PERFORMANCE OF GARLIC AND POTATO UNDER GUAVA BASED AGROFORESTRY SYSTEMS IN CHAR LAND OF TISTA RIVER BASIN

A THESIS

BY

ATIKA PARVIN SHOMA
Student No. 1805105
Session: 2018
Semester: January-June, 2019

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

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

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DEDICATED

TO MY

BELOVED PARENTS

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PERFORMANCE OF GARLIC AND POTATO UNDER GUAVA BASED AGROFORESTRY SYSTEMS IN CHARLAND OF TISTA RIVER BASIN

ABSTRACT

Two experiments were carried out at the charland of Kaunia upazila under Rangpur district, during November 2018 to March 2019 to observe the performance of garlic and potato under guava based agroforestry systems. The experiments were laid out with single factor Randomized Complete Block Design (RCBD) following three replications for garlic and four replications for potato. The treatments for garlic experiments were five distances from the tree base *i.e.* T_1 (50 cm distance from tree base), T_2 (80 cm distance from tree base), T_3 (110 cm distance from tree base), T_4 (140 cm distance from tree base) and T_5 (170 cm distance from tree base). Whereas the treatments for potato experiments were three fertilizer and manure application. *i.e.* F_0 (no fertilizer), F_1 (only cowdung @ 10 t/ha) and F_2 (only chemical fertilizer). The total number of experimental plots of garlic were15 and the size of each garlic plot was (1m×1m) = 1 m^2. On the other hand, the total number of experimental plots of potato were12 and the size of each potato plot was (2m×2m) = 4 m^2. The result of the garlic experiment revealed that the different distance from tree base had significantly effect on the growth and yield of garlic under guava based agroforestry systems. Except plant height rest of all the growth parameter like number of leaves, leaf length, leaf breadth, size of garlic, weight of garlic, number of cloves/garlic were varied significantly. Yield of garlic was also varied significantly and the highest yield (7.40 t/ha) was recorded at open condition and the lowest yield (5.46 t/ha) was recorded in closest distance from tree base. *i.e.* treatment (T_1). In case of potato experiment, it was also found that different fertilizer applications had the significantly effect on the growth and yield of potato. However, chemical fertilizer gave the best yield (10.31 t/ha) where no fertilizer gave low yield (7.17 t/ha). Again, cowdung gave the medium yield (9.88 t/ha) which was 4.17% less as compared to chemical fertilizer. From the economic analysis, it was observed that the higher BCR (3.59) was recorded in garlic cultivation at the floor of guava tree from 140 cm distance of tree base. On the other hand, the lower BCR (2.77) was recorded from 170 cm distance from tree base (open control). In case of potato cultivation in agroforestry system the higher BCR (2.07) was recorded where cowdung was applied and the lower BCR (1.81) was recorded where no fertilizer was applied. Finally, it may be concluded that garlic and potato can be cultivated successfully under newly established guava based agroforestry systems at the char land considering the additional returns as per investment in terms of money and time.

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CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

Bangladesh is one of the densely populated countries of the world having an agro-based economy which situated in the North-Eastern part of South Asia with a tropical to sub-tropical climate. Now the population of Bangladesh is about 152.25 million in the area of 147570 sq. Kilometers and growth rate is 1.37% per annum (BBS, 2013). The total forest area of the nation covers about 17% of the land (BBS, 2013). However, according to the Forest Master Plan and surveys conducted by multinational donor agencies, only 6% or a total of 0.769 million hectares land of the territory has actual tree coverage (Anonymous, 1999a). But to have benefits of the nature, any state should have at least 25% of her land covered with forests.

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). It is away out to practice agriculture without deteriorating agro-ecosystem services while maintaining or improving productivity, stability or in other words sustainability. As far the knowledge about the traditional agroforestry is concerned, there has fair understood of various aspects involved therein (Lawson and Kang, 1990; Ong *et al.,* 1991; Thakur and Singh, 2002). The Agroforestry technology play role in the light of combating hunger, poverty, diseases, environmental degradation is highly appreciable and ecological efficiency lead to increase in total production per unit of land (Garrity, 2004).

Bangladesh must move on in its pursuit to develop and strive as a nation, taking into account its vulnerability, susceptibility and capacity to manage climate risks and adaptation. In this respect, the government has taken bold steps to prepare and respond to the challenge already on us. To help the country and its people build necessary capacity and resilience, regional and international cooperation is essential. Major rivers that draws freshwater and sediment from upstream basin to the Bay of Bengal going through Bangladesh originate in neighboring countries and water flow during both summer and dry period is critical for agriculture and food and drinking water security. Collective actions are necessary now to understand risks and take actions.

Multipurpose trees and shrubs are defined as all woody perennials that are purposefully grown to provide more than one significant contribution to the production and/or service functions of a land-use system that they occupy (for example, shelter, shade, land sustainability). They are so classified according to the attributes of the plant species as well as to the plant's functional role in the agroforestry systems under consideration (Burley, 1978; Burley and von Carlowitz, 1984). Agroforestry can be applied at a) the smallest scale, where trees and shrubs might be grown around the homestead or as boundary markers, and b) at the macro scale, where the trees may be used to control water or wind erosion, as contour barriers or shelterbelts (Wood & Burley, 1991). Tree and shrubs characteristics that are particularly important to many local communities include smokiness of fuelwood, odors and flavors imparted by fuelwood or charcoal, and thorniness (case of Acacia spp., Prosopis spp., Ebanopsis ebano and Helietta for example). However, guava is an important multipurpose tree. Guava leaves are just as medicinally useful as the nutritional powerhouse fruit. The leaves of the guava tree are full of antioxidants, anti-inflammatory agents, anti bacterials, and even tannins that can have significant health benefit, from treating stomach troubles to chronic diseases like cancer. It also important for its fruit and economical value.

Garlic (*Allium sativum* L.) has been used in world cuisines as well as in herbal medicine for thousands of years and at times, has been claimed to help prevent everything from high cholesterol to cancer (Rahman *et al.,* 2012). However, there are many preparations of garlic available, particularly in health food stores, including powdered garlic, tablets and oil capsules. In order to elucidate the role of garlic in the prevention of atherosclerosis, a large number of studies have investigated its effects on serum cholesterol, Low-Density Lipoprotein (LDL) cholesterol, High-Density Lipoprotein (HDL) cholesterol and triglycerides (TG) (El-Sabban and Abouazra, 2008). Garlic juice reduced serum cholesterol and TG in human subjects (Bakhsh and Chughtai, 1984) and helped in preventing the rise of serum cholesterol, thus indicating a cholesterol-lowering property (Beier, 1990). A systematic review of randomized controlled trials in humans reported that the reduction of total cholesterol and TG with garlic therapy was evident after 1 month and persisted for at least 6 months (Silagy and Neil, 1994). A meta-analysis of controlled trials on fresh garlic showed that consuming half a clove per day decreased total serum cholesterol levels (Warshafsky *et al.,* 1993).

Potato (*Solanum tuberosum* L.) is a perennial tuber crop. It is herbaceous, succulent and dicotyledonous plant with alternate stolons underground as well as alternate leaves on the stem above ground. It is originated in the Andes near the border of Peru and Bolivia in South America and in Bangladesh cultivation of potato is started in the late 19th century (Hashem, 1990). Potatoes are the world's fourth largest food crop, following rice, wheat, and maize. This vegetable is one of the leading food crops and occupies the first position in both acreage and production among the total vegetable crop in Bangladesh (BBS, 2013). Compare to other roots and tuber and also many cereals potato tuber have a high ratio of protein to carbohydrates with ahigh nutritional value of the protein (Shekhawat *et al.,* 1994). During 2013-14, the production of potato was 8950024MT from an area of 462032ha which is 4.03% higher than previous year and average yield was 19.371 MTha-1(BBS, 2014). The crop can be used both as human food and as seed tuber.

The low consumption of vegetables creates a tremendous pressure over cereals and also causes malnutrition leading to several kinds of health hazards. To provide balance diet there would be no alternative to produce vegetable, as this would also provide vitamins and minerals. But the scope of horizontal increase in production of potato is limited in the country mainly due to shortage of land and hence shady place can be used as an effective tool. Guava, garlic and potato are very important crops for its many beneficial effect. But now-a days, the production of guava, garlic and potato are decreasing day by day for inadequate land. Since the land are decreasing in horizontally, we can increase the land vertically. For this reason, Agroforestry system can play an important role to increase the production of these crop. But in our country, the land is insufficient for this system. We can see that, in char land area agroforestry practices is done. Before, we do not find out any work in agroforestry practices under char land area. As a result, I decide to do the work in char land area under Tista river basin.

Objectives:

1. To find out the possibility of garlic production at the floor of newly established guava orchard in char land.
2. To find out the base distance from tree base of guava for garlic cultivation an agroforestry systems.
3. To find out the possibility of potato production at the floor of newly established guava orchard in char land.
4. To find out the fertilizer and manure application for potato cultivation under guava based agroforestry systems.

CHAPTER 2

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

Good amount of literature is available where efforts have been made to understand various aspects of Agroforestry systems, although information is inadequate with respect to quantification of biological interactions among the components in Agroforestry systems. Keeping this in view, an attempt has been made to review findings on Agroforestry practices with particular emphasis on potato and garlic association with guava tree. The relevant literatures pertaining to the present study have been reviewed in this chapter under the following heads:

2.1 Benefits from Agroforestry system

2.2 Effect of multipurpose trees

2.3 Charland based on agroforestry system

2.4 Performance of potato in agroforestry system

2.5 Performance of garlic in agroforestry system

2.6 Effects of fertilizers on growth and yield of potato

2.1 Benefits from Agroforestry system

Pandit *et al.* (2014) stared that Agroforestry has been recognized as one of the important systems for supporting the livelihoods of a large number of rural farmers in the Nepalese hills. However, its conservation and socio-economic values have received little attention. This resulted in increased livelihood benefits to local people. Production of goat meat and buffalo milk has increased considerably. The high economic benefits are mainly associated with the introduction of various fodder trees and grasses in private farmlands. It is concluded that the various drivers of the Agroforestry system need to be carefully attended so as to improve both positive conservation and livelihood outcomes. Enabling policy and practices are needed to initiate and support farming cooperatives in the commercialization of Agroforestry products and market the conservation values in a changing climate.

Korwar *et al.* (2014) stated that Agroforestry in rainfed areas increases livelihood security through simultaneous production of food, fodder, and firewood, and an increase in total productivity per unit area of land. To enhance rural livelihood security among the dry land farmers, several improved Agroforestry systems, commercial plantations and biofuels and bioenergy systems came into being for adoption. Agroforestry plantation-based success stories reveal livelihood security of small, marginal, and landless farmers. Steps to promote basic and promotional Agroforestry research in dry land agriculture and appropriate policy responses with extension outreach may potentially deliver better results in rainfed agriculture. Rainfed Agroforestry for livelihood security reflects the positive way in utilization of rainfed area resources.

Rahman *et al.* (2012) stated that in the Padma floodplain of Bangladesh, the traditional system of agriculture has become unsustainable due to high population growth. Mangobased Agroforestry which has been practiced by the farmers since the 1990 s, is a promising alternative and is considered as one of the few options to lift farmers out of poverty and improve livelihood security. Farmers with the least land were found to allocate a higher percentage of their land to Agroforestry, and the increased income from Agroforestry compared to other agricultural systems helps reduce relative poverty. This income maintains basic household needs, providing food security and fuel wood, and contributes to healthcare, housing and sanitation conditions, and meeting educational expenses.

Magcale-Macandog *et al.* (2010) stated that the impact of Agroforestry on food security of upland farmers is least recognized and appreciated given that the linkage between them is quite complex and not well understood. The crucial role of Agroforestry in enhancing food supply and augmenting family income is commonly ignored. Fruits from perennial crops and trees served as secondary food crops especially during lean months of food supply. The last major finding was that the adoption of Agroforestry significantly increased the level of benefits by around 42–137%, compared with the low income from continuous annual monocropping. The key to making upland farm households food secure is to increase the productivity of their farms and home gardens.

Agroforestry systems are believed to provide a number of ecosystem services; however, until recently evidence in the Agroforestry literature supporting these perceived benefits has been lacking. This special issue brings together as series of papers from around the globe to address recent findings on the ecosystem services and environmental benefits provided by Agroforestry. As prelude to the special issue, this paper examines four major ecosystem services and environmental benefits of Agroforestry: (1) carbon sequestration, (2) biodiversity conservation, (3) soil enrichment and (4) air and water quality. Past and present evidence clearly indicates that Agroforestry, as part of a multifunctional working landscape, can be a viable land-use option that, in addition to alleviating poverty, offers a number of ecosystem services and environmental benefits. This realization should help promote Agroforestry and its role as an integral part of a multifunctional working landscape the world over.

Brodt *et al.* (2009) stated that although hedgerows, windbreaks, and other biodiversity enhancing farm edge features offer the potential for ecosystem benefits without occupying much crop space, relatively few farms in California, USA include such features. We also identified social, economic, and agronomic incentives and constraints to installing biodiversity-enhancing edge features. More than one-third of the study farmers had installed native hedgerows, windbreaks, and/or grassed edges. Interviews demonstrated the importance of socially influential farmers working in tandem with public and private agencies to build initial interest in these practices. However, these features occupied less than four percent of all possible edge length. Constraints to increasing adoption included high costs, fear of harboring weeds and rodents, and lack of certainty about ecosystems benefits, highlighting the need for cost-share programs and more regionally-focused agro-ecological research

Perhaps the greatest benefit of AF systems (especially in the developing world) is their use in weed and pest management. Weeds and pests interfere with primary crop productivity, and can have huge impacts on harvest levels. Use of pesticides and herbicides in the west to control weeds has led to many unintended effects on non-target organisms, environmental degradation, and reduced sustainability of crop land. Pesticides are also relatively affordable in the west, but prohibitively expensive in much of the developing world. Although there have been contrasting studies on both sides of the issue, the general consensus is that AF crops reduce weed population due to shading. They also decrease insect attacks by providing a physical barrier to airborne pests and pathogens (Batish, *et al.,* 2008).

Gupta *et al.* (2004) stated that two Agroforestry systems were established on reclaimed mine sites in NE-Germany (Lusatia) and Central Germany (Helmstedt). The yield potential and the sustainability of yields were studied for different clones of poplar (Populus spp.), willow (Salix viminalis L.), and black locust (Robinia pseudoacacia L.), considering different rotation periods (3-, 6-, and 9-year-rotation) and approaches of soil amelioration (mineral fertilizer, compost). In the Agroforestry system in Lusatia, special emphasis was given to the interaction between trees (R. pseudoacacia) and crops (Medicago sativa L.). Considering the land equivalent ratio (LER), R. pseudoacacia hedge rows have practically no negative influence on yields of M. sativa. Hence, with regard to an increasing demand for woody biomass, alley cropping with R. pseudoacaciand crops such as M. sativa may provide a promising alternative for future land use in the temperate zone

The United Nations has set a list of Millennium Development Goals (MDG) aimed at: eradicating poverty and hunger, bettering health, nutrition, and education to people, gender equality, and environmental sustainability, particularly in the developing world. According to Batish and Daizy ("Ecological interactions in AGF overview"), *et al.* (2008), AF is substantially assisting the UN in meeting these goals.

Economic gain has been identified as the primary motivating factor in the adoption of Agroforestry in the US. Agroforestry practices must offer at least as much income potential without increasing risk, compared to current farming practices, and better scenarios for solving conservation problems than the current farming practice for adoption to take place. Incentives for Agroforestry can be implemented to provide economic or ecological benefits to the landowner and entice them to adopt practices that may have been too risky or foreign to them prior to the incentives.

National Agroforestry Center investigated the funding incentives available through the federal, state and non-governmental organizations (NGO) for the five Agroforestry practices. Cost sharing was found to be the most commonly used incentive. Other incentives such as producer grants, land rental payments, financial incentive payments and technical assistance were also identified. Most federal funding available for Agroforestry practices is distributed through the United States Department of Agriculture (USDA), while the state of Missouri funding is available through the Missouri Department of Agriculture (MDA).

The loss of biodiversity is the single greatest pitfall of modern, industrialized agriculture. AF plots can help to preserve biodiversity by providing a protective tree cover within, or alongside fields. Numerous studies have shown higher biodiversity levels in AF plots than in traditional sole cropping agriculture. AF provides a number of biodiversity conservation benefits by providing secondary habitat for species, reducing rate of conversion of primary habitats, and by creating an acceptable transition zone between primary habitats (Batish, 2008).

The economics of hedgerow systems have been studied, and results look very promising. Most studies cite the number one initial effect of hedgerow systems being an increase in productivity from the start. This is achieved through a stabilized moisture regime, and the 23 increased soil fertility has benefits alluded to previously. One study showed yields of maize increasing up to 22 percent without fertilizer addition, and up to 70 percent increase with fertilizer use (Sun, *et al.* 2008).

Dorr (2006) found a lifestyle attitude that is represented as “loss of trees as a problem” to be interested in the Agroforestry practices except for windbreaks where it was found not significant. These result shows that attitudes are not the most important factor influencing conservation practices but play an important role in whether there is interest in new practices.

Brandle *et al.* (2004) listed the following economic benefits of Agroforestry:

1. When various species are included in the design, they can contribute directly to the production of nuts, fruits, timber and other wood products. This helps to diversify and increase farming income while also providing a stock of capital in valuable timber.
2. When used in livestock production systems, they improve animal health, improve feed efficiency and contribute to the economic returns of producers.
3. The practices can also help to reduce energy consumption by the farm and improved working conditions within the farm area, which helps to save cost and increases productivity.
4. Agroforestry technology can reduce costs of production, increase productivity and provide multiple outputs.

Puri and Nair, (2004) observed the value and assessed the social, cultural and economic benefits of various tangible and intangible benefits of Agroforestry, but the socioeconomic processes involved in the success and failure of Agroforestry have not been investigated. On the other hand, the success stories of wasteland reclamation, and poplar-based Agroforestry have shown that the technologies are widely adopted when their scientific principles are understood and socio-economic benefits are convincing.

Alavalapati *et al.* (2004) ststed that Agroforestry systems (AFS) provide a mix of market goods and nonmarket goods and services. We postulate that if nonmarket goods and services can be internalized to the benefit of landowners, the adoption of AFS will increase. It has been found that the profitability of silvopasture would increase, relative to conventional ranching, if environmental services are included. Estimates of public willingness to pay for environmental services associated with silvopasture and estimates of ranchers' willingness to accept for the adoption of silvopasture will provide a scientific basis for policy development.

Increased food production can be achieved in different ways by an increase in the area of land, devoted to farming or by increasing the productivity of land already farmed. The most suitable land has already been used for farming and even the area of this land is being reduced by urban demands for more houses and roads, more industrial development and more amenity areas. So the next available alternative of raising productivity of land already farmed has gained momentum through adoption of Agroforestry practices. In a changing scenario of decreasing availability of good arable land for agriculture, degradation of soil and water resources, increasing environmental pollution, the new approaches in farming systems have made rapid strides in the last two decades. Making the country self-sufficient in food, fodder, fibre, firewood and timber production deliberate inclusion of trees in the existing farming/cropping systems and adoption of Agroforestry approaches on all kinds of land is one of the viable option to achieve sustainability while optimizing productivity. The most important factor responsible for such an achievement is the widespread adoption of Agroforestry technology (Singh *et al.,* 2008).

2.2 Effect of multipurpose trees

Agroforestry can be applied at different scales in a landscape. The smallest scale is the individual farm, where trees might be grown around the homestead or as boundary markers. At the macro scale, agroforestry practices may be applied to whole watersheds or to large expanses of open cereal farms, where the trees may be used to control water or wind erosion, as contour barriers or shelterbelts. The role of a woody perennial is not confined to its service and production functions; it must be acceptable in all respects to the farmer and to the local community. Tree characteristics that are particularly important to many local communities include smokiness of fuelwood, odours and flavours imparted by fuelwood or charcoal, and thorniness. However, the overriding factors for farmers are perceived economic benefits and the reduction of risk. A new species or technology will not be adopted by local farmers if it cannot be shown to be superior in these respects. For this reason, long-term research programmes must include the collection of appropriate economic data. Other, 'social', factors have to be taken into account when planning research, although they are more difficult to quantify than economic benefits. These include personal and community preferences, tastes, and cultural and religious behaviour; there are many examples of species that grow well on a particular site but are not favoured by farmers for such reasons. Many of these factors can be identified during diagnostic surveys of rural areas (see Chapter Two for more details). A research programme must eventually investigate these preferences, attempt to put values on community preferences and provide factual information on growth characteristics and uses of trees to help local communities and development planners in decision making. Agroforestry Systems, 1992. 1992 Kluwer Academic Publishers. Printed in the Netherlands. Improving multipurpose tree and shrub species for agroforestry systems F. OWINO International Council for Research in Agroforestry, Nairobi, Kenya Key words: multipurpose trees and shrubs, agroforestry, choice of species for improvement research, provenance trials, selection and breeding Abstract. With the aid of an example of ICRAF's tree improvement research programme for the highlands of Eastern and Central Africa, a logical approach to selection and breeding of multipurpose trees and shrubs in agroforestry context is proposed. Criteria for selection of high priority species are proposed. Some species of high potential for agroforestry develop- ment in Sub Sahara Africa are proposed. The necessary sequential research steps are discussed. Introduction Agroforestry systems are characterized by the presence of woody perenials. The specific roles such woody perennials play in agroforestry systems has formed the basis of agroforestry systems inventory [Nair, 1979]. It is recognised that several thousand multipurpose tree and shrub species across the globe could have potential roles to play in agroforestry systems development [Burley and von Carlowitz, 1984]. Most of these multipurpose tree and shrub species with agroforestry potential exist in wild and unselected populations where they are likely to exhibit wide natural variability [Burley, 1978]. Such populations can be expected to respond well to selection and breeding thus resulting in great increases in yield and adaptability to specific sites, fanning systems. Existing tree improvement programmes are largely oriented towards large-scale plantation forestry production systems. Their goals are conceived narrowly as increased wood production. Improving multipurpose tree and shrub species for agroforestry systems should have goals which differ from the above. For example, besides total biomass production, tree root symbiont relations (particularly nitrogen fixation potential) deserve greater attention. Fodder and mulch properties of tree and shrub species should be more effectively evaluated and included as criteria for selection and breeding. The ideal tree or shrub ideotype should be clearly defined taking into account (i) tree-alternate crop interactions and (ii) intended tree management practices as components of agroforestry system

2.3 Charland based on agroforestry system

Bangladesh is mainly an agriculture based country and two-thirds of the populations directly or indirectly depend on agriculture. The economy of the country draws its strength and stability mostly from agriculture. 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 labour force (BBS, 2017). This sector is playing a vital role in achieving self-sufficiency in food production. Around 75% of the people live in rural areas of which 60% depend on agriculture for their livelihood. 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 charlands 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 charlands in overall poverty reduction and economic growth of the country could not be achieved. Especially because hundreds of acres of land due to alluvial accretion in rivers not being included in Khas Khatian and not handed over to the actual landless through proper distribution, no expected result has been found in rural poverty alleviation. But proper and correct utilization of charland could have set a considerably positive trend in effective alleviation of rural poverty. Islands and bars are very common features among with them. In Bangladesh, both islands and bars are known as chars. 'Char' a tract of land surrounded by the waters of an ocean, sea, lake, or stream; it usually means anyaccretion in a river course or estuary. River water is a critical resource for the char land life and economic growth, cultural interaction and environmental development (Chowdhury, 2010). There are over 12 million people who live in char lands and struggle against the floods and associated river bank instability (Hooper, 2001). 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. These populations are living in char areas and maintaining their livelihood through char based farming systems. 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, it is necessary to cultivate tree (fruit tree) and vegetables combinedly as agroforestry system. Population of Bangladesh is increasing rapidly; therefore, demand for vegetable is increasing simultaneously. A large number of vegetables are grown in the field in our country. Most of them are grown in the winter season of which potato, sweet gourd, chilli, radish, potato, sweet potato, coriander and carrot are very common, popular and quick growing vegetables having high nutritional value and can grow easily. 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 potato and garlic in association with guava fruit trees and also observe the yield of fruit trees in char land ecosystem. Potato and garlic was grown in association guava fruit tree and also without fruit tree combination. Yield and yield attributes of potato and guava trees also recorded. Number of fruits per plant and individual fruit weight of potato and guava recorded from represented samples of potato and guava. Numbers of fruits of each mango and guava tree were recorded during harvesting time and sum of all harvested fruit from each tree also estimated. Average number of fruits of all trees treated as the number of fruit per plant of potato or guava tree. Average individual fruit weight of mango and guava was estimated from recorded total fruit weight and number fruits per plant of mango and guava trees. In thisstudy, sweet gourd was grown in association with potato and guava trees.

2.4 Performance of potato in Agroforestry systems

Paul *et al.* (2008) also reported that cane yield was enhanced (6-8%) when it was intercropped with potato for the residual effect of applied fertilizer to intercrop. Gross return and gross margin was higher in cane intercropped with potato over sole crop at both the locations. Dieme and Ourèyesy (2013) stated that the micro tuber is considered one of the most effective means of spreading basic materials, as well as transporting and preserving potato germplasm varieties. To define the optimal conditions for the potato microtuber in vitro germination of Aida, Atlas and Odessa varieties, the effects of temperature, physiological age and grade (size) were evaluated. The study conducted at three different temperature levels has demonstrated that the most favorable temperature for microtuber germination at a higher and faster germination rate was 25°C, regardless of the variety. In addition, microtubers of large caliber, greater than 4 mm, germinate more quickly, with a higher germination rate, than smaller size ones (less than 4 mm) for all genotypes. For Atlas, Aida and Odessa varieties, a germination rate equal to 86.66%, 70% and 70% respectively, was obtained for microtubers with a caliber superior to 4 mm. Physiological age influences microtuber germination. The mean length of sprouts, reached after a 7 week incubation period, was more marked at multiple sprouts and branched sprout" stages than at a "monosprout" stage. The average length was 2.35 cm, 2.48 cm and 1.5 cm, respectively. Thus, it is necessary to plant microtubers at a multiple sproutsta. Tuber yield in potato was affected by genotype /environment relations. In North Gujarat, Kufri Pukhraj established good in wide range of environment, and where as other two varieties were adapted to suitable environment only. As a main season crop, Kufri Badshah was preferably suitabe for a wide range of environment (Patel *et al.,* 2008). Avasthe *et al.* (2007) observed that nine major Agroforestry systems are in practice in the sub-stropical and mid-hill temperate zones of Sikkim, India. Among them only agrihorticultural (maize- potato) are found to be more viable and economically feasible than other system. The economics revealed that the maize-potato cultivation generated almost Rs. 48 000/- per hectare. The effect of different spacing's of poplar (5×4 m, 10×2.5 m, 15×2.5 m) on the performance of intercrops was investigated in Hisar, Haryana, India. They cultivated different agricultural crops viz., sorghum (Sorghum bicolor), cowpea (Vigna unguiculata), dhaincha (Sesbania aculeata), mungbean (Phaseolus radiatus), groundnut (Arachis hypogaea), turmeric (Curcuma longa), wheat (*Triticum aestivum*), oats (Avena sativa), berseem (*Trifolium alexandrinum*), lentil (Lens esculenta) and potato (*Solanum tuberosum*) for seven consecutive years under poplar (Populus deltoides) plantation. Results showed that yield of all crops decreased with increasing age of poplar. The yield of all crops increased with increasing poplar spacing, however, a spacing of 10 m×2.5 m seems to be the ideal for getting optimum growth and yield of agricultural crops. The yield reduction of crops was higher during the rainy season than winter season. During the rainy season, turmeric gave maximum relative yield while in winter season, both be seem and wheat were equally compatible with poplar at all the spacings, however, potato also proved promising for poplar based Agroforestry system but Calstellani and Prevosta (1961) inferred that poplar planted in rows in any direction had no significant effect on yields of crops along side up to fourth year after plantation. The effect of different spacing of poplar (5×4m, 10×2.5m, 15×2.5m) on the performance of intercrops was investigated in Hisar, Haryana, India. They cultivated different agricultural crops viz., sorghum, cowpea, dhincha, mungbean, groundnut, turmeric, wheat, oats, berseem, lentil and potato for seven consecutive years under poplar plantation. Results showed that yield of all crops decreased with cncreasing age of poplar. The yield of all crops increased with increasing poplar spacing, however, a spacing of 10m×2.5m seemsto be the pdeal for getting optimum growth and yield of agricultural crops. The yield reduction of crops was higher during the rainy season than winter season. During the rainy season, turmeric give maximum relative yield while in winter season, both berseem and wheat were equally compatible with poplar at all the spacings, however, potato also proved promising for poplar based Agroforestry system but Calstellani and Prevosta (1961) inferred that poplar planted in rows in any direation had no significant effect on yield of crops along side up to fourth year after plantation.

Tuber yield showed significantly encouraging relationship with all the character. Plant height, though had low direct effect on tuber yield and their optimistic involvement to tuber yield been largely through average tuber weight and tuber number respectively. Average tuber weight was negatively related with tuber number (Luthra, 2005). Significant difference in total and grade wise tuber yield of potato in potato varieties was noted (Chettri *et al.,* 2005). Kufri Jyoti produced more number of tubers (222.6) than Kufri Chandra Mukhi 215.8. Relationship of size of tubers and number of tubers per plant were influenced by temperature. Higher average tuber yield was in Kufri Chandramukhi (32.5 t/hac.) The cultivars however did not differ for average tuber weight (Singh and Ahmad, 2008).

During the winter season of 2001-02 at CCS Haryana Agricultural University, Hissar, an experiment was undertaken by Kumar *et al.* (2004) to examine the production potential of winter season crops under two and a half years old Eucalyptus tereticornis based agrisilviculture system at 6 m×2 m spacing. The treatments included five test crops viz., wheat (*Triticum aestivum*), berseem (*Trifolium alexandrinum*), potato (*Solanum tuberosum*), mustard (*Brassica* spp.) and lentil (Lens esculenta). All the test crops sown in the interspaces of eucalypts showed reduced plant vigour in terms of plant height, stem diameter, number of branches and yield attributes as compared to control. The yield of lentil, berseem, wheat, potato and mustard under eucalypts decreased to the tune of 16.3, 52.1, 62.3, 80.8 and 82.4 per cent, respectively. A field experiment was conducted to study the popularity of different intercrops with sugarcane at Nakla thana under Sherpur district of Bangladesh during cropping year 2000-2001. Five intercrops with sugarcane combination such as potato (*Solanum tuberosum*), onion (Allium cepa), coriander (*Coriandrum sativum*), mustard (*Brassica campestris*) and garlic (*Allium sativum*) were studied against sole sugarcane crop. In respect of agronomic performances, sugarcane with potato, sugarcane with onion and sugarcane with coriander were suitable though they produce lower cane yield than sole cane. In respect of economic profitability sugarcane with potato combination was the most profitable than the others (Al-Azad, 2004). Malik *et al.* (2005) proposed a model for predicting the changes in growth of industrial Agroforestry plantations under intercropping, weeding and fertilizer practices. The model also enabled the prediction of the growth, growth rate and felling period of Eucalyptus globulus under Agroforestry system. The model was applied to growth data of four years pulpwood plantation of E. globulus under Agroforestry practices with intercrop of potato (*Solanum tuberosum*), beans (*Phaseolus lunatus*), maize (Zea mays) and also with silvicultural practices such as weeding andfertilizer treatments in the long term Agroforestry experiments conducted in Palani Hills, Tamil Nadu, India. Eucalyptus with potato intercrop gave higher yield of pulpwood in all the trials. Eucalyptus has maximum growth at fourth year. Eucalyptus grown with compatible intercrops reached its maximum potential of active growth in 6th year. In Tamil Nadu, India, Madhu *et al.* (2005) conducted a field experiment to study the effect of lopping on biomass production of Eucalyptus globulus and yield of potato and oats in Agroforestry system. Trees which were not lopped up to the 10th year produced the highest total biomass of 436.63 t ha-1 whereas those lopped in alternate years and every year from the 4th year produced 218.29 and 140.76 t ha-1, respectively. The reduction in intercrop yield of potato was 12.4-15.6% in Agroforestry system as compared to sole crop but potato was the most profitable option, and, therefore, recommended for higher production, profitability and protection of sloping lands in the Nilgiri hills, the results was collaborating in another findings. An experiment was undertaken to study the economics of poplar (Populus) cultivation and constraints being faced by the poplar growers in Punjab, India. Three types of Agroforestry systems (AFS) were studied; AFS-I (wheat-kharif fodder), AFS-II (sugarcane for first three years and then wheat-kharif fodder for the successive years) and AFS-III (potato -kharif fodder for first year and then wheat-kharif fodder for the successive years). The highest net present value (NPV) was

Rs. 116 068.60 per acre in Ludhiana for AFS-II in 6th year while it was Rs. 126 891.90 per acre for AFSII in 6th year. However, their profitability could be further enhanced through government intervention and enhanced management of poplar plantation. Average weight of tuber increased as the night temperature decrease in two varieties. Higher day temperature also have affect on tuberization (Minhas and Kumar, 2005). Gupta *et al.* (2004) reported that Agroforestry not only uplifted the socioeconomic status of the farmers but also contributed towards the overall development of any region. Cultivation of potato and scented geranium with eucalyptus is found to be most economical in the Nilgiris area of Tamil Nadu, India. The Eucalyptus globulus + potato (Kufri Jyoti) Agroforestry system is found to be more profitable than pure Eucalyptus plantation. Tuber crops are feasible to grow under partial shade with Casurina equisitifolia. Tuber yield (turmeric, potato, taro) was higher under partial shade when the crops were grown during the second year compared with control (without tree) but was reduced markedly under complete shade. During the third year, the turmeric yield increased in partial shade while potato and taro yields declined slightly. Potato is a weather sensitive crop; its growth and production are obviously affected by environmental conditions. Temperature above 18-20oC tend to increase haulm growth and lower tuber yield. A field experiment was conducted in Gazipur, Bangladesh during winter 1991-92 and 1992-93 to determine the most productive ratio of maize cv. Barnali and potato cv. Diamant in an intercropping system. Potato intercropped with 30% maize was the best combination in terms of producing high returns, the highest gross margin (Tk. 44 094), land equivalent ratio and equivalent yield. Dagar *et al.* (2001) suggested that tuber crops are feasible to grow under partial shade with Casurina equisitifolia. Tuber yield (turmeric, potato, taro) was higher under partial shade when the crops were grown during the second year compared with control (without trees), but was reduced markedly under complete shade. During the third year, the turmeric yield increased in partial shade while potato and taro yields declined slightly.

O'brien P.J. *et al.,* (1998) carried out over 7 years, examined effects of shading and seed tuber spacing on plant growth, initiation and retention of tubers in four cultivars: Estima, Maris Piper, Maris Peer and Record. Shading by up to 75% did not affect the timing of onset or cessation of tuber initiation in Estima but shading by 50% or more delayed the completion of tuber initiation in Maris Piper compared with less severe shading. Except for intensely shaded treatments (50% or more), the majority of tubers were initiated in a very short period (4–7 days). Shading by 37% or more during the period of tuber initiation and increasing planting density, decreased number of tubers per stem initiated in all experiments, but number of tubers was not affected by shading at other stages of growth. At Cambridge, effects of shading on number of tubers>10 mm retained later in growth from normal planting dates (March to early May) were similar to effects on number of tubers initiated, but effects were much reduced or absent following later plantings at Cambridge and in both experiments in Valencia. The decreased effects of shading on number of tubers >10 mm at late plantings at Cambridge were associated with the initiation of fewer tubers at these plantings. Effects of shading, planting density and planting date on number of tubers were a consequence of changes in the frequency of occurrence and tuberization of different stolon types. Increasing shading and planting density and delaying planting reduced the number of lateral and branch stolons and the frequency of their tuberization but there were no effects on number of primary stolons or their tuberization. Consequently, at Cambridge a similar number of tubers were borne on primary stolons in shaded and unshaded crops. In Valencia a greater proportion of initiated tubers was retained at final harvest from shaded treatments than at Cambridge, which accounts for the absence of effects of shading on number of tubers >10 mm. The greater retention of tubers late in growth in Spain may have been associated with the higher peak growth rates achieved in higher radiation fluxes than at Cambridge.

Agarwal *et al.* (1995) reported that intercropping of black wattle with potato were more economically efficient in the first year of cultivation in Nilgiris in Tamil Nadu than compared to its sole stand but the yield of potato decrease as cultivation goes on.

2.5 Performance of garlic in agroforestry system

Botanically, garlic belongs to the genus Alliumfamily Alliaceae, which includes important vegetable crop such as onion (Allium cepa), leek (A. ameloprisum) and shallots (A. asacloncum). Garlic is a diploid species (2n = 2x = 16) of obligated apomixes and propagated vegetatively. Garlic is propagated asexually, but shows a high morphological diversity among cultivars. These cultivars have a wide range of adaptation to different environments. Like onion, garlic plants have thin tape shaped leaves about 30 cm long. Roots reach up to 50 cm depth or little more. Heads or bulbs are white skinned, divided into sections called cloves. Each head could have from 6 to 12 cloves, which are covered with a white or reddish papery layer or “skin” (Hector *et al.,* 2012). Sexual propagation in garlic is expected to facilitate the exchange of genetic traits from one genotype to another and to improve garlic cultivars through classical breeding. Garlic does not produce true seed but it is propagated by planting cloves. Each bulb usually contains a dozen or more cloves and planted separately. Select only larger outer cloves of the best garlic bulbs for planting because larger cloves yield larger size and mature bulbs at harvest. Do not divide the bulb until ready to plant; early separation decreases yields. Select "seed bulbs" that are large, smooth, fresh, and free from disease. To plant garlic properly, dig a hole or trench, place the unpeeled clove gently into the hole with the pointed side up (the scar [stem] end down) and cover the clove with soil. Setting the cloves in an upright position ensures a straight neck (McLaurin, 2012).Ecology Requirements and Production of Garlic The ecological requirements of garlic is with a reasonably mild winter regions which have some rainfall followed by a sunny dry summer, with good for maturity and harvesting of the bulbs are ideal for garlic production (Brewster, 1994). Very high or Excessive humidity and rainfall are unfavorable to vegetative growth, bulb formation and reduced production. The garlic plant is easily stressed by insufficient moisture and water logging during its growing period. To attain the maximum yield, the top upper surface should be moist and maintained close to field capacity for most of the growing season (Brewster, 1994). The geographical areas providing mean monthly temperature ranging from 12-24 0C is best for garlic growing. High temperature is required for optimum bulb development but cooler condition in early stages favor vegetative growth. Elevations less than 2000 m a s l is not suitable for garlic growth and production (Nonnecke, 1989).Garlic has a wide area of adaptation and cultivation throughout the world. On global basis, the leading producers are China, Korea, Thailand, Spain, Egypt and India. The productivity of garlic in many parts of the world is low due to genetic and environmental factors affecting its yield and yield related traits (Nonnecke,1989). The area covered by garlic exceeds 1,142,000 hand its average productivity is estimated to be12t ha-1in the world (FAO, 2008). World production of garlic is ranked 14^{th} among vegetables with a total of 14.5 million ton (Trejo, 2006). In Mexico, its consumption is about 400 g per capita(Chavez, 2008), and the production is considered low as compared to other countries such as China (80 % world production), India, Korea and (20 %) the rest of the world (FAOSTAT, 2011). As indicated Anonymous, (2004) the term 'seed' in the garlic refers to individual cloves separated from a bulb. The 'seed' needed per hectare are very variable as the cloves of different species vary greatly in size. When using your own planting stock, harvest the planting stock bulbs later than your main crop, as harvesting very mature bulbs increases the ease of clove separation, otherwise when out it will produce smaller bulbs. The upper 15-207cm of the soil surface should be always moist, but not wet, because most of the root system will be grown in this depth (Trejo, 2006). Yield and quality will vary with climate, region, altitude, soil and pH, cultural practices, and the variety of garlic. The term "biological elasticity" describes garlic's ability to acclimate to these factors over time. No one practice is best suited for every situation. It is advisable to conversation with local growers who have experience growing garlic and experiment with different cultural practices and varieties to discover the best combination for your operation (Siktberg *et al.,* 2006).Lighter soils will need more frequent water applications, but less water applied per application. Water stress during the growing season can cause bulbs to be smaller and is thought to also cause a multiple stem disorder (Anonymous, 2004).2.3. Growth and Development Garlic is a cool season plant it makes all vitality and leaf growth while the temperatures are cool and the day is short. As the temperature becomes warm and the day is lengthen, the plant stops making leaves and begins to form bulbs. Cloves or young plants exposed to temperatures of between 0^0 Cand 10^0 C for one to two months hastens subsequent bulbing under long days (Moore and Gough, 2010).A study in the Netherlands conducted by Messiaen and Rouamba (2004) during the life cycle of plant under go successive stages of growth and development, the dormancy of mature cloves, induced by the temperature of 25-30 0C is eliminated most quickly at 6-7 0C vegetative growth is optimal at 18-20 0C. When 12-14 leaves have been produced, bulb swelling is induced at temperature below 20^0 C. There is considerable physiological variability amongst garlic cultivars. The total growing period varies from 4 months to about 9 months. According to McLaurin, (2012) the matured garlic cloves planted in the fall go through a dormant period. Garlic cloves require a period of 6-8 weeks of cool weather after planting (below 4.4 OC to undergo verbalization inducement to bulb) by low winter temperatures.

2.6 Effects of fertilizers on growth and yield of potato

Potato (*Solanum tuberosum* L.) is the fourth most important food crop in the world after rice, maize and wheat in terms of human consumption (Karam *et al.,* 2009; Kandil *et al.,* 2011). The quantity produced yearly exceeds 300 million metric tons and more than a billion people worldwide consume potato which is rich in carbohydrates, protein, vitamins, dietary fibers, simple sugars and minerals (CIP, 2010; FAO, 2008). In Cameroon potato production exceeds 160000 tons from over 50000 hectare (FAO, 2012). In order to achieve high yield, potato requires cool weather, reasonable amount of nitrogen (N), phosphorus (P) and potassium (K) in the soil. Production in Cameroon is constrained by poor farming practices, high cost of seeds, diseases, pests and poor soil fertility management. This study is focused on soil fertility management using organic manure and inorganic fertilizers since little has been done to determine the most appropriate combination rate for optimum potato yield. As reported by Monirul *et al.* (2013), variation in the rate of application of organic manure and inorganic fertilizers could influence the yield of potato. Organic manures and their extracts have been used to improve soil fertility and in combating pests and diseases (Abbasi *et al.,* 2002; Khadem, *et al.,* 2010; Litterick *et al.,* 2004). Organic manures and composts have also been found to have a direct anti disease effect by stimulating competing micro organisms and also by inducing resistance to plant diseases (Brinton *et al.,* 1996; Ghorbani *et al.,* 2006). However, there are other contradicting evidences indicating the reverse impact of using these sources (Chauhan *et al.,* 2000). The use of fertilizers and manure to enhance soil fertility and hence crop yield improvement is a traditional method that has been in use for a very long time. On the other hand the use of compost on agricultural land has been widely accepted for sustainable agriculture (Perez *et al.,* 2007; Hargreaves *et al.,* 2008). Positive role of compost application has been reported in many crops. The application of compost increase microbial activity, nitrogen concentration and grain yield (Tejada *et al.,* 2003). Phosphorus is the second most important macro nutrient after nitrogen that plays significant role in physiological and biochemical reactions such as photosynthesis and transfer characteristics (Mehrvarz *et al.,* 2008). Phosphorus fertilizers and manure in the soil increase phosphorus uptake by plants, through favoring production of carbonic acid, the acid that increases solubility of phosphate compounds in calcareous soils (Chien, 2003). Fertilizer application has important effects on the quality and yield of potatoes (Leytem and Westermann, 2005). Potato is highly responsive to N fertilization and N is usually the most limiting essential nutrient for potatoes growth, especially on sandy soils (Errebhi *et al.,* 1998). Nitrogen supply also plays an important role in the balance between vegetative and reproductive growth for potato (Alva, 2004; White *et al.,* 2007). Many previous studies have shown that N fertilizer applications can increase dry matter content, protein content of potato tubers, total and/or marketable tuber yield (Bélanger *et al.,* 2002; Kara, 2002; Zebarth *et al.,* 2004; Zelalem *et al.,* 2009). Nitrogen fertilization has been reported to increase the average fresh tuber, plant height, leaf number and tuber weight per plant (Kandil., 2011; Semiha., 2009). The purpose of the present study was to determine the effects of animal manure and inorganic fertilizer on potato production.

CHAPTER 3

MATERIALS AND METHODS

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. In order to fulfill the objectives, two experiments were concluded.

Experiment 1: Performance of garlic under newly established guava orchard at the Tista char land influenced by the distance from tree base.

Experiment 2: Performance of potato under newly established guava orchard at the Tista char land influenced by fertilizer and manure application.

3.1 Description of the Experiment no.1

3.1.1Location

The experimental site was selected in the existing guava orchard of Kaunia upazilla under Rangpur district. The district lies between 25º18″ and 25º57″ north latitudes and between 88º56″and 89º32″east longitudes and about 34 m above the sea level.

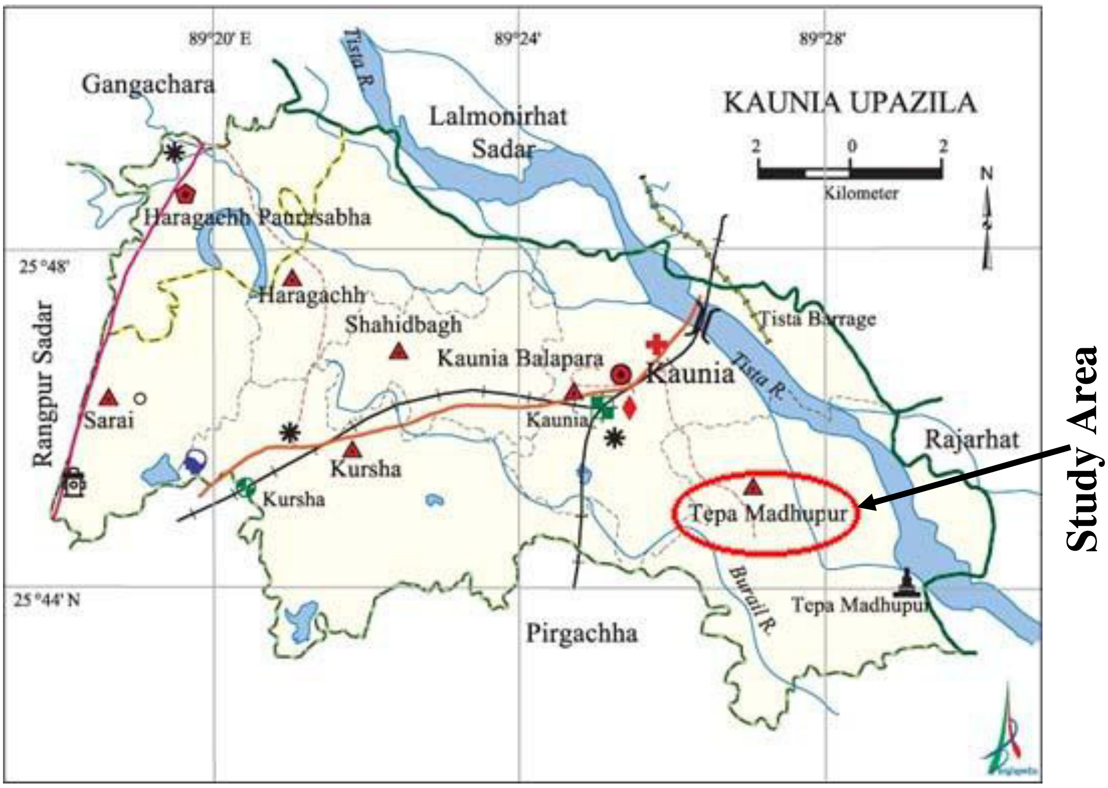

Fig: Map of Kaunia Upazila under Ragpur District

3.1.2 Soil characteristics

The experimental plot was situated in a medium high 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 6to7.5.

3.1.3 Climate and weather

Rangpur's climate is classified as warm and temperate. The summers are much rainier than the winters in Rangpur. According to Köppen and Geiger, this climate is classified as Cwa. The average temperature in Rangpur is 24.9 °C. The average annual rainfall is 2192 mm.

3.1.4 Experimental period

Duration of the experiential period was from November 2018 to March 2019.

3.1.5 Seed collection: Bulbs were collected from Bangladesh Agricultural Development Corporation (BADC) Kaunia, Rangpur.

3.1.6 Planting of cloves

Garlic has a shallow rooting depth, averaging 18 to 24 in. It is moderately tolerant of acid soils and grows best in soils with pH of 5.5 to 6.8. Light soils are best for garlic production; soils which are too heavy can cause bulb deformation.

3.1.7 Experimental design

The experiment was laid out following a two factorial Randomized Complete Block Design (RCBD) with three replications. Total number of experimental plot was 15. The size of each unit plot was 1m×1m = $1m^2$.

3.1.8 Experimental treatments

The experiment consisted of garlic production four distance from tree root zone

T_1= Garlic cultivation from 50 cm distance

T_2= Garlic cultivation from 80 cm distance

T_3= Garlic cultivation from 110 cm distance

T_4= Garlic cultivation from 140 cm distance

T_5= Control (open condition)

3.1.9 Structural Description of Guava

Local name : Guava

Scientific name : *(Psidium guajava L)*

Family : Myrtaceae

Variety : Thai peyara

Planting time **:** 15 October 2018

Planting distance **:** 4 m×4m

Common Name: Guava (*Psidium guajava* L.) is a member of the Myrtaceae family. The genus Psidium includes about 150 species, but *Psidium guajava* is the most important fruit of this genus (Pommer and Murakami, 2009). Guava is believed to have originated from an area extending from southern Mexico into or through Central America (Morton, 1987). The Spaniards and Portuguese are considered to be responsible for distribution of guava fruit to other parts of the world. The wide adaptability of the guava tree to various soils and climates may have facilitated its naturalization in tropical and sub-tropical regions worldwide. Botanically, guava fruit is a berry. Fruit are medium to large in size with an average weight of 100–250 g and 5–10 cm in diameter, and have four or five protruding floral remnants (sepals) at the apex (Fig. 10.1). Based on the cultivar, fruit can be spherical, ovoid or pyriform in shape. Fruit surface is rough to smooth, free of pubescence. Skin colour of immature and unripe fruit is mostly dark green which changes to yellowish-green, pale yellow and yellow with red blush on shoulders at ripe stage depending upon the cultivar. Pulp of ripe fruit is soft and juicy and is white, pink or salmon-red (see Plates XVIII and XIX in the colour section between pages 274 and 275). The seed cavity at the centre of fruit may be small to large with many hard to semi-hard seeds. The outer mesocarp of guava fruit is sandy or gritty in texture due to presence of stone cells (78%), which have strongly lignified cell walls, whereas endocarp tissue is rich in parenchyma cells and low in stone cells. Thick pulp, few seeds and stone cells, high sugar concentrations and typical aroma are the desirable fruit characteristics for table purposes.

Distribution

Guava is the most important fruit plant in the large family, Myrtaceae, which also includes strawberry guava, Psidium cattleianum sabine; the rose apple, Engenia jambos; Surinam cherry, Engenia uniflora; the mountain apple, Engenia malaccensis; the Java plum, Engenia cumini Merr.; and the spices cinnamon, clove, allspice, and nutmeg. Guava is classified under the genus Psidium which contains 150 species, but only *Psidium guajava* has been exploited commercially. Guava is a shrub but under high moisture conditions can grow up to 6–9 m in height and spread, with trunk diameters of 30 cm or more. The trunk is short, freely branching from the base. Branches are pliable and hence are rarely broken by winds. Leaves are usually opposite and simple, arranged in pairs; oblong or oval in shape measuring about 10–18 cm in length; smooth on the upper surface but finely pubescent on the undersurface and prominently veined. Flowers occur singly or in clusters of two to three at the leaf axils of current and preceding growth. The flowers are bisexual or called perfect flowers. They are white in color, 2.5–3.5 cm in diameter, with four or five petals, numerous stamens, and one style. Flowers open between 5 and 7 a.m., depending upon the cultivar and morning temperatures. The tubular calyx encases the bud and splits into four or five segments at anthesis. The ovary is inferior with four or five carpels, each containing numerous ovules in axile placentation. The flowers can be self-pollinated, but cross-pollination takes place most frequently, aided by bees and pollen-carrying insects. After fertilization, the flowers will develop into mature fruits.

Botanically, the fruit is a berry or capsule. It is a many-seeded berry, varying in size from 2.5 to 10 cm in diameter and from 50 to 500 g in weight. The shape of the fruit can be globose, ovoid, elongated, or pear-shaped. The color of the skin of some varieties may turn yellow when ripe; the flesh color may be pink, salmon, white, or yellow. Skin texture may be smooth or rough. The inner walls of the carpels are fleshy and of varying thickness and seeds are embedded in the pulp. The fruits may have thick flesh with only a few seeds in a small center cavity, or thin flesh with numerous seeds embedded in a large mass of pulp. The seeds are small, bony, kidney-shaped, flattened, light yellow or yellowish brown, measuring about 3–5 mm long by 2–3 mm wide. It occupies about 1.6–4.4% of the weight of fruit. Fruit growth follows a simple sigmoid curve and pulp growth parallels total fruit growth. The days from anthesis to harvest can vary from about 120 to over 220 days, depending upon temperature during fruit development. The variation between different cultivars can be up to 60 days.

Main uses: Fruits, Leaves

3.1.10 Land preparation

The land of experimental plot was opened in the first week of November 2018 with a power tiller and it was made ready for planting on 25 November 2018. The corner of the land was spaded and visible larger clods were hammered to break into small pieces. All weeds and stubbles were removed from the field. The layout was done as per experimental design. All basal dosages of fertilizers as per schedule of the experiment were incorporated in the soil and finally the plots were made ready for planting.

3.1.11 Application of fertilizers and Manures

Soil was fertilized with N-P-K-S-Zn-B-Cowdung at the rate of 115-54-165-20-4-1.7-5000 Kg ha-1 respectively. The entire amount of P-K-S-Zn-B-Cowdung and ½ of Nwere applied at final land preparation. Remaining N was applied in equal two splits at 25 and 50 DAS astop dressing. The crop was fertilized as per recommendation of Spices Research Centre (N-P-K-S-Cowdung at the rate of 100-53-167-20-5000 Kgha-1 respectively), BARI. The entire amount of P-K-S- Cowdung and ½ of N were applied at final land preparation.

3.1.12 Intercultural operation

Plant protection measures and other intercultural operations were done as and when necessary Irrigation: Irrigation was provided twice 25 and 50 DAS. Low, perennial, bulb, with hold all water during summer.

Garlic Pests: None of major concern

Garlic Disease: None of major concern

3.1.13 Harvesting

Garlic bulbs mature in an average of 6 to 10 months. Many people wait too long to harvest garlic bulbs. Once the lower 1/3-1/2 of the leaves have turned brown, and there are still mostly green leaves near the top of the plant, it is ready to harvest. Watch your plants carefully to ensure you pick them in their prime. Generally speaking, they should be dug up. Pulling on the stalks will just break the top off and leave the bulb submerged under the soil. Use a pitchfork to loosen the soil around the plant, which allows the entire plant to be lifted out of the ground freely.

3.1.14 Bio-economics of the garlic based Agroforestry system

In order to work out the economic profitability of the Agroforestry systems, the economic yield of the potato and trees was subjected to economic analysis by calculating the cost of cultivation, gross and net returns per hectare and benefit-cost rato. All these parameters were calculated on the basis of market prices prevailing at the time of the termination of experiments.

3.1.15 Total cost of production

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

3.1.16 Gross return

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

3.1.17 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 return (Tk. ha-1) – Total cost of production (Tk. ha-1)

3.1.18 Benefit-cost ratio (BCR)

Benefit-cost ratio is the ratio of gross return with total cost of production. It was calculating by using the following formula (Islam *et al.,* 2004) Benefit-cost ratio = Gross return (Tk.ha-1) / Total cost of production (Tk.ha-1)

3.1.19 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 Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

3.2 Description of the Experiment no.2

3.2.1 Location

The experimental site was selected in the existing guava orchard of Kaunia upazilla under Rangpur district. The district lies between 25º18″ and 25º57″ north latitudes and between 88º56″ and 89º32″ east longitudes and about 34 m above the sea level.

3.2.2 Soil characteristics

The experimental plot was situated in a medium high 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 6 to 7.5.

3.2.3 Climate and weather

Rangpur's climate is classified as warm and temperate. The summers are much rainier than the winters in Rangpur. According to Köppen and Geiger, this climate is classified as Cwa. The average temperature in Rangpur is 24.9 °C. The average annual rainfall is 2192 mm.

3.2.4 Experimental period

Duration of the experiential period was from November 2018 to March 2019.

3.2.5 Seed collections

Seed potato tubers were collected from Bangladesh Agricultural Development Corporation (BADC) Kaunia, Rangpur.

3.2.6 Experimental design

The experiment was laid out following a two factorial Randomized Complete Block Design (RCBD) with three replications. Total number of experimental plot was 12. The size of each unit plot was 2m x 2m = 4m2.

3.2.7 Experimental treatments

The experiment consisted of three fertilizer and manure application

F0 =No fertilizer
F1 = Cowdung @ 10 t/ha
F2 = Chemical fertilizer as per FRG 2014

3.2.8 Structural Description of Guava

Local Name : Guava

Scientific name : *(Psidium guajava L)*

Family : Myrtaceae

Variety : Thai peyara

Planting time **:** 15 October 2018

Planting distance **:** 4 m×4m

Common Name: Guava *(Psidium guajava L.)* is a member of the Myrtaceae family. The genus Psidium includes about 150 species, but *Psidium guajava* is the most important fruit of this genus (Pommer and Murakami, 2009). Guava is believed to have originated from an area extending from southern Mexico into or through Central America (Morton, 1987). The Spaniards and Portuguese are considered to be responsible for distribution of guava fruit to other parts of the world. The wide adaptability of the guava tree to various soils and climates may have facilitated its naturalization in tropical and sub-tropical regions worldwide. Botanically, guava fruit is a berry. Fruit are medium to large in size with an average weight of 100–250 g and 5–10 cm in diameter, and have four or five protruding floral remnants (sepals) at the apex (Fig. 10.1). Based on the cultivar, fruit can be spherical, ovoid or pyriform in shape. Fruit surface is rough to smooth, free of pubescence. Skin colour of immature and unripe fruit is mostly dark green which changes to yellowish-green, pale yellow and yellow with red blush on shoulders at ripe stage depending upon the cultivar. Pulp of ripe fruit is soft and juicy and is white, pink or salmon-red (see Plates XVIII and XIX in the colour section between pages 274 and 275). The seed cavity at the centre of fruit may be small to large with many hard to semi-hard seeds. The outer mesocarp of guava fruit is sandy or gritty in texture due to presence of stone cells (78%), which have strongly lignified cell walls, whereas endocarp tissue is rich in parenchyma cells and low in stone cells. Thick pulp, few seeds and stone cells, high sugar concentrations and typical aroma are the desirable fruit characteristics for table purposes.

Distribution: Guava is the most important fruit plant in the large family, Myrtaceae, which also includes strawberry guava, Psidium cattleianum sabine; the rose apple, Engenia jambos; Surinam cherry, Engenia uniflora; the mountain apple, Engenia malaccensis; the Java plum, Engenia cumini Merr.; and the spices cinnamon, clove, allspice, and nutmeg. Guava is classified under the genus Psidium which contains 150species, but only *Psidium guajava* has been exploited commercially. Guava is a shrub but under high moisture conditions can grow up to 6–9 m in height and spread, with trunk diameters of 30 cm or more. The trunk is short, freely branching from the base. Branches are pliable and hence are rarely broken by winds. Leaves are usually opposite and simple, arranged in pairs; oblong or oval in shape measuring about 10–18 cm in length; smooth on the upper surface but finely pubescent on the undersurface and prominently veined. Flowers occur singly or in clusters of two to three at the leaf axils of current and preceding growth. The flowers are bisexual or called perfect flowers. They are white in color, 2.5–3.5 cm in diameter, with four or five petals, numerous stamens, and one style. Flowers open between 5 and 7 a.m., depending upon the cultivar and morning temperatures. The tubular calyx encases the bud and splits into four or five segments at anthesis. The ovary is inferior with four or five carpels, each containing numerous ovules in axile placentation. The flowers can be self-pollinated, but cross-pollination takes place most frequently, aided by bees and pollen-carrying insects. After fertilization, the flowers will develop into mature fruits.

Botanically, the fruit is a berry or capsule. It is a many-seeded berry, varying in size from 2.5 to 10 cm in diameter and from 50 to 500 g in weight. The shape of the fruit can be globose, ovoid, elongated, or pear-shaped. The color of the skin of some varieties may turn yellow when ripe; the flesh color may be pink, salmon, white, or yellow. Skin texture may be smooth or rough. The inner walls of the carpels are fleshy and of varying thickness and seeds are embedded in the pulp. The fruits may have thick flesh with only a few seeds in a small center cavity, or thin flesh with numerous seeds embedded in a large mass of pulp. The seeds are small, bony, kidney-shaped, flattened, light yellow or yellowish brown, measuring about 3–5 mm long by 2–3 mm wide. It occupies about 1.6–4.4% of the weight of fruit. Fruit growth follows a simple sigmoid curve and pulp growth parallels total fruit growth. The days from anthesis to harvest can vary from about 120 to over 220 days, depending upon temperature during fruit development. The variation between different cultivars can be up to 60 days.

Main uses: Fruits, Leaves

3.2.9 Land preparation

The land of experimental plot was opened in the 24th November 2018 with a power tiller and it was made ready for planting on 14 November 2018. The corner of the land was spaded and visible larger clods were hammered to break into small pieces. All weeds and stubbles were removed from the field. The layout was done as per experimental design. All basal dosages of fertilizers as per schedule of the experiment were incorporated in the soil and finally the plots were made ready for planting.

3.2.10 Application of fertilizers and Manures

In case of chemically fertilized plots, only chemical fertilizer was used as per (FRG 2014) 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 DAP during the second earthing-up at the side of the rows and covered with soil.

Fertilizers	Nutrients	Nutrient dose(kg ha^{-1})
Urea	N	135
TSP	P_2O_5	30
MP	K_2O	90
Gypsum	S	10
Zinc Sulfate	Zn	2
Borax		1.5

Source: Fertilizer Recommendation Guide (FRG, 2014).

Again in case of non chemical plots, only cowdung was applied @ 10 t/ha.

3.2.11 Planting of tubers

The well-sprouted seed tubers were planted on the 25th November 2018 at a depth of 10cm in the furrows. The furrows were 60cm apart with the spacing of 25cm in each line.

3.2.12 Intercultural operations

Manual weeding was done as and when necessary to keep the plots completely free from all weeds. After irrigation, the soil was mulched by breaking the crust for aeration and to conserve soil moisture.

Earthing-up: Earthing-up was made twice during the growing period at 25 days and 40 days after planting. The second one was preceded by top dressing of the remaining half of urea.

Irrigation

Three irrigations were provided throughout the growing period. The first one was done at 30 days after planting. Subsequently two irrigations were given at 20 days interval.

Plant protection measures

Furadan 5G @10 kg/ha was applied during the final land preparation to control ant, mite, cutworm and other soil borne insects. As a preventive measure against late blight Melody

Duo 66.8 WP (Iprovelicarb 5.5%, Propineb 61.3%) was sprayed at the rate of 2.5g litre-1 water when the weather was cloudy.

3.2.13 Harvesting

Haulm killing was done before seven days of harvest. The crop was harvested on 25 February 2019 at 100 days after planting when 90% plants showed leaf senescence. At first ten sample plants were harvested from each plot and later on the rest plants were harvested.

3.2.14 Sampling and data collection

The experimental plots were observed frequently to record various changes in plant characteristics at different stages of their growth. Ten plants were selected at random from each unit plot to collect experimental data. The plants in the outer rows and at the extreme end of the two middle rows were excluded to avoid the border effects. The observations were made on the following parameters during plant growth phase and harvest, which were noted for different treatments of the experiment.

Plant height

The heights were measured from the ground level to the tip of the longest shoot at an interval of 15 days starting from 30, 45,and 60 DAP.

Leaf length

The length of the leaf was obtained with the help of centimeter scale at 30, 45, and 60 DAP.

Leaf breadth

The breadth of the leaf was obtained with the help of centimeter scale at 30, 45, and 60 DAP.

Number of leaves per plant

It was recorded with at an interval of 15 days starting from 30, 45, and 60 DAP.

Number of shoots per hill-1

It was recorded at 30DAP.

Number of tubers hill-1

It was recorded at the time of final harvest. It was recorded as the average of the 10 plants selected at random at harvest from each unit plot.

Weight of tubers hill-1

It was recorded at the time of final harvest.

Yield of tubers

This trait was recorded from the harvested tubers of all plants of each plot including the sample plants. The yield of tuber plot -1 was converted to the yield per hectare.

3.2.15 Bio-economics of the potato based Agroforestry system

In order to work out the economic profitability of the Agroforestry systems, the economic yield of the potato 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 market prices prevailing at the time of the termination of experiments.

3.2.16 Total cost of production

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

3.2.17 Gross return

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

3.2.18 Net return

Net return usually means the profit of the enterprises. Net retun was calculated by deducting the total cost of production from the gross return (Kundu, 1992).

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

3.2.19 Benefit-cost ratio (BCR)

Benefit-cost ratio is the ratio of gross return with total cost of production. It was calculating by using the following formula (Islam *et al.,* 2004) Benefit-cost ratio = Gross return (Tk.ha-1) / Total cost of production (Tk.ha-1)

3.2.20 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 Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

The results of the performance of garlic and potato under guava based Agroforestry system are presented in Table 1 to 3 and Figure no. 1 to 8.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 Effect of distances from tree base on growth, yield contributing characters and yield of garlic

4.1.1 Plant height

Plant height (cm) of garlic was recorded from the ground surface to the tip of the leaf in all the treatments. At different Days After Planting (DAP), plant height was found varied with different treatments (Table 1). At 30 DAP, the tallest plant (33.00 cm) was recorded from 170 cm distance from tree base (T_5), which was followed by T_4, T_3 and T_2, respectively whereas the shortest plant (29.27cm) was recorded from 50 cm distance from tree base (T_1). At 45 DAP, the tallest plant (47.23cm) was recorded from 170 cm distance from tree base (T_5),which was followed by T_4, T_3 and T_2, respectively whereas the shortest plant (44.4cm) was recorded from 50 cm distance from tree base (T_1).At 60 DAP, the tallest plant (64.4cm) was recorded from 170 cm distance from tree base (T_5),which was followed by T_4, T_3 and T_2, respectively whereas the shortest plant (59.4cm) was recorded from 50 cm distance from tree base (T_1). The result was partially similar with the finding of Garrity *et al.* (1992).

4.1.2 Number of leaves/plant

Number of leaves /plant was varied at different DAP among the treatments (Table 1). At 30 DAP, the maximum number of leaves/plant (7.03) was recorded from 170 cm distance from tree base (T_5) which was followed by T_4, T_3 and T_2, respectively whereas the minimum number of leaves/plant (5.83) was recorded from 50 cm distance from tree base (T_1). At 45 DAP, the maximum number of leaves/plant (7.98) was recorded from 170 cm distance from tree base (T_5) which was followed by T_4, T_3 and T_2, respectively whereas the minimum number of leaves/plant (6.10) was recorded from 50 cm distance from tree base (T_1). At 60

DAP, the maximum number of leaves/plant (8.43) was recorded from 170 cm distance from tree base (T_5) which was followed by T_4, T_3 and T_2, respectively whereas the minimum number of leaves/plant (6.36) was recorded from 50 cm distance from tree base (T_1). This finding was in agreement with the findings of Benoit *et al.,* 1986 who stated that, cooler temperatures promote lower number of total leaf and number of branches.

Table 4.1: Effect of distances from tree base on the growth of garlic under guava+garlic based agroforestry system in char land area

Treatments	Plant height (cm)			No. of leaves per plant		
	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP
50 cm distance (T_1)	29.27	44.40	59.4	5.83	6.10 b	6.36 b
80 cm distance (T_2)	30.00	45.36	61.7	6.20	6.8 ab	7.16 ab
110 cm distance (T_3)	30.13	44.73	62.8	6.56	7.32 ab	7.46 ab
140 cm distance (T_4)	32.2	45.86	63.4	6.40	7.53 a	7.76 ab
Control (open)	33.00	47.23	64.6	7.03	7.98 b	8.43 a
LSD $_{(0.05)}$	8.50	8.61	10.50	1.65	1.25	1.79
CV (%)	9.77	6.72	5.98	9.11	6.23	8.54

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

4.1.3 Leaf Length

Leaf length of garlic was significantly varied due to different distance from tree base (Table 2). At 30 DAP, the longest leaf lenght (49.96cm) was recorded from 170 cm distance of tree base (T_5) which was significantly followed by T_4, T_3 and T2,respectively,whereas the shortest leaf length (27.33cm) was recorded from 50 cm distance of tree base (T_1).Again at 45 DAP,, the longest leaf lenght (51.76cm) was recorded from 170 cm distance of tree base (T_5) which was significantly followed by T_4, T_3 and T2 ,respectively, whereas the shortest leaf length (32.43cm) was recorded from 50 cm distance of tree base (T_1). Lastly, At 60DAP, the longest leaf lenght (57.83cm) was recorded from 170 cm distance of tree base (T_5) which was significantly followed by T_4, T_3 and T_2, respectively, whereas the shortest leaf length (33.10cm) was recorded from 50 cm distance of tree base (T_1). This might be attributed due to the situation of cellular expansion and cell division of leaves under shaded condition. However, the tread of plant height and leaf length are similar.

4.1.4 Leaf breadth

Leaf breadth of garlic was influenced by the increase of gloominess which shown in (Table 2). At 30 DAP, the widest leaf breadth (3.03cm) was observed from 170 cm distance of tree base (T_5) which was followed by T_4, T_3 and T_4, respectively. On the other hand the shortenth leaf breadth (1.87 cm) was observed from 50 cm distance of tree base (T_1). Again At 45 DAP, the widest leaf breadth (3.06cm) was observed from 170 cm distance of tree base (T_5) which was followed by T_4, T_3 and T_4, respectively. On the other hand the shortenth leaf breadth (1.96 cm) was observed from 50 cm distance of tree base (T_1). At 60 DAP, the widest leaf breadth (3.46cm) was observed from 170 cm distance of tree base (T_5) which was followed by T_4, T_3 and T_4, respectively. On the other hand, the shortenth leaf breadth (2.13 cm) was observed from 50 cm distance of tree base (T_1).

Table 4.2: Effect of distances from tree base on the growth of garlic under guava+garlic based agroforestry system in char land area

Treatments	Leaf Length			Leaf Breadth		
	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP
50 cm distance (T_1)	27.33 d	32.43 d	33.1 d	1.87 c	1.96 c	2.13 c
80 cm distance (T_2)	31.13 cd	37.03 cd	42.36 cd	2.13 c	2.26 bc	2.76 b
110 cm distance(T_3)	38.3 bc	40.23 bc	46.63 bc	2.56 b	2.63 ab	2.93 ab
140 cm distance (T_4)	42.53 ab	44.53 b	52.43 ab	2.9 ab	2.96 a	3.2 ab
Control (open)	49.96 a	51.76 a	57.83 a	3.03 a	3.06 a	3.46 a
LSD $_{(0.05)}$	8.18	6.92	9.45	0.40	0.45	0.59
CV (%)	7.68	5.97	7.22	5.70	6.21	7.34

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

4.1.5 Size of garlic

The size of garlic was significantly influenced due to different distance from tree base (Table 3). The highest size of garlic (3.60 cm) was found from 170 cm distance from tree base (T_5) which was followed by T_4, T_3 and T_2, respectively. On the other hand the lowest size of garlic (2.83 cm) was found from 50 cm distance of tree base (T_1).

4.1.6 Weight of garlic

The weight of garlic was also significantly influenced due to different distance from tree base (Table 3). The maximum weight of garlic (39.26 gm) was found from 170 cm distance of tree base (T_5) which was followed by T_4, T_3 and T_2, respectively. On the other hand the minimum weight of garlic (9.43 gm) was found from 50 cm distance of tree base (T_1).

4.1.7 No. of cloves/garlic

Number of cloves/garlic was significantly influenced by the different size of garlic (Table 3). The maximum number of cloves/garlic (20.10) was found from 170 cm distance of tree base (T_5) which was followed by T_4, T_3 and T_2, respectively. On the other hand the minimum number of cloves/garlic (14.67) was found from 50 cm distance of tree base (T_1).

Table 4.3: Effect of distances from tree base on the yield contributing characters of garlic under guava+garlic based agroforestry system in char land area

Treatments	Size of garlic	Weight of garlic/plant	No. of cloves/garlic
50 cm distance (T_1)	2.83 a	9.43 c	14.67 b
80 cm distance (T_2)	3.16 a	10.87 c	16.63 ab
110 cm distance (T_3)	3.29 a	12.50 bc	16.96 ab
140 cm distance (T_4)	3.41 a	15.96 ab	18.97 a
Control (open)	3.60 a	18.16 a	20.1 a
LSD $_{(0.05)}$	0.57	4.02	4.05
CV (%)	6.24	10.68	8.25

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

4.1.8 Yield (ton/ha)

The yield of garlic (ton/ha) was significantly influenced by the different distance from tree base (Fig 1). The highest yield (7.40t/ha) was recorded from 170 cm distance of tree base (T_5) which was followed by T_4, T_3 and T_2, respectively. On the other hand the lowest yield (5.46t/ha) was found from 50 cm distance of tree base (T_1).

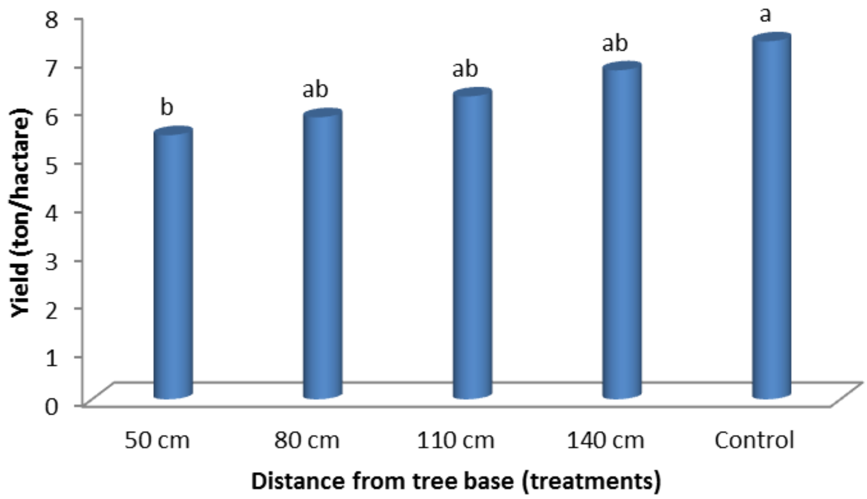

Fig 4.1: Effect of tree base distance on garlic yield

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

4.1.9 Economic analysis of Garlic

Profitability of growing garlic as inter-crop in Guava based Agroforestry system was calculated based on local market rate prevailed during experimentation. The cost of production of garlic and cost of production of tree plantation and management of trees have been summarized in appendix IV. The return of produce and the profit per taka i.e. Benefit Cost Ratio (BCR) have also been presented in Table 4.

4.1.10 Total cost of production

The values in Table 4. indicate that the total cost of production was maximum (175081 Tk. /ha) whereas the minimum cost of production (162913 Tk./ha) was recorded.

4.1.11 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. It is vary with the production system of garlic. The values in Table 4 indicate that the highest value of gross return (629845 Tk. /ha) was obtained from (T_4) On the other hand, the lowest value of gross return (452000 Tk. /ha) was obtained from (T_5).

4.1.12 Net return

Results presented in the Table 4 show that net return (454764 Tk./ha) was comparatively higher in (T_4). At the same time, the lowest net return (289087 Tk. /ha) was received from (T_5).

4.1.13 Benefit-cost ratio (BCR)

The values in Table 4 indicate that the highest benefit-cost ratio (3.53) was recorded from (T_4). On the other hand the lowest benefit-cost ratio (2.77) was observed in (T_5). Thus, it may be advocated that such type of speculation will be beneficial to the farmer as because such project provides cash money to the farmer and gradually can enrich the soil nutritionally.

Table 4.4: Economic analysis of Garlic production under Guava based Agroforestry system (ha^{-1} $year^{-1}$)

Production system	Outcome (Tk./ha)		Total cost of Production (Tk./ha)	Gross Return (Tk./ha)	Net Return (Tk./ha))	BCR
	Guava	Garlic				
50 cm distance (T_1)	125000	386400	175081	511400	336313	2.92
80 cm distance (T_2)	125000	405820	175081	530820	356339	3.03
110 cm distance (T_3)	125000	446410	175081	571410	396329	3.26
140 cm distance (T_4)	125000	504845	175081	629845	454764	3.59
Control (open)		452000	162913	452000	289087	2.77

Note: Garlic 80 Tk/kg, Guava 500Tk/Tree/Year, 25 Guava/tree, 20 tk/guava, Numbers of Guava tree 250/ha.

4.2 Effect of Fertilizer on growth, yield contributing characters and yield of potato

4.2.1 Plant height (cm)

Plant height of potato was recorded from the ground surface to the tip of the leaf in all the treatments. At different Days after Planting (DAP), plant height was found significantly varied with different treatments (Fig 2). At 30 DAP, the tallest plant (35.17cm) was found where chemical fertilizer applied (F_2) and followed by cowdung (F_1).On the other hand, the shortest plant (27.37 cm) was found where no fertilizer applied (F_0). Again At 45 DAP, the tallest plant (53.65) was found where chemical fertilizer applied (F_2) and followed by cowdung (F_1).On the other hand the shortest plant (33.10 cm) was found where no fertilizer applied (F_0). At 60 DAP, the tallest plant (58.12 cm) was found where chemical fertilizer applied (F_2) and followed by cowdung (F_1). In that time, the shortest plant (38.70 cm)was found where no fertilizer applied (F_0).The result was partially similar with the finding of Garrity *et al.* (1992).

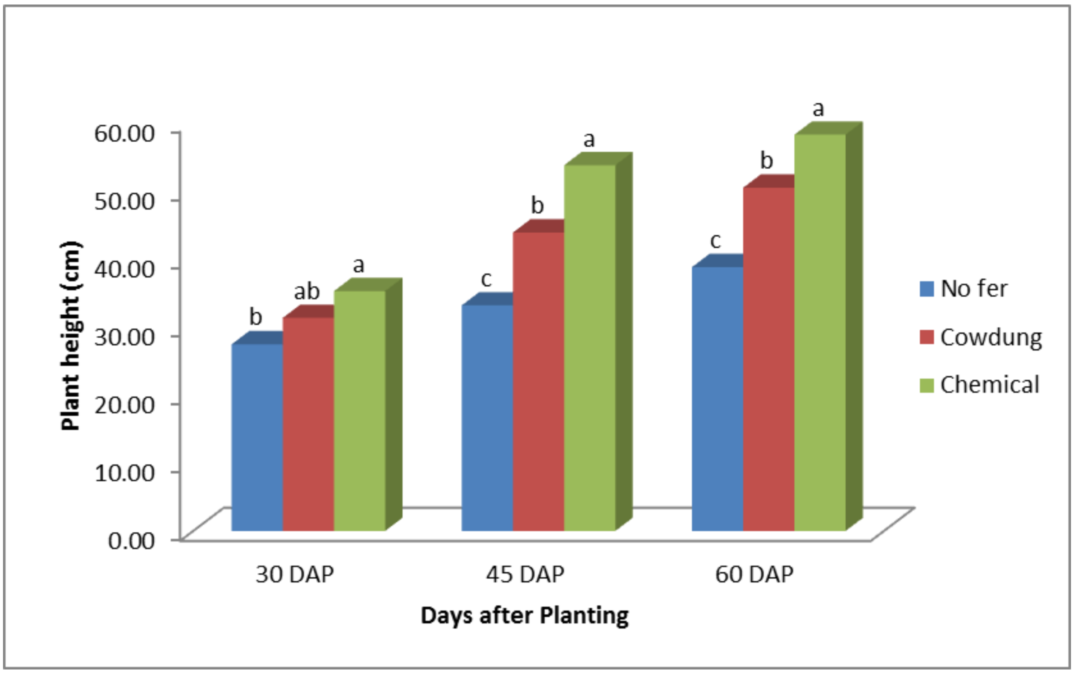

Fig 4.2: Effect of fertilizer application on plant height of potato

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

4.2.2 Number of leaves/plant

Number of leaves/plant of potato was significantly influenced by the fertilizer application which shown in (Fig 3). At 30 DAP, the maximum number of leaves/plant (12.65) was found where chemical fertilizer applied (F_2) and followed by cowdung (F_1). On the other hand, minimum number of leaves/plant (4.32) was found where no fertilizer applied (F_0). Again At 45 DAP, the maximum number of leaves/plant (17.55) was found where chemical fertilizer applied (F_2) and followed by cowdung (F1).On the other hand,minimum number of leaves/plant (11.42) was found where no fertilizer applied (F_0) At 60 DAP, the maximum number of leaves/plant (16.85)was found where chemical fertilizer applied (F_2) and followed by cowdung (F_1). However,minimum number of leaves/plant (13.80) was found where no fertilizer applied (F_0). Many researchers (Kirk and Marshall, 1992; van Delden *et al.,* 2001; Vos, 1995, Ng and Loomis, 1984;Steward *et al.,* 1981) reported that temperature profoundly influences the growth and development of the potato canopy, leaf appearance, expansion, and senescence, leaf orientation and physiological. The leaf-level photosynthetic rate also varies with temperature; air temperatures at 23°C and above increase the number of axillary branches and the leaf appearance and senescence rates (Manrique *et al.,* 1989; Marinus and Bodlaender, 1975). This finding was in agreement with the findings of Benoit *et al.,*(1986)who stated that, cooler temperatures promote lower number of total leaf and numbers of branches.

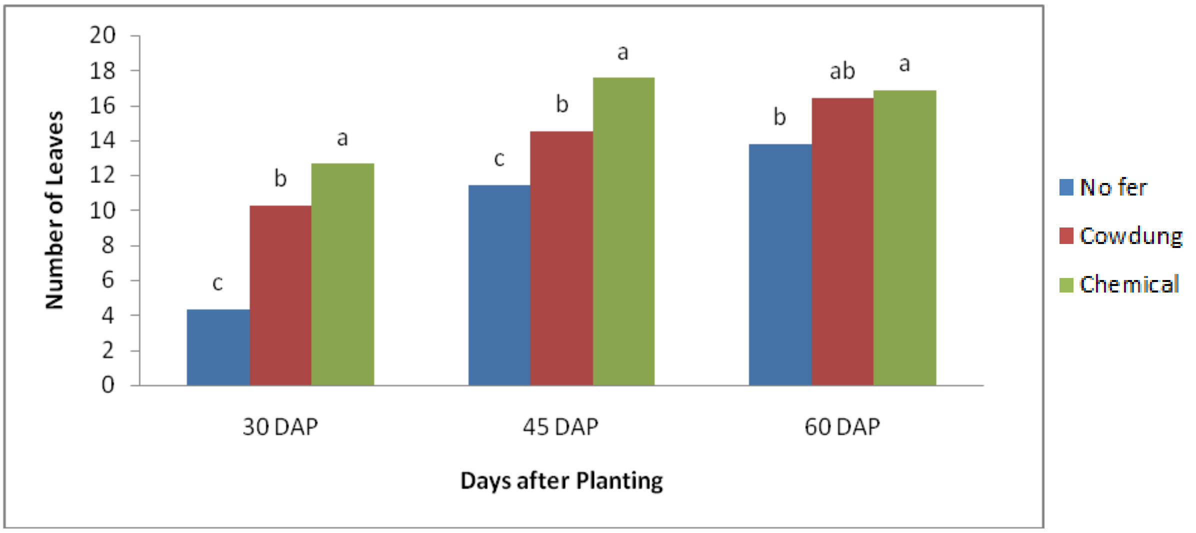

Fig 4.3: Effect of fertilizer application of number of leaves

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

4.2.3 Number of shoot /plant

Number of shoots/plant of potato were significantly influenced by the fertilizer application which shown in (Fig 4). At 30 DAP, the maximum number of shoot/plant (3.17) was found where chemical fertilizer applied (F_2) and followed by cowdung (F_1).On the other hand,minimum number of shoot/plant (2.37) was found where no fertilizer applied (F_0). AgainAt 45 DAP, the maximum number of shoot/plant (3.22) was found where chemical fertilizer applied (F_2) and followed by cowdung (F_1). However,minimum number of shoot/plant (2.62) was found where no fertilizer applied (F_0). At 60 DAP, the maximum number of shoot/plant (5.87) was found where chemical fertilizer applied (F_2) and followed by cowdung (F_1). At that time,minimum number of shoot/plant (3.02) was found where no fertilizer applied (F_0).

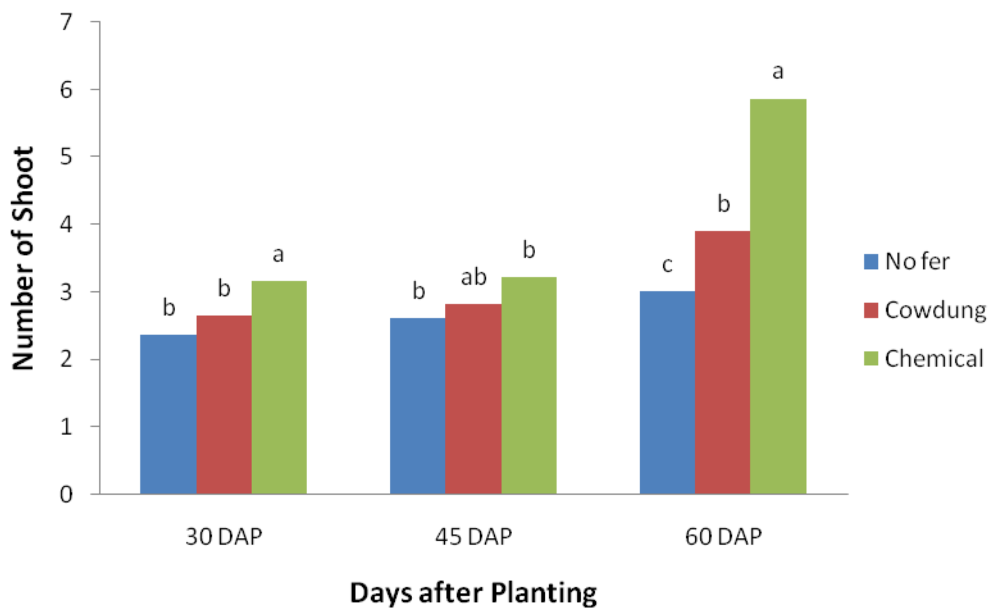

Fig 4.4: Effect of fertilizer application on number of shoot

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

4.2.4 Fresh weight of haulm/hill

Fresh weight of haulm/hillwas also significantly influenced by the fertilizer application (Fig 5). The maximum weight of haulm/hill (17.67 gm) was recorded where chemical fertilizer applied (F_2)and followed by cowdung (F_1).However, the minimum weight of haulm/hill (14.02 gm) was recorded where no fertilizer was applied(F_0).

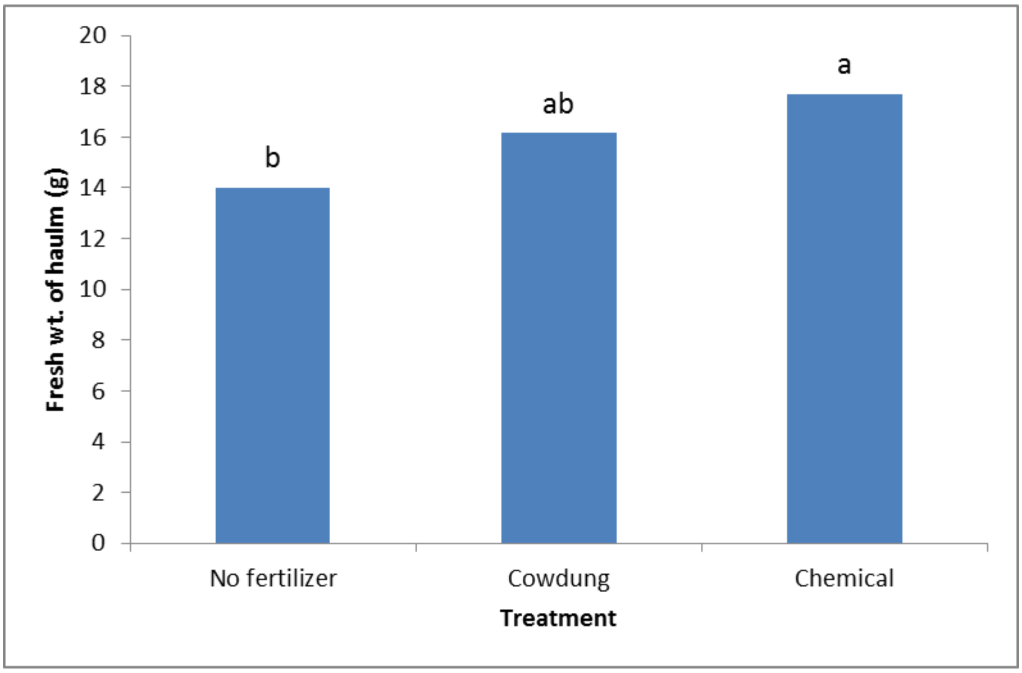

Fig 4.5: Effect of fertilizer application of Fresh wt. of haulm

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

4.2.5 Number of tuber/hill

The number of tuber/hillwas significantly influenced due to different fertilizer application which shown in (Fig 6). The maximum number of tuber/hill (10.75) was recorded where chemical fertilizer applied (F_2) and followed by cowdung (F_1). However, the minimum number of tuber/hill (5.00) was recorded where no fertilizer applied (F_0). The main growth and yield attributing character responsible for lower yield under poplar were number of tuber and weight of tuber.

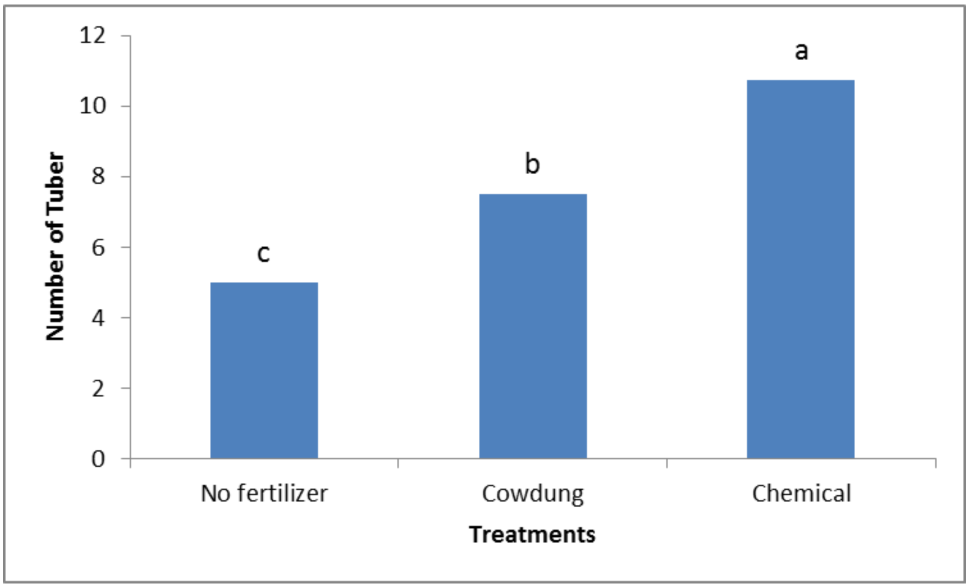

Fig 4.6: Effect of fertilizer application on number of Tuber

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

4.2.6 Weight of tuber/hill

Weight of tuber/hill was also influenced by different fertilizer applicationwhich shown in (Fig 7). The maximum weight of tuber/hill (249.45 g) was recorded where chemical fertilizer applied (F_2) and followed by cowdung (F_1). Significantly, minimum weight of tuber/hill (107.18 g) was recorded where no fertilizer applied (F_0).

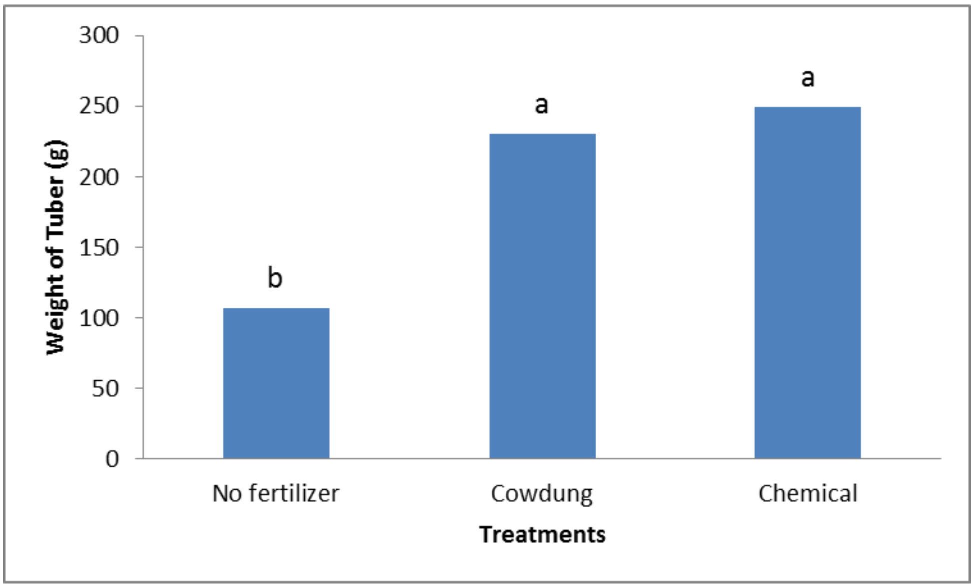

Fig 4.7: Effect of fertilizer application on weight of Tuber

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

4.2.7 Yield (ton/ha)

The yield of potato (ton/ha) was significantly affected by the different fertilizer application which shown in (Fig 8). Significantly the highest tuber yield (10.31t/ha) was recorded where chemical fertilizer applied (F_2) and followed by cowdung (F_1).The lowest tuber yield (7.17 t/ha) was recorded where no fertilizer was applied (F_0).

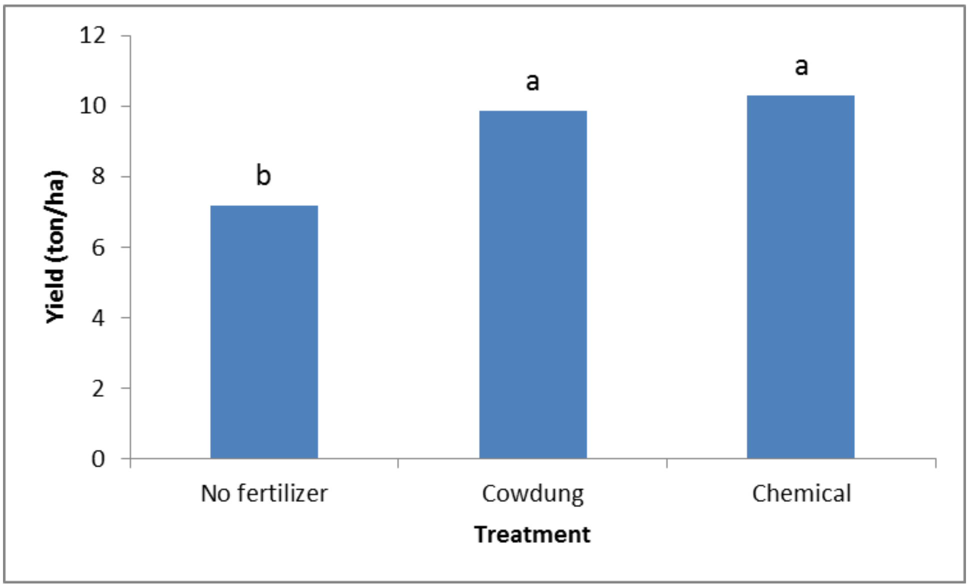

Fig 4.8: Yield of potato (ton/ha)

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

4.2.8 Economic analysis of potato

Profitability of growing potato as inter-crop in Guava based Agroforestry system was calculated based on local market rate prevailed during experimentation. The cost of production of potato and cost of production of Guava tree plantation and management of trees have been summarized in appendix V. The return of produce and the profit per taka i.e. Benefit Cost Ratio (BCR) have also been presented in Table 5.

4.2.9 Total cost of production

The values in Table 5 indicate that the total cost of production was maximum (139079 Tk. /ha) Guava+ potato based Agroforestry system where chemical fertilizer was applied and the second maximum (131851Tk/ha) where cowdung was applied. However the minimum cost of production (128461Tk./ha) where no fertilizer was applied.

4.2.10 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. It is varying with the fertilizer application and production system of potato. The values in Table 5 indicate that the highest value of gross return (279650Tk. /ha) was obtained where chemical fertilizer was applied and the second maximum (273200Tk/ha) where cowdung was applied. However the minimum gross return (232550Tk./ha) where no fertilizer was applied.

4.2.11 Net return

Results presented in the Table 5 show that net return (141349 Tk./ha) was comparatively higher in producing potato under Guava + potato based Agroforestry system where cowdung was applied and the second highest (140571 Tk/ha) where chemical fertilizer was applied. At the same time, the lowest net return (104089Tk. /ha) was received where no fertilizer was applied. Higher net return was the result of higher gross return from the Guava + potato based Agroforestry system.

4.2.12 Benefit-cost ratio (BCR)

The values in Table 5 indicate that the highest benefit-cost ratio (2.07) was recorded from Guava + potato based Agroforestry system where cowdung was applied and the second highest was (2.01) when chemical fertilizer was applied. On the other hand the lowest benefit-cost ratio (1.81) was observed where no fertilizer was applied. So, potato can profitably be cultivated in Guava based Agroforestry systems. Thus, it may be advocated that such type of speculation will be beneficial to the farmer as because such project provides cash money to the farmer and gradually can enrich the soil nutritionally.

Table 4.5: Economic analysis of potato production under Guava based Agroforestry system ($ha^{-1}year^{-1}$)

Production system	Outcome (Tk./ha)		Total cost of Production (Tk./ha)	Gross Return (Tk./ha)	Net Return (Tk./ha))	BCR
	Guava	potato				
No Fertilizer (F_0)	125000	107550	128461	232550	104089	1.81
Cowdung (F_1)	125000	148200	131851	273200	141349	2.07
Chemical (F_2)	125000	154650	139079	279650	140571	2.01

Note: Potato 15 Tk/kg, Guava 500Tk/Tree/Year, 25 Guava/tree, 20 tk/guava, Numbers of Guava tree 250/ha.

CHAPTER 5

SUMMARY AND CONCLUSIONS

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5.1 Summary

A field experiment was carried out at the Kaunia upazila under Rangpur district during November 2018 to March 2019 to evaluate the performance of garlic and potato under guava based Agroforestry system. The experiment was conducted in newly established guava orchard where the tree saplings were planted at the spacing 4 m×4 m in the year 2018. The experiment included garlic and potato. The experiment was laid out in RCBD with 3 (three) replications in garlic and 4(four) replications in potato. The five treatment combinations of the experiments were T_1= Garlic cultivation for 50 cm distance, T_2= Garlic cultivation for 80 cm distance, T_3= Garlic cultivation for 110 cm distance, T_4=Garlic cultivation for 140 cm distance and T_5= control (open condition) for garlic and three combinations of potato were F_0 = no fertilizer, F_1= cowdung @ 10 t/ha and F_2= chemical fertilizers per FRG 2014. In the treatments, guava trees population were 250 trees ha-1 respectively.

The land of experimental plot was opened in the first week of November 2018 with a power tillar and it was made ready for planting on 25 November 2018. All basal dosages of fertilizers as per schedule of the experiment were incorporated in the soil according to the BARC fertilizer recommendation guide and finally the plots were made ready for planting. Potato tubers were planting on 24th November 2018. Potato tuber was planted as intercrop in the alleys between the two tree rows according to their cultural schedules. The data were recorded on two broad heads, i) growth stage ii) harvesting stage. The data were analyzed statistically and means were adjudged by DMRT (Duncan's Multiple Range Test).

In case of the main effect of variety on the growth, yield contributing characters and yield of garlic and potato the result was found significant in respect of plant height (30 DAP, 45 DAP and 60 DAP) leaf length(30 DAP, 45 DAP and 60 DAP), leaf breadth(30 DAP, 45 DAP and 60 DAP), no. of leaf shoot-1 (30 DAP, 45 DAP and 60 DAP)1, no. of shoot hill-1 ,no. of tuber hill-1 , weight of tuber hill-1 , yield plot-1,size of garlic, weight of garlic, no. of cloves/garlic respectively. The tallest plant height of garlic (33.00,47.23,64.6 cm) at 30 DAP, 45 DAP and 60 DAP was recorded. The shortest plant height of garlic (29.27,44.4,59.4cm) at 30 DAP, 45 DAP and 60 DAP was recorded. The maximum number of leaves/plant of garlic (7.03,7.98 and 8.43)at 30 DAP, 45 DAP and 60 DAP was recorded. The minimum number of leaves/plant of garlic (5.83,6.10 and 6.36)at 30 DAP, 45 DAP and 60 DAP was recorded. Leaf length of garlic was also significantly varied due to different distance. The longest leaves (49.96,51.76 and 57.83 cm)at 30 DAP, 45 DAP and 60 DAP was recorded. The shortest leaves (27.32,32.43 and 33.10 cm)at 30 DAP, 45 DAP and 60 DAP was recorded. Leaf breadth of garlic was also significantly varied due to different distance. The longest leaves breadth (3.03,3.06 and 3.46 cm)at 30 DAP, 45 DAP and 60 DAP was recorded. The shortest leaves breadth (1.87,1.96 and 2.12 cm)at 30 DAP, 45 DAP and 60 DAP was recorded. The largest size of garlic (3.60) and smallest size of garlic (2.83) was also recorded. The maximum weight of garlic (18.16 gm) was recorded. The minimum weight of garlic (9.43 gm) was recorded. The number of cloves/garlic was (14.67, 16.63, 16.96, 18.97 and 20.1) in their different distance from tree base. Where the maximum number of cloves/garlic (20.1) and minimum number of cloves/garlic (14.67) was recorded. Yield also influenced by different distance from tree base where the maximum yield (7.40 t/ha) and minimum yield (5.46 t/ha) was recorded respectfully.

In case of potato, the tallest plant height of potato(35.17,53.65 and 58.12 cm) at 30 DAP, 45 DAP and 60 DAP was recorded where chemical fertilizer was used and the shortest plant height of potato(27.37,33.10 and 38.70 cm) at 30 DAP, 45 DAP and 60 DAP was recorded where no fertilizer was used. The maximum number of leaves/plant (12.65,17.55 and 16.85) at 30 DAP, 45 DAP and 60 DAP was recorded where chemical fertilizer was used and the minimum number of leaves/plant (4.32,11.42 and 13.80) at 30 DAP, 45 DAP and 60 DAP was recorded where no fertilizer was used. The maximum number of shoot /plant (3.17,3.22 and 5.87) at 30 DAP, 45 DAP and 60 DAP was recorded where chemical fertilizer was used and the minimum number of shoot/plant (2.37,2.62 and 3.02) at 30 DAP, 45 DAP and 60 DAP was recorded where no fertilizer was used. The maximum fresh weight of haulm/hill was (17.67gm) where chemical fertilizer was applied and the minimum weight of haulm/hill was (14.02 gm) was also recorded where no fertilizer was applied. The maximum number of tuber/hill was (10.75) where chemical fertilizer was applied and the minimum number of tuber/hill was (5.00) was also recorded where no fertilizer was applied. The maximum weight of tuber/hill was (249.45 gm) where chemical fertilizer was applied and the minimum weight of tuber/hill was (107.18 gm) was also recorded where no fertilizer was applied. The highest tuber yield/ha (10.31 t/ha) where chemical fertilizer was applied and the lowest yield/ha (7.17 t/ha) was also recorded where no fertilizer was applied.

In case of economic analysis of garlic, the total cost of production was maximum (175081Tk. /ha) whereas the minimum cost of production (162913 Tk./ha) was recorded from the open field i.e garlic grown in open field. The highest values of gross return (671400Tk. /ha) was obtained. On the other hand, the lowest value of gross return (592000 Tk. /ha) was obtained from open condition. Net return (496313Tk. /ha) was comparatively higher in producing garlic under guava + garlic based Agroforestry system .At the same time, the lowest net return (429087Tk. /ha) was received from the open field of garlic .The highest benefit-cost ratio (3.83) was recorded from guava + garlic based Agroforestry system and lowest benefit-cost ratio (3.63) was observed in open field of garlic .

Again in case of economic analysis of potato, the total cost of production was maximum (139079Tk. /ha) where chemical fertilizer was used in guava+potato based Agroforestry system whereas the minimum cost of production (128461 Tk./ha) was recorded where no fertilizer was used. The highest values of gross return (279650Tk. /ha) where chemical fertilizer was used in guava+potato based Agroforestry system whereas the minimum values of gross return (232550 Tk./ha) was recorded where no fertilizer was used. Net return (141349Tk. /ha) was comparatively higher where cowdung was used in guava+potato based Agroforestry system. At the same time, the lowest net return (104089Tk. /ha) was recorded where no fertilizer was used. The highest benefit-cost ratio (2.07) was recorded where cowdung was used in guava+potato based Agroforestry system. And lowest benefit-cost ratio (1.81) was observed where no fertilizer was used.

5.2 Conclusion

The findings of the present investigation indicate that diversification of farming system and growing garlic and potato as ground layers crops in newly established guava tree orchard at the char land area is a viable option for increasing income of farmers. Despite some negative effects of upper layer tree like guava on the growth, yield and physiological attributes of potato and garlic guava based Agroforestry system is still beneficial as it ensure higher returns because of diversified products in comparison to sole cropping. Agroforestry system considering the additional return per investment in terms of money and time. From the results and foregoing discussion, it is clear that open field is so good for the production of garlic and potato but in avocation of MPTs like guava tree at the Tista char land area it could be grown well. Again, considering the distance from guava tree base, closest distance gave less production. So, farmer can keep at least 1 m tree root zone distance from guava tree root zone for garlic cultivation. In case of potato cultivation at the floor of guava orchard using only cowdung is also a good farming practice.

5.3 Recommendations

- Garlic and potato under newly established thai guava based agroforestry system is economically viable at the char land area. To get more production of potato, garlic and guava fruit as well as to bring back equilibrium in the char land ecosystem, garlic and potato under guava based agroforestry systems are foreseeable.
- The developed model should be replicated in the guava and other fruit tree plantation of other char land area of Bangladesh.
- The present study opened the avenues for further investigation using the different suitable fruit tree species for charland agroforestry system.

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APPENDICES

APPENDICES

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

Soil characters	Physical and chemical properties
Texture	
Sand (%)	47
Silt (%	33
Clay(%	20
Textural class	Loam
CEC (meq/ 100g)	6.9
pH	4.80
Organic matter (%)	1.30
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 Resources Development Institute, Rangpur (2018)

Appendix II. Weather data of the experimental site during the period from November 2018 to March 2019

Months	* Air Temperature (^0C)			* Minimum Rainfall (mm)	* Relative Humidity (%)
	Maximum	Minimum	Average		
November 2018	28.40	16.40	22.40	10.00	80.00
December 2018	25.60	12.20	18.90	3.00	81.00
January 2019	24.40	10.30	17.35	9.00	82.50
February 2019	27.00	12.70	19.85	12.00	75.00
March 2019	31.70	15.90	23.80	26.00	68.00

Note * Monthly average

Source: Bangladesh Meterological Station.

Appendix III. Cost of production of Garlic under Guava based Agroforestry system

Treatments	Input cost										Total input cost (tk/ha)	Over head cost			Total cost of production (tk/ha)
	Non material cost (Tk/ha)			Material cost (Tk/ha)								Interest of input cost @ 8% for the crop season (tk/ha)	Interes of the value of land (tk. 300000/ha /ha) @ 8% for the crop season (tk/ha)	Miscellaneous cost @ 5% of the input cost (tk/ha)	
	Guava Tree	Garlic	Total non material cost	Seed	Fertilizer	Pesticide	Irrigation	Maintenance cost of trees	Initial plantation cost of trees	Total material cost (tk/ha)					
T_1	10000	14000	24000	60000	16200	8000	5500	8000	12000	109700	133700	10696	24000	6685	175081
T_2	10000	14000	24000	60000	16200	8000	5500	8000	12000	109700	133700	10696	24000	6685	175081
T_3	10000	14000	24000	60000	16200	8000	5500	8000	12000	109700	133700	10696	24000	6685	175081
T_4	10000	14000	24000	60000	16200	8000	5500	8000	12000	109700	133700	10696	24000	6685	175081
T_5	……	20000	20000	75400	24062	12000	7400	…….	…….	118862	138862	11108	6000	6943	162913

Note: . Cowdung 600Tk./ton; Urea 16 Tk./kg, TSP 26 Tk./kg; MP 16 Tk./kg, Gypsum 9 Tk/kg, $ZnSO_4$ 130 Tk./kg, Labour 400Tk./day, Plantation cost for Guava tree were 30 Tk./tree. Rotation year for Guava tree were 10 years.

Appendix IV. Cost of production of potato under Guava based Agroforestry system.

Treatments	Input cost										Total input cost (tk/ha)	Over head cost			Total cost of production (tk/ha)
	Non material cost (Tk/ha)			Material cost (Tk/ha)								Interest of input cost @ 8% for the crop season (tk/ha)	Interes of the value of land (tk. 300000/ha /ha) @ 8% for the crop season (tk/ha)	Miscellaneous cost @ 5% of the input cost (tk/ha)	
	Guava Tree	potato	Total non material cost	Seed	Fertilizer	Pesticide	Irrigation	Maintenance cost of trees	Initial plantation cost of trees	Total material cost (tk/ha)					
No Fertilizer	10000	24964	34964	32768	……….	5000	2304	5120	12288	57480	92444	7395	24000	4622	128461
Cowdung	10000	24964	34964	32768	3000	5000	2304	5120	12288	60480	95444	7635	24000	4772	131851
Chemical	10000	24964	34964	32768	9396	5000	2304	5120	12288	66876	101840	8147	24000	5092	139079

Note: T_1=potato+no fertilizer, T_2=potato+cowdung,T_3=potato +chemical. Cow dung 600Tk./ton; Urea 16 Tk./kg, TSP 26 Tk./kg; MP 16 Tk./kg, Gypsum 9 Tk/kg, $ZnSO_4$ 130 Tk./kg, Labour 400Tk./day, Plantation cost for Guava tree were 30 Tk./tree. Rotation year for Guava tree were 10 years.

Appendix V. Some plates of the experimental works


Plate1: Measurement of Plant height, leaf length and breadth of Garlic

Plate 2: Garlic research field under guava orchard


Plate 3: Measurement of Plant height, leaf length and breadth of Potato

Plate 4: Measurement of Plant height and breadth of Guava Tree

Plate 5: Measurement of Garlic (Diameter)

Plate 6: Harvesting of Potato