PERFORMANCE OF CAULIFLOWER AS INFLUENCED BY SPACING AND FERTILIZATION UNDER MEHOGANY BASED AGROFORESTRY IN CHARLAND OF TISTA RIVER BASIN

A THESIS

BY

SUMAIA AKTER HAPPY

Student No. 1905112

Semester: January- June, 2020

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

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

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Approved as to style and contents by

....	....
Prof. Dr. Md. Shafiqul Bari	Prof. Dr. Md. Shoaibur Rahman
Supervisor	Co-supervisor

....
Prof. Dr. Md. Shoaibur Rahman
Chairman
Examination Committee
And

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

JUNE, 2020

DEDICATED

TO MY

BELOVED PARENTS

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June, 2020 *The Authoress*

DECLARATION

I hereby declare that the work presented in this thesis entitled "**PERFORMANCE OF CAULIFLOWER AS INFLUENCED BY SPACING AND FERTILIZATION UNDER MEHOGANY BASED AGROFORESTRY IN CHARLAND OF TISTA RIVER BASIN**" has been carried out by myself and that it has not been submitted for any previous degree. All quotations have been distinguished by quotation marks and all sources of information specifically acknowledged by references to the authors.

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SUMAIA AKTER HAPPY

Student No. 1905112

M.S. Session 2019

Department of Agroforestry and Environment

Hajee Mohammad Danesh Science and Technology University,

Dinajpur-5200, Bangladesh

PERFORMANCE OF CAULIFLOWER AS INFLUENCED BY SPACING AND FERTILIZATION UNDER MEHOGANY BASED AGROFORESTRY IN CHARLAND OF TISTA RIVER BASIN

ABSTRACT

A field experiment was conducted in Jaldhakaupazila under Nilphamari district during October, 2019 to February, 2020 to evaluate the performance of cauliflower as influenced by spacing and fertilization under mehogany based agroforestry in charland of tista river basin. The experiment was laid out in two factorial RCBD with three replications. Factor A; Three spacings viz. S_1= 75 cm x 50 cm (Broader), S_2= 60 cm x 45 cm (Intermediate), S_3= 50 cm x 40 cm (Close) and Factor B; Four different fertilizer and manure applications viz. F_1= No fertilizer, F_2= Poultry manure, F_3= Cow-dung and F_4= Chemical fertilizer. In case of the main effects of different planting spacing, the maximum yield of curd with leaf (49.73 t/ha) was recorded from the closer spacing i.e. 50 x 40 cm (S_3). One the other hand, the minimum yield (20.97 t/ha) was recorded from the broader spacing i.e. 75 x 50 cm (S_1) and the maximum yield of curd without leaf (21.89 t/ha) was also recorded from the closer spacing (50 x 40 cm). Whereas the minimum yield (15.28 t/ha) was recorded from the broader spacing (75 x 50 cm). Again, in case of main effects of fertilizer and manure applications, the highest curd yield with leaf (43.54 t/ha) was recorded from the plot where chemical fertilizer (F_4) was applied whereas lowest curd yield with leaf (27.06 t/ha) was obtained from the plot where no fertilizer (F_1) was applied. Similarly, the maximum yield of curd without leaf (23.27 t/ha) was recorded from the plot where chemical fertilizer (F_4) was applied and the lowest yield of curd without leaf (9.47 t/ha) was obtained from the plot where no fertilizer (F_1) was applied. In case of interaction effects of the different planting spacings and fertilizer and manure applications, the maximum curd yield with leaf (49.73 t/ha) was recorded in the pot where maintained closer spacing with chemical fertilizer application (S_3F_4) whereas the minimum yield (20.97 t/ha) of curd with leaf was recorded in the plot where maintained broader spacing (75 x 50 cm) with no fertilizer (S_1F_1). However, the maximum curd yield without leaf (27.00 t/ha) was recorded in the plot where maintained closer spacing with chemical fertilizer (S_3F_4) whereas the minimum yield (7.73 t/ha) of curd without leaf was recorded in the plot where maintained broader spacing with no fertilizer (S_1F_1).Finally, from the economic analysis, the highest benefit-cost ratio (4.08) was recorded from the treatment 50 x 40 cm spacing + chemical Fertilizer application (S_3F_4). On the other hand, the lowest benefit-cost ratio (1.73) was observed in those plots where cauliflower was grown under 60 x 45 cm planting space with no fertilizer application (S_2F_1). So, if we consider the benefit of organic manure applications in terms of environmental benefit, soil health and safe food consumption then cultivation of cauliflower at the floor of mahogany orchard with cow-dung applications using closer spacing i.e. 50 x 40 cm may be a promising orchard based agroforestry system in the northern part of Bangladesh.

Keywords: Cauliflower, Mahogany, Planting spacing, Fertilizer dose and Char land.

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ABBREVIATIONS

AEZ	: Agro-ecological zone
BADC	: Bangladesh Agricultural Development Corporation
BBS	: Bangladesh Bureau of Statistics
BCR	: Benefit Cost Ratio
DAT	: Days after Transplanting
FAO	: Food and Agriculture Organization
FYM	: Farm Yard Manure
g	: Gram
kg	: Kilogram
m	: Meter
cm	: Centimeter
cm^3	:Cubic Centimeter
MOP	: Muriate of Potash
N	: Nitogen
RCBD	: Randomized Complete Block Design
t/ha	: Ton per Hectare
tk	: Taka
TSP	: Triple Super Phosphate

CHAPTER I
INTRODUCTION

1.1 Background information of the study

Bangladesh is one of the densely populated countries of the world having an agro-based economy which situated in the North-Eastern part of South Asia with a tropical to sub-tropical climate surrounded by Indian & Myanmar. Now the population of Bangladesh is about 164.7 million in 147570 sq. Kilometers and growth rate is 2.11% per annum. The total forest area of Bangladesh is 2.6 million hectares, which is nearly 17.4% of the total land area of the country (BBS, 2016). Due to increasing population, land holdings are being fragmented and area devoted to small scale agriculture is decreasing. In Agroforestry systems, different types and nature of species are grown in association, therefore, there is an inevitable competition for growth resources such as light, water and nutrients which may reduce the productivity of under storied crops. Agroforestry can provide a sound ecological basis for increased crop and animal productivity, more dependable economic returns, and greater diversity in social benefits on a sustained basis (Rahim, 1997).

However, under these alarming situations, agricultural production as well as forest resources must be increased by using modern new techniques. Recently, some techniques have already been advocated to overcome the future challenges, Agroforestry is one of them. Agroforestry, the integration of tree and crops/vegetables on the same area of land is a promising production system for maximizing yield (Nair, 1990) and maintaining friendly environment. Growing of crops/vegetables in association with trees is becoming popular day by day for higher productivity, versatile/multipurpose use, and environmental consciousness among the peoples (Sheikh and Khaleque, 1982). Forestry with agricultural crop can provide a sound ecological basis for increased crop and forest productivity, more dependable economic returns, and greater diversity in social benefits on a sustained basis (Rahim. 1997; Franis, 2001). Lundgren and Raintree (1982) stated that agroforestry is a collective name for all land use systems and technologies where woody perennials are deliberately used on the same land management units as agricultural crops and/or animals in some form of spatial arrangement or temporal sequence.

Agroforestry is the combination of forestry and agriculture with attributes of productivity, sustainability, and adoptability. In Bangladesh scope of Agroforestry is vast. The major venues of agroforestry are homestead, roadside, railway side, embankment side, char land, coastal area, deforested area, institutional premises, riverside etc. Among them char land is the most important venue for practicing agroforestry systems. 'Char'a is a tract of land surrounded by the waters of an ocean, sea, lake, or stream; it usually means any accretion in a river course or estuary (Chowdhury, 1988). Chars in Bangladesh have been distributed into five sub-areas: the Jamuna, the Ganges, the Padma, the Upper Meghna and the Lower Meghna rivers. There are other areas of riverine chars in Bangladesh, along the Old Brahmaputra and the Tista rivers. It is estimated that in 1993 the total area covered by chars in Bangladesh was 1,722 sqkm (Banglapedia). A large number of populations are living in these char areas and maintaining their livelihood through char based farming systems. Therefore, for increasing production, maintaining ecological balance and improving socio-economic condition of the char land people, integrated approach with crops/vegetables and trees is necessary.

Cauliflower (*Brassica oleraceavar. botrytis*) is a cool season crop grown for its immature inflorescence called curd which is a rich source of dietary nutrients and antioxidants. Cauliflower is very sensitive to growing conditions and requires more attention than cabbage, broccoli and other close relatives and hence it is regarded as the aristocrat of the cruciferae family. Cauliflower is originated from wild cabbage (*Brassica oleracea var. sylvestris)* and its center of origin is believed to be the Island of Cyprus (Kohli *et al.*, 2008). It is grown in all continents of the world, of which Asia is the leading one followed by Europe. 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. 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 of cauliflower 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 cycteine sulfoxide and glucobrassicin which have prominent anticarcinogenic 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 100g of edible portion is as follows: energy 31 calories, protein 2.4g, calcium 22mg, vitamin A 40 IU, ascorbic acid 70mg, thiamine 0.2mg, riboflavin 0.1mg and niacin 0.75mg (Khan *et al.*, 1968).

Mahogany (*Swietenia macrophylla*) (Family Meliaceae and native of Central America) is one of the best quality timbers for high class furniture and cabinet work due to its light hardwood quality in the world. On the other hand, mahogany is the most important timber tree in neo-tropical forests, has become the flagship species in debates about the feasibility of sustainable tropical forest management (Gullison *et al*., 1996). It is generally recognized that temperature increases and altered patterns of rainfall, as well as extreme events, will have an influence on livelihoods and the sustainable use of natural resources and management strategies. At the same time, increasing access to energy in both cost-effective and climate-friendly ways is a major challenge for many developing countries. Also traditional multifunctional agroforestry systems, land use approach that integrates multipurpose trees with crop production also addresses environmental degradation in tropical region offer innumerable ecological benefits (Vergara, *et al.*, 1982).

1.2 Research objectives

However, there is no conformation about the cultivation possibility of cauliflower in Char land area using organic manure. Considering the circumstances, a study was conducted at the Tista river basin Char land with the following objectives:

1. To find out effect of spacing and fertilization of performance of cauliflower under Mahogany based Agroforestry system in Char land.
2. To observe suitabale combination of spacing and fertilization for cauliflower production under Mahogany based Agroforestry system in Char land.
3. To find out the economic performance of newly established mahogany with cauliflower based Agroforestry system in char land.

CHAPTER II

REVIEW AND LITERATURE

A review of the previous research and findings of researchers having relevance to this study which were gathered from different sources like literature, journals, thesis, reports, newspaper etc. will be represented by this chapter. However, some of the literature related to this investigation are reviewed in this chapter. The relevant literatures pertaining to the present study have been reviewed in this chapter under the following heads:

2.1Concept of cauliflower and agroforestry practices in Bangladesh
2.2 Characteristics of tree species in agroforestry systems
2.3 Tree based agroforestry systems
2.4 Agroforestry: A sustainable land use technology and new venture
2.5 Charland based on agroforestry system
2.6 Effect of light, shade and temperature on cauliflower growth and development
2.7 Effect and importance of manure application

2.1 Concept of cauliflower and agroforestry practices in Bangladesh

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 tempted 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).

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, flavor 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 type where only available. With the development of tropical Indian cauliflower, it become 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 climate conditions. It is therefore important to choose thew 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 (Pradirkumar and George, 2009).

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

Acording 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".

Agroforestry should be reconsidered as a dynamic, ecologically based, natural resource management system that, through the integration of tree in farm and rangeland, diversifies and sustains production for increased social, economic and environmental benefits (Leakey, 1996).

Ally cropping is one kind of agroforestry technology that is being explored as one of the land use options in the tropics. It is a land management practice in which food crops are grown in the interspaces between rows of planed woody shrubs or tree species, usually legumes and in which the woody species are periodically pruned during the cropping season to prevent shading and to reduce competition with the companion crops and the pruning provide the addition of organic matter from the hedgerow plants to improve soil physical, biological and chemical condition: reduction in soil erosion: and harboring of beneficial predators in the hedgerows (Lal, 1991).

Agroforestry is collective name for all land use systems and technologies where woody perennils (trees, shurbs, palms, bamboo etc.) are deliberately grown on the same land management unit as agricultural crops and/or animals either in spatial mixture or in temporal sequence. There must be significant ecological non-woody components, (Lundgren and Raintree, 1982).

Harou (1983) stated that agroforestry is a combined agriculture-tree crop farming system which enables a farmer or land user to make more effective use of his land which may yield a higher net economic return on a sustainable basis. Ong (1988) reported that by intercropping trees with arable crops, biomass production per unit area could be increased substantially when the roots of trees exploit water and nutrients below the shallow root of crops and when a mixed canopy intercepts more solar energy.

Mac Dicken 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.

2.2 Tree based agroforestry systems

Agroforestry intercropping systems have been developed as an alternative to conventional mono-cropping 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). Laroche *et al.*, 2018 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. Their results showed 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 (Prodipkumar *et al.,* 2009).

Akter *et al.* (1989) mentioned that farmers also considered tree as savings and insurance against risk of crop failure and low yield, as well as assets for their children. Some farmers stated that tree would contribute towards expenses for marriage of their daughters. In tree crop agroforestry system tree species are grown and managed in the farmland along with agricultural crops. The aim is to increase the overall yield of the land. This system is also based on the principle of sustained yield (Nair, 1990).

Solanki (1998) stated that Agroforestry significantly contribute in increasing fuel wood, fodder, cash income and infrastructure in many developing countries. He also stated that Agroforestry has high potential to simultaneously satisfy' three important objectives: (i)From a business point of view, Agroforestry is an economic enterprise which aims to produce a combination of agricultural and forest crops simultaneously oil the same land area protecting and stabling the ecosystems, (ii) producing a high level of output of economic goods (fuel, fodder, small timber, organic fertilizer, etc.) and (iii) providing stable employment, improved income and material to rural populations.

According to Kohli *et al.*, (2008), reported that under unfavorable weather conditions, especially during warm cloudy nights, cauliflower curds may become loose due to elongation of individual pedicels and velvety or granular in appearance. Cauliflower curd surface sometimes shows pink tinge due to exposure to high light intensity, which leads to the formation of anthocyanin pigment, especially when the temperature is extremely low.

According to Bhat (2009), the check of vegetative growth followed by suitable temperature for transformation to curding may induce buttoning which is the development of small heads while the plants are small. Hazra and Som (1999) reported that the prevalence of high temperature than the optimum for a particular variety during curd development causes leafiness.

Muthukrishnan and Irulappan (1986) studied the variability of 95 accessions of *Abelmoschus esculenius* and *Abelmoschus nanihot* and they found significant differences among the accession for all the characters studied viz, plant height, plant spread, number of primary branches per plant, days to flowering, nodes when the first flower appear, number of leaves per plant, leaf length, leaf breadth, petiole length, number of pod per piant, pod weight and total yield variability were greatest. Akbar *et al.*, (1990) reported that wheat yield under different tree species (Mulberry, Sins. Ipil-ipil) did not show any significant difference as compared to control yield. Leonardo (1996) reported that shading (60% light reduction) reduced vegetative and fruit growth. Shading increased plant height and reduced chlorophyll content. Stomata density, transpiration rate and photosynthesis rate, yield of peppers decreased with increasing the amount of shade levels. Healcy *et al.,* (1998) reported that level of incident radiation reduced by 25% under shade-cloth decreased final yield and final leaf index, but increased canopy leaf, nitrogen concentration and radiation uses efficiency. A similar level of reduced incident radiation under solar weave shade-cloth increased final yield and radiation use efficiency (46-50%).

Senevirathna *et al.,* (2003) compared the growth, photosynthetic performance and shade adaptation of rubber (1-fevea brasiliensis genotypes PRRIC 100) plant growing in natural shade (33. 55 and 77% reduction in incoming radiation) to control plants growing in full sunlight. Stem diameter and plant height was greatest in plants grown in full sunlight and both parameters decreased with increasing shade. Total plant dry mass was highest in control plants and lowest in plants in 77% shade. Expansion of the fourth leaf whorl, monitored at 5-6 MAP, was slowest in plants in 77% shade and fasted in shade less plants, which had more leaves and higher leaf areas and inter whorl shoot lengths with increasing shade, specific leaf area was increased whereas leaf weight ratio and relative growth rate were decreased.

Rahman *et al.,* (2004) reported that except plant height all others morphological characters viz, no. of branches plant", no. of fruit plant', fruit length, fruit diameter and fruit weight of three vegetables (Tomato. Brinjal, Chili) were highest in open field condition. Among the different agroforestry system. Highest yield was obtained in Horitoki - Lemon - Vegetable based agroforestry system.

Islam *et al.,* (2008) conducted an experiment to evaluate the performance of winter vegetables under Guava-Coconut based multistate system. The result revealed that significantly vigorous plant growth as well as tallest plants were found under reduced light level whereas maximum yield recorded under fill sunlight condition.

Bari and Rahim (2009) found that multistate agroforestry systems (MAF) with different tree spacing had significant influence on the root yield of Carrot. The highest carrot root yield was recorded under sole cropping which was followed by the wider and intermediate spacing of sissoo - lemon based MAF. The reduction in yield of carrot compared to sole cropping was more at closer spacing of MAF..

Rahman (2012) evaluate that the growth performance of two winter crops viz. mustard andsweet gourd grown under 2 years old akashmoni tree saplings of four different distances. The result showed that among the morphological characteristics of winter crops plant height, length of branch, no. of siliqua per branch, length of siliqua, vine length. Fruit length, no. of fruit, and fruit diameter increased consistently with the increase of distance from sapling. The growth characteristics of Akashmoni (*Acacia auriculiformis*) significantly influenced by the interaction of the crops.

Anwar (2013) conducted an experiment to study the growth and yield of winter vegetables i.e. bottle gourd under different distance from Mahogany, Akashmoni and Lambu tree and he found that all the parameters i.e plant height, number of leaves plant", branches plant", average number of male and female flower plant', fruits plant', average weight of fruit, length of fruits, girth of fruit, fresh yield, dry yield, yield were increased gradually with increasing distance from Mahogany, Akashmoni and Lambu tree. The results of the experiment revealed that the yield of bottle gourd was increased gradually with the increase of planting distance from the tree.

2.3 Agroforestry: A sustainable land use technology and new venture

Agroforestry is an age-old and ancient practice. It is an integral part of the traditional farming system of Bangladesh. The concept of agroforestry probably originate from the realization that trees play an important role in protecting the long rang interest of agriculture and in making agriculture economically viable. The emergence of agroforestry was mainly influenced by the need to maximize the utilization of soil resources through the “marriage of forestry and agriculture” (PCARRD, 1983). This was brought about by the increasing realization that agroforestry can become an important component of ecological, social and economic development efforts.

Agroforestry is the idea of combining forestry and agriculture on the same pice of land. The basic concept of intercropping has been extended to agroforestry system. Many authors have defined agroforestry in different ways. A widely used definition given by the International Council for Research in Agroforestry (Nair, 1983) is that agroforestry is a collective name for all land use systems and practices where woody perennials are deliberately grown on the same land management or temporal sequence.

Michon and de Foresta, 2001) compared to monocultures (Gallina, Mandujano, and Gonzalez-Romero, 1996). It has also been well documented that fruit –tree-based agroforestry systems in the North Temperate Zone are able to provide the public environmental services better than monoculture annual or intensively managed orchards (Herzog, 1998). Additionally, agroforestry technologies may improve nutrient yelling (Glover and Beer, 1986; and Nair *et al.*,1999), buffer understory temperature extremes or enhance soil water balance while reducing erosion (Rao *et al.*,1998).

Yamoah *et al.*, (1986) reported beneficial effect of *Cassia siamea* hedgerows on maize crop probably due to the accumulation of more litter close to the hedgerows. Significant increase in grain yield of maize grown under *Leucaena leucocephala* was observed by Gichuru and Kang (1989) reported higher grain yield in maize grown with alley cropping than sole cropping. Non-inhibitory effort of *Leucaena leucocephala* on maize crop were reported by Lal (1989).

Solanki (1998) studied fruit trees and crops grown together in various ways. Depending on the patterns and configurations, these companion crops are known as intercrops, under planting, hedgerow planting or alley cropping. In an agroforestry system where agriculture crops are normally grown between rows of fruit trees, the agricultural crops provide seasonal revenue whereas fruit trees managed for 30-35 years give regular returns of fruits and in some cases fuel wood from pruned wood and fodder. Several kinds of crops are also crops are also under planned to take the advantages of shades provided by the canopies of fruit trees.

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

Hossain *et al.*, (2005) carried out an experiment to evaluate the performance of Indian spinach grown under Eucalyptus tree in different orientations from May to August 2003 at the Bangladesh Agricultural University, Mymensingh. The treatment involved different orientations: north, south, east and west for each of the tree. The fresh yield produced in south orientations followed by west, east and north, 56.37%, less than the open field and that of for dry yields were 52.74, 56.41, 58.14 and 59.80% less respectively.

The other potential benefit of agroforestry is that of the diversification of species grown on farm. Through this, and the domestication of an increasing number of tree species, it should be possible to make small-holder farming both more biologically diverse and more rewarding economically. Through the incorporation of a range of domesticated trees into different agroforestry practices within the same landscape, agroforestry can become, as recently defined (Leakey, 1996).

Newman (1997) specifically recommended the increase in spacing between rows with compensatory decrease in within- row distance in order to improve the performance of an understory crop besides selection of more shade-tolerant species and varieties of agricultural crops.

2.4 Charland based on agroforestry system

The country has a land area of only 14.39 million hectares, but due to the ever increasing population, per capita land area is decreasing at an average rate of 0.005 ha/cap./year since 1989 (Hossain and Bari, 1996). The capacity of our land is decreasing day by day due to intensive cropping and use of high input technologies. Agriculture remains the most important sector of Bangladesh economy, contributing 14.79% to the country’s Gross Domestic Product (GDP) and employs more than 45.1% of total labor force (BBS, 2017). Agroforestry is the combination of forestry and agriculture with attributes of productivity, sustainability, and profitability. In Bangladesh scope of Agroforestry is vast. The major venues of agroforestry are homestead, roadside, railway side, embankment side, charland, coastal area, institutional premises, riverside etc. among them charland is the most important venue for practicing agroforestry systems. ‘Char’ a tract of land surrounded by the waters of an ocean, sea, lake, or stream; it usually means any accretion in a river course or estuary (Chowdhury, 1988).

Char in Bangladesh have been distributed into five sub-areas: the Jamuna, the Ganges, the Upper Meghna and the Lower Meghna rivers. There are other areas of riverine chars in Bangladesh, along the old Brahmaputra and the Tista rivers. But compared to the chars in the major rivers, these constitute much less land area. It is estimated that in 1993 the total area covered by char in Bangladesh was 1722 sq. km. a large number of population are living in these char areas and maintaining their livelihood through char based farming systems. Therefore, for increasing production, maintaining ecological balance and improving socio-economic condition of the char land people, integrated approach with crops/vegetables and tree is necessary. There are over 12 million people who live in char lands and struggle against the floods and associated river bank instability (Hooper, 2001). Agroforestry plays a vital role in supplying not only the daily necessities of people but also in maintaining ecological basis for increased crop and animal productivity, more dependable economic returns, and greater diversity in social benefits on a sustained basis (Rahim, 1997).

2.5 Effect of light, shade and temperature on cauliflower growth and development

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 531 μmol mol^{-1} CO_2 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 14^0C, 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. 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 condition

Solar radiation is very important resource in multistoried production system because it is the energy source for photosynthesis and transpiration, hence growth and development of plants .But excessive density as well as excessive exposure or drastic reduction of solar energy may depress economics yield. In any agroforestry system, trees grown in close proximity to crop, often much more scope for useful management of light interception and distribution that do monoculture. Light is an essential factor on plant growth and development. The major light factors affecting plant growth are light quality, light intensity, photoperiod and day/night cycle (Goto, 2003).

Alley cropping Agroforestry systems has been emerged as a sound technology where tree leaves are periodically pruned to prevent shading the companion crops (Kang *et al*., 1984). The partial shading (45-50% of normal light) at 15 days after transplanting reduced grain yield of rice by 73% because of reduction in number of panicles per plant (5 1.50%), number of grain per panicle (16.70%) and increase in number of unfilled spikelet's (4l.1O%) in 25 rice cultivars (Jadhav, 1987).

Rao and Mittra (1988) observed that shading by taller species usually reduces the photosynthetically active radiation. Photo-synthetically active radiation regulates photosynthesis, dry matter production and yield of crop. The shading was responsible for suppression of maize yields while in the shorter second season, where rains ended abruptly, moisture competition was the main factor causing the drastically low yield (Singh *et at,* 1989).

Masarirambi *et al.,* (2011) reported that direct exposure to sunlight resulted in the development of yellow pigments on curds Curds left uncovered will discolored due to activation of peroxidase enzyme by sunlight and curd will loosen in the sun' heat. Chatterjee and Kabir (2002) reported that high relative humidity induced raciness 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 12 hours suppressed the leaf number as well as dry matter yield of the curd per plant.

2.6 Effect and importance of manure application

Manure is often added to stabilize 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).

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.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Char land in Jaldhaka upazila under Nilphamari District. In this chapter the materials used, the methodologies followed and the related works done during experimental period are presented. A brief description on the experimental site and season, soil, climate and weather, plant materials, land preparation, fertilizer application, experimental design and treatment combination, seed sowing, intercultural operation. Harvest, data collection, statistical analysis etc. are included here. The working procedures are given below:

3.1 Location

The experiment was conducted at the Char land in Jaldhaka upazila under Nilphamari district, Bangladesh. The experimental site was situated between 26°05' and 26°17' north latitudes and in 88°52' and 89°06' east longitudes and about 28m above the sea level

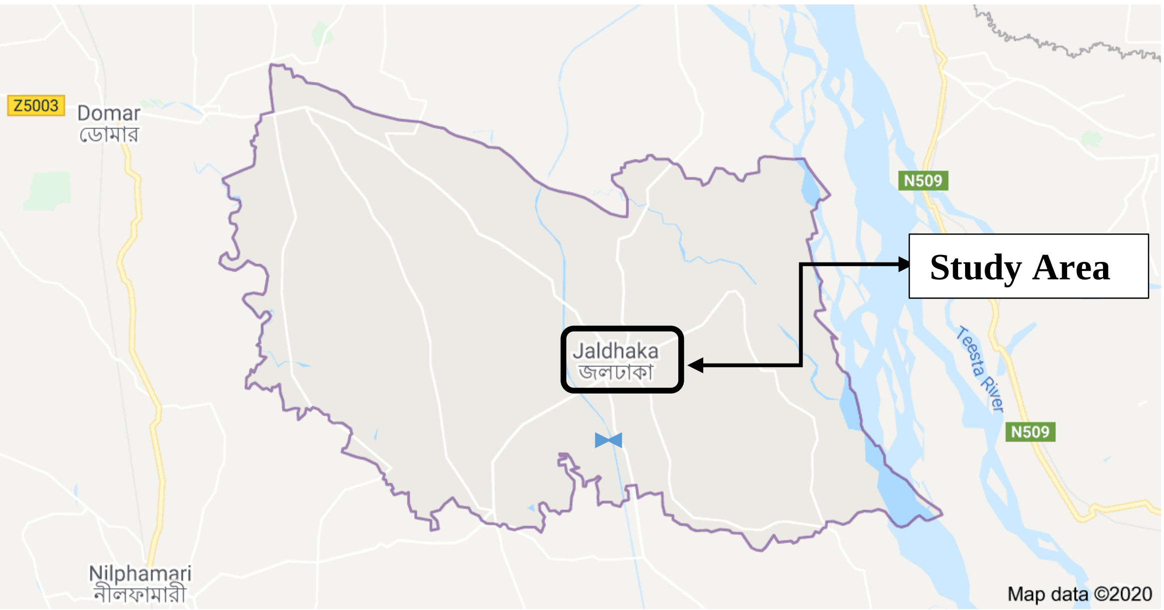


Figure 3.1: Map of Jaldhaka Upazila under Nilphamari District.

3.2 Soil characteristics:

The soil of the experimental plot situated in a low land belongs to Tista river flood plain area (under the AEZ 03). The soil was having a texture of sandy loam in nature with PH was 5.0 to 6.5. The morphological characteristics of the experimental field and physical and chemical properties of initial soil are given in Appendix I.

3.3 Climate and weather

Nilphamari's climate is classified as warm and temperate. The summers are much rainier than the winters in Nilphamari. According to Koppen and Geiger, this climate is classified as Cwa. The annual average temperature of the district varies maximum 32. 3°C to minimum 9.30°C and his annual average rainfall of the district is recorded 931 mm. Details of weather data are presented in appendix-II.

3.4 Experiment period

Duration of the experiment period was from October, 2019 to February, 2020.

3.5 Seedling growing of test crop

Seeds of the one variety (White Mount) of cauliflower were collected from Bangladesh Agricultural Development Corporation (BADC), Dinajpur.

3.6 Experimental design

The experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. Total number of experimental plot was 36. The size of each of unit plot was 3m x 1.5m.

3.7 Experimental treatments

The experiment consisted of two factors;

Factor- A (Three planting spacing)

S_1= 75 x 50 cm (Broader spacing)

S_2= 60 x 45 cm (Intermediate spacing)

S_3= 50 x 40 cm (Closer spacing)

Factor –B: (Four fertilizer and manure application)

F_1 = No fertilizer, No manure

F_2 = Poultry manure (5 ton $ha^{-1)}$

F_2= Cow-dung (10 ton $ha^{-1)}$

F_3= Chemical fertilizer (Recommendation dose of inorganic fertilizer)

Treatment Combinations

$S_1 F_1$ = Broader spacing + No fertilizer

S_1F_2 = Broader spacing + Poultry manure

S_1F_3 = Broader spacing+ Cow-dung

S_1F_4 = Broader spacing + Chemical

$S_2 F_1$ = Intermediate spacing + No fertilizer

S_2F_2 = Intermediate spacing + Poultry manure

S_2F_3 = Intermediate spacing+ Cow-dung

S_2F_4 = Intermediate spacing + Chemical

S_3F_1 = Closer spacing + No fertilizer

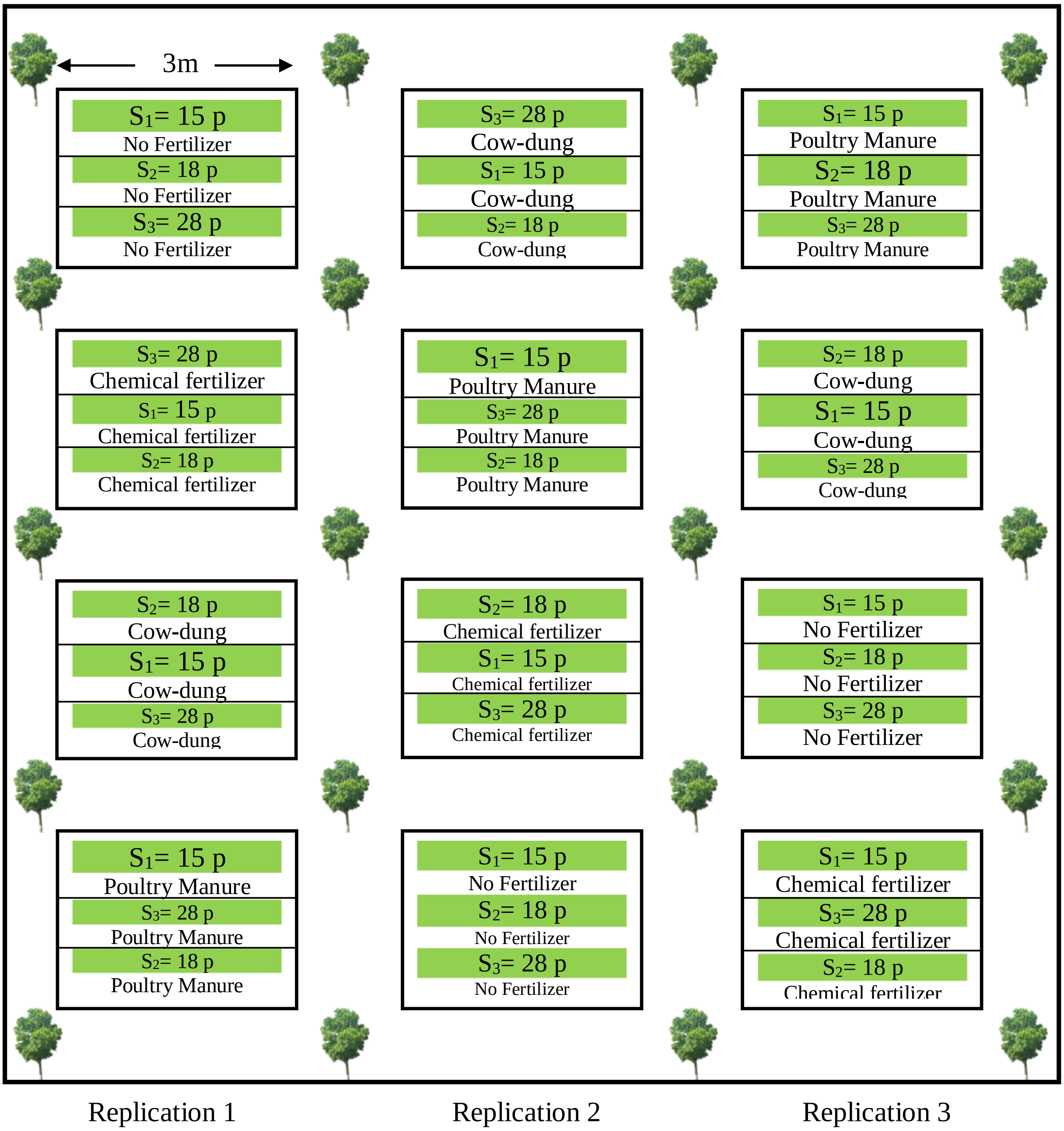
S_3F_2 = Closer spacing + Poultry manure

S_3F_3 = Closer spacing + Cow-dung

S_3F_4 = Closer spacing + Chemical

3.8 Land preparation and layout

The land of experiment plot was opened with a spade on 23 November 2019. The land was spaded several times followed by hammering to obtain tilth. All the weeds and other ambushes were removed from the field and left for several days for natural weathering before the final land preparation for seedling transplantation.



Note: Plot size 3m x 1.5m, S_1= 75 x 50 cm (Broader spacing), S_2= 60 x 45 cm (Intermediate spacing) and S_3= 50 x 40 cm (Closer spacing); *p = Number of Plant

Figure 3.2: Field layout of treatment combination under mahogany tree.

3.9 Fertilizer and manure applications

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

Types of Fertilizer	Recommended dose ha^{-1}
Urea	225 kg
TSP	225 kg
MOP	180 kg
GYP	150 kg
Borik	4.5 kg
Cowdung	10 ton
Poultry	5 ton

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 cow-dung 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 tilling stages after weeding followed by irrigation.

3.10 Plant characteristics

Local Name : Mahagony
Scientific Name : *Swietenia macrophylla*
Family : Meliaceae

3.10.1 The existing plant growth status

Planting orientation : North- South
Age of Mahogany tree : 3 years
Spacing : 10 feet by 10 feet
Main Agroforestry uses: Produces wood, silvopasture, agrosilviculture.

3.10.2 General description of mahogany

Mahogany (*Swietenia macrophylla*) (Family Meliaceae and native of Central America) is one of the best quality timbers for high class furniture and cabinet work due to its light hardwood quality in the world. On the other hand, mahogany is the most important timber tree in neo-tropical forests, has become the flagship species in debates about the feasibility of sustainable tropical forest management (Gullison *et al*., 1996). It is native to Peru and Brazil in Central America. In the Philippines, it was introduced in 1914. It was first grown in Md. Makiling in Laguna. It is one of the best quality timbers for high class furniture and cabinet work due to its light hardwood quality in the world. On the other hand, mahogany is the most important timber tree in neo-tropical forests, has become the flagship species in debates about the feasibility of sustainable tropical forest management.

According to the farmers, mahogany seedlings that they are planting came from the trees planted in the Makiling Forest Reserve. Planting of forest trees in agroforestry farms is not a common practice by the farmers. Besides the long waiting period for the trees to be harvested, problem also of bringing the timber to the market is also experienced by farmers. A community consultation was conducted to assess the factors that affect the adoption of mahogany-based agroforestry system. Based on these results, farmers are planting mahogany because of: 1) the multipurpose nature of the tree - windbreak for protection and boundary markers; 2) requires little or no maintenance; 3) savings for the future. Mahogany-based agroforestry system has the potential of evolving from rehabilitation to a restoration strategy for the degraded uplands.

3.11 Intercultural operations

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

3.11.1 Weeding

The experimental plots were kept weed free by weeding frequently.

3.11.2 Irrigation

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

3.11.3 Insect Pest control measure

In 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 (2% neem oil) and insecticides were applied fortnightly as a routine from a week after transplanting to a week before first harvesting.

3.11.4 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.

3.12 Sampling and data collection

The experiment plots were observed frequently to record various changes in plant characteristics at different stages of their growth. Then plants were selected at random from each unit plot to collect experiment 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.

3.12.1 Plant height (cm)

The heights were measured from the ground level to the tip of the longest shoot at an interval of 30 days starting from 30, 60 and 90 DAP and harvesting period.

3.12.2 Outer leaf length (cm)

The length of the leaf was obtained with the help of centimeter scale at 30, 60 and 90 DAP and harvesting time.

3.12.3 Outer leaf width (cm)

The width of the leaf was obtained with the help of centimeter scale at 30, 60 and 90 DAP and harvesting time.

3.12.4 Number of leaves per plant

It was recorded at an interval of 30 days starting from 30, 60 and 90 DAT and at harvesting period.

3.12.5 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.

3.12.6 Curd weight with leaf/plant (g)

This trait was recorded from the harvested curds with leaves of all plants of each plot including the sample plants. The yield of curd per plant were measured with the help of electric balance.

3.12.7 Yield of curd with leaf (kg/ha)

This trait was recorded from the harvested curds with leaves of all plants of each plot including the sample plants. The yield of curd per plant was converted to the yield as kilogram per hectare.

3.12.8 Yield of curds with leaves (t/ha)

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.

3.12.9 Curd weight without leaf/plant (g)

This trait was recorded from the harvested curds without leaves of all plants of each plot including the sample plants. The yield of curd per plant were measured with the help of electric balance.

3.12.10 Yield of curd without leaf (kg/ha)

This trait was recorded from the harvested curds without leaves of all plants of each plot including the sample plants. The yield of curd per plant was converted to the yield as kilogram per hectare.

3.12.11 Yield of curds without leaves (t/ha)

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.

3.13 Economic returns from cauliflower based agroforestry system

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

3.13.1 Total cost of production

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

3.13.2 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.

3.13.3 Net return

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

Net return = Gross return ($tkha^{-1}$) – Total cost of production ($tkha^{-1}$)

3.13.4 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) / Total cost of production (tk/ha).

3.14 Statistical analysis

Data were statistically analyzed using the “Analysis of variance” (ANOVA) technique with the help of statistics 10 software and MS Excel 2013. The mean differences were adjudged by Tukey HSD test.

CHAPTER IV

RESULTS AND DISCUSSIONS

This chapter represents the results of the screening of different spacing between cauliflowers with fertilizer and manure applications under mahogany tree based agroforestry system are presented in Table 4.1 to 4.17. The findings of the study and interpretation of the results under different critical sections comprising growth, yield contributing characteristics, yield, quality parameters and cost effective analysis are also presented and discussed in this chapter under the following sub-headings to achieve the objective of the study.

4.1 Main Effect of spacing on Growth, Yield Contributing Characters and Yield of Cauliflower

4.1.1 Plant height (cm)

By measuring plant height growth performance of a plant can be considered. Plant height of cauliflower was recorded from the ground surface to the tip of the leaf in 10 plants of all the treatments in cm. At different days after transplanting (DAT), plant height of cauliflower was significantly varied (Table 4.1).

Table 4.1 Main effect of different spacing on plant height of cauliflower plant at different DAT.

Treatments (Spacing)	Plant height (cm)		
	30DAP	60DAP	75DAP
S_1	26.37	41.14 a	42.83 a
S_2	26.16	39.46 ab	40.74 a
S_3	25.71	37.10 b	38.17 b
`CV (%)	7.58	6.44	5.17

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here, S_1= 75 x 50 cm (Broader spacing); S_2= 60 x 45 (Intermediate spacing); S_3= 50 x 40 (Closer spacing)

However, at the initial plant height i.e. at 30 DAT, the height were not significantly varied. Although, the highest plant height (26.37 cm) was obtained from the 75 x 50 cm (S_1) spacing which was followed by the spacing 60 x 45 cm (S_2). On the other hand, lowest plant height (25.71 cm) was obtained from the closer spacing i.e. 50x 40 cm(S_3). At 60 DAT, the highest plant height (41.14 cm) was obtained from the plot where 75 x50 cm (S_1) spacing was present among plants whereas the lowest plant height (37.10 cm) was observed from the closer spacing i.e. 50x 40 cm(S_3). Similarly, at 75 DAT, the highest plant height (42.83 cm) was recorded from the plot where 75 x 50 cm (S_1) spacing was present among plants and the lowest plant height (38.17 cm) was observed from the closer spacing i.e., 50x 40 cm(S_3). The variation in plant height as influenced by spacing was perhaps due to proper utilization of nutrient, moisture and light. Rahman *et al.,* (2007) reported that the maximum plant height was obtained where the plants were spaced 45×50 cm apart.

4.1.2 Number of leaves/plant

Number of leaves/plant of cauliflower was found significantly different due to the effects of different spacings (Table 4.2) at 30 DAT, 60 DAT and 75 DAT. In case of 30 DAT, the highest number of leaves/plant (10.07) was recorded from the 75 x 50 cm (S_1) spacing which was significantly followed by the spacing 60 x 45 cm (S_2), whereas the lowest number of leaves/plant (9.33) was observed from the closer space 50x 40 cm(S_3). At 60 DAT, the highest number of leaves/plant (13.00) was obtained from the 75 x 50 cm (S_1) spacing, whereas the lowest number of leaves/plant (11.58) was observed from the plot where 50x 40 cm(S_3) were present. At 75 DAT, the highest number of leaves/plant (13.13) was recorded from the 75 x 50 cm (S_1) spacing and the lowest number of leaves/plant (11.80) was observed from the closer space 50x 40 cm(S_3). It was observed that the number of leaves was higher in plants with wider spacing and lower in closely plants. It is probably, due to reduce inter plant competition for access to nutrients, moisture and other resources. Similar trend was reported by Kannan *et al.,*(2016).

Table 4.2 Main effect of different spacing on number of leaves of cauliflower plant at different DAT.

Treatments (Spacing)	Number of leaves/plant		
	30DAP	60DAP	75DAP
S_1 (75 x 50cm; Broader)	10.07 a	13.00 a	13.13 a
S_2 (60 x 45cm; Intermideate)	9.78 a	12.51 a	12.76 a
S_3 (50 x 40cm; Closer)	9.33 b	11.58 b	11.80 b
CV (%)	3.14	5.34	4.79

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

4.1.3 Outer leaf length (cm)

At 30 and 60 days after transplanting (DAT), outer leaf length of cauliflower was found no significantly varied due to the impact of different spacing treatments but significantly varied was found at 75 DAT (Table 4.3).However, numerically at 30 DAT, the highest outer leaf length (20.97 cm) was obtained from the broader space 75 x 50 cm (S_1) whereas the lowest outer leaf length (20.97 cm) was obtained from the closer space 50x 40 cm (S_3). Again, at 60 DAT, the highest outer leaf length (38.29 cm) was obtained from the 75 x 50 cm (S_1) spacing, whereas the lowest outer leaf length (35.98 cm) was observed from the plot where 50x 40 cm(S_3) were present. Finally, at 75 DAT, the highest outer leaf length (39.46 cm) was recorded from the 75 x 50 cm (S_1) spacing and the lowest outer leaf length (36.30 cm) was observed from the closer space 50x 40 cm (S_3).

Table 4.3 Main effect of different spacing on outer leaf length of cauliflower plant at different DAT.

Treatments (Spacing)	Outer leaf length (cm)		
	30DAP	60DAP	75DAP
S_1 (75 x 50cm; Broader)	20.97	38.29	39.46 a
S_2 (60 x 45cm; Intermediate)	20.60	36.90	37.98 ab
S_3 (50 x 40cm; Closer)	20.10	35.98	36.30 b
CV (%)	8.79	6.62	6.45

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

4.1.4 Outer leaf width (cm)

Outer leaf length of cauliflower was increased due to the impacts of different spacing treatments (Table 4.4). And there were significant different found among the outer leaf width. However, significantly at 30 DAT, the highest outer leaf width (9.00 cm) was obtained from the broader space 75 x 50 cm (S_1) whereas the lowest outer leaf width (8.43 cm) was obtained from the closer space 50x 40 cm(S_3). Again, at 60 DAT, the highest outer leaf width (14.13 cm) was recorded from the 75 x 50 cm (S_1) spacing which was significantly followed by the treatment 60 x 45 cm (S_2) space, whereas the lowest outer leaf width (12.70 cm) was observed from the plot where 50x 40 cm(S_3) were present. Finally, at 75 DAT, the highest outer leaf width (14.96 cm) was recorded from the 75 x 50 cm (S_1) spacing and the lowest outer leaf width (13.60 cm) was observed from the closer space 50x 40 cm (S_3).

Table 4.4 Main effect of different spacing on outer leaf width of cauliflower plant at different DAT.

Treatments (Spacing)	Outer leaf width (cm)		
	30DAP	**60DAP**	**75DAP**
S_1 (75 x 50cm; Broader)	9.00 a	14.13 a	14.96 a
S_2 (60 x 45cm; Intermediate)	8.77 b	13.62 a	14.23 b
S_3 (50 x 40cm; Closer)	8.43 c	12.70 b	13.60 c
CV (%)	2.58	6.45	3.45

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

4.1.5 Curd size (cm^2)

The important yield contributing character of cauliflower was curd size. With the influence of different spacing treatments, curd size was statistically similar (Table 4.5). The height curd size (226.60 cm^2) was recorded from the 75 x 50 cm (S_1) spacing which was followed by the spacing 60 x 45 cm (S_2) and that was 225.54 cm^2. On the other hand, the lowest curd size (221.49 cm^2) was recorded from the closer space 50x 40 cm (S_3).

Table 4.5 Main effect of different spacing on curd size of cauliflower.

Treatments (Spacing)	Curd size (cm^2)
S_1 (75 x 50cm; Broader)	226.60
S_2 (60 x 45cm; Intermediate)	225.54
S_3 (50 x 40cm; Closer)	221.49
CV (%)	3.19

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Formation of bigger curd at the widest spacing was probably due to the availability of more nutrients, light, moisture to the plants. On the other hand, in closer spacing plants inter plants competition resulted in the formation of small curd. Kannan *et al*., (2016), Rahman *et al.,* (2007) reported similar kind or result and our findings is in corroboration with their findings.

4.1.6 Yield of curd with leaf/plant (g)

It was showed (Table 4.6) that the yield of curd with leaf was significantly varied among different spacing treatments. The maximum yield (877.95 g) was recorded from the 75 x 50 cm (S_1) spacing i.e. in broader spacing. On the other hand, the minimum yield (660.31 g) was recorded from the closer space i.e. 50x 40 cm (S_3). Similar kind or result was reported by Kannan *et al.,* (2016) and Rahman *et al.,* (2007).

4.1.7 Yield of curd with leaf (kg/ha)

The yield of curd with leaf as kilogram per hectare land was significantly varied among different spacing treatments. The maximum yield (41085 kg/ha) was recorded from the closer space 50 x 40 cm (S_3) due to large number of curd obtain per hectare land. One the other hand, the minimum yield (29247 kg/ha) was recorded from the broader spacing i.e. 75 x 50 cm (S_1) due to the lower number of plant cultivated per hectare land.

Table 4.6 Main effect of different spacing on yield of cauliflower.

Treatments (Spacing)	Yield of curd with leaf/plant (g)	Yield of curd with leaf (kg/ha)	Yield of curd without leaf (g)	Yield of curd without leaf (kg/ha)
S_1	877.95 a	29247 c	459.59 a	15321 c
S_2	818.15 b	32716 b	421.50 b	16860 b
S_3	660.31 c	41085 a	344.97 c	21931 a
`CV (%)	4.22	4.76	7.60	5.87

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here, S_1= 75 x 50 cm (Broader spacing); S_2= 60 x 45 (Intermediate spacing); S_3= 50 x 40 (Closer spacing)

4.1.8 Yield of curd without leaf (g)

The result of the study revealed that (Table 4.6) the maximum yield (459.59 g) was recorded from the 75 x 50 cm (S_1) spacing between plants. On the other hand, the minimum yield (344.97 g) was recorded from the closer spacing i.e. 50x 40 cm (S_3) between plants.

4.1.9 Yield of curd without leaf (kg/ha)

The yield of curd without leaf as kilogram per hectare land was significantly varied among different spacing treatments (Table 4.6). The maximum yield (21931 kg/ha) was recorded from the closer spacing i.e. 50 x 40 cm (S_3) between plants due to large number of curd obtained per hectare land. One the other hand, the minimum yield (15321 kg/ha) was recorded from the closer spacing i.e. 75 x 50 cm (S_1) due to lower number of plant obtained per hectare.

4.1.10 Yield of curd with leaf (t/ha)

Among different spacing treatments, the yield of curd with leaf was observed significantly varied which is showed in figure 4.1.

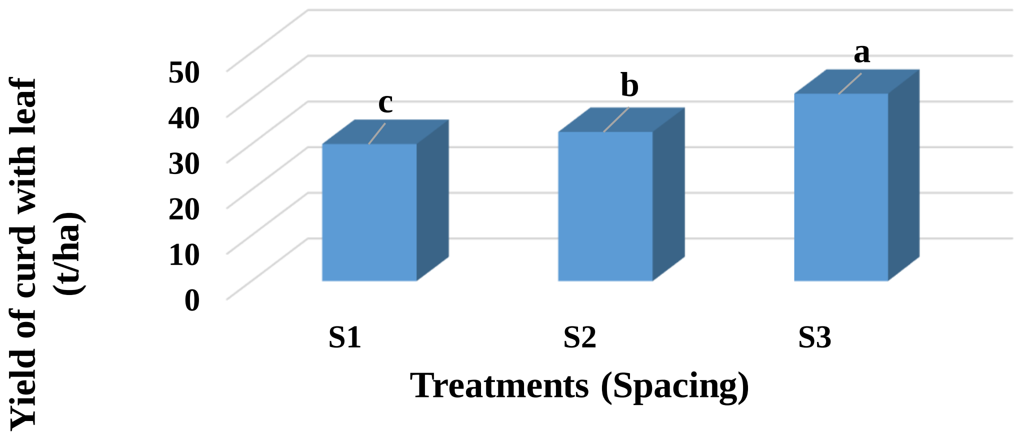


Figure 4.1 Main effect of different spacing on yield of curd with leaf (t/ha)

In a bar, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here, S_1*= 75 x 50 cm (Broader spacing);* S_2*= 60 x 45 (Intermediate spacing);* S_3*= 50 x 40 (Closer spacing)*

The maximum yield (21931 kg/ha) was recorded from the closer spacing i.e. 50 x 40 cm (S_3) between plants due to large number of curd obtained per hectare land. One the other hand, the minimum yield (15321 kg/ha) was recorded from the broader space 75 x 50 cm (S_1) due to lower number of plant obtained per hectare land. The crops grow in such close spacing yield more though main heads are smaller and these mature slightly later that case optimum spacing is followed. Rahman *et al.*, (2007), Farzana *et al.*, (2016) reported that they obtained the maximum yield of cauliflower where the plants were spaced 45×50 cm apart.

4.1.11 Yield of curd without leaf (t/ha)

The yield of curd without leaf as kilogram per hectare was significantly varied among different spacing treatments (Figure 4.2). The maximum yield (21.89 t/ha) was recorded from the closer spacing i.e. 50 x 40 cm (S_3) due to large number of curd obtained per hectare land. One the other hand, the minimum yield (15.28 t/ha) was recorded from the broader spacing i.e. 75 x 50 cm (S_1) due to lower number of plant obtained per hectare land.

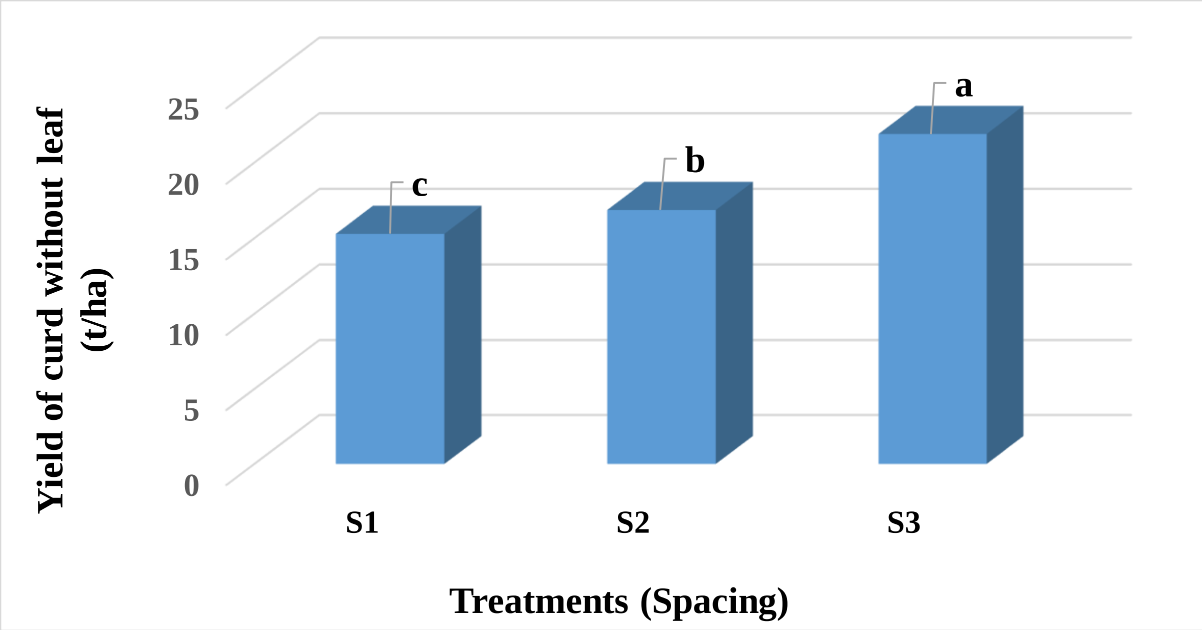


Figure 4.2 Main effect of different spacing on yield of curd without leaf (t/ha)

In a bar, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here, S_1*= 75 x 50 cm (Broader spacing);* S_2*= 60 x 45 (Intermediate spacing);* S_3*= 50 x 40 (Closer spacing)*

4.2 Main Effect of Fertilizer and Manure Applications on Growth, Yield Contributing Characters and Yield of Cauliflower

4.2.1 Plant height (cm)

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 transplanting (DAT), plant height of cauliflower was found significantly affected due to the applications of different fertilizer and manure packages (Table 4.7).At 30 DAT, the highest plant height (29.67 cm) was obtained from the plot where only chemical fertilizer (F_4) was applied which was followed by treatment where cow-dung (F_3) was applied. On the other hand, the lowest plant height (21.89 cm) was obtained from the plot where no fertilizer (F_1) was applied. At 60 DAT, the highest plant height (48.61 cm) was recorded from the plot where chemical fertilizer (F_4) was applied. Whereas, lowest plant height (33.92 cm) was obtained from the plot where no fertilizer (F_1) was applied. At 75 DAT, the highest plant height (50.92 cm) was obtained from the plot where chemical fertilizer (F_4) was applied and lowest plant height (34.97 cm) was obtained from the plot where no fertilizer (F_1) was applied. The maximum plant height was obtained from the plot where chemical fertilizer was applied. . The results indicate that the increasing rate of micronutrients significantly increase the plant height. During the growing period plant height gradually increased with time and reached to the maximum at harvest. Because chemical fertilizer has instant capability to release nutrient than organic manure. This result is also agreed by Islam *et al*. (2017) and Heeb *et al*., (2006).

Table 4.7 Main effect of fertilizer and manure applications on plant height of cauliflower plant at different DAT.

Treatments (fertilizer and manure applications)	Plant height (cm)		
	30DAP	60DAP	75DAP
F_1	21.89 b	33.92 c	34.97 c
F_2	24.09 b	36.11bc	37.10 bc
F_3	28.67 a	38.29 b	39.27 b
F_4	29.67 a	48.61 a	50.92 a
`CV (%)	7.58	6.44	5.17

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here, F_1 = No fertilizer; F_2 = Poultry Manure; F_3= Cow dung and F_4= Chemical Fertilizer

4.2.2 Number of leaves/plant

At different days after transplanting (DAT), number of shoot/plant of cauliflower was found significantly affected due to the applications of different fertilizer and manure (Table 4.8). At 30 DAT, the highest number of leaves/plant (10.68) was recorded from the plot where chemical fertilizer (F_4) was applied. Whereas lowest number of leaves/plant (8.49) was obtained from the plot where no fertilizer (F_5) was applied. At 60 DAT, the highest number of leaves/plant (14.00) was recorded from the plot where chemical fertilizer (F_4) was applied. Whereas lowest number of leaves/plant (10.57) was obtained from the plot where no fertilizer (F_1) was applied. At 75 DAT, the highest number of leaves/plant (14.11) was obtained from the plot where chemical fertilizer (F_4) was applied and lowest number of leaves/plant (10.77) was obtained from the plot where no fertilizer (F_1) was applied. Similar findings were also reported by Singh and Rajput (1976), Muthoo *et al*., (1987), Rahman *et al*., (1992).

Table 4.8 Main effect of fertilizer and manure applications on number of leaves of cauliflower plant at different DAT.

Treatments (fertilizer and manure applications)	Number of leaves/plant		
	30DAP	**60DAP**	**75DAP**
F_1	8.49 d	10.57 d	10.77 d
F_2	9.59 c	11.98 c	12.27 c
F_3	10.14 b	12.91 b	13.10 b
F_4	10.68 a	14.00 a	14.11 a
`CV (%)	3.14	5.34	4.79

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here, F_1 = No fertilizer; F_2 = Poultry Manure; F_3= Cow dung and F_4= Chemical Fertilizer

4.2.3 Outer leaf length (cm)

(Table 4.9) At 30 DAT, the highest outer leaf length (24.10 cm) was obtained from the plot where chemical fertilizer (F_4) was applied. On the other hand, lowest outer leaf length (15.36 cm) was obtained from the plot where no fertilizer (F_1) was applied. At 60 DAT, the highest outer leaf length (41.16 cm) was recorded from the plot where chemical fertilizer (F_4) was applied. Whereas lowest outer leaf length (31.61 cm) was obtained from the plot where no fertilizer (F_1) was applied. At 75 DAT, the highest outer leaf length (42.46 cm) was obtained from the plot where chemical fertilizer (F_4) was applied and lowest outer leaf length (32.26 cm) was obtained from the plot where no fertilizer (F_1) was applied. The maximum outer leaf length was obtained from the plot where chemical fertilizer was applied because chemical fertilizer has instant capability to release nutrient than organic manure. This result is also agreed by Islam *et al*., (2017) and Heeb *et al*., (2006).

Table 4.9 Main effect of fertilizer and manure applications on outer leaf length (cm) of cauliflower plant at different DAT.

Treatments (fertilizer and manure applications)	Outer leaf length (cm)		
	30DAP	**60DAP**	**75DAP**
F_1	15.36 c	31.61 c	32.26 c
F_2	21.40 b	36.40 b	37.14 b
F_3	21.37 b	39.06 ab	39.80 ab
F_4	24.10 a	41.16 a	42.46 a
`CV (%)	8.79	6.62	6.45

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here, F_1 = No fertilizer; F_2 = Poultry Manure; F_3= Cow dung and F_4= Chemical Fertilizer

4.2.4 Outer leaf width (cm)

At different days after transplanting (DAT), outer leaf width of cauliflower was found significantly affected due to the applications of different fertilizer and manure (Table 4.10). At 30 DAT, the highest outer leaf width (10.22 cm) was obtained from the plot where chemical fertilizer (F_4) was applied. On the other hand, lowest outer leaf width (6.80 cm) was obtained from the plot where no fertilizer (F_1) was applied. At 60 DAT, the highest outer leaf width (16.54 cm) was recorded from the plot where chemical fertilizer (F_4) was applied. Whereas, lowest outer leaf width (9.20 cm) was obtained from the plot where no fertilizer (F_1) was applied. At 75 DAT, the highest outer leaf width (17.47 cm) was obtained from the plot where chemical fertilizer (F_4) was applied and lowest outer leaf width (9.36 cm) was obtained from the plot where no fertilizer (F_1) was applied. The maximum outer leaf width was obtained from the plot where chemical fertilizer was applied because chemical fertilizer has instant capability to release nutrient than organic manure. This result is also agreed by Islam *et al*., (2017) and Heeb *et al*., (2006).

Table 4.10 Main effect of fertilizer and manure applications on outer leaf width (cm) of cauliflower plant at different DAT.

Treatments (fertilizer and manure applications)	Outer leaf width (cm)		
	30DAP	**60DAP**	**75DAP**
F_1	6.80 d	9.20 d	9.36 d
F_2	8.10 c	13.13 c	14.30 c
F_3	9.80 b	15.05 b	15.93 b
F_4	10.22 a	16.54 a	17.47 a
`CV (%)	2.58	6.45	3.45

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here, F_1 = No fertilizer; F_2 = Poultry Manure; F_3= Cow dung and F_4= Chemical Fertilizer

4.2.5 Curd size (cm^2)

The variation in curd size was found to be statistically significant due to the applications of different fertilizer and manure (Table 4.11). The maximum curd size (2.88.57 cm^2) was obtained from the plot where chemical fertilizer (F_4) was applied. On the other hand, minimum curd size (155.73 cm^2) was obtained from the plot where no fertilizer (F_1) was applied. Similar results have been reported by Kotur (1998), Singh (2003), Kumar and Choudhary (2002), Prasad and Yadav (2003).

Table 4.11 Main effect of fertilizer and manure applications on curd size of cauliflower.

Treatments (fertilizer and manure applications)	Curd size (cm^2)
F_1	155.73 d
F_2	220.31 c
F_3	233.57 b
F_4	288.57 a
`CV (%)	3.19

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here, F_1 = No fertilizer; F_2 = Poultry Manure; F_3= Cow dung and F_4= Chemical Fertilizer

4.2.6 Yield of curd with leaf/plant (g)

The yield of curd with leaf as gram per plant was significantly different due to the applications of different fertilizer and manure (Table 4.12). The highest yield of curd with leaf (1005.7 g) was recorded from the plot where chemical fertilizer (F_4) was applied. On the other hand, lower yield of curd with leaf (609.5 g) was obtained from the plot where no fertilizer (F_1) was applied. The maximum yield was obtained from the plot where chemical fertilizer was applied because chemical fertilizer has instant capability to release nutrient than organic manure. This result is also agreed by Islam *et al.,* (2017) and Heeb *et al.,* (2006).

4.2.7 Yield of curd with leaf (kg/ha)

The yield of curd with leaf as kilogram per hectare land was significantly different due to the applications of different fertilizer and manure (Table 4.12). The maximum yield (43577 kg/ha) was recorded from the plot where chemical fertilizer (F_4) was applied. On the other hand, minimum fruit yield (27089 kg/ha) was obtained from the plot where no fertilizer (F_1) was applied. The maximum yield was obtained from the plot where chemical fertilizer was applied because chemical fertilizer has instant capability to release nutrient than organic manure. This result is also agreed by Islam *et al*., (2017) and Heeb *et al*., (2006).

Table 4.12 Main effect of spacing on yield of cauliflower.

Treatments (fertilizer and manure applications)	Yield of curd with leaf/plant (g)	Yield of curd with leaf (kg/ha)	Yield of curd without leaf (g)	Yield of curd without leaf (kg/ha)
F_1	609.5 d	27089 c	215.25 c	9501 d
F_2	655.5 c	28934 c	404.55 b	18040 c
F_3	871.2 b	37798 b	488.12 a	21306 b
F_4	1005.7 a	43577 a	526.83 a	23302 a
`CV (%)	4.22	4.76	7.60	5.87

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here, F_1 = No fertilizer; F_2 = Poultry Manure; F_3 = Cow dung and F_4 = Chemical Fertilizer

4.2.8 Yield of curd without leaf/plant (g)

The variation in yield of curd without leaf/plant was found to be statistically significant due to the applications of different fertilizer and manure (Table 4.11). The maximum yield of curd without leaf/plant (526.83 g) was obtained from the plot where chemical fertilizer (F_4) was applied. On the other hand, minimum yield of curd without leaf/plant (215.25 g) was obtained from the plot where no fertilizer (F_1) was applied.

4.2.9 Yield of curd without leaf (kg/ha)

The yield of curd without leaf as kilogram per hectare land was significantly affected due to the applications of different fertilizer and manure (Table 4.12). The highest yield (23302 kg/ha) was recorded from the plot where chemical fertilizer (F_4) was applied whereas the lowest yield (9501 kg/ha) was obtained from the plot where no fertilizer (F_1) was applied. The most yield was obtained from the plot where chemical fertilizer was applied because chemical fertilizer has instant capability to release nutrient than organic manure.

4.2.10 Yield of curd with leaf (t/ha)

The yield of curd with leaf as ton per hectare land was significantly affected due to the applications of different fertilizer and manure (Figure 4.3).

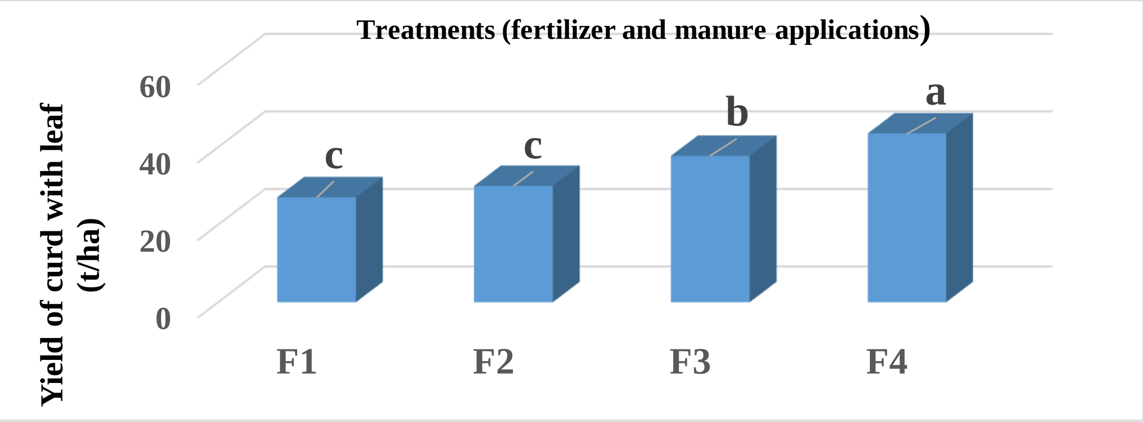


Figure 4.3: Main effect of fertilizer and manure applications on yield of curd with leaf (t/ha)

Here, F_1 = No fertilizer; F_2 = Poultry Manure; F_3= Cow dung and F_4= Chemical Fertilizer

The highest curd yield with leaf (43.54 t/ha) was recorded from the plot where chemical fertilizer (F_4) was applied. On the other hand, lowest curd yield with leaf (27.06 t/ha) was obtained from the plot where no fertilizer (F_1) was applied. The maximum yield was obtained from the plot where chemical fertilizer was applied because chemical fertilizer has instant capability to release nutrient than organic manure. This result is also agreed by Islam *et al.*, (2017) and Heeb *et al.*, (2006).

4.2.11 Yield of curd without leaf (t/ha)

Among different fertilizer and manure application treatments the yield of curd with leaf observed significantly varied showed in figure 4.4.

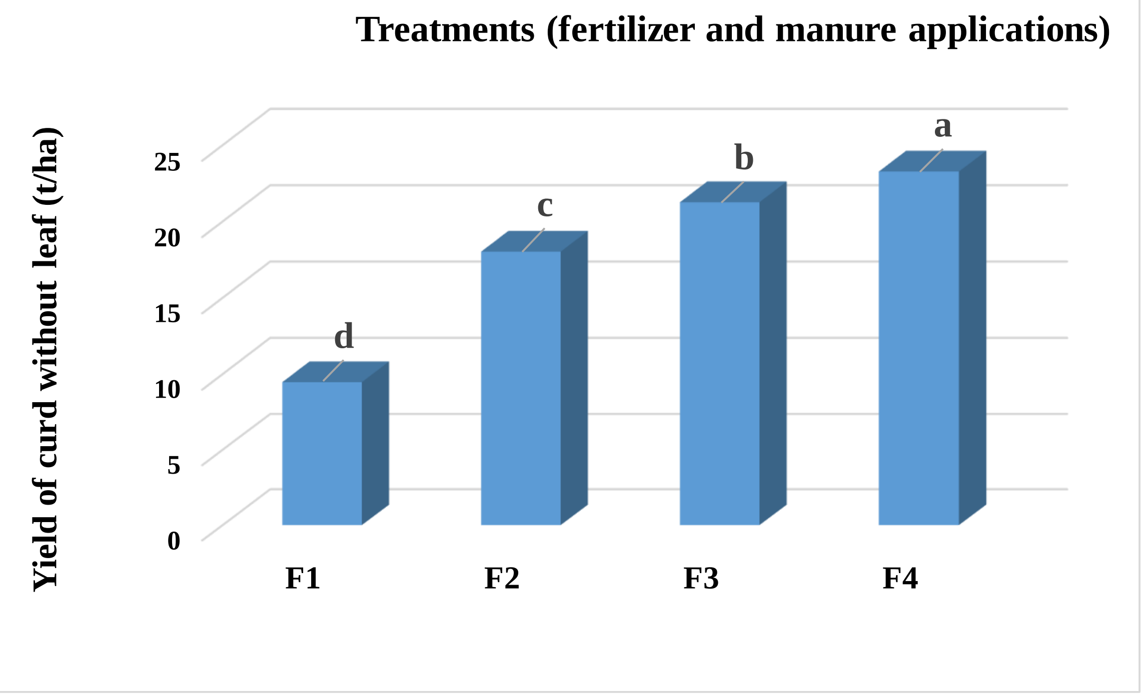


Figure 4.4: Main effect of fertilizer and manure applications on yield of curd without leaf (t/ha)

Here, F_1 *= No fertilizer;* F_2 *= Poultry Manure;* F_3*= Cow dung and* F_4*= Chemical Fertilizer*

The maximum yield of curd with leaf (23.27 t/ha) was recorded from the plot where chemical fertilizer (F_4) was applied. On the other hand, lowest yield of curd with leaf (9.47 t/ha) was obtained from the plot where no fertilizer (F_1) was applied. The maximum yield was obtained from the plot where chemical fertilizer was applied because chemical fertilizer has instant capability to release nutrient than organic manure. This result is also agreed by Islam *et al.*, (2017) and Heeb *et al.*, (2006).

4.3.1 Plant height (cm)

The interaction effect of spacing between plants and fertilizer & manure applications on the plant height of cauliflower was found significantly different at different days after planting (Table 4.13).

Table 4.13 Interaction effect of spacing and fertilizer applications on plant height of cauliflower at different DAT.

Treatments (Combination)	Plant height (cm)		
	30DAP	**60DAP**	**75DAP**
S_1F_1	21.90 d	36.43 bc	37.60 bcd
S_1F_2	26.10 abcd	38.87 b	39.37 bc
S_1F_3	28.30 abc	39.23 b	41.63 b
S_1F_4	29.17 a	50.03 a	52.73 a
S_2F_1	21.87 d	34.13 bc	34.97 cd
S_2F_2	22.87 cd	36.50 bc	37.17 bcd
S_2F_3	29.07 ab	38.77b	40.07 bc
S_2F_4	30.83 a	48.43 a	50.77 a
S_3F_1	21.90 d	31.20 c	32.33 d
S_3F_2	23.30 bcd	32.97 bc	34.77 cd
S_3F_3	28.63 abc	36.87 bc	36.10 bcd
S_3F_4	29.00 ab	47.37 a	49.27 a
CV (%)	7.58	6.44	5.17

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here,S_1F_1 = Broader spacing + No fertilizer; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing+ Cow-dung; S_1F_4 = Broader spacing + Chemical; S_2F_1 = Intermediate spacing + No fertilizer; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing+ Cow-dung; S_2F_4 = Intermediate spacing + Chemical; S_3F_1 = Closer spacing+ No fertilizer; S_3F_2 = Closer spacing+ Poultry manure; S_3F_3 = Closer spacing+ Cow-dung and S_3F_4 = Closer spacing+ Chemical.

At 30 DAT, the highest plant height (30.83 cm) was obtained from the treatment S_2F_4 (Intermediate spacing+ Chemical Fertilizer) which is significantly followed by the treatment S_1F_4 (Broader spacing + Chemical Fertilizer). On the other hand, the lowest plant height (21.90 cm) was obtained from both treatments S_1F_1 (Broader spacing + No fertilizer) and S_3F_1 (Closer spacing + No fertilizer). Similarly, at 60 DAT, the highest plant height (50.03 cm) was recorded from the treatment S_1F_4 (Broader spacing+ Chemical Fertilizer) which was significantly followed by S_2F_4 (Intermediate spacing + Chemical Fertilizer) and S_3F_4 (Closer spacing + Chemical Fertilizer). However, the lowest plant height (31.20 cm) was obtained from the treatment S_3F_1 (Closer spacing + No fertilizer). At 75 DAT, the highest plant height (52.73 cm) was obtained from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer) which was significantly followed by S_2F_4 (Intermediate spacing + Chemical Fertilizer) and S_3F_4 (Closer spacing+ Chemical Fertilizer) and the lowest plant height (32.33 cm) was obtained from the treatment S_3F_1 (Closer spacing + No fertilizer).

4.3.2 Number of leaves/plant

The interaction effect of spacing and fertilizer & manure applications on the number of leaves/plant was found significantly different at different days after planting (Table 4.14).

Table 4.14 Interaction effect of spacing and fertilizer applications on number of leaves of cauliflower at different DAT.

Treatments (Combination)	Number of leaves/plant		
	30DAP	**60DAP**	**75DAP**
S_1F_1	8.67 fg	11.03 de	11.27 ef
S_1F_2	9.90 bcde	12.57 bcd	12.67 bcde
S_1F_3	10.80 ab	13.50 ab	13.60 abc
S_1F_4	10.90 a	14.90 a	14.97 a
S_2F_1	8.53 g	10.73 de	11.00 ef
S_2F_2	9.80 cde	12.27 bcd	12.47 cde
S_2F_3	10.17 abcd	13.00 abc	13.30 abcd
S_2F_4	10.60 abc	14.03 ab	14.27 ab
S_3F_1	8.27 g	9.93 e	10.03 f
S_3F_2	9.07 efg	11.10 cde	11.67 def
S_3F_3	9.47 def	12.23 bcd	12.40 cde
S_3F_4	10.53 abc	13.07 ab	13.10 bcd
CV (%)	3.14	5.34	4.79

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here,S_1F_1 = Broader spacing + No fertilizer; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing+ Cow-dung; S_1F_4 = Broader spacing + Chemical; S_2F_1 = Intermediate spacing + No fertilizer; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing+ Cow-dung; S_2F_4 = Intermediate spacing + Chemical; S_3F_1 = Closer spacing+ No fertilizer; S_3F_2 = Closer spacing+ Poultry manure; S_3F_3 = Closer spacing+ Cow-dung and S_3F_4 = Closer spacing+ Chemical.

At 30 DAT, the highest number of leaves/plant (10.90) was obtained from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer) which is significantly followed by S_1F_3 (Broader spacing + Cow dung). On the other hand, lowest number of leaves/plant (8.27) was obtained from the treatment S_3F_1 (Closer spacing + No fertilizer) which was nearly similar with S_2F_1 (Intermediate spacing + No fertilizer). At 60 DAT, the highest number of leaves/plant (14.90) was recorded from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer). Whereas, lowest number of leaves/plant (9.93) was obtained from the treatment S_3F_1 (Closer spacing + No fertilizer). At 75 DAT, the highest number of leaves/plant (14.97) was obtained from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer) whereas lowest number of leaves/plant (10.03) was obtained from the treatment S_3F_1 (Closer spacing + No fertilizer).

4.3.3 Outer leaf length (cm)

Interaction effect of spacing and fertilizer & manure applications on the outer leaf length of cauliflower was found significantly different at different days after planting (Table 4.15). At 30 DAT, the highest leaf length (25.43 cm) was obtained from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer) which is significantly followed by S_2F_4 (Intermediate spacing + Chemical Fertilizer) and S_3F_4 (Closer spacing + Chemical Fertilizer) due to 100% light intensity and applied systematic fertilizer. On the other hand, lowest outer leaf length (15.13 cm) was obtained from the treatment S_3F_1 (Closer spacing + No fertilizer) due to 60% light intensity and without fertilizer. At 60 DAT, the highest outer leaf length (42.17 cm) was recorded from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer). Whereas, lowest outer leaf length (31.57 cm) was obtained from both treatments S_2F_1 (Intermediate spacing + No fertilizer) and S_3F_1 (Closer spacing + No fertilizer). At 75 DAT, the highest outer leaf length (43.30 cm) was obtained from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer) which is significantly followed by S_2F_4 (Intermediate spacing + Chemical Fertilizer) and lowest leaf length (31.57 cm) was obtained from both treatments S_2F_1 (Intermediate spacing + No fertilizer) which was similar with S_3F_1 (Closer spacing + No fertilizer).

Table 4.15 Interaction effect of spacing and fertilizer applications on outer leaf length (cm) of cauliflower at different DAT.

Treatments (Combination)	Outer leaf length (cm)		
	30DAP	**60DAP**	**75DAP**
S_1F_1	15.37 bc	32.97 cd	33.67 cd
S_1F_2	21.30 a	37.63 abcd	39.40 abc
S_1F_3	21.77 a	40.40 ab	41.50 ab
S_1F_4	25.43 a	42.17 a	43.30 a
S_2F_1	15.57 bc	30.97 d	31.57 d
S_2F_2	22.20 a	37.00 abcd	37.33 abcd
S_2F_3	21.07 a	38.80 abc	39.77 abc
S_2F_4	23.57 a	40.83 ab	43.27 a
S_3F_1	15.13 c	30.90 d	31.57 d
S_3F_2	20.70 ab	34.57 bcd	34.70 bcd
S_3F_3	21.27 a	37.97 abcd	38.13 abcd
S_3F_4	23.30 a	40.47 ab	40.80 abc
CV (%)	8.79	6.62	6.45

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here,S_1F_1 = Broader spacing + No fertilizer; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing+ Cow-dung; S_1F_4 = Broader spacing + Chemical; S_2F_1 = Intermediate spacing + No fertilizer; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing+ Cow-dung; S_2F_4 = Intermediate spacing + Chemical; S_3F_1 = Closer spacing+ No fertilizer; S_3F_2 = Closer spacing+ Poultry manure; S_3F_3 = Closer spacing+ Cow-dung and S_3F_4 = Closer spacing+ Chemical.

4.3.4 Outer leaf width (cm)

The outer leaf width of cauliflower was found significantly different at different days after planting due to interaction effect of spacing and fertilizer & manure applications (Table 4.16). At 30 DAT, the highest leaf width (10.50 cm) was obtained from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer) which is significantly followed by S_2F_4 (Intermediate spacing + Chemical Fertilizer). On the other hand, lowest outer leaf width (6.60 cm) was obtained from the treatment S_3F_1 (Closer spacing + No fertilizer) which is significantly followed by S_2F_1(Intermediate spacing + No fertilizer) and S_1F_1(Broader spacing + No fertilizer). At 60 DAT, the highest outer leaf width (16.97 cm) was recorded from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer). Whereas, lowest outer leaf width (8.10 cm) was obtained from the treatment S_3F_1 (Closer spacing + No fertilizer). At 75 DAT, the highest outer leaf width (18.27 cm) was obtained from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer) and lowest leaf width (8.73 cm) was obtained from the treatment S_3F_1 (Closer spacing + No fertilizer) which was nearly similar with S_2F_1 (Intermediate spacing + No fertilizer).

Table 4.16 Interaction effect of spacing and fertilizer applications on outer leaf width (cm) of cauliflower at different DAT.

Treatments (Combination)	Outer leaf width (cm)		
	30DAP	**60DAP**	**75DAP**
S_1F_1	6.97 e	10.13 ef	10.27 f
S_1F_2	8.53 c	14.27 bc	15.17 cd
S_1F_3	10.00 ab	15.14 abc	16.13 bc
S_1F_4	10.50 a	16.97 a	18.27 a
S_2F_1	6.83 e	9.37 ef	9.07 fg
S_2F_2	8.10 cd	13.60 cd	14.27 de
S_2F_3	9.90 ab	15.03 abc	16.07 c
S_2F_4	10.23 a	16.47 ab	17.53 ab
S_3F_1	6.60 e	8.10 f	8.73 g
S_3F_2	7.67 d	11.53 de	13.47 e
S_3F_3	9.50 b	14.97 abc	15.60 cd
S_3F_4	9.93 ab	16.20 ab	16.60 bc
CV (%)	2.58	6.45	3.45

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here,S_1F_1 = Broader spacing + No fertilizer; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing+ Cow-dung; S_1F_4 = Broader spacing + Chemical; S_2F_1 = Intermediate spacing + No fertilizer; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing+ Cow-dung; S_2F_4 = Intermediate spacing + Chemical; S_3F_1 = Closer spacing+ No fertilizer; S_3F_2

= Closer spacing+ Poultry manure; S_3F_3 = Closer spacing+ Cow-dung and S_3F_4 = Closer spacing+ Chemical.

4.3.5 Curd size (cm^2)

The interaction effect of spacing and fertilizer & manure applications on the curd size of cauliflower as square centre meter was found significantly different (Table 4.17). The highest curd size (291.33 cm^2) was recorded from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer) due to applied systematic fertilizer and more available light and air which was significantly followed by S_2F_4 (Intermediate spacing + Chemical Fertilizer) and S_3F_4 (Closer spacing + Chemical Fertilizer). On the other hand, lowest curd size (152.90 cm^2) was recorded from the treatment S_3F_1 (Closer spacing + No fertilizer) which was significantly followed by S_2F_1 (60 x 45 (Intermediate) + No Fertilizer) and S_1F_1 (Broader spacing + No fertilizer) due to without fertilizer.

Table 4.17 Interaction effect of spacing and fertilizer applications on curd size (cm^2) of cauliflower.

Treatments (Combination)	Curd size (cm^2)
S_1F_1 (Broader spacing + No fertilizer)	160.57 c
S_1F_2 (Broader spacing + Poultry manure)	222.27 b
S_1F_3 (Broader spacing+ Cow-dung)	235.67 b
S_1F_4 (Broader spacing + Chemical)	291.33 a
S_2F_1 (Intermediate spacing + No fertilizer)	153.73 c
S_2F_2 (Intermediate spacing + Poultry manure)	220.07 b
S_2F_3 (Intermediate spacing+ Cow-dung)	235.27 b
S_2F_4 (Intermediate spacing + Chemical)	290.50 a
S_3F_1 (Closer spacing+ No fertilizer)	152.90 c
S_3F_2 (Closer spacing+ Poultry manure)	218.60 b
S_3F_3 (Closer spacing+ Cow-dung)	229.77 b
S_3F_4 (Closer spacing+ Chemical)	283.87 a
CV (%)	3.19

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

4.3.6Yield of curd with leaf/plant (g)

Yield of curd with leaf/plant as germ was found significantly varied due to interaction effect of spacing and fertilizer & manure applications (Table 4.17). The maximum yield (1160.3 g) of curd with leaf was recorded in the plot where maintained broader spacing with chemical fertilizer (S_1F_4). On the other hand, the minimum yield (560.5 g) of curd with leaf was recorded in the plot where maintained closer spacing with no fertilizer (S_3F_1) followed by the plot where maintained closer spacing with poultry manure (S_3F_2).

Table 4.18 Interaction effect of spacing and fertilizer applications on yield of cauliflower.

Treatments (Combination)	Yield of curd with leaf/plant (g)	Yield of curd with leaf (kg/ha)	Yield of curd without leaf (g)	Yield of curd without leaf (kg/ha)
S_1F_1	632.0 ef	21000 f	233.53 e	7784 j
S_1F_2	698.6 e	23282 ef	422.77 cd	14097 gh
S_1F_3	1020.9 b	34030 d	555.17 ab	18506 ef
S_1F_4	1160.3 a	38677 cd	626.88 a	20896 cde
S_2F_1	636.0 ef	25396 ef	221.88 e	8875 ij
S_2F_2	691.8 e	27676 e	413.38 cd	16535 fg
S_2F_3	888.3 c	35533 d	502.17 bc	20087 de
S_2F_4	1056.5 b	42259 bc	548.56 ab	21942 cd
S_3F_1	560.5 f	34871 d	190.32 e	11842 hi
S_3F_2	576.1f	35844 d	377.49 d	23488 bc
S_3F_3	704.4 de	43829 b	407.02 d	25325 ab
S_3F_4	800.3 cd	49794 a	405.07 d	27067 a
CV (%)	4.22	4.76	7.60	5.87

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per Tukey HSD test) at 5% level of Significance.

Here,S_1F_1 = Broader spacing + No fertilizer; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing+ Cow-dung; S_1F_4 = Broader spacing + Chemical; S_2F_1 = Intermediate spacing + No fertilizer; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing+ Cow-dung; S_2F_4 = Intermediate spacing + Chemical; S_3F_1 = Closer spacing+ No fertilizer; S_3F_2 = Closer spacing+ Poultry manure; S_3F_3 = Closer spacing+ Cow-dung and S_3F_4 = Closer spacing+ Chemical.

4.3.7 Yield of curd with leaf (kg/ha)

The interaction effect of spacing and fertilizer & manure applications on the yieldof curd with leaf as kilogram per hectare land of cauliflower was found significantly different (Table 4.17). The highest yield (49794 kg/ha) was observed from the treatment S_3F_4 (Closer spacing + Chemical Fertilizer) due to large number of curd and applied systematic fertilizer. On the other hand, lowest yield (21000 kg/ha) was observed from the treatment S_1F_1 (Broader spacing + No fertilizer) due to small number of plants in respect of other spacing treatment and without fertilizer.

4.3.8 Yield of curd without leaf (g)

Yield of curd without leaf/plant as germ was found significantly varied due to interaction effect of spacing and fertilizer & manure applications (Table 4.17). The maximum yield of curd without leaf (662.88 g) was recorded in the plot where maintained broader spacing with chemical fertilizer (S_1F_4). On the other hand, the minimum yield (109.32 g) of curd without leaf was recorded in the plot where maintained closer spacing with no fertilizer (S_3F_1) followed by the plot where maintained intermediate spacing with no fertilizer (S_2F_1) and also where maintained broader spacing with no fertilizer (S_1F_1).

4.3.9 Yield of curd without leaf (kg/ha)

The interaction effect of spacing and fertilizer & manure applications on the yield of curd without leaf as kilogram per hectare land of cauliflower was found significantly different (Table 4.17). The highest yield (27067 kg/ha) was observed from the treatment S_3F_4 (Closer spacing + Chemical Fertilizer) due to large number of curd and applied systematic fertilizer. On the other hand, lowest yield (7784 kg/ha) was observed from the treatment S_1F_1 (Broader spacing + No fertilizer) due to small number of plants in respect of other spacing treatment and without fertilizer.

4.3.10 Yield of curd with leaf (t/ha)

It was evident from the figure 4.5 that the yield of curd with leaf per hectare land was significantly varied. The maximum yield (49.73 t/ha) was recorded in the pot where maintained closer spacing that was 50 x 40 cm with chemical fertilizer (S_3F_4).

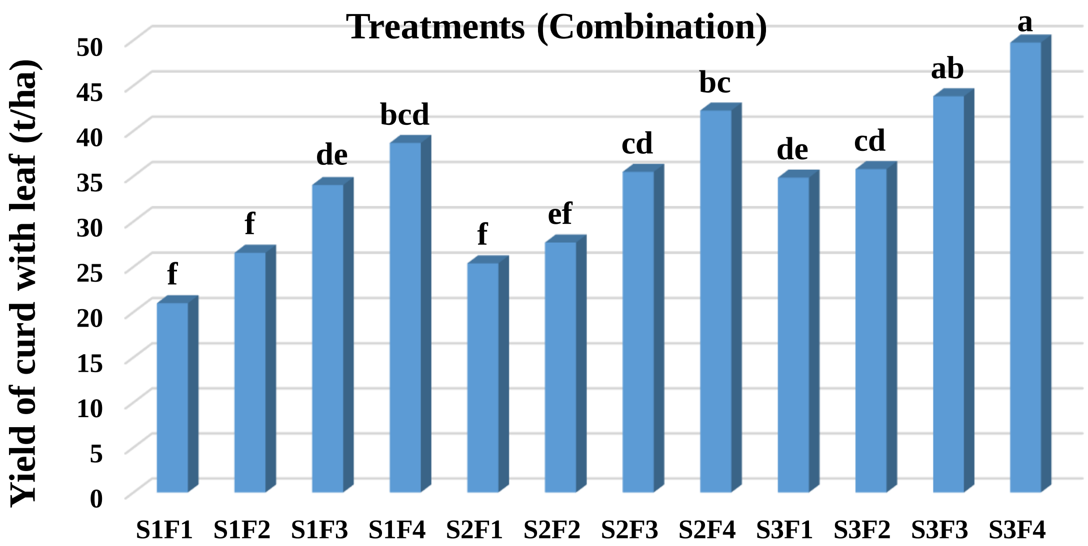


Figure 4.5 Interaction effect of different spacing and fertilizer and manure application on yield of curd with leaf (t/ha) of cauliflower

Here,S_1F_1 = Broader spacing + No fertilizer; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing+ Cow-dung; S_1F_4 = Broader spacing + Chemical; S_2F_1 = Intermediate spacing + No fertilizer; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing+ Cow-dung; S_2F_4 = Intermediate spacing + Chemical; S_3F_1 = Closer spacing+ No fertilizer; S_3F_2 = Closer spacing+ Poultry manure; S_3F_3 = Closer spacing+ Cow-dung and S_3F_4 = Closer spacing+ Chemical.

On the other hand, the minimum yield (20.97 t/ha) of curd with leaf was recorded in the plot where maintained broader spacing with no fertilizer (S_1F_1) followed by the plot where maintained Intermediate spacing with applied poultry manure (S_2F_1) and also where maintained broader spacing with applied poultry manure (S_1F_2).

4.3.11 Yield of curd without leaf (t/ha)

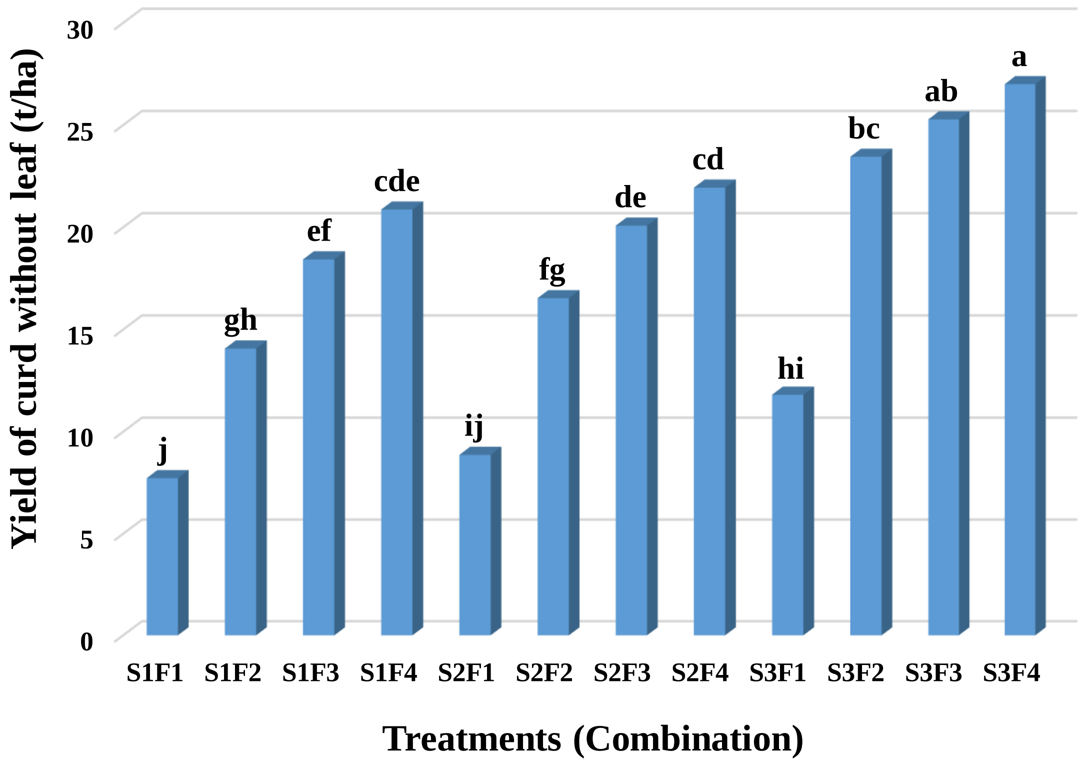


Figure 4.6 Interaction effect of different spacing and fertilizer and manure application on yield of curd without leaf (t/ha) of cauliflower

Here, S_1F_1 *= Broader spacing + No fertilizer;* S_1F_2 *= Broader spacing + Poultry manure;* S_1F_3 *= Broader spacing+ Cow-dung;* S_1F_4 *= Broader spacing + Chemical;* S_2F_1 *= Intermediate spacing + No fertilizer;* S_2F_2 *= Intermediate spacing + Poultry manure;* S_2F_3 *= Intermediate spacing+ Cow-dung;* S_2F_4 *= Intermediate spacing + Chemical;* S_3F_1 *= Closer spacing+ No fertilizer;* S_3F_2 *= Closer spacing+ Poultry manure;* S_3F_3 *= Closer spacing+ Cow-dung and* S_3F_4 *= Closer spacing+ Chemical.*

It was evident from the figure 4.6 that the yield of curd without leaf per hectare land was significantly varied. The maximum yield curd without leaf (27.00 t/ha) was recorded the On the other hand, the minimum yield (7.73 t/ha) of curd without leaf was recorded in the plot where maintained broader spacing with no fertilizer (S_1F_1) due to small number of plants in respect of other spacing treatment and without fertilizer.

4.4 Economic Analysis

Profitability of growing cauliflower as inter-crop in mahogany based agroforestry system was calculated based on local market rate prevailed during experimentation. The return of produce and the profit per taka i.e. Benefit Cost Ratio (BCR) have also been presented in Table 4.19.

4.4.1 Total cost of production

The values in Table 4.19 indicate that the total cost of production was maximum (292922 Tk. /ha) in those plots where cauliflower was cultivated with using 50 x 40 cm i.e. Closer spacing+ Cow dung (S_3F_3) whereas the minimum cost of production (198474 Tk. /ha) was recorded from those plots where 75 x 50 cm i.e. Broader spacing + No fertilizer (S_1F_1) was applied.

4.4.2 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. It is varying with the different planting spacing and mahogany based production system of cauliflower. The values in Table 4.19 indicate that the highest value of gross return (1122680 Tk. /ha) was obtained in those plots where 50 x 40 cm i.e. Closer spacing + Chemical Fertilizer (S_3F_4) was applied. On the other hand, the lowest value of gross return (351360 Tk. /ha) was obtained in those plots where 75 x 50 cm i.e. Broader spacing + No fertilizer (S_1F_1) was applied.

4.4.3 Net return

Results presented in the Table 4.19 showed that net return (834057 Tk. /ha) was comparatively higher in production of cauliflower under 50 x 40 cm i.e. Closer plant spacing with Chemical Fertilizer (S_3F_4). At the same time, the lowest net return (152886 Tk. /ha) was received from those plot where maintained 75 x 50 cm i.e. Broader planting spacing with no fertilizer (S_1F_1) was applied.

Table 4.19: Economics of cauliflower production under mahogany based agroforestry system

Treatments	Return (Tk. ha^{-1})		Gross Return (Tk. ha^{-1})	Total cost of production (Tk. ha^{-1})	Net Return (Tk. ha^{-1})	BCR
	Mahogany	Cauliflower				
S_1F_1	40000	311360	351360	198474	152886	1.77
S_1F_2	40000	563880	603880	210118	393762	2.87
S_1F_3	40000	740240	780240	218717	561523	3.57
S_1F_4	40000	835840	875840	214417	661423	4.08
S_2F_1	40000	355000	395000	228692	166308	1.73
S_2F_2	40000	661400	701400	240336	461064	2.92
S_2F_3	40000	803480	843480	248935	594545	3.39
S_2F_4	40000	877680	917680	244636	673044	3.75
S_3F_1	40000	473680	513680	272678	241002	1.88
S_3F_2	40000	939520	979520	284323	695197	3.45
S_3F_3	40000	1013000	1053000	292922	760078	3.59
S_3F_4	40000	1082680	1122680	288623	834057	3.89

Note: Cauliflower 40 Tk kg^{-1}, Mahogany 2500 Tk per Tree per Year respectively.

In a column, figures having similar letter (s) do not differ significantly. On the other hand, figures bearing different letter (s) differ significantly (as per DMRT) at 5% level of significance.

Here,S_1F_1 = Broader spacing + No fertilizer; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing+ Cow-dung; S_1F_4 = Broader spacing + Chemical; S_2F_1 = Intermediate spacing + No fertilizer; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing+ Cow-dung; S_2F_4 = Intermediate spacing + Chemical; S_3F_1 = Closer spacing+ No fertilizer; S_3F_2 = Closer spacing+ Poultry manure; S_3F_3 = Closer spacing+ Cow-dung and S_3F_4 = Closer spacing+ Chemical.

4.4.4 Benefit-cost ratio (BCR)

The values in Table 4.19 indicated that the highest benefit-cost ratio (3.89) was recorded from the treatment 50 x 40 cm i.e. Closer spacing + Chemical Fertilizer (S_2F_4). On the other hand, the lowest benefit-cost ratio (1.56) was observed in those plots where cauliflower was grown under 60 x 45 cm i.e. Intermediate planting spacing with no fertilizer (S_2F_1) application. This was happened due to both closer spacing and chemical fertilizer application gave maximum cauliflower yield whereas intermediate spacing and no fertilizer treatment gave lower yield.

CHAPTER V

SUMMARY CONCLUSIONAND RECOMMENDATIONS

5.1 Summary

A field experiment was carried out at Jaldhaka upazila under Nilphamari District, during October, 2019 to February, 2020 to evaluate the performance of cauliflower as influenced by spacing and fertilization under mehogany based agroforestry in charland of tista river basin. The experiment was laid out in two factorial RCBD with 3 (three) replications. Factor A (Plant spacing) viz. S_1= 75 x 50 cm (Broader spacing); S_2= 60 x 45 (Intermediate spacing) and S_3= 50 x 40 (Closer spacing) and Factor B (Fertilizer and manure applications) viz. F_1 = No fertilizer; F_2 = Poultry Manure; F_3= Cow dung and F_4= Chemical Fertilizer. The total numbers of experimental plots were 36. The land of experimental plot was opened in the first week of December, 2019 with a power tiller and it was made ready for planting on 15 December, 2019. Each plot there were 15, 18 and 28 plants in S_1, S_2 and S_3 treatment respectively. After immediately planting, the seedlings were watered. Seedlings were also planted around the plot for gap filling and to check the border effect. The data were recorded on two broad heads, i) growth stage ii) harvesting stage. Data were statistically analyzed using the "Analysis of variance" (ANOVA) technique with the help of statistics 10 software and Microsoft office 2013. The mean differences were adjudged by Tukey HSD test.

In case of the main effect of plant spacing on growth, yield contributing characters and yield of Cauliflower, the result was found significant in respect of plant height as cm (30, 60 and 75 DAT), number of leaves/plant (30, 60 and 75 DAT), outer leaf length as cm (30, 60 and 75 DAT), outer leaf width as cm (30, 60 and 75 DAT), curd size (cm2), yield of curd with leaf/plant (g), yield of curd with leaf (kg/ha), yield of curd without leaf/plant (g), yield of curd without leaf (kg/ha), yield of curd with leaf (t/ha), yield of curd without leaf (t/ha). The tallest plant height (42.83 cm) at 75 DAT was recorded from the plot where Broader spacing (S_1) was present among plants and the lowest plant height (38.17 cm) was observed from the closer spacing (S_3). Number of leaves/plant of cauliflower was significant due to different production system. However, highest number of leaves/plant (13.13) at 75 DAT was recorded from the broader spacing (S_1) and the lowest number of leaves/plant (11.80) was observed from the closer plant spacing (S_3). At 75 DAT, the highest outer leaf length (39.46 cm) was recorded from the broader spacing (S_1) and the lowest outer leaf length (36.30 cm) was observed from the closer spacing (S_3). The maximum outer leaf width (14.96 cm) at 75 DAT was recorded from the broader spacing (S_1) and the lowest outer leaf width (13.60 cm) was observed from the spacing (S_3). The yield of curd with and without leaf was significantly varied among different spacing treatments. The maximum yield with leaf (877.95 g) was recorded from the broader spacing (S_1) and the minimum yield (660.31 g) was recorded from the closer spacing (S_3). On the other hand, the maximum yield without leaf (459.59 g) was recorded from the broader spacing (S_1) whereas the minimum yield without leaf (344.97 g) was recorded from the closer space 50x 40 cm(S_3). Again the yield of curd with and without leaf as kilogram per hectare land was significantly varied among different spacing treatments. The maximum yield with leaf (41085 kg/ha) was recorded from the closer spacing (S_3) due to large number of curd obtain per hectare land. One the other hand, the minimum yield with leaf (29247 kg/ha) was recorded from the broader spacing (S_1) due to lower number of plant cultivated per hectare land. And the maximum yield without leaf (21931 kg/ha) was recorded from the closer spacing (S_3). One the other hand, the minimum yield (15321 kg/ha) was recorded from broader spacing (S_1). Finally, among different spacing treatments the yield of curd with and without leaf observed significantly varied. The maximum yield with leaf (21931 kg/ha) was recorded from the closer spacing (S_3) whereas the minimum yield (15321 kg/ha) was recorded from the broader spacing(S_1) i.e. 75 x 50 cm and the maximum yield without leaf (21.89 t/ha) was recorded from the closer spacing (S_3) between whereas the minimum yield (15.28 t/ha) was recorded from the broader spacing (S_1).

Again, the result of the research were showed that the main effect of fertilizer and manure were significant in respect of plant height as cm (30, 60 and 75 DAT), number of leaves/plant (30, 60 and 75 DAT), outer leaf length as cm (30, 60 and 75 DAT), outer leaf width as cm (30, 60 and 75 DAT), curd size (cm2), yield of curd with leaf/plant (g), yield of curd with leaf (kg/ha), yield of curd without leaf/plant (g), yield of curd without leaf (kg/ha), yield of curd with leaf (t/ha), yield of curd without leaf (t/ha). The tallest plant height (50.92 cm) at 75 DAT was recorded from Chemical fertilizer (F_4). On the other hand, the shortest plant height (34.97 cm) at 75 DAT was observed in those plots where no fertilizer was applied (F_1). The highest number of leaves/plant (14.11) was obtained from the plot where chemical fertilizer (F_4) was applied and lowest number of leaves/plant (10.77) was obtained from the plot where no fertilizer (F_1) was applied at 75

DAT. Outer leaf length and leaf width of cauliflower was found significantly affected due to the applications of different fertilizer and manure. The height outer leaf length (42.46 cm) at 75 DAT was recorded from Chemical fertilizer (F_4) and the shortest outer leaf length (32.26 cm) was observed in those plots where no fertilizer was applied (F_1). On the other hand, , the highest outer leaf width (17.47 cm) was obtained from the plot where chemical fertilizer (F_4) was applied and lowest outer leaf width (9.36 cm) was obtained from the plot where no fertilizer (F_1) was applied. The variation in curd size was found to be statistically significant due to the applications of different fertilizer and manure. The maximum curd size (2.88.57 cm^2) was obtained from the plot where chemical fertilizer (F_4) was applied. On the other hand, minimum curd size (155.73 cm^2) was obtained from the plot where no fertilizer (F_1) was applied. The yield of curd with and without leaf as gram per plant was significantly different due to the applications of different fertilizer and manure. The highest yield of curd with leaf (1005.7 g) was recorded from the plot where chemical fertilizer (F_4) was applied whereas lower yield of curd with leaf (609.5 g) was obtained from the plot where no fertilizer (F_1) was applied and the maximum yield of curd without leaf per plant (526.83 g) was obtained from the plot where chemical fertilizer (F_4) was applied whereas minimum yield of curd without leaf per plant (215.25 g) was obtained from the plot where no fertilizer (F_1) was applied. Finally, the yield ofcurd with and without leafas ton per hectare land was significantly affected due to the applications of different fertilizer and manure. The highest curd yield with leaf (43.54 t/ha) was recorded from the plot where chemical fertilizer (F_4) was applied whereas lowest curd yield with leaf (27.06 t/ha) was obtained from the plot where no fertilizer (F_1) was applied and the maximum yield of curd with leaf (23.27 t/ha) was recorded from the plot where chemical fertilizer (F_4) was applied whereas lowest yield of curd with leaf (9.47 t/ha) was obtained from the plot where no fertilizer (F_1) was applied.

Again, interaction effect of spacing and fertilizer & manure applications of cauliflower had significant effect of all variables. However, the tallest plant height (52.73 cm) at 75 DAT was recorded from S_1F_4 (Broader spacing + Chemical Fertilizer). On the other hand, the shortest plant height (32.33 cm) at 75 DAT was observed in S_3F_1 (Closer spacing + No fertilizer). At 75 DAT, the highest number of leaves/plant (14.97) was obtained from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer) whereas lowest number of leaves/plant (10.03) was obtained from the treatment S_3F_1 (Closer spacing +

No fertilizer). The longest outer leaf (40.30 cm) at 75 DAT was obtained from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer). On the other hand, the shortest leaf (5.95 cm) at 75 DAT, was observed from both treatments S_2F_1 (Intermediate spacing + No fertilizer) which was similar with S_3F_1 (Closer spacing + No fertilizer). The highest outer leaf width (18.27 cm) at 75 DAT was obtained from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer) and lowest leaf width (8.73 cm) was obtained from the treatment S_3F_1 (Closer spacing + No fertilizer) which was nearly similar with S_2F_1 (Intermediate spacing + No fertilizer). And the highest curd size (291.33 cm^2) was recorded from the treatment S_1F_4 (Broader spacing + Chemical Fertilizer). On the other hand, lowest curd size (152.90 cm^2) was recorded from the treatment S_3F_1 (Closer spacing + No fertilizer). Finally, yield of curd with and without leaf/plant as germ was found significantly varied due to interaction effect of spacing and fertilizer & manure applications. The maximum yield (1160.3 g) of curd with leaf was recorded in the plot where maintained broader spacing with chemical fertilizer (S_1F_4) whereas the minimum yield (560.5 g) of curd with leaf was recorded in the plot where maintained closer spacing with no fertilizer (S_3F_1) and The maximum yield of curd without leaf (662.88 g) was recorded in the plot where maintained broader spacing with chemical fertilizer (S_1F_4). On the other hand, the minimum yield (109.32 g) of curd without leaf was recorded in the plot where maintained closer spacing with no fertilizer (S_3F_1). Again, the interaction effect of spacing and fertilizer & manure applications on the yieldof curd with and without leaf as kilogram per hectare land of cauliflower was found significantly different. The highest yield (49794 kg/ha) was observed from the treatment S_3F_4 (Closer spacing + Chemical Fertilizer). On the other hand, lowest yield (21000 kg/ha) was observed from the treatment S_1F_1 (Broader spacing + No fertilizer). Finally, the interaction effect of spacing and fertilizer & manure applications on the yield of curd with and without leaf per hectare land was significantly varied. The maximum yield (49.73 t/ha) was recorded in the pot where maintained closer spacing i.e. 50 x 40 cm with chemical fertilizer (S_3F_4) whereas the minimum yield (20.97 t/ha) of curd with leaf was recorded in the plot where maintained broader spacing with no fertilizer (S_1F_1). And the maximum yield curd without leaf (27.00 t/ha) was recorded in the pot where maintained closer spacing cm with chemical fertilizer (S_3F_4) whereas the minimum yield (7.73 t/ha) of curd without leaf was recorded in the plot where maintained broader spacing i.e. 75 x 50 cm with no fertilizer (S_1F_1).

In case of economic analysis, the total cost of production was maximum (292922 Tk. /ha) in those plots where cauliflower was cultivated with using Closer spacing + Cow dung (S_3F_3) whereas the minimum cost of production (198474 Tk. /ha) was recorded from those plots where Broader spacing + No fertilizer (S_1F_1) was applied. The highest value of gross return (1122680 Tk. /ha) was obtained in those plots where Closer spacing + Chemical Fertilizer (S_3F_4) was applied. On the other hand, the lowest value of gross return (351360 Tk. /ha) was obtained in those plots where Broader spacing + No fertilizer (S_1F_1) was applied.Net return (834057 Tk. /ha) was comparatively higher in producing cauliflower under Closer plant spacing with Chemical Fertilizer (S_3F_4). At the same time, the lowest net return (152886 Tk. /ha) was received from those plot where maintained Broader plant spacing with no fertilizer (S_1F_1) was applied. The highest benefit-cost ratio (3.89) was recorded from the treatment Closer spacing + Chemical Fertilizer (S_2F_4). On the other hand, the lowest benefit-cost ratio (1.56) was observed in those plots where cauliflower was grown under Intermediate plant spacing with no fertilizer (S_2F_1) application.

5.2 Conclusion

From the findings of this study, it may be concluded that among the three plant spacing's, closer spacing i.e. 50 x 40 cm spacing gave best performance in terms of total yield of cauliflower without leaf at the floor of a young mahogany woodlot. Again, among the four fertilizers and manure application packages, completely chemical fertilizer application gave best yield. Moreover, in case of economic return, cauliflower cultivation at the floor of mahogany tree with closer planting spacing with the application of full chemical fertilizer gave maximum Benefit Cost Ratio (BCR). However, cow-dung with closer planting spacing i.e. 50 x 40 cm gave only 1.76 % yield reduction compare to closer spacing with chemical fertilizer under mahogany + cauliflower based agroforestry system. So, if we consider the benefit of organic manure applications in terms of environmental benefit, soil health and safe food consumption then cultivation of cauliflower at the floor of mahogany orchard with cow-dung applications using closer spacing i.e. 50 x 40 cm may be a promising orchard based agroforestry system in the northern part of Bangladesh.

5.3 Recommendations

- ❖ The farmers of Char land can cultivate cauliflower at the floor of a newly established mahogany woodlot successfully using both chemical and cowdung.

- ❖ This study should be repeated in different char land locations of Bangladesh like Padma char, Meghna char, Jamuna char etc. using different aged mahogany orchard with different types (Physically) of char land to obtained valid recommendation.

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APPENDICES

Appendix-I: The physical and chemical properties of soil in Jaldhaka Upazila Under Nilphamari District.

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

Source: Soil Resources Development Institute, Rangpur (2019)

Appendix II. Weather data of the experimental site during the period from November 2019 to March 2020

Months	* Air Temperature (^{0}C)			* Average Rainfall (mm)	* Relative Humidity (%)
	Maximum	Minimum	Average		
November 2019	32.9	26	29.45	0.0	85
December 2019	28	15.1	21.55	0.0	81.5
January 2020	27.1	16	21.55	0.0	86
February 2020	30	22.3	26.15	0.0	81
March 2020	34.3	22.2	28.25	0.0	76

Note * Monthly average

Source: Bangladesh Meteorological Station, Rangpur

Appendix- I I I: Production cost analysis of cauliflower cultivation under mahogany based agroforestry system.

Treatment	Input cost										Total input cost (tk/ha)	Overhead cost			Total cost of production (tk/ha)
	Non material cost (Tk/ha)			Material cost (Tk/ha)								Interest of input cost @ 8% for the crop season (tk/ha)	Interes of the value of land(tk. 300000/ha /ha) @ 8% for the crop season (tk/ha)	Miscellaneous cost @ 5% of the input cost (tk/ha)	
	Mahogany	Cauli flower	Total nonmaterial cost	Seed	Fertilizer and Manure	Pesticide	Irrigation	Maintenance cost of trees	Initial plantation cost of trees	Total material cost (tk/ha)					
S_1F_1	15000	26000	41000	26666	0	8000	3260	6850	68626	113402	154402	12352	24000	7720	198474
S_1F_2	15000	26000	41000	26666	7055	8000	3260	6850	71876	123707	164707	13176	24000	8235	210118
S_1F_3	15000	26000	41000	26666	10860	8000	3260	6850	75681	131317	172317	13785	24000	8615	218717
S_1F_4	15000	26000	41000	26666	3250	8000	3260	6850	79486	127512	168512	13480	24000	8425	214417
S_2F_1	15000	32000	47000	37037	0	8000	3260	6850	78997	134144	181144	14491	24000	9057	228692
S_2F_2	15000	32000	47000	37037	7055	8000	3260	6850	82247	144449	191449	15315	24000	9572	240336
S_2F_3	15000	32000	47000	37037	10860	8000	3260	6850	86052	152059	199059	15924	24000	9952	248935
S_2F_4	15000	32000	47000	37037	3250	8000	3260	6850	89857	148254	195254	15620	24000	9762	244636
S_3F_1	15000	45000	60000	50000	0	8000	3260	6850	91960	160070	220070	17605	24000	11003	272678
S_3F_2	15000	45000	60000	50000	7055	8000	3260	6850	95210	170375	230375	18430	24000	11518	284323
S_3F_3	15000	45000	60000	50000	10860	8000	3260	6850	99015	177985	237985	19038	24000	11899	292922
S_3F_4	15000	45000	60000	50000	3250	8000	3260	6850	102820	174180	234180	18734	24000	11709	288623

Here,S_1F_1 = Broader spacing + No fertilizer; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing+ Cow-dung; S_1F_4 = Broader spacing + Chemical; S_2F_1 = Intermediate spacing + No fertilizer; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing+ Cow-dung; S_2F_4 = Intermediate spacing + Chemical; S_3F_1 = Closer spacing+ No fertilizer; S_3F_2 = Closer spacing+ Poultry manure; S_3F_3 = Closer spacing+ Cow-dung and S_3F_4 = Closer spacing+ Chemical.

Appendix- I V: Some plates of my research

Plate 1: Preparation of field

Plate 2: Growth period

Plate 3: Harvesting period

Plate 4: Data collection