EFFECT OF EUCALYPTUS TREE ON THE GROWTH AND YIELD OF RICE (BRRI dhan51)

A THESIS

BY

SHAHORIAR ALAM

Student No. 1805099

Session: 2018

Thesis Semester: July-December, 2019

MASTER OF SCIENCE (M.S.)

IN

AGROFORESTRY AND ENVIRONMENT

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200

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DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT

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Dedicated
To my
Beloved Parents

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The Author

Effect of Eucalyptus Tree on the Growth and Yield of Rice (BRRI dhan51)

ABSTRACT

A field experiment was carried out at Kaharole upazila in Dinajpur district during August 2018 to January 2019 to evaluate the yield variation of rice (BRRI dhan51) influenced by age and distance of eucalyptus tree. The experiment was laid out following double factor Randomized Complete Block Design (RCBD) with three replications. Total numbers of the experimental plots were 27 (3 ages x 3 distances x 3 replications). The treatments of the age experiment were Y_1= Rice cultivation under 1 year aged eucalyptus tree, Y_2 = Rice cultivation under 3 year aged eucalyptus tree, Y_3 = Rice cultivation under 5 year aged eucalyptus tree. Again the treatments based on distance were D_1 = Rice cultivation from 1m distance of eucalyptus tree base, D_2 = Rice cultivation from 3m distance of eucalyptus tree base, D_3 = Rice cultivation from 5m distance of eucalyptus tree base. Data were recorded on plant height, number of effective tiller, 1000 grain weight, grain yield, straw yield, litter fall of eucalyptus (dry weight). In case of economic analysis the benefit cost ratio (BCR) was calculated. The data were analyzed statistically with Statistix 10 and means were adjusted by Tukey HSD test. The results of the research revealed from age based treatment, significantly the highest plant height and litter fall of eucalyptus was recorded (106.20 cm and 41.33g) from Y_3 treatment while the lowest plant height and litter fall was obtained (97cm and 20.56g) from Y_1 treatment. On the other hand the highest number of effective tiller/hill, 1000 grain weight, grain yield and straw yield (17.54, 22.16g, 3.67 tha^{-1}, 2.77 tha^{-1}) was found in Y_1 treatment and the lowest number of effective tiller/hill, 1000 grain weight, grain yield and straw yield was obtained (15.85, 19.32g, 2.70 tha^{-1}, 2.24 tha^{-1}) from Y_3 treatment. Considering the distances, significantly the highest plant height and litterfall of eucalyptus was recorded (107.81cm and 53.89g) from D_1treatment while the lowest plant height and litterfall was obtained (95cm and 14.67g) from D_3 treatment. On the other hand the highest number of effective tiller/hill, 1000 grain weight, grain yield and straw yield (17.22, 21.42g, 3.40 tha^{-1}, 2.73 tha^{-1}) was found in D_3 treatment and the lowest number of effective tiller/hill, 1000 grain weight, grain yield and straw yield was obtained (15.88, 20.65g, 3.00 tha^{-1}, 2.21 tha^{-1}) from D_1 treatment. The result from the interaction effect of age difference and different distances from tree base, the highest plant height and litterfall of eucalyptus was recorded (112.63 cm and 60.33g) in Y_3D_1 treatment while the lowest plant height and litterfall was obtained (91.83 cm and 6.67g) in Y_1D_3 treatment. On the other hand the highest number of effective tiller/hill, 1000 grain weight, grain yield and straw yield (18.17, 22.87g, 3.9 tha^{-1}, 3.12 tha^{-1}) was found in Y_1D_3 treatment and the lowest number of effective tiller/hill,1000 grain weight, grain yield, straw yield was obtained (15.03, 18.87g, 2.5 tha^{-1}, 2.01 tha^{-1}) Y_3D_1 treatment. It was observed that rice production from Y_3D_3 combination gave the highest net return (164173 $tkha^{-1}$). At the same time the lowest net return (36961 $tkha^{-1}$) was obtain from Y_1D_1 combination. Higher net return was the result of higher gross return from the higher yield of rice along with the value of eucalyptus tree. The highest benefit-cost ratio 3.46 was recorded from the combination of Y_3D_3 and the lowest benefit-cost ratio 1.56 was obtained from Y_1D_1 combination of eucalyptus tree based Agroforestry system. Therefore, it may be concluded from the present study that the rice production of BRRI dhan51 was gradually increased with the increase of distance from the base of eucalyptus tree and decreased with the increase of tree age. But considering monitory return, maximum return was obtained from rice cultivation with aged eucalyptus tree due to the additional value of eucalyptus timber. Finally, it can be concluded that BRRI dhan51 is suitable for rice + eucalyptus based agroforestry.

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CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa L.*) is the principal food of Bangladesh and it is the world's second important food grain. It is grown worldwide on 150 million hectares (ha) with the total production of about 503 million tons of unmilled rough rice (FAO, 2017). Bangladesh is not only a country that grows rice; it also has people who eat rice. It is the world's fourth largest country in terms of rice area and rice production (IRRI, 2014). Rice is grown as aus, aman and boro in Bangladesh throughout the year. Among the most important of these transplanted aman, it occupies about 46.30 percent of the total rice cultivated area. Rice is now being grown in Agroforestry with various species, such as Eucalyptus.

Agroforestry is a collective term for land-use systems and practices in which woody perennials were intentionally incorporated into the same unit of land-management with crops and/or livestock, either in a spatial mixture or in a temporal series. Trees in Agroforestry practices typically serve multiple purposes, including soil conservation or soil fertility enhancement, as well as one or more products being created. (Cooper *et al.* 1996).

Eucalyptus is one of the world's most planted wood plants. (FAO, 2006). Eucalyptus belongs to the Myrtaceae family, mostly from Australia in the tropical region. Eucalyptus spp. Grows in their natural habits under wide-ranging climate and edaphic conditions (Dawar *et al*., 2007). It grows rapidly, is easy to care for, tolerates drought, and can thrive in low or less fertile soil. It is a significant material for the manufacture of paper pulp and a major bio-energy source. It was exported in the late 19^{th} and early 20^{th} centuries to other parts of the world as demand for fuel and energy in Europe, South America, Asia and Africa increased (Bennett, 2011).

For a tree to qualify for Agroforestry, it should have qualities such as rapid growth, no negative effect on grain production or otherwise net returns to farmers should compensate for the loss due to lower grain production, provide shelter against crops and orchards, litter or organic matter to enrich farmers ' land, cattle fodder, fuel wood and small household timber. Eucalyptus, however, did not meet most of the requirements, but their ability to withstand unfavorable soil conditions, simple initial establishment, rapid irrigation response, fertilizers and the development of small-sized straight knot-free timber that only a few indigenous trees can generate soon became a favorite species of farmers. Eucalyptus could be grown in close spacing, like conifers, which would mean extensive production in limited areas rather than large areas being controlled.

Boundary planting under the Agroforestry system includes trees planted along borders or on boundaries in order to keep the soil from erosion and increase soil fertility (by fixing nitrogen or taking minerals from deep into the soil and depositing them by leaf-falling). In the Agroforestry model, an effective combination of nitrogen fixation and multipurpose trees with field crops plays a major role in enhancing better yield production, soil nutrient status and microbial population dynamics, which plays a major role in nutrient cycling to sustain the ecosystem. (Raj *et al.,* 2014).

Eucalyptus is also blamed for heavy use of soil moisture, leaf litter and soil humus, soil nutrient intake, less soil preservation, non-fodder and habit. In short, increasing the shortage of wood products, re-greening forests, contributing to poverty reduction, preserving and conserving biodiversity are important contributions of eucalyptus in the forest sector. Due to increasing population pressure with increased need for food and shelter, deforestation (Raj and Toppo, 2014) is inevitable, resulting in loss of forest cover, but by Agroforestry practices the forest cover is retained up to 33%. Agroforestry also offers opportunities for living by cultivation of water, gum, resin, fiber, fruit, apiculture and sericulture (Dhyani *et al.,* 2012; Kittur and Bargali, 2013). Therefore, Agroforestry has many opportunities, such as enhancing overall (biomass) productivity, increasing soil fertility, soil sustainability, nutrient cycling, improving micro-climate, sequestration of carbon, bio-drainage, bio-energy and bio-fuel, etc. (Bargali *et al.,* 2004; Bargali *et al., 2009).* An important role in the environmental sustainability and suitability of any Agroforestry process is the interplay and complementary between negative and positive interactions. Only if positive interactions outweigh negative interactions can it yield positive results (Singh *et al., 2013).*

In Bangladesh, a densely populated country, rice production is of vital importance from both economic and food security points of view (BBS, 2012). Rice solely occupies 76.7% in the total are under cultivation (Sattar, 2000). There are three major rice types widely cultivated in the country, Aus, Aman and Boro. In the 2011-2012 harvest season, Aus, Aman and Boro rice consist of 9.87 percent, 48.40 percent, and 41.73 percent, respectively. Boro or winter rice is grown under irrigated conditions from January to June, while Transplanted Aman (T.

Aman or monsoon rice) is grown between July and December, mostly under rain-fed conditions. (Wang *et al.,* 2005).

Distance from the tree base played a major role in increasing grain crops and yielding them. With the rise in distance from the boundary tree line, the yield of cereal crops increased. Further, as a distance increase the grain yield also increase (Ram *et al.,* 2011). Age difference of boundary plantation trees effects on crops production in agri-silvicultural system. By increasing age canopy size also increases and reduces availability of sunlight. At the reduced light conditions may be due to lower production of photosynthesis under low light conditions for a longer period (Chaturvedi *et al.,* 2016; Miah *et al.*, 1999).

Specifically Dinajpur district in the northern part of Bangladesh is prominent for year-round rice production through sole crop cultivation as well as bound planting with various multipurpose tree species mainly Eucalyptus. Until giving any suggestion on the Agroforestry system based on rice and eucalyptus tree, need to carefully study the significant impact on rice yield of different age and distance from the Eucalyptus tree base. The following targets were considered for the present experiment in the context of the above situation.

Objectives:

1. To determine the yield variation of rice influenced by different ages of eucalyptus tree.
2. To observe the yield variation of rice due to different distances from the base of eucalyptus tree.
3. To evaluate the benefit cost ratio of rice + eucalyptus based cropland Agroforestry influenced by different age and base distance of the eucalyptus trees.

CHAPTER 2

REVIEW OF LITERATURE

The research was conducted to observe the performance of the Agroforestry system based on rice BRRI dhan51 under different age and distance from Eucalyptus tree. Recently, modern Agroforestry practices are being expanded in Bangladesh's crop field. The farmers grow different trees in the crop field to get the maximum benefit. Yet tree directly affects the yield of the crop. There is little literature directly related to this topic. Literatures are therefore checked and discussed below under the following subheads in a way that relates to the topic of interest from home and abroad.

2.1 Concepts of Agroforestry

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 Yield and associated components of rice

2.7 Rice based cropland Agroforestry

2.8 Eucalyptus based Agroforestry system

2.9 Allelochemical effect of Eucalyptus on associated crop

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2.1 Concepts of Agroforestry

Agricultural forestry is an ancient practice. It is an integral part of Bangladesh's conventional agricultural systems. The idea of Agroforestry probably stems from the fact that trees play an important role in preserving farming's long-range interests and making farming 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 previously considered as two separate areas, but these activities are now considered complementary. This has been brought about by the increasing realization that Agroforestry can become an important component of efforts for environmental, social and economic growth.

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

Saxena (1984) pointed out that Agroforestry uses the interspaces between tree rows to intercrop with agricultural crops and that this does not hinder the growth and development of the trees but enables farmers to derive additional income in addition to the benefits obtained from the use of fuel and timber from trees.

From a bio-economic point of view, Harou (1983) claimed that Agroforestry is a hybrid agriculture-tree crop farming system that allows a farmer or land user to make more efficient use of their land that can sustainably produce a higher net economic return.

MacDicken and Vergara (1990) state that Agroforestry is a form of land management or use (i.e. land use system) combining trees or shrubs with agricultural / horticultural crops and/or animals.

Ong (1988) recorded that biomass production per unit area could be substantially increased by combining trees with arable crops when the roots of trees harvest water and nutrients below the shallow roots of crops and more solar energy is absorbed by mixed canopy.

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).

According to Solanki (1998), in many developing countries, Agroforestry can contribute significantly to increasing demand for fuel wood, food, cash and infrastructure. He also claimed that Agroforestry has a high potential to simultaneously achieve three important goals: It preserves and stabilizes biodiversity (ii) produce low-level economic goods (fuel, fodder, small timber, organic fertilizer, etc.) (ii) provide stable employment, increased income and basic materials for rural populations.

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).

2.2 Tree-crop interaction

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.

Dhukia *et al.* (1988) observed that four forage crops (Trifoliuma lexandrium, oats, Viciafaba and Trifolium foenum-graecum) and two forage crops (Triticum aestivum and Cicer arietinum) were grown under Dalbergia sissoo and Albizia lebbeck during the rabies season of 1984-87. Trifolium alexandrium follower by oats gave the highest fresh fodder and dry matter yields under both plantations. Yields decreased from trees under 4 years of age relative to trees below 3 years of age. Wheat gave higher yields than *Cicea rarietinum* under both plantations. Yields of all crops under the *Dalbergia sissoo* plantation were higher than under the *Albizia lebbeck* plantation.

Basri *et al.* (1990) found that there was significant competition between hedgerow trees for nutrients and light with upland rice crops. Competition was most serious in the 2-3 rice rows closed in the hedgerows where yields were reduced by 50-70% compared to those in the middle of the lane. Khan and Aslam (1974) studied the effect on wheat yield of single sissoo (Dalbergia sissoo) tree. Yield was in a quadrate of 1m2 from plots. The squares are taken from the tree base at a distance of 3 m, 4.5 m and 6 m. One quadrate was taken from the center of the field, that is, far from the trees ' impact. The grain yield showed a 30.88 percent decrease, 23.6 percent decrease and 12.7 percent decrease at a range of 3, 4.3 and 6 m respectively compared to the open field. The tree was grown under irrigated condition as well as the crops.

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 azadirachta* (*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*.

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.

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 *Boras susflabellifer* in rice paddy fields in Bangladesh 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).

Khan and Ehrenreich (1994) calculated the impact of Acacia nilotica's boundary planting on the growth and yield of rice (*Oryza sativa*) crops under irrigated condition. The results showed that tillers m-2, grains panicle-1 and 1000-grain weight was adversely affected by close proximity to trees, but grain yield was marginally lowest near the largest trees.

2.3 Importance of Light in Agroforestry

The yield benefit of traditional intercropping was explained in terms of stronger capture of growth resource utilization (Willy *et al.,* 1986). Agroforestry systems ' retention of wealth is likely to be greater than in single crops (Ong *et al.*, 1991).

Limiting light (Shade) is undoubtedly the most important factor affecting under-story plant quality. Higher light ingestion by understory crops is the secret to establishing a compatible tree crop combination in Agroforestry. In India, shading by trees is commonly believed to be responsible for low crop yields (Ong *et al.,* 1992). Okigbo and Geenl and (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.

Incorporating a variety of tree and plant species, the Agroforestry system offers much more potential for useful light collection and distribution management than monoculture forests and agricultural crops (Miah *et al.,* 1996).

The potential benefits as results of combining field crops with trees are so obvious from consideration to the waste of light resources experienced in orchard and tree crop orientations (Jackson, 1987). One of the major constraints of microclimate and growth in Agroforestry practice is solar radiation. Interaction among the trees and solar geometry produce the particular solar climate of a tree/corm system. These interaction and effects include interception of radiation by tree stands of various densities, effect of canopy structure, effect spacing, effect of latitude and time of year on solar paths, shade from single crowns and spectral quality of sunlight under partial shade (Reifsnyder, 1987).

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

The extent of competition in Agroforestry, essentially crop yield, depends on resource division, primarily on light and water between tress and crops (Howord *et al.*, 1995).

2.4 Characteristics of Tree Species in Agroforestry Systems

In an Agroforestry process, choice of suitable tree species is a critical factor. Nair (1980) considered the most suitable species of plants that could grow together as an important factor in ensuring Agroforestry sources.

The most appropriate species for this system remains an open question for research. King (1979) listed the characteristics at tree species that should be grown with agricultural crops:

a. They should tolerate relatively high incidence of pruning.
b. They should have a low crown diameter to bole diameter ratio.
c. They should be light branching in their habit.
d. They should be tolerant of side shade.
e. Their phyllotoxy should permit penetration of the light of the ground.
f. Their phenology, particularly with reference to leaf flushing and leaf fall, should be advantageous to growth of the annual crop in conjunction with which their being raised.
g. The rate litter fall and litter decomposition should have positive effect on the soil.
h. The above ground changes over time in structure and morphology should be such that retain or improve those characteristics which reduce competition for solar energy, nutrient and water.
i. Their root systems and root growth characteristics should ideally result in exploration of soil layers that are different to those being tapped by agricultural crops.

Rachie (1983) outlined the following factors to be included in the choice of woody legumes for intercropping with annuals in the tropics of low land:

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

Purohit (1984) suggested to selecting those species which would (i) not compete for moisture, space and air (ii) supply nitrogen in the soil (iii) provide food, fodder, fuel and timber (iv) maintain proper ecosystems (v) have no toxic effects to the crops; and (vi) have thin and erect leaves. Singh *et al.* (1984) opined that suitable species should be multipurpose, well-adapted to different sites, easy to establish: have nitrogen-fixing ability, rapid growth and ability to coppice.

Hegde and Mac Dicken (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.

Nevertheless, all the above-mentioned parameters can not be chosen. Researchers should therefore pick which points have most and which are suited to local conditions of soil and climate.

2.5 Performance of Crop in Agroforestry Systems

There was a different response from different crops to Agroforestry systems. Plant and plant species and their compatibility, spacing between tree lines, management practices, soil and climatic factors affect the quality of field crops in Agroforestry systems.

Production decreased by 48 percent and 18 percent respectively during ear formation and rice milking (Park and Kwon, 1975). Nayak and Murty (1980) recorded that rice yield reduction occurs in 75, 50 and 25% of normal light by 47, 57 and 74%. Nayak and Murty (1980) recorded a 47, 57 and 74 percent reduction in rice yields in 75, 50 and 25 percent of normal light, respectively, due to impaired dry matter production, panicle numbers and grains per panicle.

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.

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

Jadhav (1987) reported that partial shading (45-50% of normal light) at 15 days after transplanting reduced grain yield of rice by 73 percent bed a use 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. Rabarimandim (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.

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

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

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

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

Growth of trees and seasonal yields of under story crops were measured by Hicking and Islam (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.

Pandey *et al.* (1999) reported that rice yield was positively related to distance from the tree. Impact of the trees was the 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.) Wild. Ex. Delile trees, locally known as babul, in rice fields of smallholder farmers in Madhya Pradesh State of central India, an area with sub humid 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 is 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 lebbock* trees and *Acacia nilotica*, respectively. The result of the second experiment indicated that the lower reduction in yield of adjacent crop with wider the tree spacing the result of the third experiment showed that root and shoot pruning increased the grain yield of wheat by 22%. The highest increase in the yield of rice (27%) and radish (72%) were obtained due to pruning of *Acacia nilotica* two and three times a year respectively. Pruning of *Albizia lebbeck* three times a year contributed to the highest increase in rice (50%) and radish (35%) yields.

Nandal *et al.* (1999) had evolved under the Sissoo tree 5 rice cultivars. Dry matter yield, leaf area index, spiklets m-1, seed spike-1 and test weight under the tree canopy are reduced in their experimental grain yield compared to crops growing outdoors.

Chaturvedi and Ingram (1989) reported that pre-flowering shade (50 percent shade) resulted in reduced area of the leaf, tiller number, spikelet per panicle, while post-flowering shade reduced fraction of filled spikelet and grain weight in rice.

2.6 Yield and associated components of rice

Chowdhury *et al.* (1993) reported that cultivar BR23 showed superior performance over Pajam in terms of yield and production, i.e. amount of active tillers hill-1. Panicle size, weight of 1000 picks, yields of grain and straw. On the other side, Pajam grows significantly larger seeds, more full panicle-1 spikelets, and unfilled panicle-1 spikelets.

Alim *et al.* (1962) tested five fine rice cultivars namely, Badshabhog, Basmati, Hatisail and Radhunipagal for five years and found that Basmati showed the best performance followed by Gobindhabhog and badshabhog. They also reported that Badshabhog yielded 2.6 t ha^{-1} and each of Daudkhani (other fine rice cultivars) and Hatsail yielded 2.69 t ha^{-1} and each of the authors further reported about a cross between Daudkhani and Indrasail which resulted and average yield of 2.87 t ha^{-1}.

An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during T. aman season, 2002 to study the effect of different level of nitrogen on growth and yield of transplant aman rice. The experiment included four treatments viz. 0, 60, 80 and 100 kg N ha^{-1}. Nitrogen level significantly influenced growth and yield components. The highest number of effective tillers $hill^{-1}$ (9.20), maximum grains $panicle^{-1}$ (100.80) and highest grain yield (5.34 t ha^{-1}) were obtained with 80 kg N ha^{-1}. The highest straw yield (6.98 t ha^{-1}) was obtained at the highest nitrogen level (100 kg N ha^{-1}). The highest harvest index (44.50%) was observed at 80 kg N ha^{-1}. Results showed that 80 kg

N ha^{-1} was optimum to produce maximum yield of transplant aman rice cv. BRRI dhan32 (Rahman *et al.*, 2007)

BRRI (1991) reported that the number of effective tillers produced by some transplant aman rice ranged from 7 to 14 and it significantly differed from variety to variety. In local varieties, namely, Haloi, Tilockachari, Nizersail and latishail, the number of effective tillers $hill^{-1}$ were 9.7, 9.3, 10.8 and 9.0, respectively. According to BRRI (1994) reports, rice variety Tulsimala produced the highest number of spikelets $panicle^{-1}$ and BRRI produced the lowest number of spikelets $panicle^{-1}$. In another study of BRRI, BR14 (3.75 t ha^{-1}) produced the highest yield while BR5 (2.61 t ha^{-1}) produced the lowest one.

BINA (1993) assessed the quality of four varieties / advanced lines in terms of plant height, number of non-bearing tillers, panicle length and panicle-1 sterile spikelets. Results showed that there was no significant difference in grain yield.

BRRI (1995) reported that varietals performances of BR4, BR10, BR22, BR23 and BR25 varieties including two local checks Challish and Nizersail transplanted at 20 cm×20 cm spacing with 2-3 seedling $hill^{-1}$. The results indicated that BR4, BR10, BR11, Challish and Nizersail produced yield of 4.38, 3.12, 3.12, 3.12 and 2.7 t ha^{-1}, respectively. Challish verity earlier that all other varieties.

BRRI (1999) reported that three proposed fine grain aromatic rice varieties viz., Khaskani, Basmati-D and Katarbhog were tested along with two check varieties at four locations each in the project and outreach area. BR5 was used as a standard check and Kalizira Khirkon and Khirshapati as local checks. Khaskani gave the highest mean yield of 2.81 and 2.75 t ha^{-1} in the 144 and 148 days, respectively, whereas the mean yield of Basmati-D (2.34 t ha^{-1}) and 148 days, respectively, whereas the mean yield of Basmati-D (2.34 t ha^{-1}) and Katribhog (2.04 t ha^{-1}) could not exceed of standard check BR5 (2.66 t ha^{-1}) in the project areas. But in the outreach area, the mean yield of Basmati-D (2.32 t ha^{-1}) and Katarghog (2.32 t ha^{-1}) was similar to BR5 (2.4 t ha^{-1}).

BRRI (2000) reported that the performance of three proposed varieties BR 4384-2b-2-2-4, BR 4384-2B-2-6 and BR 4384-2B-2-2-HR3 was tested along with two standard checks and one local check in 11 locations in T. aman. Kataribhog and Khashaniwer used as standard check and Chinking, Basmati, Kalizira, Phlippine Katrai, Chinigura. Chiniatop and Bashful as local checks. In Sonagazi and Bogra Sadar, the yield performance of the proposed varieties was excellent with more than 4.0 t ha^{-1} yield. Hence, about 30% higher yield was obtained from the proposed varieties over the checks.

Dwivedi (1997) reported that Kamini, RP615, Harbans, Basmati, Kasturi and Sugandha varieties of fine rice produced 2.43, 194, 1.92, 20.1 and 2.65 t ha^{-1} respectively.

2.7 Rice based cropland Agroforestry

Nayak *et al.* (2014) reported that the sissoo trees had different pruning rates (0, 25, 50 and 75 percent intensity) and three rice varieties (IR-36, MR-219 and WGL-32100) had been grown with sissoo, including in open condition. Irrespective of rice varieties, higher net monetary return was recorded in sissoo 50% pruning + rice crop (40311 ha) followed by 75% pruning (40186 ha), 25% pruning (36517 ha) and -1 lowest in no pruning + paddy (25859 ha). Irrespective of pruning intensity, MR-219 recorded significantly higher monetary return (38715 ha) closely followed by IR-36 (38363 ha). WGL-32100 recorded the lowest net monetary return (`30675 ha).

Kajal *et al.* (2015) reported that the highest grain yield (3.66 t ha^{-1}) was found in Binadhan-7, which is followed by BRRI dhan 49 (3.41t ha^{-1}) and the lowest grain yield (3.13 t ha^{-1}) was recorded in Kataribhog (V_3) when grown in sole crop. In case mango based production system, the highest grain yield (3.41 t ha^{-1}) was found in open condition (T_2) and the lowest grain yield (3.39 t ha^{-1}) was recorded in mango + rice production system (T_1). Finall, the grain yield (t ha^{-1}) was also influenced due to the interaction of production system and variety. The highest grain yield (3.68 t ha^{-1}) was found in sole cropping of BINAdhan-7 and the lowest grain yield (3.03 t ha^{-1}) was recorded in mango + kataribhog based Agroforestry system treatment combination.

Amin *et al.* (2010) reported that the partial shade effect was significantly found in unfilled grain / panicle, 1000 grain weight and grain yield. In partial shade condition the highest unfilled grain / panicle (16.16) was found under Guava and lowest (12.1) in open field. The highest weight of 1000 grain was 20.40g obtained in open field followed by mango (20.22g) and the lowest weight of 1000 grains was 20.12g found under Guava. The highest yield of rice (3.86 t/ha) was produced in open field followed by Kalo Koroi (3.78 t/ha) and the lowest (3.66 t/ha) under guava. The result showed that the production of rice might be ranked as Open field > Kalokoroi > Mango > Guava. Therefore, it may be predicted that most of the modern transplanted aman rice varieties can be grown in association with early aged multipurpose trees; but their degree of suitability might be prescribed as BR11 > BR10 > BRRIdhan33 > BRRI dhan39 >Sorna. The study also revealed that BR11 with Kalokoroi was the best association for maximum grain yield of rice.

Alamgir *et al.* (2016) note that growing Acacia catechu trees on rice fields is one of Bangladesh's Rajshahi region's traditional crop and Agroforestry network. Detailed information on farm operations and plant calendar including system outputs was discussed with the farming system. System dynamics was also evaluated. PRA exercises were conducted for a biophysical assessment. The information was collected on informant wise and cross-checked. Best growth of trees observed under rain-fed conditions. Higher density of trees found in un-irrigated fields. Trees were better managed in small plots. In general, density of *khoir* trees was found higher in small holdings (less than 2 ha) with secured land tenure. Trees on farms were of uneven age indicating the *khoir* + rice system biologically sustainable. The ease of establishment of *Khoir* seedlings, the low cost of its maintenance, and less vulnerability to any serious pest or disease, easy marketability of products rated high in the farmer’s preference for *khoir.* They appreciate the versatility of the wood for a variety of farm uses though its prime economic use to them is for production of *lali* for *katha.* They also get *pitch khoir* as by product of *katha* (red dyestuff for textiles and paper) production. The multiple products and services offered and the ease of managing the trees on crop fields without causing any immediate or long-term reduction in crop yield seemed to be the most important factors that encourage the farmers to continue this traditional practice.

Singh *et al.*(1997) reported that productivity, sustainability and economics of agriculture, forestry and Agroforestry land use practices were compared over a six year period in a split plot experiment on a moderately alkali soil of the Central Soil Salinity Research Institute, Karnal, India. Three commercial trees of the area formed the main plot treatments and four crop sequences were the sub-plots. The trees were: poplar (*Populus deltoides*), Acacia (*Acacia nilotica*) and Eucalyptus (*Eucalyptus tereticornis*), and the crop sequences were (1) rice (*Oryza sativa*)-wheat (*Triticum aestivum*) for four years followed by guinea grass (*Panicum maximum*)-oats (*Avena sativa*) for two years; (2) rice-Berseem (*Trifolium alexandrium*) for four years followed by cowpea (*Vigna unquiculata*)-Berseem for two years; (3) pigeonpea (*Cajanus cajan*)/sorghum (*Sorghum bicolor*)-mustard (*Brassica juncea*) for three years followed by turmeric (*Curcuma longa*) for three years and (4) no intercrops (only trees). Eucalyptus and poplar gained maximum height, girth and woody biomass in six years when they were intercropped with rice crops in sequences 1 and 2 Acacia attained maximum growth in the absence of intercrops. Protein content in guinea grass was more under tree canopies than in the open. Soil amelioration during five years followed the order: Acacia based system > poplar > Eucalyptus > sole crops. The benefit-cost ratio was highest (2.88) in poplar based system and minimum (1.86) in Acacia based system. The study indicated that growing trees and agricultural crops together is a better land use option in terms of productivity, maintenance of soil conditions and economics.

2.8 Eucalyptus based Agroforestry system

For goats, sheep and cattle, Eucalyptus globules trees are unpalatable (Pohjonen and Pukkala, 1990). Consequently, they have a distinct advantage as boundary planting in the prescribed inter-row spacing and are directed east-west or north-south. In this environment, eucalypt boundaries produce harvestable tree crop within four to five years after planting 25. The outcome of yield is depends upon tree spacing, density, type and nature of existing bund plantation and their shading effects which include effects on morphology (internodes length, leaf area) and effects on flower initiation/fruit-set of associated crops (Kidanu *et al,* 2005).

Bisht *et al.* (2015) reported that the soil properties under different spacing's of Eucalypts based Agroforestry system at two stages of crop growing season i.e. before sowing of wheat in October and after harvest of wheat in April. Availability of macro-nutrients (N, P and K) and organic carbon were determined under 3 m × 3 m, 6 m × 1.5 m and 17 m × 1 m × 1 m (paired row) spacing of Eucalypts plantation of surface soil (0-15 cm depths). The soil samples were also analyzed under control (sole crop). Under this study, the organic carbon (0.47%) and N (199.8 kg ha-1), P (15.6 kg ha^{-1}) and K (226.4 kg ha^{-1}) contents were recorded maximum under 3 m × 3 m spacing of Eucalypts based Agroforestry system after the harvesting of wheat crop as compared to other spacing's and sole crop.

RAJ *et al.* (2016) reported that Agroforestry system as an ecologically sustainable land use option alternative to the prevalent subsistence farming patterns for conservation and development. It is an old traditional practice but recently named as an Agroforestry. A large hectare is available in the form of boundaries, bunds, wastelands where this system can be adopted. *Eucalyptus* is a cropland Agroforestry tree species planted along with various annual crops like paddy, wheat, and cereals and other cash crops in farmers' lands either in scattered or in bund. The main purpose of this review to provide/generates an idea about how *Eucalyptus* on bund behaves with associated crops i.e. interaction between both are studied in many aspects comprises outcome of yield, which is depends upon tree spacing, density, type and nature of existing bund plantation, their shading effects on morphology (internodes length, leaf area) and flower initiation/fruit-set of associated crops and their negative impacts on ecosystem includes competition of trees with crops for resources, allelopathic effects, rapid growth of trees occupy space of crops, etc. This review also includes carbon sequestration ability of *Eucalyptus* plantation with their growth and price trend behavior.

Leonardo *et al.* (2016) stated that agronomic practices adequacy plays a key role in the integrated crop-livestock systems development. The objective of this study was to determine how the phytomass accumulation, yield compounds and oat (*Avena sativa* L. cv. IPR 126) yield were influenced by nitrogen levels (12 and 80 kg N ha^{-1}) at five equidistant positions between two adjacent eucalyptus (*Eucalyptus dunnii* Maiden) double line tracks [20 m (4 m × 3 m)] in intercropping system (IS) and traditional no-till agriculture (without trees) in subtropical Brazil. The experiment was conducted in a split-block in a randomized block design with four replicates. At the end of the oat cycle, there was compensation for the lower spikelet's per panicle number by the greater grain per spikelet number, and for higher harvest indexes where oat accumulated less phytomass in environments with high inter specific interaction. The nitrogen levels increase the oat yield differently at positions relative to the trees in the IS. Therefore different nitrogen levels should be used at those distances to increase nitrogen use efficiency inside IS in subtropical Brazil.

Forest Department planted *Eucalyptus camal dulensis* in Bangladesh. A maximum of 218 provenances of 37 species were introduced and experimentally planted, but only 4 species (*Eucalyptus citriodora, Eucalyptus brassiana, Eucalyptus camaldulensis,* 1985) were found to be productive for potential planting programs.

Eucalyptus was introduced in Bangladesh in the 19th century as ornamental plants to decorate parks, roadside or botanical gardens, like many other developing countries. *Eucalyptus citriodora* was probably introduced in the eastern part of Bangladesh in 1930 (Davidson and Das, 1985) and later spread throughout the country (Hassan, 1994).

2.9 Allelochemical effect of Eucalyptus on associated crop

Amalraj and Shankarnarayan (1986) examined the inhibition of the germination of *Pennisetum typhoides, Sesamum indicum, Vigna radiate* and *Vigna aconitifolia* by the aqueous extracts of *Balanites roxburghii* leaf fruit. The germination rate was decreased in all at 10 percent extract concentration, but the result was only statistically significant for *Pennisetum typhoides*.

Pravin *et al.* (2017) carried out a study to determine the all elopathic effect solid bamboo *Dendrocalamus stocksii* on growth and yield of paddy. Results revealed that in lab experiment the increasing concentration of the leaf leachates had inhibitory effect on growth parameters (germination, plumule and radicle length) of paddy *(Oriza sativa)*, except the leachates of lower concentration (25% concentration), which had stimulatory effect on plumule length, the effect was concentration dependent. In pot culture experiment the leaf leachates had both stimulatory and inhibitory effect on yield parameters. Stimulatory effect was observed for number of tillers per plant, number of seeds per panicle, test seed weight (except 100% concentration), and straw yield per hectare as compared to control. While inhibitory effect was observed for number of panicles per plant, seed yield per plant (except 50 per cent concentration) and grain yield per hectare (except 50 % concentration).

Ayeni and Kayode (2013) worked on allelopathic effects of extracts derived from the residues of sorghum stem and maize inflorescence on the germination and growth of okra (*Abelmoschus esculentus* L.). Both crop residues (powder) inhibited the growth of okra. The degree of inhibition increased with increase in the concentration of the extracts, thus suggesting that the effects of the extracts from the residues were concentration dependent. Seeds treated with extracts from maize inflorescence revealed that there were no significant differences in the number of leaves at harvest, dry root weight and relative growth rate when compared to the results obtained in the control experiments. The degree of retardation was more pronounced in seeds treated with extracts derived from the residues of maize inflorescence.

The allelopathic effect of three tree species (*Azardiracta indica, Vitellaria paradoxa, and Parkia biglobosa*) on germination and growth of cowpea was investigated in the Southern Guinea Savannah agro ecological zone of Nigeria. Results showed that the tree species brought about considerable inhibition in the germination of cowpea seeds and in its growth parameters. The statistical germination value of the cowpea seeds under the tree species had decreased value thus indicating that growth inhibitions were seriously felt. It was apparent that *Parkia biglobosa* (53.33) and *Vitellaria paradoxa* (60.00) had more inhibitory effect on cowpea seeds germ inability than that of *Azardiracta indica*. (63.33) while all the treatments are lower than that of control (100). The tree species had similar inhibition capability in the cowpea plant height, stem circumference, number of leaves, above grand biomass and below grand biomass. (Aleem *et al.*, 2014).

Gulzar and Siddiqui (2015) conduct research to investigate the effect of aqueous extract from *Calotropis procera* on the growth of *Brassica oleracea var botrytis.* They found that higher concentrations of extract (60% and 80%) significantly reduced germination percentage, radicle length, plumule length, dry matter accumulation, and relative water content of the *brassica* seedlings as compared to control. The reparatory effect increases with the increase in the concentration of three types of extract used, with more pronounced effect noticed by leaf extract followed by fruit and flower extract. There were significant interactions among the different concentrations of extracts used, type of extract with respect to germination percentage, seedling length, dry biomass, and relative water content. The effect of pot based assay in relation to chlorophyll content was significantly reduced and antioxidant enzymes [superoxide dismutase (SOD), peroxidase (POD), and catalase (CAT) activities] show both significant and non-significant effect on antioxidant enzymes based on concentrations of extract and extract type used. The antioxidant enzymes show the significant decrease in its activity at low concentrations (20% and 40%) and non-significant increase at higher concentration (60% and 80%) of extracts in contrast to control.

Albuquerque *et al.* (2010) observed that the phenomenon of allelopathy has recently received greater attention from researchers and farmers worldwide crop failures and low yields caused by the reseeding, over seeding, crop rotation and replanting of fruit trees in orchards are believed to be caused by allelopathic activity. Moreover, the expensive and environmentally impacting herbicides for weed control have motivated studies directed at developing cheaper, environmentally-friendly alternatives. The release and dynamics of allelochemicals in the soil are discussed herein. Examples of allelopathic crops, the allelochemicals produced and their uses in cropping systems are also presented along with current research trends regarding allelopathy.

Adhikary (2017) conducted a research to evaluate the allelopathic effect of *Xanthium indicum L.* on seedling growth and total chlorophyll content in green gram (*Phaseolus radiatus* L.). The results showed that different concentrations of various types of aqueous leachate of test weed (5, 10, 15, 20 and 25%) were reduced seedling growth and total chlorophyll content. The findings reveals that there might have diversified group of allelochemicals present in test weed which leached to soil medium and there after absorbed by crop plant where they reduced or inhibited the intermediate metabolic pathways as a result seedling growth and total chlorophyll content reduced.

Mubeen *et al.* (2012) conducted a study to evaluate the allelopathic effects of water extracts of sorghum and sunflower alone and in combination on the germination and seedling growth of rice and weeds *viz., Trianthema portulacastrum, Dactyloctenium aegyptium* and *Eleusine indica*. Distilled water treatment was included as control. Sorghum and sunflower water extracts when applied in combination caused maximum inhibitory effects on time taken to 50% germination, mean germination time of *E. indica* seeds and germination index of *T. portulacastrum* seeds as compared to the sole application of these water extracts. Water extracts of sorghum and sunflower when applied alone or in combination increased the root, shoot length and the seedling biomass of rice over control. Combined application of sorghum and sunflower water extracts has overall more inhibitory effects on the germination of rice, *T. portulacastrum, D. aegyptium* and *E. indica* when compared to their sole application.

The task of Manimegalai *et al.* (2012) in agriculture is to work out aspects of allelopathy in organic, controlled and manipulated ecosystems. Extracts are prepared using distilled water from dried leaves. The sterilized fifty seeds were put in petridishes with specific *Tectona grandis* leaf extract concentrations (5, 10, 25, 50, 75 and 100%). Seeds with distilled water were maintained as control. The emergence of radical was taken as criteria for germination from 2nd day after sowing. Germination percentage was the maximum in 5% extract treatment and the percentage of germination was gradually decreased as the concentration of extract increased. A low percentage of germination was observed in 100% concentration of leaf extract. The 5% extract alone showed a promontory effect, while the other concentrations exhibited inhibitory effect. The intensity of inhibition increased as the concentration of the leaf extract increased.

Azadiracta indica, or Neem Tree, is a Southeast Asian-born evergreen tree. For decades, all parts of the tree were used medicinally. It is widely used today as well as biological insecticide in toothpastes, soaps and lotion. Neem (*Azadiracta indica*) is a versatile tree native to South and Southeast Asia, Japan, tropical USA, South America, Australia and Africa (Bokhari and Aslam, 1985; Von Maydell, 1986).

2.10 Boundary Plantation trees on Cropland

Tree growing on farm boundaries is a very common practice, but to avoid conflicts, it requires agreement among the neighbors concerned. On a border, there are different ways of sharing trees. Two rows of trees are sometimes planted, one on each side of the boundary, and each farmer then grows and maintains his own trees. With this model, a downside is that it occupies more land than one line. If trees are grown in a single row, the neighbors can agree on ownership of every second tree, for example. In such cases it is recommended that trees of the same species are grown, although it may be difficult to keep track of which tree belongs to which farmer. If different species are chosen, one species may outcome the other and one of the two farmers is disadvantaged. Another option is for the neighbors to agree to own trees in different sections of the boundary. This may be easier than owning every second tree and it is then possible to choose different species for different sections according to the farmers' preferences (Cadenasso *et al.,* 2003; Tengnäs, 1994). In small-scale farming areas boundary planting is usually enough to reduce wind speed, and there is no need to establish windbreaks. Trees on boundaries which are regularly pollarded can meet most of a family's need for firewood. In addition, other products and services are obtained and the boundary is effectively demarcated.

If the trees are not well managed there may be negative effects on crops, and if competitive species are planted root competition may be a problem. Conflicts with neighbors may arise if the sharing arrangements are not well handled (Beer, 1991; Rizvi *et al.,* 2016).

The tradition of growing scattered trees on farmlands is quite old and hasn't changed much over the centuries; these trees are multipurpose, used for shade, fodder, fuel wood, berries, vegetables and medicinal uses. Trees such as Eucalyptus and Populus are also often grown on farm boundaries in Punjab and Haryana in agricultural fields or on field bonds. Examples of traditional Indian Agroforestry systems are shifting cultivation in Northeast India and Taungya in Kerala, West Bengal, and Uttar Pradesh, and to a limited extent in Tamil Nadu, Andhra Pradesh, Orissa, and Karnataka, as well as in the Northeast Hill regions. Certain types of Agroforestry systems are home gardens, wood lots, large Eastern Himalayan cardamom plantations and plantations elsewhere, and Alder-based agriculture in Northeast India (Murthy *et al.,* 2013).

Singh *et al.* (1989) reported an enhancement in SOC by 33.3 to 83.3% for *Populus deltoides* and *Eucalyptus* hybrid with *Cymbopogon* sp., with a greater increase in SOC under *Populus deltoides* plantation. Soil organic carbon has been reported to have improved for Agroforestry plantations ranging in age from 6 years (Maikhuri *et al.*, 2000) to 20 years (Saha *et al.*, 2007). In a Poplar based Agroforestry system, trees could sequester higher soil organic carbon up to 30cm depth during the first year of plantation (6.07 t/ha/yr) than in subsequent years (1.95-2.63 t/ha/yr) with greater soil carbon storage in sandy clays than loamy sand (Gupta *et al.*, 2009). Traditional *Prosopis cineraria* based systems lead to a 50% increase in SOC largely due to leaf litter (Venkateswaralu, 2010). Samra and Singh (2010) observed an increase in soil organic carbon status of surface soil by 0.39 to 0.52% under *Acacia nilotica* + *Sacchram munja* and 0.44 to 0.55% under *Acacia nilotica* + *Eulaliopsis binata* after 5 years.

Further, trees on farms have the potential to improve productivity in two ways. Tree-crop combination can increase the amount of water that is used on farm and can also increase the productivity of water that is used by increasing biomass of trees or crops produced per unit of water. Evidence from semi-arid India and Kenya has shown that the greater productivity of Agroforestry systems is primarily due to the higher amount of water used (Murthy *et al.*, 2005). Higher biomass of ecosystems is associated with higher diversity, and higher species diversity leads to greater carbon sequestration. The management of agricultural lands will therefore play an important role in enhancing carbon sinks and in turn reducing emissions. Land use management measures such as conservation of existing tree cover, promotion of Agroforestry, etc. will not only have positive impacts on biodiversity but also promote the use of biomass fuels, replacing the fossil fuels, thereby contributing to net reduction in CO_2 emissions. Also, an integrated farming approach would bring about change in soil quality, ground water level and thereby improving agricultural productivity, giving the farmer a diversity of products. Tree cultivation on agricultural land improves biomass productivity per unit area and also uses nutrients from different soil layers. Further, land such as bund and avenues that are hitherto not cultivated would increase the tree cover of the landscape (Gopalakrishnan *et al.*, 2011).

Hasanuzzaman *et al.*, (2014) observed that Agricultural cropland is an important production system in Bangladesh's southwest region. This study focused on the composition and management of current cropland Agroforests by florists. A total of 313 cropland Agroforests were surveyed and 83% of respondents practiced pure Agroforestry while the remaining 17%

practiced fisheries Agroforestry. A total of 18 forest trees and 2 shrubs were recorded from 11 families and 59 species of agricultural crops were from 28 families. A higher proportion (79%) of cropland Agroforests were occupied small land areas (0.12−0.80 ha). About 63% of respondents planted trees for fruit production and 47% for timber production, and 35% of respondents engaged in commercial production (35%). *Swietenia macrophylla* was the most prevalent species (relative prevalence 20.83) followed by *Mangifera indica* (relative prevalence 15.57) and *Cocos nucifera* (relative prevalence 7.08). Shorter spacing was used for timber and fuel wood species and wider spacing for fruit trees. A wide range of rotation periods, from 5 to 25 years, was observed for both cases. The use of chemical fertilizer was highest followed by cow dung and compost in cropland Agroforestry. Overall management practices of cropland Agroforestry in southwest Bangladesh were determined by the end product and local demand.

Cropland Agroforestry practice is, however, a relatively a new idea and is only recently adopted in some areas of Bangladesh. Cropland Agroforest includes planting of trees and protecting naturally growing trees in the crop lands (Abedin and Quddus, 1990a; Roy and Siddique, 1997; Ahmed, 2001) along the margins of smaller crop fields and sometimes within the larger crop fields (Roy and Siddique, 1997). Various vegetables, pulses, cereal crops, and cash crops are cultivated at the early stages and shade tolerant crop species are usually cultivated after 10 to 15 years (Chowdhury, 1997). *Azadirachta indica*, *Melia azadirachta*, *Eucalyptus* spp., *Artocarpus heterophyllus*, *Ziziphus* spp., *Cocos nucifera*, *Syzygium* spp. *Mangifera indica*, *Dalbergia sissoo*, *Swietenia macrophylla*, *Albizia* spp. *Leucaena leucocephala*, *Litchi chinensis* and *Acacia* spp. are commonly planted in Agroforestry plots in Bangladesh without much consideration for productivity, sustainability, environmental conservation, land suitability or local demand (Quddus, 2001; Hasanuzzaman *et al.*, 2006; Zaman *et al.*, 2010a). Information on types of Agroforestry or homestead Agroforestry is available in Bangladesh but information on cropland Agroforestry is limited. Moreover, there is almost no information on cropland Agroforests in southwestern Bangladesh. The present study was aimed to provide information about existing cropland Agroforests, particularly their vegetation and management practices. This will help researchers and developers to devise interventions aimed at increased productivity, sustainability and environmental conservation.

People plant trees on all possible types of land in southwest Bangladesh i.e. in croplands and on the boundaries of shrimp/fish culture areas. Mostly two types of cropland Agroforestry practices i.e., pure Agroforestry (83%) and Agroforestry with fisheries (17%) were found in the study area. About 63% of respondents planted trees for fruit production and 47% planted trees for timber, and 35% of respondents tended commercial plots. These results are similar to those reported by Kamaluddin (1997) and Khaleque (1988). Farmer's plant various a totals of 18 tree species and 2 shrubs (10 native and 10 exotic species) were identified from 11 families. Fabaceae, Meliaceae and Palmae accounted for the highest number of species in the cropland Agroforests of southwestern Bangladesh. Kabir and Webb (2008) recorded a total of 146 tree species in the homesteads of southwestern Bangladesh, Uddin *et al.*, (2002) recorded 35 tree species in the southeast, Zaman *et al.*, (2010b) recorded 62 tree species in the north and Ahmed *et al.* (2004) recorded 39 tree species in central Bangladesh. The differences are probably due to the primary products expected from the cropland Agroforests and the species that can grow without sacrificing much of the crop yield. This could be the reason for observing smaller number of tree species in the cropland Agroforests compared to other Agroforestry/homestead forest (Chowdhury, 1997). Among the trees and shrubs, Mahogany (*Swietenia macrophylla)*, Mango (*Mangifera indica*), Coconut (*Cocos nucifera)*, Date (*Phoenix sylvestris*), Palm (*Borassus flabellifer)*, Plum (*Ziziphus* spp.), Litchi (*Litchi chinensis*), Bettle-nut (*Areca catechu*) and Lemon (*Citrus limon*) were identified as major species with relative prevalence (*R*P) ranging from 20.83 to 1.17. *Swietenia macrophylla* was the most prevalent species (*R*P =20.83) in cropland Agroforests in southwest Bangladesh. Regionally, *Artocarpus heterophyllus* (*R*P = 26.28) in central Bangladesh, *Mangifera indica* (*R*P = 32.58) in northern Bangladesh and *Areca catechu* (*R*P = 6.15) in various homesteads of Bangladesh are the most prevalent species (Ahmed *et al.* 2004; Chowdhury, 1997; Zaman *et al.*, 2010a). About 57% of cropland Agroforest farmers in our study area preferred *Swietenia macrophylla* for timber production because of its high market value of timber, small crown with thin branches, straight single stem with a long clear bole, and fast growing characteristics (Mayhew and Newton, 1998). This species can grow in a range of soil types, including alluvial soils, heavy clays, and lateritic soils (Lamprecht, 1989). Neem (*Azadirachta indica*), Ghora neem (*Melia azadirachta*) and Lombu (*Khaya anthotheca*) were also planted as timber species but a small number of respondents (1.0%) preferred Akashmoni (*Acacia auriculiformis*), Sissoo (*Dalbergia sissoo*) and Eucalyptus (*Eucalyptus camaldulensis*) as timber species in our study area. *Eucalyptus camaldulencis* was the most common timber species in northern Bangladesh (Ahmed, 2001).

Nine fruit tree species were identified in the croplands of the study area. Many respondents (41%) planted *Mangifera indica* as a fruit tree followed by *Cocos nucifera* (26%), *Phoenix sylvestris* (24%), *Ziziphus* spp. (11%) and *Areca catechu* (7%). Fruit trees are the most common tree species in the croplands and homesteads of Bangladesh and *Mangifera indica* is the dominant species in every Agroforestry practices in every region of Bangladesh (Chowdhury, 1997; Millat-e-Mustafa *et al.,* 1996; Kamaluddin, 1997). Other species such as, Plum (*Ziziphus* spp.), Litchi (*Litchi chinensis*), Jackfruit (*Artocarpus heterophyllus*), Coconut (*Cocos nucifera*), Date (*Phoenix sylvestris*), Palm (*Borassus flabellifer*) and Bettle-nut (*Areca catechu*) were also found as fruit trees. The mixture of several tree species is more frequent than monoculture in the crop fields of southwest Bangladesh (Chowdhury and Satter, 1992). Only four tree species were used as fuel wood among the identified 18 tree species in the cropland agroforests of our study area. Most of the respondents planted *Albizia saman* for fuel wood but, *Leucaena leucocephala*, *Albizia rechardiana* and *Acacia nilotica* were also recorded as fuel wood species. Farmers planted trees in their croplands to get additional benefits other than agricultural crops, including increased income, supply of fuel wood, timber, construction materials; control of soil erosion and insurance against risk of crop failure (Chowdhury, 1997). Almost all respondents (90%) of our study area commented that gross household income increased due to practice of cropland Agroforestry. Crop yields decline, however, when trees are grown to full size (Chowdhury and Satter, 1992).

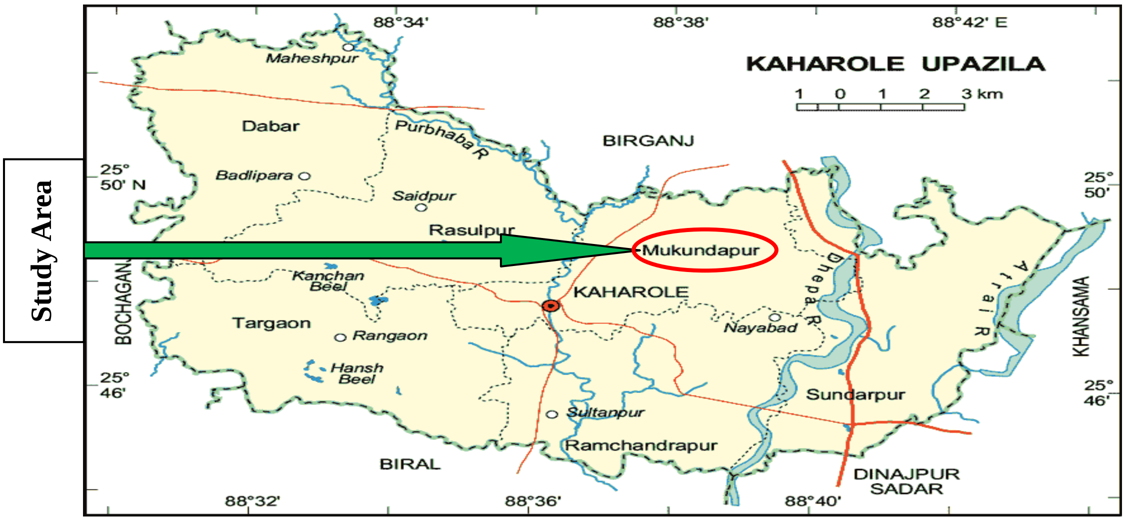
CHAPTER 3

MATERIALS AND METHODS

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

3.1 Location of the Experimental plot

The site of the experiment is situated at Mukundapur, Kaharole upazila (Dinajpur district) area 205.54 sq km, located in between 25°44' and 25°53' north latitudes and in between 88°30' and 89°43' east longitudes. It is bounded by Birganj upazila on the north, Dinajpur sadar and Biral upazilas on south, Khansama and Dinajpur sadar upazilas on the east, Bochaganj upazila on the west. The experimental plots were at Kaharole upazila of Dinajpur district and about 38 m above the sea level.



Map: Khaharol upazila

3.2 Soil Characteristics

The experimental plots were situated in a medium - high area belonging to the Old Himalayan Piedmont plain (AEZ No.1). Land was well-drained and drainage system was well developed. The soil texture was sandy loam in nature. The details soil properties are presented in Appendix-I.

3.3 Climate and weather

The experimental site was located in a tropical climate characterized by heavy rainfall from July to August and minimal rainfall during the rest of the year. The Appendix contains maximum and minimum monthly temperatures, rainfall and relative humidity observed during the experimental period. Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (August 2018 to January 2019) are included in the Appendix-II.

3.4 Experimental Period

Duration of the experimental period was from August 2018 to January 2019.

3.5 Experimental design and treatment

The experiment was laid out following double factor Randomized Complete Block Design (RCBD) with three replications. Total number of the experimental plots were 27. The two factors are-

Factor A: Age of the Eucalyptus tree

Y_1 = 1year

Y_2 = 3year

Y_3 = 5year

Factor B: Distance from the base of eucalyptus tree

D_1 = 1m distance from tree base

D_2 = 3m distance from tree base

D_3 = 5m distance from tree base

3.6 Land preparation

The land was spaded several times followed by laddering to obtain good tilth. All the weeds and rubbishes were removed from the field and then left exposed to natural weathering for several days before the land was finally prepared for seedling transplanting.

3.7 Fertilizer Application

The following fertilizer and manure doses were applied in the field according to Fertilizer Recommendation Guide (2012).

Table: Fertilizer dose per hectare

Types of Fertilizer	Recommended dose
Cow dung	7-10 ton/ha
Urea	180 kg/ha
TSP	100 kg/ha
MOP	70 kg/ha
Gypsum	60 kg/ha

One-third of urea and entire amount of other fertilizers were applied as basal dose at the time of land preparation. The individual plot was spaded and fertilizers were incorporated before seedling transplanting. The remaining two-third of urea was top dressed in two equal splits at early tillering and late tillering stage after weeding followed by irrigation.

3.8 Experimental materials

3.8.1 Crop species and varieties

Rice (*Oryza sativa L.*) was used in this experiment. BRRI dhan51 variety was used as experimental crop. The brief description of this variety is given below.

Rice Variety: BRRI dhan51

The rice variety BRRI dhan51 is developed by Bangladesh Rice Research Institute (BRRI), Gajipur, Bangladesh. This variety developed from an old variety Bijoy11 with the inoculation of 'SUB 1'gen. It has the ability to stay under water up to 15 days in flood affected area. This variety was released in 2010. The main characteristics of this variety are: plant height 90 cm, rice medium-thin and white in color. Need less fertilizer then other variety. Planting time is July 15 to August 20 and harvesting time is December. Days of maturity 142-154 days. Average yield 4.5 ton/ha.

3.8.2 Botanical description of the eucalyptus during the study period

General characteristics Eucalyptus:

Bangladesh planted Eucalyptus in 1867. But a large degraded forest area was planted with eucalyptus within a short period of time. Recently many areas of Bangladesh's northern districts such as Rangpur, Dinajpur, Nilphamari, Lalmonirhat etc. are extensively planted with eucalyptus. Eucalyptus plants at low prices are available. Besides, people can get rapid return as the plant grows really quickly. These have made the tree famous with planting. Yet unplanned planting of this tree can be cause of long run damage of our ecosystem as it invades other more helpful trees in the planting area.

We know that eucalyptus has several exotic features such as high water demand, good nutrient absorption, allelopathy effects, area desertification, soil erosion, etc. Mixed planting with proper management is also suggested for these peculiarities farmers propose that eucalyptus planting needs to be done on marshy land.

Nevertheless, Eucalyptus ' full usage has not been tapped; the introduction of alternative uses will increase the species ' economic significance. Adequate management and plant mixing can reduce environmental uncertainty on eucalyptus. Environmental factors considerations should have priority in crop rotations, while improved technology will sustain productivity. It is essential for efficient production to select suitable provenances for specific sites. In Bangladesh, horizontal and vertical expansion of the planting of eucalyptus is possible without serious environmental effects. It is also possible to extend the species ' economic importance. To encourage eucalyptus planting in the state, extensive research needs to be undertaken.

The existing eucalyptus tree growth status is given below-

1. 0ne year aged tree
    - Average plant height 4.20 m
    - Average basal diameter 12.70 cm
2. Three year aged tree
    - Average plant height 9.60 m
    - Average basal diameter 23.50 cm

3. Five year aged tree
    - Average plant height 11.30 m
    - Average basal diameter 31.90 cm

3.9 Sawing of rice seeds in seed bed

Seeds of BRRI dhan51 were sown on 2nd August 2018 in seed bed.

3.10 Seedling transplanted in main field

28 days old seedling of BRRI dhan51 was transplanted in the main field maintaining plant to plant distance 20 cm and line to line distance 25 cm in 30th August 2018.

3.11 Intercultural operation

Intercultural operations such as weeding and irrigation were given uniformly in each plot. Weeding was done two times on 15 and 45 days after transplanting. The field was irrigated as per needed. Plant protection measure such as insecticide and fungicide spray was required at the panicle initiation stage against different types of past and insects were found in the field.

3.12 Harvesting, threshing and weighting

The crop was harvested on 21th to 28th December 2018 on the basis of maturity. The grain and straw were separated by hand threshing and plot wise. Weight of grain and straw was recorded in kg/plot later expressed in ton/ha.

3.13 Sampling and data collection

For data collection, randomly selected ten plants were harvested from each plot. The harvested crops were then threshed plot wise and grain yield was recorded plot wise on 14% moisture basis as ton/ha. Weight of straw yield was recorded after 4 days of sun dry.

Data was collected on 6 parameters-

- Plant height (cm)
- Number of effective tiller/hill
- 1000 grain wt.(g)
- Grain yield(ton/ha)

- Straw yield (ton/ha)
- Litter fall of eucalyptus /m^2 (dry weight)

3.14 Procedure of data recording

A brief outline of data recording procedure is given below:

3.14.1 Plant height

The plant height was measured from the ground level to the top of flag leaf. From each plot 10 hills were measured and finally averaged the plant height.

3.14.2 Number of effective tiller/hill

The number of effective tillers was counted from 10selected hill.

3.14.3 Thousand grain weight

Thousand grains were randomly selected from each seed stock obtained from each plot and it was dried in an oven up to 14% moisture content. Then weight was taken on an electric balance.

3.14.4 Grain yield (tha^{-1})

Weight of grain was converted into ton/ha.

3.14.5 Straw yield (tha^{-1})

Weight of straw was converted into ton/ha.

3.14.6 Litter fall of eucalyptus /m^2 (dry weight)

Litter fallen from eucalyptus was collected from selected one meter area of each plot and it was dried in an oven. Then weight was taken on an electric balance.

3.15 Bio-economics of the rice under different aged eucalyptus tree based Agroforestry production systems

To assess the economic viability of Agroforestry systems, agricultural rice yield was subjected to economic analysis by calculating the cost of production, gross and net yield per hectare and benefit-cost ratio. All of these parameters are calculated based on the prevailing market rates when the experiments were terminated.

Total cost of production

The rice cultivation value was estimated on the basis of per hectare. Cost elements such as human labor and mechanical power costs, material costs (including seed costs, fertilizers and manures, pesticides, bamboos, ropes, etc.), land use costs and operating capital interest (Appendix III) were included.

Gross return

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

Net return

Net return usually means the profit of the enterprises. Net return was calculated by deducting the total cost of production from the gross return (Kundu, 2002).

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

Benefit-cost ratio (BCR)

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

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

3.16 Statistical analysis

The calculated data were statistically analyzed using the (ANOVA) “Analysis of Variance” technique with the help of the computer package Statistix10. Mean comparisons were done by Tukey HSD test at 5% level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

The result obtained from the present study along with statistical analysis of data have been presented and discussed in this chapter. The present study regarding age differences of eucalyptus tree on the crop field boundary and distance differences of rice plant from eucalyptus tree base effect on rice yield production of transplanted aman rice variety cv. BRRI dhan51. The results and related discussion are presented in this chapter under the following sub heads.

4.1 Effect of age of eucalyptus tree on the growth and yield of BRRI dhan51

4.1.1 Plant height

The effect of age of eucalyptus on plant height of rice was found significantly different (table 4.1). The highest plant height (106.20 cm) was found in five year aged tree ($Y_{3)}$ followed by three year aged tree (Y_2) (101.84 cm). The lowest plant height of rice (97.00 cm) was found under one year aged tree (Y_1). Garrity *et al.* (1992) observed that plant height was higher in shading condition than in open condition in alley cropping of upland rice.

4.1.2 Number of effective tiller/hill

Number of effective tiller per hill of rice was influenced by the age of the eucalyptus tree found significantly different (Table 4.1). The highest number of effective tiller per hill (17.54) was found in one year aged tree (Y_1). On the other hand, the lowest number of effective tiller per hill (15.85) was obtained from five year aged tree (Y_3) which was statistically identical to three year aged tree (Y_2).

4.1.3 1000 grain weight

1000 grain weight of rice was influenced by the age of the eucalyptus tree found significantly different (table 4.1). The highest 1000 grain weight of rice (22.16) was found in one year aged tree (Y_1) which was statistically identical to three year aged tree (Y_2). On the other hand, the lowest 1000 grain weight of rice (19.32) was obtained from five year aged tree (Y_3).

4.1.4 Grain yield (tha^{-1})

Grain weight per hectare of rice was influenced by the age of eucalyptus tree significantly different (Table 4.1). The highest grain weight/ha (3.67 ton) of rice was found in one year aged tree (Y_1) followed by three year aged tree (Y_2) (3.20 ton). On the other hand, the lowest grain weight/ha (2.70 ton) of rice was obtained from five year aged tree (Y_3).

4.1.5 Straw yield (tha^{-1})

Straw weight per hectare of rice was influenced by the age of eucalyptus tree found significantly different (Table 4.1). The highest straw weight ha^{-1} (2.77 ton) was found in one year aged tree (Y_1) treatment. On the other hand the lowest straw weight/ha (2.24 ton) was obtained from five year aged tree (Y_3) which was statistically identical to three year aged tree (Y_2).

4.1.6 Litter fall of eucalyptus/m^2

Litter fall of eucalyptus/m^2 was influenced by the age of eucalyptus tree found significantly different (Table 4.1). The highest litter fall/m^2 (41.33g) was found in five year aged tree (Y_3) followed by three year aged tree (Y_2) (36.33g). On the other hand, the lowest litter fall (20.56g) was obtained from one year aged tree (Y_1).

Table 4.1: Main Effect of different tree age on the growth and yield of rice

Treatment	Plant height (cm)	Number of effective tiller/hill	1000 grain wt.	Grain yield (t/ha)	Straw yield (t/ha)	Litter fall of eucalyptus /m2 (dry wet)
Y_1	97.00 b	17.54 a	22.16 a	3.67 a	2.77 a	20.56 c
Y_2	101.84ab	16.24 b	21.58a	3.20 b	2.40 b	36.33 b
Y_3	106.20 a	15.85 b	19.32 b	2.70 c	2.24 b	41.33 a
CV (%)	5.70	5.27	3.00	9.96	12.14	9.22

* In a column different letters are significantly different at $P \le 0.05$, 0.01 and 0.001 by Tukey HSD test.

Note: Y_1 = 1year, Y_2 = 3year, Y_3 = 5year

4.2 Effect of distance from the base of eucalyptus tree on the growth and yield of BRRI dhan51

4.2.1 Plant height

The effect of distances from the base of eucalyptus tree on plant height of rice was found significantly different (table 4.2). The highest plant height (107.81 cm) was found in one meter distance from tree base (D_1) followed by three meter distance from tree base (D_2) (101.59 cm). On the other hand the lowest plant height of rice (95 cm) was obtained from five meter distance from tree base (D_3) treatment.

4.2.2 Number of effective tiller/hill

Number of effective tiller per hill of rice was influenced by the distance from the base of the eucalyptus tree found significantly different (Table 4.2). The highest number of effective tiller per hill (17.22) was found in five meter distance from tree base (D_3) which is statistically identical to three meter distance from tree base (D_2). On the other hand, the lowest number of effective tiller per hill (15.88) was obtained from one meter distance from tree base (D_1).

4.2.3 1000 grain weight

1000 grain weight of rice was influenced by the distance from the base of the eucalyptus tree found different (table 4.2). Here the highest 1000 grain weight of rice (21.42 g) was found in five meter distance from tree base (D_3) followed by three meter distance from tree base (D_2) (20.99 g). On the other hand, the lowest 1000 grain weight of rice (20.65 g) was obtained from one meter distance from tree base (D_1) treatment.

4.2.4 Grain yield (tha^{-1})

Grain weight per hectare of rice was influenced by the distance from the base of eucalyptus tree found significantly different (Table 4.2). The highest grain weight/ha (3.40 ton) of rice was found in five meter distance from tree base (D_3) treatment followed by three meter distance from tree base (D_2) (3.17 ton). On the other hand, the lowest grain weight/ha (3.00 ton) of rice was obtained from one meter distance from tree base (D_1) treatment.

4.2.5 Straw yield (tha^{-1})

Straw weight t/ha of rice was influenced by the distance from the base of eucalyptus tree found significantly different (Table 4.2). The highest straw weight per ha. (2.73 ton) was found in five meter distance from tree base (D_3) treatment. On the other hand the lowest straw weight/ha (2.21 ton) was obtained from one meter distance from tree base (D_1) which was statistically identical to three meter distance from tree base (D_2) treatment.

4.2.6 Litter fall of eucalyptus/m2

Litter fall of eucalyptus/m2 was influenced by the distance from the base of eucalyptus tree found significantly different (Table 4.2). The highest litterfall/m^2 (53.89 g) was found in one meter distance from tree base (D_1) followed by three meter distance from tree base (D_2) (29.67 g). On the other hand, the lowest litterfall (14.67 g) was obtained from five meter distance from tree base (D_3) treatment.

Table 4.2: Main Effect of tree base distance on the growth and yield of rice

Treatment	Plant height (cm)	Number of effective tiller/hill	1000 grain wt.	Grain yield (t/ha)	Straw yield (t/ha)	Litterfall of eucalyptus /m2 (dry
D_1	107.81 a	15.88 b	20.65 b	3.00 b	2.21 b	53.89 a
D_2	101.59 b	16.53 ab	20.99 ab	3.17 ab	2.46 ab	29.67 b
D_3	95. c	17.22 a	21.42 a	3.40 a	2.73 a	14.67 c
CV (%)	5.70	5.27	3.00	9.96	12.14	9.22

* In a column different letters are significantly different at $P \leq 0.05$, 0.01 and 0.001 by Tukey HSD test.
Note: D_1 = 1m distance from tree base, D_2 = 3m distance from tree base, D_3 = 5m distance from tree base

4.3 Interaction effect of tree age and tree base distance of Eucalyptus trees

4.3.1 Plant height

From the interaction effect of tree age and different distance from eucalyptus tree base, the plant height of rice was shown different (table 4.3). The highest plant height of rice (112.63cm) was found in five year aged tree with one meter distance (Y_3D_1) combination. The lowest plant height of rice (91.83cm) was found in one year aged tree with five meter distance (Y_1D_3) combination.

4.3.2 Number of effective tiller/hill

Number of effective tiller $hill^{-1}$ of rice was affected by the interaction of tree age of eucalyptus tree and different distance from tree base (table 4.3). The highest number of effective tiller $hill^{-1}$ (18.17) was observed in one year aged tree with five year distance (Y_1D_3) combination. The lowest number of effective tiller $hill^{-1}$ (15.03) was recorded in five year aged tree with one meter distance (Y_3D_1) combination.

4.3.3 1000 grain weight

1000 grain weight of rice was also influenced by the interaction of tree age of eucalyptus and different distance from the tree base found significantly different (Table 4.3). Significantly, the highest 1000 grain weight of rice (22.87g) was found in one year aged tree with five meter distance (Y_1D_3) combination. On the other hand, the lowest 1000 grain weight of rice (18.87g) was obtained from five year aged tree with one meter distance (Y_3D_1) combination which is statistically identical to Y_3D_2 (19.31g) and Y_3D_3(19.77g).

4.3.4 Yield (tha^{-1})

Grain yield of rice per hectare was influenced by the interaction effect of tree age and different distance from tree base found significantly different (Table 4.3). Significantly, the highest grain yield of rice per hectare (3.9 ton) was found in one year aged tree with five meter distance (Y_1D_3) combination which was statistically identical to Y_1D_2 (3.6 ton). On the other hand, the lowest grain yield per hectare of rice (2.5 ton) was obtained from five year aged tree with one meter distance (Y_3D_1) combination.

4.3.5 Straw weight (tha^{-1})

Straw yield of rice per hectare was influenced by the interaction effect of tree age and different distance from the eucalyptus tree base found different (Table 4.3). The highest straw yield of rice per hectare (3.12 ton) was found in one year aged tree with five meter distance (Y_1D_3) combination. On the other hand, the lowest straw weight per hectare of rice (2.01ton) was obtained from five year aged tree with one meter distance (Y_3D_1) combination.

4.3.6 Litter fall of eucalyptus/m^2 (dry weight)

The interaction effect of tree age and different distance from the eucalyptus tree base, influenced on litter fall of eucalyptus/m^2 (dry weight) found significantly different (Table

4.3). The highest litter fall of eucalyptus/m^2 (60.33 g) was found in Y_3D_1 combination. On the other hand, the lowest litter fall of eucalyptus/m2 (6.67g) was obtained from Y_1D_3 combination.

Table 4.3: Interaction effect of tree age and tree base distance of Eucalyptus trees

Treatment	Plant height (cm)	Number of effective tiller/hill	1000 grain wt.	Grain yield (t/ha)	Straw yield (t/ha)	Litter fall of eucalyptus g/m^2 (dry wet)
Y_1D_1	102.75 abc	16.85 abc	21.10 c	3.5 abc	2.46 bcd	43.33 b
Y_1D_2	96.42 cd	17.61 ab	22.52 ab	3.6 ab	2.73 ab	11.67 ef
Y_1D_3	91.83 d	18.17 a	22.87 a	3.9 a	3.12 a	6.67 f
Y_2D_1	108.05 ab	15.75cd	20.65 abc	3.0 cdef	2.17 cd	58.00 ab
Y_2D_2	101.68 bcd	16.02 cd	21.15 c	3.2 bcde	2.37 bcd	35.00 c
Y_2D_3	96.00 cd	16.95abc	21.62 bc	3.4 abcd	2.67 abc	16.00 e
Y_3D_1	112.63 a	15.03d	18.87 d	2.5 f	2.01 d	60.33 a
Y_3D_2	106.87 ab	15.97 cd	19.31 d	2.7 ef	2.29 bcd	42.33 b
Y_3D_3	101.43 bcd	16.55 bc	19.77 d	2.9 def	2.42 bcd	21.33 d
CV (%)	5.70	5.27	3.00	9.96	12.14	9.22

* In a column different letters are significantly different at P≤0.05, 0.01 and 0.001 by Tukey HSD test.

Note: Y_1D_1= 1year with 1m distance, Y_1D_2= 1year with 3m distance, Y_1D_3= 1year with 5m distance, Y_2D_1 = 3year with 1m distance, Y_2D_2 = 3year with 3m distance, Y_2D_3 = 3year with 5m distance, Y_3D_1 = 5year with 1m distance, Y_3D_2 = 5year with 3m distance, Y_3D_3 = 5year with 5m distance

4.4 Economic analysis

Profitability of growing rice BRRI dhan51 as inter-crop in Eucalyptus tree distance (1m, 3 m and 5 m) and age (1 yr, 3yr and 5yr) based Agroforestry production system was calculated based on local market rate prevailed during experimentation. The cost of production of rice BRRI dhan51 and cost of production of different aged eucalyptus tree plantation and management have been summarized in appendix III. The return of produce and the profit per taka i.e. Benefit Cost Ratio (BCR) have been presented in Table 4.4.

4.4.1 Total cost of production

The values in Appendix III indicate that the total cost of production was highest (66652 tk/ha) in all the rice + five year aged eucalyptus based cropland Agroforestry (i.e. Treatment Y_3D_1, $Y_3D_{2,}$ and $Y_3D_{3,}$). But the lowest cost of production (66014 tk/ha) was recorded from all the rice + one year aged eucalyptus tree based cropland Agroforestry (i.e. Treatment $Y_1D_{1,}$ Y_1D_2 and Y_1D_3).

4.4.2 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. The highest value of gross return (230825 tk. /ha) was obtained from the five meter distance of five year aged eucalyptus tree based Agroforestry production system. On the other hand, the lowest value of gross return (102975 tk. /ha)was obtained from the one meter distance of one year aged eucalyptus tree based Agroforestry production system.. The highest gross return was obtained due to yield of rice with the value of eucalyptus tree (Table 4.4).

4.4.3 Net return

Results presented in the Table 4.4 show that net return (164173 tk/ha) was comparatively higher in producing rice from the five meter distance and five year age (Y_3D_3) of eucalyptus tree based Agroforestry production system followed by Y_3D_2, Y_3D_1, Y_2D_3 eucalyptus tree based Agroforestry production system. At the same time, the lowest net returns (36961tk. /ha) was received from the one meter distance and one year aged (Y_1D_1) combination. Higher net return was the result of higher gross return from the higher yield of rice along with the value of eucalyptus tree.

Table 4.4: Economics of rice BRRI dhan51 production under the different aged eucalyptus tree and different distance of eucalyptus tree based Agroforestry system.

Treatment	Return			Gross return (tk/ha)	Cost of production (tk/ha)	Net income (tk/ha)	BCR
	Tree (tk/ha)	Rice yield (tk/ha)	Straw yield (tk/ha)				
Y_1D_1	33800	56875	12300	102975	66014	36961	1.56
Y_1D_2	33800	58500	13650	105950	66014	39936	1.60
$Y1D_3$	33800	63375	15600	112775	66014	46761	1.71
Y_2D_1	104000	48750	10850	163600	66353	97247	2.47
Y_2D_2	104000	52000	11850	167850	66353	101497	2.53
Y_2D_3	104000	55250	13350	172600	66353	106247	2.60
Y_3D_1	171600	40625	10050	222275	66652	155623	3.33
Y_3D_2	171600	43875	11450	226925	66652	160273	3.40
Y_3D_3	171600	47125	12100	230825	66652	164173	3.46

Tree=130tk/1year tree, 400tk/3year tree and 660tk/5year tree (4 month), Rice=16.25tk/kg, Straw=5tk/kg.

Note: Y_1D_1= 1year with 1m distance, Y_1D_2= 1year with 3m distance, Y_1D_3= 1year with 5m distance, Y_2D_1 = 3year with 1m distance, Y_2D_2 = 3year with 3m distance, Y_2D_3 = 3year with 5m distance, Y_3D_1 = 5year with 1m distance, Y_3D_2 = 5year with 3m distance, Y_3D_3 = 5year with 5m distance

4.4.4 Benefit-cost ratio

The highest benefit-cost ratio of 3.46 was recorded from the five meter distance with five year age (Y_3D_3) of eucalyptus tree based Agroforestry production system followed by Y_3D_2, Y_3D_1. The lowest benefit-cost ratio of 1.56 was observed in Y_1D_1 i.e. in one meter distance with one year aged eucalyptus tree based Agroforestry production system. So, rice can profitably be cultivated from the five meter distance (D_3) and five year age (Y_3) of eucalyptus tree based Agroforestry production system. Thus, it may be advocated that such type of speculation will be beneficial to the farmer as because such production system not only provides cash money to the farmer but also gradually can enrich the soil nutritionally.

Discussion

Throughout the world, there is a huge diversity of Agroforestry systems in which the introduction of bushes and trees has many benefits. Trees strengthen the soil's microclimate and water holding ability. Compared to the past several decades, this method is now becoming popular among the country's farmers. The present research has been undertaken to evaluate the performance of growth, yield and yield contributing characters of BRRI dhan51 in association with 1, 3 and 5 meter distance from 1, 3 and 5 year aged Eucalyptus tree. Reduction of yield and yield contributing characteristics of rice varieties at different distances and age from the Eucalyptus tree-rice association may be due to the effect of shading (lack of appropriate light intensity). Nonetheless, research report in relation to the study lower grain yield under shade was not available due to the combined effect of reducing the amount of active tillers hill-1, plant height and increase in panicle sterility, 1000 grain weight. Jadhav (1987); Ingram (1989) and Chaturvedi reported similar findings.

Combining agricultural crops with eucalyptus trees for the production of pulpwood could yield higher profits than either pure planting. Individual farmers ' profitability of eucalyptus planting varies with farm gate prices and trees yield, which in turn depends on soil quality, spacing, and production technology. The land's opportunity cost is an important factor that affects the planters' net return. We used the net yield crops such as chilies, cotton, green gram, black gram upland rice on land with poor soil.

To qualify for Agroforestry, a tree should have qualities such as rapid growth, no negative effect on grain production or otherwise net income for farmers and compensate for the loss due to lower grain production, provide shelter against crops and orchards, litter or organic matter to enrich farmers' land, cattle feed, fuel wood and small wood for domestic oil. Eucalyptus, however, did not meet most of the requirements, but their ability to resist unfavorable soil conditions, simple initial establishment, rapid irrigation response, fertilizers, and small-sized straight knot-free timber that only a few indigenous trees could produce soon became a favorite species of farmers. Eucalyptus could be grown in close spacing, like conifers, which would mean intensive planting in limited areas rather than managing large fields. India's population grew at a rate of 2.78 per cent per year, which meant more houses for shelter, fuel wood for heating and cooking, and clothing and paper. In order to produce the industrial quantities of consumables, the industry needed raw materials. Eucalypts were the only plants which increased production could be grown in the farmlands.

In order to control the number and distribution of plants in the plantation area, plant spacing is important. Optimum spacing between crop cultivation must be compromised in Agroforestry plantations as well as optimizing wood yield and reducing maintenance and consumption costs. In particular, when it is planned to increase agricultural crops in combination with planting, wider spacing must be followed to protect crops from shading as well as free movement of agricultural machinery. Moisture plays a key role in assessing the distribution of eucalyptus in Agroforestry plantations. Wider spacing is practiced in dry areas where soil moisture is the limiting factor. In irrigated plantations, closer spacing is adopted, as the cost for irrigation increases with wider spacing. In shallow soils unless fertilized, the spacing will also have to be wider for providing more spacing for root development. In wet areas, on the other hand, where ridges are prepared on drain ploughs, spacing has to be coordinated with the drainage pattern. Where there is market for small diameter stems, close spacing is usually adopted. Closer spacing can be adopted for production of fuel wood, and small diameter poles for pulp wood or pit props. Also when main objective is to get the maximum production of saleable volume, closer spacing at short rotation helps. With wider spacing's and short rotation, there is a loss of volume production since the site is not fully occupied and the mean tree size increases. Furthermore, the stem taper is decreased by wider spacing resulting in a reduction in percentage conversion when the log is saw. Taking into account the above principles, the farmers have adopted the specific spacing according to the amount of harvestable products (Maithani and Sharma, 1987).

CHAPTER 5

SUMMARY AND CONCLUSION

Summary

The field experiment was carried out at Kaharole upazila in Dinajpur district during August 2018 to January 2019 to evaluate the variation and economic performance of BRRI dhan51 under different ages and distances base eucalyptus tree based Agroforestry system. The experiment was laid out following double factor Randomized Complete Block Design (RCBD) with three replications. Total numbers of the experimental plots were 27. The treatments of the experiment were Y_1= Rice cultivation under 1 year aged eucalyptus tree, Y_2 = Rice cultivation under 3 year aged eucalyptus tree, Y_3 = Rice cultivation under 5 year aged eucalyptus tree and D_1 = Rice cultivation from 1m distance of eucalyptus tree base, D_2 = Rice cultivation from 3m distance of eucalyptus tree base, D_3 = Rice cultivation from 5m distance of eucalyptus tree base.

The experimental field was opened with a spade on 2nd August 2018 and seeds of BRRI dhan51 were sown at the same day in seed bed. 28 days old seedling of BRRI dhan51 was transplanted in the main field maintaining plant to plant distance 20 cm and line to line distance 25 cm in 30th August 2018. Weeding was done two times on 15 and 45 days after transplanting (DAT). The field was irrigated as per needed. Plant protection measure was done as per required. For collecting data on several plant parameters 10 randomly selected plants were uprooted from each plot.

The data were recorded based on Plant height (cm), Number of effective tiller/hill, 1000 grain weight (g), Grain yield(ton/ha), Straw yield (ton/ha), Litter fall of eucalyptus /m^2 (dry weight). Incase of economic analysis the benefits and cost ratio was done. The data were analyzed statistically and means were adjusted by Tukey HSD test.

The results were showed on age different based treatment significantly, the highest plant height (106.20 cm) was found in Y_3 treatment (5 year aged tree) and the lowest (97.00 cm) was obtained from Y_1 treatment (1 year aged tree). On the other hand the highest number of effective tiller/hill (17.54) was found in $Y_1$and the lowest number of effective tiller/hill (15.85) was obtain from Y_3treatment.On the other hand highest 1000 grain weight (22.16 g) was found in Y_1 treatment and the lowest was Y_3 (19.32 g), the highest grain weight (3.67 t)

was found from Y_1 and the lowest (2.70 t) was obtain from Y_3 treatment. On the other hand straw weight (2.77 t) from Y_1 was the highest and the lowest (2.24 t) straw production obtain from Y_3 treatment. Highest amount of litterfall of eucalyptus (41.33 g) was obtained from Y_3 and the lowest amount (20.56 g) was found from Y_1 treatment.

The result obtain from different distance based finding significantly, the highest plant height (107.81 cm) was found in D_1 (1m distance) treatment and the lowest (95 cm) was obtain from D_3 (5m distance) treatment. On the other hand the highest number of effective tiller/hill, 1000 grain weight, grain yield/ha, straw yield ton/ha was obtained (17.22, 21.42g, 3.40t/ha, 2.73t/ha respectively) from D_3 (5m distance) treatment and the lowest (15.88, 20.65g, 3.00t/ha, 2.21t/ha) respectively from D_1 (1m distance). On the other hand the highest amount of litterfall (53.89g/m^2) was found from D_1 treatment and the lowest amount (14.67g) was obtained from D_3 treatment.

The result from the interaction effect of age difference and different distance from eucalyptus tree base, the highest plant height (112.63 cm) was found in Y_3D_1 and the lowest plant height (91.83 cm) was obtain from Y_1D_3 combination. On the other hand the highest number of effective tiller/hill, 1000 grain weight, grain yield/ha, straw yield ton/ha was obtain (18.17, 22.87g, 3.9t/ha, 3.12t/ha respectively) from Y_1D_3 combination and the lowest (15.03, 18.87g, 2.5t/ha, 2.01t/ha) respectively from Y_3D_1combinatin. The highest litter fall of eucalyptus/m^2 (60.33 g) was found inY_3D_1 treatment combination. On the other hand, the lowest litterfall of eucalyptus/m^2 (6.67g) was obtained from Y_1D_3 treatment combination

It was observed that rice production from Y_3D_3 combination gave the highest net return (164173 tk/ha) followed by (160273 tk/ha) from Y_3D_2 combination and (155623 tk/ha) from Y_3D_1 combination. At the same time the lowest net return (36961 tk/ha) was obtain from Y_1D_1 combination followed by (39936 tk/ha) from Y_1D_2 combination and (46761 tk/ha) from Y_1D_3 combination. Higher net return was the result of higher gross return from the higher yield of rice along with the value of eucalyptus tree. The highest benefit-cost ratio 3.46 was recorded from the combination of Y_3D_3 and the lowest benefit-cost ratio 1.56 was obtained from Y_1D_1 combination of eucalyptus tree based Agroforestry system.

Conclusion

It may be concluded from the present study that the rice production of BRRI dhan51 were gradually increased with the increase of distance from the base of eucalyptus tree and decreased with the increase of tree age. But in case of monetary return maximum return was obtained from rice cultivation with aged eucalyptus tree due to the additional value of eucalyptus timber.

Recommendation

1. Farmer of Dinajpur district could grow BRRI dhan51 with eucalyptus tree in the boundary plantation cropland Agroforestry system for better monetary return.
2. The experiment was done with only one rice variety. So, to get a valid recommendation, more experiments should be done in different region of Bangladesh with different rice variety.

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APPENDIX

Appendix I. The physical and chemical properties of soil in experimental field situated in Rasulpur under Kaharole upazila, Dinajpur

Soil characters	Physical and chemical properties
Texture	
Sand (%)	64
Silt (%	29
Clay(%	7
Textural class	Sandy loam
CEC (meq/ 100g)	8.12
p^H	6.3
Organic matter (%)	1.09
Total nitrogen (%)	0.11
Sodium (meq/ 100g)	0.05
Calcium (meq/ 100g)	1.05
Magnesium (meq/ 100g)	0.27
Potassium (meq/ 100g)	0.18
Phosphorus (µg/g)	21.0
Sulphur (µg/g)	2.42
Boron (µg/g)	0.36
Iron (µg/g)	5.31
Zinc (µg/g)	0.73

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

Appendix II. Weather data of the experimental site during the period from August 2018 to January 2019

Months	* Air Temperature (^0F)			* Average Rainfall (mm)	* Relative Humidity Average (%)
	Maximum	Minimum	Average		
August	99	78	87	52.4	81
September	94	77	85	22.5	81
October	93	67	80	36.5	79
November	87	56	71	0	75
December	81	52	66	9.2	75
January	78	47	62	1.1	72

Note * Monthly average

Source: www.timeanddate.com

Appendix III. Cost of production for Rice-Eucalyptus tree based Agroforestry system.

Treatment	Input cost										Total input cost (Tk/ha)	Over head cost			Total cost of production
	Non material cost (Tk/ha)					Material cost (Tk/ha)						Interest o f input cost @ 8% for the crop season (Tk/ha)	Interest of the value of land (Tk. 300000/ha) @ 8% for the crop season (Tk/ha)	Miscella -neous cost @ 5% of the input cost (Tk/ha)	
	Trees	Rice Production	Mainte-nance cost of trees	Initial plantatio n cost of trees	Total non-materi al cost	Seedlings	Fertilizers	Pesticides	Irrigation	Total material cost (Tk/ha)					
1year tree+Rice	3500	27000	1210	2150	33860	1490	9950	1500	1000	13940	47800	3824	12000	2390	66014
3year tree+Rice	3500	27000	1510	2150	34160	1490	9950	1500	1000	13940	48100	3848	12000	2405	66353
5year tree+Rice	3500	27000	1774	2150	34424	1490	9950	1500	1000	13940	48364	3869.12	12000	2418.2	66651.3

Note: Urea 16 Tk/kg, MP 17 tk/kg, Labor 250 tk/day, Plantation and maintenance cost for eucalyptus were 25 and 10 tk/tree.

Appendix IV: Some Plates of research plot of the experiment

Plate 1: Effect of Eucalyptus on rice Production

Plate 2: Data recording in the Lab.