the study area is characterized by a heavy rainfall during Kharif season (April to September). While a scanty rainfall during the rest period i.e. during the Rabi season (October to March). The mean maximum temperature in the summer (March to September) was 35°C and the mean minimum temperature in the winter (November to March) was 11.9°C. Information regarding monthly maximum and minimum temperature, rainfall humidity and the average intensity of sunlight under the litchi tree was recorded during the study period are presented in Appendix-II.

3.4 Experimental Design and Treatments of the Study

The experiment was carried out in concentric row design (satisfying Randomized complete block design) with three replications for each treatment. There are five treatments i.e. four different orientation (various shade level) of litchi tree for production on Indian Spinach in association with pineapple and one control plot.

The treatments were as follows:

T_1 = North orientation (37.12% shade)

T_2 = South orientation (22.03% shade)

T_3 = East orientation (48.61% shade)

T_4 = West orientation (40.16% shade)

T_5 = Open field / Control plot (Full sunlight)

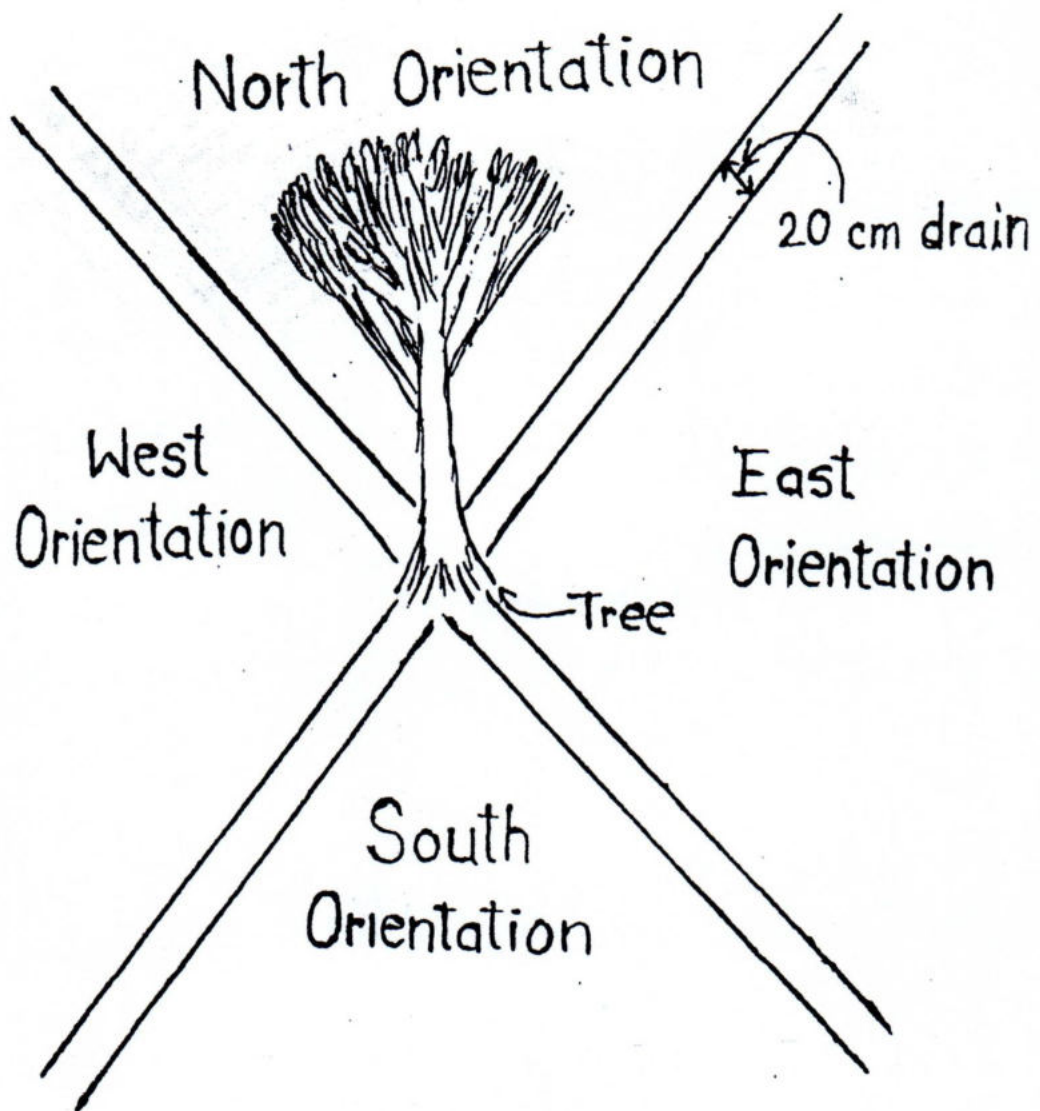


Plate 1: Schematic diagram showing construction of orientation

3.5 Description of Litchi Tree

The litchi tree used for the study was one of the old trees established at the eastern side of Agroforestry farm. It was 30 years old large tree. The structural description of tree was as follows-

Tree height-15 m

Base girth-2.03 m

Canopy diameter-10.5 m

3.6 Land Preparation and Crops Establishment

The land was opened in the early February 2007 and then prepared thoroughly by tractor and spading also. Harrowing was done for several times to obtain a good tilth. The weeds and stubbles were removed from the field and the bigger clods were broken into smaller pieces. Each orientation occupied 19.63 m² of land. Starting concentric rows of pineapple was started at 2 m distance from tree base. For pineapple cultivation, row to row and plant to plant distance was 50 cm. and 40 cm. respectably. Indian spinach was cultivated between the two rows of pineapple variety i.e. Giant kew. Seeds of Indian spinach were sown continuously through the middle of two pineapple rows and finally 50 cm plant to plant distances was maintained. The planting date of pineapple was 13 February 2007 and sowing date of Indian spinach was 10 April 2007.



Plate 2: Plate showing the layout activities for lower storey production under litchi tree.



Plate 3: Plate showing planting of pineapple crowns in different rows at different orientations.



Plate 4: Plate showing the established experiment field at different orientations of litchi tree in combination of pineapple and Indian spinach.

3.7 Fertilizer Application

Recommended doses of fertilizers for pineapple cultivation were described in the following table:

Name of fertilizer	Amount of fertilizer / plant
Urea	30 g
TSP	10 g
MP	25 g
Cow dung	290 g
Gypsum	10 g

Source: Kripsi Projukti Hat Boi (Part-2).

TSP, gypsum and cow dung were applied to soil during the bed preparation. Urea and MP were applied to the field after 4 to 5 MAT (Month after planting) in 5 doses during experimentation. No fertilizer was applied for the Indian spinach in this experiment to save the production cost.

3.8 Irrigation

Pineapple requires enough moisture during the flowering stage, thus irrigation was applied in the experimental field at two to three weeks intervals during the dry season.

3.9 Intercultural Operation

Weeding was done periodically whenever necessary. Weed free condition is always necessary for pineapple production.

3.10 Pest and Diseases Control

It is a very important fact to control pest and diseases. Out break of Milibug was controlled by applying Malathian 57 EC @ 8 cc in 2.5 liter water. Seedlings of pineapple were treated by Bordeaux mixture (4:4:50) before planting to avoid the stem rot disease. For Indian spinach Bavistin (2 g l⁻¹) was applied 10 days intervals to prevent the pest and diseases.

3.11 Harvesting

We collected the whole Indian spinach at 35 (DAS) days after sowing for consumption and sell as the vine height was elongated enough. After words, the vegetables (Indian spinach) were regenerated and at 70 DAS, second harvesting was done.



Plate 5: Plate showing the harvesting of Indian spinach from different orientations.



Plate 6: Plate showing of measurement different parameters in the experimental field.

3.12 Sampling and Data Collection

For Indian spinach: Indian spinach was harvested at two times and all the data were recorded at both harvesting time. First was at 35 days after sowing (DAS) and the second one was done at 35 days after first harvesting (70 DAS). The following parameters were recorded:

- I) Vine length (cm)
- II) Number of leaves per plant
- III) Leaf size (cm²)
- IV) Base girth of vine (cm)
- V) Stem fresh weight plant⁻¹
- VI) Leaf fresh weight plant⁻¹ (g)
- VII) Leaf dry weight plant⁻¹ (g)
- VIII) Stem dry weight plant⁻¹ (g)

For pineapple: The growth performance of pineapple were recorded up to one year. The data were collected three times i.e. at 4 month after planting (MAP), 8 MAP and 12 MAP, respectively. The following parameters were recorded:

- I) Plant height (cm)
- II) Number of leave plant⁻¹
- III) Leaf size (cm²)
- IV) Leaf dry weight (g)

For data collection, 5 representative sample plants were selected from each row of each orientation. Scale, blade, knife and electrical balance were used to record data for each parameter. One representative leaf of

each study plant was separated for dry matter detection. After sun drying, the collected leaves were dried in the oven. For determining dry weight plant⁻¹, single leaf dry weight was multiplied by number of leaf plant⁻¹.

Light Intensity Measurement

Light intensity was measured by the light spectrophotometer (LUX meter). Light measuring was done at three different times in a day (at 9.30 am, 12.30 pm and 3.30 pm) for two days per week round the year (Appendix-iii). Average light intensity per day was calculated from the mean of three reading of each day. Monthly average light intensity was obtained by 30 times multiplication of per day. Average light intensity diurnal variation of light intensity is shown in Fig. 1 and average light intensity at different orientations is shown in Fig. 2.

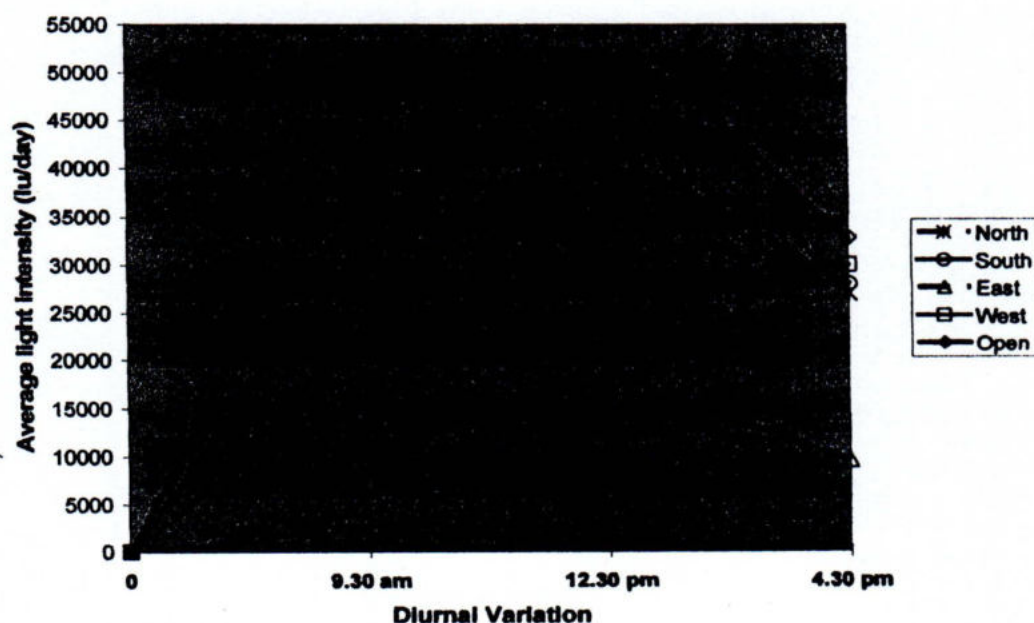


Fig. 1.: Light interception at different orientations of litchi tree due to diurnal variation during April to June 2007

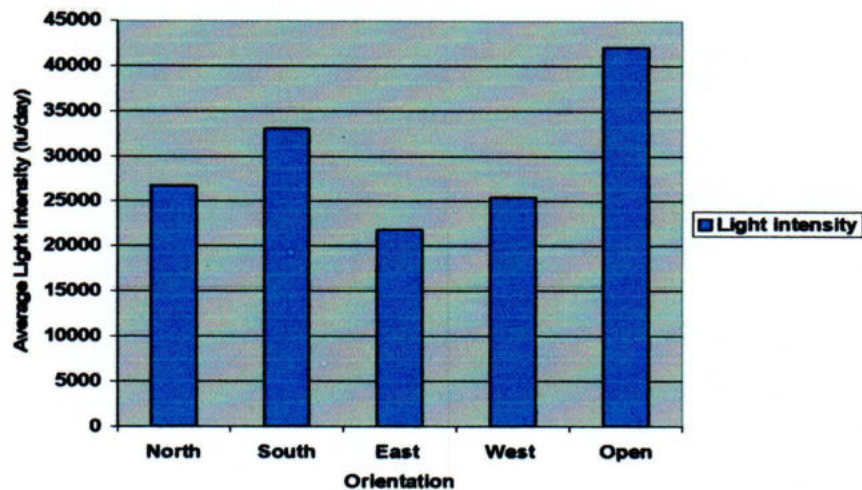


Fig. 2: Average light interception (lux) per day at different orientation of litchi tree from April to June 2007.

3.13 Data analysis

The data on various growth and yield contributing characters of Indian spinach and pineapple were statistically analyzed to determine the significant variation of the result due to different orientations effect of litchi based multistoried production system. The analysis of variance for each of the studied character was done by F (variance ratio) test following Randomized Complete Block Design (RCBD). These data were analyzed statistically following ANOVA technique and means separations were adjusted by DMRT test at 1% and 5% level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

Orientational effect of Litchi tree on different parameters of Indian spinach are described bellow

4.1 Vine length

Vine height of Indian spinach grown between the rows of pineapple was significantly affected by different orientations of litchi tree (Table 1 and Table 2). Indian spinach grew vigorously under Litchi tree than that of open field. Significantly the largest vine height (69.33 and 59.67cm at the first and second harvesting dates, respectively) was found in east orientation of litchi tree, which was statistically similar (Table 1) to that of west orientation (61.33 and 50.33 cm, respectively). Significantly the shortest vine height was recorded in open field (41.00 and 27.67 cm in both sampling dates). The moderate vine height observed in north and south orientation was also statistically identical. The longest vine height of Indian spinach in east orientation might be due to heaviest shade created by Litchi tree (48.61% shade) as compared to other orientations. Similar result was found by Miah *et al.* (2007) in case of egg plant under heaviest shade of Eucalyptus-cane association. Higher plant height under reduced light level was also reported by Islam (1995) in mungbean and Murshed (1996) in chick pea. This may attributed due to the stimulation of the cellular expansion and cell division under shaded condition.



Plate 7: Performance of Indian spinach at 30 DAS



Plate 8: Plate showing the growth of Indian spinach at different orientations.

4.2 Leaf number

Number of leaf per plant of Indian spinach was significantly affected by different orientations of litchi tree in association with pineapple (Table 1 and Table 2). The highest number of leaves was recorded in the open field at both harvesting dates (17.3 and 30.0 at 35 DAS and 70 DAS, respectively). At 35 DAS, number of leaf per plant recorded in north, south and west orientations were 17.00, 17.00 and 16.33, respectively which were statistically similar. But incase of second harvesting date (70DAS) number of leaves (28.0) under south orientation was statistically similar to that of open field (Table 2). The lowest number of leaves (23.6) was recorded in the east orientation which was statistically similar to that of north (26) and east orientation (23.6). Similar observation was also reported by Miah *et al.* (2007) in egg plant open field condition compared to different shade level of Eucalyptus-cane association. Ali (1999) also observed that number of leaf per plant of red amaranth gradually decrease in drumstick tree canopy compared to leaves number per plant obtained in open field.

4.3 Leaf Area

Leaf area of Indian spinach was significantly influenced by different orientations of litchi tree in association with pineapple (Table 1 and Table 2). At first harvesting date (35 DAS), significantly the highest leaf area was recorded in the open field (185.2 cm²), which was statistically similar to that of south orientation (174.7 cm²). Significantly the lowest leaf area was found in the east orientation (107.3 cm²) which was statistically similar to that of north (141.0 cm²) and west orientation (132.6 cm²). At second harvesting date, significantly the highest leaf area was also found in open field (109.6

cm²) (Table 2) followed by south orientation (58.4 cm²). But the leaf area values produced at south (58.42 cm²), north (58.5 cm²), east (55.7 cm²) and west (57.2 cm²) orientations were statistically similar. Similar observation was also reported by Ali (1990) who observed smaller size of leaf of red amaranth at different orientations under guava and drumstic trees compared to open field.

4.4 Vine Base Girth

Base girth of Indian spinach grown in association with pineapple at different orientation under litchi tree was significantly lower compared to open field at final harvesting time. At first harvesting date (35 DAS) there was no significant variation among the orientations, although numerically the highest base girth was found in open field (4.43 cm). At second harvesting date, significantly the highest vine base girth of Indian spinach was recorded in the open field (4.93 cm), which was statistically similar to that of north (4.50cm), south (4.66 cm) and west orientation (4.6 cm) (Table 2). Significantly the lowest vine base girth was found in east orientation (4.27 cm). Similar observation was also reported by Hossain *et al.* (2005) in the performance of Indian spinach grown in association with eucalyptus tree.

Table 1. Orientational effect of litchi tree on the performance of Indian spinach at 35 days after sowing (DAS)

Treatment	Vine length (cm)	No. of leaf plant ⁻¹	Base girth of vine (cm)	Leaf area (cm ²)	Leaf fresh weight plant ⁻¹ (g)	Stem fresh weight plant ⁻¹ (g)	Leaf dry weight plant ⁻¹ (g)	Stem dry weight plant ⁻¹ (g)
North	50.00 b	17.00 a	4.10 a	141.0 bc	58.20 ab	29.80 c	5.83 ab	3.533b
South	49.67 b	17.00 a	4.40 a	174.7 ab	58.63 ab	35.80 c	6.067 ab	5.06a
East	69.33 a	15.00 b	4.033 a	107.3 c	32.60 c	46.83 a	5.33 b	3.33 b
West	61.33 ab	16.33 a	4.067 a	132.6 bc	39.07 c	40.23 a	5.75 ab	3.43 b
Open	41.00 c	17.33 a	4.43 a	185.2 a	72.00 a	29.97 c	6.467 a	5.33 a
C V%	9.10	8.66	9.40	12.47	11.54	8.66	10.27	12.40

In a column, figures having similar letter(s) do not differ significantly where as figure (s) bearing dissimilar letter(s) differ significantly by DMRT.

Table 2. Orientational effect of litchi tree on the performance of Indian spinach at 70 days after sowing (DAS)

Treatment	Vine height (cm)	No. of Leaf Plant ⁻¹	Base girth of vine (cm)	Leaf area (cm ²)	Leaf fresh weight plant ⁻¹ (g)	Stem fresh weight plant ⁻¹ (g)	Leaf dry weight Plant ⁻¹ (g)	Stem dry weight plant ⁻¹ (g)
North	39.67 bc	26.00 b	4.50 ab	58.50 b	31.70 b	35.30 ab	6.000 b	5.50 ab
South	31.00 c	28.00 ab	4.66 ab	58.42 b	37.30 ab	33.40 ab	6.167 b	4.40 b
East	59.67a	23.67 b	4.267 b	55.75 b	20.87 b	44.87 a	5.067 c	4.37 b
West	50.33 b	25.67 b	4.67 ab	57.25 b	29.53 b	37.97 ab	5.267 c	5.17 ab
Open	27.67c	30.00 a	4.933 a	109.6 a	45.17 a	30.97 b	7.200 a	6.17 a
C V%	11.40	13.51	9.75	10.23	12.24	14.14	9.88	5.50

In a column, figures having similar letter(s) do not differ significantly where as figure (s) bearing dissimilar letter(s) differ significantly by DMRT.

4.5 Leaf Fresh Weight

Leaf fresh weight per plant of Indian spinach was significantly influenced by different orientations of litchi tree in association with pineapple (Table 1 and Table 2). At first harvesting date (35 DAS), significantly the highest leaf fresh weight was recorded in open field (72.0 g), which was statistically similar to that of north (58.2 g) and south (58.6 g) orientations. Significantly the lowest leaf fresh weight per plant was found in the east orientation (32.6 g), which was statistically similar to that of west orientation (39.07 g). At second harvesting date (70 DAS), significantly the highest leaf fresh weight was also found in the open field (45.17 g), which was statistically similar to that of south orientation (37.30 g). Significantly the lowest leaf fresh weight was recorded in the east orientation (20.87g), which was statistically similar to that of north (31.70 g) and west (29.53 g) orientations. Similar observation was found in open field reported by Miah *et al.* (2005) in turmeric and zinger under different light levels.

4.6 Stem Fresh Weight

Stem fresh weight per plant was significantly affected by different orientations of litchi tree in association of pineapple (Table 1 and Table 2). At first harvesting date (35 DAS), significantly the highest stem fresh weight per plant was recorded in east orientation (46.83 g), which was significantly identical to that of west orientation (40.23 g) of litchi tree. Significantly the lowest stem fresh weight per plant was found in the north orientation (29.80 g), which was statistically similar to that of south orientation (35.809 g) and open field (29.97 gm). At second harvesting date (70 DAS), significantly highest stem fresh weight per plant was found in the east orientation (44.87 g), which was statistically similar to that of north (35.30 g), south (37.30 g) and west (37.97 g) orientations of litchi tree.

Significantly the lowest stem fresh weight per plant was recorded in the open field (30.97 g). Similar observation was found by Hossain *et al.* (2005) for Indian spinach in association of eucalyptus trees.

4.7 Leaf Dry Weight

Leaf dry weight (per 100 g) was significantly influenced by different orientation of litchi tree in association of pineapple (Table 1 and Table 2). At first harvesting date, significantly the highest leaf dry weight (per 100 g) was recorded in the open field (6.467 g), which was statistically similar to that of north (5.83 g), south (6.06 g) and west (5.75 g) orientations of litchi tree. Significantly the lowest leaf dry weight was found in the east orientation (5.33 g). At second harvesting date, significantly the highest leaf dry weight (per 100 g) was found in the open field (7.20 g) followed by south orientation (6.17 g), which was statistically similar to that of north orientation (6.0 g). Significantly the lowest leaf dry weight was recorded in east orientation (5.06 gm), which was statistically similar to that of west orientation (5.27 g). This variation of dry matter production might be different due to variation of light intensity as photosynthesis is directly related to light intensity or light duration per day and dry matter production is directly proportional to the rate of photosynthesis. Similar observation was found by Hossain *et al.* (2005) that leaf dry weight (per 100 g) increase in open field with increase of light level in Indian spinach cultivation under eucalyptus tree.



Plate 9: Demonstration of different parts of Indian spinach for calculating dry matter parameter.

4.8 Stem Dry Weight

Stem dry weight (per 100g m) was significantly affected by different orientation of litchi tree in association of pineapple (Table 1 and Table 2). Significantly the highest stem dry weight (per 100 g) was recorded in the open field (5.33 g) which was statistically identical to that of south orientation (5.06 g) at the first harvesting date (35 DAS). Significantly the lowest stem dry weight (per 100 g) was found in the east orientation (3.33 g), which was statistically similar to that of north (3.53 g) and west (3.43 g) orientation of litchi tree. At the second harvesting date, significantly the highest stem dry weight per plant was also found in the open field (6.17 g) which was statistically similar to that of north (5.5 g) and west (5.17 g) orientation of litchi tree. Again, significantly the lowest stem dry (per 100 g) was recorded in the east orientation (4.37 g) which was statistically similar to that of south orientation (4.40 g). Similar observation was found by Hossain *et al.* (2005) in Eucalyptus-Indian spinach association.

4.9 Yield of Indian Spinach

The yield of indian spinach produced with pineapple was greatly affected by the orientational effect of litchi tree (Table 3.)

Table 3: Orientalational effect on yield of Indian spinach grown in between two concentric rows of pineapple.

Treatment	Yield		Total yield/plant (gm)	Yield (kg)/Orientation (19.63 m ²)
	1 st Harvesting (gm/plant)	2 nd Harvesting (gm/plant)		
North	88.0	67.0	155	12.17
South	94.43	70.7	165.13	12.96
East	79.43	65.74	145.17	11.39
West	79.30	67.5	146.8	11.52
Open Field	101.97	76.14	178.11	13.98

The highest yield was found in the open field (13.98 kg) and the lowest yield was observed in the east orientation (11.39 kg). Different orientations i.e. north, south and west orientation produced 12.17 kg, 12.96 kg, and 11.52 kg, respectively.

The yield of different orientation (t/ha) is represented in the fig. 3.

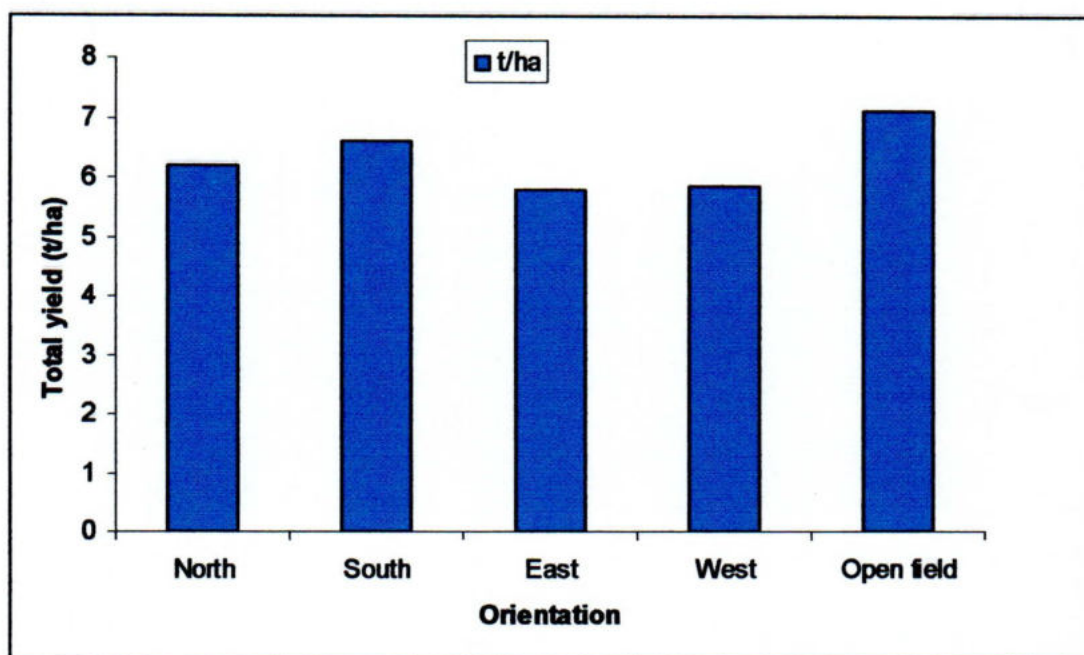


Fig. 3. Total yield (ton ha^{-1}) of Indian spinach grown with pineapple at different orientations of litchi tree.

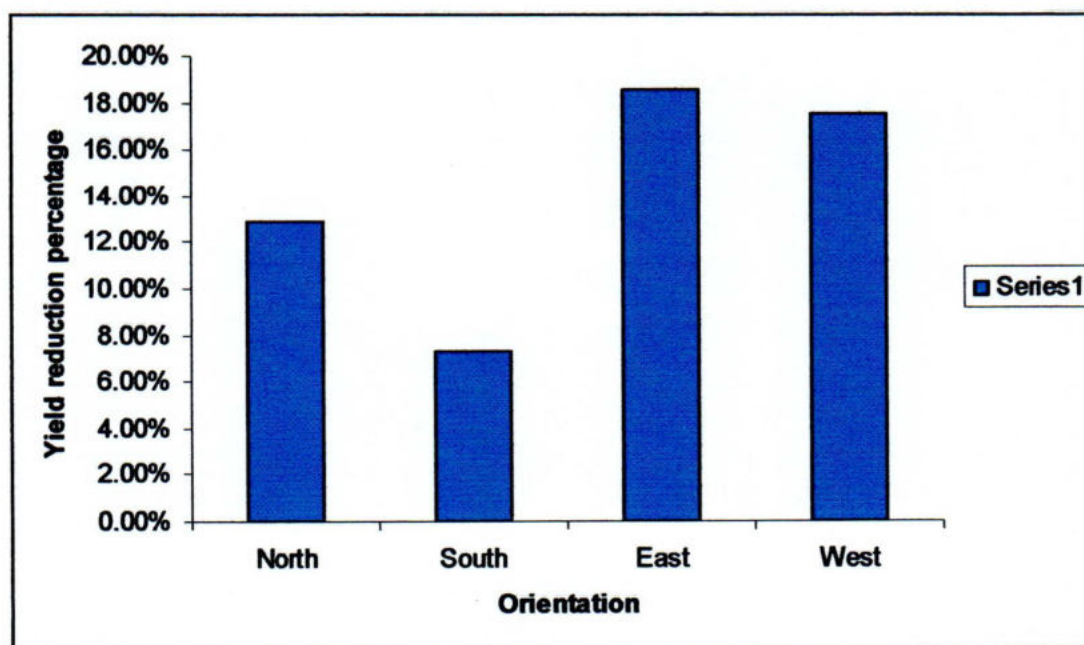


Fig. 4. Yield reduction of Indian spinach in association of pineapple at different orientation of litchi tree as compared to open field.

Orientational effect of Litchi tree on different parameters of pineapple are described below

4.10 Plant Height

Plant height of pineapple was significantly influenced by different orientations with litchi tree in association of Indian spinach (Table 4, Table 5 and Table 6). At first sampling date (4 MAP), significantly the highest plant height was recorded in east orientation (51.23 cm), which was statistically similar to that of north (49.43 cm) and south (50.25 cm) orientations. Moderate plant height was observed in south orientation (46.04 cm). Significantly the lowest plant height was found in the open field (40.5 cm). At second sampling date (8 MAP), significantly the highest plant height was also found in east orientation (61.17 cm), which was statistically similar to that of north (55.90 cm) and west (57.33 cm) orientations. Moderate plant height was observed in the south orientation (50.17 cm). Significantly the lowest plant height was recorded in open field (42.67 cm). At the third sampling date (12MAP), significantly the highest plant height was also recorded in the east orientation (70.43 cm), which was statistically similar that of north (68.33 cm) and west (69.40 cm) orientations. Moderate plant height was also observed in the south orientation (65.25 cm). Significantly the lowest plant height was trend in the open field (56.43 cm). This may be attributed due to the stimulation of cellular expansion and all division under shaded condition .Similar observation was found by Hossain *et al.* (1999) in Jackfruit, pineapple based agroforestry system.



Plate 10. Disease (Leaf blight) found at vegetative stage of pineapple (at 8 MAP)

Table 4. Morphological characteristics of pineapple (Giant Kew) at 4 month after planting (4 MAP)

Treatment	Plant height (cm)	No of leaf plant⁻¹	Leaf size (cm²)	Leaf dry weight (%)
North	49.43a	22.95ab	161.2a	9.97 a
South	46.04b	22.25ab	161.2a	11.32 a
East	51.23a	25.00a	178.4a	11.57 a
West	50.25a	23.90ab	170.5a	10.33 a
Open	40.5 c	20.67c	140.2b	9.8 a
CV%	8.61	9.31	12.95	13.95

In a column, figures having similar letter(s) do not differ significantly where as figure (s) bearing dissimilar letter(s) differ significantly by DMRT.

Table 5. Morphological characteristics of pineapple (Giant Kew) at 8 month after planting (8 MAP)

Treatment	Plant height (cm)	No of leaf plant⁻¹	Leaf size (cm²)	Leaf dry weight (%)
North	55.90ab	23.00ab	290.20a	9.90% a
South	50.17b	22.05 b	288.84a	10.18% a
East	61.17a	24.33a	339.9a	10.59% a
West	57.33a	23.20a	310.50a	10.97% a
Open	42.67c	17.00c	208.6b	8.72% b
CV%	9.56	4.81	8.46	4.5%

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing dissimilar letter (s) differ significantly by DMRT.

Table 6. Morphological characteristics of pineapple (Giant kew) at 12 month after planting (12 MAP)

Treatment	Plant height (cm)	No of leaf plant⁻¹	Leaf size (cm²)	Leaf dry weight (%)
North	68.33a	23.40a	235.40a	11.88% a
South	65.25b	23.05 a	230.40a	12.29% a
East	70.43a	25.33a	259.2a	15.40% a
West	69.40a	23.30a	250.40a	15.38% a
Open	56.43c	18.00b	220.0b	12.35% a
CV%	4.50	6.28	12.08	2.15%

In a column, figures having similar letter(s) do not differ significantly where as figure (s) bearing dissimilar letter(s) differ significantly by DMRT.

4.11 Leaf Number

Number of leaf of pineapple was significantly affected by the different orientation of litchi tree in association of Indian spinach (Table 4, Table 5 and Table 6). At the first sampling date (4 MAP) significantly the highest leaf number were recorded in east orientation (25.0) which was statistically similar to that of north (22.9), south (22.2) and west (23.9) orientation of litchi tree. Significantly the lowest leaf number was found in the open field (20.6). At the second sampling date (8 MAP), significantly the highest leaf number were also recorded in east orientation (24.3), which was statistically similar to that west orientation (23.2) and north orientation (23.0). Moderate leaf number was found in the south orientation. Significantly the lowest leaf number was recorded in open field (17.0). At the third sampling date (12 MAP), significantly the highest leaf number was recorded in east orientation, which was statistically identical to that of north (23.4), south (23.1) and west (23.3) orientations of litchi tree. Significantly the lowest leaf number was recorded in the open field (18.0). Similar observation was found by Hossain *et al.* (1999) in jackfruit pineapple based agroforestry system.

4.12 Leaf Size

Leaf size plant⁻¹ was significantly affected by the different orientation of litchi tree in association of Indian spinach (Table 4, Table 5 and Table 6). At the first sampling date (4 MAP), significantly the highest leaf size was found in the east orientation (178.4 cm²) which was statistically identical to that of north (161.2 cm²), south (161.3 cm²) and west (170.5 cm²) orientations. Significantly the lowest leaf size was observed in the open field (140.2 cm²). At the second sampling date (8 MAP), similar pattern of results were found like the first sampling date. Significantly the highest leaf

size was found in the east orientation (339.9 cm^2) which was statistically identical to that of north (290.2 cm^2), south (288.84 cm^2) and west (310.50 cm^2) orientation. Significantly the lowest leaf size was found in the open field (208.6 cm^2). At the third sampling date (12 MAP), significantly the highest leaf size was found in the east (229.3 cm^2) orientation which was statistically identical to that of north (235.40 cm^2), south (230.40 cm^2) and west (250.40 cm^2) orientation. Significantly the lowest leaf size was observed in the open field (220.0 cm^2). This may be attributed due to stimulation of cellular expansion and cell division under shaded conditions. Similar observation was found by Miah *et al.* (2005) in turmeric in heaviest shade condition of different light levels. Similar observation was also found in Hossain *et al.* (1999) in jackfruit pineapple based agroforestry system.

4.13 Leaf Dry Weight

Leaf dry weight plant^{-1} was significantly affected by the different orientation of litchi tree in association of Indian spinach (Table 4, Table 5 and Table 6). At the first sampling date (4 MAP), there was no significant effect of different orientation of litchi tree on leaf dry weight of pineapple. At the second sampling date (8 MAP) significantly the highest leaf dry weight was found in west orientation (10.97%) which was statistically identical to that of north (9.90%), south (10.18%) and east (10.59%) orientations. Significantly the lowest leaf dry weight was observed in the open field (8.72%). At the third sampling date (12 MAP), there was also no significant effect of different orientations of litchi tree on leaf dry weight of pineapple. Similar observation was found by Hossain *et al.* (1999) in jackfruit–pineapple based agroforestry system.

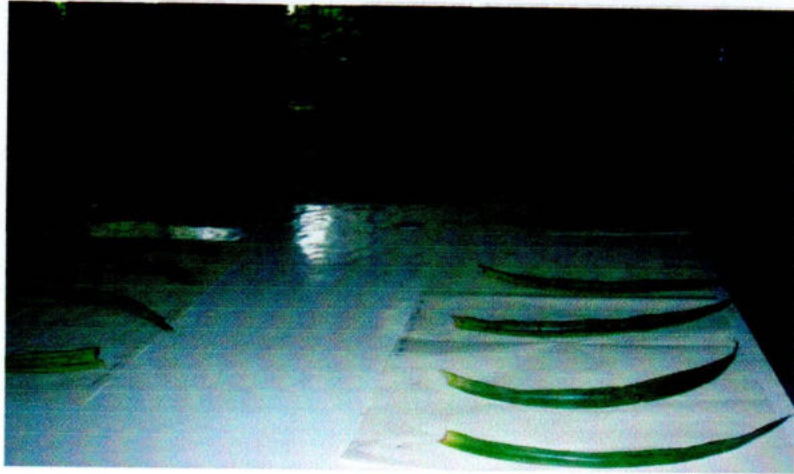


Plate 11: Leaves of pineapple from different treatments for data recording.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

The results of the present study showed that among four different orientation of litchi tree, the East possesses heaviest shade (48.61%) which was followed by West (40.16%), North (37.12%) and South (22.03%), respectively. The largest plant of Indian spinach as well as pineapple was recorded in East orientation. But in case of Indian spinach, all other parameters, except plant height performed better in the open field and all the values gradually decreased with the increased of average shade created by different orientations. On the other hand, pineapple exhibited the highest values for all its growth parameters in the east orientation as those possesses the maximum shade. Performance of Indian spinach and pineapple grown under different orientations of litchi tree varied significantly.

However, the results of the present study were achieved based on single season trial and specific tree species, which may not be predictable for other tree species. Similar experiment should be repeated at least in another season with the same tree at different agro-ecological regions. Moreover, the results guided us that the litchi orchard in northern part of Bangladesh has the potentiality to produce pineapple as well as Indian spinach with their association.

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Appendices

Appendix I: Nutrient fact of Indian spinach per 100 g edible portion.

Moisture	92.1 g	Thiamine	0.03 mg
Fat	0.7 g	Nicotinic acid	0.5 mg
Fibre	0.6 g	Calcium	73 mg
Protein	2.0 g	Oxalic acid	658 mg
Minerals	1.7	Iron	10.9 mg
Carbohydrates	2.9 g	Potassium	206 mg
Magnesium	84 mg	Sulphur	30 mg
Phosphorus	21 mg	Vitamin A	9300 I.U.
Sodium	58.5 m ^g	Riboflavin	0.07 mg
Copper	0.01 mg	Vitamin C	28 mg
Chlorine	54 in&		

Source: Aykroyd, 1956.

Appendix II: Monthly average temperature, relative humidity, total rainfall in the experiment site during the period from April to December 2007

Month	Air temperature (°C)		Relative humidity (%)	Total rainfall (mm)
	Max.	Min.		
April	32.8	21.1	83	54
May	13.9	21.5	77	213
June	33.2	23.2	82	333
July	32.0	25.8	85	369
August	32.4	26.2	84	466
September	32.0	25.0	89	97
October	31.6	21.0	90	0
November	27.5	15.5	72	0
December	26.6	11.9	85	

Source: Weather Yard, Wheat Research Center, Dinajpur.

**Appendix III. Representation of yearly light intensity (lux) from February
2007 to January 2008:**

Month	Orientation	Dis.	At 9.30 AM	At 12.30 PM	At 3.30 PM
February'07	North	D1	7820	4980	2530
		D2	125040	12250	4210
		D3	16050	18500	5580
		D4	22500	20500	6050
	West	D1	5480	7890	3870
		D2	7020	14950	4950
		D3	12500	35000	5950
		D4	21050	36900	6850
	South	D1	5950	6490	1450
		D2	9260	7550	2050
		D3	29500	19500	2990
		D4	30100	20100	4050
	East	D1	26600	9460	2520
		D2	30000	16020	3380
		D3	32500	37500	4050
		D4	33500	37800	5010
March'07	North	D1	9820	9080	9530
		D2	19540	19250	10500
		D3	29050	28500	14500
		D4	32500	0500	20500
	West	D1	6480	8890	7870
		D2	8020	15950	12500
		D3	13500	385000	20500
		D4	20100	395000	20050
	South	D1	5050	7490	16382
		D2	10050	9550	20370
		D3	30500	20100	21590
		D4	32500	30050	25000
	East	D1	27600	1060	3020
		D2	30200	18020	4100
		D3	32500	38500	6050
		D4	32500	39000	8050

April'07	North	D1	12585	10361	21050
		D2	39130	20215	25000
		D3	40100	42910	29050
		D4	42500	49050	30000
	West	D1	4022	5877	23150
		D2	6716	10050	25300
		D3	10570	42783	29950
		D4	32088	45050	30500
	South	D1	3978	4043	21382
		D2	5356	6590	23370
		D3	12150	13210	24070
		D4	39050	40830	26350
	East	D1	33700	8176	3912
		D2	35860	11990	4960
		D3	39900	17750	6800
		D4	40400	37900	8795
May'07	North	D1	14585	12361	27466
		D2	40133	23215	30000
		D3	42966	48916	30400
		D4	43566	51916	31666
	West	D1	5522	6877	27150
		D2	7716	10215	28300
		D3	13570	47783	30175
		D4	32988	49383	32000
	South	D1	4748	4983	23482
		D2	6356	7566	26375
		D3	131500	15210	26825
		D4	40060	43683	28350
	East	D1	38700	9176	4412
		D2	39860	13990	5960
		D3	41000	19392	7672
		D4	42400	38980	9695
June'07	North	D1	19900	8570	18386
		D2	29400	51800	22333
		D3	33400	53500	23320
		D4	34000	53900	25100

June'07	West	D1	13150	6040	15453
		D2	15940	10240	19426
		D3	25300	53200	21020
		D4	33500	54000	27850
	South	D1	8730	5450	10820
		D2	9830	7280	19350
		D3	15020	12900	21667
		D4	198000	53000	27333
	East	D1	11500	8040	6837
		D2	17560	12450	9867
		D3	21400	15920	11770
		D4	24300	18300	13473
July'07	North	D1	42000	11850	31200
		D2	47150	52150	31500
		D3	48450	54700	31800
		D4	48900	54800	32000
	West	D1	7185	7920	28000
		D2	9980	10470	30300
		D3	13600	52700	32000
		D4	19550	54000	32100
	South	D1	7060	5730	4950
		D2	8200	6630	28300
		D3	19100	9600	28700
		D4	45000	51500	29000
	East	D1	45500	8450	5030
		D2	47000	12650	7130
		D3	48150	51400	7430
		D4	48700	53400	8570
August'07	North	D1	47700	12400	23500
		D2	48600	17600	27600
		D3	48900	54200	27700
		D4	49500	54800	28500
	West	D1	6010	7360	16200
		D2	6690	11900	16700
		D3	10330	53300	17200
		D4	17570	54400	29800

	South	D1	4510	4960	19600
		D2	5770	6680	23200
		D3	14450	36000	24500
		D4	44300	53500	25000
	East	D1	46100	9950	4870
		D2	46900	15070	5920
		D3	47300	53800	7780
		D4	47400	54000	8730
September'07	North	D1	19100	13140	17250
		D2	23400	23900	20800
		D3	35000	32100	23000
		D4	38500	51300	23100
	West	D1	6680	8200	14850
		D2	8850	19020	15500
		D3	17050	47300	17250
		D4	38900	50100	20500
	South	D1	5850	5010	4740
		D2	8900	10140	5300
		D3	19300	22200	6400
		D4	41200	45600	9170
	East	D1	39300	12300	5560
		D2	42400	23800	7800
		D3	42700	44500	9160
		D4	43000	46400	10450
October'07	North	D1	10100	11040	10020
		D2	19900	20900	17500
		D3	29500	30100	19900
		D4	37500	40500	20100
	West	D1	5480	7200	10800
		D2	7050	17020	13500
		D3	15050	40500	14200
		D4	35000	49500	19500
	South	D1	4850	4010	3740
		D2	7900	10040	5100
		D3	19200	20200	6050
		D4	39050	40500	8170

	East	D1	38100	10300	4560
		D2	40400	20800	6800
		D3	41700	40500	8160
		D4	42000	42000	9950
November'07	North	D1	6900	10850	1844
		D2	10900	15950	2560
		D3	13400	19650	3180
		D4	38000	20900	3380
	West	D1	2840	8150	1470
		D2	4150	14000	2210
		D3	8900	43200	2530
		D4	32900	45000	2600
	South	D1	4050	4700	1015
		D2	6290	8700	1107
		D3	35500	13050	1530
		D4	37700	22400	2030
	East	D1	37100	8120	1093
		D2	38000	11340	1403
		D3	39500	40800	1650
		D4	39600	42500	1820
December'07	North	D1	7060	4650	1744
		D2	11350	4260	2460
		D3	12370	9850	3080
		D4	31900	12860	3250
	West	D1	3190	4660	1370
		D2	4090	7530	3110
		D3	8100	18500	2400
		D4	21300	28500	2530
	South	D1	8700	3400	1010
		D2	20800	4650	1105
		D3	33200	9650	1430
		D4	33500	12080	1930
	East	D1	32000	5250	1000
		D2	32600	8140	1330
		D3	34800	26000	1550
		D4	35600	30400	1720

January'08	North	D1	6820	6980	2230
		D2	11240	10210	3210
		D3	14060	14490	3980
		D4	21900	18250	4370
	West	D1	3480	5890	1870
		D2	5020	12650	2690
		D3	10120	34000	4150
		D4	17700	36000	4460
	South	D1	4600	4490	1130
		D2	8260	6550	1870
		D3	24600	17500	2540
		D4	29000	19800	3460
	East	D1	24600	7460	1420
		D2	28000	14120	2180
		D3	30900	36300	2710
		D4	31300	36500	3220

Appendix IV: Total yield (ton ha⁻¹) of Indian spinach grown with pineapple at different orientation under litchi tree.

Treatment	Total yield (ton/ha)
North	6.19
South	6.60
East	5.80
West	5.9
Open field	7.12

Appendix V: Yield reduction of Indian spinach in association of pineapple at different orientation of litchi tree compared to open field.

Treatment	Yield reduction (%)
North	13.06
South	7.30
East	18.53
West	17.13

Appendix VI. Map of Dinajpur Sadar Upazila showing the study area

