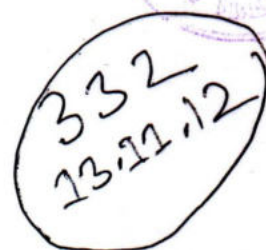


**VARIETAL PERFORMANCE OF NAPIER (*Pennisetum
purpureum*) FODDER UNDER MANGO BASED
AGROFORESTRY SYSTEM**



A THESIS

BY

FARJANA YESMIN

Student No. 1005007

Session: 2010-2011

Thesis Semester: March-August, 2012

MASTER OF SCIENCE (M.S.)

IN

AGROFORESTRY

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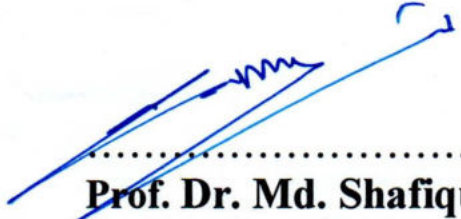
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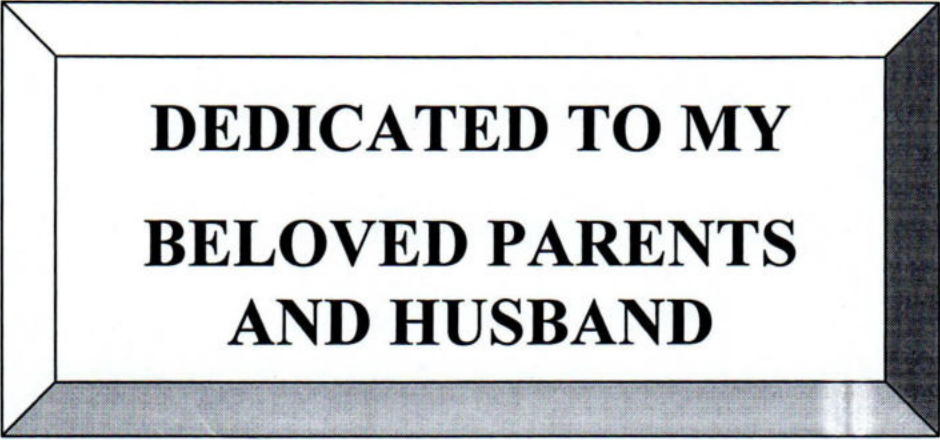

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JULY 2012

BISMILLA-HEER- RAHMANIR- RAHEEM

All praises are due to Almighty Allah, Who kindly enabled the
Author to complete the present research work



**DEDICATED TO MY
BELOVED PARENTS
AND HUSBAND**

DECLARATION

I declare that, the dissertation entitled “**VARIETAL PERFORMANCE OF NAPIER (*Pennisetum purpureum*) FODDER UNDER MANGO BASED AGROFORESTRY SYSTEM**” submitted to the Hajee Mohammad Danesh Science and Technology University, Dinajpur, for the degree of M S in Agroforestry is an original research outlined and carried out by me. No part of the thesis has been submitted elsewhere for any degree.

July, 2012

Fargana Yesmin
The Author

VARIETAL PERFORMANCE OF NAPIER (*Pennisetum purpureum*) FODDER UNDER MANGO BASED AGROFORESTRY SYSTEM

ABSTRACT

An experiment was conducted at the Agroforestry Research Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur during May to July 2010 to investigate the performance of napier fodder varieties under mango (*Mangifera indica*) orchard. The experiment was consisted of 2 factors RCBD with 3 (three) replications. Among the two factors, one factor A was two production systems: S_1 = mango + napier and S_2 = napier (sole crop); another factor B was three napier varieties: V_1 = BARI Napier- 1 (Bazra), V_2 = BARI Napier-2 (Arusha) and V_3 = BARI Napier-3 (Hybrid). The experimental results revealed that the main effect of variety on growth, yield contributing characters and yield of napier fodder were significantly varied from each other. The highest yield (4.97, 10.93 and 5.13 tha^{-1} at 1st, 2nd and 3rd harvest, respectively) was recorded in variety Bazra whereas the lowest yield (2.14, 5.47 and 2.85 tha^{-1} at 1st, 2nd and 3rd harvest, respectively) was recorded in variety Hybrid. Again, the yield of napier fodder were significantly influenced by the main effect of different production systems. The highest yield (10.01, 21.56 and 10.64 tha^{-1} at 1st, 2nd and 3rd harvest, respectively) of napier was recorded under mango based AGF system. Significantly, the lowest yield (8.28, 19.54 and 8.71 tha^{-1} at 1st, 2nd and 3rd harvest, respectively) was recorded in open condition i.e. sole cropping. Moreover, the interaction effect of different napier fodder variety and production system on the yield of napier was found significantly different at different harvest. The highest yield (6.53, 12.13 and 5.60 tha^{-1} at 1st, 2nd and 3rd harvest, respectively) was recorded in mango based AGF system with Bazra variety and the lowest yield (1.88, 5.60 and 2.85 tha^{-1} at 1st, 2nd and 3rd harvest, respectively) was found in mango based AGF system with Hybrid variety. Therefore, the suitability of napier cultivation under mango based AGF system may be ranked as Bazra > Arusha > Hybrid variety. Again, in case of economical analysis the BCR of mango based AGF system (3.91) was superior over sole cropping (3.28). So, from the findings it may be concluded that the cultivation of napier in the floor of mango orchard ensures higher revenue to the farmers compared to its sole cropping.

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CHAPTER 1

INTRODUCTION

Agroforestry is an integrated approach of using the interactive benefits from combining trees and shrubs with crops and/or livestock. It combines agricultural and forestry technologies to create more diverse, productive, profitable, healthy and sustainable land-use systems (USDA National Agroforestry Center). According to the World Agroforestry Centre, Agroforestry is a collective name for land use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land management unit. The integration can be either in a spatial mixture or in a temporal sequence. There are normally both ecological and economic interactions between woody and non-woody components in agroforestry. In agroforestry systems, trees or shrubs are intentionally used within agricultural systems, or non-timber forest products are cultured in forest settings. Knowledge, careful selection of species and good management of trees and crops are needed to optimize the production and positive effects within the system and to minimize negative competitive effects.

Silvopasture agroforestry system combine livestock grazing on forage crops or pastures within actively managed tree or shrub crops. Cattle, sheep and goats are the most common livestock incorporated into silvopasture systems and they may be deployed entirely within a private farm/woodlot.

Although biomass yield is the single most important criteria to select a fodder, there are other criteria like proportion of botanical fractions (e.g. leaf and stem), nitrogen and energy content of fodder are very important to be considered in selecting a fodder. The proportions of botanical fractions and their internal structure determine the nutritive value and intake of forages. Ruminants, particularly small ruminants naturally select leaf against stem because the former is more nutritious than the latter. It was reported that botanical fractions of straw might differ widely and has a significant effect on their chemical composition, physical characteristics and digestibility. Factors affecting proportions of botanical fractions and their nutritive value therefore may have important implications to manipulate nutritive value and intake of forages by animals. Islam et al. The proportion of leaf in forages can be increased by both agronomic factors or by selecting variety, the latter is often considered as one of the most significant factors influencing the proportions of botanical fractions of straw. Among non-legume perennial fodder, the yield potential of napier grass (*Pennisetum purpureum*) varieties was higher than other forages in Bangladesh.

Pennisetum purpureum (Napier Grass) is a species of grass native to the tropical grasslands of Africa. It has a very high productivity as a forage grass for livestock and wildlife. It was planted in Kenya on artificial terraces helping to stop erosion. ABC Science reports that "A team of Australian and Chinese scientists claims to have pioneered a method, using it as a Phytoremediation (Phytoremediation consists of

mitigating pollutant concentrations in contaminated soils, water, or air, with plants able to contain, degrade, or eliminate metals, pesticides, solvents, explosives, crude oil and its derivatives, and various other contaminants from the media that contain them) plant, to decontaminate polluted land and provide an ecologically renewable energy resource in the process. It is generally grown as a pure pasture. However, it has been sown in alternate rows with such legumes as *Pueraria phaseoloides* in Puerto Rico, *Centrosema pubescens* (Venezuela) and *Neonotonia wightii* in Uganda. Cutting or grazing management will have to be adjusted to favor the legume to maintain a satisfactory mixed sward.

Bangladesh has only 8.16 million hectares of arable land, the most densely populated countries of the world struggling hard to feed her more than 140 million people. Even the arable land is shrinking @ 86000 ha per year (BBS, 2011). So, there is no scope to allot crop field for fodder cultivation. Therefore, the current fodder deficit is likely to be amplified further with declining land: man ratio. Under this alarming situation, Bangladesh poses a big challenge to existing agriculture system for their fodder requirements. Therefore, development of appropriate and satisfactory safeguards against such situations should be the primary concern for optimal utilization of marginal lands. It is possible to bring unutilized land like the floor of different orchard under fodder production by using latest technologies. The utilization of the floor of mango orchard by planting fodder grasses i.e. fodder grass-mango based agroforestry system may be an alternative avenue to overcome the increasing demand of fodder.

Mango (*Mangifera indica*) is popular fruit in Bangladesh especially, in northern part due to its edaphoclimatic adaptability. In the northern part, the mango is an integral component of homestead gardening. However, day by day mango gardens are increasing. Now a days growing of different annual crops in association with mango is practiced by farmers but without much scientific considerations. So, we should develop some protocol and findings, which are beneficial for the growers. Keeping in view the manifold advantages associated with integration fodder grass like napier and mango into agroforestry production system, a study was conducted with mango as upperstorey and three Napier fodder grass cultivar as groundstorey components with the following objectives:

1. to study the productivity of napier fodder varieties grown under mango based agroforestry systems;
2. to evaluate different napier fodder variety for different quality traits under agroforestry system
3. to increase the land use efficiency by intercropping fodder grass in mango orchards;

CHAPTER 2

REVIEW OF LITERATURE

The research was carried out to observe the performance of three napier fodder varieties under mango tree in the different shading conditions. In recent times, the modern practices of agroforestry are extended in the fruit tree orchard in Bangladesh. The farmers are growing fodders under tree lots to get maximum benefit. But trees directly influence fodders 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 Concept of agroforestry systems
- 2.2 Tree-crop interaction
- 2.3 Importance of light in agroforestry
- 2.4 Characteristics of tree species in agroforestry systems
- 2.5 Performance of crop in agroforestry systems
- 2.6 Fruit tree based agroforestry systems
- 2.7 Performance of napier fodder in agroforestry systems

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 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 or animal in some form of spatial arrangement or temporal sequence.

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

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

From a business point of view agroforestry is an economic enterprise which aims to produce a combination of agricultural and forest crops simultaneously on the same land area.

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

MacDicken and Vergara (1990) state that agroforestry 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 3 important objectives: (i) protecting and stabilizing the ecosystems (ii) producing a high level output of economic goods (fuel, fodder, small timber, organic fertilizer etc) (ii) providing stable employment, improved income and basic material to rural populations.

2.2 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 quadrates were taken at a distance of 3m, 4.5m and 6m 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, 4.3 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 2 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 4 years old trees compared with those under 3 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 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 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. It has 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 (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 ind 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 (Reifsnnyder, 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

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 (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 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 Ingram (1989) 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.

The influence of *Acacia nilotica* on the growth and yield of associated wheat crop under irrigated condition in India was examined by (Sharma, 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, 1.64 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 than 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).

Growth of trees and seasonal yields of understorey crops were measured by Hicking *et al.* (1998) over a five year period for 4 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 rood pruning reduced average tree girths by up to 19% and average tree volume b up to 41% depending on intensity of pruning. The crops monitored were *Oryza sativa*, *Triticum aestivum*, *Corchorus oletorius*, 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 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 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 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 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 lebbek* three times a year contributed to the highest increase in rice (50%) and radish (35%) yields

2.6 Fruit tree based agroforestry systems

Osei *et al.* (2002) have undertaken an experiment to compare the merits of four cacao-coconut intercropping systems with the traditional cultivation of cacao under *Gliricidia sepium* shade at the Cocoa Research Institute of Ghana. Cacao seedling girth was not affected when intercropped with coconut but was significantly ($P=0.01$) reduced when intercropped with *G. sepium*. High density cacao facilitated better early canopy formation. Yield of cacao spaced at 2.5 m triangular (1739 plants ha⁻¹) with coconut at 9.8 m triangular (105 plants ha⁻¹) was significantly higher ($P=0.05$) than from the other treatments during 1993/94 to 1995/96. Widely spaced coconuts intercropped with cacao spaced at 3 m $\times$ 3 m showed better flowering and gave higher coconut yields, but cacao spaced at 2.5 m triangular under coconuts spaced at 9.8 m triangular was more profitable than the other treatments. Moisture stress was the greatest in cacao system with *G. sepium* shade and this could be responsible for the low yield of cacao in that treatment. It is suggested that properly arranged high density cacao under widely spaced coconuts can be a profitable intercrop system for adoption by cacao farmers in Ghana.

To evaluate the possibility of coffee production in the non-traditional and tribal area of Madhya Pradesh, India, yield variation in *Coffea robusta* (*C. canephora*) cv. Sanramon under different canopy shades was carried out by Gupta and Awasthi (1999). The experiment was conducted on 5 year old plants grown without shade, or with shade

provided by mango, mango + banana, guava, guava + banana or teak (*Tectona grandis*). Mango, guava and teak were aged 50, 10 and 45 years, respectively. The coffee yield was highest (mean for 5 years of 345 kg/ha) under mango + banana, followed by guava + banana (294 kg/ha), with lower yields in pure stands of mango, guava and teak. Yield was zero under control conditions (no shade).

Korikanthimath *et al.* (2000) conducted an experiment at Sirsi, Karnataka during 1992-95 to explore the possibility of cultivating cardamom (*Elettaria cardamomum* Maton) as a mixed crop with coconut. The average size of coconut holdings is as low as 0.22 ha and 98% of the holdings are below 2 ha. The results revealed that tall coconuts and short cardamom plants with varying rooting patterns and spacings intercepted solar energy at different vertical heights, and their roots (rhizosphere) absorbed nutrients and soil moisture at different depths and lateral distances. The coconut canopy provided adequate shade for shade-loving cardamom in this multi-storeyed cropping system. Intercropping with cardamom reduced coconut yield compared with coconuts in monoculture (mean values of 85.7 compared with 91.3 nuts/palm), but intercropping with high value cardamom increased overall profits (cardamom yields in 1993-94 and 1994-95 were 15.66 and 554.2 kg/ha, respectively).

An experiment was conducted by Sharma (1992) with six irrigated litchi orchards consisting of plants of different age groups (15-50 yr) around Jandwal and Kandwal areas in Kangra District, Himachal Pradesh to study the effects of shelterbelts of 3 species (*Eucalyptus*, *Grevillea* and *Leucaena*) on growth and yield of litchi plants. The

shelterbelts were planted either earlier or after the establishment of the litchi orchards. Five litchi plants were selected randomly in different farmers' fields and at different distances from the shelterbelts, and data on plant height, girth, spread, leaf area and yield of litchis recorded during 1989-90. The results indicate that *Eucalyptus* had an inhibitory effect on growth and yield of litchis, which decreased with increasing distance from the shelterbelt. Growth at all distances from *Grevillea* and *Leucaena* shelterbelts was better than that associated with *Eucalyptus*. Best litchi growth was near *Leucaena* shelterbelts.

Gosh (1987) carried out field trials of 3 tier cropping systems during 1983-84 at the experimental farm of the Central Tuber Crops Research Institute, Kerala. The first tier comprised 4 perennial species: coconut, banana, *Eucalyptus* hybrid (*E. tereticornis*) and *Leucaena leucocephala*. The second tier contained cassava and the third tier groundnut and French bean. Pure stands of perennials and cassava were also maintained separately as controls and all the crop species received recommended doses of fertilizers. Significantly better vegetative growth of cassava plants was observed when grown in association with banana, while no significant differences were recorded in the growth of the plants raised in pure and mixed stands with the other perennial species. Similarly, maximum fresh tuber yield was obtained from the cassava plants under banana. Tuber yield of cassava under *E. tereticornis*, however, was minimum and significantly less than that of the pure stand. Yield differences among other treatment combinations were not significant. Growth of banana and *L. leucocephala* was adversely affected by cassava during the first 12 months, whereas in *E. tereticornis* intercropped with cassava small

increases in growth occurred up to 18 months old. However, stem girths of *E. tereticornis* and *L. leucocephala* were greater in pure stands than in mixed stands with cassava. *L. leucocephala* gave better herbage yield in a pure stand. Banana fruiting at 18 months after planting was less in banana/cassava plots than in the pure stand. There were significant differences in leaf area index and nutrient uptake of cassava under different perennials. Again, the results of the trials on sloping ground at the Central Tuber Crops Research Institute in Kerala in 1983-86 when cassava was planted under the canopy of coconut, banana, Eucalyptus or *Leucaena spp.* Cassava stimulated the growth of Eucalyptus but reduced the growth of *Leucaena spp.*, particularly during the first 6-12 months of establishment. Shading by Eucalyptus increased from 15.0 to 52.6% over a 3-year period whereas shading by other perennials was observed only in adjacent rows of cassava. Growth and tuber yield of cassava in each year was greater when grown under banana than under any other crop and averaged 28.4 t/ha compared with 26.3 t for cassava grown in pure stand and 11.3 t when grown under Eucalyptus with groundnuts. *Vigna unguiculata* grown between rows of cassava reduced tuber yields less than the groundnuts and gave a fresh pod yield of 4.81 t/ha. Although the presence of cassava increased groundnut pod yield (1.07 t/ha), the perennial tree species, especially Eucalyptus, significantly reduced yield (0.41 t).

In a field study in 1997/98 in Kerala, yield correlations of twenty five green gram (*Vigna radiata*) genotypes grown under the shade of coconut trees were examined by Rajeswari and Kamalam (1999). They reported that seed yield/plant was positively associated with all the characters except the days to flowering, days to first harvest and

seeds/pod. Pods/plant and pod length were the prime characters for yield improvement in green gram under partially shaded conditions.

The coconut based mixed species systems in the tropics often aim at improved resource capture through incorporating several trees and field crops. Productivity of palms and the associated tree components in such mixed systems are, however, known to vary in response to the tree characteristics, planting pattern/geometry and shade tolerance of the components. The effects of three fast growing trees (*Vateria indica*, *Ailanthus triphyssa* and *Grevillea robusta*) grown in association with coconut palms following two planting geometries (single row and double row), on the productivity of coconuts and growth of multipurpose trees were studied in Kerala, India, during 1992-96 by Kumar and Kumar (2002). *A. triphyssa* demonstrated better growth than others with mean annual increments of 118 and 2.62 cm year⁻¹ for height and basal stem diameter (at 50 months after planting), respectively, compared to 98 and 1.26 cm year⁻¹ for *G. robusta*, which showed the next best height growth. Shade tolerance appears to be a major determinant of tree growth rates. It is concluded that integrating shade tolerant timber trees in the coconut based production systems could increase the overall productivity and profitability of coconut farms with no adverse effect on the main crop yield in the short term.

The effect of irrigation and 3 multiple crop systems: (A) + black pepper (*Piper nigrum*) + cocoa + elephant foot yam; (B) banana + black pepper + acidlime + arrowroot and (C) banana + betelvine + pineapple + elephant foot yam, on arecanut yield in a 16-year-old plantation was studied in Jalpaiguri and Coochbehar, West Bengal between 1983 and 1988 by Singh and Baranwal (1993). In general,

irrigation increased the yield of all crops compared with rainfed crops. The cultivation of mixed intercrops did influence the yield of arecanut; in crop system A (irrigated), the yield of arecanut rose by 4.1%, but arecanut yields decreased in all other plots by 10.5-24.2%. This decrease in yield was not as great as that observed in the control plot

A series of experiments carried out in 1988-90 by Aiyelaagbe and Jolaoso (1992) at Ibadan, south-western Nigeria. In these experiments papaya (*Carica papaya*) trees were intercropped with okra (*Abelmoschus esculentus*), watermelon (*Colocynthis citrullus/Citrullus lanatus*), sweet potato (*Ipomoea batata*), bush greens (*Amaranthus hybridus*), jews' mallow (*Corchorus olitorius*) and *Solanum gilo*. Sweet potato and *S. gilo* caused marked reduction in the yield of papaya. Land Equivalent Ratio (LER) values for papaya intercropped with okra, watermelon, sweet potato, bush greens, jews' mallow and *S. gilo* were 3.86, 3.13, 2.06, 1.86, 1.60 and 1.54, respectively, indicating that all the combinations were more advantageous than the monocrop of papaya. Monetary value of the mixtures, however, indicated that the inclusion of intercrops of sweet potato or *S. gilo*, is disadvantageous. It is suggested that although intercropping in papaya orchards is beneficial, it should be limited to the early vegetative and late fruiting phases of papaya when the Leaf Area Index (LAI) of papaya is low. A relay of okra followed by watermelon or bush greens, followed by jews' mallow (or sweet potato grown for fodder), is considered suitable for cropping in the alleys of papaya.

Leucaena leucocephala (var. K8) growth (height, collar diameter and diameter at breast height) and yield data (fresh and dry weight of

fodder and fuel) are reported by Gill *et al.* (1992) from the first year investigation (1990-91) of an intercropping trial at Jhansi, Uttar Pradesh, with mango (*Mangifera indica* 4 varieties, 'Amrapali', 'Mallika', 'Deshari' and 'Langra' were tested) which also included various other crops. Each 10×10 m subplot included one mango tree, 2 leucaena trees, and one of 4 intercrops: a fallow control; fodder crops (cowpeas and oats); grain crops (peanuts and wheat); and vegetables (Lady Fingers [*Abelmoschus esculentus*] and onions). They reported that above ground biomass yields of *L. leucocephala* ranged from 0.87 to 1.22 dry t/ha. Best leucaena fodder yields were in plots intercropped with vegetables and best fuelwood yields in plots intercropped with grain crops (this system also supported the best total biomass yields). Both leucaena and mango (height, collar diameter and canopy width) growth were better in plots with intercrops than in fallow plots.

Emebiri and Nwufu (1994) carried out experiments at the Teaching and Research farm of the Federal University of Technology, Nigeria (Lake Nwaebere campus) during 1991-92 cropping season to study the yield of *Telfairia occidentalis* (a leafy vegetable fluted pumpkin) grown at various distances (3, 4, 5 and 6m) from a row of mango trees. The results support the suggestion that crops whose harvestable parts are vegetative tend to be less affected when grown in proximity to trees, provided water is not limited.

A field trial was conducted by Braconnier (1998) on Santo Island, Vanuatu, where maize was intercropped with coconut palms, or grown in monocultures under full sunlight or with shading to give light transmission rates of 70, 40 and 30%. Under artificial shade, there was

a simple linear relation between yield and photosynthetically active radiation (PAR). Applying this relation to the maize-coconut intercropping system gave an estimated yield slightly higher than the actual harvest, possibly due to the difference between radiation interception by shading canvas and that obtained with a coconut cover. Root competition between the two crops was not detected. Maize net assimilation response to PAR was similar in all light treatments.

Field trials on the performance of mango-ginger (*Curcuma amada*) conducted at Vellayani (Kerala, India) by Jayachandran and Nair (1998) for 2 seasons under varying levels of shade revealed that rhizome yield under open and 25% shade were similar indicating that the crop is shade tolerant and is suitable for intercropping situations. Another field trial at Coimbatore, Tamil Nadu, Babu and Nagarajan (1993) studied the growth and development of 7 soyabean cultivars under shade in a coconut plantation. Greater shoot height, internodal elongation and lower leaf area index were the most significant growth changes noticed under shade. Leaf net photosynthesis, CGR and seed yield were also reduced under shade. Cv. Co 1, UGM 30 and UGM 37 recorded higher yield under shade when compared with other cultivars tested.

An experiment was conducted by Nizam and Jayachandran (1997) using three sizes of seed rhizomes (5, 10 and 15 g) of ginger cultivars Kuruppampady, Maran, Nedumangadu and Rio de Janeiro. These were planted in the open, or as an intercrop in a 30 year old coconut plantation, at Thiruvananthapuram, Kerala, India. The crop was harvested 8 months after planting, when volatile oil, non-volatile ether

extract (NVEE), crude fibre and starch contents were analysed. Volatile oil and starch contents were not significantly influenced by rhizome size. NVEE was significantly influenced by rhizome size in open conditions; plants raised from 15 g rhizomes had significantly higher NVEE than plants raised from 5 or 10 g rhizomes. However, this effect was not observed in the intercropping treatment. In open conditions, plants raised from 5 g rhizomes had the highest crude fibre contents, but when grown as an intercrop plants raised from 15 g rhizomes had the highest crude fibre contents. The variety Kuruppampady recorded the highest NVEE under open and intercropped conditions.

In a field trial conducted during 1994-95 and 1995-96 by Hegde *et al.* (2000) to investigate the performance of ginger cv. Suprabha grown as intercrop in an adult arecanut plantation (30-year-old) at the Agricultural Research Station (Pepper), Sirsi, Karnataka, India, and its performance was compared with those planted under open conditions. Ginger plants grown as intercrop were significantly taller than those under open conditions (pure crop) when measured 200 days after planting and had significantly lower number of functional leaves and tillers per clump. Interception of photosynthetically active radiation (PAR) by ginger was maximum at 110 DAP, both in open conditions (1.088 ly/min) and in the intercrop (0.788 ly/min). Percentage of PAR intercepted by ginger out of total PAR was the lowest at 170 DAP in both open (74.4%) and under arecanut shade (56.41%). Mean duration of ginger crop grown in open conditions was 184.5 days, while it was 198.5 days when grown as intercrop. Per plant yield of ginger under arecanut plantation was significantly higher (154.5 g) when compared

to open conditions (118.8 g/plant). Individual rhizomes of ginger grown in arecanut plantation were slightly bigger (4.5 g/rhizome) than the crop grown in open (3.4 g/rhizome). Yield of arecanut was not affected due to intercropping with ginger during the two years study. However, there was slight improvement in the yield of arecanut (3.20 kg chali/palm) when compared to monocropping of arecanut (2.59 kg Chali/palm).

Fifty cassava lines were evaluated by Sreekumari *et al.* (1998) for tuber yield under shade in a coconut garden in Kerala, India. Comparative information on the effect of shade on growth and development of 16 genotypes was gathered by raising them simultaneously in uniform shade in a 'shade house' as well as in the open conditions. Yield was significantly reduced under shade. Reduced number of sprouts, increased plant height, longer internodes, bigger leaves, reduced number of leaves and increased leaf longevity were the other salient morphological changes noticed under shade.

Ravishankar and Muthuswamy (1986) intercropped *Zingiber officinale* in a six-year old arecanut plant. They reported a progressive improvement of dry matter production in tops up to 210th day while in rhizome it continued up to 240th day after planting. Singh *et al.* (1986) from a survey of 190 farms of varying size on which arecanuts were intercropped with five cash crops, inferred that ginger was one among the crops which can be profitably intercropped with arecanuts. Aiyadurai (1986) stated that turmeric is not adversely affected by partial shade. He reported 67.2 to 89.6 q ha⁻¹ of fresh turmeric yields under rainfed conditions.

Pushkaran *et al.* (1985) reported that in trials over 3 years, 14 cultivators of turmeric (*Curcuma longa* L.) were grown in a coconut plantations with the palms spaced at 8 m x 8 m. The yield of turmeric ranged from 4.78 t ha⁻¹ (cv. Ventimetta) to 17.36 t ha⁻¹ (cv. Annruthaparri Kothapetto). Jaswal *et al.* (1993) reported that the plant height, number of tillers per plant, number of leaves per plant, the yield per plant, yield per hectare, rhizome length and rhizome breadth of ginger and turmeric were better under poplar intercrops compared to when grown as pure crops. Among different spacings of poplar (5x5m, 5x4m and 5x3m); 5x4m was found to be most suitable for ginger and 5x5m for turmeric. Moreover, Sundararaj and Thulasidas (1976) emphasized that turmeric performs well under partial shade but dense shade affects the yield adversely. They added that it is being recommended as an economic intercrop with coconut in coconut gardens. A yield of 8.61 t ha⁻¹ of ginger and 10.64 t ha⁻¹ of turmeric was obtained when intercropped under coconuts in India, which like other intercropped cash crops, was found to yield in the range of 60 to 75 per cent of the yield obtained from crops raised on open areas (Nair, 1979; Nelliath and Bhat, 1979). Of nine cultivars of turmeric intercropped in a coconut plantation, the highest yield was obtained for cv. sungatham (18.86 t ha⁻¹) and the lowest 9.3 t/ha for cv. Armour.

Satheesan and Ramadasan (1980) studied relative performance of turmeric raised as an intercrop in coconut garden and as a pure crop. The incident Photosynthetically active radiation (PAR) at any given time of the day was about 50 per cent less under the coconut canopy.

They observed that the leaf area index (LAI) and crop growth rate (CGR) reached their maximum much earlier in the pure crop than in the intercrop. This difference in the growth rate during the initial period of rhizome development was reflected in the significant differences observed in the final yield of the intercrop (4.8 t ha⁻¹ and pure crop (7.0 t ha⁻¹). They further added that the yield superiority observed in the pure crop was attributed to the higher CGR during rhizome formation and development, and higher solar energy input under open conditions during this period.

2.7 Performance of napier fodder in Agroforestry systems

Roothaert (1999) a trial was conducted in the central Kenyan highlands to determine the dry matter intake (DMI) by dairy heifers for napier grass (*Pennisetum purpureum*) plus supplements of either fresh *Calliandra calothyrsus*, fresh *Moms alba* (mulberry), dried *Manihot glaziovii* (cassava tree), fresh *Leucaena diversifolia* (leucaena) or dairy meal. Five Ayrshire heifers were stall fed and exposed to each diet in a latin square design, providing five replicates in five periods. Napier grass was supplied ad libitum and supplements at 25% of estimated daily DMI. Plant parts, twig diameters, crude protein (CP) content, in vitro digestibility and, in sacco rumen degradability of consumed material were determined. DMI for supplements and napier were significantly different at $p < 0.05$; intake of digestible crude protein, rumen degradable dry matter and digestible dry matter were significantly different at $p < 0.001$. Animals were able to select parts of the tree fodder with higher contents of CP, higher in vitro digestibility and higher rumen degradability than the average of the offered supplement. Ash content, condensed and soluble tannins

were higher but neutral detergent fibre and acid detergent fibre contents were lower in offered than left over tree fodder. Thickness of consumed branches increased with rainfall figures and measured up to 5 mm for leucaena, 9 mm for mulberry and 12 mm for calliandra. Studies such as this one will enable researchers to estimate the feeding values of different fodder trees and enable them to recommend optimum rations including these fodders. Through comparison of DMI, indications of palatability of tree fodders can be obtained. Of the fodder tree species tested in this experiment, mulberry and cassava tree had the highest potential in terms of milk production levels. Experiments are needed feeding these two species to lactating cows. © 1999 Elsevier Science B.V. All rights reserved.

- Devendra, (1993) reported that Napier grass was unfertilised and allowed to grow 1.5-2 m tall before it was cut. In this way napier was providing a low quality basal diet representing farmers situation in the dry season. The grass was chopped with a hand chopper to pieces of about 2 cm length. *Calliandra calothyrsus*, *Leucaena diversifolia* and *Manihot glaziovii* (cassava tree) were planted at a density of 20000 trees ha⁻¹, *Moms alba* (mulberry) at 30000 trees ha⁻¹. Calliandra and leucaena were planted with seedlings while mulberry and cassava tree were planted with cuttings. Cutting height of all trees was 50 cm. The first harvest for the experiment started 9 months after planting date, when all species had shown good growth. The fodder of calliandra, mulberry and leucaena that was offered to the heifers consisted of leaves and succulent twigs, and was fed fresh. During the last months, the fodder also included green pods of calliandra and leucaena. The

leaves of cassava tree were harvested together with one third of the petioles. This fodder of cassava tree was then detoxified through sun drying, a process that destroys the precursors of HCN. One batch of commercial dairy meal was bought that lasted throughout the experiment.

Hughes (1998) reported that the experimental design was a Latin square with five heifers, five periods and five treatments. In one period all heifers were on a different treatment. Each heifer was allocated a different treatment every period, in order to obtain five replicates per treatment. Napier grass was fed ad libitum to all heifers throughout the experiment at 10% above the average consumption. The treatments were different fodder supplements: calliandra, mulberry, leucaena, cassava tree and a control of dairy meal. The amount of DM of supplement offered was calculated for each animal at a rate of 0.625% of the live weight (25% of the total DM intake, which was estimated at 2.5% of live weight). The amounts were revised every 2 weeks. Each treatment period lasted 3 weeks. Although leucaena contains the toxin mimosine, dietary inclusion level was below the safe threshold of 30%, and the species used, *L. diversifolia*, is known to contain less mimosine than the more often used *L. leucocephala*. The amounts of feeds offered were recorded every feeding time, the amounts left over were weighed and recorded every morning at 8.00 am. Grass and tree fodder left overs could easily be separated. Samples of offered and left over feeds were taken weekly and dried at 60°C. Voluntary intake of the different tree supplements was measured through mean DM intake of supplement. The heifers were weighed weekly.

Kumar *et al.* (2000) said that the adapted tree+grass combinations make a valuable contribution to forage production in the Indian peninsula, but knowledge of the interactive effects between trees and grasses on their production is limited. We, therefore, conducted a field experiment involving combinations of four trees and grasses, besides monospecific grass controls, for seven years, to investigate grass productivity in association with leguminous and non-leguminous multipurpose trees (MPT) having disparate canopy architecture, and to assess the end-of-rotation soil fertility changes. Post rotation changes in herbage productivity were evaluated by growing teosinte (*Zea mexicana*) for three years. The four MPTs were *Acacia auriculiformis*, *Ailanthus triphysa*, *Casuarina equisetifolia* and *Leucaena leucocephala*. Grasses included *Pennisetum purpureum* (hybrid napier), *Brachiaria ruziziensis* (congo signal), *Panicum maximum* (guinea grass) and teosinte. Lower tree branches were pruned from fifth year. Understorey herbage production increased until three years in all tree+grass combinations, but declined subsequently, as tree crowns expanded. Overall, casuarina among MPTs, and hybrid napier and guinea grass among forage crops, were more productive than others. Pruning MPTs generally favoured greater herbage production. Understorey light levels for acacia, ailanthus, casuarina and leucaena were 17, 60, 55 and 55% of that in the open at five years. During the post-rotation phase, MPT plots were characterised by higher soil nutrient capital and consequently teosinte yields were higher than in the treeless control treatment. All previous tree-grass combinations showed an increasing trend till two years after MPT felling. Yield levels declined subsequently, despite at variable rates. Careful selection of the tree and

grass components is, therefore, crucial for optimising herbage productivity in silvopastoral systems.

Kiyoshi Nagasuga and Fumitake Kubota (2006) reported that the acclimation to light condition is associated with change in water transport system in napiergrass. In this study, the effects of shading on shoot hydraulic resistance and morphology of napiergrass (*Pennisetum purpureum* Schumach.) were investigated. In the plants under shading (to 30% of full sunlight) for 30 days (S plants), total hydraulic resistance of a shoot (R_{shoot}) increased from that of full sunlight (control). In the plants grown under shade condition for 24 d followed by full sunlight conditions for 6 d (SF), the R_{shoot} value was intermediate between that of control and S plants. A similar response to shading was found in total hydraulic resistance of a stem (R_{stem}), which accounted for more than 60% of R_{shoot} , but the total hydraulic resistance of the leaves was not significantly affected by shading. Leaf length, leaf area and stem length were larger, but the stem cross-sectional area (SA) was smaller in S and SF plants than in the control plants. SF plants showed similar leaf length, leaf area and stem length to those in S plants, but the SA in SF plants was slightly larger. Normalization of R_{stem} by SA and stem length decreased the difference among the treatments, indicating the increase of R_{shoot} and R_{stem} under shading resulted from the decrease of SA and the increase of stem length. Acclimation to light condition is associated with change in water transport system in napiergrass. In this study, the effects of shading on shoot hydraulic resistance and morphology of napiergrass (*Pennisetum purpureum* Schumach.) were investigated. In the plants under shading (to 30% of full sunlight) for 30 days (S plants), total

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Orodho (2006) reported that the high potential agricultural areas of Kenya are very densely populated and holding sizes are very small; natural grazing is no longer available so cattle have to be fed on crop residues, cultivated fodder and some concentrates. Dairy cattle, in very small herds or singly, are now kept under stall feeding and zero grazing and exotic breeds or their crosses with zebu are preferred to better valorize the fodder. Fresh milk is an important and profitable product in many areas and is increasingly being produced as an income source for smallholders. The serious fall in the price of coffee, previously a major cash crop, has led to its being partially replaced by fodder in some areas. The minute farm size precludes grazing so for a long time the emphasis has been on high-yielding fodders for cutting: Napier

Grass (*Pennisetum purpureum*) has become by far the most important due to its wide ecological range (from the coast to over 2,000 metres), high yield and ease of propagation and management; sometimes herbaceous legumes or fodder shrubs are associated with the grass but their use is limited and their economics poorly documented. Kenya has a long history of pasture and fodder research and some of the studies and research on Napier Grass in Kenya are described below – these have mainly been on its agronomy with some on feeding value. Most, practically all the cultivars in widespread use are old, at least half a century since their introduction and there is a lack of new cultivars of Napier Grass and of serious studies on other grasses which might supplement it to widen the genetic base of fodders for small-farm use. There are now serious problems of emerging diseases, both fungal and mycoplasmal, which threaten Napier Grass in Eastern Africa and, unless resistant cultivars and alternative fodders are found, the smallholder dairy industry will be in trouble.

Eleonora *et al.* (2002) reported that the research was conducted in the experimental farm of the EPAMIG-Leopoldina, MG, to evaluate intake of elephantgrass, the effectiveness of limiting grazing time to four daily hours for keeping intake close to maintenance level, and the weight gain of thirty-six steers during five successive periods of thirty-six days, during the rainy season. The treatments were: free access to pasture (unlimited grazing) and restricted grazing. The availability of green dry matter varied from 4.0 to 7.8 kg/100kg LW. The average daily weight gain of animals with free access to pasture was 516.5 g and their dry matter intake corresponded to 1.61 times that from the restricted grazing ones. The estimated gain per hectare was 423.5 kg,

which is within the range reported for elephantgrass in Brasil. Metabolizable energy intake, per unit metabolic size, remained stable in the first three periods and increased in the last two, during which the highest weight gains of the animals. Four daily hours grazing period ensured intake close to maintenance level.

Abate *et al.* (2008) observed that the fodder crops that are or could be used in the high-potential areas of Kenya for purposes of maximizing animal production are identified and discussed in terms of their nutritive value and efficient utilization by animals. The DM productivity of most of the fodder crops was found to be about five times that produced by a common pasture species such as Rhodes grass (*Chloris gayana*). Data on in vivo digestibility, intake and performance of livestock when fed fodder are lacking, however, and information on chemical composition is scanty. It is suggested that feed resources be expanded to include crops other than the now well established Napier grass (*Pennisetum purpureum*) and that the defoliation practiced on maize be tried on other cereal crops. In a multi-disciplinary approach, it was recommended that research be directed towards evaluation of food crops which also double as fodder, and to multipurpose trees and shrubs, for the benefit of farmers in the high-potential areas.

CHAPTER 3

MATERIALS AND METHODS

In this chapter 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 are described below:

3.1 Description of the Experimental Site

3.1.1 Location

The experimental site was selected in the existing mango orchard of the Agroforestry Research Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur. The geographical location of the site was between 25° 13' latitude and 88° 23' longitude, and about 37.5m above the sea level.

3.1.2 Soil characteristics

The experimental plot was situated in a medium high land belonging to the old Himalayan Piedmont Plain area (AEZ 01). Land was well-drained as drainage system was well developed. The soil texture was sandy loam in nature. The detail soil properties are presented in Appendix-I.

3.1.3 Climate

The experimental site was situated under the tropical climate characterized by heavy rainfall from July to August and scanty rainfall the rest period of the year. Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (May 2010 to July 2010) are included in the Appendix-II.

3.2 Experimental period

May to July 2010

3.3 Cuttings collections

Napier cuttings were collected from Bangladesh Livestock Research Institute, Savar, Dhaka.

3.4 Experimental design

Factorial RCBD with 3 (three) replication

3.5 Experimental treatments

The experiment consisted of 2 (two) factors:

Factor A: (Production systems)

S_1 = Mango + Napier

S_2 = Napier (sole crop)

Factor B: (Napier varieties)

V_1 = BLRI Napier -1 (*Penicitum peripurium* Var. 1) (Bazra)

V_2 = BLRI Napier -2 (*Penicitum peripurium* Var. 2) (Arusha)

V_3 = BLRI Napier -3 (*Penicitum peripurium* Var. 3) (hybrid)

Treatment combinations:

The treatments of the experiments will be as mentioned below-

S_1V_1 = Mango+ BLRI Napier -1

S_1V_2 = Mango+ BLRI Napier -2

S_1V_3 = Mango+ BLRI Napier -3

S_2V_1 = Open+ BLRI Napier -1 (Mono/sole cropping of BLRI Napier -1 variety)

S_2V_2 = Open+ BLRI Napier -2 (Mono/sole cropping of BLRI Napier -2 variety)

S_2V_3 = Open+ BLRI Napier -3 (Mono/sole cropping of BLRI Napier -3 variety)

In mango+napier based Agroforestry production system, the average light interception for the growth of the ground layered crops i.e. napier was 63 to 70%. Again, in the sole cropping of napier, it was cultivated under full sunlight (i.e. open conditions). In this treatment 100% sunlight was prevailed.

Mango tree			Open		
R ₁	R ₂	R ₃	R ₁	R ₂	R ₃
S ₁ V ₁	S ₁ V ₃	S ₁ V ₂	S ₂ V ₁	S ₂ V ₃	S ₂ V ₂
S ₁ V ₂	S ₁ V ₁	S ₁ V ₃	S ₂ V ₂	S ₂ V ₁	S ₂ V ₃
S ₁ V ₃	S ₁ V ₂	S ₁ V ₁	S ₂ V ₃	S ₂ V ₂	S ₂ V ₁

Note: Plant to plant distance= 35 cm, Line to line distance= 70 cm and plot size= 5m x5m

Fig 1. Layout of treatments combinations in mango trees with control open field.

3. 6 Napier varieties and plant characteristics

BLRI Napier -1 (*Peniclitum peripurium* Var. 1) (Bazra)

It is used as fodder crop. The plants tiller freely and a single clump may produce 50 tillers under favourable climatic and soil conditions. Unfortunately, the grass is coarse-textured, the leaf blade and sheaths hairy, leaf margins sharply toothed and stems less juicy and fibrous. In 1953, a cross was made in India with bajra which is more succulent, leafy, fine textured, palatable, fast growing and drought resistant. Compared to Napier grass, Hybrid Napier produces more tillers and numerous leaves. It grows faster and produces more herbage but the stems are hard and the plants less persistent. Pusa Giant Napier has larger leaves, softer and less persistent hairs on leaf blades and sheaths and less sharp leaf edges. The stems are also less fibrous than Napier. The tillers are more numerous and grow faster. The grass grows throughout the year in the tropics. The optimum temperature is about 31°C. Light showers alternated with bright sunshine are very congenial to the crop. Total water requirement of the grass is about 800-1000 mm. Hybrid *Pennisetum* can grow on a variety of soils. Light loams and sandy soils are preferred to heavy soils. The grass does not thrive well on waterlogged and flood prone lands. Phenomenal yields are obtained from very deep fertile soil rich in organic matter. It tolerates pH ranging from 5 to 8. Hybrid Napier requires a deep, thorough weed free and compact seedbed. Three or four ploughings followed by disc harrowing is ideal. The popular hybrids are Pusa Giant Napier, Gajraj, NB-5, NB-6, NB-21 and NB-35. Planting is done with the onset of southwest monsoon. Being a sterile hybrid, the grass is planted by rooted slips or by stem cuttings. Cuttings of moderately mature stems (3 months old) and preferably from the lower two thirds of the stem

length sprout better than the older stems. The cuttings with three nodes are stuck into the soil with the basal end down, either vertically or at an angle to such a depth that two nodes remain within the soil and one above the soil surface. The under ground nodes develop roots and shoots while the upper ones develop shoots only. A spacing of 60 x 60 cm is recommended for pure crop of Hybrid Napier. In intercropping system, spacing is adjusted to accommodate the companion crops. The planting rate depends upon the spacing and the weight of the cuttings or rooted slips used. It is modified in crop mixtures or intercropping with other forage crops. Farm yard manure @ 25 t/ha, and P₂O₅ and K₂O @ 50 kg/ha each may be applied at the time of land preparation. Apply N @ 200 kg/ha in two or three split doses followed by gentle raking, if possible. The field should be provided with good drainage during the rainy season, as the crop cannot withstand water stagnation. Frequency of irrigation depends upon the rainfall and weather conditions. Early intercultivation once or twice is necessary before the plants establish and grow vigorously. Subsequently, intercultivation should be given as and when necessary. The first cut is taken 9 -10 weeks after planting. Subsequent cuts are taken after four to six weeks or when the plant attains a height of 1.5 m. Annually at least six to eight cuts are possible. In order to encourage quicker regeneration from the basal buds, stubbles of 10-15 cm is left out at harvest. Green fodder yield ranges! 200-250 t/ha per year from 6-8 cuttings. The grass can be intercropped with legumes such as cowpea, Calapogonium, Centrosema and Glycine legumes. Intercropping with legumes improves the quality of fodder. Hybrid Napier is superior in quality than Napier grass and contains about 10.2% crude protein and 30.5%

crude fibre. The leaves are larger and greener, the sheaths are softer and the margins less serrated and hence the herbage is more palatable. It is juicier and succulent at all stages of growth. It is less fibrous and more acceptable. The oxalate content of some of the varieties may be high. It can be mitigated if harvested at longer intervals (45 to 60 days). The grass is ideal for green fodder, silage and hay. The fodder can be chaffed and ensiled. Legume fodders may be mixed with the grass in tile ratio of 1:2 to produce better balanced silage. The fodder can also converted into hay during the dry summer periods. The chaffed material is exposed to the sun only for a day. Further drying is done under the shade to preserve the colour. The quality of the silage or hay remains more or less the same as green fodder.

BLRI Napier -2 (*Peniclitum peripurium* Var. 2) (Arusha)

It is a perennial stoloniferous grass widely grown throughout the tropics and sub-tropics in areas with rainfall in excess of 1250 mm per annum. It will cease growth in dry seasons if water is not available. It has long runners which can spread rapidly, roots vigorously at the nodes, has thick hairy stems, slightly hairy leaves 10–30 cm long and 8–20 mm wide and can grow up to 1–1.5 m high. Stolons may be 4 m long. Probably native to Africa but naturalized in America, it is especially important in the South and Central American tropics. It is now widely cultivated in many countries amongst which are Australia, Fiji, the Philippines, Puerto Rico and Cuba. Seed production is poor and it is popular because of its ease of propagation from cuttings (hand-planted or disced), rapid establishment, high yields, quality and palatability of feed produced and tolerance of waterlogged and flooded conditions. Arusha should not be grazed shorter than about 45 cm

average height (45–55 cm. In wet areas it can become a problem by blocking drainage channels.

BLRI Napier -3 (*Peniclitum peripurium* Var. 3) (hybrid)

It is also a robust perennial forming large broad clumps spreading by stem bases rooting from nodes or by short rhizomes and propagated by stem cuttings or divided rootstocks. With erect stems this vigorous and productive grass can vary from 2–6 m in height. There are a range of varieties differing not only in height but also in size of leaves, thickness of stems and flowering behaviour. Leaves are commonly long (50–100 cm) and narrow (15– 30 mm) with a prominent midrib and rough edges. *P. purpureum* grows naturally throughout tropical Africa and has now been introduced to nearly all tropical and many sub-tropical areas. It is well suited to areas with rainfall of more than 1,000 mm, but cannot tolerate flooding or waterlogged soils. Although capable of high production under open conditions (60 t ha⁻¹ yr⁻¹ of dry matter), and somewhat shade tolerant. Napier is not really suited for general use under coconut due to the difficulties of grazing, management and locating fallen nuts, and because its excessive demand for nutrients and moisture causes competition with coconut palms unless heavy rates of fertilizer is applied. However, it's potential for rapid growth and high yields and its drought tolerance that its root systems can extend down to 450 cm) mean that it is ideally suited to zero grazing and for use as a fodder or cut-and-carry crop. He recommended that Napier could be used for small intensive forage production areas under high fertilizer applications, but preferably in the less shady areas of plantations (light transmission > 80%) to obtain best results. In fact some authors argue that this fodder crops system is

3.7 Mango tree plant characteristics

Scientific name: *Mangifera indica* L.

Family: Anacardiaceae (cashew family)

Common name: Mango

It has been grown throughout the tropical and subtropical world for thousands of years and has become an integral part of many cultures. There are many different names for mangos around the world today reflect the cultures and languages spoken by people who grow them. Many of the names have common derivations, reflecting the origins and spread of the mango tree along with the spread of human communities.

Distribution: All tropical and subtropical regions.

Size: Mangos are long-lived evergreen trees that can reach heights of 15-30 m (50-100 ft). Most cultivated mango trees are between 3 and 10 m (10-33 ft) tall when fully mature, depending on the variety and the amount of pruning. Wild, non-cultivated seedling trees often reach 15 m (50 ft) when found in favorable climates, and they can reach 30 m (100 ft) in forest situations. The trees can live for over 100 years and develop trunk girths of over 4 m (13 ft).

Habitat: Grows from sea level to 1200 m (3950 ft) in tropical latitudes; however, most commercial varieties are grown below 600 m (1950 ft); rainfall 400-3600 mm (16-140 in), fruits best with a well defined winter dry period.

Canopy: Mango trees typically branch 0.6-2 m (2-6.5 ft) above the ground and develop evergreen, dome-shaped Mangos grown in heavily forested areas branch much higher than solitary trees and have an umbrella-like form.

Root: The mango has a long taproot that often branches just below ground level, forming between two and four major anchoring taproots that can reach 6 m (20 ft) down to the water table.

Growth rate: Fast, >1.5 m/yr (5 ft/yr) in ideal condition.

Main agroforestry uses: Home gardens, silvopasture.

Main uses: Fruit, flavoring, medicinal, timber.

Yield: Typically, yields are often less than 5 mt/ha (2.2 t/ac) but can reach 20-30 mt/ha (9-13.5 t/ac); single trees can produce 200-300 kg (440-660 lb) of fruit in heavy cropping years and as low as 5 kg in bad years.

Soil: Tolerates a range of soils; optimal pH 5.5-7.5.

Intercropping: Compatible with other similarly vigorous species, as well as animal grazing.

Invasive potential: Not an aggressively invasive species.

3.8 Land Preparation

The land of the experimental plot was opened on 05 May 2010 with a power tiller and it was made ready for sowing on 15 May 2010 by sloughing with a country plough followed by laddering. The corners of the land were spaded and visible larger clods were hammered to break into small pieces. All weeds and stubble were removed from the land. The layout was done as per experimental design. All basal doses of fertilizers as per schedule of the experimental were incorporated into the soil and finally the plots were made ready for sowing.

3.9 Application of fertilizer and manure

The fertilizers used as a general dose in the experimental plots were urea @ 200 kg ha⁻¹. Used of recommended doses of manure and TSP, SSP, Gypsum and Boric acid.

3.10 Cuttings of napier

Every 20 days the Napier fodders were cutting at the base and weighted for data collection.

3.11. Sampling and data collection procedure

For collecting data on several plant characters, 10 (2 from each orientation) randomly selected plants were uprooted from each plot before harvesting. The harvested fodder crops were then weighted plot-wise and was recorded plot-wise on fresh moisture basis as ton /ha. From the 10 selected plants per plot the following parameters were recorded.

- Plant height (cm)
- Number of leaf
- Leaf length
- Leaf breadth
- Number of tiller Plant⁻¹
- Yield
- Dry weight

3.11.1 Plant height

The plant height was measured from the ground level to the top of the leaf. From each plot 10 hills were measured and averaged at 30, 45 and 60 days after planting (DAP).

3.11.2 Number of leaf

Number of leaf was counted from the selected hills at 30, 45 and DAT (Days after planting).

3.11.3 Leaf Length

Leaf Length was measured by measuring in 30, 45 and 60 DAP by scale in cm.

3.11.4 Length of leaf blade

Length of leaf blade was measured by measuring scale in cm at 30, 45 and 60 DAP.

3.11.5 Number of tiller plant⁻¹

Number of tiller was counted from the selected plants at 30, 45 and 60 days after transplanting (DAP).

3.11.6 Yield

The harvested fodders were weighted plot-wise on fresh moisture basis. The weight of fodders was recorded in kg/plot. The fodder yield was later expressed in ton/ha.

3.11.7 Dry weight

A sample weight (1000g) of freshly harvested fodder leaves was taken and the fodder grass were cut into small pieces and firstly, air-dried in the laboratory. Air-dried sample was then oven dried for 48 hours at $70^{\circ}\text{C} \pm 2^{\circ}\text{C}$ in an oven. After drying, it was weighted in an electric balance having a sensitivity of 0.1mg.

3.12 Bio-economics of the napier-mango based agroforestry system.

3.12.1 Total cost of production

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

3.12.2 Gross return

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

3.12.3 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)

3.12.4 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 Statistical Analysis

Data collected from different parameters were compiled and tabulated in proper form. The statistical analysis ANOVA was done following RCBD design with the help of computer package MSTATC programme. The means were adjudged by Duncan's New Multiple Range Test (Gomez and Gomez, 1984).



Plate 1. Land preparation in mango orchard



Plate 2. Data collection at growth phase of Napier



Plate 3. Napier grown under mango based agroforestry system



Plate 4. Sole cropping of Napier fodder

CHAPTER 4

RESULTS AND DISCUSSION

The results of the study are presented in this chapter under different critical sections comprising growth, yield contributing characteristics, yield and quality parameters of three napier grass varieties and their cost-effective analysis. The experiment was conducted during 16 May 2010 to 15 July 2010 to achieve the objectives of the study. The results are critically discussed here experiment-wise citing accessible literature.

4.1 Main effect of variety on the growth, yield contributing characters and yield of napier fodder

4.1.1 Plant height (cm)

Plant height of napier grass was recorded from the ground surface to the tip of the leaf in all the treatments. The plant height of napier grass varied significantly (Table 1) at different Days After Planting like 30 DAP, 45 DAP and 60 DAP. Significantly, the tallest plant (89.88 cm, 127.0 cm, and 157.8 cm at 30 DAP, 45 DAP and 60 DAP) was observed in Bazra (V_1) which was statistically identical with the napier hybrid Arusha (V_2). The dwarf plant (73.22 cm, 119.2 cm and 132.9 cm at 30 DAP, 45 DAP and 60 DAP) was found in hybrid napier fodder (V_3). This might be occurred due to their genetical variation.

4.1.2 Number of tiller Plant⁻¹

Number of tiller plant⁻¹ of napier grass variety varied significantly at 30 DAP. At 30 DAP, the maximum number of tiller (2.52) was observed in Bazra (V_1) which was statistically identical with Arusha. Consequently, minimum number of tiller (2.00) was experienced in

hybrid napier grass (V₃). However, no significant variation among the treatment was observed at 45 DAP and 60 DAP. At 45 DAP and 60 DAP, the maximum number of tiller (4.50 and 5.67) was recorded in V₁ while minimum number of tiller (4.00 and 5.00) was found in V₃.

4.1.3 Number of leaf

Napier grass variety responded significantly with respect to number of leaf at different DAP (table 1). Significantly, the maximum number of leaf (41.33, 53.33 and 62.17 at 30 DAP, 45 DAP and 60 DAP, respectively) was recorded in Bazra which was statistically identical with Arusha. On the other hand, minimum number of leaf (36.00, 44.50 and 54.17 at 30 DAP, 45 DAP and 60 DAP) was recorded in napier hybrid variety i.e in V₃.

4.1.4 Leaf length (cm)

Leaf length (cm) of napier grass variety was varied also significantly at different DAP (table 2). Significantly, the longest leaf (50.52 cm, 62.31 cm and 70.82cm at 30 DAP, 45 DAP and 60 DAP, respectively) was observed in Bazra followed by in V₂ i.e. in Arusha. Consequently, the shortest leaf (44.39 cm, 60.19 cm and 66.43 cm at 30 DAP, 45 DAP and 60 DAP, respectively) was found in napier hybrid grass variety.

Table 1. Main effect of variety on the growth parameters of napier grass

Treatments	Plant height (cm)			Number of tiller			Number of leaf		
	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP
V ₁	89.88a	127.0a	157.8a	2.52 a	4.50	5.67	41.33a	53.33a	62.17 a
V ₂	84.05a	123.9ab	153.4b	2.50 a	4.33	5.33	37.83b	52.17a	57.33ab
V ₃	73.22b	119.2b	132.9b	2.00 b	4.00	5.00	36.00b	44.50b	54.17 b
Level of Sig.	**	**	**	**	ns	ns	**	**	**
CV (%)	9.09	4.51	4.99	12.24	14.58	11.56	5.42	3.85	9.20

N.B. Same letter(s) in the table do not vary significantly but different letters vary significantly. ** =1% Level of significance, * = 5% Level of significance, ns= Not significant, CV= Coefficient of variance

4.1.5 Leaf breadth (cm)

Leaf breadth (cm) napier grass variety do not vary significantly among themselves at 30 DAP and 45 DAP (table 2). However, significant variation among the napier grass variety was observed at 60 DAP. The maximum leaf breadth (1.59 cm, 1.77cm and 2.67 cm at 30 DAP, 45 DAP and 60 DAP) was recorded in Bazra. On the other hand, minimum leaf breadth (1.49 cm, 1.61cm and 2.59 cm at 30 DAP, 45 DAP and 60 DAP) was recorded in napier hybrid variety.

4.1.6 Yield (tha^{-1})

Yield (tha^{-1}) of napier varieties were varied significantly at different DAP (table 2). Significantly, the highest yield (4.97 tha^{-1} , 10.93 tha^{-1} and 5.13 tha^{-1} at 1st, 2nd and final harvest, respectively) was recorded in V_1 i.e. in Bazra. Significantly, the lowest yield (2.14 tha^{-1} , 5.47 tha^{-1} and 2.85 tha^{-1} at 1st, 2nd and final harvest, respectively) was recorded in napier hybrid variety (V_3). Again the intermediate yield (3.87 , 8.20 and 4.23 t/ha at 1st, 2nd and final harvest, respectively) was found in the arusha napier variety (V_2).

Table 2. Main effect of variety on the yield and yield attributing characters of napier grass

Treatments	Leaf length (cm)			Leaf breadth (cm)			Yield (tha^{-1})		
	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP	1 st harvest	2 nd harvest	3 rd harvest
V_1	50.52a	62.31 a	70.82a	1.59	1.77	2.67a	4.97 a	10.93 a	5.13 a
V_2	46.31b	60.40b	67.44b	1.55	1.77	2.63ab	3.87 ab	8.20 ab	4.23 a
V_3	44.39b	60.19b	66.43b	1.49	1.61	2.59 b	2.14 b	5.47 b	2.85 b
Level of Sig.	**	**	**	ns	ns	**	**	**	**
CV (%)	4.41	2.24	2.38	7.05	7.12	2.29	15.23	17.42	16.52

N.B. Same letter in the table do not vary significantly but different letters vary significantly. ** =1% Level of significance, * = 5% Level of significance, ns= Not significant, CV= Coefficient of variance

4.1.7 Dry Weight (g)

Significance variation in terms of dry weight was also observed among the different napier variety (fig. 2). Significantly, maximum dry weight (141.1 g) was recorded in Bazra (V_1). On the other hand, the minimum dry weight (132.5 g) was recorded in napier arusha variety (V_2).

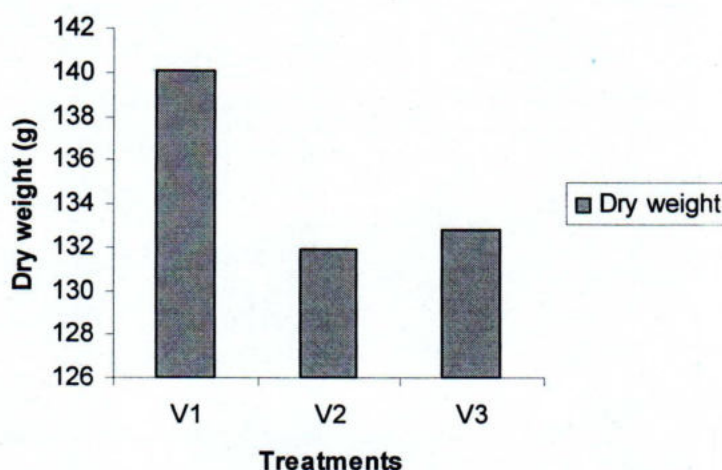


Fig 2. Dry weight of napier fodder influenced by different variety

4.2 Main effect of the production system on the growth, yield contributing character and yield of Napier fodder

4.2.1 Plant height (cm)

Napier grown under mango based agroforestry systems was more vigorous than those grown in sole cropping i.e. in full sun light conditions (Table 3). It exhibited considerably higher height under mango based Agroforestry system. At 30 DAS the tallest plant (84.32 cm) was observed in mango + napier based Agroforestry system (S_1) where as the shortest plant (82.45 cm) was observed in sole cropping of napier (S_2). Again at 45 DAS the tallest plant (125.82 cm) was observed in mango + napier based Agroforestry system (S_1) on the other hand the shortest plant (123.91 cm) was observed in sole cropping of napier (S_2). Significantly at 60 DAS the tallest plant (150.05 cm) was observed in mango + napier based Agroforestry

system (S₁) on the other hand the shortest plant (148.07 cm) was observed in sole cropping of napier (S₂).

4.2.2 Number of tiller Plant⁻¹

Number of tiller plant⁻¹ of napier was significantly observed in different production system (Table.3). At 30 DAS the maximum number of tiller plant⁻¹ (2.73) was recorded in mango + napier based Agroforestry system (S₁) where as the minimum number of tiller plant⁻¹ (2.33) was recorded in sole cropping of napier (S₂). However, at 45 DAP and 60 DAP number of tiller plant⁻¹ of napier was non significant whereas highest number of tiller plant⁻¹ was recorded in mango+ napier based Agroforestry system (S₁) and the lowest was recorded in sole cropping of napier (S₂).

Table 3. Main effect of production system on the growth parameters of napier grass

Treatments	Plant height (cm)			Number of tiller			Number of leaf		
	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP
Mango+Napier (S ₁)	84.32a	125.82a	150.05a	2.73a	4.33	5.44	39.00a	52.78a	60.22a
Open (S ₂)	82.45b	123.91b	148.07b	2.33b	4.22	5.22	37.78b	49.22b	55.56
Level of Sig.	*	*	**	*	ns	ns	*	**	**
CV (%)	9.09	4.51	4.99	12.24	14.58	11.56	5.42	3.85	9.20

N.B. Same letter in the table do not vary significantly but different letters vary significantly. ** =1% Level of significance, * = 5% Level of significance, ns= Not significant, CV= Coefficient of variance

4.2.3 Number of leaf Plant⁻¹

Number of leaf Plant⁻¹ of napier was significantly observed in different production system (Table.3). At 30 DAP maximum number of leaf (39.00) was recorded in mango + napier based Agroforestry system (S₁) where as the minimum number of leaf (37.78) was observed in sole cropping of napier (S₂). In case of 45 DAP, the maximum number

of leaf (52.78) was recorded in mango + napier based Agroforestry system (S₁) where as the minimum number of leaf (49.22) was observed in sole cropping of napier (S₂). Again, at 60 DAP the maximum number of leaf (60.22) was recorded in mango + napier based Agroforestry system (S₁) where as the minimum number of leaf (55.56) was observed in sole cropping of napier (S₂).

4.2.4 Leaf length (cm)

Length of leaf of napier was significantly observed in different production system (Table 4). At 30 DAP the maximum length of leaf (48.27 cm) was recorded in mango + napier based Agroforestry system (S₁) where as the minimum length of leaf (46.88 cm) was observed in sole cropping of napier (S₂). In case of 45 DAP, the maximum length of leaf (62.18 cm) was recorded in mango + napier based Agroforestry system (S₁) where as the minimum length of leaf (60.74 cm) was observed in sole cropping of napier (S₂). Again, at 60 DAP maximum length of leaf (70.45 cm) was recorded in mango + napier based Agroforestry system (S₁) where as the minimum length of leaf (68.00 cm) was observed in sole cropping of napier (S₂).

Table 4. Main effect of production system on the yield and yield attributing characters of napier grass

Treatments	Leaf length (cm)			Leaf breadth (cm)			Fresh yield (tha ⁻¹)		
	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP	1 st harvest	2 nd harvest	3 rd harvest
Mango+Napier (S ₁)	48.27a	62.18a	70.45a	1.56	1.72	2.92a	10.01a	21.56a	10.64a
Open (S ₂)	46.88b	60.74b	68.00b	1.52	1.71	2.65b	8.28 b	19.54b	8.71 b
Level of Sig.	**	**	**	ns	ns	*	**	**	**
CV (%)	4.41	2.24	2.38	7.05	7.12	2.29	15.23	17.42	16.52

N.B. Same letter in the table do not vary significantly but different letters vary significantly. ** =1% Level of significance, * = 5% Level of significance, ns= Not significant, CV= Coefficient of variance

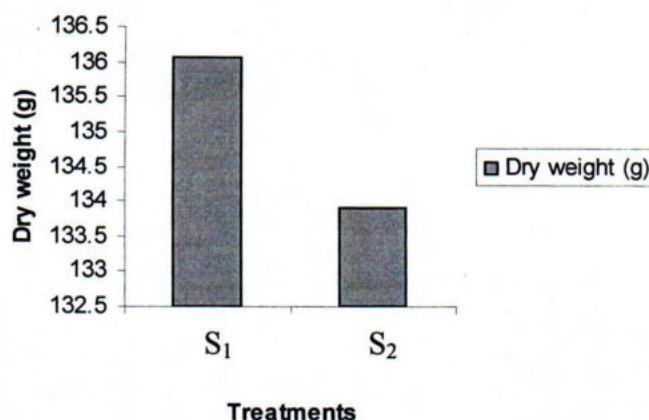


Fig 3. Dry weight of napier influenced by different production system

4.3 Interaction effect of variety and production system on the growth, yield contributing and yield of napier fodder

4.3.1 Plant height (cm)

The interaction effect, of variety and production system on the plant height of napier grass was found significantly different at different DAP (table 5). At 30 DAP the tallest plant of napier grass (94.66 cm) was recorded in V₁S₁ (Mango + Bazra based AGF) which was statistically identical with V₁S₂ (sole cropping Bazra) and V₂S₁ (Mango + Arusha based AGF), where as the shortest plant of napier grass (70.37 cm) was recorded in V₃S₂ i.e. sole cropping of hybrid napier grass variety. Again at 45 DAP the tallest plant of napier grass (132.3 cm) was recorded in V₁S₁ (Mango + Bazra based AGF) which was statistically similar with V₁S₂ (sole cropping Bazra), V₂S₁ (Mango + Arusha based AGF) and V₂S₂ (sole cropping Arusha). On the other hand, the shortest plant of napier grass (116.5 cm) was recorded in V₃S₁ (Mango + Napier hybrid variety based AGF). Significantly at 60 DAP the tallest plant of napier grass (176.6 cm) was recorded in V₁S₁ (Mango + Bazra based AGF) which was statistically identical with V₁S₂ (sole cropping Bazra). On the other hand, the shortest plant of napier grass (139.1 cm) was recorded in V₃S₂ i.e. sole cropping of

hybrid napier grass variety. This might be attributing due to the stimulation of cellular expansion and cell division of leaf sheath under shading condition. The result was partially similar with the findings of Garrity *et al.* (1992).

4.3.2 Number of tiller Plant⁻¹

Interaction of variety and production on the number of tiller plant⁻¹ of napier grass was found significantly different at DAP (table 5). At 30 DAP the highest (3.00) number of tiller plant⁻¹ of napier grass was recorded in V₁S₁ (Mango + Bazra based AGF) which was statistically identical with V₂S₂ (sole cropping Arusha). On the other hand, lowest (2.00) number of tiller plant⁻¹ of napier grass was observed in V₁S₂ (sole cropping Bazra) which is statistically similar with V₂S₁ (Mango + Arusha based AGF), V₃S₁ (Mango + Napier hybrid based AGF) and in V₃S₂ i.e. sole cropping of hybrid napier grass variety. However, number of tiller at 45 DAP was found non significant. But at 60 DAP, number of tiller plant⁻¹ of napier grass varied significantly. At 60 DAP the highest (6.33) number of tiller plant⁻¹ of napier grass was recorded in V₁S₁ (Mango + Bazra based AGF) which was statistically similar with V₂S₂ (5.67). Consequently, lowest (5.00) number of tiller plant⁻¹ of napier grass was observed in V₁S₂ (sole cropping Bazra) which is statistically similar with V₂S₁ (Mango + Arusha based AGF), V₃S₁ (Mango + Napier hybrid based AGF) and in V₃S₂ i.e. sole cropping of hybrid napier grass variety.

Table 5. Interaction effect of variety and production system on the growth parameters of napier fodder

Treatments	Plant height (cm)			Number of tiller			Number of leaf		
	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP
V ₁ S ₁	94.66 a	132.3 a	176.6a	3.00a	4.00	6.33a	42.00a	61.67 a	69.33 a
V ₁ S ₂	91.88 a	121.9abc	170.7a	2.00b	4.00	5.00b	40.67a	59.67 a	65.67ab
V ₂ S ₁	85.10ab	128.1 ab	136.1b	2.00b	4.00	5.00b	41.33a	47.00 b	58.67bc
V ₂ S ₂	76.22bc	121.7abc	134.5b	3.00a	4.67	5.67ab	30.67b	42.67 c	45.33 d
V ₃ S ₁	76.08bc	116.5 c	131.4b	2.00b	5.00	5.00 b	33.67b	43.67bc	52.67cd
V ₃ S ₂	70.37 c	119.7 bc	139.1b	2.00b	4.00	5.00 b	42.00a	45.33bc	55.67bc
Level of Sig.	**	**	**	**	ns	**	**	**	**
CV (%)	9.09	4.51	4.99	12.24	14.58	11.56	5.42	3.85	9.20

N.B. Same letter in the table do not vary significantly but different letters vary significantly. ** =1% Level of significance, * = 5% Level of significance, ns= Not significant, CV= Coefficient of variance

4.3.3 Number of leaf

The interaction effect of variety and production system on number of leaf per plant of napier grass was significantly influenced (Table 5). The maximum number of leaf per plant of napier grass at 30 DAP (42.00) was recorded in V₁S₁ (Mango + Bazra based AGF) which was statistically identical with V₃S₂ i.e. sole cropping of hybrid napier grass variety, V₁S₂ (sole cropping Bazra) and V₂S₁ (Mango + Arusha based AGF) . On the other hand, minimum number of leaf per plant of napier grass at 30 DAP (30.67) was recorded in V₂S₂ (sole cropping Arusha) which was statistically alike with V₃S₁ (Mango + Napier hybrid based AGF). Significantly, in 45 DAP maximum number of leaf per plant of napier grass (61.67) was recorded in V₁S₁ (Mango + Bazra based AGF) which was statistically identical with sole cropping Bazra (59.67). Moreover, the minimum number of leaf per plant of napier grass at 45 DAP (42.67) was recorded in V₂S₂ (sole cropping Arusha) which was statistically comparable with V₃S₁ (Mango + Napier hybrid based AGF) and in V₃S₂ i.e. sole cropping of hybrid napier grass variety.

Again, at 60 DAP the maximum number of leaf per plant of napier grass (69.33) was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with sole cropping Bazra (65.67). Consequently, the minimum number of leaf per plant of napier grass at 60 DAP (45.33) was recorded in V_2S_2 (sole cropping Arusha) which was statistically comparable with V_3S_1 (Mango + Napier based AGF).

4.3.4 Leaf length (cm)

Interaction effect of variety and production system on leaf length (cm) of napier grass vary significantly at different DAP (table 6). At 30 DAP the maximum length of leaf (51.92 cm) was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with sole cropping Bazra (49.88 cm) and V_2S_2 (49.12 cm) i.e. sole cropping Arusha. On the other hand, minimum length of leaf (41.63 cm) was recorded in V_3S_1 (Mango + Napier hybrid based AGF) which were statistically equivalent with V_3S_2 i.e. sole cropping of hybrid napier grass variety. Again, at 45 DAP the maximum length of leaf (62.92 cm) was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with sole cropping Bazra (61.83 cm), V_2S_2 (61.68 cm) i.e. sole cropping Arusha and V_3S_1 (Mango + Napier hybrid based AGF). Consequently, the minimum length of leaf (58.70 cm) was recorded in V_3S_2 i.e. sole cropping of hybrid napier grass variety which was statistically identical with V_2S_2 (58.96 cm) i.e. sole cropping Arusha. Moreover, at 60 DAP the maximum length of leaf (70.88 cm) was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with sole cropping Bazra (70.76 cm), V_2S_2 (70.03 cm) i.e. sole cropping Arusha and V_3S_1 (Mango + Napier hybrid based AGF). Consequently, the minimum length of leaf (63.09 cm) was

4.3.6 Yield (t ha⁻¹)

Yield of napier was taken at three intervals (table 6). At 1st harvest, highest yield was obtained from V₁S₁ (6.53 tha⁻¹) which was statistically similar with sole cropping Bazra (4.13 tha⁻¹), V₂S₁ (3.60 tha⁻¹) and V₂S₂ (3.40 tha⁻¹). On the other hand, lowest yield (1.88 tha⁻¹) was recorded from V₃S₁ (Mango + Napier hybrid based AGF) which was statistically similar with V₃S₂ (2.40 tha⁻¹) i.e. sole cropping of hybrid napier grass variety. Moreover, at 2nd harvest highest yield was obtained from V₁S₁ (12.13 tha⁻¹) which was statistically similar with sole cropping Bazra (9.73 tha⁻¹). Consequently, lowest yield (1.88 tha⁻¹) was recorded from V₃S₂ i.e. sole cropping of hybrid napier grass variety which was statistically similar (5.60 tha⁻¹) with V₃S₁ (Mango + Napier hybrid based AGF). Again, at 3rd harvest highest yield was obtained from V₁S₁ (5.60 tha⁻¹) which was statistically similar with sole cropping Bazra (5.27 tha⁻¹) and V₂S₁ (4.67 tha⁻¹). On the other hand, lowest yield (2.84 tha⁻¹) was recorded from i.e. sole cropping of hybrid napier grass variety which was statistically similar (2.85 tha⁻¹) with V₃S₁ (Mango + Napier hybrid based AGF).

Table 6. Interaction effect of variety and production system on yield and yield attributing characters of napier grass

Treatments	Leaf length (cm)			Leaf breadth (cm)			Fresh yield (tha ⁻¹)		
	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP	1 st harvest	2 nd harvest	3 rd harvest
V ₁ S ₁	51.92 a	62.92a	70.88a	1.69 a	1.90a	2.68 a	6.53 a	12.13 a	5.60 a
V ₁ S ₂	49.88ab	61.83a	70.76a	1.67 a	1.93a	2.68 a	4.13 ab	9.73 a	5.27 a
V ₂ S ₁	47.15 b	61.68a	70.03a	1.49ab	1.61b	2.69 a	3.60 ab	8.13 b	4.67 a
V ₂ S ₂	49.12ab	58.96b	64.84b	1.53ab	1.57b	2.68 a	3.40 ab	8.27 b	3.20 b
V ₃ S ₁	42.75 c	61.70a	69.77a	1.45 b	1.65b	2.50 b	1.88 b	5.60 c	2.85 b
V ₃ S ₂	41.63 c	58.70b	63.09b	1.42 b	1.63b	2.57ab	2.40 b	5.33 c	2.84 b
Level of Sig.	**	**	**	**	**	**	**	**	**
CV (%)	4.41	2.24	2.38	7.05	7.12	2.29	15.23	17.42	16.52

N.B. Same letter in the table do not vary significantly but different letters vary significantly. ** =1% Level of significance, * = 5% Level of significance, ns= Not significant, CV= Coefficient of variance

4.3.7 Dry Weight (g)

Dry weight of napier grass was significantly influenced by interaction effect of variety and production system (fig 4). Significantly, maximum dry weight (149.00 g) was recorded in V_1S_2 i.e. sole cropping of bazra which was statistically significant with V_1S_1 (Mango + Bazra based AGF), V_2S_1 (Mango + Arusha based AGF) and V_3S_1 (Mango+ napier hybrid based AGF). On the other hand, minimum dry weight was recorded from V_2S_2 (124.7 g) i.e. sole cropping of Arusha which was statistically similar with sole cropping of napier hybrid grass variety.

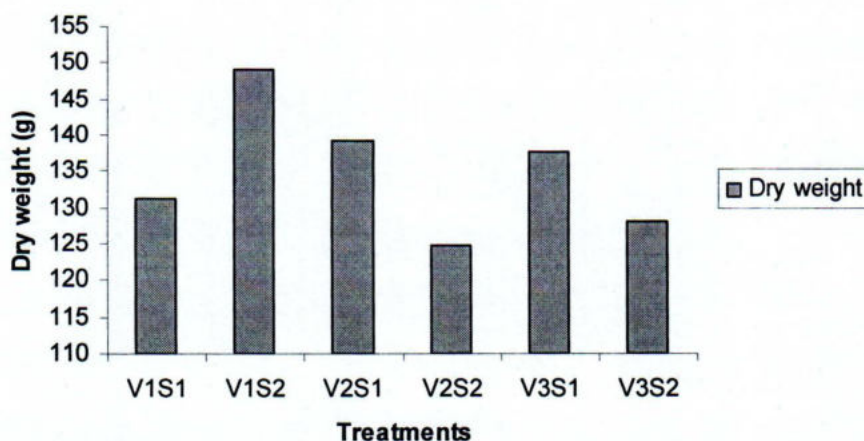


Fig 4. Interaction effect of variety and production on dry weight of napier

4.4 Economic analysis

Profitability of growing napier as inter-crop in mango based agroforestry system was calculated based on local market rate prevailed during experimentation. The cost of production of napier and cost of production of tree plantation and management of trees have been summarized in appendix V. The return of produce and the profit per taka i.e. Benefit Cost Ratio (BCR) have also been presented in Table 7.

4.4.1 Total cost of production

The values in table 7 indicate that the total cost of production was maximum 64349 Tk./ha in Mango + napier based agroforestry system (S_1) whereas the minimum cost of production 23594 Tk./ha was recorded from the sole cropping of napier (S_2) i.e. napier grown in open field.

4.4.2 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. The values in table 7 indicate that the highest value of gross return 251673 Tk. /ha was obtained from Mango + napier based agroforestry system (S_1). On the other hand, the lowest value of gross return 77500 Tk. /ha) was obtained from sole cropping of napier (S_2).

4.4.3 Net return

Results presented in the table 7 show that net return 187324 Tk. /ha was comparatively higher in producing napier under mango + napier based agroforestry system (S_1). At the same time, the lowest net return 53906 Tk. /ha was received from the sole cropping of napier (S_2).

CHAPTER 5

SUMMARY AND CONCLUSION

Summary

A field experiment was carried out at the agroforestry farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during 15 May 2010 to July 2010 to evaluate the performance of 3 planted napier varieties in mango tree based agroforestry system. The experiment was conducted in newly established mango orchard where the tree saplings were planted at the spacing 6 m×6 m in the year 2008. The experiment included three recommended modern napier varieties viz; Bazra, Arusha and napier hybrid variety. The experiment was laid out in RCBD with 3 (three) replications. The treatment combinations of the experiment were $V_1 S_1$ = Mango+Bazra, $V_1 S_2$ = sole cropping of Bazra, $V_2 S_1$ = Mango+Arusha, $V_2 S_2$ = sole cropping of Arusha, $V_3 S_1$ = Mango+napier hybrid variety, $V_3 S_2$ = sole cropping of napier hybrid variety. In the treatments, mango trees population were 257 trees ha⁻¹ respectively. Before planting the seedlings of napier, the land was fertilized by using fertilizer as per required doses. Seedlings of napier were planted 15th May 2010 in to the main plots. The data were analyzed statistically and means were adjusted by DMRT (Duncan's Multiple Range Test).

In case of the main effect of variety on the growth, yield contributing characters and yield of napier plant height of napier grass varied significantly at different Days After Planting (30 DAP, 45 DAP and 60 DAP). The tallest plant was observed (89.88 cm, 127.0 cm, and 157.8 cm at 30 DAP, 45 DAP and 60 DAP) in Bazra (V_1) which was

statistically identical with Arusha (V_2) at 30 DAP and 45 DAP. The dwarf plant was found (73.22 cm, 119.2 cm and 132.9 cm) in hybrid napier grass (V_3) at 30 DAP, 45 DAP and 60 DAP. In case of number of tiller, the maximum number of tiller (2.52) was observed in Bazra (V_1) which was statistically identical with Arusha (2.50). Consequently, minimum number of tiller (2.00) was experienced in hybrid napier grass (V_3). However, no significant variation among the treatment was observed at 45 DAP and 60 DAP. At 45 DAP and 60 DAP, the maximum number of tiller (4.50 and 5.67) was recorded in V_1 while minimum number of tiller (4.00 and 5.00) was found in V_3 . Again, maximum number of leaf (41.33, 53.33 and 62.17 at 30 DAP, 45 DAP and 60 DAP) was recorded in Bazra which was statistically identical with Arusha at 45 DAP and 60 DAP. On the other hand, minimum number of leaf (36.00, 44.50 and 54.17 at 30 DAP, 45 DAP and 60 DAP) was recorded in napier hybrid variety i.e. in V_3 . Furthermore, the longest leaf (50.52 cm, 62.31 cm and 70.82 cm at 30 DAP, 45 DAP and 60 DAP) was observed in Bazra followed by in V_2 i.e. in Arusha. Consequently, the shortest leaf (44.39 cm, 60.19 cm and 66.43 cm at 30 DAP, 45 DAP and 60 DAP) was found in napier hybrid grass variety. However, napier grass variety do not vary significantly among themselves at 30 DAP and 45 DAP but vary significantly at 60 DAP. The maximum leaf breadth (1.59 cm, 1.77 cm and 2.67 cm at 30 DAP, 45 DAP and 60 DAP) was recorded in Bazra. On the other hand, minimum leaf breadth (1.49 cm, 1.61 cm and 2.59 cm at 30 DAP, 45 DAP and 60 DAP) was recorded in napier hybrid variety. On the other hand, highest yield (4.97 tha^{-1} , 10.93 tha^{-1} and 5.13 tha^{-1} at 30 DAP, 45 DAP and 60 DAP) was recorded in V_1 i.e. in Bazra. However, lowest yield (2.14 tha^{-1} , 5.47 tha^{-1} and 2.85 tha^{-1} at 30 DAP, 45 DAP and 60

DAP) was recorded in napier hybrid variety. Furthermore, maximum dry weight (141.1 g) was recorded in V₁ (Bazra). On the other hand, minimum dry weight was recorded in napier hybrid variety.

In case of the main effect of production system on the growth, yield contributing characters and yield of napier, the tallest plant (84.32 cm) at 30 DAS was observed in mango + napier based Agroforestry system (S₁) whereas the shortest plant (82.45 cm) was observed in sole cropping of napier (S₂). Again at 45 DAS the tallest plant (125.82 cm) was observed in mango + napier based Agroforestry system (S₁) on the other hand the shortest plant (123.91 cm) was observed in sole cropping of napier (S₂). Significantly at 60 DAS the tallest plant (150.05 cm) was observed in mango + napier based Agroforestry system (S₁) on the other hand the shortest plant (148.07 cm) was observed in sole cropping of napier (S₂). Again, at 30 DAS the maximum number of tiller plant⁻¹ (2.73) was recorded in mango+ napier based Agroforestry system (S₁) whereas the minimum number of tiller plant⁻¹ (2.33) was recorded in sole cropping of napier (S₂). However, at 45 DAP and 60 DAP number of tiller plant⁻¹ of napier was non significant whereas highest number of tiller plant⁻¹ was recorded in mango+ napier based Agroforestry system (S₁) and the lowest was recorded in sole cropping of napier (S₂). Moreover, at 30 DAP maximum number of leaf (39.00) was recorded in mango+ napier based Agroforestry system (S₁) whereas the minimum number of leaf (37.78) was observed in sole cropping of napier (S₂). In case of 45 DAP, maximum number of leaf (52.78) was recorded in mango+ napier based Agroforestry system (S₁) whereas the minimum number of leaf (49.22) was observed in sole cropping of napier (S₂). Again, at

60 DAP maximum number of leaf (60.22) was recorded in mango+ napier based Agroforestry system (S_1) where as the minimum number of leaf (55.56) was observed in sole cropping of napier (S_2). On the other hand, at 30 DAP maximum length of leaf (48.27 cm) was recorded in mango+ napier based Agroforestry system (S_1) where as the minimum length of leaf (46.88 cm) was observed in sole cropping of napier (S_2). In case of 45 DAP, maximum length of leaf (62.18 cm) was recorded in mango+ napier based Agroforestry system (S_1) where as the minimum length of leaf (60.74 cm) was observed in sole cropping of napier (S_2). Again, at 60 DAP maximum length of leaf (70.45 cm) was recorded in mango+ napier based Agroforestry system (S_1) where as the minimum length of leaf (68.00 cm) was observed in sole cropping of napier (S_2). However, breadth of leaf do not significantly differ at 30 DAP and 45 DAP. In this period highest leaf breadth (1.56 cm and 1.72 cm at 30 DAP and 45 DAP) was recorded in mango+ napier based Agroforestry system (S_1) where as the minimum breadth of leaf (1.52 cm and 1.71 cm at 30 DAP and 45 DAP) was observed in sole cropping of napier (S_2). However, at 60 DAP significant variation in leaf breadth was observed. In this time, highest leaf breadth (2.92 cm) was recorded in mango+ napier based Agroforestry system (S_1) where as the minimum breadth of leaf (2.65 cm) was observed in sole cropping of napier (S_2). Furthermore, Yield of napier was taken at three intervals. At 1st harvest, highest yield (10.01 tha^{-1}) was obtained from mango+ napier based Agroforestry system (S_1) where as the lowest yield (8.28 tha^{-1}) was recorded from sole cropping of napier (S_2). Moreover, at 2nd harvest, highest yield (21.56 tha^{-1}) was obtained from mango+ napier based Agroforestry system (S_1) where as the lowest yield (19.54 tha^{-1}) was recorded from

sole cropping of napier (S_2). Again, at 3rd harvest, highest yield (10.64 tha^{-1}) was obtained from mango+ napier based Agroforestry system (S_1) where as the lowest yield (8.71 tha^{-1}) was recorded from sole cropping of napier (S_2). Moreover, maximum dry weight (136.06 g) was recorded in mango+ napier based Agroforestry system (S_1) whereas the minimum (133.90 g) dry weight was recorded in sole cropping of napier.

The interaction effect of variety and production system on growth, yield contributing character and yield of napier had significant effect on plant height height of napier grass at different Days after Planting (DAP). At 30 DAP the tallest plant of napier grass (94.66 cm) was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with V_1S_2 (sole cropping Bazra) and V_2S_1 (Mango + Arusha based AGF), where as the shortest plant of napier grass (70.37 cm) was recorded in V_3S_2 i.e. sole cropping of hybrid napier grass variety. Again at 45 DAP the tallest plant of napier grass (132.3 cm) was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically similar with V_1S_2 (sole cropping Bazra), V_2S_1 (Mango + Arusha based AGF) and V_2S_2 (sole cropping Arusha). On the other hand, the shortest plant of napier grass (116.5 cm) was recorded in V_3S_1 (Mango + Napier hybrid grass variety). Significantly at 60 DAP the tallest plant of napier grass (176.6 cm) was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with V_1S_2 (sole cropping Bazra). On the other hand, the shortest plant of napier grass (139.1 cm) was recorded in V_3S_2 i.e. sole cropping of hybrid napier. Consequently, at 30 DAP the highest (3.00) number of tiller plant⁻¹ of napier fodder was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with V_2S_2 (sole cropping Arusha). On the other hand, lowest

(2.00) number of tiller plant⁻¹ of napier grass was observed in V₁S₂ (sole cropping Bazra) which is statistically similar with V₂S₁ (Mango + Arusha based AGF), V₃S₁ (Mango + Napier hybrid based AGF) and in V₃S₂ i.e. sole cropping of hybrid napier grass variety. However, number of tiller at 45 DAP was found non significant. But at 60 DAP, number of tiller plant⁻¹ of napier grass varied significantly. At 60 DAP the highest (6.33) number of tiller plant⁻¹ of napier grass was recorded in V₁S₁ (Mango + Bazra based AGF) which was statistically similar with V₂S₂ (5.67). Consequently, lowest (5.00) number of tiller plant⁻¹ of napier grass was observed in V₁S₂ (sole cropping Bazra) which is statistically similar with V₂S₁ (Mango + Arusha based AGF), V₃S₁ (Mango + Napier hybrid based AGF) and in V₃S₂ i.e. sole cropping of hybrid napier grass variety. On the other hand, maximum number of leaf per plant of napier grass at 30 DAP (42.00) was recorded in V₁S₁ (Mango + Bazra based AGF) which was statistically identical with V₃S₂ i.e. sole cropping of hybrid napier grass variety, V₁S₂ (sole cropping Bazra) and V₂S₁ (Mango + Arusha based AGF). On the other hand, minimum number of leaf per plant of napier grass at 30 DAP (30.67) was recorded in V₂S₂ (sole cropping Arusha) which was statistically alike with V₃S₁ (Mango + Napier hybrid based AGF). Significantly, in 45 DAP maximum number of leaf per plant of napier grass (61.67) was recorded in V₁S₁ (Mango + Bazra based AGF) which was statistically identical with sole cropping Bazra (59.67). Moreover, minimum number of leaf per plant of napier grass at 45 DAP (42.67) was recorded in V₂S₂ (sole cropping Arusha) which was statistically comparable with V₃S₁ (Mango + Napier hybrid based AGF) and in V₃S₂ i.e. sole cropping of hybrid napier grass variety. Again, at 60 DAP the maximum number of leaf per plant of napier grass (69.33)

was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with sole cropping Bazra (65.67). Consequently, minimum number of leaf per plant of napier grass at 60 DAP (45.33) was recorded in V_2S_2 (sole cropping Arusha) which was statistically comparable with V_3S_1 (Mango + Napier hybrid based AGF). On the other hand, at 30 DAP the maximum length of leaf (51.92 cm) was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with sole cropping Bazra (49.88 cm) and V_2S_2 (49.12 cm) i.e. sole cropping Arusha. On the other hand, minimum length of leaf (41.63 cm) was recorded in V_3S_1 (Mango + Napier hybrid based AGF) which were statistically equivalent with V_3S_2 i.e. sole cropping of hybrid napier grass variety. Again, at 45 DAP the maximum length of leaf (62.92 cm) was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with sole cropping Bazra (61.83 cm), V_2S_2 (61.68 cm) i.e. sole cropping Arusha and V_3S_1 (Mango + Napier hybrid grass variety). Consequently, minimum length of leaf (58.70 cm) was recorded in V_3S_2 i.e. sole cropping of hybrid napier grass variety which was statistically identical with V_2S_2 (58.96 cm) i.e. sole cropping Arusha. Moreover, at 60 DAP the maximum length of leaf (70.88 cm) was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with sole cropping Bazra (70.76 cm), V_2S_2 (70.03 cm) i.e. sole cropping Arusha and V_3S_1 (Mango + Napier hybrid based AGF). Consequently, minimum length of leaf (63.09 cm) was recorded in V_3S_2 i.e. sole cropping of hybrid napier grass variety which was statistically identical with V_2S_2 (64.84 cm) i.e. sole cropping Arusha. Again, at 30 DAP the maximum breadth of leaf (1.69 cm) was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with sole cropping Bazra (1.67 cm), V_2S_1 (1.49 cm) and V_2S_2

(1.53 cm) i.e. sole cropping Arusha. On the other hand, minimum breadth of leaf (1.42 cm) was recorded in V_3S_2 i.e. sole cropping of hybrid napier grass variety which were statistically equivalent with V_3S_1 (Mango + Napier hybrid based AGF). Moreover, at 45 DAP the maximum breadth of leaf (1.93 cm) was recorded in V_1S_1 (Mango + Bazra based AGF) which was statistically identical with sole cropping Bazra (1.93 cm). On the other hand, minimum breadth of leaf (1.57 cm) was recorded in V_2S_2 (1.53 cm) i.e. sole cropping Arusha which were statistically equivalent with V_2S_1 (1.61 cm), V_3S_1 (Mango + Napier hybrid based AGF) and V_3S_2 i.e. sole cropping of hybrid napier grass variety. Again, at 60 DAP the maximum breadth of leaf (2.69 cm) was recorded in V_2S_2 which was statistically identical with V_1S_1 (Mango + Bazra), V_1S_2 (sole cropping Bazra), V_2S_1 (2.68 cm) and V_3S_2 i.e. sole cropping of hybrid napier grass variety (2.57 cm). However, minimum breadth of leaf (2.50 cm) was recorded in V_3S_1 (Mango + Napier hybrid based AGF). In addition to these, at 1st harvest, highest yield was obtained from V_1S_1 (6.53 tha^{-1}) which was statistically similar with sole cropping Bazra (4.13 tha^{-1}), V_2S_1 (3.60 tha^{-1}) and V_2S_2 (3.40 tha^{-1}). On the other hand, lowest yield (1.88 tha^{-1}) was recorded from V_3S_1 (Mango + Napier hybrid based AGF) which was statistically similar with V_3S_2 (2.40 tha^{-1}) i.e. sole cropping of hybrid napier grass variety. Moreover, at 2nd harvest highest yield was obtained from V_1S_1 (12.13 tha^{-1}) which was statistically similar with sole cropping Bazra (9.73 tha^{-1}). Consequently, lowest yield (1.88 tha^{-1}) was recorded from V_3S_2 i.e. sole cropping of hybrid napier grass variety which was statistically similar (5.60 tha^{-1}) with V_3S_1 (Mango + Napier hybrid based AGF). Again, at 3rd harvest highest yield was obtained from V_1S_1 (5.60 tha^{-1}) which was statistically similar with

napier can profitably be cultivated in mango based agroforestry systems. Thus, it may be advocated that such type of production system will be beneficial to the farmer as because such practice provides cash money to the farmer.

Conclusion

The findings of the present investigation indicate that diversification of farming system and growing napier as ground layers crops in mango tree orchard is a viable option for increasing income of farmers. One napier variety like Bazra has been grown successfully as intercrops in the floor of mango tree orchard. The presence of tree canopies did not influence on the growth and yield of napier variety like Bazra. Despite some negative effects of upper layer tree like mango on the growth, yield and physiological attributes, of napier and mango based agroforestry system is still beneficial as it ensure higher returns because of diversified products in comparison to sole cropping. From an economic point of view, it was also pragmatic that napier variety Bazra found to be better in case of yield and more remunerative in comparison to other napier varieties like arusha and hybrid napier variety under mango based agroforestry systems in this study. From the results and foregoing discussion, it is clear that open field is so good for the production of napier but in avocation of MPTs like mango tree it could be grown well.

Recommendation

Napier-mango based agroforestry systems are economically viable under the conditions analyzed. To get highest production napier may be grown in the floor of mango orchard. Moreover, the developed

model should be applied in the mango orchard of the northern side of Bangladesh. It may be also advocated that to get a vital recommendation this study should be repeated in different location of the country.

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Appendix II. Weather data of the experimental site during the period from May 2009 to July 2010

Months	* Air Temperature (C)			* Relative Humidity (%)
	Maximum	Minimum	Average	
May	31.85	24.68	28.26	88.50
June	33.70	28.45	31.07	85.92
July	32.26	28.10	30.18	83.45

Note * Monthly average

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

Appendix III. Summary of analysis of variance (mean square) of the growth, yield contributing characters of napier as influenced by the variety

Treatment	Degree of Freedom	Plant height (cm)			Number of tiller			Number of leaf			Leaf length (cm)		
		30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP
Replication	2	546.514	126.122	399.199	0.844	1.696	1.042	14.000	11.954	0.292	1.042	10.292	14.000
Factor-A	2	428.484**	92.597**	1057.304**	20.443**	80.300**	7.042**	48.16**	9.342**	0.042**	0.153**	257.417*	49.000*
Error	10	56.113	30.948	54.505	1.735	3.738	0.375	8.095	3.680	0.149	0.375	0.244	8.095

Appendix IV. Summary of analysis of variance (mean square) of the yield contributing characters and yield of napier as influenced by the variety

Treatment	Degree of Freedom	Fresh Yield at			Leaf breadth (cm) at			Dry weight (g)
		1 st harvest	2 nd harvest	3 rd harvest	30 DAP	45 DAP	60 DAP	
Replication	2	10.292	5.175	2.771	0.844	11.954	1.696	1.042
Factor-A	2	257.417**	1.212**	0.265**	8.128**	55.65**	18.163**	0.375**
Error	10	0.244	1.238	0.077	1.735	3.680	3.738	0.375



Appendix VII. Summary of analysis of variance (mean square) of the growth, yield contributing characters of napier as influenced by the interaction effect of variety and production system

Treatment	Degree of Freedom	Plant height (cm)			Number of tiller			Number of leaf			Leaf length (cm)		
		30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP
Replication	2	546.514**	126.122**	7.167	6.292	0.448	1.219	0.000	0.10	0.010	0.001	7.167	6.292
Factor-AB	2	277.052**	157.493**	123.444**	181.500**	8.251*	37.153*	0.004**	0.010*	0.003*	0.009*	88.167*	160.167**
Error	10	56.113**	30.948**	7.071	1.815	3.246	3.254	0.001	0.001	0.001	0.001	7.071	1.815

Appendix VIII. Summary of analysis of variance (mean square) of the yield contributing characters and yield of napier as influenced by interaction effect of variety and production system

Treatment	Degree of Freedom	Fresh Yield			Leaf breadth (cm)			Dry weight (g)	
		1 st harvest	2 nd harvest	3 rd harvest	30 DAP	45 DAP	60 DAP		
Replication	2	0.231	0.844	11.954	1.696	0.292	0.667	1.042	
Factor-AB	2	0.531**	0.156 *	9.342**	8.295*	0.042**	0.042 ^{ns}	0.153**	
Error	10	0.178	1.735	3.680	3.738	0.149	0.333	0.375	

Appendix XI. Cost of production of napier under mango 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)									Interest of input cost @ 8% for the crop season (tk/ha)	Interes of the value of land (tk. 300000/ha) @ 8% for the crop season (tk/ha)	Miscellaneous cost @ 5% of the input cost (tk/ha)	
	Tree	Napier	Total non material cost	Seed	Fertilizer	Pesticide	Irrigation	Maintenance cost of trees	Initial plantation cost of trees	Total material cost (tk/ha)					
T ₁	8425	8200	16725	1820	2060	350	600	5020	5040	22480	39250	3136	20000	1963	64349
T ₂		10000	10000	2700	4560	950	900			9110	19110	1529	8000	955	23594

Note: T₁=mango+napier, T₂=open. Cow dung 500Tk./ton; Urea 8 Tk./kg, TSP 16 Tk./kg; MP 15 Tk./kg, Gypsum 6 Tk/kg, ZnSO₄ 35 Tk./kg, Labour 120 Tk./day, Plantation cost for mango tree were 25 Tk./tree. Rotation year for Mango were 60 years