PRODUCTION POTENTIALITY OF GIMA KALMI UNDER MANGO AND GAMARI TREE BASED AGROFORESTRY SYSTEM IN CHAR LAND

A THESIS

BY

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Student No. 1805339

Semester: January- June, 2020

MASTER OF SCIENCE (M.S.)
IN
AGROFORESTRY AND ENVIRONMENT

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

JUNE 2020

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JUNE 2020

DEDICATED

TO MY

FAMILY & RIJVEE

DECLARATION

I hereby declare that the work presented in this thesis titled "**PRODUCTION POTENTIALITY OF GIMA KALMI UNDER MANGO AND GAMARI TREE BASED AGROFORESTRY SYSTEM IN CHAR LAND"** has been carried out by myself and that it has not been submitted for any previous degree. All questions have been distinguished by quotation marks and all sources of information specifically acknowledged by references to the authors.

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June, 2020 *The Authoress*

PRODUCTION POTENTIALITY OF GIMA KALMI UNDER MANGO AND GAMARI TREE BASED AGROFORESTRY SYSTEM IN CHAR LAND

ABSTRACT

A field experiment was conducted in the char land of Gangachara Upazila under Rangpur district during July, 2019 to September, 2019 to evaluate the performance of Gima Kalmi under Mango and Gamari tree based agroforestry system influenced by different production systems and fertilizers application packages. The experiment was laid out in two factorial RCBD with 4 (four) replications. Factor A was three production systems viz. S_1= Mango + Gima Kalmi, S_2= Gamari + Gima Kalmi, S_3= Gima Kalmi sole cropping and Factor B was four fertilizer and manure application packages viz. F_0= No Fertilizer, F_1= only cow-dung @ 10 t/ha, F_2= only poultry manure @ 5 t/ha and F_3= only chemical fertilizer as per Standard Recommendation Guide. The total numbers of experimental plots were 48. The result of the experiment revealed that plant height [30, 45, 60 and 75 DAS (Days after sowing)] as cm, number of leaves/plant (30, 45, 60 and 75 DAS), number of branches/plant (30, 45, 60 and 75 DAS), weight of fresh leaves/plant (30,45, 60 and 75 DAS) as gm, yield (30, 45, 60 and 75 DAS) as (t/ha) of Gima Kalmi significantly varied due to the different production systems and fertilizer applications when cultivated under the Mango and Gamari tree based agroforestry system in char land of Tista river basin. In case of main effects of different production systems, the maximum yield (9.08 t/ha) was recorded from Gima Kalmi sole cropping i.e. in treatment S_3, whereas moderate yield (7.51 t/ha) was recorded from Mango + Gima Kalmi based agroforestry system i.e. in treatment S_1. On the other hand, the minimum yield (3.82 t/ha) was recorded from Gamari + Gima Kalmi based agroforestry system i.e. in treatment S_2. In case of main effects of fertilizer and manure applications, the highest yield (9.42 t/ha) was recorded from the plot where fully chemical fertilizer (F_3) was applied whereas the lowest yield (3.71 t/ha) was obtained from the plot where no fertilizer (F_0) was applied. Again, in case of interaction effects the maximum yield (10.54 t/ha) was recorded in the plot where Gima Kalmi was cultivated as sole cropping using only chemical fertilizer (S_3F_3) whereas the minimum yield (14.2 t/ha) was recorded in the plot where Gima Kalmi was cultivated at the floor of Gamari woodlot with no fertilizer (S_2F_0). From the economic analysis, it was found that the highest benefit-cost ratio (4.15) was recorded from Mango + Gima Kalmi based agroforestry system (S_1) followed by Gamari + Gima Kalmi based agroforestry system (S_2). On the other hand, the lowest benefit-cost ratio (2.93) was observed in Gima Kalmi sole cropping (S_3). Finally, it may be concluded that Gima Kalmi can be cultivated successfully under newly established Mango and Gamari based agroforestry systems at the char land considering the additional returns as per investment in terms of money and time in the char land of Tista River Basin.

Key words: Gima Kalmi, Mango Tree, Gamari Tree, Agroforestry and Char land

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CHAPTER 1
INTRODUCTION

1.1 Background information of the study

Agroforestry as a land use system that integrates trees, crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible and socially acceptable to the farmers (Nair, 1979). There must be significant ecological and economical interactions between the woody and non-woody components (Lundgren and Raintree, 1982). Through agroforestry, important forest products and desirable forest environment may be obtained almost everywhere in the country (Manandhar, 1986). Bangladesh is one of the most densely populated countries in the world bearing about 164.7 million inhabited in the area of 147570 sq kilometers. Bangladesh is also an agricultural country (Worldometers, 2020). The total forest area of the nation covers about 17% of the land (BBS, 2016) but the effective tree covered area is estimated at around 10%. This remaining forest is also shrinking gradually due to encroachment for human habitation and agricultural expansion.

To maximize the crop production to feed the increasing population various types of practices such as mixed cropping, alley cropping, multistoried cropping system are adopted in Bangladesh. Like other districts, Rangpur is also a highly populated district in Bangladesh. Rapid population growth has created severe pressure on the agricultural land. But there are huge char area in Rangpur district under the Tista river basin. In this context Mango and Gamari based agroforestry practices can play an important role to improve the production level in this district as well as in the whole country by producing different types of vegetables and spices with Mango fruit and Gamari wood.

Mango (*Mangifera indica*) is the favorite fruit in Bangladesh and has been repeatedly acclaimed as the king of fruits (Ahmed, 1994). Mango belongs to the family Anacardiaceae is a tropical to sub-tropical fruit. It is important economic and delicious fruit. The plant starts bearing 3 to 5 years after planting and reaches their maximum bearing capacity within 12-15 years. In Bangladesh, mango ranks first in terms of area and third in production (BBS, 2008). So, combined production of vegetables and mango play important role in human nutrition as sources of vitamins and minerals which are not in adequate qualities in other food items such as wheat, rice etc. Cultivating various vegetables and spices especially in the early developing stage of mango tree (generally 1 to 10 years) under the mango tree, there is a great scope for increasing the production of vegetables throughout. The average annual net returns of the traditional agrosilvicultural practices were found much higher than the agriculture (Abedin and Quddus, 1991). Mango is the popular fruit. But the farmers are losing their interest in such kind of agroforestry system due to some problems. Agroforestry system especially Mango based agroforestry may be popular among the farmers if effective measures are taken for increasing production and different management practices.

Gamari (*Gmelina arborea*) is a fast growing deciduous tall tree with branches attaining a height of 15-35 m. The trunk can be 3-5m in diameter. It is suitable tree for rapid forestation. It is like to the local people for its light but durable timber. The tree is available in Chittagong and Chittagong hill tracts and Sylhet hilly area. But it can be cultivated in char land also.

Gima Kalmi (*Ipomoea aquatica*) is a leafy vegetable which belongs to the family Convolvulaceae. The vegetable crop is also known as Kangkong, swamp cabbage, water convolvulus, water spinach etc. It is an excellent source of Vitamin-A. In Bangladesh most of the vegetable are produced in summer and winter seasons, while in between these two seasons (Shinohara, 1978). Aquatic type of local Kalmi is naturally grown in ponds or marshy land of Bangladesh. Gima Kalmi is a special significance, because it grows on upland soil with an appreciable yield potential of foliage.

For proper crop production, application of fertilizer and manure is one of the most important factors. Fertilizer increases the vegetative growth of plants and produces good quality foliage and promotes carbohydrate synthesis. For successful production, Gima Kalmi requires early and rapid vegetative growth, which could be influenced by application of fertilizers and manure.

1.2 Research problem

Gima Kalmi is usually recommended for enrichment of human diet but unfortunately this crop cannot be successfully grown during the summer and rainy season in Bangladesh when serious scarcity of vegetables prevails that time due to cultivable land unavailability. However, agroforestry system can play an important role to increase the production of this crop. So, it is necessary to test the performance of this crop under different agroforestry system using different intercultural approaches. But in our country, the land is insufficient for this system. Therefore, in char land area which is increasing in Bangladesh and fruit tree based agroforestry system may be a good option in these land area. Unfortunately, there are not enough study and information regarding the possibility of Gima Kalmi based agroforestry practices in char land. Considering these circumstances, an experiment was conducted at the char of Rangpur district under Tista River with the following objectives.

1.3 Research Objectives:

- To find out the possibility and economic output of Gima Kalmi production at the floor of Mango garden and Gamari tree woodlot in char land.
- To find out the impact of different fertilizers and manures application packages on the yield of Gima Kalmi under Mango and Gamari based agroforestry practices in char land.
- To find out the economic performance of Gima Kalmi-tree based agroforestry practices.

CHAPTER 2

REVIEW OF LITERATURE

There are huge amount of literature is available to understand various aspects of Agroforestry systems, although information is in adequate with respect to quantification of biological interactions among the components in agroforestry systems especially in char land. Keeping this in view, an attempt has been made to review findings on Agroforestry practices with particular emphasis on Gima Kalmi association with Mango and Gamari tree. The relevant literatures pertaining to the present study have been reviewed in this chapter under the following heads:

2.1 Concept of agroforestry and importance
2.2 Agroforestry in Bangladesh context
2.3 Effect of fruit trees on agroforestry system
2.4 Char land based on agroforestry system
2.5 Mango based agroforestry system
2.6 Importance of studies summer vegetables

2.1 Concept of Agroforestry and importance

Agroforestry- the integration of trees with annual crop cultivation, livestock production and other farm activities-is a series of land management approaches practiced by more than 1.2 billion people worldwide. Integration increase farm productivity when the various components occupy complementary niches and their associations are managed effectively. Potential for the diversification of crop production lies in the great range of lesser-used indigenous foods found in forests and staple crops (see background paper on the contribution of forest to sustainable diets (Malezieux, 2013).

Agroforestry has been promoted as a sustainable and ecologically sound alternative approach to manage upland landscapes. It involves the integration of annual and perennial food crops as well as livestock, which renders social, economic and environmental benefits (Leaky, 1996). However, the question is whether it is financially attractive for farmers to adopt.

Throughout the world, at one period or another in its history, it has been the practice to cultivate tree species and agricultural crops in intimate combination. The examples to numerous. Verma *et al.* (2016) stated that ‘Agroforestry has been defined as a dynamic ecologically based natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels’.

According to Alao and Shuaibu (2013). “Agroforestry include the optimal use of land for both agricultural and forestry production on a sustainable basis including the improvement of the quality of soil. This is in addition to the socio-economic benefits that are accruable from agroforestry. Indeed, the advantage of agroforestry is all encompassing and germane to a sustainable production system and livelihood”.

Reduced access and increased prices of wood-based biomass have led to initiatives to promote agroforestry cultivation. Where agroforestry is practiced by smallholders, less fuel wood needs to be purchased, there is less reliance on collecting from natural stands and less time is involved in collection. This leaves more time for income-generating activities, especially for women, who are usually the major fuel wood collectors (Sinclair 1999).

Hasanuzzaman *et al.* (2014) stated that cropland agroforestry is an important production system in the southwest region of Bangladesh. This study focused on the floristic composition and management of existing cropland agro-forests. A total of 313 cropland agro forests were surveyed and 83% respondents practiced pure agroforestry while the remaining 17% practiced agroforestry with fisheries. A total of 18 forest trees and 2 shrubs were recorded from 11 families and 59 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.

A number of studies have been undertaken to determine the financial viability of agroforestry systems. Many of these studies have sought to examine the financial cost of establishing, managing and producing various combinations of agricultural and timber crops as well as the potential gross revenues and profitability (Grado and Husak, 2004). The adoption of agroforestry systems has proven a financially viable and an attractive land use alternative in various settings throughout the world (Garrett 1994, Grado and Husak, 2004). The increased financial benefits from practicing agroforestry may stem from increased biophysical productivity or reduction in input costs (Franzel, 2004).

Franzel (2004) observed that analyzing the economics of agroforestry practices is more complicated than of annual crops because of the complexity of agroforestry systems and the time lag between tree establishment and harvest. Also, the analysis should include the valuation of all components of the ecological systems, including the agriculture, forestry, wildlife, livestock and other activities to (Grado and Husak, 2004).

Agroforestry is being practiced from the time immemorial in different countries in different forms. John Bene of Canada gave first widely accepted definition. According to Bene *et al.* (1977) agroforestry is a sustainable management system for land that increases overall production, combines agricultural crops, tree crops and forest plants and/or animal simultaneously or sequentially and applies management practices that are compatible with the cultural patterns of a local population.

Alao and Shuaibu (2013) stated that agroforestry has been defined as a dynamic ecologically based natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. This paper highlighted agroforestry practices and concepts in sustainable land use systems. The benefit derivable from the interface between forest trees and agricultural crops are enormous. They include the optimum use of land for both agricultural and forestry production on a sustainable basis including the improvement of the quality of soil. This is in addition to the socio-economic benefits that are accruable from agroforestry. Indeed, the advantage of agroforestry is all encompassing and germane to a sustainable production system and livelihood.

Lundgren and Raintree (1982) stated that agroforestry is the collective name for all land use systems and technologies where woody perennials are deliberately grown on the same land management units as agricultural crops and/or animals in some form of spatial arrangement or temporal sequence. There must be significant ecological and economical interactions between the woody and non-woody components.

Nair (1983) defined agroforestry as a collective name for all land use systems and practices where woody perennials are deliberately grown on the same land management unit as agricultural crops or animals in some form of spatial arrangement or temporal sequence.

From a business point of view, agroforestry is an economic enterprise which aim to produce a combination of agricultural and forest crops simultaneously on the same land area (Duldulao, 1983).

Jackson (1987) stated that agroforestry systems that incorporate a range of tree and crop species of far much more scope for useful management of light interception and distribution than monoculture forest and agricultural crops. The potential benefits as a result of combining field crops with trees are so obvious from consideration of the waste nutrient resources experienced in orchards and tree crop combination.

Agroforestry system offers a great scope for efficient nutrient use because of their distinct root system. Trees is known to be deep rooted and are desired as “Nutrient pump” which use nutrients from below the crop rooting zone and recycled them to the crop in litter fall and in the green pruning (Beer, 1988).

Akhter *et al.* (1989) mentioned that farmers also consider tree as savings and insurance against risk of crop failure and low yield, as well as assets for their children. Some farmers stated that tree would contribute toward expenses for marriage of their daughters.

Agroforestry is practiced on home garden (Millat-e-Mustafa, 1997), cropland (Roy, 1996) forestlands etc. However, the sustainability of these practices, a major concern in Bangladesh. Agroforestry is considered an efficient and sustainable land use option especially suited for resources poor farmers (Stocking *et al.* 1990).

Agroforestry can provide a sound ecological basis for increased crops and animal productivity more dependable economic returns and greater diversity in social benefits on a sustainable basis (Saka *et al.* 1990).

Abedin and Quddus (1990) reported that successful introduction of fast growing exotic tree species and increasing awareness of the multipurpose use of indigenous tree species, the potential of agroforestry for environments improvement and in sustaining increased output of food and forest produce needs to be exploited.

According to Fernandes and Nair (1990) the term agroforestry refers to land use practices involving deliberate management of multipurpose trees and invariably livestock within the compounds of individual houses, the whole crop-tree- animal units being intensively managed by family labor. It can therefore, be seen that home gardens display many agroforestry features: the intimate mixture of diversified agricultural crops and multipurpose trees fulfils most of the fundamental needs of the local populations, and their multistoried configuration and high species diversity avoid the environmental deterioration commonly associated with monoculture production systems.

Khandaker (1991) reported that agroforestry system is traditional in the homesteads of moist tropical world including rural areas of Bangladesh since the establishment of houses. This system could be considered as potential technology for rural poverty alleviation because of its diversified functions.

Lawrence and Hardostry (1992) mentioned that the landowners cited potential advantages to practicing agroforestry were land use diversity (25%), enhanced productivity (18%), aesthetics (13%), income diversity (13%) and the most frequently identified potential obstacles to practicing agroforestry were: lack of information (28%), lack of technical assistance (18 percent), establishment cost (14%) and the fact that it is not an established practice (14%). They also found that the responses suggested there is great potential for application of agroforestry throughout the state, and non-industrial private forestland owners were selected for future study of this potential.

Anoja and Wickramasinghe (1992) reported that village agroforestry systems in Sri Lanka associated with age-old tree-use practices that have evolved through farmers' experience to meet survival needs. The benefits of village agroforestry systems were diverse, but food products were of outstanding importance among them.

Agroforestry system that incorporate a range of tree and crop species offer much more scope for useful management of light interception and distribution than do monoculture forests and agricultural crops (Miah, 1993).

Agroforestry is a dynamic, ecologically based, natural resource management system that, through the integration of trees in farm and rangeland, diversifies and/or sustains agricultural production for increased social, economic and/or environmental benefits (Leaky, 1996).

Wickramasinghe (1997) illustrated that agroforestry is important for income, nutrition and health, for reducing economic reducing economic risk and for improving food security at health, for reducing economic risk and for improving food security at household level.

Home gardens were seen as having potential role to play in maintaining biological diversity at both his species and sub species level.

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

Despite the apparent simplicity and productivity of monoculture agriculture, there are numerous advantages to be gained from the inclusion of tree species. Trees provide food, feed, fiber, fuel, medicines, timber, pole and other products and, in providing additional outputs, can increase the value of an agricultural system. The multiple outputs of tree systems can reduce the risk associated with agriculture. If the one species fails to produce, either because of insect attack or adverse weather, there is the possibility of production from a second species. With two outputs, some market risk is alleviated, if the selling price of one output is low, it may not be so with the second output (Wojtkowski,1998).

Nasaruddin *et al.* (2000) carried out a study in Malaysia to analyze the current agroforestry practices adopted there and reported that agrosilvicultural is the main system being practiced, which is reflected in the major tree/crop components in a given site.

Basavaraju and Gururaja (2000) concluded that selection of suitable tree species for agroforestry is important. However, it is not always possible to select tree species having all the desirable characteristics for agroforestry, because of different production and protection goals. It is stated that in such cases, agroforestry systems have to be managed through planting optimum tree density of trees, proper special arrangement and pruning and thinning of tree crown and roots to reduce the negative effects of trees.

Scherr and Franzel (2000) stated that successful diffusion and adoption of new agroforestry practices depends not only upon the technical performance of those practices and their fit with farming systems, but also on the broader policy management. Key policy factors relate to: tree germ plasm supply, agricultural input supply, markets for agroforestry products, land and forest tenure systems and strategies and institutional arrangements for extension and research support. On-farm research during the technology development process provides a strategic opportunity to begin evaluating policy constraints and ways to address them.

Neupane and Thapa (2001) cited that the practices which minimize the rate of soil degradation, increase crop yields and raise farm income are key to sustain agricultural productivity in the hills of Nepal. They also stated that agroforestry has great potential for enhancing food production and farmers' economic conditions in a sustainable manner through its positive contributions to household income.

2.2 Agroforestry in Bangladesh context

Agroforestry is comparatively a new concept in Bangladesh, but some of its systems such as homestead agroforestry, have been existing in this country for long unknown periods.

According to Hossain and Shailo (1987), the present annual demand of fuel wood in the country stands in 2.04 million m^3 and the timber at 0.92 million m^3 whereas the supply is presently 0.61 million m^3 and 0.76 million m^3, resulting in a deficit of 1.42 million m^3 of fuel wood and 0.16 million m^3 of timber. There is possibility of meeting this deficit through the practice of agroforestry system.

Nair (1979) reported that Agroforestry is not a new enterprise since it has been practiced under different conditions and in diverse locations at least a century. The taungya system is the most popular and very ancient agroforestry system originated with the Burmese (Myanmar) hill-farming experience using teak as the forest crop and was later adapted in Bangladesh at Kaptai in Chittagong district in the early 1870s.

Abedin *et al.* (1990) mentioned that Agroforestry is considered as one of the strategies for augmenting tree production for a country like Bangladesh where there is a little scope of developing pure forest due to obvious priority for food crop production.

According to Haque (1996) at least 20% of the total land area of the country outside of the forest coverage may be brought under the coverage of trees if afforestation is applied properly and extensively. Through agroforestry, the people of Bangladesh can get more food, enough timber as well as better environment to live in.

2.3 Effect of fruit trees on agroforestry system

Pathak and Dagar (2000) compared prevalent agroforestry systems in various ecological zones and found that the number of plant species per unit area, canopy layers, and the animal species dependent upon them show greater richness in tropical ecological zones than in arid or subtropical zones.

A majority of agroforestry system are found in the tropics and sub-tropics where fruit-trees constitute an important component of agroforestry systems (Nair 1991). In these contexts, the interactions between the characteristics of agroforestry system and the agroforestry belongs to the multiple cropping paradigm using plant interactions to increase or at least to maintain crop production with lower inputs and to enhance ecological services (Gaba *et al.* 2015). It is mostly based on full inter cropping or relay cropping depending on if plants are grown together during their whole-growing cycle or a part of it, respectively (Parrotta *et al.* 2015).

The fruit-based system can be placed in a broader agroforestry classification structure described by Nair (1990) and generally described as an agrosilvicultural, production-oriented system used on sloping lands in a highland moist tropical ecological zone. Although common, the fruit-based system is not uniform, but rather is made up of many different practices or subsystems. An important step in understanding the spread and possible impacts of the fruit-based cropping system is to classify and describe the subsystems in use. An objective of this survey is to develop a practical field-level classification structure for tree fruit-based agroforestry according to physical attributes and functions. The scope of the survey and classification is limited to the fruit-based system used in one watershed area in the high land sand does not cover all agroforestry systems or all of northern Thailand. Many, but not all, of the fruit-based cropping practices observed are agrosilvicultural mixtures of fruit and other trees with annual crops. Some subsystems do not strictly fit common agroforestry definitions, but are still included to provide a complete picture of fruit cropping activities.

In contrast to agroforestry practices that focus solely on services such as erosion control, the fruit-based system can contribute products for market or home consumption as well. Planting fruit has generally been regarded as an environmentally acceptable high land cropping option by non-government and government agencies alike, including the Royal Forestry Department (RFD), (Poffenberger and Mc Gean, 1993) although chemical use and dry-season irrigation have been identified as potential problem issues for fruit cropping as well (Rerkasem and Rerkasem, 1994).

2.4 Char land based on agroforestry system

The country has a land area of only 14.39 million hectares, but due to the ever increasing population, per capital and area is decreasing at an average rate of 0.005ha/cap./year since 1989 (Hossain and Bari, 1996). The capacity of our land is decreasing day by day due to intensive cropping and use of high input technologies. Agriculture remains the most important sector of Bangladesh economy, contributing 14.79% to the country's Gross Domestic Product (GDP) and employs more than 45.1% of total labor force (BBS, 2017). Agroforestry is the combination of forestry and agriculture with attributes of productivity, sustainability, and adoptability. In Bangladesh scope of agroforestry is vast. The major venues of agroforestry are homestead, roadside, railway side, embankment side, char land, coastal area, deforested area, institutional premises, riverside etc. Among them char land is the most important venue for practicing agroforestry systems. 'Char' a tract of land surrounded by the waters of an ocean, sea, lake, or stream; it usually means any accretion in a river course or estuary (Chowdhury, 1988). Bangladesh is one of the largest deltas of the world. It has a remarkable flood prone area. Char lands in Bangladesh is a unique asset. This extensive stretch of resource can play an extraordinary role in reducing poverty of a huge number landless people of the country. But till date government not being in absolute control of the char lands and most of the these being in possession of a section of land- grabbers and not properly distributed among the actual landless poor, the effective utilization of thousands of acres of char lands in overall poverty reduction and economic growth of the country could not be achieved.

Chars in Bangladesh have been distributed into five sub-areas: The Jamuna, the Ganges, the Padma, the Upper Meghna and the Lower Meghna rivers. There are other areas of riverine chars in Bangladesh, along the Old Brahmaputra and the Tista rivers. But compared to the chars in the major rivers, these constitute much less land area. It is estimated that in 1993 the total area covered by chars in Bangladesh was 1,722 sq. km (Banglapedia).

A large number of populations are living in these char areas and maintaining their livelihood through char based farming systems. Therefore, for increasing production, maintaining ecological balance and improving socio-economic condition of the char land people, integrated approach with crops/vegetables and trees is necessary. There are over 12 million people who live in char lands and struggle against the flood sand associated river bank instability (Hooper, 2001). Agroforestry plays a vital role in supplying not only the daily necessities of people but also in maintaining ecological balance. Agroforestry can provide a sound ecological basis for increased crop and animal productivity, more dependable economic returns, and greater diversity in social benefits on a sustained basis (Rahim, 1997). To meet up the demand of vegetable as well as fruit and wood, it is necessary to cultivate tree (fruit tree and woodlot) in association with vegetables as agroforestry system. Considering the above facts, this study was undertaken for developing a viable agroforestry practices at the char of Tista river basin to observe the morphological characteristics and yield of Gima Kalmi was grown in association with Mango and Gamari tree.Yield of Gima Kalmi also recorded.

2.5 Mango based agroforestry system

Mango base agroforestry have got a number of desirable attributes as a good agroforestry combination, particularly in the context of Bangladesh. Abedin and Quddus (1990) recorded 28 different tree species in the homestead of the Barind Tract in Rajshahi district. *Mangifera indica* and *Phoenix sylvestris* were the most dominant species, whereas *Artocarpus heterophyllus* was only of minor occurrence. They also mentioned that the average tree density was higher in Potuakhali and Rangpur (1.5 and 1.4 trees/10 m2 respectively) than in Rajshahi (0.7) where the annual rainfall is the lowest in Bangladesh. Miah *et al.* (1990) found that farmers generally prefer fruit trees over fuel/timber species in their homestead.

The purpose of the study was to determine the diversity and distribution of fruit speciesi n the homestead and to explore the relationship between farmers' characteristics and fruit diversity in their homestead. In the study, 28 fruit species were identified. Among 28 fruit species. Banana, Mango and Jujube were found in the 100% homestead surveyed. The Relative Prevalence of most common species like Banana, Betel nut. Coconut, Date, Mango, Papaya, Guava, Jujube were very high while that of less common species like Kaow, Pineapple, Litchi, Star apple etc. were found very low. Black berry and Jujube were found highly diverse (0.986) fruit species followed by Mango (0.984), Jackfruit (0.984). The traditional homestead fruit production system and fruit diversity in the study area was found very poor due to management practices. Fruit diversity should be increased to fulfill the nutritional needs as well as to conserve the genetic resources and environmental balance (Rhman and Hasanuzzaman, 2009).

Mannan (2000) in a study of 3 agro-ecological region found higher fruit diversity than that of vegetable and timber. Sellathurai (1997) also found higher diversity in his study. Mannan (2000) found higher fruit diversity in Gazipur than that of Bandarban and Naogaon. He also found fruit diversity ranged from 0.000 to 0.920 over the region. Mango was found highly diverse fruit species in the fruit group. Mannan *et al.* (2004) found fifty-seven different mango local varieties at 150 house hold.

The Relative Prevalence of most common species like Banana, Betel nut, Coconut, Date, Mango, Papaya, Guava were very high while that of less common species like Kaow, Pineapple, litchi was found very low. Alam *et al.* (1990) found mango as the most prevalent among the horticultural species followed by guava, jackfruit, coconut and jujube. Chowdhury and Sattar (1992) found coconut as the most prevalent among the fruit species followed by jackfruit, date palm, banana and mango. Mannan (2000) observed Mango as the most prevalent among the fruit species followed by Jackfruit, guava, jujube, coconut etc.

Singh *et al.* (2013) conducted a field experiments to investigate the suitability and profitably with different intercrops of cowpea, French bean, arhar, soya bean, lentil, black gram and chickpea in mango orchard (cv. Himsagar). The age of the plant is 7 years old with a spacing of 10 x 10 m which provide the utilization of land space between the plants as an intercrop. Pooled data reveals that the maximum number of fruits 192.41 tree and yield 46.09 kg / tree were found in Mango + Cowpea whereas maximum fruit weight (254.16 g) in Mango + Lentil. Most of the physical parameters such as fruit length and breadth maximum were recorded (8.20 cm and 7.21cm respectively) in Mango + Cowpea. But in case of peel weight (35.67 g) was highest in Mango + Soya bean whereas the higher stone weight (35.79 g) was in sole crop (Mango) only. Again, pulp weight and pulp: stone ratio (193.53 g and 5.80 g) were observed in Mango + French bean respectively. The quality parameters such as TSS, reducing sugar, vitamin c, acidity and shelf-life showed non- significant variation among the different treatments. From an experiment, the results demonstrate the potential of leguminous crops to improve the ecological stability in traditional fruit orchards. *Cajanus cajan* achieved the highest yield of dry biomass (11.04 t/ha) and the treatment with *Phaseolus vulgaris* produced 0.73 t/ha. The soil cover integrating leguminous crops increases soil fertility and benefits insect populations. Mango yield was highest in combination with *Phaseolus acutifolius* (9.13 t/ha) and *Cajanuscajan* (7.42 t/ha). Additionally, more abundance and diversity of insect population was observed when intercropping leguminous crops between the mango trees Agreda *et al.* (2006) achieved the highest yield of dry biomass (11.04 t/ha) and the treatment with *Phaseolus vulgaris* produced 0.73 t/ha. The soil cover integrating leguminous crops increases soil fertility and benefits insect populations. Mango yield was highest in combination with *Phaseolus acutifolius* (9.13 t/ha) and *Cajanus cajan* (7.42 t/ha). Additionally, more abundance and diversity of insect population was observed when intercropping leguminous crops between the mango trees Agreda *et al.* (2006).

A mango based cropping study was conducted with ginger, turmeric, tomato, cowpea, French bean, ragi, niger and upland paddy by Swain (2014). The results of the study revealed that the mango + guava + cowpea combination exhibited better performance which has been reflected in the form of plant height, girth, canopy area, fruit weight and fruit yield of mango closely followed by Mango + Guava + French bean system. The mango plants, under study, however, did not exhibit any kind of variation in quality parameters in fruits. The leguminous intercrops, cowpea and French bean, were the most effective crop because of their desirable impact on improvement of nutrient status of soil and plant of mango orchard. Highest LER was obtained with mango + guava +cowpea combination (4.17) followed by mango + guava + French bean. The highest benefit, cost ratio (2.02) was recorded in the mango + guava + cowpea combination, which was almost similar to that of mango + guava + turmeric, mango + guava + French bean and mango + guava + tomato. The mango plants when planted at a spacing of 10 × 10 m provide an ample scope for growing of short duration crops as intercrops during initial years. The inter row space in mango remains underutilized in the early growing period and during which short duration, location specific and market driven crops may be grown as inter crops and filler crops thus, allowing one to grow more than one crop and also to efficiently utilize the space and other natural resources. The intercrops under mango base agroforestry not only generate an extra income but the practice also helps to check the soil erosion through ground coverage and improves the physical-chemical properties of the soil. Different crops cultivation base on fruit garden is one of the techniques of land utilization for optimum production. Experimental evidences have also proved that yield stability is grater with intercropping than sole cropping. Different other crops based on fruit forest can provide substantial yield advantages compared with sole cropping.

Behera *et al.* (2014) stated that demand of food can probably be met through more intensive crop production with increase in productivity per unit area and time. Mango trees provide enough space even if they are fully grown as they do not cover much area. It is possible to grow a mixed fruit orchard, such as mango intercropped with other fruit crops, vegetables and spices during initial years of establishment. Intercropping in mango with suitable crops bring good income and improves the fertility of the soil. During the first few years, intercropping can be practiced with no shortage of irrigation. Intercropping of some intercropping can be practiced with no shortage of irrigation. Intercropping of some vegetables and spices in plantation can be practiced if sufficient irrigation and manuring facilities are available.

Behera *et al.* (2014) also studied on development of mango based intercropping and observed that it is the need of hour to increase production along with increasing income of mango growers. Keeping the above facts in to consideration different intercrops like pineapple, turmeric and ginger were tried in mango orchard with and without application of bio fertilizers. Growing of intercrops like ginger, turmeric and pineapple with bio fertilizers and inorganic fertilizers in mango orchard revealed that maximum mango yield was recorded intercropping with turmeric with application of bio fertilizers (36.87 quintal per hectare) followed by intercropping with ginger with application of bio fertilizers (34.47 quintal per hectare) and minimum was recorded in control (22.07 quintal per hectare) where no intercrop was grown over the two years of investigation. The percentage increase of yield over control is 40%. The application of bio fertilizers also increased the yield over control and inorganic fertilizers to the ton of 48% and 20%, respectively.

Linda (1990) mentioned that the high diversity of plant species in village home gardens ensure continuous production of fruits and vegetables, fuel woods, timbers medicinal and cash crops.

Lai (1988) found in his study that application of appropriate technology in relation to production and management of trees and crops in the homesteads, better utilization of land can be achieved with the creation of better living environment there.

Sarker *et al.* (2014) conducted a comparative study with a total of 85 mango growing farmers by interviewing. They observed that Baring ecosystem (Rajshahi Region) is unfavorable for field crop production but suitable for production of fruits like mango, litchi and jujube etc.

Abedin *et al.* (1990) mentioned that agroforestry is considered as one of the strategies for augmenting tree production for a country like Bangladesh where there is a little scope of developing pure forest due to obvious priority for food crop production.

2.6 Importance of studies summer vegetables

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

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

Gima Kalmi (*Ipomoea reptans*) is very important leafy vegetables from the nutritional point of view. It is very an excellent source of Vitamin A. One hundred grams of it edible portion contains 87.6 g water, 1.1 g minerals, 0.1 g fat, 9.4 g carbohydrate, 107 mg calcium, 3.9 mg iron, 10740 microgram carotene, 0.14 mg vitamin B_1 ,0.4 mg vitamin B_2, .52 mg C, 1.8 g protein and 46 kilocalories (Anon, 1983). Leafy vegetables such as Gima Kalmi, Spinach, Indian spinach and Amaranth are commonly close to “Spinach group” of vegetables (Shinohara, 1980).

Shafi *et al.* (2016) was conducted an experiment at the Germplasm Centre, Horticulture Farm, Bangladesh Agricultural University, Mymensingh during the period from April to May 2007 to study the effect of different levels of fertilizer and canopy on the growth and yield of Gima Kalmi (Kangkong). The experiment consisted of four fertilizer levels viz., no fertilizer, recommend fertilizer, 20% and 40% less fertilizer of recommended dose and three canopy structure viz. no canopy (open area), lemon canopy and guava canopy were included in this experiment. The result revealed that plant height, number of leaves per plant, number of branches per plant, fresh weight of foliage per plant, yield per plot and yield per hectare grown under lemon and guava canopy showed significantly reduction than those grown in no canopy. The ranked order of different canopy structure for better performance were no canopy>lemon canopy>guava canopy. The maximum plant height and number of leaves, number of branches, fresh weight of foliage per plant were observed in recommended dose of fertilizer. A total of 7.39 t/ha yield was obtained at recommended dose of fertilizer at 45 DAP, whereas the lowest yield (5.79 t/ha) was found from the control treatment (no fertilizer).

Akand *et al.* (2015) was conducted an experiment in the horticulture of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to June 20013 to find out the influence of different dose of fertilizer management on the growth and yield of Gima Kalmi. The experiment consisted of four levels of fertilizer, such as F0: No fertilizer, F_1: Cow dung: 15 t/ha, F_2: Poultry litter: 7 t/ha and F_3: Inorganic fertilizer (Urea: 200 kg/ha + TSP: 100 kg/ha + MP: 200 kg/ha). At 75 DAS the longest (25.55 cm) plant was obtained from F_3, while the shortest (18.14 cm) plant was recorded from control condition. The maximum (55.56) number of leaves per plant was recorded from F_3, while the minimum (36.66) number of leaves per plant was recorded from control condition. The highest (10.69%) dry matter content of foliage was obtained from F_3, while the lowest (7.91%) dry matter content of foliage was recorded from control condition. The highest (16.28 t/ha) yield was recorded from F_3, while the lowest (12.81 t/ha) yield was recorded from control condition.

Nashrin *et al.* (2002) was conducted to study the effect of different levels of nitrogen and spacing on the growth and yield of Gima Kalmi. Four nitrogen levels viz., 0, 30, 50 and 60 kg N/ha and four levels of spacing viz., 30 x 10 cm^2, 30 x 15 cm^2, 30 x 25 cm^2 and 30 x 30 cm^2, were included in this experiment. The maximum plant height, number of leaves per plant, number of branches per plant, fresh weight of leaves per plant, fresh weight of stems per plant, were observed in the above nitrogen application and plant spacing. The highest yield (6.10 t/ha) was obtained at 60 kg N ha¯1 at 90 days after sowing (DAS), whereas the lowest yield 3.58 t/ha in control treatment. The maximum growth and yield of the plant were observed in 30 X 30 cm^2 and 30 X 10 cm^2 spacing at all the dates of harvests. The highest yield 6.10 t ha^{-1} was found at the closest spacing (30 X 10 cm^2) whereas the lowest yield 4.15 t ha^{-1} in the widest spacing 30 X 30 cm^2 at 90 DAS.

CHAPTER 3

MATERIALS AND METHODS

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

3.1 Location

The experiment was situated at the char land in Gangachara Upazila under Rangpur district, Rangpur, Bangladesh. The experimental site is situated between 26°05' and 26°17' north latitudes and in 88°52' and 89°06' east longitudes and about 28m above the sea level.

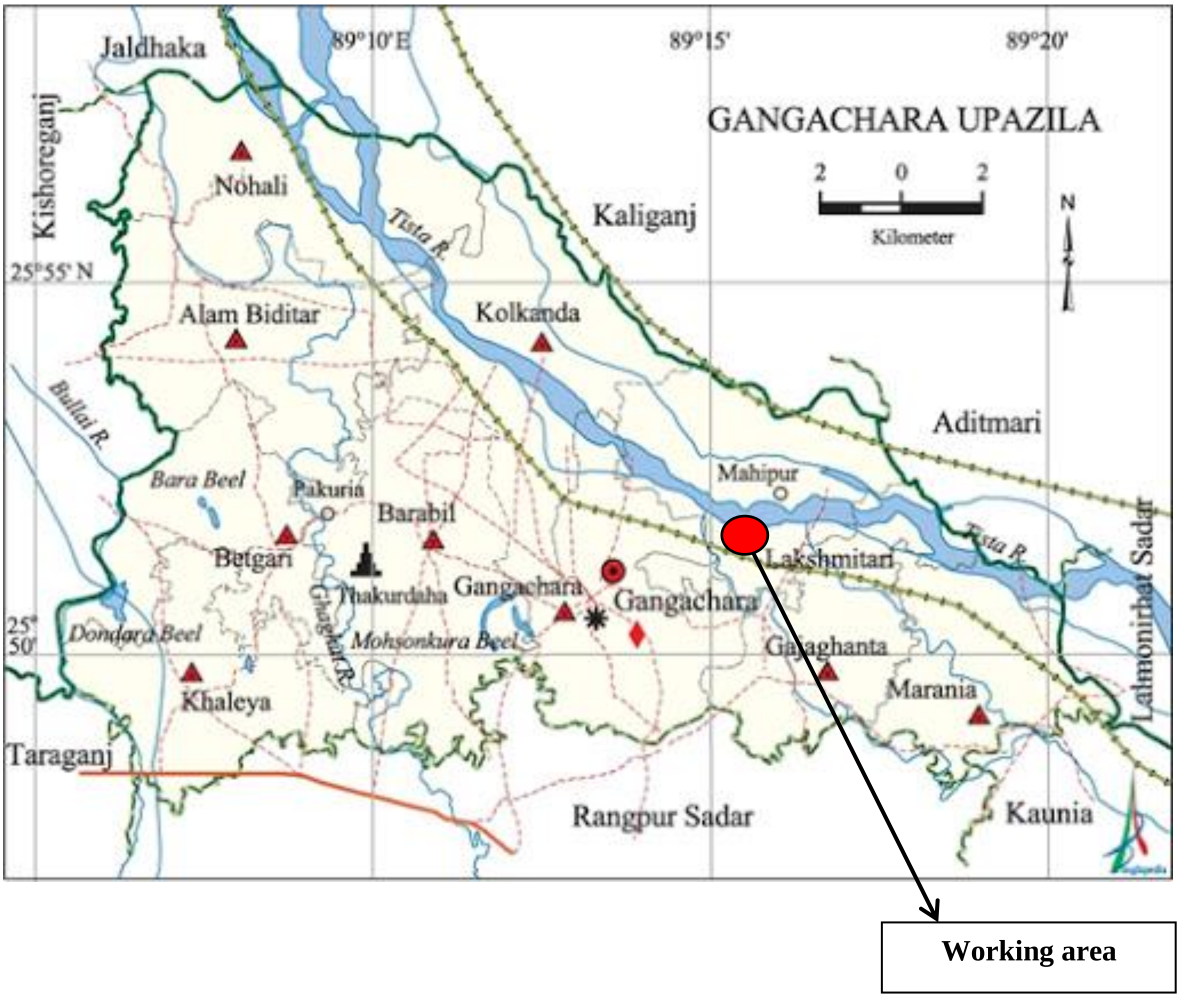

Fig. 1: Map of Gangachara Upazila under Rangpur district

3.2 Soil characteristics

The experimental plot was situated in a low land belonging to the Tista river flood plain area (AEZ 03). Land was well-drained as drainage system was well developed. The soil texture was sandy loam in nature. The soil pH was 5.1 to 6.1. Details of soil characteristics are presented in appendix- l.

3.3 Climate and weather

Rangpur's climate is classified as warm and temperate. The summers are much rainier than the winters in Rangpur. According to Koppen and Geiger, this climate is classified as Cwa. The annual average temperature of the district varies maximum 32. 6°C to minimum 9.30°C and his annual average rainfall of the district is recorded 931 mm. Details of weather data are presented in appendix-II.

3.4 Experimental period

Duration of the experiential period was from July to September 2019.

3.5 Planting material

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

3.6 Treatments

The present experiment comprised of two factors.

Factor A. (Production systems)

- Gima Kalmi + Mango tree (S_1)
- Gima Kalmi + Gamari tree (S_2)
- Gima Kalmi sole cropping (S_3)

Factor B. (Fertilizer and Manure applications)

- No fertilizer(F_0)
- Only Cow dung @ 10 t/ha (F_1)
- Only Poultry @ 5 t/ha (only) (F_2)
- Full chemical @ FRG 2012 (F_3)

Treatment combinations:

- S_1F_0 = Mango + Gima Kalmi + No fertilizer
- S_1F_1 = Mango + Gima Kalmi + Cow-dung
- S_1F_2 = Mango + Gima Kalmi + Poultry manure
- S_1F_3 = Mango + Gima Kalmi + Chemical fertilizer
- $S_2 F_0$ = Gamari + Gima Kalmi + No fertilizer
- S_2F_1 = Gamari + Gima Kalmi + Cow-dung
- S_2F_2 = Gamari + Gima Kalmi + Poultry manure
- S_2F_3 = Gamari + Gima Kalmi + Chemical fertilizer
- S_3F_0 = Gima Kalmi sole+ No fertilizer
- S_3F_1 = Gima Kalmi sole + Cow-dung
- S_3F_2 = Gima Kalmi sole + Poultry manure
- S_3F_3 = Gima Kalmi sole + Chemical fertilizer

3.7 Experimental design and layout

Three experimental area were taken to set up the experiment. The well prepared land was laid out following Randomized Complete Block Design with four replications. Each experimental area was first divided into four unit i.e. 16 plots. In the three areas there were 48 plots.

Mango Tree				**Gamari Tree**				**Gima Kalmi sole**			
R_2	R_2	R_3	R_4	R_1	R_1	R_1	R_1	R_1	R_1	R_1	R_1
S_1F_0	S_1F_1	S_1F_2	S_1F_3	S_2F_0	S_2F_1	S_2F_2	S_2F_3	S_3F_0	S_3F_1	S_3F_2	S_3F_3
S_1F_1	S_1F_0	S_1F_3	S_1F_2	S_2F_1	S_2F_0	S_2F_3	S_2F_3	S_3F_1	S_3F_0	S_3F_3	S_3F_2
S_1F_2	S_1F_3	S_1F_0	S_1F_1	S_2F_2	S_2F_3	S_2F_0	S_2F_1	S_3F_2	S_3F_3	S_3F_0	S_3F_1
S_1F_3	S_1F_2	S_1F_1	S_1F_0	S_2F_3	S_2F_2	S_2F_1	S_2F_0	S_3F_3	S_3F_2	S_3F_1	S_3F_0

Fig. 2: Lay out of treatment combination in production systems with fertilizer and manure applications.

3.8 Plant characteristics

Mango (*Mangifera indica*), Mango is a species of flowering plant in the sumac and poison ivy family Anacardiaceae. It is native to Indian subcontinent where it is indigenous. Hundreds of cultivated varieties have been introduced to other warm regions of the world. It is a larger fruit tree capable of growing to height and crown width of about 30 meters (100ft) and trunk circumference of more than 3.7meters (12ft). The species domestication is attributed to India around 2000 BCE. Mango was brought to East Asia around 400-500 BCE in the 15^{th}century to Africa and Brazil by Portuguese explorers. The species was assessed and first named in botanical nomenclature by Linnaeus in 1753. Mango is the national fruit of India, Pakistan and the Philippines and national tree of Bangladesh. The tree is more known for its fruits rather than its timber. The wood is susceptible to damage from fungi and insects. The wood is used for musical instruments such as ukuleles, plywood and low-cost furniture. The details of Mango tree were:

Mango variety: Hariavanga

Age: two years

Spacing: 16ft X 16ft

Orientation: East-west

Canopy size: 7ft X 6ft (N-S*E-W)

Gamari (*Gmelina arborea***),** It is a rapidly growing tree, which due to its drought tolerance and excellent wood properties, is emerging as an important plantation species. Local name: Gamari, Gambar, Gumbar. *Gmelina arborea* is a fast growing deciduous tree, which though grows on different localities at altitudes up to 1500 meters and prefers moist fertile valleys with 750-4500 mm rainfall. It does not thrive on ill-drained soils and remains stunted on dry, sandy or poor soils; drought also reduces it to a shrubby form.

The *Gmelina arborea* tree attains moderate to large height up to 30 m with girth of 1.2 to 4.5 m with a clear bole of 9-15 m. It has a smooth whitish grey (ashy) corky bark, warty with lenticular tubercles exfoliating in regular patches when old. It is a treat to see the *Gmelina arborea* tree standing straight with clear bole having branches on top and thick foliage forming a conical crown on the top of the tall stem. The bark is light grey colored, exfoliating in light colored patches when old, blaze thick, a chlorophyll layer just under the outer bark, pale yellow white inside.

Gmelina arborea wood is pale yellow to cream colored or plukish-buff when fresh, turning yellowish brown on exposure and is soft to moderately hard, light to moderately heavy, lustrous when fresh usually straight to irregular or rarely wavy grained and medium course textured. Flowering takes place during February to April when the tree is more or less leafless whereas fruiting starts from May onwards up to June.

This tree is commonly planted as a garden and an avenue tree and also in villages along agricultural land, on village community lands and on wastelands. It is light demander, tolerant of excessive drought, but moderately frost hardy, has good capacity to recover in case of frost- injury. This tree coppices (a thicket of small trees or shrubs; coppice) very well with vigorous growth. The details of Gamari tree were:

Gamari age: two years

Spacing: 12ftx 12ft

Orientation: North-South

Canopy size: 5ft X 4ft (N-S*E-W)

3.9 Land preparation

The land was opened with spade on 3rd July 2019. The land was ploughed and also cross ploughed followed by laddering to obtain good tilth. The land was leveled and corners of the plots were trimmed and clods were broken into small pieces as far as possible. All weeds and stables were collected and removed. The land was finally prepared before sowing.

3.10 Application of fertilizers and manures

Fertilizers	Nutrients	Nutrient dose(kg ha^{-1})
Urea	N	130
TSP	P_2O_5	32
MP	K_2O	65
Gypsum	S	18
Zinc Sulfate	Zn	1.7
Borax	B	0.55

*Source: Fertilizer Recommendation Guide (FRG, 2012).

In case of chemically fertilized plots, only chemical fertilizer was used as per (FRG, 2012) half of urea and full doses of TSP, MP were applied as the basal dose in furrows made on both sides of the seed rows and mixed properly with soil at planting. On the other hand, the remaining urea was applied at 40 DAS.

Again in case of non-chemical plots, only cow dung was applied @ 10 t/ha and only poultry manure was applied @ 5 t/ha. In case of no fertilizer plots there was no chemical fertilizer or manure was applied.

3.11 Seed sowing

Direct sowing method was followed in this experiment. Gima Kalmi seeds were sown on July5, 2019. Two seeds were sown in each planting hole at one cm depth are covered with a thin layer of soil. Thinning was done seven days after emergence and only one seedling was allowed to grow in each hill.

3.12 Intercultural operation

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

3.13 Harvesting

The harvest was done from all plots from 30, 45, 60, and 75 DAS. The plants were cut at a length of 2 cm from the ground level and data were recorded on several characters.

3.14 Collection of data

For collection of data 10 plants were randomly selected from each plot.

Plant height: Plant height was measured in centimeter from the ground level to the tip of leaves at harvest and the average was calculated from 10 samples plants.

Number of leaves per plant: The total number of leaves was counted from the sampled plants and their average was calculated as the number of leaves per plant.

Number of branches per plant: The total numbers of branches were conducted from 10 randomly selected plants and their average was calculated as the number of branches per plant.

Weight of fresh leaves per plant (g), The weight of fresh leaves per plant conducted from 10 randomly selected plants leaves weight and their average was calculated as the weight of fresh leaves per plant.

Yield per plot: Yield per plot was recorded by harvesting all plants in each plot and taking their weights by a simple balance and the weight was recorded in kilogram (Kg).

Yield per hectare: Per plot yield was converted into yield per hectare was express in metric ton (t).

3.15 Bio-economics of the Gima Kalmi based agroforestry system

In order to work out the economic profitability of the agroforestry system, the economic yield of Gima Kalmi and trees was subjected to economic analysis by calculating the cost of cultivation, gross and net returns per hectare and benefit-cost ratio. All these parameters were calculated on the basis of local market prices prevailing at the time of the termination of experiment.

3.16 Total cost of production

The cost of cultivation of the Gima Kalmi was worked out on the basis of per hectare. The initial plantation cost of the Mango and Gamari saplings were included in this study. The management cost items like human labor and mechanical power costs, material cost (including cost of seed, fertilizers and manure, pesticide, bamboos, ropes etc.) land use cost and interest on operating capital.

3.17 Gross return

Gross return is the monetary value of total product and by-product. Per hectare gross their respective market prices.

3.18 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.

Net return = Gross returns (Tk/ha) – Total cost of production (Tk/ha)

3.19 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

Benefit-cost ratio = Gross return (Tk/ha) / Total cost of production (Tk/ha).

3.20 Statistical analysis

Data were statistically analyzed using the “Analysis of variance” (ANOVA) technique with the help of statistics 10. The mean differences were adjudged by Tukey HSD test.

CHAPTER 4

RESULTS AND DISCUSSION

The results of the performance of Gima Kalmi under Mango and Gamari based Agroforestry systems are presented in Table 1-15. In this chapter, moreover, the findings of the study and interpretation of the results under different critical sections comprising growth, yield contributing characteristics, yield and quality parameters and cost-effective analysis are presented and discussed in this chapter under the following sub-headings to achieve the objective of the study.

4.1 Main effect of production systems on the growth, yield contributing characters and yield of Gima Kalmi

4.1.1 Plant Height

The plant height of Gima Kalmi was found statistically significant different due to the different production systems (Table 1). At 30 DAS, the tallest plant (17.71cm) was found in sole cropping (S_3), moderate height (16.21 cm) was found in Mango + Gima Kalmi based agroforestry system (S_1) and the smallest plant height (13.21cm) was found in Gamari + Gima Kalmi (S_2) based agroforestry system. Similarly, at 45 DAS, the tallest plant height (23.58 cm) was found in sole cropping (S_3) whereas moderate plant height (21.78 cm) was found in Mango + Gima Kalmi based agroforestry system (S_1) and the lowest plant height (19.77 cm) was found in Gamari + Gima Kalmi based agroforestry system (S_2). Correspondingly, at 60 DAS, maximum plant height (25.69 cm) was found in sole cropping (S_3), the lowest plant height (20.85 cm) was in Gamari + Gima Kalmi based agroforestry system (S_2) and moderate plant height (23.84 cm) was found in Mango+ Gima Kalmi based agroforestry system (S_1). Again, at 75 DAS, highest plant height (21.06 cm) was found in Gima Kalmi sole cropping (S_3) which was followed Mango + Gima Kalmi based agroforestry system(S_1), and the lowest plant height (18.59 cm) was in Gamari + Gima Kalmi based agroforestry system(S_2). Plant height depends upon a lot of factors like availability of required quality of water, mineral, nutrients, light, temperature etc. The findings of this experiment is in agreement with Shafi *et al.* (2016).

Table 1: Main effect of production systems on the plant height of Gima Kalmi in char land

Treatments	Plant height			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
Mango + Gima Kalmi (S_1)	16.21ab	21.78ab	23.84ab	19.56ab
Gamari + Gima Kalmi (S_2)	13.96b	19.77b	20.85b	18.59b
Gima Kalmi sole cropping (S_3)	17.71a	23.58a	25.69a	21.06a
CV (%)	17.26	13.20	15.97	10.76

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

4.1.2 Number of leaves per plant

Numbers of leaves/plant were also significantly disposed by the different production system (Table 2). At 30 DAS, the maximum number of leaves (24.95) was observed from sole cropping of Gima i.e. treatment S_3, whereas moderate number of leaves (22.84) was found from Gamari + Gima Kalmi based agroforestry system i.e. treatmentS_2, and the minimum number of leaves (22.56) was observed from Mango + Gima Kalmi based agroforestry system i.e. treatment S_1. Again at 45 DAS, the maximum number of leaves (38.62) was observed from sole cropping of Gima i.e. treatment S_3, which was followed by S_1, and the minimum number of leaves (35.10) was observed in Gamari + Gima Kalmi based agroforestry system i.e. treatment S_2. Similarly, at 60 DAS, the maximum number of leaves (46.61) was observed in sole cropping of Gima Kalmi i.e. treatment S_3, whereas minimum number of leaves (42.05) was observed from Gamari + Gima Kalmi based agroforestry system i.e. treatment S_2 and the moderate number of leaves/plant (42.85) was found in Mango + Gima Kalmi based agroforestry system i.e. treatment S_1. Finally, at 75 DAS, the maximum number of leaves (48.75) was recorded from sole cropping of Gima Kalmi i.e. treatment S_3, moderate number of leaves (45.14) was found from Mango + Gima Kalmi based agroforestry system i.e. treatment S_1, which was followed by S_2. The highest number of leaves was found due to the effect of temperature, pressure.

Table 2: Main effect of production systems on the number of leaves per plant of Gima Kalmi in char land

Treatments	Number of leaves per plant			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
Mango + Gima Kalmi (S_1)	22.56b	36.65ab	42.85b	45.14b
Gamari + Gima Kalmi (S_2)	22.84b	35.10b	42.05b	44.24b
Gima Kalmi sole cropping (S_3)	24.95a	38.62a	46.61a	48.75a
CV (%)	9.97	7.39	6.3	5.18

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

4.1.3 Number of branches per plant

The effect of production systems the number of branches/plant was observed statistically significant in at different DAS. At 30 DAS, the maximum number of branches/plant (3.64) was observed from sole cropping of Gima Kalmi i.e. treatment S_3, which was followed by S_1, and the minimum number of branches/plant (2.74) was found from Gamari + Gima Kalmi based agroforestry system i.e. treatment S_2. Similarly, at 45 DAS, the maximum number of branches/plant (8.70) was recorded from sole cropping of Gima Kalmi i.e. treatment S_3, which was followed by $S_{1,}$ whereas minimum number of branches/Plant (7.03) observed in Gamari + Gima Kalmi based agroforestry system i.e. treatment S_2. The number of branches/plant at 60 DAS and 75 DAS, was not found significant.

Table 3: Main effect of production systems on the number of branches per plant of Gima Kalmi in char land

Treatments	Number of branches per plant			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
Mango + Gima Kalmi (S_1)	3.2ab	7.66ab	8.77a	9.16a
Gamari +Gima Kalmi (S_2)	2.74b	7.03b	7.99a	8.55a
Gima Kalmi sole cropping (S_3)	3.64a	8.70a	9.23a	10.03a
CV (%)	19.9	19.2	19.77	18.73

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

4.1.4 Weight of fresh leaves per plant (g)

Weight of fresh leaves/plant was varied with different production systems significantly at different DAP. At 45 DAS, the maximum weight of fresh leaves/plant (40.06 g) was observed from sole cropping of Gima i.e. treatment S_3, whereas moderate weight of fresh leaves/plant (37.63 g) was found from Mango + Gima Kalmi based agroforestry system i.e. treatment S_1, and minimum weight of fresh leaves/plant (36.23 g) was observed in Gamari + Gima Kalmi based agroforestry system i.e. treatment S_2. Similarly, at 60 DAS, the maximum weight of fresh leaves/plant (47.05 g) was observed from sole cropping of Gima Kalmi i.e. treatment S_3, the minimum weight of leaves/plant (44.74 g) was observed from Gamari + Gima Kalmi based agroforestry system i.e. treatment S_2 and the moderate weight of fresh leaves/plant (45.3 g) was found from Mango + Gima Kalmi i.e. treatment S_1 based agroforestry system. At 30 and 75 DAS weight of fresh leaves/plant was not found significant.

Table 4: Main effect of production systems on the fresh weight of leaves per plant (g) of Gima Kalmi in char land

Treatments	Fresh weight of leaves per plant (g)			
	30 DAP	45 DAP	60 DAP	75 DAP
Mango + Gima Kalmi (S_1)	18.06	37.63ab	45.3ab	27.50a
Gamari + Gima Kalmi (S_2)	17.13	36.23b	44.74b	26.45a
Gima Kalmi sole cropping (S_3)	18.37	40.06a	47.05a	28.22a
CV (%)	15.02	10.16	9.08	15.31

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

4.1.5 Yield per hectare (ton)

The effect of production systems was observed significant in yield of Gima Kalmi (t/ha) at different DAS. At 30 DAS, the maximum yield (5.01 t/ha) was observed from sole cropping of Gima Kalmi (S_3), whereas the moderate yield (4.21 t/ha) was found from Mango + Gima Kalmi based agroforestry system (S_1), and the minimum yield (3.82 t/ha) observed in Gamari + Gima Kalmi based agroforestry system (S_2). Again at 45 DAS, the maximum yield (7.49 t/ha) was observed from sole cropping of Gima Kalmi (S_3), which was followed by Mango + Gima Kalmi based agroforestry system (S_1), and the minimum yield (6.31 t/ha) was observed from Gamari + Gima Kalmi based agroforestry system (S_2). Similarly, at 60 DAS, the maximum yield (9.04 t/ha) was observed from sole cropping of Gima Kalmi (S_3), whereas minimum yield (7.51 t/ha) was observed from Gamari + Gima Kalmi based agroforestry system (S_2) and the moderate yield (7.90 t/ha) was found from Mango + Gima Kalmi based agroforestry system (S_1). However, the yield under tree was found 10-15% low compare than open or sole cropping. At 75 DAS, yield of Gima Kalmi was not found significant. Indeed, in open condition i.e. in full sin light condition, the Gima Kalmi plant got adequate light and less competition for plant nutrients. Therefore, open condition gave the maximum yield. This result is in agreement with the findings of Shafi *et al.* (2016).

Table 5: Main effect of production systems on the yield (t/ha) of Gima Kalmi in char land

Treatments	Yield (t/ha)			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
Mango +Gima Kalmi (S_1)	4.21b	7.16ab	7.90ab	7.86ab
Gamari +Gima Kalmi (S_2)	3.82b	6.31b	7.51b	7.39b
Gima Kalmi sole cropping (S_3)	5.01a	7.49a	9.04a	8.75a
CV (%)	18.76	18.45	18.84	19.45

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

4.2 Main effect of fertilizer and manure applications on the growth, yield contributing characters and yield of Gima Kalmi

4.2.1 Plant height

Plant height of Gima Kalmi at different DAS was varied significantly due to the impact of different fertilizers and manures application under Mango and Gamari based agroforestry system in the char land area. At 30 DAS, the highest plant height (18.47 cm) was found where chemical fertilizer was applied i.e. treatment (F_3) and it was followed by cow dung (F_1) and poultry manure (F_2). On the other hand, the lowest plant height (12.46 cm) was found where no fertilizer was applied i.e. treatment (F_0). Again at 45 DAS, the tallest plant height (24.64 cm) was found where chemical fertilizer was applied i.e. in treatment (F_3) which was followed by cow dung (F_1) and poultry manure (F_2). On the other hand, the shortest plant height (19.39 cm) was found where no fertilizer i.e. treatment (F_3) was applied. At 60 DAS, the tallest plant height (25.09 cm) was found where chemical fertilizer i.e. treatment (F_3) was applied and it was followed by cow dung (F_1) and poultry manure (F_2). In that time, the shortest plant height (20.79 cm) was found where no fertilizer i.e. treatment (F_0) was applied. Again, at 75 DAS, the tallest plant height (22.22 cm) was found where chemical fertilizer i.e. treatment (F_3) was applied which was also followed by cow dung (F_1) and poultry manure (F_2) applications. On the other hand, the shortest plant height (17.25 cm) was found where no fertilizer i.e. treatment (F_0) was applied.

Table 6: Main effect of fertilizer and manure on the plant height of Gima Kalmi in char land

Treatments	Plant height			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
No fertilizer(F_0)	12.46c	19.39b	20.79b	17.25c
Cow dung (F_1)	17.55ab	21.8ab	24.31ab	20.47ab
Poultry (F_2)	15.35bc	20.99b	23.65ab	19.01bc
Full chemical (F_3)	18.47a	24.64a	25.09a	22.22a
CV (%)	17.26	13.20	15.97	10.76

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

4.2.2 Number of leaves per plant

Number of leaves/plant was varied at different DAS among the treatments (Table 7). At 30 DAS, the maximum number of leaves/plant (26.15) was recorded from Chemical fertilizer applied i.e. treatment (F_3) which was followed by cow dung (F_1) and poultry manure applied plot (F_2), whereas the minimum number of leaves/plant (20.35) was recorded from no fertilizer applied i.e. treatment (F_0). At 45 DAS, the maximum number of leaves/plant (41.39) was recorded at treatment (F_3) which was followed by (F_1) and (F_2) treatments. On the other hand, the minimum number of leaves/plant (32.25) was recorded from no fertilizer applied i.e. treatment (F_0). At 60 DAS, the maximum number of leaves/plant (50.04) was recorded from chemical fertilizer applied i.e. treatment (F_3) which was followed by cow dung (F_1) and poultry manure (F_2) respectively, whereas the minimum number of leaves/plant (37.69) was recorded from no fertilizer applied i.e. treatment (F_0). At 75 DAS, the maximum number of leaves/plant (52.31) was recorded from chemical fertilizer applied i.e. treatment (F_3) which was followed by cow dung (F_1) and poultry manure (F_2) respectively, whereas the minimum number of leaves/plant (39.70) was recorded from no fertilizer applied i.e. treatment (F_0).

Table 7: Main effect of fertilizer and manure on the number of leaves per plant of Gima Kalmi in char land

Treatments	Number of leaves per plant			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
No fertilizer(F_0)	20.35c	32.25c	37.69d	39.70d
Cow dung (F_1)	24.16ab	38.30b	46.22b	47.90b
Poultry (F_2)	23.12b	35.21c	41.40c	44.26c
Full chemical (F_3)	26.15a	41.39a	50.04a	52.31a
CV (%)	9.97	7.39	6.30	5.18

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

4.2.3 Number of branches per plant

Number branches/plant was varied at different DAS among the treatments (Table 8). At 30 DAS, the maximum number of branches/plant (3.58) was recorded from Chemical fertilizer applied plot i.e. treatment (F_3) which was followed by cow dung (F_1) and poultry manure applied plot (F_2) respectively, whereas the minimum number of branches/plant (2.60) was recorded from no fertilizer applied plot i.e. treatment (F_0). At 45 DAS, the maximum number of branches/plant (8.87) was recorded from chemical fertilizer applied i.e. treatment (F_3) which was followed by cow dung (F_1) and poultry manure (F_2) applied plot respectively, on the other hand, the minimum number of branches/plant (6.67) was recorded from no fertilizer applied plot i.e. treatment (F_0). At 60 DAS, the maximum number of branches/plant (10.04) was recorded from chemical fertilizer applied plot i.e. treatment (F_3) which was followed by cow dung (F_1) and poultry manure (F_2) respectively, whereas the minimum number of branches/plant (7.28) was recorded from no fertilizer applied plot i.e. treatment F_0. At 75 DAS, the maximum branches/plant (10.53) was recorded from chemical fertilizer applied i.e. treatment (F_3) which followed by (F_1) and(F_2) respectively, whereas the minimum branches/plant (7.79) was recorded from no fertilizer applied i.e. treatment (F_0).

Table 8: Main effect of fertilizer and manure on the number of branches per plant of Gima Kalmi in char land

Treatments	Number of branches per plant			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
No fertilizer(F_0)	2.60b	6.76b	7.28b	7.79b
Cow dung (F_1)	3.38a	7.99ab	9.01ab	9.85a
Poultry (F_2)	3.13ab	7.55ab	8.32ab	8.81ab
Full chemical (F_3)	3.58a	8.87a	10.04a	10.53a
CV (%)	19.9	19.2	19.77	18.73

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

4.2.4 Weight of fresh leaves per plant (g)

At different DAS weight of fresh leaves/plant was varied among the treatments (Table 9). At 30 DAS, the maximum weight of fresh leaves/plant (20.49 g) was recorded from Chemical fertilizer applied plot i.e. treatment (F_3) which was followed by cow dung (F_1) and poultry manure (F_2) respectively, whereas the minimum weight of fresh leaves/plant (15.12 g) was recorded from no fertilizer applied plot i.e. treatment (F_0). At 45 DAS, the maximum weight of fresh leaves/plant (43.11 g) was recorded from chemical fertilizer applied plot i.e. treatment (F_3) which was followed by cow dung (F_1), poultry manure (F_2), on the other hand, the minimum weight of fresh leaves/plant (32.64 g) was recorded from where no fertilizer applied i.e. treatment (F_0). At 60 DAS, the maximum weight of fresh leaves/plant (49.20 g) was recorded from chemical fertilizer applied plot i.e. treatment (F_3) which was followed by cow dung (F_1) and poultry manure (F_2) respectively, whereas the minimum weight of fresh leaves/plant (42.02 g) was recorded from no fertilizer applied plot i.e. treatment (F_0). At 75 DAS, the maximum weight of fresh leaves/plant (29.80 g) was recorded from chemical fertilizer applied plot i.e. treatment (F_3) which was followed by cow dung (F_1) and poultry manure (F_2) respectively, whereas the minimum weight of fresh leaves/plant (24.97 g) was recorded from where no fertilizer applied i.e. treatment (F_0).

Table 9: Main effect of fertilizer and manure on the fresh weight of leaves per plan of Gima Kalmi in char land

Treatments	Weight of fresh leaves per plant			
	30 DAS	45 DAS	60 DAS	75 DAS
No fertilizer(F_0)	15.12c	32.64c	42.02c	24.97c
Cow dung (F_1)	18.76ab	39.63ab	46.76ab	28.14ab
Poultry (F_2)	17.04bc	36.51bc	44.8ab	26.65bc
Full chemical (F_3)	20.49a	43.11a	49.20a	29.80a
CV (%)	15.02	10.16	9.08	15.31

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

4.2.5 Yield per hectare (ton)

At different DAS, yield (t/ha) was found varied with different treatments (Table 6). At 30 DAS, the maximum yield (5.0 t/ha) was recorded from where Chemical fertilizer applied i.e. treatment (F_3) which was followed by cow dung (F_1) and poultry manure (F_2) respectively, whereas the minimum yield (3.71 t/ha) was recorded from no fertilizer applied plot i.e. treatment (F_0). At 45 DAS, the maximum yield (7.98 t/ha) was recorded from chemical fertilizer applied plot i.e. treatment (F_3) which was followed by cow dung ($F_{1)}$, poultry manure (F_2), on the other hand, the minimum number of leaves/plant was (5.92 t/ha) recorded from where no fertilizer applied i.e. treatment (F_0). At 60 DAS, the maximum yield 9.42 (t/ha) was recorded from chemical fertilizer applied i.e. treatment (F_3) which was followed by cow dung (F_1) and poultry manure (F_2) respectively, whereas the minimum yield 6.66 (t/ha) was recorded from no fertilizer applied i.e. treatment (F_0). At 75 DAS, the maximum yield (8.94 t/ha) was recorded from chemical fertilizer applied i.e. treatment (F_3) which was followed by cow dung (F_1) and poultry manure (F_2) respectively, whereas the minimum yield (6.97 t/ha) was recorded from no fertilizer applied plot i.e. treatment (F_0). Cow dung and poultry manure gave a little bit lower 6.71% and 21.25%, respectively than chemical fertilizer.

Table 10: Main effect of fertilizer and manure on the yield (t/ha) of Gima Kalmi in char land

Treatments	Yield (t/ha)			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
No fertilizer(F_0)	3.71b	5.92b	6.66b	6.97b
Cow dung (F_1)	4.51a	7.26ab	8.75a	8.25ab
Poultry (F_2)	4.16ab	6.77ab	7.76ab	7.85ab
Full chemical (F_3)	5.0a	7.98a	9.42a	8.94a
CV (%)	18.76	18.45	18.84	19.45

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

4.3 Interaction effect of production systems and fertilizer and manure applications on the growth, yield contributing characters and yield of Gima Kalmi

4.3.1 Plant height

The interaction effect of production systems and fertilizer and manure applications on the plant height of Gima Kalmi were significantly varied at different DAS. The interaction effect has been presented in Table 11.

Table 11: Interaction effect of production system and fertilizer and manure on Plant height in char land

Treatments	Plant height			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
S_1F_0	12.32bc	19.18ab	22.84ab	16.96bc
S_1F_1	18.15ab	22.6ab	24.27ab	20.33abc
S_1F_2	15.45abc	20.72ab	23.43ab	18.81abc
S_1F_3	18.92ab	24.60ab	24.84ab	22.14ab
S_2F_0	11.04c	17.80b	15.75b	16.03c
S_2F_1	15.50abc	18.66b	22.62ab	19.55abc
S_2F_2	13.08bc	19.58ab	21.91ab	18.09bc
S_2F_3	16.21abc	23.04ab	23.13ab	20.7abc
S_3F_0	14.02abc	21.2ab	23.78ab	18.76abc
S_3F_1	19.01ab	24.14ab	26.04a	21.54ab
S_3F_2	17.52abc	22.69ab	25.62a	20.14
S_3F_3	20.30a	26.28a	27.32a	23.82a
CV%	17.26	13.20	15.97	10.76

Here, S_1F_0 = Mango + Gima Kalmi + No fertilizer, S_1F_1 = Mango + Gima Kalmi + Cow-dung,
S_1F_2 = Mango + Gima Kalmi + Poultry manure, S_1F_3 = Mango + Gima Kalmi + Chemical fertilizer,
$S_2 F_0$ = Gamari + Gima Kalmi + No fertilizer, S_2F_1 = Gamari + Gima Kalmi + Cow-dung,
S_2F_2 = Gamari + Gima Kalmi + Poultry manure, S_2F_3 = Gamari + Gima Kalmi + Chemical fertilizer,
S_3F_0 = Gima Kalmi sole + No fertilizer, S_3F_1 = Gima Kalmi sole + Cow-dung,
S_3F_2 = Gima Kalmi sole + Poultry manure, S_3F_3 = Gima Kalmi sole + Chemical fertilizer.
In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

At 30, 45, 60 and 75 DAS the maximum plant height (20.30 cm, 26.28 cm, 27.32 cm, 23.42 cm, respectively) was recorded from those plots where sole cropping of Gima Kalmi was present with chemical fertilizer i.e. treatment S_3F_3 and the minimum plant height (11.04 cm, 17.08 cm, 15.75 cm, 16.03 cm, respectively) was recorded from those plots where no fertilizer was applied under Gamari based agroforestry system i.e. treatment $S_2F_{0.}$

4.3.2 Number of leaf per plant

The interaction effect of production system and fertilizer and manure on number of Gima Kalmi was found significant at different DAS. The interaction effect has been presented in Table 12.

Table 12: Interaction effect of production system and fertilizer and manure on number of leaf per plant in char land

Treatments	Number of leaf per plant			
	30 DAS	45 DAS	60 DAS	75 DAS
S_1F_0	19.47c	32.23de	36.45de	39.42de
S_1F_1	23.51abc	37.95abcd	45.32bc	46.6bc
S_1F_2	21.29bc	35.11bcde	40.34cde	43.52cd
S_1F_3	25.96ab	41.3ab	48.16ab	51.02ab
S_2F_0	19.46c	30.04e	36.03e	37.52e
S_2F_1	23.21abc	36.79abcd	44.09bc	46.49bc
S_2F_2	23.71abc	34.01cde	40.60cde	42.99cde
S_2F_3	24.96abc	39.56abc	47.48ab	49.99ab
S_3F_0	22.12abc	34.49cde	40.6cde	42.17cde
S_3F_1	25.76ab	40.17abc	49.26ab	50.61ab
S_3F_2	24.36abc	36.5bcde	43.22bcd	46.28bc
S_3F_3	27.54a	43.32a	53.38a	55.93a
CV%	9.97	7.39	6.30	5.18

Here, S_1F_0 = Mango + Gima Kalmi + No fertilizer, S_1F_1 = Mango + Gima Kalmi + Cow-dung,
S_1F_2 = Mango + Gima Kalmi + Poultry manure, S_1F_3 = Mango + Gima Kalmi + Chemical fertilizer,
S_2F_0 = Gamari + Gima Kalmi + No fertilizer, S_2F_1 = Gamari + Gima Kalmi + Cow-dung,
S_2F_2 = Gamari + Gima Kalmi + Poultry manure, S_2F_3 = Gamari + Gima Kalmi + Chemical fertilizer,
S_3F_0 = Gima Kalmi sole + No fertilizer, S_3F_1 = Gima Kalmi sole + Cow-dung,
S_3F_2 = Gima Kalmi sole + Poultry manure, S_3F_3 = Gima Kalmi sole + Chemical fertilizer.
In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

At 30, 45, 60, and 75 DAS the maximum number of leaves/plant (27.54, 43.32, 53.38 and 55.93, respectively) was recorded from those plots where sole cropping of Gima Kalmi was present with chemical fertilizer i.e. treatment S_3F_3 and the minimum number of leaves/plant (19.46, 30.04, 36.03 and 37.52, respectively) was recorded from those plots where no fertilizer was applied under Gamari based agroforestry system i.e. treatment S_2F_0.

4.3.3 Number of branches per plant

The interaction effect of production system and fertilizer and manure on number of branches/plant of Gima Kalmi was observed significant at different DAS (Table 13). At 30 DAS, the maximum number of branches/plant (4.17) was recorded from the plot where sole cropping of Gima Kalmi was present with chemical fertilizer i.e. treatment S_3F_3 and minimum number of branches/plant (2.38) was recorded from those plots where no fertilizer was applied under Gamari based agroforestry system i.e. treatment S_2F_0. At 45 DAS maximum number of branches/plant (10.0) was recorded from that plot where sole cropping of Gima Kalmi was present with chemical fertilizer i.e. treatment (S_3F_3) and the minimum plant height(6.21cm) was recorded from that plot where no fertilizer was applied under Gamari based agroforestry system i.e. treatment (S_2F_0). At 60 DAS maximum number of branches/plant (11.02) was recorded from treatment (S_3F_3) and the minimum number of branches/plant (6.63) was recorded from treatment(S_2F_0). At 75 DAS, the maximum number of branches/plant (11.16) was recorded from treatment S_3F_3 and the minimum number of branches/plant (7.31) was recorded from treatment (S_2F_0)

Table 13: Interaction effect of production system and fertilizer and manure on number of branches per plant in char land

Treatments	Number of branches per plant			
	30 DAS	45 DAS	60 DAS	75 DAS
S_1F_0	2.53b	6.62ab	7.51ab	7.60a
S_1F_1	3.40ab	7.93ab	9.18ab	9.71a
S_1F_2	3.10ab	7.42ab	8.50ab	8.77a
S_1F_3	3.77ab	8.67ab	9.88ab	10.55a
S_2F_0	2.308b	6.21b	6.63b	7.31a
S_2F_1	3.01ab	7.23ab	8.40ab	8.83a
S_2F_2	2.78ab	6.75ab	7.75ab	8.20a
S_2F_3	2.79ab	7.94ab	9.22ab	9.87a
S_3F_0	3.13ab	7.46ab	7.73ab	8.47a
S_3F_1	3.77ab	8.83ab	9.45ab	11.02a
S_3F_2	3.50ab	8.49ab	8.72ab	9.48a
S_3F_3	4.18a	10.0a	11.02a	11.16a
CV%	19.90	19.20	19.77	18.73

Here, S_1F_0 = Mango + Gima Kalmi + No fertilizer, S_1F_1 = Mango + Gima Kalmi + Cow-dung, S_1F_2 = Mango + Gima Kalmi + Poultry manure, S_1F_3 = Mango + Gima Kalmi + Chemical fertilizer, $S_2 F_0$ = Gamari + Gima Kalmi + No fertilizer, S_2F_1 = Gamari + Gima Kalmi + Cow-dung, S_2F_2 = Gamari + Gima Kalmi + Poultry manure, S_2F_3 = Gamari + Gima Kalmi + Chemical fertilizer, S_3F_0 = Gima Kalmi sole + No fertilizer, S_3F_1 = Gima Kalmi sole + Cow-dung, S_3F_2 = Gima Kalmi sole + Poultry manure, S_3F_3 = Gima Kalmi sole + Chemical fertilizer.
In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

4.3.4 Weight of fresh leaves per plant (g)

The interaction effect of production system and fertilizer and manure on weight of fresh leaves/plant Gima Kalmi was observed significant at different DAS and it has been presented in Table 14. At 30 and 75 DAS the weight of fresh leaves/plant was not found statistically significant. At 45 DAS and 60 DAS maximum weight of fresh leaves/plant (45.71 g and 51.44 g) was found from those plots where sole cropping of Gima Kalmi was present with chemical fertilizer i.e. treatment (S_3F_3) and the minimum weight of fresh leaves/plant was (31.34 g and 41.31 g,) recorded from those plots where no fertilizer was applied under Gamari + Gima Kalmi i.e. treatment (S_2F_0) which was followed by Mango + Gima Kalmi with no fertilizer i.e. treatment (S_2F_0).

Table 14: Interaction effect of production system and fertilizer and manure on the weight of fresh leaves per plant in char land

Treatments	Weight of fresh leaves per plant (g)			
	30 DAS	45 DAS	60 DAS	75 DAS
S_1F_0	15.36a	32.19c	41.44c	24.91a
S_1F_1	18.90a	38.89abc	46.54abc	28.29a
S_1F_2	17.23a	36.51abc	44.58bc	26.91a
S_1F_3	20.76a	42.92ab	48.58ab	29.89a
S_2F_0	14.54a	31.34c	41.31c	24.20a
S_2F_1	17.87a	37.85abc	45.0abc	27.15a
S_2F_2	16.28a	35.02bc	43.8bc	25.52a
S_2F_3	19.85a	40.70abc	48.04ab	28.94a
S_3F_0	15.50a	34.40bc	43.31bc	25.80a
S_3F_1	19.52a	42.13ab	47.91ab	28.97a
S_3F_2	17.61a	38.01abc	46.02abc	27.52a
S_3F_3	20.85a	45.71a	51.44a	30.57a
CV%	15.02	10.16	9.08	15.31

Here, S_1F_0 = Mango + Gima Kalmi + No fertilizer, S_1F_1 = Mango + Gima Kalmi + Cow-dung,
S_1F_2 = Mango + Gima Kalmi + Poultry manure, S_1F_3 = Mango + Gima Kalmi + Chemical fertilizer,
S_2F_0 = Gamari + Gima Kalmi + No fertilizer, S_2F_1 = Gamari + Gima Kalmi + Cow-dung,
S_2F_2 = Gamari + Gima Kalmi + Poultry manure, S_2F_3 = Gamari + Gima Kalmi + Chemical fertilizer,
S_3F_0 = Gima Kalmi sole + No fertilizer, S_3F_1 = Gima Kalmi sole + Cow-dung,
S_3F_2 = Gima Kalmi sole + Poultry manure, S_3F_3 = Gima Kalmi sole + Chemical fertilizer.
In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

4.3.5 Yield per hectare (ton)

Yield of Gima Kalmi was (t/ha) varied at different DAS due to the interaction effect of production systems and fertilizer and manure applications (Table 15).

Table 15: Interaction effect of production system and fertilizer and manure on number of Yield (t/ha) in char land

Treatments	Yield (t/ha)			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
S_1F_0	3.71ab	5.85ab	5.95c	6.88a
S_1F_1	4.32ab	7.92ab	8.66abc	8.54a
S_1F_2	3.98ab	6.54ab	7.82abc	7.57a
S_1F_3	4.83ab	7.90ab	9.15abc	8.44a
S_2F_0	3.20b	5.38b	6.44bc	6.42a
S_2F_1	3.96ab	6.35ab	7.81abc	7.27a
S_2F_2	3.65ab	6.12ab	7.21abc	7.68a
S_2F_3	4.48ab	7.38ab	8.58abc	8.19a
S_3F_0	4.23ab	6.54ab	7.60abc	7.58a
S_3F_1	5.25a	7.53ab	9.78ab	8.94a
S_3F_2	4.86ab	7.23ab	8.25abc	8.30a
S_3F_3	5.69a	8.65a	10.54a	10.19a
CV%	18.76	18.45	18.84	19.45

Here, S_1F_0 = Mango + Gima Kalmi + No fertilizer, S_1F_1 = Mango + Gima Kalmi + Cow-dung,
S_1F_2 = Mango + Gima Kalmi + Poultry manure, S_1F_3 = Mango + Gima Kalmi + Chemical fertilizer,
$S_2 F_0$ = Gamari + Gima Kalmi + No fertilizer, S_2F_1 = Gamari + Gima Kalmi + Cow-dung,
S_2F_2 = Gamari + Gima Kalmi + Poultry manure, S_2F_3 = Gamari + Gima Kalmi + Chemical fertilizer,
S_3F_0 = Gima Kalmi sole + No fertilizer, S_3F_1 = Gima Kalmi sole + Cow-dung,
S_3F_2 = Gima Kalmi sole + Poultry manure, S_3F_3 = Gima Kalmi sole + Chemical fertilizer.
In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly (as per Tukey HSD test)

At 30, 45, and 60 DAS, the maximum yield (5.69 t/ha, 8.65 t/ha, 10.54 t/ha, respectively) was recorded from those plot where sole cropping of Gima Kalmi was present with chemical fertilizer i.e. treatment (S_3F_3) and the minimum yield (3.20 t/ha, 5.34 t/ha, and 6.44 t/ha, respectively) was recorded from those plots where no fertilizer was applied under Gamari based agroforestry system i.e. treatment ($S_2F_{0.}$). At 75 DAS, the yield (t/ha) was not found significant.

4.4.1 Total cost of production

The values in Table 16 indicated that the maximum value of the total cost of production (81933Tk/ha) was recorded in Gamari + Gima based Agroforestry system where cost of production was moderate (75338 Tk/ha) in Mango + Gima based agroforestry system, whereas the minimum cost of production (50555 Tk/ha) was found in Gima Kalmi sole cropping.

4.4.2 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. It is varying with the fertilization and production system of Gima. The values in Table 16 indicate that the highest value of gross return (312725 Tk/ha) was obtained in Mango + Gima based agroforestry system, the second maximum (298500 Tk/ha) was in Gamari + Gima based agroforestry system and the minimum gross return (148445tk/ha) was obtained in Gima sole.

4.4.3 Net return

The values in Table 16 indicate that the highest net return (237337 Tk/ha) was recorded from Mango + Gima based agroforestry system, the second highest (216567 Tk/ha) was found from Gamari + Gima based agroforestry system. And lowest net return (97890 Tk/ha) was found in sole cropping of Gima Kalmi.

4.4.4 Benefit-cost ratio (BCR)

The values in Table 16 indicated that the highest benefit-cost ratio i.e. BCR 4.15 was recorded from Mango + Gima Kalmi based agroforestry system, the second highest BCR 3.64 was found from Gamari + Gima Kalmi based agroforestry system. The lowest benefit cost ratio 2.93 was found in sole cropping of Gima Kalmi. So, Gima Kalmi can profitably be cultivated in Mango based agroforestry systems. Indeed, in agroforestry system, additional return was come from both Mango and Gamari.

Table 16: Economics analysis of Gima Kalmi production under different tree based Agroforestry system (ha^{-1} $year^{-1}$)

Treatments	Return (Tk./ha)			Gross Return (Tk/ha)	Total cost of production (Tk/ha)	Net Return (Tk/ha)	BCR
	Mango	Gamari	Gima				
S_1	184725	…….	128000	312725	75338	237337	4.15
S_2	…….	178500	120000	298500	81933	216567	3.64
S_3	…….	……..	148445	148445	50555	97890	2.93

Note: Gima Kalmi 10 Tk/Kg, Mango 225 Tk/Tree/Year, Gamari 250 Tk/Tree/Year.

S_1= Mango + Gima Kalmi

S_2 = Gamari + Gima Kalmi

S_3 = Gima Kalmi sole cropping

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

A field experiment was carried out at the Char Land of Tista River under Gangachara Upazila under Rangpur district during July 2019 to September 2019 to evaluate the effect of production system and application of fertilizer and manure on Gima Kalmi under Mango and Gamari based agroforestry system. The experiment was laid out in RCBD with 4 replications. There are 2 types of treatments, A. Production system: 1. Mango+ Gima Kalmi (S_1) 2. Gamari +Gima Kalmi (S_2) 3. Gima Kalmi sole cropping (S_3), B. Fertilizer and manure application: F_0= No fertilizer, F_1= cow dung @ 10 t/ha, F_2= poultry manure @ 5 t/ha and F_3= chemical fertilizers per FRG 2012. Data on yield components were collected at different DAS from 10 randomly selected plants from each plot except the total yield which was determined by taking weights of all plants from each plot during harvest.

The land of experimental plot was opened in 3rd July 2019 with a ladder and it was made ready for planting. All basal dosages of fertilizers as per schedule of the experiment were incorporated in the soil according to the Fertilizer Recommendation Guide and finally the plots were made ready for planting. Gima seeds were sown on 5th July 2019. The data were recorded at vegetative i) growth stage ii) harvesting stage. The data were analyzed statistically and means were adjudged by Tukey HSD test.

In case of the main effect of production systems on growth, yield contributing characters and yield of Gima Kalmi, the result was found significant in respect of plant height as cm (30, 45, 60 and 75 DAS), number of leaves/plant (30, 45, 60 and 75 DAP), number of branches/plant (30 and 45 DAS), weight of fresh leaves/plant as (45, and 60 DAS)), yield of Gima Kalmi (30, 45,60 and 75 DAS). The tallest plant height (25.69 cm) at 60 DAS was recorded from Gima Kalmi sole cropping based agroforestry system i.e. treatment (S_3) and the lowest plant height (20.85 cm) was observed from Gamari + Gima Kalmi based agroforestry system i.e. treatment (S_2). Number of leaves/plant of Gima Kalmi was significant due to different production system. However, highest number of leaves/plant (48.75) at 75 DAS was recorded from the Gima sole cropping i.e. treatment (S_3) and the lowest number of leaves/plant (44.24) was observed from the Gamari + Gima Kalmi based agroforestry system i.e. treatment (S_2). At 45 DAS, the highest number of leaves/branches (8.7) was recorded from Gima sole cropping i.e. treatment (S_3) and the lowest number of leaves/branches (7.03) was observed from the Gamari + Gima Kalmi based agroforestry system i.e. treatment (S_2). The maximum weight of fresh leaves/plant (47.05 g) at 60 DAS was recorded from the Gima sole cropping i.e. treatment (S_3) and the lowest fresh leaves/plant (44.74 g) was observed from the Gamari + Gima Kalmi based agroforestry system i.e. treatment (S_2). The maximum yield (9.04 t/ha) was recorded from the Gima sole cropping i.e. treatment (S_3), whereas the minimum yield (7.51 t/ha) was recorded from the Gamari + Gima Kalmi based agroforestry system i.e. treatment (S_2) at 60 DAS.

Again, the result of the research was showed that the main effect of fertilizer and manure were significant in respect of plant height as cm (30, 45, 60 and 75 DAS), number of leaves/plant (30, 45, 60 and 75 DAS), Number of branches/plant (30, 45, 60 and 75 DAS), weight of fresh leaves/plant as (g) (30, 45, 60, and 75 DAS), yield of Gima Kalmi as (t/ha) (30, 45, 60, and 75 DAS). The tallest plant height (25.09 cm) at 60 DAS was recorded from chemical fertilizer (F_3). On the other hand, the shortest plant height (20.79 cm) at 60 DAS was observed in those plots where no fertilizer was applied (F_0). The highest number of leaves/plant (52.31) was obtained from the plot where chemical fertilizer (F_3) was applied and lowest number of leaves/plant (39.70) was obtained from the plot where no fertilizer (F_0) was applied at 75 DAS. The maximum number of branches/plant (10.53) was recorded from chemical fertilizer (F_3) and the minimum number of branches/plant (7.79) was observed in those plots where no fertilizer was applied (F_0) at 75 DAS. On the other hand, the highest weight of fresh leaves/plant (49.2 g) was obtained from the plot where chemical fertilizer (F_3) was applied and lowest weight of fresh leaves/plant (42.02 g) was obtained from the plot where no fertilizer (F_0) was applied at 60 DAS. Finally, the yield of Gima Kalmi (t/ha) was significantly affected due to the applications of different fertilizers and manures application. The maximum yield (9.42 t/ha) was recorded from the plot where chemical fertilizer (F_3) was applied. On the other hand, the lowest yield (6.66 t0n/ha) was obtained from the plot where no fertilizer (F_0) was applied at 60 DAS.

Again, interaction effect of spacing and fertilizer & manure applications of Gima Kalmi had significant effect of all variables. However, the tallest plant (27 cm) at 60 DAS was recorded from S_3F_3 (Gima Kalmi sole + Chemical Fertilizer). On the other hand, the shortest plant (15.75 cm) was observed in S_2F_0 (Gamari + Gima Kalmi + No fertilizer). At 75 DAS, the highest number of leaves/plant (55.93) was obtained from the treatment S_3F_3

(Gima Kalmi sole + Chemical Fertilizer) whereas the lowest number of leaves/plant (37.52) was obtained from the treatment S_2F_0 (Gamari + Gima Kalmi + No fertilizer). At 60 DAS, the maximum branches/plant (11.02) was obtained from the treatment S_3F_3 (Gima Kalmi sole + Chemical Fertilizer). On the other hand, the minimum branches/plant (6.63) was observed from treatments S_2F_0 (Gamari + Gima Kalmi + No fertilizer). The highest weight of fresh leaves/plant (51.44 g) at 60 DAS was obtained from the treatment S_3F_3 (Gima Kalmi sole + Chemical Fertilizer) and the lowest weight of fresh leaves/plant (41.31 g) was obtained from the treatment S_2F_0 (Gamari + Gima Kalmi + No fertilizer) which was nearly similar with S_1F_0 (Mango + Gima Kalmi + no fertilizer). Finally, the yield the maximum yield (10.54 t/ha) was recorded in the pot where with chemical fertilizer (S_3F_3). On the other hand, the minimum yield (5.95 t/ha) was recorded in the plot S_1F_0 (Mango + Gima Kalmi + no fertilizer) which was nearly similar with S_2F_0 (Gamari + Gima Kalmi + No fertilizer).

According to performance the ranked order of production system was Gima Kalmi sole> Mango> Gamari. According to the performance the ranked order of fertilizer and manure applications were chemical fertilizer> cow dung> poultry manure> no fertilizer. According to the experimental results it may be concluded that two species can be used in agroforestry system by different management practices. In benefit cost ratio, it was found the highest benefit-cost ratio (4.15) was recorded from Mango + Gima Kalmi (S_1) based agroforestry system which was followed by Gamari + Gima Kalmi (S_2) based agroforestry system. The lowest benefit-cost ratio of (2.93) was observed in sole cropping of Gima Kalmi (S_3).

5.2 Conclusion

From the present study it was concluded that Gima Kalmi (Kangkong) can be grown under Mango and Gamari canopy although 10-15% yield was reduced as compared to no canopy i.e. sole cropping of Gima Kalmi because of light, nutrient, water etc. competition in char land of the Tista river. However, if we consider the additional product of Mango and Gamari tree under agroforestry systems gave more economical values than Gima Kalmi as sole cropping. Moreover, Gima Kalmi production using cow dung and poultry manure under Mango and Gamari based agroforestry system gave a little bit lower 6.71% and 21.25% respectively, yield reduction as compare to that system where chemical fertilizer was applied. But, if we consider the benefit of organic manure applications in terms of environmental benefit, soil health and safe (chemical free) Gima Kalmi production then cultivation of Gima Kalmi at the floor of mango orchard and Gamari woodlot with cow dung and poultry manure applications may be a promising agroforestry system in the char land of the northern part of Bangladesh.

5.3 Recommendations

1. The Gima Kalmi can be grown at the floor of a young Mango orchard and young Gamari woodlot successfully using organic manure (cow dung and poultry) in the char land area of Bangladesh.

2. The present study opened the new avenue for further investigation with the combination of fruit and woody trees and Gima Kalmi production simultaneously using organic manure in the unfertile char land.

3. Gima Kalmi cultivation with organic fertilizer (cow dung and poultry manure) are economically viable under Mango and Gamari based agroforestry system in char land. So, it can be suggested to the farmers of char land to practice it extensively.

4. This study should be repeated in different char land locations of Bangladesh like Padma char, Meghna char, Jamuna char etc. using different aged Mango orchard and Gamari woodlot to obtain valid recommendation.

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APPENDICES

Appendix I: The physical and chemical properties of soil in Gangachara Upazila, Under Rangpur District.

Soil characters	Physical and chemical properties
Texture	
Sand (%)	48
Silt (%	33
Clay(%	20
Textural class	Sandy Loam
CEC (meq/ 100g)	6.9
Ph	5.10
Organic matter (%)	1.15
Total nitrogen (%)	0.070
Sodium (meq/ 100g)	0.07
Calcium (meq/ 100g)	2.97
Magnesium (meq/ 100g)	1.27
Potassium (meq/ 100g)	0.22
Phosphorus (µg/g)	31.33
Sulphur (µg/g)	14.01
Boron (µg/g)	0.27
Iron (µg/g)	5.30
Zinc (µg/g)	1.46

Source: Soil analysis at the SRDI, Dinajpur (2019)

Appendix II: Weather data of the experimental site during the period from July 2019 to September 2019

Months	* Air Temperature (^{0}C)			* Average Rainfall (mm)	* Relative Humidity (%)
	Maximum	Minimum	Average		
July, 2019	31.29	26.11	28.7	461	75
August,2019	34.6	11.30	22.95	352	78
September, 2019	26.5	16	21.25	315	77

Note * Monthly average

Source: Bangladesh Meteorological Station, Rangpur

Appendix III: Production cost analysis of Gima Kalmi cultivation under Mango and Gamari based agroforestry system.

Treatment	Input cost										Total input cost (Tk/ha)	Overhead cost			Total cost of production (Tk/ha)
	Non material cost (Tk./ha)			Material cost (Tk/ha)								Interest of input cost @ 8% for the crop season (Tk./ha)	Interest of the value of land(Tk. 300000/ha) @ 8% for the crop season (Tk/ha)	Miscellaneous cost @ 5% of the input cost (Tk/ha)	
	Tree	Gima Kalmi	Total non-material cost	Seed	Fertilizer and Manure	Pesticide	Irrigation	Maintenance cost of trees	Initial plantation cost of trees	Total material cost (Tk/ha)					
S_1	12855	6000	18855	5000	5550	2000	1500	4050	10000	28100	46955	2728	24000	1705	75388
S_2	17140	6000	23140	5000	5550	2000	1500	4050	12000	30100	53240	2888	24000	1805	81933
S_3	---	5500	5500	7000	6500	25000	2000	----	----	18000	23500	1880	24000	1175	50555

Note: Urea 12 Tk/Kg, TSP 22 Tk/Kg, MP 24 Tk/Kg, Labour 120 Tk/Day, Plantation cost for Mango, Gamari were 20, 15 Tk/Tree, respectively.

S_1= Mango + Gima Kalmi, S_2 = Gamari + Gima Kalmi and, S_3 = Gima Kalmi sole

Appendix IV: Some plates of the experiment

Plate 1: Field preparation

Plate 2: Gamari + Gima Kalmi based agroforestry system

Plate 3: Mango + Gima Kalmi based agroforestry system

Plate 4: Gima Kalmi sole cropping