VARIETAL PERFORMANCE OF CAULIFLOWER INFLUENCED BY DIFFERENT FERTILIZER AND MANURE APPLICATIONS UNDER MANGO BASED AGROFORESTRY SYSTEM

A THESIS

BY

SHAHANA SULTANA

Registration No. 1605449

Thesis Semester: July-December, 2017

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

DECEMBER 2017

Dedicated
To
My Beloved Parents

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VARIETAL PERFORMANCE OF CAULIFLOWER INFLUENCED BY DIFFERENT FERTILIZER AND MANURE APPLICATIONS UNDER MANGO BASED AGROFORESTRY SYSTEM

ABSTRACT

A field experiment was conducted in the Agroforestry and Environment Research Field, Hajee Mohammad Danesh Science and Technology University, Dinajpur, during October 2016 to February 2017 to evaluate the varietal performance of cauliflower influenced by different fertilizer and manure applications under mango based agroforestry system. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. Three cauliflower varieties viz. Aksel (V_1), Snowball-1 (V_2) and Maghi (V_3) were considered as factor A; while fertilizer and manure applications viz. no fertilizer (F_1), chemical fertilizer (F_2), cowdung (F_3) and poultry (F_4) were factor B. The data were collected at 15, 30, 45 and 60 DAT (days after transplanting) for plant height (cm), number of leaves per plant,outer leaf length (cm),outer leaf width (cm), curd size (cm^2), yield of curd (t ha^{-1}). The results revealed that fertilizer and manure applications had significant effect on the growth, yield contributing characters and yield of different cauliflower varieties.In case of main varietal effects, the highestand the lowest curd yield (30.78t ha^{-1}) and (20.00t ha^{-1}) were recorded in Snowball-1andAksel respectively. Again, in case of main effect of fertilizer and manure applications, the highest curd yield (36.47t ha^{-1}) was found in chemical fertilizer application and the lowest yield (20.32 t ha^{-1}) was found in no fertilizer application. Furthermore in case of the interaction effect of variety and fertilizer and manure applications, the maximumcurd yield (32.27 t ha^{-1}) of cauliflower was recorded in Snowball-1varietywith chemical fertilizer application and the minimum yield (19.52 t ha^{-1}) was recorded invariety Aksel with no fertilizer application. On the other hand, from the economic analysis, it was observed that the highest BCR (3.17) was found in the plot where Snowball-1 variety was cultivated with chemical fertilizerwhereas the lowest BCR (2.38) was received where variety Aksel was grown without fertilizer. Finally,it may be concluded that monitoring the yield and economic return among the three cauliflower varieties and different fertilizer and manure applications, the best performance according to yield were Snowball-1>Maghi>Aksel and chemical fertilizer>cowdung>poultry>no fertilizer under mango based agroforestry system. Though chemical fertilizer application gave maximum economic return, cauliflower variety Snowball-1 using cowdung may be a viable option for safe cauliflower production by considering the environmental benefit.

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LIST OF ABBREVIATION

AEZ	= Agro-Ecological Zone
BARC	= Bangladesh Agriculture Research Council
BBS	= Bangladesh Bureau of Statistics
BCR	= Benefit Cost Ratio
cm	= Centimeter
DAT	= Days per transplanting
e.g.	= For example
g	= Gram
tha^{-1}	= Ton per hectare
i.e.	= That is
kg	= Kilogram
MT	= Metric ton
M	= Mitre
MOP	= Muriate of Potash
tk	= Taka
TSP	= Triple Super Phosphate
Var.	= Variety
Viz.	= Vise- versa

CHAPTER 1

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis*) under the family Brassicaceae is one of the most important cole crops in the tropic and temperate regions of the world (Siddiqui, 2004). Cauliflower is a winter seasonal, herbaceous plant originating along the maritime areas of Europe, including the Mediterranean and Asia Minor. From 1985 to 2001, the area of Cole crops has increased in Asia by 14.3 % as compared to the world by 9.5 % (Boss *et al.,* 2002). The name cauliflower has originated from the Latin words 'Caulis' meaning stem and 'Florish' meaning flower. Dr. Jemson at Saharanpur first introduced it to Indian Subcontinent in 1822 during the period of East India Company (Rai and Yadav, 2005). Over the last two decades crops in the Brassicaceae (Cruciferae) have been the focus of intense research based on their human health benefits (Traka and Mithen, 2009).

The edible curd is a rich source of protein, minerals and vitamins, which protects human from certain cancers and heart diseases. There is a great demand of cauliflower all over the world throughout the year. It contains glucocinolates, which in crushed leaves is broken down by myrosinase enzyme to give better taste and goitrogenic substance. It is a source of sinigrin, is othiocyanates, S-methyl cysteine sulfoxide and glucobrassicin which have prominent anti-carcinogenic property. It has high quality of protein and peculiar in stability of vitamin C after cooking. Cauliflower contains 92.7 %water and the food value per 100 g of edible portion is as follows: energy 31 calories, protein 2.4 g, calcium 22 mg, vitamin A 40 IU, ascorbic acid 70 mg, thiamine 0.2 mg, riboflavin 0.1 mg and niacin 0.75 mg(Khan *et al*., 1968).

The acreage of cauliflower cultivation in Bangladesh is about 9,400 ha and the annual production amount in about 73,000 m tons. Thirty days old seedlings are very suitable for transplanting in October-November, yield ranges 25-30 m tons/ha. In Bangladesh, out of 283.32 thousand hectares of vegetables growing area, cauliflower covers 4.64% of the total land and contributes 8.57% of total production (BBS, 2014). The production of vegetables including cauliflower is increasing day by day in Bangladesh. Among all the vegetables produced in the country, cauliflower dominates a major share in terms of total cropping area and production. It grows in all the districts of Bangladesh, but plenty of cauliflower is produced in the region of Dhaka, Jessore, Rajshahi, Rangpur, Tangail and Kustia. The acreage of cauliflower cultivation in Bangladesh is about 47,749 acre and the annual production amount is about 268484 metric tons (BBS, 2016). The country has 8.20 million hectare arable land against the huge population (Hasan and Solaiman, 2012). More than 70% of the population depends on agriculture. So there is limited scope to increase cauliflower production horizontally due to agricultural land scarcity. So, we should give more emphasis of vertical expansion of cauliflower production and this may be done through proper cauliflower based agroforestry system.

Indeed, Agroforestry has been a collective term for land use system and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land management unit, either in a spatial mixture or a temporal sequence. Trees in agroforestry system generally fulfill multiple purposes, involving the protection of soil and improvement of its fertility, as well as production of one or more products (Cooper *et al.,* 1996). In Bangladesh, a large number of vegetables are now grown of which most of them are grown in winter season. Among the different winter vegetables, cauliflower is the important one. Through cauliflower is very common to all and has good production potential in Bangladesh climate, but it was not systematically tested in agroforestry system.

Now-a-days the demand of organic vegetables are increasing day by day. Organic manures improve the texture, structure, humus, color, aeration, water holding capacity and microbial activity of soil. All these in turn increase production and reduces environmental pollution (Pare *et al*., 2000). Fifty years ago, there was 5% organic matter in the soil of Bangladesh but in recent it becomes very low (0.5%) (Paull 2010). This alarming situation may be the result of using chemical fertilizer. Our farmers are habituated in using chemical fertilizers more readily compared to organic fertilizer. It's the high time to reduce the use of chemical fertilizer to ensure quality food and environment.

Mango (*Mangifera indica* Linn) is the most important fruit of Bangladesh and is known as "King of fruits". It is one of the most common and popular fruits in Bangladesh. Besides having delicious taste, captivating flavor with multifarious color, it is an excellent source of nutrients. It is good source of Vitamin A, B_6, C, E and K (Salvin 2012). This delicious fruit is particularly rich in nutrients such as protein, iron, fiber, thiamine, ascorbic acid etc. It decreases the risk of cancer and also a great natural remedy for diabetics. In Bangladesh mango occupies about an area of 50,491 ha with a production of 187220 tones according to (BBS, 2016). Increase of production are now a time-demand. Mango orchards are increasing day by day in the northern part of Bangladesh. The owners of mango orchards also using the floor of young orchard for different agricultural crop production. Whereas there are huge scope of organic vegetable like cauliflower production at the floor of young mango orchard. Information regarding safe cauliflower production under mango based agroforestry system is very scant in Bangladesh. As it is a complex cultivation technique (cauliflower + fertilizer and manure application), it need scientific justification as well as environmental safety. Above all which variety grows well under mango floor is also a considerable fact. Keeping this view in mind the present experiment was undertaken with the following objectives-

1. To investigate the possibility of organic cauliflower production at the floor of mango orchard.
2. To find the suitable variety of cauliflower at the floor of mango orchard influenced by chemical fertilizer and manure application.

3. To find out the economic performance of organic cauliflower production under mango based agroforestry system.

CHAPTER 2

REVIEW OF LITERATURE

The research was executed to observe the performance of winter vegetable cauliflower varieties in association with different fertilizer and manure application under mango based agroforestry system. In recent times, the practice of agroforestry are expanded in the vegetable fields in Bangladesh. Now-a-days farmers are growing trees in the crop field for getting maximum profit. The yield of vegetables is influenced directly by the tree in agroforestry system. Good amount of literature is available where efforts have been made to understand various aspects of agroforestry systems, although information is incommensurate with respect to quantification of biological interactions among the components in agroforestry systems. Therefore, literatures related to the subject interest from home and abroad are reviewed and outlined in this section. The relevant literatures pertaining to the present study have been reviewed under the following heads:

2.1 Concepts of agroforestry
2.2 Agroforestry practices in Bangladesh
2.3 Characteristics of tree species used in agroforestry system
2.4 Tree based agroforestry System
2.5 Crop performance in agroforestry system
2.6 Importance of organic manure
2.7 Importance of studied cauliflower
2.8 Importance of light, shade and temperature on cauliflower cultivation
2.9 Performance of cauliflower under mango tree

2.1 Concepts of agroforestry

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

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

ICRAF (1993) defined ‘Agroforestry is a collective name for all land-use systems and technologies, where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components'.

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

Reduced access and increased prices of wood-based biomass have led to initiatives to promote agroforestry cultivation. Where agroforestry is practiced by smallholders, less fuel wood needs to be purchased, there is less reliance on collecting from natural stands and less time is involved in collection. This leaves more time for income-generating activities, especially for women, who are usually the major fuel wood collectors (Thorlakson and Neufeldt, 2012).

Agroforestry is a dynamic, ecologically based, natural resources management system that through the integration of trees in farmland and range land, diversities and sustains production for increased social, economic and environmental benefits for land users at all levels (Michelsen *et al.,* 1993). ‘Agroforestry should be reconsidered as a dynamic, ecologically based, natural resource management system that, through the integration of trees in farm and rangeland, diversifies and sustains production for increased social, economic and environmental benefits (Leakey, 1996).
Agroforestry is an age-old practice but modern concept is now being developed. It is a sustainable management system for land that combines agricultural crops, trees, forest plants and/or animals simultaneously or sequentially, and applies management practices that are compatible with the cultural patterns of the local population (Raintree, 1997).

Home gardens represent intimate, multistory combinations of various trees and crops, sometimes in association with domestic animals, around the homestead. This concept has been developed around the rural settings and subsistence economy under which most home gardens exist (ed). The practice of home gardening is now being extended to urban settings (Drescher *et al.,* 2006) as well as with a commercial orientation (Abdoellah *et al.,* 2006; Yamada and Osaqui, 2006).

MacDicken and Vergara (1990) stated that agroforestry is a means of managing or using land (i.e. a land use system) that combines trees or shrubs with agricultural / horticultural crops and / or livestock. From a business point of view, agroforestry is an economic enterprise which aims to produce a combination of agricultural and forest crops simultaneously in the same land area.

According to Solanki (1998), agroforestry can significantly contribute in increasing demands of fuel wood, fodder and cash flows and infrastructures in many developing countries. He also stated that agroforestry has high potential to simultaneously satisfy 3 important objectives: (i) protecting and stabilizing the ecosystems, (ii) producing a high level of output of economic goods (fuel, fodder, small timber, organic fertilizer etc.) and (iii) producing stable employment, improved income and basic material to rural populations.

Agroforestry does not mean planting trees in the fields or other places; rather it provides farmers with an effective land management system that can ensure more production in a balanced ecological environment (Haque *et al*., 1996). Saka *et al.,* (1990) stated that an agroforestry system can provide a sound ecological basis for increased crop and animal productivities, more dependable economic returns and greater diversities in social benefits on a sustained basis. Bhatia and Singh (1994) observed that agroforestry systems in India plays an important role in increasing biomass production, maintaining soil fertility, conserving and improving soil averting risk.

Agroforestry is one of most productive and so far the most successful system to increase forest area and production in the country. It improves the socio-economic conditions of the farmers by increasing profitability, sustain ability and crop security through balanced soil utilization fertility preservation. It makes environment friendly and may contribute to reducing global worming (Haque *et al.,* 1996).

2.2 Agroforestry Practices in Bangladesh

The potentialities of agroforestry are generally investigated through their biophysiological phenomena, cost benefit analysis, and possible impact upon poverty reduction. There have been inadequate studies on the actual impacts of agroforestry intervention on small landholders and of farmers' attitudes toward these agroforestry programs. Drawing upon the findings of an empirical study, this article explores the effects of small-scale agroforestry on upland community development in the Chittagong Hill Tracts, Bangladesh. More specifically, the study clarifies the merits and demerits of different agroforestry systems as perceived by farmers, their impacts on the rural economy and the environment, farmers' attitudes toward the adoption of agroforestry, and impacts of various government policies. Field data were collected by administering questions to 90 randomly selected smallholders of the Upland Settlement Project (USP), as well as from project staff. The research tools employed were semi structured interviews, group discussions, and uncontrolled observations. The results indicated that the agroforestry interventions have in fact increased farmers' income through employment and the selling of farm products, as well as by improving the ecological conditions of these areas through reduction of soil erosion, increasing tree coverage, and maintaining soil fertility. The adoption of different agroforestry systems was governed mainly by the farmers' interests in following these techniques, their ability to cultivate the land in the prescribed manner, and the market demand for their products. The major obstacles that prevented increased agroforestry improvements included lack of confidence in new land-use systems, inappropriate project design (e.g., top-down innovation approach), and policy issues regarding land tenure. Recommendations are proposed to strengthen social capital in local organizations to enhance the livelihoods of the upland communities (Nath *et al.,* 2005).

Meeting the needs for a growing world population calls for multifunctional land use, which can meet the multiple demands of food and fuel production, environmental and biodiversity protection, and has the capacity for adaptation or resilience to climate change. Agroforestry, a land-use system that integrates trees and shrubs with crops and/or livestock production, has been identified by the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) as a ‘win–win’ approach that balances the production of commodities (food, feed, fuel, fiber, etc.) with non-commodity outputs such as environmental protection and cultural and landscape amenities.

Evidence is now coming to light that supports the promotion of agroforestry in temperate developed countries as a sustainable alternative to the highly industrialized agricultural model with its associated negative environmental externalities. This paper reviews this evidence within the 'ecosystem services' framework to evaluate agroforestry as part of a multifunctional working landscape in temperate regions. Establishing trees on agricultural land can help to mitigate many of the negative impacts of agriculture, for example by regulating soil, water and air quality, supporting biodiversity, reducing inputs by natural regulation of pests and more efficient nutrient cycling, and by modifying local and global climates. The challenge now lies in promoting the adoption of agroforestry as a mainstream land use through research, dissemination of information and policy changes (Smith *et al.,* 2013).

As in other mountain regions of Asia, agricultural lands in the Chittagong Hill Tracts (CHT) of Bangladesh are undergoing degradation due primarily to environmentally incompatible land use systems such as distorted from of shifting cultivation (*jhum*) requiring the slashing and burning of vegetation every year. Agroforestry is considered to be environmentally suitable for the mountainous areas like CHT, as the rate of soil erosion under such systems is considerably less than *jhum*. To design strategies in the pursuit of promoting agroforestry its financial and economic benefits need to be evaluated systematically. Based on three criteria such as benefit–cost ratio, net present value, and return to labor, this paper evaluated the financial and economic benefits of agroforestry and *jhum* using farm household data. Information was collected from farm households and agricultural commodity traders through questionnaire surveys, case studies, focus group discussions, and key informant interviews following a two-stage sampling method. The results show that economic returns from agroforestry are better than from *jhum* in terms of all the three criteria. When economic benefits of two land use systems are analyzed by taking into account the cost of nutrient depletion arising from soil erosion, agroforestry appears to be more attractive than *jhum*. The analysis revealed that despite higher environmental and economic benefits the low adoption of agroforestry is largely attributed to policy and institutional constraints such as insecure land tenure, complicated transit rules, double levy on agricultural commodities, and farmers' poor socio-economic condition. Findings of the study indicate that there is a prospect for promoting agroforestry by eliminating the existing policy and institutional barriers combined with the provision of necessary support services and facilities (Rasul and Thapa, 2006).

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 a 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 (Jose, 2009).

Azadirachta indica A. Juss, *Dalbergia sissoo* Roxb., and *Melia azedarach* L. are little studied species in nutrient return capabilities from leaf litter decomposition to maintenance of the soil fertility despite their importance in agroforestry practices of Bangladesh. A leaf litter decomposition experiment was conducted using a litterbag technique to assess the nutrient return efficiency of these species. The decomposition rate of leaf litter was highest for *M. azedarach* and lowest for *D. sissoo*. Rainfall and temperature of study sites showed a significant ($p<0.05$) positive relationship with the rate of leaf litter decomposition.

The highest decay constant was observed for *M. azedarach* (6.67). Nitrogen and Phosphorus concentration in leaf litter showed a decreased trend sharply at the end of the first month, whereas rapid decrease of Potassium concentration was reported within 10 days. Conversely, higher concentration of nutrient was observed at the later stages of decomposition. All three species showed a similar pattern of nutrient release (K > N > P) during the decomposition process of leaf litter. Among the studied species, *D. sissoo* was best in terms of N and P return and *A. indica* was best in terms of K return (Hossain *et al.,* 2011).

Biodiversity conservation is one of the important ecosystem services that has been negatively impacted by anthropogenic activities. Natural forests (NF) harbor some of the highest species diversity around the world. However, deforestation and degradation have resulted in reduced forest land cover and loss of diversity. Homegarden agroforestry (AF) systems have been proven to be an intermediary for biodiversity conservation. In this study, we evaluate the effectiveness of home garden AF practices to conserve tree species diversity in Bangladesh and compare them with tree species diversity in NF. A total of nine locations were selected for this synthesis from published literature which comprised of five AF sites and four NFs. Shannon–Weiner Diversity Index (H) was similar for home-garden AF (3.50) and NF (2.99), with no statistical difference between them. Based on non-metric multi-dimensional scaling (NMDS) ordination analysis, the AF and NF plots showed distinct separation. However, Bray–Curtis dissimilarity index ranged from 0.95 to 0.70 indicating nearly no overlap in species composition to significant overlap between AF and NF. Based on our results, we conclude that AF can serve as an important ecological tool in conserving tree species diversity, particularly on landscapes where NF fragments represent only a small fraction of the total land area. Creating and maintaining AF habitats in such human dominated landscapes should be part of the biodiversity conservation strategy (Bardhan *et al.,* 2012).

Takdira (2017) conducted an experiment to study the prospect of litchi based agroforestry system for organic tomato production and she found all the parameters i.e, plant height, outer leaf length, outer leaf width, no. of fruits per plant, yield are higher in litchi based agroforestry system than sole cropping of tomato. Israt (2017) studied on effect of bark and stem exudates of *Eucalyptus camaldulensis* L. on agricultural crops. From the study it was recorded that germination of Maize, Country bean and Bottle gourd seeds was affected by different concentrations of bark and stem exudates of *Eucalyptus camaldulensis*. It was concluded that if Eucalyptus is incorporated with a wider spacing for agroforestry practice, inhibitory effect might be reduced by reducing the concentration of its litterfall.

Shamima (2017) studied on the suitability of mango based agroforestry systems for organic carrot production in HSTU, Dinajpur. The study showed that The suitability of the cultivation of carrot considering fertilizer and manure applications under mango based agroforestry systems may be ranked as Chemical fertilizer>Cowdung + poultry>Cowdung>Poultry > No fertilizer. Jannatul (2017) conducted an experiment on Potentiality of homestead agroforestry on the livelihood of some Chitmahals of Lalmonirhat and Kurigram district. It was found that in case of plant diversity, the number of plant species were more or less similar in both chitmahal and non-chitmahal areas. But the homestead plant diversity in non-chitmahal area was less compared to chitmahal area. Well planned integrated land use systems combining vegetables, fruits and woody perennials production with the farmer's needs, goals and resource base can lead to viable farming systems towards sustainable livelihood in the coming future.

Mamun (2015) observed that the application of organic manure gave 25.62% less production as compared to chemical fertilizer application. But, considering the benefit of organic manure application in terms of environmental benefit, soil health and safe potato production then cultivation of potato variety lady rosette at the floor of mango orchard with organic manure application may be a promising orchard based agroforestry system in the northern part of Bangladesh.

An experiment was conducted by Bali (2012) to study the growth and yield of winter vegetables under different spacing from lemon and guava tree, and it was found that all the parameters parameters i.e, plant height, outer leaf length, outer leaf width, no. of fruits per plant, yield were increased gradually with increasing distance from lemon and guava tree. The result of the experiment revealed that the yield of Okra was increasing gradually with the increase of planting distance from tree to tree.

A study was done by Belali (2011) on homestead agroforestry and species composition in Sonargaon upazila of Narayangonj district. He stated that the homesteads in Sonargaon upazila of Narayangonj district are cluster with nearly 78 different tree species, 11 crop species and on average 25.75 tree species were found in homestead.

Yasmin *et al*., (2010) observed a total of 68 different tree species in the homestead and cropland area of which Akashmoni, Eucalyptus, Mehogoni, Neem, Coconut and Bokain were dominant. On an average 22.75 and 4 tree species were found in homestead and cropland area respectively. Shabuj et al. (2010) observed a total of 32 different tree species in the homestead of which Eucalyptus, Ipil-ipil, Mehogoni, Neem, Coconut, Betelnut were found in homestead. Ten different agroforestry practices were identified from the study area within four different layers.

Nahidur (2009) stated that agroforestry practice had significant role in improving the economic status of the people. It is implied that if people are encouraged to plant trees in their homestead, thereby the people can live in a health environment at the same time if can ensure the supply of timber, fuel, fodder, nutrient and other products. Therefore, there is a great scope to improve the prevailing homestead agroforestry practices with modern agroforestry technologies for maximization of income of the farmers.

Partha (2009) stated that CARE assisted Road side agroforestry program bring a change in the socioeconomic status of the participants through increasing income generating capacity and using the waste land of the road side. The program also improved the overall environmental condition and prevented the soil erosion.

A total of five agroforestry practices viz. Palmyra palm- rice based agroforestry practices, pond size agroforestry practices, MPTs plantation the border of rice field, ailed based agroforestry practices and homestead agroforestry practices in the study area. It was recommended that the selection and introduction of fast growing trees and multipurpose tree species are suitable for agroforestry practices for socioeconomic improvement of the farmers (Pulok 2008).Well planned and well managed agroforestry can play an important role in solving acute problem of food, fuel, fodder, soil fertility and ecology. It was also concluded that agroforestry system practices are highly profitable and plant significant role in improving the economical status of the farmers (Hafizul, 2007).

2.3 Characteristics of tree species used in agroforestry system

While selecting tree species for agroforestry systems, the following desirable characteristics should be taken into consideration. Though all desirable characters are not found in a single species, but their multiple uses are taken care of. (Hellin *et al.,* 1999)

- Tree species selected should not interfere with soil moisture
    - Tree species selected for agroforestry should have very less water requirement
    - Should not compete with main agricultural crops for water.
    - Tree species should be deep tap rooted so that they can draw water from deep strata of the soil.
- Tree species should not compete for plant nutrients

  - Tree species should not utilize more plant nutrients
  - They should help in building soil fertility,
  - Leguminous tree species which fix atmospheric nitrogen in their roots should be prefer.
  - The root system and root growth characteristics should ideally result in to exploration of soil layers that are different to those being trapped by agricultural crops.
- Tree species should not compete for sunlight
  - Tree species should not interrupt sunlight falling on the crops.
  - Tree species should be light branching in their habit.
  - Trees permit the penetration of light into the ground and promote better crop, pasture growth and yield.
  - Tree species can withstand pruning operation if it possess dense canopy.
- Tree species should have high survival rate and easy establishment
  - Trees species should have high survival percentage,
  - Leave little or no gaps after transplanting.
  - Hardy tree species are easy to establish.
  - They have less mortality percentage because they can tolerate transplanting shocks easily.
  - Trees should have the ability to regenerate lateral roots within a short period of time after transplanting.
- Tree species should have fast growing habit and easy management
  - Tree species for agroforestry system should be essentially fast growing,
  - Rapid growth, especially in the early years,
  - Tree should have short rotation (the period between planting and final harvesting)
  - Fast growing species such as Poplar, *Casuriana, Leucaena leucocephala* etc. are important species which provide lot of opportunities to be planted in AFS
- Tree species should have wider adaptability

- A tree species selected for agroforestry combinations must have a wider adaptability.

- Tree species should have high palatability as a fodder
  - Most of the Indian farmers rear livestock separately and cut and carry method of fodder production is quite prevalent.
  - Therefore, in agroforestry, farmer must select those tree species which are palatable to livestock and had a high digestibility.
- Tree species should have shelter conferring and soil stabilization attributes
  - Some tree species, because of their inherent growth habit and adaptability, are especially helpful in providing protection for soils, crops and livestock. Poplars (*Populus* spp.), Willows (Salix spp.), *Casurina equisetifolia*, etc. for example, have been extensively used in soil erosion control because of their extensive root system and ability to grow in water-logged soils.
- Tree species should have capability to withstand management practices
  - Many agroforestry systems demand extensive pruning and lopping of the trees in order to maximize production. In such cases, the trees must be able to withstand such treatment without drastically restricting growth rate.
- Tree species should have nutrient cycling and nitrogen fixation attributes
  - Within an agroforestry system, trees can play an important role in recycling nutrients, leached down through the soil profile and minerals released from weathering parent material such as rocks and sediments.
  - These nutrients are used in the growth and development of the tree, many returning to the top-soil in form of dead leaves, twigs, flowers and seeds which slowly decompose on the surface, or are eaten by animals.

  - Although all trees play some role in maintaining the nutrient status of the soil through recycling.
  - Deciduous trees drop most of their leaves in autumn leaving a thick mat of leaves on the ground, whereas most evergreen species maintain some level of litter fall throughout the year.
  - Another important factor is the ability of many tree species to convert atmospheric nitrogen into organic nitrogen for their own use through complex symbiotic relationship between Rhizobium bacteria and their fine roots.
  - The bacteria form nodules on the roots which can convert nitrogen gas, as it is in the atmosphere, into usable nitrogen for the plant.
  - Most leguminous trees and some non-leguminous ones, such as *Acacia, Leucaena* and *Prosopis* as well as *Casuarina spp.* fix the atmospheric nitrogen.
  - The litter of these nitrogen fixing trees is generally high in nitrogen, thus increasing the nitrogen status of the soil.

- Tree species should have easily decomposable leaves
  - The suitable tree species for agroforestry will be that one in which fallen leaves decompose with fast rate.
  - The leaves of most of the legume tree species are small in size, decompose quickly and easily, and add a large quantity of organic matter and nutrients to the soil.
  - Tree species having broad leaves such as teak, mango and banyan should not be preferred for agroforestry system.
  - They contain more fibred matter and also require longer time for decomposition. Further, broad leaves when fall on the tender crop plants, block their photosynthetic activities.
- Tree species should have their multiple uses
  - The selected tree species should have multiple uses.

- The tree should yield more than one of the main produce like fuel wood, leaf fodder, edible fruit, edible flower and fiber.

- Tree species should have high yield potential
  - High yield potential is the most important criterion of selection of tree species for agroforestry systems as the main aim is to obtain overall more output per unit area. Care should be taken before collection of seeds and seedlings that they are being procured from reliable source.

2.4 Tree based agroforestry system

Agroforestry intercropping systems have been developed as an alternative to conventional monocropping systems to address environmental, social and economic issues in a wide array of agricultural contexts. As research on the biological properties of these systems tends to demonstrate their potential, fostering their integration in agricultural landscapes requires an in-depth understanding of local stakeholders' perceptions. Our study used the strengths, weaknesses, opportunities and threats approach in combination with the analytical hierarchy process (SWOT-AHP) to investigate the factors influencing local stakeholders' decision to integrate agroforestry intercropping systems in two Regional County Municipalities and their perception of the relative suitability of three agroforestry intercropping system designs (crop-oriented, tree-oriented and landscape aesthetic-oriented). We conducted focus groups with farmers, farm and forestry advisors, urban planners and local authorities in a very intensive and a very extensive agricultural landscape in Quebec (Canada) and compared the results between stakeholders within and across the areas. Our results show that social factors seem to have more impact than biophysical factors on the decision to integrate agroforestry intercropping systems in intensive and extensive agricultural landscapes. The relative value given to the decision factors varies greatly across stakeholders' categories and areas. Agroforestry intercropping systems designed to meet crop production needs or landscape aesthetic purposes are perceived as more suitable in both agricultural contexts than the tree-oriented design. Our results highlight crucial issues for agroforestry intercropping system deployment and the development of relevant agroforestry system designs through collective decision-making processes (Laroche *et al.,* 2018).

Agroforestry entails different life forms including mixtures of trees that occupy different soil strata and exhibit a certain degree of spatial complementarity in resource use. However, rigorous experimental studies characterising root interactions in tree–tree systems are notoriously few. We present here the available empirical evidence to support the hypothesis that occurrence of two or more tree species close to one another may favour diminished lateral spread and/or deeper root penetration of the woody components and closer the tree components are located greater will be the subsoil root activity. These evidences are based on either root excavation studies in coconut-based multistorey production systems, or ^{32}P soil injection experiments involving binary mixtures of coconut+ interplanted dicot multipurpose trees (*Vateria indica*, *Ailanthus triphysa* or *Grevillea robusta*), and bamboo (*Bambusa bambos*) + teak (*Tectona grandis*) or Malabar white pine (*V. indica*). The excavation study denotes a spatially segregated root distribution pattern of the component species. Furthermore, in the coconut + dicot tree system, interplanted dicot trees absorbed considerable quantities of the radio-label applied to the palm, which declined log-linearly with distance from the palms, signifying a substantial potential for “capturing” the lower leaching nutrients, at proximal distances. Likewise, lower teak/*Vateria* root activity in the surface horizons and higher activity in the deeper layers, when bamboo clumps were nearby and vice versa when they were farther apart, implied that proximity of species/individuals favoured competitive downward displacement of roots. Nutrient pumping and/or current transfer of nutrients between the rhizospheres of the two associated crops are also possible. In designing sustainable agroforestry systems, it is, therefore, advantageous to mix trees with divergent root growth habits (Kumar *et al.,* 2018).

Alley cropping multi-rows of shrub willow hybrids and grassland is a promising temperate agroforestry practice for an environmentally sound provision of bio-energy feedstock. The effect of willows, aged 2–3 years, on two grassland mixtures (clover-grass, diversity oriented mixture) was determined at three positions along the tree-crop interface at a study site in Central Germany. Willows modified the incident light on understory along the interface. Biennial mean daily light integral at position south-west (SW) was 22 mol m^{-2} w^{-1}, in the center of the alley 30 mol m^{-2} w^{-1} and at position north-east (NE) 26 mol m^{-2} w^{-1}. Accordingly, soil temperature was lower at the positions SW and NE being adjacent to the willows. There was no clear pattern of the distribution of volumetric soil moisture content along the tree-crop interface in 15 cm depth, except that moisture content was highest in 35 cm depth at SW position in both years. In the early establishment phase, the diameter at breast height (DBH) of pooled inner willow rows (17 mm) was significantly different from pooled outer rows (21 mm). Direction had a significant influence on DBH in 2012, but not in 2013. The impact of willows on productivity of the two grassland mixtures was not confirmed until the third year after establishment. Dry matter yield was on par with those reported for single-cropped grassland adjacent to the agroforestry system. Sward composition of clover-grass changed along the tree-crop interface. Dry matter contribution of legumes was lower at the position SW. No remarkable impact of trees on quality parameters of grassland mixtures were found along the interface. Horizontal and vertical growth of the trees may modify the microclimate during the life-span of the alley cropping system consisting of willows and grassland. More research is needed on long-term monitoring of competitive, complementary and facilitative effects along the tree-crop interface (Ehret *et al.,* 2018).

Agricultural pollution consists a serious concern for environmental protection managers. Among the pollutants, nitrates, phosphoric compounds and organic pesticides from agricultural activities are the most common and hazardous to the environment and human health.

Several mitigation techniques have been proposed to control these pollutants from entering aquatic systems. Agroforestry, which is the common cultivation of crops and trees, is one such mitigation technique. In the present study, the efficiency of agroforestry systems in pollutant reduction is reviewed. A search of relevant international literature was conducted using Scopus, Science Direct and Google Scholar search engines, using relevant keyword combinations for agrochemical pollution abatement with trees. More than 2000 results were found and the most relevant were selected and extensively studied, and are summarized here. From the current knowledge, it can be generally seen that tree roots in agroforestry systems are able to reduce nitrogen and phosphorus residues in soils from 20% up to 100%, have the potential to reduce pesticides leaching and runoff in considerable amounts (up to 90% for runoff), and simultaneously they provide additional benefits to the ecosystems including erosion control, improvement of soil quality and positive effects on biodiversity (Pavlidis, G. and Tsihrintzis., 2018).

Under changing land use in tropical Asia, there is evidence of forest product diversification through implementation of tree-based farming by smallholders. This paper assesses in two locations, West Java, Indonesia and eastern Bangladesh, current land use conditions from the perspective of smallholder farmers, the factors that facilitate their adoption of tree farming, and the potential of landscape-scale approaches to foster sustainable land management. Data were collected through rapid rural appraisals, focus group discussions, field observations, semi-structured interviews of farm households and key informant interviews of state agricultural officers. Land at both study sites is typically fragmented due to conversion of forest to agriculture and community settlement. Local land use challenges are associated with pressures of population increase, poverty, deforestation, shortage of forest products, lack of community-scale management, weak tenure, underdeveloped markets, government decision-making with insufficient involvement of local people, and poor extension services. Despite these challenges, smallholder tree farming is found to be successful from farmers' perspectives. However, constraints of local food crop cultivation traditions, insecure land tenure, lack of capital, lack of knowledge, lack of technical assistance, and perceived risk of investing in land due to local conflict (in Bangladesh) limit farmers' willingness to adopt this land use alternative. Overcoming these barriers to adoption will require management at a landscape scale, including elements of both segregation and integration of land uses, supported by competent government policies and local communities having sufficiently high social capital (Rahman *et al.,* 2017).

Agroforestry is an appealing option for sequestering carbon on agricultural lands because it can sequester significant amounts of carbon while leaving the bulk of the land in agricultural production. Simultaneously, it can help landowners and society address many other issues facing these lands, such as economic diversification, biodiversity, and water quality. Nonetheless, agroforestry remains under-recognized as a greenhouse gas mitigation option for agriculture in the US. Reasons for this include the limited information-base and number of tools agroforestry can currently offer as compared to that produced from the decades-worth of investment in agriculture and forestry, and agroforestry’s cross-cutting nature that puts it at the interface of agriculture and forestry where it is not strongly supported or promoted by either. Agroforestry research is beginning to establish the scientific foundation required for building carbon accounting and modeling tools, but more progress is needed before it is readily accepted within agricultural greenhouse gas mitigation programs and, further, incorporated into the broader scope of sustainable agricultural management. Agroforestry needs to become part of the agricultural tool box and not viewed as something separate from it. Government policies and programs driving research direction and investment are being formulated with or without data in order to meet pressing needs. Enhanced communication of agroforestry’s carbon co-benefit, as well as the other benefits afforded by these plantings, will help elevate agroforestry awareness within these discussions. This will be especially crucial in deliberations on such broad sweeping natural resource programs as the US Farm Bill (Schoeneberger, 2009).

The environmental services that agroforestry practices can provide, and especially their potential contribution to the conservation of biodiversity, have only recently attracted wider attention among agroforestry and conservation scientists. This new view is consistent with the ecosystem approach to natural resource management advocated by the Convention on Biological Diversity. This collection of six papers, which is based on a Workshop held in June–July 2004, brings together studies of biodiversity impacts of traditional agroforestry practices from Central and South America, Africa and Asia. The contributions highlight the considerable potential of traditional agroforestry practices to support biodiversity conservation, but also show their limits. These include the importance of sufficient areas of natural habitat and of appropriate hunting regulations for maintaining high levels of biodiversity in agroforestry land use mosaics, as well as the critical role of markets for tree products and of a favourable policy environment for agroforestry land uses. In combination the case studies suggest that maintaining diversity in approaches to management of agroforestry systems, along with a pragmatic, undogmatic view on natural resource management, will provide the widest range of options for adapting to changing land use conditions (McNeely and Schroth, 2006).

This paper describes recent research findings on resource sharing between trees and crops in the semiarid tropics and attempts to reconcile this information with current knowledge of the interactions between savannah trees and understorey vegetation by examining agroforestry systems from the perspective of succession. In general, productivity of natural vegetation under savannah trees increases as rainfall decreases, while the opposite occurs in agroforestry. One explanation is that in the savannah, the beneficial effects of microclimatic improvements (e.g. lower temperatures and evaporation losses) are greater in more xeric environments. Mature savannah trees have a high proportion of woody above-ground structure compared to foliage, so that the amount of water 'saved' (largely by reduction in soil evaporation) is greater than water 'lost' through transpiration by trees. By contrast, in agroforestry practices such as alley cropping where tree density is high, any beneficial effects of the trees on microclimate are negated by reductions in soil moisture due to increasing interception losses and tree transpiration. While investment in woody structure can improve the water economy beneath agroforestry trees, it inevitably reduces the growth rate of the trees and thus increases the time required for improved understorey productivity. Therefore, agroforesters prefer trees with more direct and immediate benefits to farmers. The greatest opportunity for simultaneous agroforestry practices is therefore to fill niches within the landscape where resources are currently under-utilised by crops. In this way, agroforestry can mimic the large scale patch dynamics and successional progression of a natural ecosystem (Ong and Leakey1999).

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

2.5 Crop performance in agroforestry system

Trees grown on farms for their non-timber forest products such as fruits, nuts, and spices constitute the basis for many vibrant and sustainable farming systems throughout the world. Yet, compared to other types of trees, research on horticultural and agronomic management of such trees and systems to optimize total system-yield and understand tree—crop interactions is scarce. Farmers prefer fruit-producing species to other trees for on-farm planting (Raintree, 1992), and appreciate the dual contributions of food for consumption and the potential for income generation (Delobel *et al*., 1991). Miah *et al.* (1995) reported that the mean light availability on crop rows decreased as they approached the trees rows across the alleys. The rate of decrease was greater in unpruned that in pruned alleys. Rice and mungbean yield decreased linearly with the reduced percent light incidence, rice yields decreased 47 kg/ha and mungbean yields decreased 10 kg/ha. In pruning regimes, mungbean yields decreased more in pruned conditions (13 kg/h) than in un pruned condition (9 kg/ha).

Wallace (1996) said that in agroforestry, multistrata canopies offer scope for regulating the light distribution between the plant components and also of using the light more efficiently over all. Miah *et al.,* (1995) stated that agroforestry system that incorporates a range of tree and crop species offers much more scope for useful management of light interception and distribution than do monoculture forests and agricultural crops. Fruit trees are considered advantageous because of the relatively high returns to labor resulting from low labor inputs (compared with annual crops); moreover, fruit tree-based systems also offer a more uniform distribution of income throughout the year than annual crop systems. However, the relatively “free” availability of forest-based timber- and fuel wood products in some areas are seen as disincentives for growing tree species for those purposes (Hellin *et al*., 1999).

The rate and extent to which biophysical resources are captured and utilized by the components of an agroforestry system are determined by the nature and intensity of interactions between the components. The net effect of these interactions is often determined by the influence of the tree component on the other component(s) and/or on the overall system, and is expressed in terms of such quantifiable responses as soil fertility changes, microclimate modification, resource (water, nutrients, and light) availability and utilization, pest and disease incidence, and allelopathy. The paper reviews such manifestations of biophysical interactions in major simultaneous (e.g., hedgerow intercropping and trees on croplands) and sequential (e.g., planted tree fallows) agroforestry systems. In hedgerow intercropping (HI), the hedge/crop interactions are dominated by soil fertility improvement and competition for growth resources. Higher crop yields in HI than in sole cropping are noted mostly in inherently fertile soils in humid and sub-humid tropics, and are caused by large fertility improvement relative to the effects of competition. But, yield increases are rare in semiarid tropics and infertile acid soils because fertility improvement does not offset the large competitive effect of hedgerows with crops for water and/or nutrients. Whereas improved soil fertility and microclimate positively influence crop yields underneath the canopies of scattered trees in semiarid climates, intense shading caused by large, evergreen trees negatively affects the yields. Trees in boundary plantings compete with crops for above- and belowground resources, with belowground competition of trees often extending beyond their crown areas. The major biophysical interactions in improved planted fallows are improvement of soil nitrogen status and reduction of weeds in the fallow phase, and increased crop yields in the subsequent cropping phase. In such systems, the negative effects of competition and micro-climate modification are avoided in the absence of direct tree–crop interactions (Rao *et al.,* 1997).

Maize and cowpea were grown as sole stands or in agroforestry systems containing grevillea trees (*Grevillea robusta* A. Cunn.). Crop and system performance were examined over a 4.5-year-period (nine growing seasons) commencing in October 1991; failure of the rains caused the loss of one cropping season. A rotation of cowpea (*Vigna unguiculata* L.) and maize (*Zea mays* L.) was grown during the first five seasons after planting the trees, while maize was grown continuously during the final four seasons. Sole maize was also grown under spectrally neutral shade netting which reduced incident radiation by 25, 50 or 75% to establish the relative importance of shade and below-ground competition for water and nutrients in determining the performance of understorey crops. The above-ground biomass and grain yield of understorey crops were not significantly affected by the presence of grevillea during the first four seasons, but were greatly reduced in subsequent seasons as the trees became increasingly dominant; maize yields reached 50% of the sole crop values only once during the final four seasons, when rainfall was unusually high. The hypothesis that competition for water was the primary limiting factor for understorey crops was supported by the observation that above-ground biomass and grain yield were greater in the shade net treatments than in agroforestry maize, demonstrating that shade was not solely responsible for the substantial yield losses in the latter treatment. Performance ratios (ratio of values for the agroforestry system relative to sole stands) for total above-ground and trunk biomass in grevillea were initially low, reflecting the impact of competition with associated crops during tree establishment, but increased to unity within 2.5 years. Performance ratios for the understorey crops exhibited the reverse trend, initially being close to unity but approaching zero for three of the final four seasons. Performance ratios were never close to unity for both trees and crops during the same season, indicating that there was always competition for available resources irrespective of crop species or tree size. The implications for agroforestry system design and future research are discussed (Lott *et al.,* 2000).

Samsuzzaman *et al.* (2002) carried out three studies in Bangladesh to find out the effect of tree species on crops and alternative management practices for better system productivity. The first experiment revealed that the highest yield of mustard (0.788 t/ha) and rice (2.89 t /ha) was obtained under *Albizia lebbeck* trees and *Acacia nilotica*, respectively. The result of the second experiment indicated that the lower reduction in yield of adjacent crop with wider the tree spacing the result of the third experiment showed that root and shoot pruning increased the grain yield of wheat by 22%. The highest increase in the yield of rice (27%) and radish (72%) were obtained due to pruning of *Acacia nilotica* two and three times a year respectively. Pruning of *Albizia lebbeck* three times a year contributed to the highest increase in rice (50%) and radish (35%) yields. The response of different crops to the agroforestry systems was different. The performance of field crops in agroforestry systems is influenced by the tree and crop species and their compatibility, spacing between tree lines, management practices, soil and climatic factors. Teel and Buck (2002) stated that light demanding understory species may be intercropped initially to provide early returns from plantations and after canopy closure, shade tolerant species such as ginseng and goldenseal can be intercropped.

Removing atmospheric carbon (C) and storing it in the terrestrial biosphere is one of the options, which have been proposed to compensate greenhouse gas (GHG) emissions. Agricultural lands are believed to be a major potential sink and could absorb large quantities of C if trees are reintroduced to these systems and judiciously managed together with crops and/or animals. Thus, the importance of agroforestry as a land-use system is receiving wider recognition not only in terms of agricultural sustainability but also in issues related to climate change. The objective of this paper was to analyze C storage data in some tropical agroforestry systems and to discuss the role they can play in reducing the concentration of CO_2 in the atmosphere. The C sequestration potential of agroforestry systems is estimated between 12 and 228 Mg ha^{-1} with a median value of 95 Mg ha^{-1}. Therefore, based on the earth's area that is suitable for the practice (585–1215 × 10^6 ha), 1.1–2.2 Pg C could be stored in the terrestrial ecosystems over the next 50 years. Long rotation systems such as agroforests, homegardens and boundary plantings can sequester sizeable quantities of C in plant biomass and in long-lasting wood products. Soil C sequestration constitutes another realistic option achievable in many agroforestry systems. In conclusion, the potential of agroforestry for CO_2 mitigation is well recognised. However, there are a number of shortcomings that need to be emphasized. These include the uncertainties related to future shifts in global climate, land-use and land cover, the poor performance of trees and crops on substandard soils and dry environments, pests and diseases such as nematodes. In addition, more efforts are needed to improve methods for estimating C stocks and trace gas balances such as nitrous oxide (N_2O) and methane (CH_4) to determine net benefits of agroforestry on the atmosphere (Albrecht and Kandji, 2003)

Growing of trees as woodlots on farms for five to seven years in rotation with crops was considered as a potential technology to overcome the shortage of wood, which is a common problem to many parts of sub-Saharan Africa. The paper summarizes the results of trials conducted at Tabora and Shinyanga in northwestern Tanzania on rotational woodlots, to evaluate tree species for wood production and yields of maize grown in association with and after harvest of trees. On acid sandy soils at Tabora, *Acacia crassicarpa* A. Cunn. exBenth grew fast and produced 24 to 77 Mg ha^{-1} of wood in four to five years. On alkaline Vertisols at Shinyanga, seven years old woodlots of *Acacia polyacantha* Willd and *Leucaena leucocephala* (Lam.) De Wit. Produced 71 and 89 Mg ha^{-1} of wood, respectively. Intercropping of maize between trees was possible for two years without sacrificing its yield. The first maize crop following *A. crassicarpa* woodlots gave 29 to 113% greater yield than the crop after natural fallow. *Acacia polyacantha* and *L. leucocephala* woodlots also increased the subsequent maize yields over a three-year period. The increase in crop yields after woodlots was attributed partly to accumulation of greater amounts of inorganic N in the topsoil compared to the traditional fallow, and partly to other effects. Thus medium-term rotational woodlots are likely to contribute to meet the wood requirements of rural people and thereby help protect the natural woodlands in sub-Saharan Africa (Nyadzi *et al.,* 2003).

Nine major Agroforestry systems are in practice in the sub-tropical and mid-hill temperate zones of Sikkim, India. Among them only agri-horticultural (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. 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.

The influence of dispersed trees on microclimatic conditions, gas exchange and productivity of maize (*Zea mays* L.) in a *Grevillea robusta*-based agroforestry system in semi-arid Kenya was examined to test the hypothesis that the benefits of shade seen in savannah ecosystems may be outweighed by competition for below-ground resources. Meristem temperature, cumulative thermal time, intercepted radiation, spatial distribution of shade and gas exchange were determined for maize grown as sole crops, in an agroforestry system, or under shade nets providing 25 or 50% reductions in incident radiation to discriminate between effects of shade and below-ground competition. The major benefit of shade was to reduce exposure to the supra-optimal temperatures experienced in many tropical regions, and which are predicted to become increasingly common by climate change models.

However, although trees decreased photosynthetic photon flux density (*PPFD*) incident on understorey maize by *ca*. 30%, the yield reduction was much greater than in the 25% shade net treatment in four seasons providing contrasting rainfall. Maize yield was unaffected by 50% artificial shade in the driest season (168 mm) but decreased with increasing shade when rainfall was high (628 mm). Shade reduced meristem temperature and delayed flowering by 5–24 days depending on treatment and seasonal rainfall. Thermal time to flowering in the agroforestry system doubled from 600 to 1200 °C day as rainfall decreased. Photosynthetic and transpiration rates for understorey maize were similar to the 25 and 50% shade treatments when rainfall was high, but were *ca*. 10% of those for unshaded sole maize in dry seasons. *PPFD*-saturated photosynthetic rate was initially similar in all treatments but fell sharply in the agroforestry system as the season progressed. Radiation conversion coefficients did not differ between unshaded sole and understorey maize. The results suggest that the ameliorative influence of tree shade was greater in low rainfall seasons, as in savannah systems, but that potential benefits were outweighed by below-ground competition. This may be managed by root-pruning trees. (Lott *et al.,* 2009).

The many benefits of agroforestry are well-documented, from ecological functions such as biodiversity conservation and water quality improvement, to cultural functions including aesthetic value. In North American agroforestry, however, little emphasis has been placed on production capacity of the woody plants themselves, taking into account their ability to transform portions of the landscape from annual monoculture systems to diversified perennial systems capable of producing fruits, nuts, and timber products. In this paper, we introduce the concept of multifunctional woody polycultures (MWPs) and consider the design of long-term experimental trials for supporting research on agroforestry emphasizing tree crops. Critical aspects of long-term agroforestry experiments are summarized, and two existing well-documented research sites are presented as case studies. A new long-term agroforestry trial at the University of Illinois, "Agroforestry for Food," is introduced as an experiment designed to test the performance of increasingly complex woody plant combinations in an alley cropping system with productive tree crops. This trial intends to address important themes of food security, climate change, multifunctionality, and applied solutions. The challenges of establishing, maintaining, and funding long-term agroforestry research trials are discussed (Lovell *et al.,* 2017).

U.S. agricultural and rural communities face ongoing challenges including profitability and environmental stresses that threaten the livelihoods and well-being of many who work the land and/or live in rural areas. Ongoing concerns exist regarding the sustainability of small family farms. Using sustainable agricultural practices and promoting locally produced specialty crops will provide new opportunities for small farms to be both profitable and environmentally sustainable. Specialty nut crops and Non-Timber Forest Products crops (e.g. eastern black walnut, elderberry, log-grown shiitake mushrooms, ginseng) produced in perennial polycultures (e.g. agroforestry systems, AFS) offer opportunities to introduce environmentally, economically and socially sustainable agricultural systems that create new opportunities for farmers, ranchers, forest landowners, and families in rural communities. An integrated, long-term approach involving cultivar selection and breeding, field production techniques, market and consumer studies, sound financial decision support tools and grower training is needed to bring specialty crops into the sustainable agriculture mainstream. This chapter summarizes recent research carried by the University of Missouri Center for Agroforestry (UMCA) on specialty crops, focusing on edible tree nuts (chestnuts and black walnuts), fruits and berries (elderberry), and other potential specialty crops (Mori *et al.,* 2017).

Two contour hedgerow (*Gliricidia sepium* and *Leucaena leucocephala*) systems with and without miniature trenches were evaluated as conservation measures in the shifting cultivated degraded Eastern Ghats Highlands of Odisha, India. Staggered planting of hedgerows at 0.5 × 0.5 m spacing in two parallel lines with miniature trenches (0.3 m width and 0.3 m depth) in between two lines were laid out across 5 and 10 % slopes. The treatment *Gliricidia* + miniature trench (G + MT) reduced runoff by 23.3–32.5 %, soil loss by 49.5–52.7 %, loss of soil organic carbon (SOC), N, P, and K by 44.1–47.6, 61.5–62.2, 54.8–58.1, and 53.1–56.3 %, respectively, over no conservation treatment (control), whereas the same for the treatment *Leucaena* + miniature trench (L + MT) was 18.6–18.9, 42.4–43.7, 30.9–40.2, 41.9–56.3, 47.3–47.9, and 38.5–47.8 %, respectively, over control. Within 0–20 cm soil profile, G + MT sequestered 1.62 Mg ha^{-1} $year^{-1}$ SOC, of which 0.93 Mg ha^{-1} $year^{-1}$ was sequestered due to soil reclamation and 0.69 Mg ha^{-1} $year^{-1}$ was retained due to the barrier effect, whereas L + MT sequestered 1.21 Mg ha^{-1} $year^{-1}$ SOC. The trench treatments with *Gliricidia* and *Leucaena* hedgerows were 3.8–4.7 and 3.7–5.3 % more efficient to stock SOC within 40 cm soil profile than no trench treatment. The decrease of SOC stock by 40–102 kg ha^{-1} $year^{-1}$ in the control plots from the initial level indicated the ongoing erosion process in unprotected lands. The findings will help to promote hedgerow based agroforestry for resource conservation and improved SOC sequestration in sloping lands (Adhikary *et al.,* 2017).

According to Sida*et al.,* (2018) *Faidherbia albida* parklands cover a large area of the Sudano-Sahelian zone of Africa, a region that suffers from soil fertility decline, food insecurity and climate change. The parklands deliver multiple benefits, including fuel wood, soil nutrient replenishment, moisture conservation, and improved crop yield underneath the canopy. Its microclimate modification may provide an affordable climate adaptation strategy which needs to be explored. We carried out an on-farm experiment for three consecutive seasons in the Ethiopian Central Rift Valley with treatments of *Faidherbia* trees with bare soil underneath, wheat grown beneath *Faidherbia* and wheat grown in open fields. We tested the sensitivity of wheat yield to tree-mediated variables of photosynthetically active radiation (PAR), air temperature and soil nitrogen, using APSIM-wheat model. Results showed that soil moisture in the sub-soil was the least for wheat with tree, intermediate for sole tree and the highest for open field. Presence of trees resulted in 35–55% larger available N close to tree crowns compared with sole wheat. Trees significantly reduced PAR reaching the canopy of wheat growing underneath to optimum levels. Midday air temperature was about 6 °C less under the trees than in the open fields. LAI, number of grains spike^{-1}, plant height, total aboveground biomass and wheat grain yield were all significantly higher ($P < 0.001$) for wheat associated with *F. albida* compared with sole wheat. Model-based sensitivity analysis showed that under moderate to high rates of N, wheat yield responded positively to a decrease in temperature caused by *F. albida* shade. Thus, *F. albida* trees increase soil mineral N, wheat water use efficiency and reduce heat stress, increasing yield significantly. With heat and moisture stress likely to be more prevalent in the face of climate change, *F. albida*, with its impact on microclimate modification, maybe a starting point to design more resilient and climate-smart farming systems.

2.6 Importance of organic manure

Manure is often added to stabilise anaerobic digesters especially when co-digesting high energy substrates such as whey. While different researchers have attributed its beneficial effect to various components including alkalinity, nutrients or trace elements this research instead aimed to determine whether microorganisms, such as lactic acid bacteria which are naturally present in the feedstocks, were having a notable beneficial effect on biogas production. Casein whey and cow manure were co-digested with primary sludge and produced 151.1% biogas compared to the control reactor digesting primary sludge alone. It was found that targeting the microorganisms in the manure via autoclaving decreased reactor performance to only 112.8% compared to the control potentially indicating that the manure is providing a probiotic effect. It was also found that storing casein whey (which is needed to balance out its seasonal production peaks) produces microorganisms that play a similarly important role as evidenced by the decrease in performance from 151.1% to 112.9% when they were removed via filtration (Brown *et al.,* 2018).

Biofuel crops are gaining importance because of the need to replace non-renewable sources. Also, due to the increasing amounts of wastes generated, there is the need to recycle them to the soil, both to fertilize crops and to improve soil physical properties through organic matter increase and microbiological changes in the rhizosphere. We therefore studied the influence of six biofuel crops (elephant grass, giant cane, sugarcane, blue gum, black cottonwood, willow) on the decomposition rate and enzymatic activity of composted municipal solid waste and poultry manure. Organic amendments were incubated in the field (litterbag method), buried near each plant or bare soil. Biomass decrease and dehydrogenase, urease and acid phosphatase level in amendments was monitored over a 180-day period. Soil under the litterbags was analyzed for the same enzymatic activity and organic matter fractions (last sampling). After 365 days, a fractionation of organic matter was carried out in both amendments and soil under the litterbags (Cordovil *et al.,* 2017).

Urban farmers in Harare grow vegetables in soils fertilized with poultry manure (PM) and sewage sludge (SS). Feed and storage management influence nutrient supply of these organic amendments. Nitrogen mineralization of PM and SS were determined in a non-leaching and aerobic incubation experiment. Effects of these amendments on yield, nitrogen (N) and heavy metal uptake by vegetables grown in soils treated with 150 kg N ha^{-1} from compound mineral fertilizer (7 N:14 P_2O_5:7 K_2O), PM (2.26% N) and SS (3.26% N) were studied. Phosphorus (P) and potassium (K) were added at rates of 50 kg P ha^{-1} and 60 kg K ha^{-1}, respectively. A second crop was grown without adding amendments. Poultry manure mineralized faster than SS. Yield was significantly higher ($p < 0.05$) in mineral fertilizer amended soil for the first crop whilst organic amendments resulted in significantly higher yield in the second crop. First-crop nitrogen uptake increased by 53% and 100% *(Brassica napus*), 92% and 158% (*Brassica juncea*) over the control for SS and PM, respectively. Zinc, copper, cadmium and nickel uptake was higher with SS than in the other treatments and their concentrations were lower than European Union permissible limits. Poultry manure can be used in place of mineral fertilizer, whilst SS requires early or supplementary application of mineral N for early plant growth (Nyamasoka *et al.,* 2017).

Maize crop is a key source of food and livelihood for millions of people in many countries of the world. However, its productivity is highly constrained in the humid ultisols environment owing to low soil fertility status among other factors. This experiment was conducted at the Experimental Farm, Faculty of Agriculture, University of Benin, Benin City, Nigeria between the period of May and August, 2014 and repeated during the period in 2015 to evaluate the effect of different animal manures on the growth and yield of maize (*Zea mays* L.). The trial involved five treatments (control, rabbit manure, goat manure, poultry manure and cattle manure) laid out in randomized complete block design and replicated three times. All manures were applied at 300 kg N ha^{-1}.Data were collected on plant height, stem girth, number of leaves, leaf area index and total dry matter at 50 % tasseling day. Data were also collected on yield and yield components of maize. Results showed The application of animal manures significantly ($P<0.5$) increase plant height, leaf area index, number of leaves, total dry matter, ear length and grain yield Over control. The highest ear yield (11.61 t ha^{-1}) and grain yield (5.77 t ha^{-1}) was observed in plots treated with rabbit manure compared to the lowest ear and grain yields (7.05 and 3.66 t ha^{-1} respectively) from control. However, rabbit manure treated plants were not significantly superior to other manures. It is suggested that poultry manure adopted by maize growers for high productivity of maize under intense and continuous cropping of humid ultisols location due to ease of availability, collection and high nutrient composition (Law-Ogbomo *et al.,* 2018).

Alum [$KAl(SO_4)_2 \cdot 12H_2O$] is often added to chicken manure to limit P solubility after land application. This is generally ascribed to the formation of Al-PO_4 complexes. However, Al-PO_4 complex formation could be affected by the matrix of chicken manure, which varies with animal diet. Alum was added to KH_2PO_4 (as a reference material) and two manures from typical chicken farms in China, one from an intensive farm (CMIF) and another from free-ranging chickens (CMFR). These were subsequently incubated with soils for 100 d to investigate P transformations. Alum reduced water-soluble colorimetrically reactive phosphorus (RP) from soils amended with manure more effectively than in soils amended with KH_2PO_4. Alum addition lowered Mehlich-3 RP in soils with CMFR but had no influence on Mehlich-3 RP in CMIF- or KH_2PO_4–amended soils. A comparison of P in digested Mehlich-3 extracts with RP in undigested samples showed significantly increased P in digests of alum-treated CMFR only. Fractionation data indicated that alum treatment increased P in the NH_4F-RP (Al-P) fraction only in soils with KH_2PO_4, but not in soils with manure treatments. Furthermore, NaOH-extracted nonreactive P was markedly higher in soil with alum-treated CMFR relative to normal CMFR. The CMFR manure was assumed to contain higher concentrations of organic P because these chickens were fed grains only. These results suggest that the formation of alum-organic P complexes may reduce P solubility. By comparing alum-treated KH_2PO_4 and manures, it appears that organic matter in manure could interfere with the formation of Al-PO_4 complexes (Huang *et al.,* 2018).

Gangadhar *et al.,* (2017) conducted a 90 day experiment in out-door, soil-based (10 cm), cement tanks to evaluate the effect of three manures viz. cattle dung, poultry manure and press mud provided at iso-nitrogenous levels, on the growth and nutrient composition of periphyton grown on sugarcane bagasse. Water quality analysis revealed that tanks applied with cattle dung recorded lower ($P>0.05$) pH and those with poultry manure showed higher ($P>0.05$) phosphate content. Total pigment content and biomass of periphyton (dry matter) and plankton (dry weight) showed higher values in poultry manure treatment. Press mud treatment recorded lower plankton dry matter. Crude protein and fat contents were higher ($P<0.05$) in periphyton from poultry manure treatment. Other proximate composition parameters showed no difference ($P>0.05$) among periphyton from different treatments. The proximate composition of plankton also showed higher crude protein, fiber and ash values in poultry manure. The study revealed that poultry manure is superior to cattle dung and press mud, considering the total pigment content, biomass and crude protein content of periphyton and plankton biomass.

For years, anaerobic digestion processes have been implemented for the management of organic wastes, agricultural residues, and animal manure. Wet anaerobic digestion still represents the most common technology, while dry fermentation, dedicated to the treatment of solid inputs (TS > 20%) can be considered as an emerging technology, not in terms of technological maturity, but of diffusion. The first agricultural dry anaerobic digestion plant constructed in Italy was monitored from the start-up, for over a year. The plant was fed with manure and agricultural products, such as corn silage, triticale, ryegrass, alfalfa, and straw. Three Combined Heat and Power units, for a total installed power of 910 kW_e, converted biogas into thermal and electric energy. The monitoring included the determination of quality and quantity of input feedstocks, of digestate (including recirculation rate), of leachate, biogas quality (CH_4, CO_2, H_2S), biogas yield, energy production, labor requirement for loading, and unloading operations. The results of the monitoring were compared to performance data obtained in several full scale wet digestion plants. The dry fermentation plant revealed a start-up phase that lasted several months, during which the average power resulted in 641 kW_e (70.4% of nominal power), and the last period the power resulted in 788 kW_e (86.6% of installed power). Improving the balance of the input, the dry fermentation process demonstrated biogas yields similar to wet anaerobic digestion, congruent to the energy potential of the biomasses used in the process. Furthermore, the operation of the plant required significant man labor, mainly related to loading and unloading of the anaerobic cells (Chiumenti *et al.,* 2018).

Biogas slurry, a by-product of biogas production generated from anaerobic digestion of animal waste and crop residues, is often considered a waste product. Being a cheap source of organic matter and plant nutrients, its application may improve soil fertility, and yield quality and quantity. Field experiments were conducted at Lahirirhat Farming System Research and Development site, Rangpur, Bangladesh, to assess effects of biogas slurry in combination with synthetic fertilizer on tomato (*Solanumlyco persicum* L.) yield and profitability. Treatments included: soil test-based fertilizer, synthetic fertilizer+cow dung manure @ 5 t•ha^{-1}, synthetic fertilizer+cow dung bioslurry @ 5 t•ha^{-1}, synthetic fertilizer + poultry manure @ 3 t•ha^{-1}, synthetic fertilizer + poultrybioslurry @ 3 t•ha^{-1}, and farmer practice. Fruit yield was higher for plants grown with synthetic fertilizer+cow dung bioslurry compared with other fertilizer treatments and the farmer practice. Application of synthetic fertilizer+ poultrybioslurry resulted in the highest fruit yield; plants maintained with the farmer practice yielded the least. The highest gross return and gross margin were obtained from plants treated with synthetic fertilizer+cow dung bioslurry. Synthetic fertilizer+ poultrybioslurry treated plants returned the highest gross return and gross margin. Application of synthetic fertilizer in combination with bioslurry has potential in increasing tomato yield and economic return of farmers (Ferdous *et al.,* 2018).

According to Koffi *et al.,* (2018) ‘’Animal wastes may be promoted as an alternative to mineral fertilizers that remain unaffordable to the overwhelming part of smallholder farmers in Sub-saharan Africa. However for an efficient use, mechanisms that underly their impact on crops should be well understood. This study was conducted in mesocosm to evaluate impacts of two ways of composted poultry litter (CPL) addition on growth and nutrient use efficiency by cucumber. It included three treatments with five-bucket replicates each: Control, CPL applied on soil surface (CS) or buried to 10 cm-depth (CB). Dry CPL was added at the rate of 0.5 kg bucket^{-1}. At harvest, root distribution was examined in the 0-5, 5-10 and 10-20 cm depths. Dry biomasses of roots, shoot and fruits were also determined and allowed for calculation of diverse indexes of biomass allocation (root: shoot ratio, root weight ratio, stem weight ratio, leaf weight ratio) and nutrient use efficiency (factor productivity of the compost, partial factor productivity of nutrients, agronomic efficiency of compost, and apparent agronomic efficiency of nutrients). The results showed that application of CPL led to a significant improvement of all considered parameters except for the leaf weight ratio which was higher in the control (44.1±3.3) than in CS (28.1±1.9) and CB 31.2±3.5). Total lateral root length was significantly higher in CS than in CB (113.5±10.7 cm *vs.* 75.5±9.0 cm). The number of lateral roots per plant in the 0-5 cm soil layer was higher in CS than in CB (5.4 *vs.* 1 root plant^{-1}); the reverse was observed in 5-10 cm (1.2 *vs.* 4.4 root plant^{-1}). Both fresh fruit yield and total dry mass were positively correlated to root attributes. These were themselves negatively impacted by soil acidity. All nutrient use efficiency indexes were higher in CS than CB. The CPL improved the agronomic performance of cucumber particularly when applied at soil surface.''

Vegetable waste is one of the major organic residues available for sustainable bio-energy production. The aim of this work is to study the influence of pH-value on process stability, hydrolysis, and degradation degree and methane production in two-stage anaerobic system. A mixture of vegetable wastes with carrot mousse, carrots, celery, cabbage and potatoes was treated in two-stage system at target pH-values 5.5 and 6 in acidification reactor (AR). At pH 6, high concentrations of organic acids were recorded whereas high amount of hydrolysate was produced at pH 5.5. The chemical oxygen demand (COD) concentration in the hydrolysate produced in AR was 21.85% higher at pH 6 compared to pH 5.5, whereas the overall specific methane yield was slightly higher at pH 5.5 (354.35 ± 31.95 and 326.79 ± 41.42 L kg^{-1}oDM, respectively). It could be shown, that the described two-stage system is well suited for manure-free digestion of vegetable waste (Ravi *et al.,* 2018).

A field experiment was conducted on a deep Vertisol of Bhopal, India to compare root and shoot biomass, chlorophyll content, enzyme activity and nodulation in three cropping systems at three combinations of organic manure and inorganic-fertilizer: 75%NPK + 5 t farmyard manure (FYM), 75%NPK + 1.5 t poultry manure (PM), and 75%NPK + 5 t phosphor compost (PC) vis-a-vis 0%, 75% and 100% of fertilizer-NPK. In general, nodule number and its mass were lower in intercrop soybean than sole soybean. Also there was decrease in the nodule number with higher NPK dose. The FYM treated plots recorded 22.0% and 7.6% higher nodule mass than poultry manure and phosphor compost plots, respectively. Also, the total chlorophyll content was higher in organically treated plots than that in 100% NPK particularly at 30 days after sowing (DAS, pre-flowering). In sorghum the peak nitrate reductase (NR) activity was recorded at 60 DAS while in soybean it was at 30 DAS. The NR activity was higher in intercrop sorghum than that in sole sorghum. Maximum NR activity was observed in 100% NPK. Soybean/sorghum intercropping system recorded significantly higher roots and shoots biomass than sole soybean and sorghum. The crop growth rates were relatively rapid during 30–60 DAS and followed the order; intercropping > sole sorghum > sole soybean. With the increase in NPK dose from 0% to 100% there was significant improvement in the dry matter (DM) production in sole sorghum and soybean/sorghum intercropping system. Soybean as preceding crop recorded the highest DM, chlorophyll content, NR activity in wheat while these values were the lowest in sorghum–wheat system (Ghosh *et al.,* 2004).

2.7 Importance of studied Cauliflower

Cauliflower is grown for its fleshy immature inflorescence which is known as curd. Cauliflower occupies the pride position among cole crops due to its delicious taste, flavour and nutritive value. It enjoys first position among the different cole crops cultivated all over the world (Saravaiya and Patel, 2005).

Cauliflower was considered as a temperate crop when snowball types only were available. With the development of tropical Indian cauliflower, it became possible to cultivate in tropics and throughout the year in North Indian plains (Gopalakrishnan, 2007). Now-a-days, with advances in breeding programme, a number of varieties suitable for different temperature ranges have been developed. This genotypic variation has made cultivation of cauliflower possible over a range of climatic conditions. It is therefore important to choose the appropriate variety with respect to climatic condition to enable curd formation. But compared to other vegetables, hybrids are very popular in cool season crops due to their high yield, uniform maturity, earliness and wider adaptability (Pradeepkumar and George, 2009).

Cauliflower was first introduced to India from England in 1822. Within a period of one hundred years, these introduced varieties underwent selection by local growers when seed production was attempted by them in North Indian plains. Selections were made for early maturity and wider adaptability to hot and humid conditions. These types are commonly known as Indian or tropical cauliflowers which are good for early sowing and early harvest (ICAR, 2004).

The development of tropical varieties of cauliflower at IARI, New Delhi, enhanced the spreading of its cultivation to non-traditional areas of Karnataka and Tamil Nadu (Pradeepkumar *et al.,* 2002). Some cauliflower cultivars initiate curd formation at about the same rate whether they are grown under cool or very warm weather conditions. Other cultivars require more than twice as long a time to form curds under high - temperature conditions than under cool or moderate temperatures. The delay or retardation of curd formation is the result of lack of sufficient growing time during which the temperature is below a critical value. This critical temperature appears to vary with different cultivars (Liptay, 1981).

Wurr *et al.,* (1988) based on experiments conducted at Wellesbourne, reported that cauliflower plants showed maximum rate of vernalization between 5°C and 17°C and at temperatures lower and higher than this range, reduced vernalization rates were observed which resulted in large variation in the mean number of leaves formed at the time of curd initiation which ranged between 22 and 36.7 leaves. Fujime and Hirose (1980) investigated the effects of diurnal variation of temperature on curd formation of cauliflower by growing under low temperature during one part of the day and high temperature. Selection of optimum planting time and proper nutrient sources have direct bearing on the economic viability of the production system and may bring higher return from off-season cauliflower. Significant role of planting dates on the performance of vegetables have been reported by different researchers (Pandey, 2007; Dilruba *et al.,* 2009; Gautam *et al.,* 2006).

2.8 Importance of light, shade and temperature on cauliflower cultivation

Wheeler *et al.,* (1995) reported that Radiation conversion coefficient in cauliflower is found to be higher at elevated CO_2 levels and it increased by 42% at 531µmol mol-1 CO2 concentration but decreased slightly with increase in temperature. Olesen and Grevsen (1997) reported that radiation conversion coefficient appeared to be largely unaffected by temperatures above 14°C, but it declined with increase in irradiance. They also reported that in high irradiance treatments, reductions in leaf area expansion rate and dry matter production rate were observed in cauliflower and broccoli.

In an experiment conducted at Lombok, Indonesia to determine whether tropical cauliflower cv. Milky was able to produce curds in the high, non-inducing temperatures of the lowland tropics, Jaya *et al.,* (2002) observed that the high temperature and irradiance during the curd growth phase resulted in poor quality curds. Rahman *et al.,* (2007), based on their experiment done at UK reported that leaf area, stem length, fresh and dry weights of leaf and stem at four weeks after curd initiation were significantly higher in high incident radiation conditions during summer than in the low incident radiation conditions during winter. Curd growth parameters like curd length, diameter, fresh and dry weights were also significantly higher in the high incident radiation conditions compared to low incident radiation conditions. But the curd dry matter accumulation was more efficient under low radiation levels compared to high radiation levels.

Rahman *et al.* (2007) found out a clear positive linear relationship between the accumulated incident radiation integral and logarithm of plant dry weight. Similar relationship was also observed in curd dry matter accumulation. Radiation conversion coefficients for both plant and curd of cauliflower were observed to be higher under lower incident radiation levels than higher radiation levels. Thus they indicated that the rate of increase per unit incident radiation integral is greater under lower radiation conditions.

Masarirambi *et al.,* (2011) reported that direct exposure to sunlight resulted in the development of yellow pigments on curds. Curds left uncovered will discolour due to activation of peroxidise enzyme by sunlight and curd will loosen in the sun's heat. Chatterjee and Kabir (2002) reported that high relative humidity induced riciness in some cultivars of cauliflower.

Cauliflower performed better at the humid region in terms of curd circumference and compactness. Ajithkumar (2005) based on the experiment conducted at Anand, Gujarat, reported that the number of days taken for the completion of juvenile phase showed significant negative correlation with forenoon relative humidity. In a pre-transplanting light treatment experiment, Khan and Holliday (1968) observed that increasing natural daylight from 8 to 12 hours suppressed the leaf number as well as the dry matter yield of the curd per plant.

Cauliflower varieties are classified based on optimum temperature for curd initiation and availability period viz, early (20-27ºC and September-

October), mid-early (20-25ºC and October-November), mid-late (16-18 ºC and November-December), and late (12-16 ºC and December-January) even there are sub groups within each group (Thamburaj and Sing, 1998). Bose and Som (1986) stated that the optimum average temperature for curd formation is 17 ºC and the early cultivars or lines form curds at 20-25 ºC and late cultivars or lines form at around 10 ºC. With the development of tropical Bangladeshi cauliflowers and introduction of F1hybrids by Japanese seed companies in addition to the temperate or Snowball type, it has been now become possible to grow cauliflower almost throughout the year particularly in the northern and central part of Bangladesh. These F1 hybrids are high yielder and more adaptive to the cultivation of wide range of climatic condition.

Wheeler *et al.,*(1995) observed the canopy light extinction coefficient of cauliflower as 0.4 which may be associated with a slightly erect leaf inclination. According to Olesen and Grevsen (1997), canopy light extinction coefficient is 0.55 for cauliflower and 0.45 for broccoli. The lower extinction coefficient in broccoli compared to cauliflower was because of the presence of more erect leaves and there was no significant influence of irradiance was detected. Phuwiwat (2000) carried out a study in Thailand to determine the growth and yield of net house grown cauliflower under three shade levels and reported that cauliflower plants exhibited adaptation to the reduced light by increasing plant height, leaf area per plant and the leaf chlorophyll content.

Alt *et al.,* (2001) reported that shaded cauliflower plants had higher stem to leaf ratios than non-shaded plants. Rahman *et al.,* (2007) reported that growth and development of cauliflower after curd initiation declined with increasing shade levels. Leaf area and leaf dry weight were reduced progressively with increasing shade levels both during autumn and summer plantings and these reductions were found to be consistent throughout the growing period after curd initiation. Curd growth also followed the same pattern. Decrease in stem dry weight was found to be twice under higher incident radiation integral during summer than that under low radiation integral during autumn.

2.9 Performance of cauliflower under mango tree

Agroforestry is a land use system, which contributes pragmatically offers not only a sustained productivity, but also its sustainability over the longer period. Through this present study we introduce a new strategy through Agro-Horti cropping system in New-Alluvial zone where traditional monocropping practices is neither providing a gainful employment opportunity, nor it generates sufficient income to meet the day-to-day expenditure of a family. To find out suitable Agro-Horti model, field experimental was conducted at Horticultural Research Station, Mandouri, B.C.K.V. Nadia. The fruit plants were planted at a spacing of 10m × 10m And the gross plot size was around 7500 m^2.This alternative Agri+Horti system includes five intercrops, namely rice, mustard, lentil, cauliflower and wheat. As a kharif crop, we planted upland paddy followed by lentil along with a fruit crop of mango. In addition, cauliflower, mustard and wheat were sowed as rabi crops in the vicinity of the mango tree for the year 2014-15, 2015-16. Experimental results revealed an increasing rate of farmer's income in addition to the improvement of the soil health compared to the previous monocropping system. In case of sole Mango cropping the income was 1, 65, 600. The maximum gross income was recorded when mango was intercropped with cauliflower (rabi crop) and it fetched a total return around Rs. 3,52,995followed by mango intercropped with lentil i.e. about Rs. 2,49,448. Fruit based Agri-Horti system not only increased the total return but also built up the soil health in term of the increase of the soil OC, pH and available N, P, K etc. Therefore, present study recommend an alternative Agri-horti intercropping systems for the better livelihood, income and sustaining soil-health over the New alluvial zone of West Bengal.(Mondal *et al.,* 2017).

An experiment was conducted to investigate the effects of intercrops on the yield of mango cultivar 'Dashehari' with the aim to maximize the production potential and economic returns from mango-based intercropping systems (mono and companion) at the Central Institute for Subtropical Horticulture, Lucknow. The treatments under mono-intercropping system were mango alone (control), mango+ brinjal ('Rajni'), mango+ bottlegourd ('Varad'), mango+ cauliflower ('Girja') and mango+ cabbage ('Indam 296') under companion intercropping system. On the basis of the season of cultivation, the intercrops brinjal and bottle gourd were transplanted during March 2010 and cabbage, cauliflower and bottle gourd during November 2010. Cultivation of brinjal as an intercrop in mango orchard recorded significantly highest yield (19.38 t/ha) followed by bottle gourd (13.54 t/ha) than the other intercropping systems. The lowest yield (8.50 t/ha) was recorded with cabbage as an intercrop. Intercropping of brinjal also proved beneficial for increasing the yield (4.55 t/ha) of mango by 8.6% compared to control. The nutritional level of soil in different crop combination also varied with decreasing levels of organic carbon, K, Zn, Cu, manganese and Fe along with elevating the level of these nutrients in cauliflower, cabbage and brinjal crop combination respectively. The highest monetary return (Rs. 160300/ha) was obtained with brinjal in mango orchard as compared to Rs. 49920/ha in mango sole crop. Intercropping was effective in sustaining income and employment generation especially during the pre-production phase and "off" year especially for small and marginal farmers. Thus, intercropping in mango orchards can help farmers for year round production, employment, reduced cost of cultivation and increase monetary returns besides providing nutritional security (Singh *et al.,* 2011).

The economic analysis of the intercropping investigation provide an evidence on the need for generalization of the intercropping between dwarf mango trees cauliflower crops for increasing the net income, soil use efficiency and food security via increasing the agricultural production of area unit. The cost of producing the cauliflower crops under the net cover is less than the open field regarding to the high cost of insecticides program under the open field condition. These results agreed with George and Jeruto (2010) who mentioned the advantages of intercropping are risk minimization, effective use of available resources, efficient use of labour, increased crop productivity, erosion control and food security (Jodha1979,Bekunda and Woomer, 1996, 1999, Owuor *et al.,* 2002).

CHAPTER 3

MATERIALS AND METHODS

This chapter deals with the materials and methods used in conducting the experiment. The brief description of location of the experimental site, soil, climate, materials used and methodology followed in the experiment are described here. The details are described below:

3.1 Location

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

3.2 Soil characteristics

The experimental plot was situated in a medium high land belonging to the old Himalayan Piedment Plain area (AEZ 01). Land was well-drained as drainage system was well developed. The soil texture was sandy loam in nature. The soil pH was 6.1 found in the field. The detailed soil properties are presented in Appendix- I.

3.3 Climate

The experimental site was situated in the sub-tropical region characterized by heavy rainfall during the months from May to September and scanty rainfall in the rest period of the year. Comparatively low temperature and plenty of sunshine characterize rabi season. Details of the metrological data of average maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (15 October 2016 to March 2017) are included in the Appendix-II.

3.4 Experimental period

Duration of the experiential period was from October 2016 to February 2017.

3.5 Seedling growing of test crop

Seeds of the three varieties of cauliflower were collected from Bangladesh Agricultural Development Corporation (BADC), Naishipur, Dinajpur. Then seedlings were produced at the research farm of the department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur.

3.6 Experimental design

The experiment was laid out following a two factorial Randomized Complete Block Design (RCBD) with three replications. Total numbers of experimental plot were 36. The size of each unit plot was 1.5m × 2m.

3.7 Experimental treatments

The experiment consisted of two factors;

Factor A: (Three cauliflower varieties)

V_1= Aksel

V_2= Snowball-1

V_3= Maghi

Factor B: (Fertilizer & manure application)

F_1= No fertilizer

F_2= Chemical fertilizer

F_3= Cow dung

F_4= Poultry

Treatments combinations:

V_1F_1= Aksel + No fertilizer

V_1F_2= Aksel + Chemical fertilizer

V_1F_3= Aksel + Cowdung

V_1F_4= Aksel + Poultry

V_2F_1= Snowball-1 + No fertilizer

V_2F_2= Snowball-1 + Chemical fertilizer

V_2F_3= Snowball-1 + Cow dung

V_2F_4= Snowball-1 + Poultry

V_3F_1= Maghi + No fertilizer

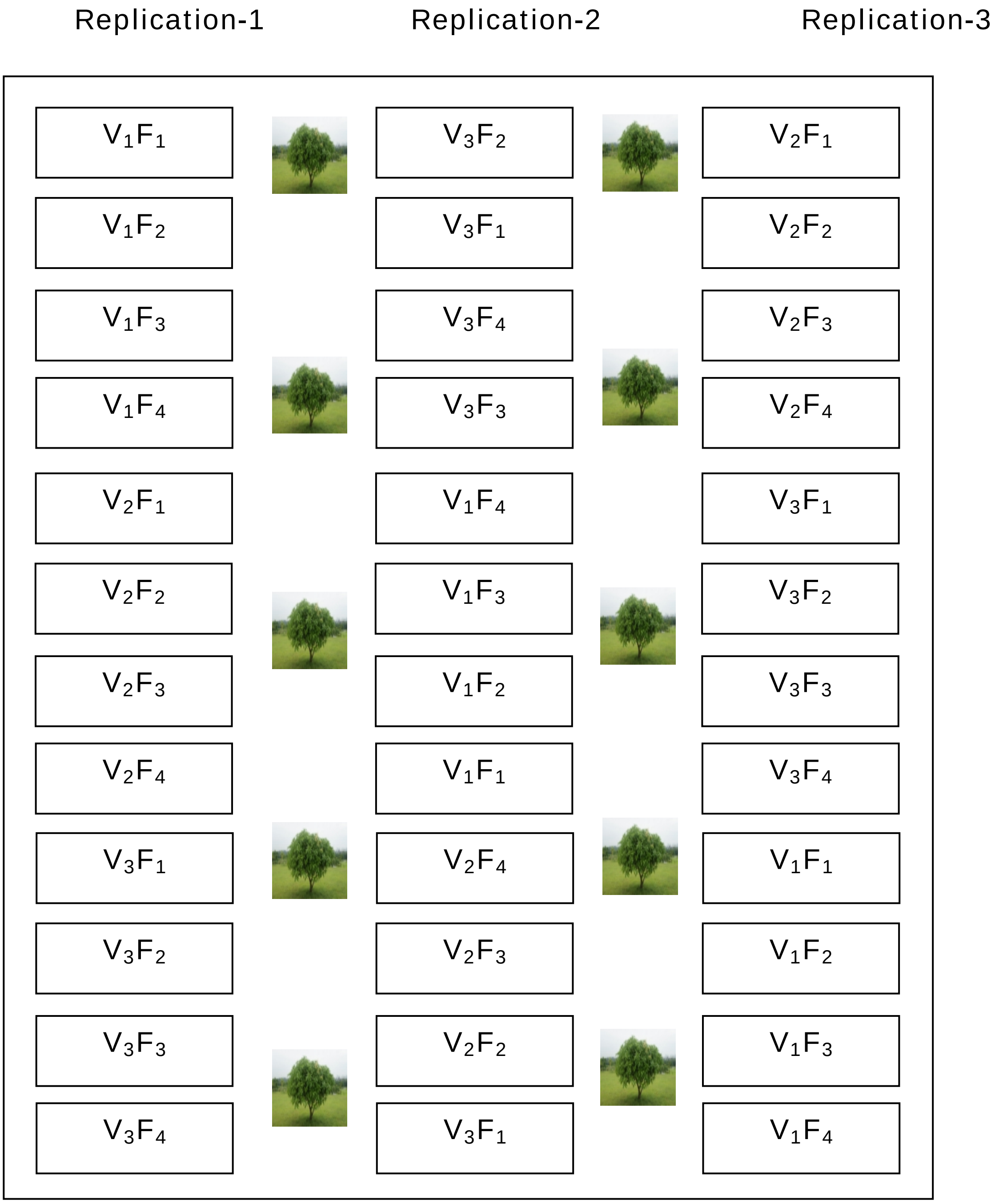
V_3F_2= Maghi + Chemical fertilizer

V_3F_3= Maghi + Cow dung

V_3F_4= Maghi + Poultry

3.8 Land preparation and layout

The land of experimental plot was opened with a spade on 15 October 2016. The land was spaded several times followed by hammering to obtain good tilth. All the weeds and other major rubbishes were removed from the field and left for several days for natural weathering before the final land preparation for seedling transplantation.



Note. Plant to plant distance 60cm, line to line 40cm and plot size 1.5 m × 2m

Figure 1: Layout of treatment combinations under mango tree

3.9 Application of fertilizers and manure

The following fertilizer and manure doses were applied in the field according to recommended doses as Fertilizer Recommended Guide (2014)

Types of Fertilizer	Recommended dose per ha
Urea	180 kg
TSP	100 kg
MOP	70 kg
Cowdung	10 ton/ha
Poultry	5 ton/ha

One-third of urea and entire amount of other fertilizers were applied as basal dose at the time of final land preparation in the plots where chemical fertilizer applied. The manures like cowdung and poultry as per the treatments were applied during land preparation. The individual land was spaded and incorporated before seedling transplanting. The remaining two-third of urea was top dressed in to equal splits at early tillering stages after weeding followed by irrigation.

3.10 Plant characteristics

Local name: Am

Scientific name: *Mangifera indica L.*

Family: Anacardiaceae (cashew family)

Variety: Amropali

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

Amropali is one of the finest Indian mango varieties. It is a quick growing mango variety. Fruits are very attractive, medium and elongated in shape. The test is superb with an excellent sugar acid blend.

The existing plant growth status was:

- Planting orientation : North-South
- Mango variety : Amropali
- Age of mango tree : 7 years
- Spacing : 6m × 6m
- Average plant height : 6.11m,
- Average basal diameter : 13.06cm
- Average canopy diameter : 255.6cm

Main agroforestry uses: Home gardens, silvopasture, agrosilviculture.

Importance:

Mango is a shade-bearer tree. It witstands normal frosts but suffers both from severe droughts to frosts. Temperature above 45^0c with strong winds damage the fruit, requiring wind breaks around the orchard. Large trees withstand fire well. It is easily killed by girdling.

Health benefits of mango:

- Mango is one of the major source of vit.-A in Bangladesh. Most of the people eat it easily from their home garden.
- Mango, like citrus fruits, is an excellent source of vitamin C; 100 g fresh fruits provide 71.5 mg or 119% of daily-recommended value. Studies suggest that consumption of fruits rich in vitamin C helps the human body develop resistance against infectious agents and scavenge harmful, pro-inflammatory
- Mango fruit contains 70 calories per 100g, comparable to that in the table-grapes. It has no saturated fats or cholesterol, but composes of good amounts of dietary fiber, vitamins, and antioxidants etc
- Research studies suggest that oligonol, a low molecular weight polyphenol, is found abundantly in mango fruit. Oligonol is thought to have anti-oxidant and anti-influenza virus actions. In addition, it helps improve blood flow in organs, reduce weight, and protect skin from harmful UV rays.
- Further, it is a very good source of B-complex vitamins such as thiamin, niacin, and folates. These vitamins are essential since they function by acting as co-factors to help the body metabolize carbohydrates, protein, and fats.

Yields: Typically, yields are often less that 5 mt/ha (2.23 t/ac) but can reach 20-30mt/ha; single trees can produce 200-300 kg (440-660 lb) of fruit in heavy cropping years and as low as 4 kg in bad years.

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

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

3.11 Intercultural operations

The following intercultural operations were accomplished for better growth and development of the plants during the period of the experiment.

Weeding

The experimental plots were kept weed free by weeding frequently.

Irrigation

Three irrigations were provided throughout the growing period as sufficient soil moisture is essential for the vegetables.

Plant protection measures

Plant protection measures were done whenever they were necessary.

Insect Pests

In organic cauliflower plots neem oil were applied as bio pesticide. Nogos@ 4% was applied against insect pests like aphids, caterpillar, stem borer, leaf webber and moths. The bio pesticide and insecticides were applied fortnightly as a routine from a week after transplanting to a week before first harvesting.

3.12 Harvesting

Curds were harvested as soon as they reach the proper market size. The usual practice of harvesting in which the curd with the stem is cut was followed. The curds were packed with the outer leaves untrimmed.

3.13 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 (cm)

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, 60 DAT and at harvesting period..

Outer leaf length (cm)

The length of the leaf was obtained with the help of centimeter scale at 15, 30, 45, 60 DAT and harvesting time.

Outer leaf width (cm)

The width of the leaf was obtained with the help of centimeter scale at 15, 30, 45, 60 DAT and harvesting time.

Number of leaves per plant

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

Curd size (cm^2)

The curd size was recorded at the harvesting time. Length of curd was multiplying with width to measure the curd size.

Yield of curds with leaves ($tonha^{-1}$)

This trait was recorded from the harvested curds out leaves of all plants of each plot including the sample plants. The yield of curd plot $^{-1}$ was converted to the yield per hectare.

Yield of curds without leaves ($tonha^{-1}$)

This trait was recorded from the harvested curds without leaves of all plants of each plot including the sample plants. The yield of curd plot $^{-1}$ was converted to the yield per hectare.

3.14 Economic returns from cauliflower based agroforestry system

In order to work out the economic profitability of the agroforestry systems, the economic yield of the cauliflower 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.

Total cost of production

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

Gross return

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

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})

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:

Benefit-cost ratio = Gross return (Tk.ha^{-1}) / Total cost of production (Tk.ha^{-1}).

3.15 Statistical analysis

Data were statistically analyzed using the "Analysis of variance" (ANOVA) technique with the help of MSTAT- C. The mean differences were adjudged by Duncan's Multiple Range Test (DMRT) according to (Gomez and Gomez, 1984).

CHAPTER 4
RESULTS AND DISCUSSION

The results obtained from the present study along with statistical analysis of data have presented and discussed in the chapter. The present study regarding varietal performance and fertilizer effect on cauliflower under mango based agroforestry system was presented. The summery of analysis of variance for all yield contributing characters and growth parameters studied have been presented here under the following sub-headings to achieve the following objectives.

4.1 Main effect of variety on growth, yield contributing characters and yield of cauliflower

4.1.1 Plant height (cm)

Plant height is an important growth parameter considering performance. Plant height of cauliflower was recorded from the ground surface to the tip of the leaf in 10 plants of all the treatments. At different days after planting (DAT), there was no significant difference on plant height of different varieties (Table 1). However at 15 DAT, the highest plant height (17.81cm) was recorded from the variety snowball-1 (V_2), which was followed by the variety maghi (V_3) and aksel (V_1). Numerically at 30 DAT, the tallest plant height (28.31 cm) was observed in variety maghi (V_3) followed by the variety snowball-1 (V_2) and aksel (V_1). Again at 45 DAT, the tallest plant height (45.63cm) was recorded from the variety snowball-1 (V_2) and the shortest plant height (43.01 cm) was observed from the variety aksel (V_1) (Plate-1). Finally, at 60 DAT, the highest plant height (54.83cm) was recorded from the variety snowball-1 (V_2) which was insignificantly followed by the variety maghi (V_3) and aksel (V_1). Similar trend of plant height was observed at harvesting time. Due to the genetical character of it grow rapidly. So maximum height was found in snowball-1 variety.



Aksel (V_1) Snowball-1 (V_2) Maghi (V_3)

Plate: 1: Plant height of different verities

Table 1: Main effect of variety on plant height

Treatments (variety)	Plant height (cm)				
	15 DAT	30 DAT	45 DAT	60 DAT	Harvesting Time
Aksel (V_1)	16.42	26.43	43.01 b	54.60	60.26
Snowball-1 (V_2)	17.81	27.52	45.63 a	54.83	60.37
Maghi (V_3)	16.51	28.31	44.67 ab	54.76	60.79
CV%	11.97	11.70	5.24	4.54	3.51

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at $P \leq 5\%$ level.

4.1.2 Outer leaf length (cm)

Outer leaf length of cauliflower was varied due to the varietal dissimilation (Table 2). However, numerically at 15 DAT, the highest outer leaf length (11.33 cm) was recorded from maghi variety (V_3) whereas the shortest outer leaf length (9.20 cm) was observed from aksel (V_1). Again at 30 DAT, the highest outer leaf length (23.16 cm) was recorded from maghi variety (V_3) followed by snowball-1variety (V_2) and the shortest outer leaf length (20.42 cm) was observed from aksel variety (V_1). Even at 45 DAT, the highest outer leaf length (33.10 cm) was recorded in maghi variety (V_3) and the shortest outer leaf length (28.24 cm) was observed in aksel variety (V_1). Finally, at 60 DAT, the highest outer leaf length (40.55cm) was recorded from maghi variety (V_3) which was followed by snowball-1 variety (V_2) and the shortest outer leaf length (38.23cm) was observed in aksel variety (V_1). Maghi variety has broader leaf type character than the others. Due to this characteristics maghi variety gave the highest leaf length value.

Table 2: Main effect of variety on outer leaf length

Treatments (variety)	Outer leaf length (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
Aksel (V_1)	9.20 c	20.42 b	28.24 c	38.23 b
Snowball-1 (V_2)	10.17 b	22.38 a	31.20 b	39.60 ab
Maghi (V_3)	11.33 a	23.16 a	33.10 a	40.55 a
CV%	7.94	9.46	4.21	5.54

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at $P \leq 5\%$ level.

4.1.3 Outer leaf width (cm)

Outer leaf width of cauliflower was increased due to the varietal impacts (Table 3). But there is no significant different among the outer leaf width. However, numerically at 15 DAT, the highest outer leaf width (4.97 cm) was recorded from Snowball-1 variety (V_2) which was followed by maghi variety (V_3) and the shortest outer leaf width (4.23 cm) was observed from aksel variety (V_1). Again at 30 DAT, the highest outer leaf width (8.84 cm) was recorded from Snowball-1variety (V_2) which was followed by aksel variety (V_1) and maghi variety (V_3). On the other hand at 45

DAT, the shortest outer leaf width (12.43 cm) was observed from aksel variety (V_1) and the highest outer leaf width (12.84 cm) was recorded from snowball-1 variety (V_2). Similarly at 60 DAT, the highest outer leaf width (16.54cm) was recorded from snowball-1 variety (V_2) and the shortest outer leaf width (14.40 cm) was observed from maghi variety (V_3) which was followed by sksel variety (V_1). Snowball-1 variety was flatted shape type and for this reasons that variety gave highest outer leaf width.

Table 3: Main effect of variety on outer leaf width

Treatments (variety)	Outer leaf width (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
Aksel (V_1)	4.23 b	8.66	12.43 b	15.28 b
Snowball-1 (V_2)	4.97 a	8.84	12.84 a	16.54 a
Maghi (V_3)	4.83 a	8.68	12.83 a	14.40 b
CV%	7.76	14.55	3.47	7.69

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at P ≤ 5% level.

4.1.4 Number of leaves per plant

Number of leaves per plant was not varied significantly with the varietal comparison (Table 4). At 15 DAT, the highest number of outer leaf per plant (6.37) was recorded from maghi variety (V_3) which was followed by snowball-1 variety (V_2) and aksel variety (V_1). But at 30 DAT, the highest number of outer leaf per plant (10.63) was recorded from maghi variety (V_3) which was followed by snowball-1 variety (V_2) and the lowest number of outer leaf per plant (9.91) was observed from aksel variety (V_1). Again at 45 DAT, the number of outer leaf per plant (14.37) was recorded from maghi variety (V_3) whereas the lowest number of outer leaf per plant (13.72) was observed from aksel variety (V_1) which was followed by snowball-1variety (V_2). Even at 60 DAT, the highest number of outer leaf per plant (18.52) was recorded from maghi variety (V_3) which was followed by snowball-1 variety (V_2) and aksel variety (V_1). Similar trend was observed at harvesting time.

Table 4: Main effect of variety on number of outer leaf per plant

Treatments (variety)	Number of Leaf				
	15 DAT	30 DAT	45 DAT	60 DAT	Harvesting Time
Aksel (V_1)	6.22	9.91 b	13.72 b	18.04	18.46
Snowball-1 (V_2)	6.31	10.39 a	13.97 b	18.18	18.68
Maghi (V_3)	6.37	10.63 a	14.37 a	18.52	18.71
CV%	4.76	5.18	3.13	5.51	4.25

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at $P \leq 5\%$ level.

4.1.5 Curd size (cm^2)

The important yield contributing character of cauliflower was curd size. With the influence of variety the fresh curd weight of cauliflower per plant was significantly varied (Table 5). The highest curd size ($239.0 cm^2$) was recorded from snowball-1 (V_2) whereas the lowest curd size ($200.5 cm^2$) was recorded from Aksel (V_1) which was significantly followed by Maghi (V_3).

Aksel(V_1)

Snowball-1 (V_2)

Maghi (V_3)

Plate 2: Curd of the three varieties of cauliflower before harvesting

Table 5: Main effect of variety on curd size

Treatments (variety)	Curd Size (cm^2)
Aksel (V_1)	200.5 b
Snowball-1 (V_2)	239.0 a
Maghi (V_3)	205.8 b

CV%	6.49

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at P ≤ 5% level.

4.1.6 Yield of curd with leaf per plant (g)

It was showed (Table. 6) that the yield of curd with leaf per plant was significantly varied among different varieties. The maximum yield (1045g) was recorded from the variety snowball-1 (V_2) whereas the minimum yield (994.5g) was recorded from the variety aksel (V_1) which was followed by maghi variety (V_3). Snowball-1 variety favours low temperature and moisture condition for better growth than the other two varieties.

4.1.7 Yield of curd with leaf per Plot (Kg)

The yield of Curd with leaf per plot was significantly varied among different varieties (Table. 6). The maximum yield (16.71kg) was recorded from the variety Snowball-1 (V_2) which was followed by maghi variety (V_3) and the minimum yield (16.01kg) was recorded from the variety aksel (V_1).

4.1.8 Yield of curd with leaf (ton ha^{-1})

Yield of curd with leaf per hectare land was significantly varied among different varieties (Table. 6). The maximum yield (55.71 t ha^{-1}) was recorded from the variety Snowball-1(V_2) which was followed by maghi variety (V_3) and the minimum yield (53.37t ha^{-1}) was recorded from the variety aksel (V_1).

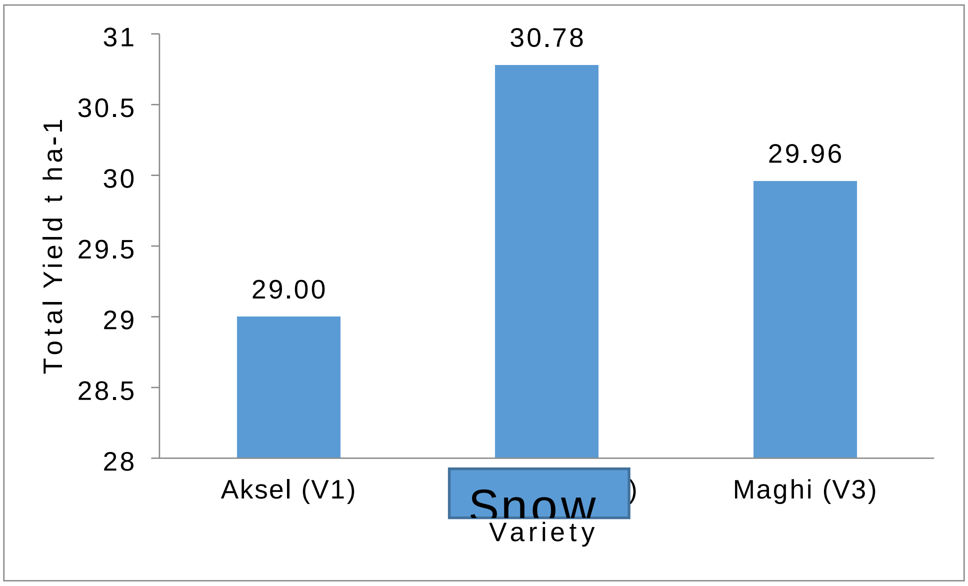


Figure 2: Main effect of variety on yield of Cauliflower

4.1.9 Yield of curd without leaf per plant (g)

Yield of cauliflower curd without leaf per plant was not significantly varied among the varieties used in the study (Table.6). The maximum yield (536.3g) was recorded from the variety snowball-1 (V_2) which was significantly followed by maghi (V_3) and aksel (V_1).

4.1.10 Yield of curd without leaf per plot (kg)

Yield of cauliflower curd without leaf per plot was significantly varied among the varieties used in the study (Table.6). The maximum yield (9.235kg) was recorded from the variety snowball-1 (V_2) which was significantly followed by maghi (V_3) and the minimum yield (8.701kg) was recorded from the variety aksel (V_1).

4.1.11 Yield of curd without leaf (ton ha^{-1})

It was showed (Figure. 2) the yield of cauliflower curd without leaf per hectare was significantly varied among the varieties used in the study. The maximum yield (30.78 t ha^{-1}) was recorded from the variety snowball-1 (V_2) which was followed by maghi variety (V_3) and the minimum yield (29.00 t ha^{-1}) was recorded from the variety aksel (V_1).

Table 6: Main effect of variety on yield

Treatments (variety)	Total yield (weight of leaf+ curd) g/plant	Total yield (weight of leaf+ curd) kg/plot	Total yield (weight of leaf+curd) t ha^{-1}	Total yield (weight of leaf-curd) g/plant	Total yield (weight of leaf-curd) kg/plot
Aksel (V_1)	994.5 b	16.01 b	53.37 b	509.2	8.701 b
Snowball-1 (V_2)	1045. a	16.71 a	55.71 a	536.3	9.235 a
Maghi (V_3)	1005. ab	16.24 ab	54.14 ab	518.5	8.989 ab
CV%	5.40	3.87	3.87	7.16	4.55

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at P ≤ 5% level.

4.2 Main effect of fertilizer and manure application on growth, yield contributing characters and yield of Cauliflower

4.2.1 Plant height (cm)

Plant height is an important growth parameter considering its productivity performance. Plant height of cauliflower was recorded from the ground surface to the tip of the leaf in all fertilizer and manure application. At different days after planting (DAT) the plant height was significantly varied with different fertilizer and manure applications (Table. 6). However at 15 DAT, the highest plant height (20.84cm) was recorded from that plot where chemical fertilizer was applied (F_2) and it was followed by that plot where cowdung was applied (F_3). On the other hand, shortest plant was observed (12.26 cm) in that plot where no fertilizer was applied (F_1).

No fertilizer Chemical Cowdung Poultry

Plate 3: Plant height influence by different treatment at 30 DAT

Similarly at 30 DAT, the highest plant height (32.35cm) was recorded from that plot where chemical fertilizer was applied (F_2) and it was followed by that plot where cowdung was applied (F_3). Whereas the shortest plant height (22.79 cm) was recorded from that plot where no fertilizer was applied (F_1) which was followed by that plot where poultry manuring was applied (F_4). Again, 45 DAT the highest plant height (51.26cm) was recorded from that plot where chemical fertilizer was applied (F_2) whereas the shortest plant was observed (35.13 cm) in that plots where no fertilizer was applied (F_1). Similar trend of plant height was observed at 60 DAT and harvesting time. This might be occurred due to their fertilizer treatment. Chemical fertilizers are always provide immediate supply of nutrients to plants and for this F_1 (chemical fertilizer) gave highest value. Partially similar result was found by Garrity *et al.,* (1992). Hasan and Solaiman (2012) noted that chemical fertilizer had faster nutrient effect and organic manure needed longer period for nutrients releasing. Same authors showed that plant height also depended on type of fertilizers.

Table 7: Main effect of fertilizer and manure application on plant height of cauliflower

Treatments	Plant Height (cm)

(fertilizer)	15 DAT	30 DAT	45 DAT	60 DAT	Harvesting time
F_1 (No fertilizer)	12.26 c	22.79 c	35.13 d	47.12 d	53.28 d
F_2 (Chemical fertilizer)	20.84 a	32.35 a	51.26 a	60.48 a	65.64 a
F_3 (Cowdung manure)	19.08 a	28.69 b	48.62 b	58.04 b	63.50 b
F_4 (Poultry manure)	15.45 b	25.85 bc	42.74 c	53.28 c	59.48 c
CV (%)	11.97	11.70	5.24	4.54	3.51

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at $P \leq 5\%$ level.

4.2.2 Outer leaf length (cm)

Outer leaf length of cauliflower was also significantly varied with the variation of fertilizer and manure application (Table.8). At 15 DAT, the largest outer leaf length (12.31cm) of Cauliflower was observed in those plots in which chemical fertilizer was applied (F_2) whereas the shortest outer leaf length (8.123 cm) was observed in those plots in which no fertilizer was applied (F_1). At 30 DAT, the largest outer leaf length (26.07 cm) was recorded in those plots in which chemical fertilizer was applied (F_2) which was significantly followed by those plot in which cowdung was applied (F_3). On the other hand the shortest outer leaf length (16.73 cm) was recorded in those plots in which no fertilizer was applied (F_1). At 45 DAT, the longest outer leaf length (34.26 cm) was recorded in those plots in which chemical fertilizer was applied (F_2) whereas the shortest outer leaf length (24.11 cm) was recorded in those plots in which no fertilizer was applied (F_1). Similar trend of plant height was observed at 60 DAT.

Table 8: Main effect of fertilizer and manure application on Outer leaf length at different DAT

Treatments (fertilizer)	Outer leaf length (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
F_1(No fertilizer)	8.12 c	16.73 c	24.11 c	33.79 d
F_2 (Chemical fertilizer)	12.31 a	26.07 a	34.26 a	43.96 a
F_3 (Cowdung manure)	10.42 b	24.13 a	32.87 b	41.46 b
F_4 (Poultry manure)	10.08 b	21.02 b	32.14 b	38.64 c
CV (%)	7.94	9.46	4.21	5.54

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at $P \leq 5\%$ level.

4.2.3 Outer leaf width (cm)

Outer leaf length of cauliflower was also significantly varied with the fertilizer and manure (Table. 9). At 15 DAT, the largest outer leaf width (5.76cm) of cauliflower was observed in those plots in which chemical fertilizer was applied (F_2) whereas the shortest outer leaf width (3.50cm) was observed in those plots in which no fertilizer was applied (F_1). At 30 DAT, the largest outer leaf width (9.92cm) was recorded in those plots in which chemical fertilizer was applied (F_2) which was significantly followed by those plot in which cowdung was applied (F_3). On the other hand the shortest outer leaf length (6.66cm) was recorded in those plots in which no fertilizer was applied (F_1). At 45 DAT, the longest outer leaf length (13.88cm) was recorded in those plots in which chemical fertilizer was applied (F_2) whereas the shortest outer leaf length (11.04cm) was recorded in those plots in which no fertilizer was applied (F_1). Similar trend of plant height was observed at 60 DAT.

Table 9: Main effect of fertilizer and manure application on outer leaf width at different DAT

Treatments (fertilizer)	Outer leaf width (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
F_1 (No fertilizer)	3.50 d	6.66 c	11.04 d	13.67 c
F_2 (Chemical fertilizer)	5.76 a	9.92 a	13.88 a	17.17 a
F_3 (Cowdung manure)	5.02 b	9.83 a	13.33 b	15.61 b
F_4 (Poultry manure)	4.43 c	8.49 b	12.55 c	15.17 b
CV (%)	7.76	14.55	3.47	7.69

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at $P \leq 5\%$ level.

4.2.4 Number of leaves per plant

Number of leaves cauliflower were also significantly varied due to the fertilizer and manure (Table. 10). At 15 DAT, the maximum number of leaves (7.03) was observed in those plots in which Chemical fertilizer was applied (F_2) whereas the minimum number of leaves was observed (5.34) in those plots in which no fertilizer was applied (F_1). Again at 30 DAT, the maximum number of leaves (11.50) was observed in those plots in which chemical fertilizer was applied (F_2) whereas the minimum number of leaves was observed (8.77) in those plots in which no fertilizer was applied (F_1). Similarly at 45 DAT, the maximum number of leaves (16.16) was observed in those plots in which chemical fertilizer was applied (F_2) and minimum number of leaves was observed (11.22) in those plots in which no fertilizer was applied (F_1). Similar trend of plant height was observed at 60 DAT and harvesting time. Murmu *et al.* (2013) found that organic manure increases crop productivity, nitrogen utilization efficiency, and soil health compared to chemical fertilizer.

Table 10: Main effect of fertilizer and manure application on number of outer leaf per plant at different DAT

Treatments (fertilizer)	Number of Leaf				
	15 DAT	30 DAT	45 DAT	60 DAT	Harvesting time
F_1 (No fertilizer)	5.34 c	8.77 c	11.22 d	15.78 c	16.29 d
F_2 (Chemical fertilizer)	7.03 a	11.50 a	16.16 a	20.78 a	20.82 a
F_3 (Cowdung manure)	6.52 b	10.72 b	15.14 b	18.68 b	19.43 b
F_4 (Poultry manure)	6.29 b	10.26 b	13.54 c	17.76 b	17.92 c
CV (%)	4.76	5.18	3.13	5.51	4.25

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at P ≤ 5% level.

4.2.5 Curd size (cm^2)

With the variation of fertilizer and manure application fresh curd size of cauliflower per plant was significantly varied (Table.11).


No fertilizer


Chemical


Cowdung


Poultry

Plate 4: Curd size influence by different treatment at harvesting time

The highest curd size (254.40cm^2) was recorded from those plots where chemical fertilizer was applied (F_2). On the other hand the shortest curd size (168.10cm^2) was observed in those plots where no fertilizer was applied (F_1) (Table. 10). Organic manure has multiple benefits due to the balanced supply of nutrients, including micronutrients, increased soil nutrient availability due to increased soil microbial activity, the decomposition of harmful elements, soil structure improvements and root development, and increased soil water availability. From the table (Table.10) it was also found that cowdung manuring (F_2) gave the second highest curd size (226.40cm^2).

Table 11: Main effect of fertilizer and manure application on curd size

Treatments (fertilizer)	Curd size (g)
F_1 (No fertilizer)	168.10 d
F_2 (Chemical fertilizer)	254.40 a
F_3 (Cowdung manure)	226.40 b
F_4 (Poultry manure)	211.30 c
CV (%)	6.49

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at $P \leq 5\%$ level.

4.2.6 Yield of curd with leaf per plant (g)

The contents of the data showed (Table. 12) revealed that the treatments had significant effect on yield of curd with leaf per plant due to fertilizer variation. The highest yield (1210g) was recorded from the plots in which chemical fertilizer was applied (F_2) whereas the lowest yield was observed (838.4g) in those plots in which no fertilizer was applied (F_1).

4.2.7 Yield of curd with leaf per Plot (Kg)

The yield of curd with leaf per plot was significantly varied among different fertilizer and manure application (Table. 12). The maximum yield (19.76kg) was recorded from the plots in which chemical fertilizer was applied (F_2) whereas the lowest yield was observed (12.80kg) in those plots in which no fertilizer was applied (F_1).

4.2.8 Yield of curd with leaf (ton ha^{-1})

It was evident from the figure (Table.12) that the yield of curd with leaf per hectare land was significantly varied among different fertilizer and manure application. The highest yield (65.88 ton ha^{-1}) was recorded from the field in those plots in which chemical fertilizer was applied (F_2) whereas the lowest yield was observed (42.67 ton ha^{-1}) in those plots in which no fertilizer was applied (F_1). Olaniyi and Ojetayo (2011) and Sarker *et al.* (2003) reported that differences in head weight and yield depended on fertilizer type.

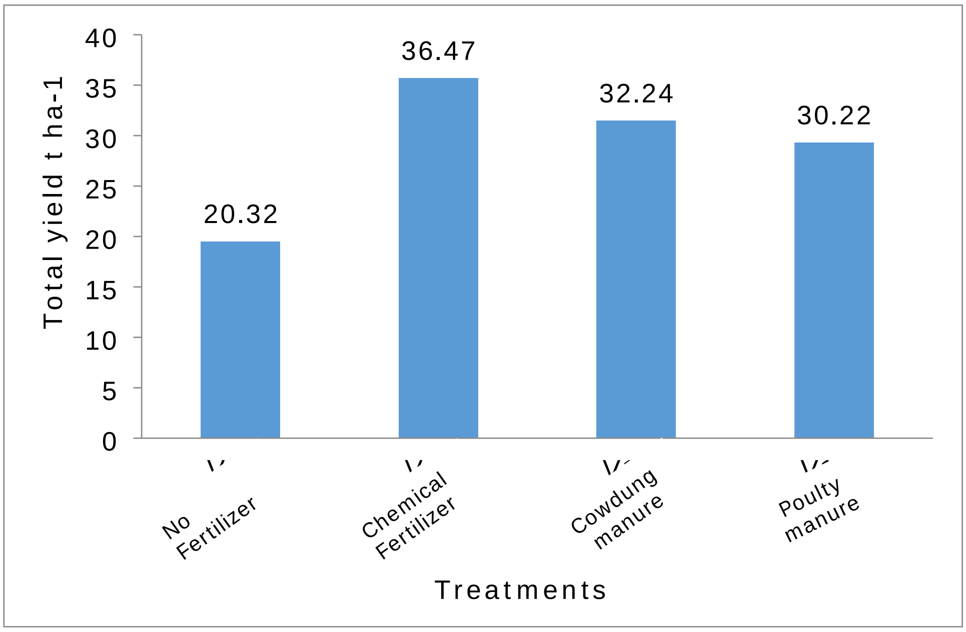


Figure 3: Main effect of fertilizer and manure applications on yield of cauliflower

4.2.9 Yield of curd without leaf per plant (g)

The maximum yield (632.40g) was recorded from the plots in which chemical fertilizer was applied (F_2) whereas the lowest yield was observed (376.20g) in those plots in which no fertilizer was applied (F_1) (Table.12).

4.2.10 Yield of curd without leaf per Plot (kg)

The maximum yield (10.94kg) was recorded from the plots in which chemical fertilizer was applied (F_2) whereas the lowest yield was observed (6.094kg) in those plots in which no fertilizer was applied (F_1) (Table.12).

4.2.11 Yield of curd without leaf (ton ha^{-1})

It was showed (Fig.3) that the yield of cauliflower curds without leaf per hectare was significantly varied among the variation of fertilizer and manure application. The maximum yield (36.47t ha^{-1}) was recorded from the plots in which chemical fertilizer was applied (F_2) whereas the lowest yield was observed (20.32t ha^{-1}) in those plots in which no fertilizer was applied (F_1). Adding organic manuring enhanced the soil structure conditions, creates conducive conditions for good root development (Arisha *et al.* 2003) and mineralization by microorganisms. Due to this cowdung manuring (F_1) gave second highest yield (32.67 ton ha^{-1}).

Table 12: Main effect of fertilizer and manure application on yield

Treatments (fertilizer)	Total yield (weight of leaf+ curd) g/plant	Total yield (weight of leaf+ curd) kg/plot	Total yield (weight of leaf+curd) t ha^{-1}	Total yield (weight of leaf-curd) g/plant	Total yield (weight of leaf-curd) kg/plot
F_1(No fertilizer)	838.40 c	12.80 d	42.67 d	376.20 d	6.09 d
F_2 (Chemical fertilizer)	1210.00 a	19.76 a	65.88 a	632.40 a	10.94 a
F_3(Cowdung manure)	1023.00	16.68 b	55.60 b	573.70 b	9.80 b

	b				
F_4 (Poultry manure)	986.40 b	16.04 c	53.47 c	502.90 c	9.06 c
CV (%)	5.40	3.87	3.87	7.16	4.55

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at $P \leq 5\%$ level.

4.3 Interaction effect of variety and fertilizer application on growth, yield contributing characters and yield of cauliflower

4.3.1 Plant height (cm)

The interaction effect of variety and fertilizer application on the plant height of cauliflower was significantly different at different days after planting (Table 13). However, at 15 DAT, the largest plant height (21.21cm) of cauliflower was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) followed by the plots where maghi and aksel variety were grown with chemical fertilizer (V_3F_2 and V_1F_2) and also the plots where snowball-1 variety and maghi variety were grown with cowdung manuring ($V_2F_3$and V_3F_3). On the other hand, the shortest plant height of cauliflower (10.24 cm) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1) followed by the plot where maghi variety was grown with no fertilizer (V_3F_1). Similar trend was found at 30 DAT, the highest plant height (34.59cm) of cauliflower was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) whereas the shortest plant height of cauliflower (21.84 cm) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1). Again at 45 DAT, the plant height was statistically similar. Numerically, the highest plant height of cauliflower (53.19 cm) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2). On the other hand, the lowest plant height of cauliflower (33.40 cm) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1). Finally, at 60 DAT, the highest plant height of cauliflower (61.07 cm) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2). On the other hand, the lowest plant height of cauliflower (44.25 cm) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1). Similar trend of plant height was observed at harvesting time.

4.3.2 Outer leaf length (cm)

The interaction effect of variety and fertilizer application on outer leaf length of cauliflower was varied significantly at different days after planting (Table 14). Numerically at 15 DAT, the largest outer leaf length (13.98cm) of cauliflower in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) whereas the shortest outer leaf length of cauliflower (6.76 cm) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1) followed by the plot where snowball-1 variety was grown with no fertilizer (V_2F_1). Again at 30 DAT, the largest outer leaf length (27.70cm) of cauliflower in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2). On the other hand, the shortest outer leaf length of cauliflower (14.80 cm) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1). Even at 45 DAT, the largest outer leaf length of cauliflower (36.73 cm) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2). On the other hand, the lowest outer leaf length of cauliflower (20.28 cm) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1). Finally at 60 DAT, the highest outer leaf length of cauliflower (44.57 cm) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2). On the other hand, the lowest outer leaf length of cauliflower (32.80 cm) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1).

Table 13: Interaction effect of variety and fertilizer application on plant height of cauliflower at different DAT

Treatment Combination	Plant height (cm)				
	15 DAT	30 DAT	45 DAT	60 DAT	Harvesting time
V_1F_1	10.24 e	21.84 d	33.40 d	44.25 g	52.29 g
V_1F_2	20.46 a	30.00 abc	49.51 ab	60.13 a	65.11 ab
V_1F_3	16.63 bc	27.99 bcd	45.87 bc	57.85 abc	64.40 abc
V_1F_4	16.12 cd	25.88 cd	41.93 c	53.43 cde	59.67 de
V_2F_1	14.11 cd	23.22 d	37.25 d	50.12 ef	54.75 fg
V_2F_2	21.21 a	34.59 a	53.19 a	61.07 a	66.20 a
V_2F_3	20.72 a	27.69 bcd	49.99 ab	57.01 abc	62.02 bcd
V_2F_4	15.19 cd	24.59 cd	44.21 c	51.15 def	58.07 ef
V_3F_1	12.44 de	23.32 d	34.75 d	46.98 fg	52.80 g
V_3F_2	20.86 a	32.45 ab	51.08a	60.25 a	65.60 ab
V_3F_3	19.90 ab	30.40 abc	49.98 ab	59.25 ab	64.07 abc
V_3F_4	15.03 cd	27.07 bcd	42.09 c	55.27 bcd	60.69 cde
CV%	11.97	11.70	5.24	4.54	3.51

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at $P \leq 5\%$ level.

Here, V_1F_1= Aksel + No fertilizer + No pesticide, V_1F_2= Aksel + Chemical fertilizer + Normal pesticide, V_1F_3= Aksel + Cowdung + Neem oil spray as bio-pesticide, V_1F_4= Aksel + Poultry + + Neem oil spray as bio-pesticide, V_2F_1= Snowball-1 + No fertilizer + No pesticide, $V_2F_{2=}$ Snowball-1 + Chemical fertilizer + Normal pesticide, V_2F_3= Snowball-1 + Cow dung + Neem oil spray as bio-pesticide, V_2F_4= Snowball-1 + Poultry + Neem oil spray as bio-pesticide, V_3F_1= Maghi + No fertilizer + No pesticide, V_3F_2= Maghi + Chemical fertilizer + Normal pesticide, V_3F_3= Maghi +

Cow dung + Neem oil spray as bio-pesticide, V_3F_4= Maghi + Poultry + Neem oil spray as bio-pesticide.

Table 14: Interaction effect of variety and fertilizer application on outer leaf length of cauliflower at different DAT

Treatment Combination	Outer leaf length (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
V_1F_1	6.76 h	14.80 f	20.28 g	32.83 e
V_1F_2	10.77 bcde	24.37 abc	32.30 cd	44.50 a
V_1F_3	9.35 efg	21.80 cd	30.52 de	42.90 ab
V_1F_4	8.64 fg	20.71 cd	29.85 e	39.47 bc
V_2F_1	8.05 gh	16.19 ef	27.09 f	33.20 e
V_2F_2	13.98 a	27.70 a	36.73 a	44.57 a
V_2F_3	11.11 bc	26.56 ab	32.33 cd	42.50 ab
V_2F_4	10.62 cde	19.07 de	31.63 cde	38.13 cd
V_3F_1	9.56 def	19.19 de	24.95 f	35.35 de
V_3F_2	12.18 b	26.13 ab	33.74 bc	42.82 ab
V_3F_3	10.80 bcde	24.02 abc	35.75 ab	38.97 bcd
V_3F_4	10.97 bcd	23.28 bc	34.95 ab	38.32 cd
CV%	7.94	9.46	4.21	5.54

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at P ≤ 5% level.

Here, V_1F_1= Aksel + No fertilizer + No pesticide, V_1F_2= Aksel + Chemical fertilizer + Normal pesticide, V_1F_3= Aksel + Cowdung + Neem oil spray as bio-pesticide, V_1F_4= Aksel + Poultry + + Neem oil spray as bio-pesticide, V_2F_1= Snowball-1 + No fertilizer + No pesticide, $V_2F_{2=}$ Snowball-1 + Chemical fertilizer + Normal pesticide, V_2F_3= Snowball-1 + Cow dung + Neem oil spray as bio-pesticide, V_2F_4= Snowball-1 + Poultry + Neem oil spray as bio-pesticide, V_3F_1= Maghi + No fertilizer + No pesticide, V_3F_2= Maghi + Chemical fertilizer + Normal pesticide, V_3F_3= Maghi + Cow dung + Neem oil spray as bio-pesticide, V_3F_4= Maghi + Poultry + Neem oil spray as bio-pesticide.

4.3.3 Outer leaf width (cm)

The interaction effect of variety and fertilizer application on outer leaf width of cauliflower was varied significantly at different days after planting (Table 15). At 15 DAT, the largest outer leaf width (6.26cm) of cauliflower was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) and the shortest outer leaf width of cauliflower (3.31 cm) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1). Again at 30 DAT, the largest outer outer leaf width (10.51cm) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) whereas. On the other hand, the shortest outer leaf width (6.49 cm) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1). At 45 DAT, the largest outer leaf width of cauliflower (13.96 cm) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) whereas the lowest outer leaf width of cauliflower (9.67 cm) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1). Finally at 60 DAT, the highest outer leaf width of cauliflower (18.20 cm) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) whereas and the lowest outer leaf width of cauliflower (13.07 cm) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1).

4.3.4 Number of leaves per plant

Number of leaves per plant was not varied significantly (Table 16). However, numerically at 15 DAT, the highest number of outer leaf per plant (7.27) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) and the lowest number of leaf (5.20) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1). Again at 30 DAT, the highest number of outer leaf per plant (11.70) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) whereas the lowest number of outer leaf per plant (8.23) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1). At 45 DAT, the highest number of outer leaf per plant (16.43) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) whereas. On the other hand the lowest number of outer leaf per plant (10.83) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1). Similar trend was followed at 60 DAT. But during harvesting time the lowest number of outer leaf per plant (15.80) was in the plot where snowball-1 variety was grown with no fertilizer (V_2F_1) whereas the highest number of outer leaf per plant (20.93) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2).

Table 15: Interaction effect of variety and fertilizer application on outer leaf width

Treatment Combination	Outer leaf width (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
V_1F_1	3.29 f	6.49 c	9.67 g	13.07 e
V_1F_2	5.28 bcd	9.29 a	13.90 a	16.89 ab
V_1F_3	4.55 e	9.69 a	13.27 abc	16.97 ab
V_1F_4	3.82 f	9.06 ab	12.52 cde	16.47 abc
V_2F_1	3.31 f	6.65 c	11.79 ef	13.42 e
V_2F_2	6.26 a	10.51 a	13.96 a	18.20 a

V_2F_3	5.44 bc	10.21 a	13.28 abc	15.84 bcd
V_2F_4	4.81 cde	8.15 abc	12.29 def	14.97 bcde
V_3F_1	3.91 f	6.83 bc	11.66 f	14.52 cde
V_3F_2	5.75 ab	9.95 a	13.78 a	16.42 abc
V_3F_3	5.06 cde	9.59 a	13.43 ab	14.03 de
V_3F_4	4.67 de	8.28 abc	12.83 bcd	14.08 de
CV%	7.76	14.55	3.47	7.69

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at P ≤ 5% level.

Here, V_1F_1= Aksel + No fertilizer + No pesticide, V_1F_2= Aksel + Chemical fertilizer + Normal pesticide, V_1F_3= Aksel + Cowdung + Neem oil spray as bio-pesticide, V_1F_4= Aksel + Poultry + + Neem oil spray as bio-pesticide, V_2F_1= Snowball-1 + No fertilizer + No pesticide, $V_2F_{2=}$ Snowball-1 + Chemical fertilizer + Normal pesticide, V_2F_3= Snowball-1 + Cow dung + Neem oil spray as bio-pesticide, V_2F_4= Snowball-1 + Poultry + Neem oil spray as bio-pesticide, V_3F_1= Maghi + No fertilizer + No pesticide, V_3F_2= Maghi + Chemical fertilizer + Normal pesticide, V_3F_3= Maghi + Cow dung + Neem oil spray as bio-pesticide, V_3F_4= Maghi + Poultry + Neem oil spray as bio-pesticide.

Table 16: Interaction effect of variety and fertilizer application on number of outer leaf per plant

Treatment Combination	Number of outer leaf per plant (Outer)				
	15 DAT	30 DAT	45 DAT	60 DAT	Harvesting time
V_1 F_1	5.33 e	8.23 f	10.83 e	15.53 e	15.80 g

V_1F_2	7.10 ab	11.37 abc	15.80 ab	20.57 ab	20.87 a
V_1F_3	6.40 cd	10.17 de	15.10 bc	18.43 c	19.73 ab
V_1F_4	6.40 cd	9.87 e	13.67 d	17.63 cd	17.77 ef
V_2F_1	5.20 e	8.27 f	11.53 e	15.77	16.47 fg
V_2F_2	7.27 a	11.70 a	16.43 a	21.03 a	20.93 a
V_2F_3	6.63 bcd	11.10 abcd	15.67 ab	18.53 c	19.23 bcd
V_2F_4	6.37 cd	10.50 bcde	13.83d	17.70 cd	17.87 def
V_3F_1	5.50 e	9.80 e	11.30 e	16.03 de	16.60 fg
V_3F_2	6.73 bc	11.43 ab	16.23 a	20.73 ab	20.67 ab
V_3F_3	6.53 cd	10.90 abcd	14.67 c	19.07 bc	19.33 bc
V_3F_4	6.10 d	10.40 cde	13.13 d	17.93 c	18.13 cde
CV%	4.76	5.18	3.13	5.51	4.25

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at $P \leq 5\%$ level.

Here, V_1F_1= Aksel + No fertilizer + No pesticide, V_1F_2= Aksel + Chemical fertilizer + Normal pesticide, V_1F_3= Aksel + Cowdung + Neem oil spray as bio-pesticide, V_1F_4= Aksel + Poultry + + Neem oil spray as bio-pesticide, V_2F_1= Snowball-1 + No fertilizer + No pesticide, V_2F_2= Snowball-1 + Chemical fertilizer + Normal pesticide, V_2F_3= Snowball-1 + Cow dung + Neem oil spray as bio-pesticide, V_2F_4= Snowball-1 + Poultry + Neem oil spray as bio-pesticide, V_3F_1= Maghi + No fertilizer + No pesticide, V_3F_2= Maghi + Chemical fertilizer + Normal pesticide, V_3F_3= Maghi + Cow dung + Neem oil spray as bio-pesticide, V_3F_4= Maghi + Poultry + Neem oil spray as bio-pesticide.

4.3.5 Curd size (cm^2)

The highest curd size (295.30cm^2) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) whereas the lowest curd size (151.70 cm^2) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1) was followed by the plot where maghi variety was grown with no fertilizer (V_3F_1). (Table. 17).

Table 17: Interaction effect of variety and fertilizer application on curd size

Treatment Combination	Curd size (g)
V_1F_1 (Aksel + No fertilizer + No pesticide)	151.70 e
V_1F_2 (Aksel + Chemical fertilizer + Normal pesticide)	232.60 b
V_1F_3 (Aksel + Cowdung + Neem oil spray as bio-pesticide)	223.00 bc
V_1F_4 (Aksel + Poultry + + Neem oil spray as bio-pesticide)	215.70 bcd
V_2F_1 (Snowball-1 + No fertilizer + No pesticide)	199.90 cd
V_2F_2 (Snowball-1 + Chemical fertilizer + Normal pesticide)	295.30 a
V_2F_3 (Snowball-1 + Cow dung + Neem oil spray as bio-pesticide)	235.70 b

V_2F_4 (Snowball-1 + Poultry + Neem oil spray as bio-pesticide)	224.90	bc
V_3F_1 (Maghi + No fertilizer + No pesticide)	152.60	e
V_3F_2 (Maghi + Chemical fertilizer + Normal pesticide)	235.40	b
V_3F_3 (Maghi + Cow dung + Neem oil spray as bio-pesticide)	220.60	bc
V_3F_4 (Maghi + Poultry + Neem oil spray as bio-pesticide)	193.40	d
CV%	6.49	

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at $P \leq 5\%$ level.

4.3.6 Yield of curd with leaf per plant (g)

The maximum yield (1260g) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) followed by the plots where maghi and aksel variety were grown with chemical fertilizer (V_3F_2 and V_1F_2). On the other hand the minimum yield (803.30g) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1) followed by the plot where maghi variety was grown with no fertilizer (V_3F_1). (Table. 18).

4.3.7 Yield of curd with leaf per plot (Kg)

The yield of curd with leaf per plot was significantly varied (Table 18). The maximum yield (20.19kg) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) followed by the plots where maghi and aksel variety were grown with chemical fertilizer (V_3F_2 and V_1F_2). On the other hand the minimum yield (12.52kg) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1) followed by the plot where maghi variety was grown with no fertilizer (V_3F_1).

4.3.8 Yield of curd with leaf (ton ha^{-1})

It was evident from the (Table.18) that the yield of curd with leaf per hectare land was significantly varied. The maximum yield (67.29 ton ha^{-1}) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) followed by the plots where maghi and aksel variety were grown with chemical fertilizer (V_3F_2 and V_1F_2). On the other hand the minimum yield (41.72ton ha^{-1}) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1) followed by the plot where maghi variety was grown with no fertilizer (V_3F_1).

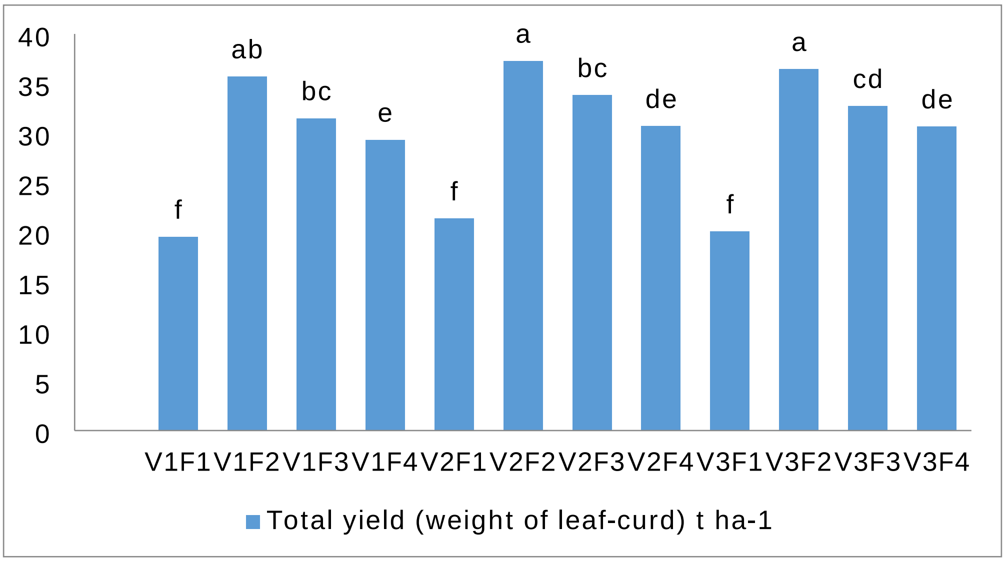


Figure 4: Interaction effect of variety and fertilizer applications on yield of cauliflower

4.3.9 Yield of curd without leaf per plant (g)

The maximum yield (633.30g) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) followed by the plots where maghi and aksel variety were grown with chemical fertilizer (V_3F_2 and V_1F_2) and also the plots where Snowball-1 variety and maghi variety were grown with cowdung manuring (V_2F_3 and V_3F_3). On the other hand the minimum yield (369.70g) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1) followed by the plot where maghi variety was grown with no fertilizer (V_3F_1). (Table. 18).

4.3.10 Yield of curd without leaf per Plot (kg)

The yield of curd without leaf per plot was significantly varied (Table 18). The maximum yield (11.18kg) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) followed by the plots where maghi and aksel variety were grown with chemical Fertilizer (V_3F_2 and V_1F_2). On the other hand the minimum yield (5.86kg) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1) followed by the plot where maghi variety was grown with no fertilizer (V_3F_1).

4.3.11 Yield of curd without leaf (ton ha^{-1})

It was evident from the (Figure. 4) that the yield of curd with leaf per hectare land was significantly varied. The maximum yield (37.27 ton ha^{-1}) was recorded in the plot where snowball-1 variety was grown with chemical fertilizer (V_2F_2) followed by the plots where maghi and aksel variety were grown with chemical fertilizer (V_3F_2 and V_1F_2). On the other hand the minimum yield (19.52ton ha^{-1}) was recorded in the plot where aksel variety was grown with no fertilizer (V_1F_1) followed by the plot where maghi variety was grown with no fertilizer (V_3F_1).

Table 18: Interaction effect of variety and fertilizer application on yield

Treatment Combination	Total yield (weight of leaf+ curd) g/plant	Total yield (weight of leaf+ curd) kg/plot	Total yield (weight of leaf+ curd) t ha^{-1}	Total yield (weight of leaf- curd) g/plant	Total yield (weight of leaf- curd) kg/plot
V_1F_1	803.30 c	12.52 d	41.72 d	369.70 e	5.86 f
V_1F_2	1198.00 a	19.54 a	65.12 a	631.30 a	10.71 ab
V_1F_3	1007.00 b	16.21 bc	54.03 bc	562.00 bc	9.44 cde
V_1F_4	969.30 b	15.78 c	52.59 c	473.70 d	8.79 e
V_2F_1	861.70 c	13.08 d	43.61 d	388.30 e	6.41 f
V_2F_2	1260.00 a	20.19 a	67.29 a	633.30 a	11.18 a
V_2F_3	1041.00 b	17.10 b	57.01 b	589.70 ab	10.14 bc
V_2F_4	1016.00 b	16.47 bc	54.91 bc	533.70bcd	9.21 de
V_3F_1	850.30 c	12.81 d	42.69 d	370.70 e	6.02 f
V_3F_2	1173.00 a	19.57 a	65.22 a	632.7 a	10.93 a
V_3F_3	1022.00 b	16.72 bc	55.75 bc	569.30abc	9.81 cd
V_3F_4	974.30 b	15.87 c	52.91 c	501.30 cd	9.19 de

CV%	5.40	3.87	3.87	7.16	4.55

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at P ≤ 5% level.

Here, V_1F_1= Aksel + No fertilizer + No pesticide, V_1F_2= Aksel + Chemical fertilizer + Normal pesticide, V_1F_3= Aksel + Cowdung + Neem oil spray as bio-pesticide, V_1F_4= Aksel + Poultry + + Neem oil spray as bio-pesticide, V_2F_1= Snowball-1 + No fertilizer + No pesticide, $V_2F_{2=}$ Snowball-1 + Chemical fertilizer + Normal pesticide, V_2F_3= Snowball-1 + Cow dung + Neem oil spray as bio-pesticide, V_2F_4= Snowball-1 + Poultry + Neem oil spray as bio-pesticide, V_3F_1= Maghi + No fertilizer + No pesticide, V_3F_2= Maghi + Chemical fertilizer + Normal pesticide, V_3F_3= Maghi + Cow dung + Neem oil spray as bio-pesticide, V_3F_4= Maghi + Poultry + Neem oil spray as bio-pesticide.

4.4 Economic analysis

Cauliflower cultivation with different fertilizer application as inter-cropping in mango based agroforestry system was calculated based on local market rate prevailed during the experiment. The cost of production of cauliflower and tree plantation and management of trees have been summarized in appendix-II. The returns of produces and the profit i.e. Benefit cost ratio (BCR) have also been presented in (Table 18).

4.4.1 Total cost of production

The values presented in (Table 19) indicate that the total cost of production was minimum (144938 tk/ha) where aksel variety was cultivated and no fertilizer was applied (V_1F_1) whereas the maximum cost of production (167335 tk/ha) was recorded from the plot where snowball-1 variety was cultivated and chemical fertilizer was applied (V_2F_2).

Table 19: Economics of cauliflower production under mango based agroforestry system

Treatment	Return (Tk/ha)		Gross Return (Tk/ha)	Total Cost of Production (Tk/ha)	Net Return (tk/ha	BCR
	Mango	Cauliflower				

					)	
V_1F_1	15060	195200	345800	144938	200862	2.39
V_1F_2	15060	357000	507600	162713	344887	3.11
V_1F_3	15060	314800	465400	153221	312179	3.04
V_1F_4	15060	293100	443700	150509	293191	2.95
V_2F_1	15060	213700	364300	149560	214740	2.44
V_2F_2	15060	372700	523300	167335	355965	3.17
V_2F_3	15060	338100	488700	157843	330857	3.13
V_2F_4	15060	306900	457500	155131	302369	2.95
V_3F_1	15060	200600	351200	147311	203889	2.38
V_3F_2	15060	364400	515000	165086	349914	3.12
V_3F_3	15060	327100	477700	155594	322106	3.07
V_3F_4	15060 0	306500	457100	152882	304218	2.99

Note: Cauliflower 10tk/kg, Mango 1600tk/tree/ year.

Here, V_1F_1= Aksel + No fertilizer + No pesticide, V_1F_2= Aksel + Chemical fertilizer + Normal pesticide, V_1F_3= Aksel + Cowdung + Neem oil spray as bio-pesticide, V_1F_4= Aksel + Poultry + + Neem oil spray as bio-pesticide, V_2F_1= Snowball-1 + No fertilizer + No pesticide, $V_2F_{2=}$ Snowball-1 + Chemical fertilizer + Normal pesticide, V_2F_3= Snowball-1 + Cow dung + Neem oil spray as bio-pesticide, V_2F_4= Snowball-1 + Poultry + Neem oil spray as bio-pesticide, V_3F_1= Maghi + No fertilizer + No pesticide, V_3F_2= Maghi + Chemical fertilizer + Normal pesticide, V_3F_3= Maghi + Cow dung + Neem oil spray as bio-pesticide, V_3F_4= Maghi + Poultry + Neem oil spray as bio-pesticide.

4.4.2 Gross Return

Gross Return is an important indicator to find crop cultivation is profitable or not. It was vary with the variety and fertilizer application of cauliflower. The result indicated that (Table 18) the highest value of gross return (523300tk/ha) was obtained from the plot where snowball-1variety was cultivated and chemical fertilizer was applied (V_2F_2). On the other hand the lowest value of gross return (345800tk/ha) was obtained from the plot where aksel variety was cultivated and no fertilizer was applied (V_1F_1).

4.4.3 Net return

The result presented in the table (Table 18) that the net return (355965tk/ha) obtained from the plot where snowball-1 variety was cultivated and chemical fertilizer was applied (V_2F_2) was higher than the net return (200862tk/ha) obtained from the plot where aksel variety was cultivated and no fertilizer was applied (V_1F_1).

4.4.4 Benefit cost ratio (BCR)

The value in the table (Table. 18) indicates that the highest benefit cost ratio (BCR) (3.17) was obtained from the plot where snowball-1 was cultivated and chemical fertilizer was applied (V_2F_2) which was followed by where snowball-1 and cowdung (3.13) was applied (V_2F_3), where maghi and chemical fertilizer (3.12) was applied (V_3F_2) and where aksel and chemical fertilizer (3.11) was applied (V_1F_2). On the other hand the lowest benefit cost ratio (2.38) was obtained from the plot where maghi and no fertilizer were applied (V_3F_1).

CHAPTER 5

SUMMARY, CONCLUSION & RECOMMENDATIONS

5.1 Summary

The present experiment was conducted at the agroforestry and environment research farm of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during October 2016 to February 2017 to evaluate the performance of organic cauliflower viz. Aksel variety, Snowball-1variety and Maghi variety under mango based agroforestry system. The experiment was conducted in newly established mango (Amropally) orchard of multipurpose tree. The experiment was two factorial. Factor A: (Three cauliflower varieties) Aksel variety (V_1), Snowball-1variety (V_2) and Maghi variety (V_3). Factor B: (Fertilizer & manure application) No Fertilizer (F_1), Chemical Fertilizer (F_2), Cow dung (F_3) and Poultry (F_4). The experiment was laid out in two factorial RCBD with three replications. The unit plot size was 1.5m × 2m ($3m^2$) and 15 plants are accommodated in each plot following a spacing 40cm × 30cm. The transplanting was done late afternoon on 1 November, 2016. All basal dosages of fertilizers and manures as per schedule of the experiment were incorporated in the soil according to the BARC fertilizer recommendation guide, 2014. From each plot 10 plants are randomly selected for data collection. The data were recorded on two broad heads, 1) growth stage, 2) harvesting stage. The data were analyzed statistically and means were adjusted by DMRT.

In case of the main effect of variety on the growth, yield contributing characters and yield of cauliflower, the result was found significantly different in respect of plant height (15, 30, 45 and 60DAT), outer leaf length (15, 30, 45, 60 DAT and harvesting time), outer leaf width (15, 30, 45, 60 DAT and harvesting time), no. of Leaves/plant (15, 30, 45, 60 DAT and harvesting time), curd size and yield. The tallest plant height (17.81, 27.52, 45.63, 54.83, 60.37cm at 15, 30, 45, 60DAT and harvesting time) was recorded from the varietySnowball-1 variety (V_2). On the other hand, the shortest plant height (16.42, 26.43, 43.01, 54.60, and 26.60cm at 15, 30, 45, 60DAT and harvesting time) was observed from the variety Aksel variety (V_1). However, the longest outer leaf length (11.33, 23.16, 33.10 and 40.55 cm at 15,30, 45 and 60 DAT) was recorded from the variety Maghi variety (V3). On the other hand, the shortest leaf (9.20, 20.42, 28.24 and 38.23 cm at 15, 30, 45 and 60 DAT) was observed from the variety Aksel variety (V_1). Cauliflower outer leaf width was also influenced due to their varietal characters. The widest leaf (4.97, 8.84, 12.84 and 16.54 at 15, 30, 45 and 60 DAT) was recorded from the variety snowball-1 variety (V_2). On the other hand, minimum width of leaf (4.23, 8.66, 12.43 and 15.28 at 15, 30, 45 and 60 DAT) was observed from aksel variety (V_1). The maximum number of leaves per plant (6.37, 10.63, 14.37, 18.52 and 18.71 at 15, 30, 45, 60 DAT and harvesting time) was recorded from maghi variety (V_3). On the other hand, minimum number of leaves per plant (6.22, 9.91, 13.72, 18.04 and 18.46 at 15, 30, 45, 60 DAT and harvesting time) was observed aksel variety (V_1). The highest curd yield (30.78t ha^{-1}) was recorded in Snowball-1variety (V_2) and the lowest yield (20 t ha^{-1}) was recorded in aksel variety (V_1).

In case of the main effect of fertilizer and manure were significantly different on growth, yield contributing characters and yield of cauliflower. The tallest plant height (20.84, 32.35, 51.26, 60.48, and 65.64 cm at 15, 30, 45, 60DAT and harvesting time) was recorded from the plot where chemical fertilizer (F_2) was applied. On the other hand, the shortest plant height (12.26, 22.79, 35.13, 47.12 and 53.28 cm at 15, 30, 45, 60 DAT and harvesting time) was observed from the plot where no fertilizer (F_1) was applied. However, the longest outer leaf length (12.31, 26.07, 34.26 and 43.96 cm at 15, 30, 45 and 60 DAT) was recorded from the plot where chemical fertilizer (F_2) was applied. On the other hand, the shortest outer leaf length (8.12, 16.73, 24.11 and 33.79cm at 15, 30, 45 and 60 DAT) was observed from the plot where no fertilizer (F_1) was applied. The widest leaf (5.76, 9.92, 13.88 and 17.17 at 15, 30, 45 and 60 DAT was recorded from the plot where chemical fertilizer (F_2) was applied. On the other hand, minimum width of leaf (3.50, 6.66, 11.04 and 13.67 at 15, 30, 45 and 60 DAT) was observed from the plot where no fertilizer (F_1) was applied. The maximum number of leaves per plant (7.03, 11.50, 16.16, 20.78 and 20.82 at 15, 30, 45, 60 DAT and harvesting time) was recorded from the plot where chemical fertilizer (F_2) was applied. On the other hand, minimum number of leaves per plant (5.34, 8.77, 11.22, 15.78 and 16.29 at 15, 30, 45, 60 DAT and harvesting time) was observed from the plot where no fertilizer (F_1) was applied. The highest curd size (254.40cm^2) and yield (36.47t ha^{-1}) was recorded in the plot where chemical fertilizer (F_2) was applied and the lowest curd size (168.10cm^2) and yield (20.32t ha^{-1}) was recorded in the plot where no fertilizer (F_1) was applied.

Again, in case of interaction effect of variety and Fertilizer & manure application of cauliflower had significant effect on plant height (15, 30, 45, 60 DAT and harvesting time), outer leaf length (15, 30, 45 and 60 DAT), outer leaf width (15, 30, 45 and 60 DAT), no. of leaves/plant, curd size and yield respectively. The tallest plant height (21.21, 34.59, 53.19, 61.07 and 66.20 cm at 15, 30, 45, 60DAT and harvesting time) was recorded in the treatment V_2F_2 (snowball-1 + chemical fertilizer). On the other hand, the shortest plant height (10.24, 21.84, 33.40, 44.25 and 52.29 cm at 15, 30, 45, 60DAT and harvesting time) was observed from the treatment V_1F_1 (aksel + no fertilizer). However, the longest outer leaf length (6.76, 14.80, 20.28, and 32.83 cm at 15, 30, 45 and 60 DAT) was recorded from the treatment V_2F_2 (snowball-1 + chemical fertilizer). On the other hand, the shortest outer leaf length (13.98, 27.70, 36.73 and 44.57cm at 15, 30, 45 and 60 DAT) was observed from the treatment V_1F_1 (aksel + no fertilizer). The widest leaf (6.26, 10.51, 13.96 and 18.20 at 15, 30, 45 and 60 DAT was recorded from the treatment V_2F_2 (snowball-1 + chemical fertilizer). On the other hand, minimum width of leaf (3.29, 6.49, 9.67 and 13.07 at 15, 30, 45 and 60 DAT) was observed from the treatment V_1F_1 (aksel + no fertilizer). The maximum number of leaves per plant (7.27, 11.70, 16.43, 21.03 and 20.93 at 15, 30, 45, 60

DAT and harvesting time) was recorded from the treatment V_2F_2 (snowball-1 + chemical fertilizer). On the other hand, minimum number of leaves per plant (5.33, 8.23, 10.83, 15.53 and 15.80 at 15, 30, 45, 60 DAT and harvesting time) was observed from the treatment V_2F_2 (snowball-1 + chemical fertilizer). The highest curd size (295.30 cm^2) and yield (37.27 ton ha^{-1}) was recorded in the treatment V_2F_2 (snowball-1 + chemical fertilizer) and the lowest curd size (151.70 cm^2) and yield (19.52 ton ha^{-1}) was recorded in the treatment V_1F_1 (aksel + no fertilizer).

Again in case of economic analysis, the total cost of production was maximum (167335tk/ha) in snowball-1 variety where chemical fertilizer (V_2F_2) was applied whereas the minimum cost of production (144938 tk/ha) was in aksel variety where no fertilizer (V_1F_1) was applied. The highest gross return (523300tk/ha) was recorded in snowball-1 variety where chemical fertilizer (V_2F_2) was applied and the minimum gross return (345800 tk/ha) was recorded in aksel variety where no fertilizer (V_1F_1) was applied. Highest net return (355965 tk/ha) was found in Snowball-1 variety where chemical fertilizer (V_2F_2) was applied whereas the lowest net return (200862 tk/ha) was in aksel variety where no fertilizer (V_1F_1) was applied. The highest benefit cost ratio (3.17) was recorded in snowball-1 variety where chemical fertilizer (V_2F_2) was applied whereas the lowest benefit cost ratio (2.38) was in aksel variety and no fertilizer (V_1F_1) application.

5.2 Conclusion

From the findings of the present study it may be concluded that, the diversification of farming system and cultivation of cauliflower as ground layers crops in mango tree orchard is a viable option for accretive the farmer’s income. In case of cauliflower production under mango +

cauliflower based agroforestry system application of chemical fertilizer as well as cow dung may be a good practice. It was also found that the suitability of cultivating different variety was ranked as Snowball-1> Maghi> Aksel (according to yield). However, finally it may be concluded that the production of cauliflower was higher in chemical fertilizer application. But considering the benefit of organic manure (cowdung) application in terms of environmental benefit, soil health and food safety then cultivation of cauliflower variety Snowball-1 at the floor of mango orchard with organic manure application may be a promising orchard based agroforestry system in the northern part of Bangladesh.

5.3 Recommendations

1. Cauliflower can be grown at the floor of young mango orchard using organic manure like cowdung and poultry as an agroforestry practice.
2. Farmers or mango orchard owner can cultivate cauliflower variety Snowball-1 with only cowdung manuring at the mango floor for additional income.
3. This study should be repeated in different location of the country using different aged mango orchard to obtained valid recommendation.

APPENDICES

Appendix-I: The soil properties of Agroforestry and Environment farm HSTU, Dinajpur.

Soil characters	Physical and chemical properties
Texture	
Sand (%)	67
Silt (%	33
Clay (%	5
Textural class	Sandy loam
CEC (meq per 100g)	8.00
pH	6.1
Organic matter (%)	1.25
Total nitrogen (%)	0.10
Sodium (meq per 100g)	0.06
Calcium (meq per 100g)	1.30
Magnesium (meq per 100g)	0.40
Potassium (meq per 100g)	0.26
Phosphorus (µg perg)	25.0
Sulphur (µg perg)	3.1
Boron (µg perg)	0.28
Iron (µg perg)	5.30
Zinc (µg perg)	0.90

Source: Soil Resources Development Institute, Dinajpur (2016).

Appendix II. Monthly records of different weather data at the period from October 2016 to March 2017

Month	** Air Temperature (ºC)					
	Maximum	Minimum	Average	**Relative Humidity (%)	*Rainfall (mm)	*Sunshine (hrs.)
October	21.8	18.0	19.9	83.0	1.0	269.7
November	32.8	21.1	26.9	85.0	5.0	280.4
December	32.9	22.7	27.8	90.0	10.0	250.1
January	35.5	27.6	31.5	92.0	13.0	220.1
February	36.5	28.6	32.55	90.0	8.0	230.1
March	37.5	29.6	33.55	88.5	00	235.4

Note * Monthly average

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

Appendix-III: Cost of production for Indian spinach in mango based agro forestry 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) @ 8% for the crop season (tk/ha)	Miscellaneous cost @ 5% of the input cost (tk/ha)	
	Mango Tree	Cauli-flower	Total non-material cost	Seedling	Fertilizer	Pesticide	Irrigation	Maintenance cost of trees	Initial plantation cost of trees	Total material cost (tk/ha)					
V_1F_1	11675	38420	50095	26500	0	0	3260	6850	23860	60470	110565	8845	20000	5528	144938
V_1F_2	11675	38420	50095	26500	10860	4870	3260	6850	23860	76200	126295	10104	20000	6315	162713
V_1F_3	11675	38420	50095	26500	5650	1680	3260	6850	23860	67800	117895	9432	20000	5895	153221
V_1F_4	11675	38420	50095	26500	3250	1680	3260	6850	23860	65400	115495	9240	20000	5775	150509
V_2F_1	11675	38420	50095	30590	0	0	3260	6850	23860	64560	114655	9172	20000	5733	149560
V_2F_2	11675	38420	50095	30590	10860	4870	3260	6850	23860	80290	130385	10431	20000	6519	167335
V_2F_3	11675	38420	50095	30590	5650	1680	3260	6850	23860	71890	121985	9759	20000	6099	157843
V_2F_4	11675	38420	50095	30590	3250	1680	3260	6850	23860	69490	119585	9567	20000	5979	155131
V_3F_1	11675	38420	50095	28600	0	0	3260	6850	23860	62570	112665	9013	20000	5633	147311
V_3F_2	11675	38420	50095	28600	10860	4870	3260	6850	23860	78300	128395	10272	20000	6420	165086
V_3F_3	11675	38420	50095	28600	5650	1680	3260	6850	23860	69900	119995	9600	20000	6000	155594
V_3F_4	11675	38420	50095	28600	3250	1680	3260	6850	23860	67500	117595	9408	20000	5880	152882

Appendix IV: Some plates of the research activities

Plate 5: Land Preparation

Plate 6: Seedling Transplantation of Cauliflower

Plate 7: Tagging at the experimental plots

Plate 8: Vegetative growth stage

Plate 9: Measuring Vegetative growth

Plate 10: Harvesting of Cauliflower

Plate 11: Weighing with Leaves of Cauliflower

Plate 12: Weighing without Leavesof Cauliflower

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