PERFORMANCE OF CAULIFLOWER PRODUCTION UNDER MANGO BASED AGROFORESTRY SYSTEM INFLUENCED BY SPACING AND FERTILIZER IN CHARLAND

A THESIS

BY

MAHBUBA AKTER

Student No. 1805338

Thesis Semester: January- June, 2020

MASTER OF SCIENCE (MS)
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HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200

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JUNE, 2020

DEDICATED

TO

MY

BELOVED PARENTS

AND

RESPECTED TEACHER

DECLARATION

I hereby declare that the work presented in this thesis title "**Performance of Cauliflower Production Under Mango Based Agroforestry System Influenced by Spacing and Fertilizer in Charland"** has been carried out by myself and that it has not been submitted for any previous degree. All questions have been distinguished by quotation marks and all sources of information specifically acknowledged by references to the authors.

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June, 2020 *The Authoress*

PERFORMANCE OF CAULIFLOWER PRODUCTION UNDER MANGO BASED AGROFORESTRY SYSTEM INFLUENCED BY SPACING AND FERTILIZER IN CHARLAND

ABSTRACT

A field experiment was conducted in the charland of Gangachara Upazilla under Rangpur district during October, 2019 to December, 2019 to evaluate the performance of cauliflower production under mango based agroforestry system influenced by different plant spacings and different fertilizer application packages. The experiment was laid out in a two factorial RCBD with 3 (three) replications. Factor A was three plant spacings viz. S_1= 75 × 50 cm (Broader spacing), S_2= 60 × 45 (Intermediate spacing), S_3= 50 × 40 (Closer spacing) and Factor B was four Fertilizer and manure application packages viz. F_0= No Fertilizer, F_1= Cow-dung, F_2= Poultry manure and F_3= Chemical fertilizer. The total number of experimental plots were 36. The result of the experiment revealed that plant height (30, 60 and 75 DAP) as cm, number of leaves/plant (30, 60 and 75 DAP), outer leaf length (30, 60 and 75 DAP) as cm, outer leaf width (30, 60 and 75 DAP) as cm, yield curd weight without leaf/plant (g), yield of curd without leaf/plot (kg/ha) and yield of curd without leaf/hectare (t/ha) of cauliflower significantly varied due to different plant spacings and fertilizer and manure applications at cultivated under the mango based agroforestry system. In case of main effect of different plant spacings, the maximum curd yield without leaf (14703 kg/ha) was recorded from the closer spacing i.e. 50 cm x 40 cm (S_3). On the other hand, the minimum yield (8.8 t/ha) was recorded from the broader spacing i.e. 75cm × 50 cm (S_1). In case of main effects of fertilizer and manure applications, the highest curd yield without leaf (17.1 t/ha) was recorded from the plot where fully chemical fertilizer (F_3) was applied whereas the lowest yield (8.7 t/ha) was obtained from the plot where no fertilizer (F_0) was applied. Again, in case of interaction effects of the different plant spacings and fertilizer and manure applications, the maximum curd yield without leaf (49.73 t/ha) was recorded in the plot where maintained closer spacing i.e. 50cm x 40 cm with chemical fertilizer (S_3F_4) whereas the minimum curd yield without leaf was (20.97 t/ha) was recorded in the plot where maintained broader spacing i.e. 75 cm x 50 cm with no fertilizer (S_1F_1). Similarly, the maximum curd yield without leaf per hectare (21.48 t/ha) was recorded in the plot where maintained closer spacing i.e. 50 cm x 40 cm with chemical fertilizer application (S_3F_3). On the other hand, the minimum curd yield without leaf per hectare (6.52 t/ha) was recorded in the plot where maintained broader spacing i.e. 75 cm x 50 cm with no fertilizer application (S_1F_0). From the economic analysis, the highest benefit-cost ratio (4.08) was recorded from the treatment 75 cm x 50 cm i.e. broader spacing + Chemical Fertilizer application (S_1F_3). The lowest benefit-cost ratio (1.74) was observed in those plots where cauliflower was grown under 60 cm x 45 cm i.e. intermediate spacing with no fertilizer (S_2F_0) application. Moreover, in case of economic return, cauliflower cultivation at the floor of mango tree with broader planting space and the application of full chemical fertilizer gave maximum BCR.

Key word: Charland, Cauliflower, Agroforestry, Mango, Spacings.

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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 the area of 147570 sq. Kilometers and population growth rate is 1% per annum (World Bank, 2017). The total forest area of the nation covers about 17% of the land (BBS, 2016). Due to increasing population, land holdings are being fragmented and area devoted to small scale agriculture is decreasing. Under this circumstances, agroforestry may be a good farming option to increase the both forest and agricultural production in Bangladesh. Indeed, agro forestry 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).

Mango (*Mangifera indica*) belongs to the genus *Mangifera* of the family Anacardiaceae. Mango has become naturalized and adapted throughout the tropics and subtropics. It is the most popular and tasty fruit in Bangladesh and it contains adequate quantity of carotene or vitamin A and minerals. It is called the king of fruits. Mango plays an important part in the diet and cuisine of many diverse cultures Mango is cultivated in almost all districts of Bangladesh. But a good quality and high value mango is grown well in the districts of north-western and south-western region because of soil and weather condition. But now-a-days, mango is cultivated commercially in all districts of Bangladesh. Mango trees are recognized as national tree of Bangladesh, and eaten throughout the world (Slavin and Lioyd, 2012).

Cauliflower (*Brassica oleraceae var. botrytis L.*) is one of the most popular cruciferous vegetable crops cultivated for its white curds as edible part. It is being grown round the year for its white and tender curd vegetables and thrives best in a cool, moist climate and it does not withstand very low temperature or too much heat (Din *et al.,* 2007). Cauliflower is a very tasty and much popular vegetable in Bangladesh as well as all over the world. Due to the increasing consumption of cauliflower products, the crop is becoming promising. Although Bangladesh is producing a good amount of cauliflower and it is using for the preparation of different delicious food but the average yield of cauliflower is low in Bangladesh compared to other countries. Plant density as management practices and micronutrients is prerequisite for increasing the production of cauliflower in Bangladesh (Kannan *et al.,* 2016). Plant spacing is an important aspect of crop production for maximizing the yield (Rahman *et al.,* 2007a). It helps to increase the number of leaves, branches and healthy foliage. Densely planted crop obstruct the proper growth and development. On the other hand, wider spacing ensures the basic requirements but decrease the total number of plants as well as total yield. Crop yield may be increased up to 25% by using optimum spacing (Hossain *et al.,* 2015). Cauliflower responds well to macronutrients–nitrogen, phosphorus and potassium. However, chemical fertilizers are also essential for its proper growth and yield especially boron and molybdenum (Rahman *et al.*, 2007b). Boron application increased plant height, number of leaves per plant, length and width of the leaf, plant spread, main head weight and head yield both per plant and per hectare (Moniruzzaman *et al.*, 2007). On the other hand, due to boron deficiency water soaked areas appear on the stem and head surface, gradually the stem becomes hollow and curd turns brown. Again the molybdenum deficiency appears on young plant with chlorosis of leaf margins and gradually the whole leaf turns white. They also become cupped and wither, eventually. The leaf dies and the growing point also collapses (Ningawale *et al.*, 2016). It was known that there could be many genetic and environmental effects on the yield (Yazici *et al.*, 2017). Considering the above all perspective, the present study was undertaken to investigate the effect of plant spacing and different levels of chemical fertilizers and organic manure specially cow-dung and poultry manure on cauliflower to find out the suitable combination of plant spacing and nutrients under mango based agroforestry system which can ameliorate the growth and yield attributes of cauliflower.

Charland is the most important venue for practicing agroforestry systems. Chars in Bangladesh have been distributed into five sub-areas: the Jamuna, the Ganges, the Padma, the Upper Meghna and the Lower Meghna rivers. There are other areas of riverine chars in Bangladesh, along the Old Brahmaputra and the Tista rivers. But compared to the chars in the major rivers, the constitute much less land area. 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 Charland people, integrated approach with crops/vegetables and trees is necessary. So, this practice can address the demand of agricultural production. Charland farmers can practice agroforestry to improve their livelihood.

1.2 Research problem

However, the farmers of Charland are not aware about agroforestry systems. Even those farmers of Charland who have mango orchard are recently starting to cultivate different kinds of vegetables and spices at the floor of young mango orchard. But usually they are using chemical fertilizers and not conscious about which plant spacing will give much yield and economic benefits. Still, the Charland farmers donot cultivate high marketable vegetable like cauliflower under agroforestry system. So, we need to identify the suitable plant spacing for organic cauliflower production in the floor of mango orchard in Charland.

1.3 Research objectives

Considering the above circumstances, the present study was conducted with mango as upper-story and cauliflower as ground-story components using different fertilizer and manure applications package and different planting spacings with the following objectives:

1. To test the yield performance of cauliflower with different treatment of fertilizer doses and different plant spacings at the floor of a young mango orchard in the char of Tista river.
2. To assess the economic outputs of cauliflower-mango based agroforestry systems using different fertilizer packages and planting spacings

CHAPTER II

REVIEW OF LITERATURE

Agroforestry is an effective land management practice that simultaneously addresses biophysical, economical and socio ecological components. Such kind of diversity and interaction leads to a greater functional and structural complexity compared to conventional agro-ecosystems. 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:

2.1 Concepts of agroforestry

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

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

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

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

Hasanuzzaman *et al.,* (2014) stated that cropland agroforestry is an important production system in the southwest region of Bangladesh. This study focused on the floristic composition and management of existing cropland agro-forests. A total of 313 cropland agro forests were surveyed and 83% respondents practiced pure agroforestry while the remaining 17% practiced agroforestry with fisheries. A total of 18 forest trees and 2 shrubs were recorded from 11 families and 59 fuel wood species and wider spacing for fruit trees. A wide range of rotation periods, from 5 to 25 years, was observed for both cases.

Agroforestry practices are increasingly promoted as options that can contribute to food security, biodiversity conservation and the provision of a range of other ecosystem services (Pretty *et al.,* 2006 and Jackson *et al.,* 2013). This has led to demands for effective ways to scale-up agroforestry so that large numbers of people benefit. The term ‘scaling-up’ comes from a research and development (R and D) model that envisages research being done to identify possible improvements to agricultural practice, testing and refining these interventions in pilot locations, and then widely disseminating the refined interventions (Linn *et al.,* 2012). Each of these stages may be more or less participatory. There has been extensive work on principles and methods for scaling-up agricultural changes in general (Linn *et al.*, 2012) with an emerging focus on social processes in agricultural innovation systems (Kilelu *et al.*, 2013).

Broadly, agroforestry has been defined as systems where trees interact with agriculture. This can be applied at a range of scales to focus on trees in agricultural landscapes (Zomer *et al.*, 2009), or on a set of agricultural practices comprising tree species, their management and interaction with other components of the farm or forest systems within which they are embedded (Sinclair 1997).

Within agroforestry science and praxis at the present time, there are innovations relating to two different concepts of scale: the operational scale at which work is done (field, farm, landscape, region, nation or planet) and the extent to which agroforestry options deriving from any of these scales of operation is adopted (scaling-up). There are interactions amongst these concepts because the challenges of scaling-up vary with the scale of operation. Recent, high-profile, policy papers that specifically call for scaling up agroforestry (Montpellier Panel 2013; De Schutter O. 2011 and NEPAD 2003) imply a focus on spreading improved field-scale technology, which is promoting agroforestry practices on farms. This is echoed in papers that review and promote sustainable, agro-ecologically based or 'perennialised' agriculture (Montpellier Panel 2013; Garrity *et al.*, 2010; Altieri *et al.*, 2012; Pretty *et al.*, 2011 and Glover *et al.*, 2012). Here, we review the evidence on how effective efforts to spread technology options have been, and then explore how a broader conception of scaling-up, that embeds research within development praxis, can address the limitations that emerge.

Long *et al.*, (2003) studied that the lacquer tree (*Toxicodendron vernicifiuum*) based agroforestry system is a very important farming system with development potential in western Yunnan, southwest China. It is, however, less understood in scientific fields. The Lemo people (a branch of the Bai minority nationality) traditionally grow lacquer trees interplant with upland food crops in Sweden fields. During a 10–15 year fallow period, farmers can harvest various products from lacquer trees, including resin for selling or trading, leafy shoots for vegetable, pericarps for making wax, roots and leaves for pesticide, dry resin for medicine, and seeds for vegetable oil extraction. The Lemo people believe the lacquer tree is the most important crop in their community. The lacquer agroforestry system provides the Lemo people with food, cash income and environmental benefits. Further studies on the lacquer agroforestry system will be indispensable to improve this system so as to disseminate it to other communities.

Agroforestry can contribute to household income/consumption directly through the production of goods (fruits, poles, fuel wood) and indirectly through goods and services such as fodder for livestock, reduction of land degradation, improved soil and water conservation. In addition, other benefits can be realized downstream through reduction of soil erosion and/or increased water flow control. These systems at a more aggregate level can also provide services for international consumers, through benefits for example of carbon sequestration and protection of international waters (FAO, 2011).

Alao *et al*., (2013) stated that agroforestry has been defined as a dynamic ecologically based natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. This paper highlighted agroforestry practices and concepts in sustainable land use systems. The benefit derivable from the interface between forest trees and agricultural crops are enormous. They include the 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.

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

2.2 Effects of organic manures and inorganic fertilizers on the growth and development of crop.

Deore *et al.,* (2010) determined the effects of foliar applications of a novel organic liquid fertilizer on growth and yield in chili (*Capsicum annum* L. var. Shama). The pot experiments were carried out in Botanical garden, Fergusson College, Pune. Plants were sprayed with five doses (1% - 5%) of novel organic liquid fertilizer along with untreated control plants. *Capsicum* which belongs to family Solanaceae is referred to as red pepper. Chili is an important commercial crop of India grown for its green fruits as vegetable and red form as spice. Many food industries have been using chilies in preparation of processed products and pharmaceutical preparations. The present investigation has revealed the consistent and significant results for growth parameters due to applications of novel organic liquid fertilizer. Out of five different treatments, the 3% treatment resulted in maximum, plant height; number of branches per plant; leaf number; leaf area; fresh and dry weight of the plant; number of fruits per plant and total yield.

Singh *et al.*, (2009) stated that pH having 5.3 to 5.5 to study the effect of organic sources of nutrients viz., vermicompost, FYM and along with inorganic fertilizers in French bean under irrigated condition with an objective to study growth and yield without degrading soil quality by using various nutrient compositions. In this investigation, vermicompost treatment (T2) recorded the highest in all observations except biomass of whole plant (above and ground biomass) which was recorded highest in N: P: K (T1) treatment this may be due to high composition of Nitrogen in inorganic fertilizers which supplement to the plant's vegetative phase. Thus it may be concluded that vermicompost was found useful than any other type of treatments under irrigated condition of Srinagar valley.

Ullah *et al.,* (2010) conducted a field experiment at the Horticultural Farm of Bangladesh Agricultural University (BAU), Mymensingh during the period from December 2004 to April 2005 to evaluate the effect of manures and fertilizers on the yield of brinjal. The maximum branching (20.1) with the highest number fruits/plant (15.2), fruit length (14.1 cm) and fruit diameter (4.3 cm) were found combined applications of manures and fertilizers. The highest yield (45.5 t ha-1) was also obtained from the combined applications of organic and inorganic sources of nutrients. Applications of mustard oil cake or poultry manure alone gave better performance compared to only chemical fertilizers. The organic matter content and availability of N, P, K and S in soil were increased by organic matter applications. On the other hand, soil pH was increased with chemical applications than organic.

Kumar *et al.,* (2014) conducted a study to investigate the influence of different organic manure doses on the herbage biomass and essential oil yield and oil quality of patchouli *Pogostemon cablin* (Blanco) Bench under Teak based agroforestry system. He concluded that, among seven treatment of different organic manure tested, the 100% vermicompost exhibited significantly high dry herbage yield, essential oil yield and oil content (%) in first second and third harvest per year from patchouli crop under teak based agroforestry system.

Huez López *et al*., (2011) worked on the effect of two sources of nitrogen on plant growth, and fruit yield of chili pepper (*Capsicum annuum* L.) cv. An organic source extracted from grass clippings in rates of 120 and 200 kg N ha-1, and another inorganic (ammonium nitrate) in rate of 120 kg ha-1 were combined with low, moderate and high (1.5, 4.5, and 6.5 dS m-1) salinity levels arranged in a randomized complete block design replicated four times. Salinity treatments reduced dry matter production, leaf area, relative growth rate and net assimilation rate but increased leaf area ratio. The organic fertilizer produced higher fruit yields than the inorganic fertilizer. The highest fruit yield was obtained with the increased rate of organic N. The fruit number was more affected by salinity than the individual fruit weight.

Vimala *et al.*, (2007) studied that four rates (0, 20, 40, 60 t/ha) of organic fertilizer (processed poultry manure) and three rates of inorganic fertilizer (0, 2 and 3 t/ha) were evaluated on bird chili grown on an upland clay soil. Significant effects of processed poultry manure (PPM) and inorganic fertilizer (NPK) rates on yield were obtained. Interaction effects between PPM and NPK were not significant. Yield increased significantly from 6.46 t/ha at zero fertilizer to 15.49 t/ha at 20 t/ha PPM + 2 t/ha inorganic fertilizer (N: P2O5:K2O: MgO = 12:12:17:2). The optimum rate of inorganic fertilizer was 1.91 t/ha. The optimum rate of organic fertilizer was 52 t/ha. Fertilizers had no significant effect on fruit weight, but had a significant effect on fruit length. Nutrient contents did not differ significantly, except for fruit Ca, Fe and Mn and leaf Mg and Mn. Most soil chemical properties improved with increasing rates of organic fertilizer.

Rahman *et al.*, (2012) carried out an experiment to investigate the effects of bio compost, cow dung compost and NPK fertilizers on growth, yield and yield components of chili. There were 15 treatments viz. T1= bio compost (3 kg/pot) + NPK, T2= bio compost (2 kg/pot) + NPK, T3= bio compost (1.5 kg/pot) + NPK, T4= bio compost (3 kg/pot), T5= bio compost (2 kg/pot), T6= bio compost (1.5 kg/pot), T7= cow dung compost 3 kg/pot + NPK, T8= cow dung compost (2 kg/pot) + NPK, 9= cow dung compost (1.5 kg/pot) + NPK, T10= cow dung compost (3 kg/pot), T11= cow dung compost (2 kg/pot), T12= cow dung compost (1.5 kg/pot), T13= NPK, T14= bacterial suspension, T15= control (only soil). Bio compost and NPK significantly ($p = 0.05$) influenced the growth and yield of chili. The treatment bio compost (3 kg/pot) + NPK (T1) produced the highest germination (%), vigour index, growth and yield of chili and the lowest yield and yield contributing parameters were recorded in control (T15). The results suggest that inorganic fertilizers (NPK) with bio compost (3 kg/pot) is suitable for better production of chili that may increase soil fertility and this integrated approach could be contributed to improve crop production.

Vitkar *et al.*, (2007) conducted an experiment in Maharashtra, India, to determine the effect of organic and inorganic fertilizers on the growth and green fruit yield of chili (*Capsicum annuum*) during 2003-04. Treatments comprised: a control, 100 or 50% recommended NPK rate (RDF), 100, 50 or 25% N through vermicompost and/or 100, 50 or 25% N through neem cake. Treatment with 50% N through vermicompost + 50% N through neem cake produced the highest plant height, number of primary branches, number of fruits per plant, fruit weight, fruit length, fruit diameter and total yield per hectare compared to all the other treatments including the control variant.

Chanda *et al.,* (2011) conducted field trials by using different fertilizers having equal concentration of nutrients to determine their impact on different growth parameters of tomato plants. Six types of experimental plots were prepared where T1 was kept as control and five others were treated by different category of fertilizers (T2-Chemical fertilizers, T3-Farm Yard Manure (FYM), T4-Vermicompost, T5 and T6- FYM supplemented with chemical fertilizers and vermicompost supplemented with chemical fertilizer respectively). The treatment plots (T6) showed 73% better yield of fruits than control, Besides, vermicompost supplemented with N.P.K treated plots (T5) displayed better results with regard to fresh weight of leaves, dry weight of leaves, dry weight of fruits, number of branches and number of fruits per plant from other fertilizers treated plants.

Umrao *et al.,* (2013) conducted experiment on effect of organic fertilizers on the growth and yield of garlic (*Allium sativum*) under *Tectona grandis* based agroforestry system with seven treatments each in open and shade conditions. The treatment combinations used were control, FYM, vermicompost, neem cake, 50% FYM + 50% vermicompost, 50% FYM + 50% neem cake, 50% vermicompost + 50% neem cake. The results showed that different treatment of organic fertilizers had a positive effect on the growth and yield of plants under both open and shaded conditions but plants grown under shade conditions performed better in comparison to the ones grown in the open. Among all the treatment combination the applications of FYM have better influence on growth and yield of garlic under open and shade conditions but more yield was obtained with the applications of FYM under light shade of trees.

2.3 Effect of multipurpose and fruit trees

In these contexts, the interactions between the characteristics of AFS and the behavior of fruit-trees receive an increasing interest for crops such as coffee (e.g., shade versus productivity; Cerdan *et al.*, 2012) and cocoa (e.g., spatial structure and biodiversity versus productivity (Deheuvels *et al.*, 2012) or pests and diseases (Gidoin *et al.*, 2014). It is likely between the two world wars, along with a generalized specialization of all production systems in agriculture, that the increasing demand for fruits entailed the disintegration of these fruit-tree-based AFS and fruit hedges, and the emergence of orchard systems precursors of modern intensive orchards, mechanized crop and fodder production (Herzog 1998).

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

Recent research efforts have shown that these waters can successfully be explored for establishment of trees and developing suitable Agroforestry systems (Dagar 2014; Dagar *et al.*, 2014b, 2016b; Dagar and Minhas 2016; Yadav and Dagar 2016).

Hellin *et al*., (1999) observed that fruit trees are considered advantageous because of the relatively high returns to labor resulting from low labor inputs (compared with annual crops); moreover, fruit tree-based systems also offer a more uniform distribution of income throughout the year than annual crop systems. However, the relatively "free" availability of forest-based timber- and fuel wood products in some areas are seen as disincentives for growing tree species for those purposes.

2.4 Agroforestry System Based on Mango

Rathore *et al.,* (2013) studied that first phase (1995–2005), five mango based agri-horticultural models (AHM) viz. Mango + cowpea–toria, mango + cluster bean/okra–toria, mango + sesame–toria, mango + black gram–toria and mango + pigeon pea in addition to sole mango plantation (no intercrop) and in second phase (2005–2010), two mango based AHM (mango + colocasia and mango + turmeric) in addition to sole mango (no intercrop) were studied. The mean maximum cowpea equivalent yield (t ha^{-1}) was harvested from cowpea (1.84) followed by okra (1.21), black gram (1.11), sesame (0.68) and mean minimum with pigeon pea (0.58). The crop yield reduction among the mango based AHM was observed from third year to tenth year. The positive correlation was found between light transmission and intercrops yields amongst all models during both phases. However, the correlation between mango canopies spread and intercrop yields shown negative trends. The yield reduction in intercrops varied from 37.0–52.6 % during first phase and 20.6–23.5 % during second phase of experimentation compared to sole crop. The results revealed that the fruit based AHM were effective in improving fruit yields of the mango. The mean maximum fruit yield of mango (7.02 t ha^{-1}) was harvested with cowpea–toria crop rotation followed by black gram–toria (6.59 t ha^{-1}) and minimum fruit yield (5.76 t ha^{-1}) realized with sole mango tree during first phase (1999–2005). Likewise, mean maximum fruit yield (13.71 t ha^{-1}) from mango tree was obtained in the turmeric block followed by (13.00 t ha^{-1}) in colocation block and minimum fruit yield with sole mango tree

(11.86 t ha^{-1}). All the treatments of AHM recorded higher soil moisture as compared to sole mango plantation during both phases. The moisture retention under different AHM was in the order of cowpea (13.32 cm) > black gram (13.29 cm) > pigeon pea (13.27 cm) > okra (12.42 cm) > sesame (12.17 cm) > sole mango (11.62 cm) during first phase, whereas moisture retention was observed in the order of turmeric (14.20 cm) > colocation (14.01 cm) > sole mango (12.60 cm) during second phase. The cowpea–toria crop rotation with mango gave maximum benefit: cost ratio followed by okra–tori under rain fed conditions. Besides economic viability of cowpea–tori with mango, this system had improved tree growth as well as fruit yield of mango. In the second phase, mango + turmeric yielded more benefit than mango + colocation system. In the first phase, the mango + cowpea–tori system improved organic carbon, total nitrogen, phosphorus, potash and reduced pH by 49.0, 56.3, 48.6, 58.5 and 11.6 %, respectively as compared to initial values whereas mango + turmeric system increased organic carbon, nitrogen, phosphorus, potash and reduction in pH by 51.0, 45.0, 29.7, 29.0 and 3.4 %, respectively over initial values within soil depths of 0–30 cm during second phased. Mango based AHM is recommended for adoption with selective intercrops up to 15 years of age of mango plantation for multiple outputs and good economic viability without impairing site fertility.

Rahman *et al.,* (2012) studied that the traditional system of agriculture has become unsustainable due to high population growth. Mango-based agroforestry which has been practiced by the farmers since the 1990s, is a promising alternative and is considered as one of the few options to lift farmers out of poverty and improve livelihood security. This paper examines the potential of mango-based agroforestry to improve livelihoods, using data collected by rapid rural appraisal, farmer participatory research, stakeholder analysis and a farm household survey in six representative villages in the floodplain. Farmers with the least land were found to allocate a higher percentage of their land to agroforestry, and the increased income from agroforestry compared to other agricultural systems helps reduce relative poverty. This income maintains basic household needs, providing food security and fuelwood, and contributes to healthcare, housing and sanitation conditions, and meeting educational expenses.

Alam *et al.,* (2011) stated that the cultivation of different plants around homesteads for subsistence and cash income has been a long tradition in Bangladesh. This study explores stand structure, composition, and biodiversity within the homestead agroforests of the drought-prone, northwestern region of Bangladesh. In 96 randomly selected homesteads within 3 study villages, we identified 56 tree species. Among those, *Mangifera indica* (mango) was the most popular fruit bearing species. Four non-parametric diversity indices were derived to provide a characterization of biodiversity. The Sørenson similarity index was also used to compare the similarity of species among different landholding size classes. The overall Shannon-Wiener biodiversity index and Pielou's evenness index values were 1.82 and 0.45, respectively. This study confirms that the farmers had strong preference for fruit species over timber yielding ones, and because of better growth performance natives were preferred over exotics.

Shinde *et al.,* (2010) found that the grain yield plant^{-1} indicated positive and highly significant correlation with straw yield plant^{-1}, harvest index and weight of grains on main ear head at phenotypic and genotypic level, while number of fingers on main ear head at genotypic level only. Under mango based agroforestry system, path analysis indicated that finger length, harvest index, number of fingers on main ear head and straw yield plant"^{1} had direct positive effect on grain yield at genotypic level. Selection programme based on number of fingers on main ear head and straw yield plant^{-1} will be effective for grain yield improvement in finger millet under mango based agroforestry system.

2.5 Vegetable Based Agroforestry System

Hanif *et al.*, (2010) conducted a field experiment and the treatments were three okra variety viz. hybrid okra variety, BARI-1 and local okra variety, which were used as ground layer crop. There was also control (sole cropping) treatment. The aim of the experiments was to study the growth performance and selection of potential okra variety under litchi based agroforestry system. The yield contributing parameters were maximum in sole cropping of hybrid okra. The yield was highest (10.24 t ha-1) in mono-cropping of hybrid okra and the lowest yield (4.24 t ha-1) was found in T6 (Litchi + Local okra variety). But the litchi based agroforestry system ensures higher return and more sustainable than sole cropping. The suitability of okra variety may be ranked as Okra hybrid variety > BARI-1 okra > Local okra variety.

Rathore *et al.,* (2013) conducted an experiment where a total of 15 years of experimentation period (1995–2010) was divided into two phases. In the first phase (1995–2005), five mango based agri-horticultural models (AHM) viz. Mango + cowpea–toria, mango + cluster bean/okra–toria, mango + sesame–toria, mango + black gram–toria and mango + pigeon pea in addition to sole mango plantation (no intercrop) and in second phase (2005–2010), two mango based AHM (mango + colocasia and mango + turmeric) in addition to sole mango (no intercrop) were studied. The mean maximum cowpea equivalent yield (t ha^{-1}) was harvested from cowpea (1.84) followed by okra (1.21), black gram (1.11), sesame (0.68) and mean minimum with pigeon pea (0.58). The crop yield reduction among the mango based AHM was observed from third year to tenth year. The positive correlation was found between light transmission and intercrops yields amongst all models during both phases.

Kan *et al*., (2008) conducted a survey with 133 households during 2003–2005 showed that the surveyed farmers managed 17 different tree-crop simultaneous systems with 97% of all sites including fruit species. The annual components were commercially the more important and were given the highest priority—with cereals (47%), vegetables (27%), fodder (19%) and cash crops (7%). Irrespective of tree species and plantation age, the most frequently observed tree density was 200–500 trees ha^{-1}, although subject to large variations. The dominance of younger trees <10 years (41%) was evidence of the recent interest in TIS and was obviously linked to recent land reforms and change in land ownership. The knowledge of TIS management among those surveyed was rather superficial. The interaction between agroforestry, environmental research and farmers' practices must be improved given the growing interest and significance of TIS for the rural population, and the government must increase private landowners' participation in farm management and decision-making.

Pouliot *et al.,* (2012) stated that in Western Africa, interactions between trees and agricultural crops are a key element in determining parkland management in an agricultural environment that is rapidly changing. Eggplant (*Solanum melongena*), chili pepper (*Capsicum annuum*), taro (*Colocasia esculenta*) and pearl millet *(Pennisetum glaucum*) were tested for their shade tolerance under *Parkia biglobosa* trees in south-central Burkina Faso using a split-plot design. Soil characteristics, chlorophyll fluorescence and crop growth and yield were measured to quantify the effect of *P. biglobosa* on the crops and their environment. The experiment ran during 2 years. *P. biglobosa* suppressed the vegetative growth and yield of pearl millet in both years. Eggplant and chili pepper were severely injured by the rains and produced fruits only during the first year. Eggplant yields were suppressed by trees to between one third and one tenth of the yield in the control plots. However, chili pepper yields increased by up to 150% when grown under the tree canopy compared to the control. In both years, the vegetative growth and yield of taro was higher when grown in the shade than outside the tree canopy.

Miah *et al.,* (2008) conducted a field experiment to investigate the growth and yield performance of tomato under eight years old Sissoo and three years old Ghora neem trees. The treatments were two timber species i.e T2: Ghoraneem (*Melia azedarach*) and T3: Sissoo (*Dalbergia sissoo*) with one control plot (T1: open field). Except plant height all the growth and yield contributing characters of tomato showed the highest values under open field followed by ghoraneem. Under sissoo significantly tallest plant (12.3 cm) was recorded but all other parameters were found significantly lowest. The study revealed that tomato can easily be grown under three years ghoraneem orchard without significant yield loss although open field produced the highest yield (71.11 t ha-1) eight years sissoo orchard should not be allowed for tomato production as the yield under sissoo was severely poor.

In Tamil Nadu, India, Madhu *et al., (*2005) conducted a field experiment to study the effect of lopping on biomass production of *Eucalyptus globulus* and yield of potato and oats in agroforestry system. Trees which were not lopped up to the 10th year produced the highest total biomass of 436.63 t/ha whereas those lopped in alternate years and every year from the 4th year produced 218.29 and 140.76 t/ha, respectively. The reduction in intercrop yield of potato was 12.4-15.6% in agroforestry system as compared to sole crop but potato was the most profitable option, and, therefore, recommended for higher production, profitability and protection of sloping lands in the Nilgiri hills, the results was collaborating in another fimdings.

2.6 Concept of cauliflower

Cauliflower was first introduced to India from Enfland in 1822. Within a period of one hundred years, these introduced varities underwent selection by local growers when seed production was ttempted 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 considerded 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 adaptablity (Pradeepkumar and George, 2009).

The development tropical varieties of cauliflower at IARI, New Delhi, enhanced the spreading of its cultivation to non-traditional areas of Karnataka and Tamil Nadu (Pradeepkumar *et al.,* 2002). Some cauliflower cultivar initiate curd formation at about the same rate whether they are grown under cool or very warm weather conditions. Other cultivars require more than twice as long a time to form curds under high- temperature conditions than under cool or moderate temperatures. The delay or retardation of curd formation is the result of lack of sufficient growing time during which the temperature is below a cortical value. This critical temperature appears to vary with different cultivars. Cauliflower plants showed maximum rate of vernalization between 5^0C and 17^0C and at temperatures lower and higher than this range, reduced vernalization rates were observed which ranged between 22 and 36.7 leaves (Liptay, 1981).

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

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

Rahman *et al.,* (2007) found out a clear positive linear ralationship 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).

Masarirambi *et al.,* (2011) reported that direct exposure to sunlight resulted in the development of yellow pigments on curds Curds left uncovered will discoloue due to activation of peroxidise 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.

Cauliflower varies are classified based on optimum temperature for curd initiation and availability period viz, early (20-27^0 and Sep-Oct), mid-early (20-25^{0}C and Oct-Nov), mid-late (16-18^{0}C and Nov-Dec), and late (12-25^{0}C and Dec-Janu) even there are sub groups within each group (Thamburaj and Sing, (1998).

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

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

2.8 Effect and importance of Manure Applications

Nyamasoka *et al.,* (2017) reported that the 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.

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

CHAPTER III

MATERIALS AND METHODS

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

Fig 3.1: Map of Gangachara upazila under Rangpur 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 5.10 to

6.10. The morphological characteristics of the experimental tield and physical and chemical properties of initial soil are given in Appendix I.

3.3 Climate and weather

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

3.4 Experiment period

Duration of the experiment period was from 24 October, 2019 to 22 December, 2019

`3.5 Seedling growing of test crop

Seeds of the cauliflower were collected from Rural Development Academy (RDA), Bogra. The variety of cauliflower was Mountain cauliflower.

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: (Spacings)

S_1= 75 x 50 cm (Broader spacing)

S_2= 60 x 45 (Intermediate spacing)

S_3= 50 x 40 (Closer spacing)

Factor –B: (Fertilizer and manure applications)

F_0 = No fertilizer

F_1 = Cow-dung

F_2 = Poultry manure

F_3= Chemical fertilizer

Treatment combinations

S_1F_0 = Broader spacing + No fertilizer

S_1F_1 = Broader spacing + Cow-dung

S_1F_2 = Broader spacing + Poultry manure

S_1F_3 = Broader spacing + Chemical fertilizer

$S_2 F_0$ = Intermediate spacing + No fertilizer

S_2F_1 = Intermediate spacing + Cow-dung

S_2F_2 = Intermediate spacing + Poultry manure

S_2F_3 = Intermediate spacing + Chemical fertilizer

S_3F_0 = Closer spacing + No fertilizer

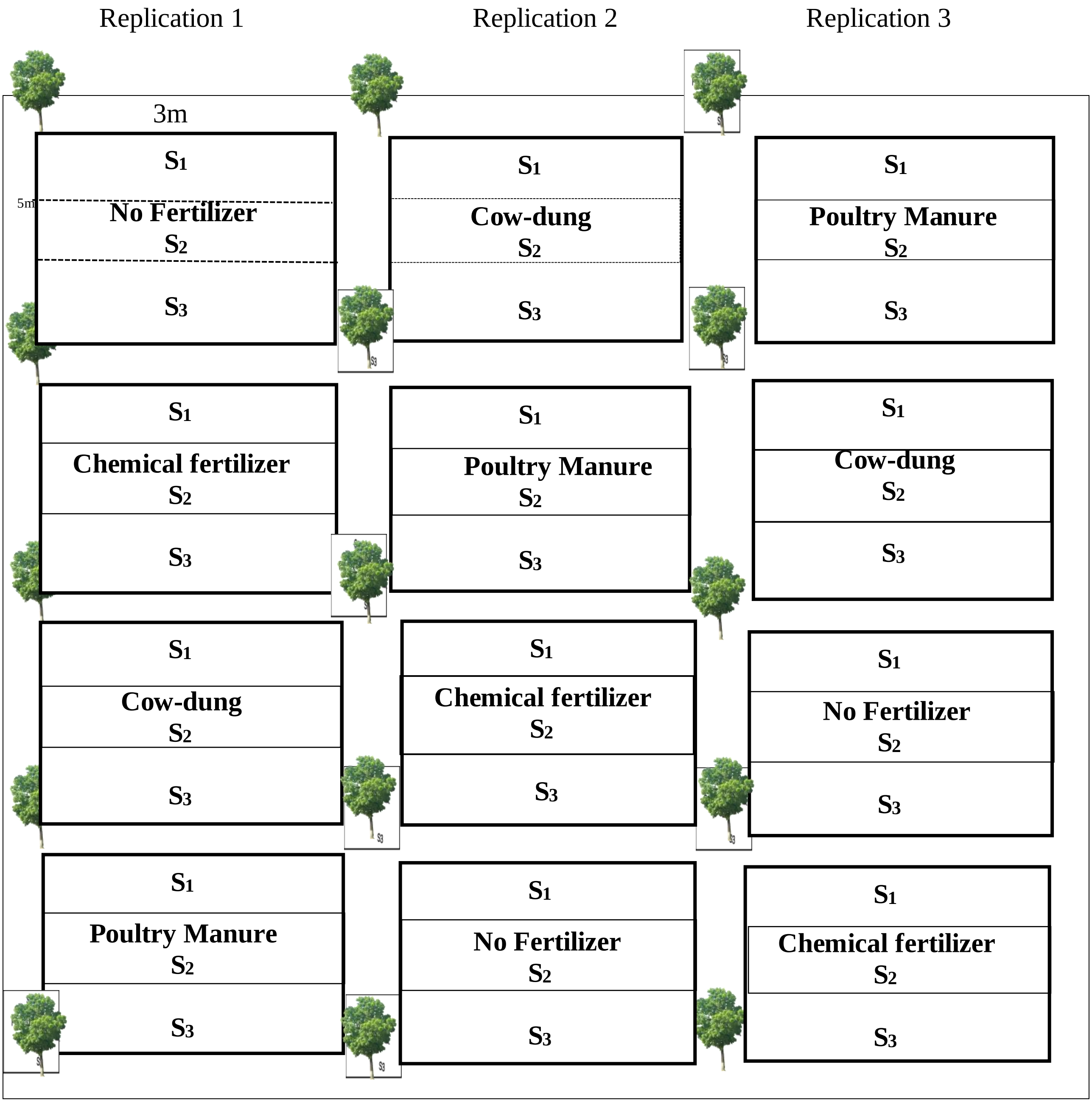
S_3F_1 = Closer spacing + Cow-dung

S_3F_2 = Closer spacing + Poultry manure

S_3F_3 = Closer spacing + Chemical fertilizer

3.8 Land preparation and layout

The land of experiment plot was opened with a spade on 01 December, 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

Fig 3.2: Field layout of treatment combination under mango 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 per ha
Urea	22.5kg
TSP	22.5kg
MOP	18kg
Gypsum	15kg
Boric powder	2kg
Cow-dung	10 ton
Molybdenum	1.5 kg
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: Mango

Scientific name: *Mangifera indica L.*

Family: Anacardiaceae

Distribution

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

Botanic Description

Mango is long-lived evergreen trees that can reach heights of 15-30 m (50100ft). Most cultivated mango trees are between 3 and 10 m (10-33) tall when fully mature depending on the variety and the amount of pruning. Wild non-cultivated seedling trees often reach 15 m (50) when found in favorable climates, and they can live for over 100years and develop trunk girths of over 4m (13ft). Grows from sea level to1200m (3950ft) tropical latitudes; however, most commercial varieties are grown below 600m (1950ft); rainfall 400-3600mm (16-140in), fruits best with a well-defined winter dry period. Mango trees typically branch 0.6-2 m (2-6.5 ft) above the ground and develop evergreen, dome-shaped Mango grown in heavily forested areas branch much higher than solitary trees and have an umbrella-like form. The Mango has a long taproot that often branches just below ground level, forming between two and four major anchoring taproots that can reach 6 m (20 ft) down to the water table. Fast, >1.5 m/yr (5 ft/yr) in ideal conditions. The details of mango tree were:

Planting orientation : East-West

Mango variety : Harivhanga

Age of mango tree : 1 years

Spacing : 8m x 8m

Average plant height : 2.5 m

Main agroforestry uses: Home gardens, silvopasture.

Main uses: Fruit, flavoring, medicinal, timber.

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 Tagging

Tagging was done at 30 DAP

Figure 3.3: Tagging

3.11.3 Irrigation

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

3.11.4 Plant protection measures

Plant protection measures were done whenever they were necessary.

3.11.5 Insect Pest

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

3.11.6 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 30, 60 and 75 Days after planting (DAP). Height was measured by using centimeter scale from the soil surface to the tip of the plant.

Figure 3.4: Measuring plant height with the help of centimeter scale at 30 DAP

3.12.2 Number of leaves per plant

It was recorded at 30, 60 and 75 Days after planting (DAP) by counting.

Figure 3.5: Counting leaves per plant

3.12.3 Outer leaf length (cm)

The length of the leaf was obtained with the help of centimeter scale at 30, 60 and 75 DAP.

Figure 3.6: Measuring length of the leaf with the help of centimeter scale at 60 DAP

3.12.4 Outer leaf width (cm)

The width of the leaf was obtained with the help of centimeter scale at 30, 60 and 75 DAP.

3.12.5 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.

Figure 3.7: Measuring weight of curd per plant with the help of electric balance.

3.12.6 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.

3.12.6 Yield of curd without leaf (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 per plant was converted to the yield as ton 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 mango was worked out on the basis of per hectare. The initial plantation cost of the litchi sapling was included in this study. The management cost of litchi tree was also included. The total cost included the cost items like human labor and mechanical power costs, materials cost (including cost of seeds, fertilizers and manures, pesticide, bamboos, ropes etc.), land use cost and interest on operating capital.

3.13.2 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.

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 statistix 10 software and MS Excel 2013. The mean differences were adjudged by Tukey HSD test.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter represents the results of the screening of different spacing between cauliflower with fertilizer and manure applications under mango tree based agroforestry system are presented in Table 4.1 to 4.16 and Figure 4.1 to 4.3. 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 Effect of spacing on Growth, Yield Contributing Characters and Yield of Cauliflower

4.1.1 Plant height (cm)

Plant height of cauliflower was recorded from the ground surface to the tip of the leaf in five plants of all the treatments. At different days after transplanting (DAT), plant height of cauliflower was significantly varied (Table 4.1).

Table 4.1 Effect of different spacings on plant height of cauliflower plant at different DAP.

Treatments (Spacings)	Plant height (cm)		
	30DAP	60DAP	75DAP
S_1	26.02 a	38.35 a	46.42 a
S_2	20.39 b	35.56 b	43.07 b
S_3	17.50 c	31.73 c	42.38 b
`CV (%)	4.16	7.44	4.86

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 probability.

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

However, at the initial plant height i.e. at 30 DAT, the height was not significantly varied. Although, the highest plant height (26.02 cm) was obtained from the 75 x 50 cm (S_1) spacing. On the other hand, the lowest plant height (17.50 cm) was obtained from the closer spacing i.e. 50 x 40 cm (S_3). At 60 DAP, the highest plant height (38.35 cm) was obtained from the plot where (75 cm × 50 cm) spacing was present among plants whereas the lowest plant height (31.73 cm) was observed from the closer spacing (50cm × 40 cm). Finally, the significantly superior plant height (46.42 cm) was observed from the broader spacing (75 cm × 50 cm) treatment at 75 DAP, while the shortest plant (42.38 cm) was found from the closer spacing (50 cm × 40 cm) which was statistically similar (43.07 cm) to S_2 (60 cm × 45 cm) treatment. 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 the maximum plant height where the plants were spaced (45 cm × 50 cm) apart.

4.1.2 Number of leaves/plant

Number of leaves per plant of cauliflower was significantly influenced by the different plant spacings at 30, 60 and 75 DAP (Table 4.2). An increasing trend in the number of leaves per plant was found up to harvest for all the treatments.

Table 4.2 Effect of different spacings on number of leaves of cauliflower plant at different DAP.

Treatments (Spacings)	Number of leaves/plant		
	30DAP	**60DAP**	**75DAP**
S_1	9.23 a	13.86 a	17.58 a
S_2	9.73 a	12.80 b	16.25 b
S_3	8.23 b	11.38 c	16.22 b
CV (%)	6.64	6.68	6.44

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 probability.

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

At 30 DAP, the highest number of leaves per plant (9.73) was recorded from S_2 treatment which was statistically similar (9.23) to S_1 treatment, whereas the lowest number of leaves per plant (8.23) was found from S_3 (Table 4.2) treatment at the same growth stage of plant. After 60 DAP, the highest number of leaves per plant (13.86) was recorded from S_1 treatment, whereas the lowest number of leaves per plant (11.38) was found from S_3. Finally, the highest number of leaves per plant (17.58) was recorded from S_1 treatment at 75 DAP, whereas the lowest number of leaves per plant (16.22) was found from S_3 which was statistically similar (16.25) to S_2 treatment. 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).

4.1.3 Outer leaf length (cm)

Outer leaf length of cauliflower showed significant differences due to different plant spacing at 30, 60 and 75 DAP (Table 4.3).

Table 4.3 Effect of different spacings on outer leaf length of cauliflower plant at different DAP.

Treatments (Spacings)	Outer leaf length (cm)		
	30DAP	**60DAP**	**75DAP**
S_1	21.27 a	38.19 a	40.57 a
S_2	20.12 ab	36.46 b	38.95 b
S_3	19.25 b	34.88 c	37.00 c
CV (%)	7.70	4.21	3.52

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 probability.

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

However, numerically at 30 DAP, the highest outer leaf length (21.27 cm) was obtained from the broader spacing i.e. 75 x 50 cm (S_1) whereas the lowest outer leaf length (19.25 cm) was obtained from the closer spacing i.e. 50 x 40 cm (S_3). Again, at 60 DAP, the highest outer leaf length (38.19 cm) was obtained from the broader spacing i.e. 75 x 50 cm (S_1), whereas the lowest outer leaf length (34.88 cm) was observed from the plot where spacing 50 x 40 cm (S_3) were present. Finally, at 75 DAP, the highest outer leaf length (40.67 cm) was recorded from the broader spacing i.e. 75 x 50 cm (S_1) and the lowest outer leaf length (37.00 cm) was observed from the closer spacing i.e. 50 x 40 cm (S_3).

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 at different days after planting (DAP). However, numerically at 30 DAP, the highest outer leaf width (9.48 cm) was obtained from the broader spacing i.e. 75 x 50 cm (S_1) whereas the lowest outer leaf width (8.42 cm) was obtained from the closer spacing i.e. 50 x 40 cm (S_3).

Table 4.4 Effect of different spacings on outer leaf width of cauliflower plant at different DAP.

Treatments (Spacings)	Outer leaf width (cm)		
	30DAP	**60DAP**	**75DAP**
S_1	9.48 a	14.23 a	16.24 a
S_2	8.82 b	13.55 a	15.40 b
S_3	8.42 c	12.47 b	14.48 c
CV (%)	4.38	7.04	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 DMRT) at 5% level of probability.

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

Again, at 60 DAP, the highest outer leaf width (14.33 cm) was recorded from the broader spacing i.e. 75 x 50 cm (S_1) which was significantly followed by the intermediate spacing i.e. 60 x 45 cm (S_2), whereas the lowest outer leaf width (12.47 cm) was observed from the plot where 50 x 40 cm (S_3) spacing were present. Finally, at 75 DAP, the highest outer leaf width (16.24 cm) was recorded from the broader spacing i.e. 75 x 50 cm (S_1) and the lowest outer leaf width (14.48 cm) was observed from the closer spacing i.e. 50 x 40 cm (S_3).

4.1.5 Curd weight without leaf/plant (g)

It was showed (Table 4.5) that the yield of curd without leaf was significantly varied due to different plant spacing. The highest weight of curd without leaf per plant (266.50 g) was observed from S_1 treatment, while the lowest weight of curd per plant (239.33 g) was found from

S_3 treatment which was closely followed (242.33 g) to S_2 treatment. Formation of bigger curd at the widest spacing was probably due to the availability of more nutrients, light, moisture to the plants indicate maximum weight. On the other hand, in closer spacing plants inter plants competition resulted in the formation of small curd which indicate minimum weight. Similar kind or result was reported by Kannan *et al.,* (2016) and Rahman *et al.,* (2007).

Broader (S_1) **Intermediate (S_2)** **Closer (S_3)**

Plate 1: Curd of without leaf obtain from different plant spacings of cauliflower after harvest

Table 4.5 Effect of different spacings on yield of cauliflower

Treatments (Spacings)	Curd weight without leaf/plant (g)	Yield of curd without leaf (kg/ha)
S_1	266.50 a	8833 c
S_2	242.33 b	9667 b
S_3	239.33 b	14703 a
`CV (%)	5.81	4.66

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 probability.

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

4.1.6 Yield of curd without leaf (kg/ha)

The yield of curd without leaf as kilogram per hectare land was significantly differences due to different plant spacing (Table 4.6). The maximum yield (14703 kg/ha) was recorded from the closer spacing (50 cm × 40 cm) due to large number of curd obtained per hectare land. One the other hand, the minimum yield (8833 kg/ha) was recorded from the broader spacing (75 cm × 50 cm) due to lower number of plant obtained per hectare. Farzana *et al.*, (2016) reported the maximum yield of cauliflower where the plants were spaced (45cm×50 cm) apart.

4.1.7 Yield of curd without leaf (t/ha)

Curd yield without leaf as ton per hectare of cauliflower showed significantly significant differences due to different plant spacing (Figure 4.1). The highest curd yield without leaf per hectare (14.70 t/ha) was observed from S_3 treatment, while the lowest curd yield per hectare (8.83 t/ha) was found from S_1 treatment. 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).

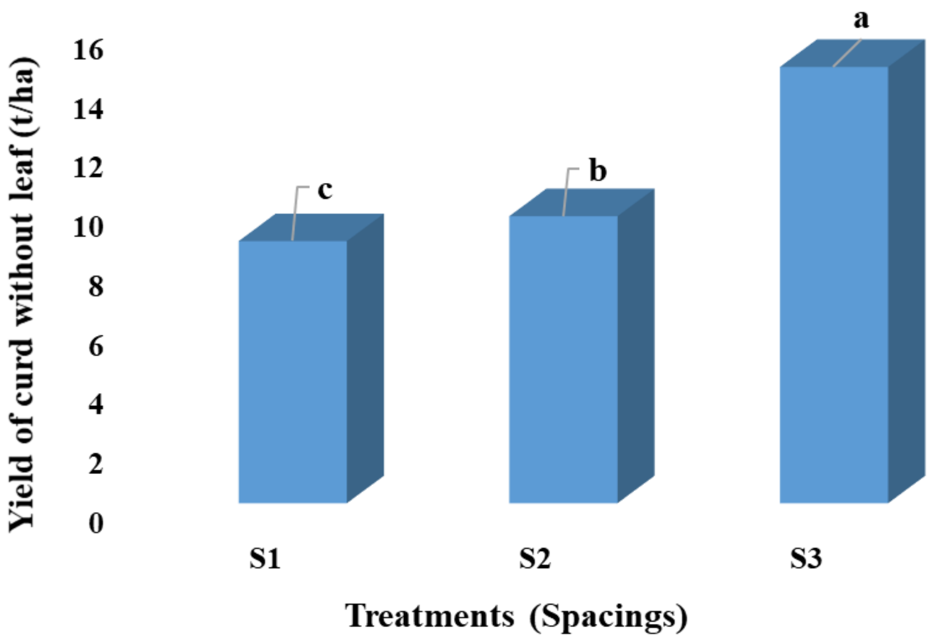


Figure 4.1 Effect of different spacing on yield of curd without leaf (t/ha)

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

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

4.2.1 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 5 plants of all the treatments. At different days after transplanting (DAP), plant height of cauliflower was found significantly affected due to the applications of different fertilizer and manure (Table 4.6). At 30 DAP, the highest plant height (26.79 cm) was obtained from the plot where chemical fertilizer (F_3) was applied. On the other hand, lowest plant height (17.86 cm) was obtained from the plot where no fertilizer (F_0) was applied

Table 4.6 Effect of fertilizer and manure applications on plant height of cauliflower plant at different DAP.

Treatments (fertilizer and manure applications)	Plant height (cm)		
	30DAP	**60DAP**	**75DAP**
F_0	17.86 d	25.12 c	38.11 d
F_1	19.25 c	35.40 b	42.43 c
F_2	21.31 b	36.22 b	45.45 b
F_3	26.79 a	44.12 a	49.83 a
`CV (%)	4.16	7.44	4.86

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 probability.

Here, F_0 = No fertilizer; F_1 = Cow dung; F_2= Poultry Manure and F_3= Chemical Fertilizer

At 60 DAP, the highest plant height (44.12 cm) was recorded from the plot where chemical fertilizer (F_3) was applied. Whereas, lowest plant height (25.12 cm) was obtained from the plot where no fertilizer (F_0) was applied. At 75 DAP, the highest plant height (49.83 cm) was obtained from the plot where chemical fertilizer (F_3) was applied and lowest plant height (38.11 cm) was obtained from the plot where no fertilizer (F_0) 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).

4.2.2 Number of leaves/plant

At different days after transplanting (DAP), number of shoot/plant of cauliflower was found significantly affected due to the applications of different fertilizer and manure (Table 4.8). At 30 DAP, the highest number of leaves/plant (12.68) was recorded from the plot where chemical fertilizer (F_3) was applied. Whereas, lowest number of leaves/plant (6.57) was obtained from the plot where no fertilizer (F_0) was applied. At 60 DAP, the highest number of leaves/plant (15.06) was recorded from the plot where chemical fertilizer (F_3) was applied. Whereas, lowest number of leaves/plant (10.51) was obtained from the plot where no fertilizer (F_0) was applied. At 75 DAP, the highest number of leaves/plant (21.38) was obtained from the plot where chemical fertilizer (F_3) was applied and lowest number of leaves/plant (13.70) was obtained from the plot where no fertilizer (F_0) was applied which was closely followed (15.02) to F_1 treatment. Similar findings were also reported by Singh and Rajput (1976), Muthoo *et al.,* (1987), Rahman *et al.*, (1992)

Table 4.7 Effect of fertilizer and manure applications on number of leaves of cauliflower plant at different DAP.

Treatments (fertilizer and manure applications)	Number of leaves/plant		
	30DAP	60DAP	75DAP
F_0	6.57 d	10.51 d	13.70 c
F_1	7.88 c	11.81 c	15.02 c
F_2	9.12 b	13.33 b	16.62 b
F_3	12.68 a	15.06 a	21.38 a
`CV (%)	6.64	6.68	6.44

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 probability.

Here, F_0 *= No fertilizer;* F_1 *= Cow dung;* F_2*= Poultry Manure and* F_3*= Chemical Fertilizer*

4.2.3 Outer leaf length (cm)

Outer leaf length of cauliflower was found significantly influenced due to the applications of different fertilizer and manure at different days after transplanting (DAP) (Table 4.8). At 30 DAP, the highest outer leaf length (24.69 cm) was obtained from the plot where chemical fertilizer (F_3) was applied. On the other hand, lowest outer leaf length (14.38 cm) was obtained from the plot where no fertilizer (F_0) was applied.

Table 4.8 Effect of fertilizer and manure applications on outer leaf length (cm) of cauliflower plant at different DAP.

Treatments (fertilizer and manure applications)	Outer leaf length (cm)		
	30DAP	**60DAP**	**75DAP**
F_0	14.38 d	31.07 c	33.35 d
F_1	19.39 c	34.70 b	36.84 c
F_2	22.39 b	39.18 a	41.51 b
F_3	24.69 a	41.09 a	43.66 a
`CV (%)	7.70	4.21	3.52

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 probability.

Here, F_0 *= No fertilizer;* F_1 *= Cow dung;* F_2*= Poultry Manure and* F_3*= Chemical Fertilizer*

At 60 DAP, the highest outer leaf length (41.09 cm) was recorded from the plot where chemical fertilizer (F_3) was applied which was closely followed (39.18 cm) to F_3 treatment. Whereas, lowest outer leaf length (31.07 cm) was obtained from the plot where no fertilizer (F_0) was applied. Finally at 75 DAP, the highest outer leaf length (43.66 cm) was obtained from the plot where chemical fertilizer (F_3) was applied and lowest outer leaf length (33.35 cm) was obtained from the plot where no fertilizer (F_0) 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).

4.2.4 Outer leaf width (cm)

At different days after transplanting (DAP), outer leaf width of cauliflower was found significantly affected due to the applications of different fertilizer and manure (Table 4.9). At 30 DAP, the highest outer leaf width (10.71 cm) was obtained from the plot where chemical fertilizer (F_3) was applied. On the other hand, lowest outer leaf width (7.06 cm) was obtained from the plot where no fertilizer (F_0) was applied.

Table 4.9 Effect of fertilizer and manure applications on outer leaf width (cm) of cauliflower plant at different DAP.

Treatments (fertilizer and manure applications)	Outer leaf width (cm)		
	30DAP	**60DAP**	**75DAP**
F_0	7.06 d	9.29 d	10.70 d
F_1	8.19 c	13.09 c	15.30 c
F_2	9.67 b	14.76 b	16.60 b
F_3	10.71 a	16.53 a	18.89 a
`CV (%)	4.38	7.04	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 DMRT) at 5% level of probability.

Here, F_0 = No fertilizer; F_1 = Cow dung; F_2= Poultry Manure and F_3= Chemical Fertilizer

At 60 DAP, the highest outer leaf width (16.53 cm) was recorded from the plot where chemical fertilizer (F_3) was applied. Whereas, lowest outer leaf width (9.29 cm) was obtained from the plot where no fertilizer (F_0) was applied. At 75 DAP, the highest outer leaf width (18.89 cm) was obtained from the plot where chemical fertilizer (F_3) was applied and lowest outer leaf width (10.70 cm) was obtained from the plot where no fertilizer (F_0) 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).

4.2.5 Yield of curd without leaf/plant (g)

The yield of curd without leaf as gram per plant was significantly different due to the applications of different fertilizer and manure (Table 4.10). The highest yield of curd without leaf (394.00 g) was recorded from the plot where chemical fertilizer (F_3) was applied. On the other hand, lower yield of curd without leaf (194.56 g) was obtained from the plot where no fertilizer (F_0) 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).

F_3 F_2 F_1 F_0

Plate 2: Curd of without leaf obtain from different fertilizer and manure applications of cauliflower after harvest

Table 4.10 Effect of fertilizer and manure applications on yield of cauliflower

Treatments (fertilizer and manure applications)	Curd weight without leaf/plant (g)	Yield of curd without leaf (kg/ha)
F_0	194.56 b	8716 b
F_1	201.00 b	9062 b
F_2	208.00 b	9382 b
F_3	394.00 a	17111 a
CV (%)	5.81	4.66

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 probability.

Here, F_0 = No fertilizer; F_1 = Cow dung; F_2= Poultry Manure and F_3= Chemical Fertilizer

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 4.10). The highest yield (17111 kg/ha) was recorded from the plot where chemical fertilizer (F_3) was applied which was followed by F_1 and F_2 treatments whereas the lowest yield (8716 kg/ha) was obtained from the plot where no fertilizer (F_0) 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.

4.2.11 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 4.2.

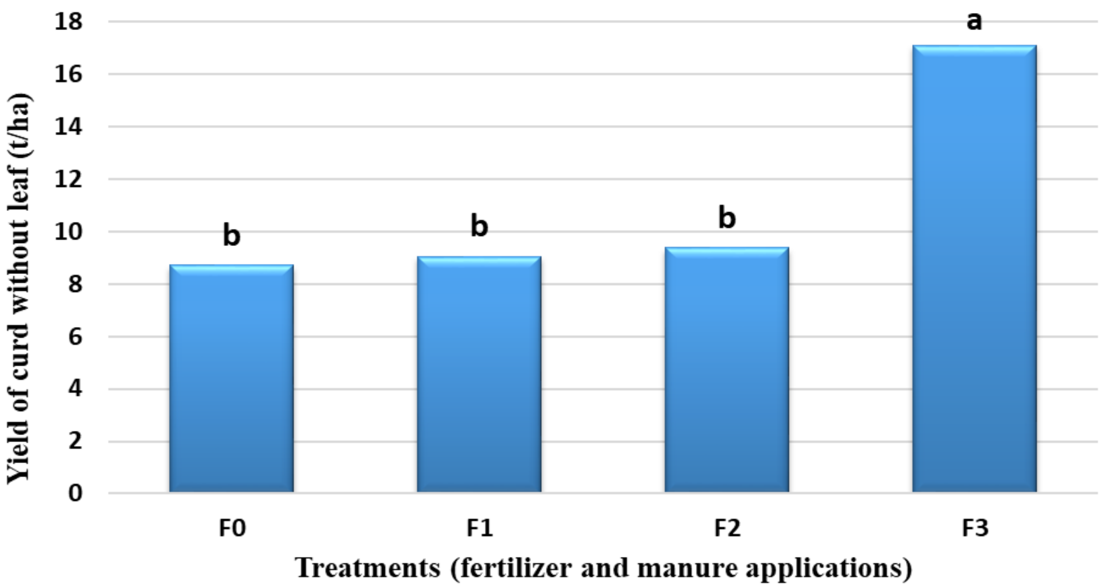


Figure 4.2: Effect of fertilizer and manure applications on yield of curd without leaf (t/ha)

Here, F_0 = No fertilizer; F_1 = Cow dung; F_2= Poultry Manure and F_3= Chemical Fertilizer

The maximum yield of curd without leaf (17.11 t/ha) was recorded from the plot where chemical fertilizer (F_3) was applied. On the other hand, lowest yield of curd without leaf (8.72 t/ha) was obtained from the plot where no fertilizer (F_0) 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 Interaction effect of spacing and fertilizer and manure applications on growth, yield contributing characters and yield of cauliflower under mango based agroforestry system.

4.3.1 Plant height (cm)

The interaction effect of spacing and fertilizer & manure applications on the plant height of cauliflower was found significantly different at different days after planting (Table 4.11).

Table 4.11 Interaction effect of spacing and fertilizer and manure applications on plant height of cauliflower at different DAP.

Treatments (Combination)	Plant height (cm)		
	30DAP	**60DAP**	**75DAP**
S_1F_0	19.75 cde	28.27 ef	40.17 de
S_1F_1	21.33 c	37.94 bcd	44.81 bcd
S_1F_2	26.50 b	37.30 bcd	47.77 ab
S_1F_3	36.50 a	49.88 a	52.93 a
S_2F_0	17.92 def	23.63 f	36.77 e
S_2F_1	19.07 cde	37.95 bcd	41.34 cde
S_2F_2	20.23 cd	38.17 bc	44.60 bcd
S_2F_3	24.33 b	42.50 ab	49.56 ab
S_3F_0	15.92 f	23.45 f	37.39 e
S_3F_1	17.19 ef	30.31 def	41.14 cde
S_3F_2	17.33 ef	33.19 cde	43.98 bcd
S_3F_3	19.55 cde	39.97 bc	47.00 abc
CV (%)	4.16	7.44	4.86

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 probability.

Here, S_1F_0 = Broader spacing + No fertilizer; S_1F_1 = Broader spacing + Cow-dung; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing + Chemical fertilizer; S_2F_0 = Intermediate spacing + No fertilizer; S_2F_1 = Intermediate spacing + Cow-dung; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing + Chemical fertilizer; S_3F_0 = Closer spacing + No fertilizer; S_3F_1 = Closer spacing + Cow-dung; S_3F_2 = Closer spacing + Poultry manure and S_3F_3 = Closer spacing + Chemical fertilizer

At 30 DAP, the highest plant height (36.50 cm) was obtained from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer). On the other hand, lowest plant height (15.92 cm) was obtained from treatments S_3F_0 (Broader spacing + No fertilizer). At 60 DAP, the highest plant height (49.88 cm) was recorded from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer). Whereas, lowest plant height (23.45 cm) was obtained from the treatment S_3F_0 (Closer spacing + No fertilizer) which is significantly followed by S_2F_0 (Intermediate spacing + no Fertilizer). At 75 DAP, the highest plant height (52.93 cm) was obtained from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer) which is significantly followed by S_2F_3 (Intermediate spacing + Chemical Fertilizer) and S_1F_2 (Broader spacing + Chemical Fertilizer) and lowest plant height (36.39 cm) was obtained from the treatment S_3F_0 (Closer spacing + No fertilizer) which is significantly followed by S_2F_0 (Intermediate 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 4.12). At 30 DAP, the highest number of leaves/plant (14.20) was obtained from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer). On the other hand, lowest number of leaves/plant (5.33) was obtained from the treatment S_3F_0 (Closer spacing + No fertilizer). At 60 DAP, the highest number of leaves/plant (16.93) was recorded from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer). Whereas, lowest number of leaves/plant (9.67) was obtained from the treatment S_3F_0 (Closer spacing + No fertilizer). At 75 DAP, the highest number of leaves/plant

(23.27) was obtained from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer) whereas lowest number of leaves/plant (13.33) was obtained from the treatment S_3F_0 (Closer spacing + No fertilizer) which was followed by the treatments S_2F_0 (Closer spacing + No fertilizer).

Table 4.12 Interaction effect of spacing and fertilizer and manure applications on number of leaves of cauliflower at different DAP.

Treatments (Combination)	Number of leaves/plant		
	30DAP	**60DAP**	**75DAP**
S_1F_0	6.70 fg	11.20 def	14.20 de
S_1F_1	7.33 ef	12.93 bcde	15.73 de
S_1F_2	8.67 de	14.37 bc	17.10 cd
S_1F_3	14.20 a	16.93 a	23.27 a
S_2F_0	7.67 ef	10.67 ef	13.57 e
S_2F_1	8.97 de	12.00 cdef	14.23 de
S_2F_2	9.77 cd	13.63 bcd	16.40 de
S_2F_3	12.50 ab	14.90 ab	21.03 ab
S_3F_0	5.33 g	9.67 f	13.33 e
S_3F_1	7.33 ef	10.50 ef	15.10 de
S_3F_2	8.93 de	12.00 cdef	16.37 de
S_3F_3	11.33 bc	13.33 bcd	19.83 bc
CV (%)	6.64	6.68	6.44

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 probability.

Here, S_1F_0 = Broader spacing + No fertilizer; S_1F_1 = Broader spacing + Cow-dung; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing + Chemical fertilizer; S_2F_0 = Intermediate spacing + No fertilizer; S_2F_1 = Intermediate spacing + Cow-dung; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing + Chemical fertilizer; S_3F_0 = Closer spacing + No fertilizer; S_3F_1 = Closer spacing + Cow-dung; S_3F_2 = Closer spacing + Poultry manure and S_3F_3 = Closer spacing + Chemical 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 4.13). At 30

DAP, the highest leaf length (26.03 cm) was obtained from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer). On the other hand, lowest outer leaf length (13.63 cm) was obtained from the treatment S_3F_0 (Closer spacing + No fertilizer) due to 60% light intensity and without fertilizer.

Table 4.13 Interaction effect of spacing and fertilizer and manure applications on outer leaf length (cm) of cauliflower at different DAP.

Treatments (Combination)	Outer leaf length (cm)		
	30DAP	**60DAP**	**75DAP**
S_1F_0	15.07 efg	32.73 def	34.78 ef
S_1F_1	20.57 bcd	36.60 bcd	38.87 cd
S_1F_2	23.40 abc	41.13 ab	43.15 ab
S_1F_3	26.03 a	42.30 a	45.47 a
S_2F_0	14.44 fg	30.97 ef	33.30 ef
S_2F_1	19.20 cde	34.94 cde	37.06 de
S_2F_2	22.23 abcd	38.90 abc	41.77 abc
S_2F_3	24.60 ab	41.03 ab	43.67 a
S_3F_0	13.63 g	29.50 f	31.97 f
S_3F_1	18.39 def	32.57 def	34.60 ef
S_3F_2	21.53 abcd	37.50 bc	39.60 bcd
S_3F_3	23.43 abc	39.94 ab	41.84 abc
CV (%)	7.70	4.21	3.52

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 probability.

Here, S_1F_0 = Broader spacing + No fertilizer; S_1F_1 = Broader spacing + Cow-dung; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing + Chemical fertilizer; S_2F_0 = Intermediate spacing + No fertilizer; S_2F_1 = Intermediate spacing + Cow-dung; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing + Chemical fertilizer; S_3F_0 = Closer spacing + No fertilizer; S_3F_1 = Closer spacing + Cow-dung; S_3F_2 = Closer spacing + Poultry manure and S_3F_3 = Closer spacing + Chemical fertilizer

At 60 DAP, the highest outer leaf length (42.30 cm) was recorded from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer). Whereas, lowest outer leaf length (29.50 cm) was obtained from treatment S_3F_0 (Closer spacing + No fertilizer). At 75 DAP, the highest outer leaf length (45.47 cm) was obtained from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer) which was significantly followed by S_2F_3 (Intermediate spacing + Chemical Fertilizer) and lowest leaf length (31.97 cm) was obtained from both treatments S_3F_0 (Intermediate spacing + No fertilizer).

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 4.14).

Table 4.14 Interaction effect of spacing and fertilizer and manure applications on outer leaf width (cm) of cauliflower at different DAP.

Treatments (Combination)	Outer leaf width (cm)		
	30DAP	**60DAP**	**75DAP**
S_1F_0	7.67 ef	10.13 ef	11.64 f
S_1F_1	8.77 de	14.13 bcd	16.20 cde
S_1F_2	10.00 bc	15.45 abc	17.35 bcd
S_1F_3	11.50 a	17.20 a	19.77 a
S_2F_0	6.90 f	9.37 ef	10.63 f
S_2F_1	8.10 e	13.60 cd	15.63 de
S_2F_2	9.68 bcd	14.77 abc	16.60 bcd
S_2F_3	10.60 ab	16.47 ab	18.73 ab
S_3F_0	6.60 f	8.37 f	9.83 f
S_3F_1	7.70 ef	11.53 de	14.07 e
S_3F_2	9.33 cd	14.07 bcd	15.83 cde
S_3F_3	10.03 bc	15.93 abc	18.18 abc
CV (%)	4.38	7.04	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 DMRT) at 5% level of probability.

Here, S_1F_0 = Broader spacing + No fertilizer; S_1F_1 = Broader spacing + Cow-dung; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing + Chemical fertilizer; S_2F_0 = Intermediate spacing + No fertilizer; S_2F_1 = Intermediate spacing + Cow-dung; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing + Chemical fertilizer; S_3F_0 = Closer spacing + No fertilizer; S_3F_1 = Closer spacing + Cow-dung; S_3F_2 = Closer spacing + Poultry manure and S_3F_3 = Closer spacing + Chemical fertilizer

At 30 DAP, the highest leaf width (11.50 cm) was obtained from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer). On the other hand, lowest outer leaf width (6.60 cm) was obtained from the treatment S_3F_0 (Closer spacing + No fertilizer) which is significantly followed by S_2F_0 (Intermediate spacing + No fertilizer). At 60 DAP, the highest outer leaf width (17.20 cm) was recorded from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer). Whereas, lowest outer leaf width (8.37 cm) was obtained from the treatment S_3F_0 (Closer spacing + No fertilizer). At 75 DAP, the highest outer leaf width (19.77 cm) was obtained from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer) and lowest leaf width (9.83 cm) was obtained from the treatment S_3F_0 (Closer spacing + No fertilizer) which was nearly similar with S_2F_0 (Intermediate spacing + No fertilizer).

4.3.6 Curd weight without 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 4.15).

Table 4.15 Interaction effect of spacing and fertilizer and manure applications on yield of cauliflower

Treatments (Combination)	Curd weight without leaf/plant (g)	Yield of curd without leaf (kg/ha)
S_1F_0	198.33 c	6518 e
S_1F_1	202.67 c	6740 de
S_1F_2	211.00 c	7037 de
S_1F_3	454.00 a	15037 b
S_2F_0	193.33 c	7703 de
S_2F_1	199.00 c	7926 de
S_2F_2	205.33 c	8222 d
S_2F_3	371.67 b	14815 b
S_3F_0	192.00 c	11926 c
S_3F_1	201.33 c	12518 c
S_3F_2	207.67 c	12888 c
S_3F_3	356.33 b	21481 a
CV (%)	5.81	4.66

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 probability.

Here, S_1F_0 = Broader spacing + No fertilizer; S_1F_1 = Broader spacing + Cow-dung; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing + Chemical fertilizer; S_2F_0 = Intermediate spacing + No fertilizer; S_2F_1 = Intermediate spacing + Cow-dung; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing + Chemical fertilizer; S_3F_0 = Closer spacing + No fertilizer; S_3F_1 = Closer spacing + Cow-dung; S_3F_2 = Closer spacing + Poultry manure and S_3F_3 = Closer spacing + Chemical fertilizer

The maximum yield (454.00 g) of curd without leaf was recorded in the plot where maintained broader spacing i.e. 75 x 50 cm with chemical fertilizer (S_1F_3). On the other hand, the minimum yield (192.00 g) of curd with leaf was recorded in the plot where maintained closer spacing i.e. 50 x 40 cm with no fertilizer (S_3F_0) closely followed by the plot where maintained closer spacing with no fertilizer (S_3F_0).

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 4.15). The highest yield (21481 kg/ha) was observed from the treatment S_3F_3 (Closer spacing + Chemical Fertilizer) due to large number of curd and applied systematic fertilizer. On the other hand, lowest yield (65.18 kg/ha) was observed from the treatment S_1F_0 (Broader spacing + No fertilizer) due to small number of plants in respect of other spacing treatment and without fertilizer.

4.3.11 Yield of curd without leaf (t/ha)

It was evident from the figure 4.3 that the yield of curd without leaf per hectare land was significantly varied. The maximum yield curd without leaf per hectare (21.48 t/ha) was recorded in the pot where maintained closer space that was 50 x 40 cm with chemical fertilizer (S_3F_3).

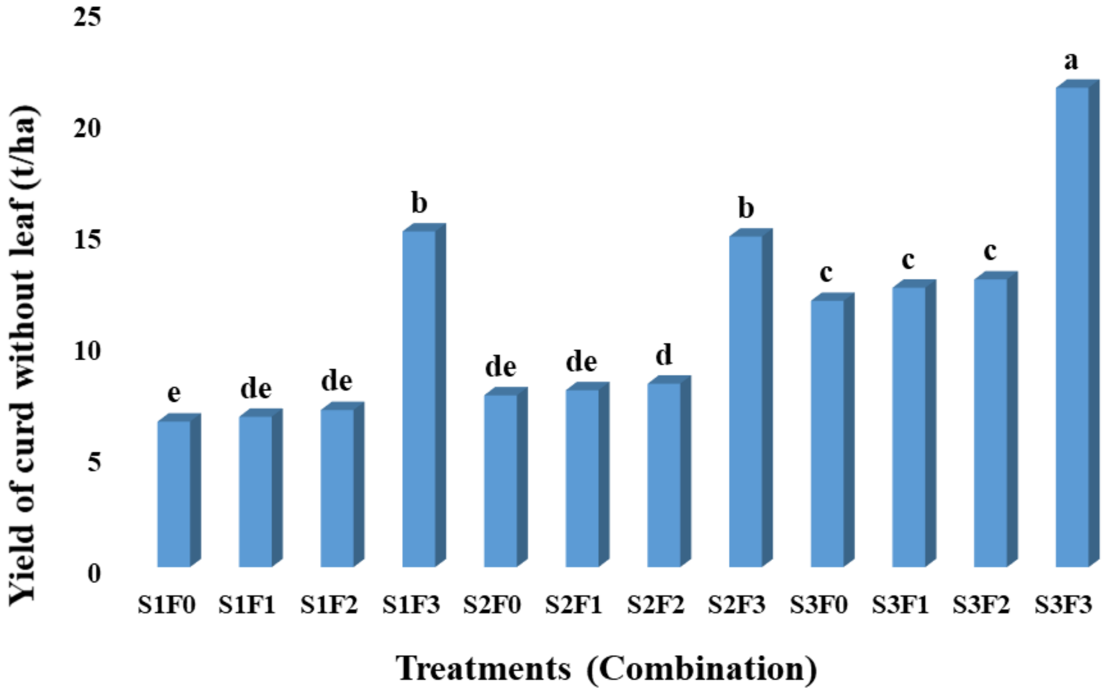


Figure 4.3 Interaction effect of different spacing and fertilizer and manure application on yield of curd without leaf (t/ha) of cauliflower

Here, S_1F_0 = Broader spacing + No fertilizer; S_1F_1 = Broader spacing + Cow-dung; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing + Chemical fertilizer; S_2F_0 = Intermediate spacing + No fertilizer; S_2F_1 = Intermediate spacing + Cow-dung; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing + Chemical fertilizer; S_3F_0 = Closer spacing + No fertilizer; S_3F_1 = Closer spacing + Cow-dung; S_3F_2 = Closer spacing + Poultry manure and S_3F_3 = Closer spacing + Chemical fertilizer

On the other hand, the minimum yield curd without leaf per hectare (6.52 t/ha) of curd without leaf was recorded in the plot where maintained broader space (75 x 50 cm) with no fertilizer (S_1F_0) 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 mango 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 4.16.

4.4.1 Total cost of production

The values in Table 4.16 indicate that the total cost of production was maximum (294052 Tk. /ha) in those plots where cauliflower was cultivated with using 50 x 40 cm i.e. Closer spacing + Cow dung (S_3F_1) whereas the minimum cost of production (199554 Tk. /ha) was recorded from those plots where 75 x 50 cm i.e. Broader spacing + No fertilizer (S_1F_0) 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 mango based production system of cauliflower. The values in Table 4.16 indicate that the highest value of gross return (1127680 Tk. /ha) was obtained in those plots where 50 x 40 cm i.e. Closer spacing + Chemical Fertilizer (S_3F_3) was applied. On the other hand, the lowest value of gross return (356360 Tk. /ha) was obtained in those plots where 75 x 50 cm i.e. Broader spacing + No fertilizer (S_1F_0) was applied.

4.4.3 Net return

Results presented in the Table 4.16 show that net return (837927 Tk. /ha) was comparatively higher in producing cauliflower under 50 x 40 cm i.e. Closer plant spacing with Chemical Fertilizer (S_3F_3). At the same time, the lowest net return (156806 Tk. /ha) was received from those plot where maintained 75 x 50 cm i.e. Broader plant spacing with no fertilizer (S_1F_0) was applied.

Table 4.16: Economics of cauliflower production under mango 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
	Mango	Cauliflower				
S_1F_0	45000	311360	356360	199554	156806	1.79
S_1F_1	45000	563880	608880	219797	389083	2.77
S_1F_2	45000	740240	785240	211198	574042	3.72
S_1F_3	45000	835840	880840	215498	665342	4.08
S_2F_0	45000	355000	400000	229772	170228	1.74
S_2F_1	45000	661400	706400	250065	456335	2.82
S_2F_2	45000	803480	848480	241466	607014	3.51
S_2F_3	45000	877680	922680	245766	676914	3.75
S_3F_0	45000	473680	518680	273808	244872	1.89
S_3F_1	45000	939520	984520	294052	690468	3.35
S_3F_2	45000	1013000	1058000	285453	772547	3.71
S_3F_3	45000	1082680	1127680	289753	837927	3.89

Note: Cauliflower 40 Tk kg^{-1}, Mango 3000 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 probability.

Here, S_1F_0 = Broader spacing + No fertilizer; S_1F_1 = Broader spacing + Cow-dung; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing + Chemical fertilizer; S_2F_0 = Intermediate spacing + No fertilizer; S_2F_1 = Intermediate spacing + Cow-dung; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing + Chemical fertilizer; S_3F_0 = Closer spacing + No fertilizer; S_3F_1 = Closer spacing + Cow-dung; S_3F_2 = Closer spacing + Poultry manure and S_3F_3 = Closer spacing + Chemical fertilizer

4.4.4 Benefit-cost ratio (BCR)

The values in Table 4.16 indicate that the highest benefit-cost ratio (4.08) was recorded from the treatment 75 x 50 cm i.e. broader spacing with Chemical Fertilizer (S_1F_3). On the other hand, the lowest benefit-cost ratio (1.74) was observed in those plots where cauliflower was grown under 60 x 45 cm i.e. Intermediate plant spacing with no fertilizer (S_2F_0) application.

CHAPTER V

SUMMARY CONCLUSIONAND RECOMMENDATIONS

5.1 Summary

A field experiment was carried out at Gangachara under Rangpur District, during October, 2019 to December, 2019 to evaluate the performance of cauliflower production under different plant spacing with different inorganic and organic fertilizer doses under mango based agroforestry system. The experiment was laid out in two factorial RCBD with 3 (three) replications. Factor A (Plant spacing) viz. S_1= 75 cm × 50 cm (Broader spacing); S_2= 60 cm × 45 cm (Intermediate spacing) and S_3= 50 cm × 40 cm (Closer spacing) and Factor B (Fertilizer and manure applications) viz. F_0 = No fertilizer; F_1 = Cow dung; F_2 = Poultry Manure and F_3 = Chemical Fertilizer. The total numbers of experimental plots were 36. The land of experimental plot was opened in the first week of October, 2019 with a power tiller and it was made ready for planting on 23 October. 30 days old healthy seedlings were uprooted from the nursery beds and were transplanted in the experimental plots during early morning on 24 October, 2019. Each plot there were 15, 18 and 28 plants in S_1, S_2 and S_3 treatments 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 weight without leaf/plant (g), yield of curd without leaf (kg/ha), yield of curd without leaf (t/ha). The tallest plant height (46.42 cm) at

75 DAT was recorded from the plot where broader spacing (75 cm × 50 cm) was present among plants and the lowest plant height (42.38 cm) was observed from the closer spacing (50 cm × 40 cm). Number of leaves/plant of cauliflower was significant due to different production system. However, highest number of leaves/plant (17.58) at 75 DAT was recorded from the broader spacing (75 cm × 50 cm) and the lowest number of leaves/plant (16.22) was observed from the closer plant spacing (50 cm × 40 cm). At 75 DAT, the highest outer leaf length (40.67 cm) was recorded from the Broader spacing (S_1) and the lowest outer leaf length (37.00 cm) was observed from the closer spacing (S_3). The maximum outer leaf width (16.24 cm) at 75 DAT was recorded from the Broader spacing (S_1) and the lowest outer leaf width (14.48 cm) was observed from the closer spacing (S_3). The highest weight of curd without leaf per plant (266.50 g) was observed from S_1 treatment that was broader spacing, while the lowest weight of curd per plant (239.33 g) was found from S_3 treatment that was closer spacing. The maximum curd yield without leaf (14703 kg/ha) was recorded from the closer spacing (S_3). One the other hand, the minimum curd yield without leaf (8833 kg/ha) was recorded from the broader spacing (S_1). Finally, curd yield without leaf as ton per hectare of cauliflower showed significantly significant differences due to different plant spacing. The maximum yield (14.70 t/ha) was recorded from the closer spacing (S_3) between whereas the minimum yield (8.83 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 weight without leaf/plant (g), yield of curd without leaf (kg/ha), yield of curd without leaf (t/ha). The tallest plant height (49.83 cm) at 75 DAT was recorded from Chemical fertilizer (F_3). On the other hand, the shortest plant height (38.11 cm) at 75 DAT was observed in those plots where no fertilizer was applied (F_0). The highest number of leaves/plant (21.38) was obtained from the plot where chemical fertilizer (F_3) was applied and lowest number of

leaves/plant (13.70) was obtained from the plot where no fertilizer (F_0) 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 (43.66 cm) at 75 DAT was recorded from Chemical fertilizer (F_3) and the shortest outer leaf length (33.35 cm) was observed in those plots where no fertilizer was applied (F_0). On the other hand, the highest outer leaf width (10.71 cm) was obtained from the plot where chemical fertilizer (F_3) was applied and lowest outer leaf width (7.06 cm) was obtained from the plot where no fertilizer (F_0) was applied. The highest yield of curd without leaf (394.00 g) was recorded from the plot where chemical fertilizer (F_3) was applied. On the other hand, lower yield of curd without leaf (194.56 g) was obtained from the plot where no fertilizer (F_0) was applied. And the highest yield (17111 kg/ha) was recorded from the plot where chemical fertilizer (F_3) was applied which was followed by F_1 and F_2 treatments whereas the lowest yield (8716 kg/ha) was obtained from the plot where no fertilizer (F_0) was applied. Finally, the yield of curd with and without leaf as ton per hectare land was significantly affected due to the applications of different fertilizer and manure. The maximum yield of curd without leaf (17.11 t/ha) was recorded from the plot where chemical fertilizer (F_3) was applied. On the other hand, lowest yield of curd without leaf (8.72 t/ha) was obtained from the plot where no fertilizer (F_0) was applied.

Again, interaction effect of spacing and fertilizer & manure applications of cauliflower had significant effect of all variables. However, the tallest plant height (52.93 cm) at 75 DAT was recorded from S_1F_3 (Broader spacing + Chemical Fertilizer). On the other hand, the shortest plant height (36.39 cm) at 75 DAT was observed in S_3F_0 (Closer spacing + No fertilizer). At 75 DAP, the highest number of leaves/plant (23.27) was obtained from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer) whereas lowest number of leaves/plant (13.33) was obtained from the treatment S_3F_0 (Closer spacing + No fertilizer). The longest outer leaf length (45.47 cm) at 75 DAT was obtained from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer). On the other hand, the shortest leaf length (31.97 cm) at 75 DAT, was observed from both treatments S_3F_0 (Closer spacing + No fertilizer). The highest outer leaf width (19.77 cm) at 75 DAT was obtained from the treatment S_1F_3 (Broader spacing + Chemical Fertilizer) and lowest leaf width (9.83 cm) was obtained from the treatment S_3F_0 (Closer spacing + No fertilizer) which was nearly similar with S_2F_0 (Intermediate spacing + No fertilizer).

Yield of curd with leaf/plant as germ and yield of curd without leaf as kilogram per hectare land were found significantly varied due to interaction effect of spacing and fertilizer & manure applications. The maximum yield (454.00 g) of curd without leaf was recorded in the plot where maintained broader spacing (75 cm × 50 cm) with chemical fertilizer (S_1F_3). On the other hand, the minimum yield (192.00 g) of curd with leaf was recorded in the plot where maintained closer spacing (50 cm × 40 cm) with no fertilizer (S_3F_0) closely followed by the plot where maintained closer spacing with no fertilizer (S_3F_0). And the highest yield of curd without leaf as kilogram per hector land (21481 kg/ha) was observed from the treatment S_3F_3 (Closer spacing + Chemical Fertilizer) due to large number of curd and applied systematic fertilizer. On the other hand, lowest yield (65.18 kg/ha) was observed from the treatment S_1F_0 (Broader spacing + No fertilizer). Finally, the yield of curd without leaf per hectare land was significantly varied. The maximum yield curd without leaf per hectare (21.48 t/ha) was recorded in the pot where maintained closer space that was (50 cm × 40 cm) with chemical fertilizer (S_3F_3). On the other hand, the minimum yield curd without leaf per hectare (6.52 t/ha) of curd without leaf was recorded in the plot where maintained broader spacing (75 cm × 50 cm) with no fertilizer (S_1F_0).

In case of economic analysis, the total cost of production was maximum (294052 Tk. /ha) in those plots where cauliflower was cultivated with using (50 cm × 40 cm) i.e. Closer spacing + Cow dung (S_3F_1) whereas the minimum cost of production (199554 Tk. /ha) was recorded from those plots where (75 cm × 50 cm) i.e. Broader spacing + No fertilizer (S_1F_0) was applied. The highest value of gross return (1127680 Tk. /ha) was obtained in those plots where (50 cm × 40 cm) i.e. Closer spacing + Chemical Fertilizer (S_3F_3) was applied. On the other hand, the lowest value of gross return (356360 Tk. /ha) was obtained in those plots where (75 cm × 50 cm) i.e. Broader spacing + No fertilizer (S_1F_0) was applied. Net return (837927 Tk. /ha) was comparatively higher in producing cauliflower under (50 cm × 40 cm) i.e. Closer plant spacing with Chemical Fertilizer (S_3F_3). At the same time, the lowest net return (156806 Tk. /ha) was received from those plot where maintained (75 cm × 50 cm) i.e. Broader plant spacing with no fertilizer (S_1F_0) was applied. The highest benefit-cost ratio (4.08) was recorded from the treatment (75 cm × 50 cm) i.e. broader spacing + Chemical Fertilizer (S_1F_3). On the other hand, the lowest benefit-cost ratio (1.74) was observed in those plots where cauliflower was grown under 60 x 45 cm i.e. Intermediate plant spacing with no fertilizer (S_2F_0) application.

5.2 Conclusion

From the findings of this study, it may be concluded that among the three plant spacing's, closer spacing (50 cm × 40 cm) gave the best performance in terms of total cauliflower curd yield without leaf at the floor of a young mango orchard in the Charland area of the Tista river basin. Again, among the four fertilizer and manure application packages, completely chemical fertilizer gave the best yield. Moreover, in case of economic return, cauliflower cultivation at the floor of mango tree with broader planting space and the application of full chemical fertilizer gave maximum BCR. However, cauliflower production using poultry manure with closer planting spacing (50 cm × 40 cm) under mango based agroforestry system gave only 1.66 % yield reduction as compare to that system where chemical fertilizer was applied. So, if we consider the benefit of organic manure applications in terms of environmental benefit, soil health and safe cauliflower production then cultivation of cauliflower at the floor of mango orchard with poultry manure applications may be a promising orchard based agroforestry system in the Charland of the northern part of Bangladesh.

5.3 Recommendations

1. The cauliflower can be grown at the floor of a young one year mango orchard successfully using organic manure in the Charland area of Bangladesh.
2. The present study opened the new avenue for further investigation with the combination of woody trees and cauliflower production simultaneously using organic manure in the unfertile Charland.
3. Cauliflower closer planting systems with organic fertilizer (Poultry manure) are economically viable under mango based agroforestry system. So, it can be suggested to the farmers to practice it extensively.
4. This study should be repeated in different Charland locations of Bangladesh like Padma char, Meghna char, Jamuna char etc. using different age mango orchard to obtained valid recommendation.

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APPENDICES

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

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

Source: Soil Resources Development Institute, Rangpur (2019)

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

Months	* Air Temperature (^0C)			* Average Rainfall (mm)	* Relative Humidity (%)
	Maximum	Minimum	Average		
August 2019	34.6	11.30	22.95	12.6`	78
September 2019	26.5	16	21.25	28.5	77
October 2019	18	10.5	14.25	14.6	86
November 2019	14	5.8	9.9	12.5	90
December 2019	14	-1	6,5.	14.4	85

Note * Monthly average

Source: Bangladesh Meteorological Station, Rangpur

Appendix III. Factorial ANOVA tables.

Source	DF	SS	MS	F-Value	Pr(>F)
		1.Plant height (cm) at 30 DAT			
Replication	2	1.58	0.788		
Factor A	2	451.05	225.525	286.71	0.0000
Factor B	3	415.97	138.657	176.28	0.0000
A×B	6	188.79	31.465	40.00	0.0000
Error	22	17.30	0.787		
Total	35	1074.69			
		2.Plant height (cm) at 60 DAT			
Replication	2	64.81	32.404		
Factor A	2	264.96	132.478	19.30	0.0000
Factor B	3	1640.34	546.779	79.68	0.0000
A×B	6	98.00	16.334	2.38	0.0634
Error	22	150.97	6.862		
Total	35	2219.08			
		3.Plant height (cm) at 75 DAT			
Replication	2	50.214	25.107		
Factor A	2	112.211	56.105	12.31	0.0003
Factor B	3	659.106	219.702	48.22	0.0000
A×B	6	10.857	1.809	0.40	0.8728
Error	22	100.230	4.556		
Total	35	932.618			
		4. Number of leaves/plant at 30 DAT			
Replication	2	7.677	3.8386		
Factor A	2	13.834	6.9169	19.11	0.0000
Factor B	3	186.359	62.1196	171.63	0.0000
A×B	6	14.193	2.3655	6.54	0.0005
Error	22	7.963	0.3619		
Total	35	230.026			
		5. Number of leaves/plant at 60 DAT			
Replication	2	3.067	1.5336		
Factor A	2	37.271	18.6353	25.95	0.0000
Factor B	3	103.762	34.5874	48.16	0.0000
A×B	6	3.763	0.6271	0.87	0.5301
Error	22	15.799	0.7182		
Total	35	163.662			

Source	DF	SS	MS	F-Value	Pr(>F)
6. Number of leaves/plant at 75 DAT					
Replication	2	4.642	2.321		
Factor A	2	14.407	7.204	6.25	0.0071
Factor B	3	303.310	101.103	87.67	0.0000
A×B	6	9.446	1.574	1.37	0.2720
Error	22	25.371	1.153		
Total	35	357.176			
7. Outer leaf length (cm) at 30 DAT					
Replication	2	47.554	23.777		
Factor A	2	24.635	12.318	5.08	0.0153
Factor B	3	535.506	178.502	73.62	0.0000
A×B	6	1.245	0.208	0.09	0.9971
Error	22	53.341	2.425		
Total	35	662.283			
8. Outer leaf length (cm) at 60 DAT					
Replication	2	4.753	2.377		
Factor A	2	65.979	32.990	13.94	0.0001
Factor B	3	549.014	183.005	77.32	0.0000
A×B	6	2.922	0.487	0.21	0.9713
Error	22	52.071	2.367		
Total	35	674.740			
9. Outer leaf length (cm) at 75 DAT					
Replication	2	12.485	6.243		
Factor A	2	76.473	38.237	20.50	0.0000
Factor B	3	580.096	193.365	103.66	0.0000
A×B	6	1.912	0.319	0.17	0.9820
Error	22	41.037	1.865		
Total	35	712.005			
10. Outer leaf width (cm) at 30 DAT					
Replication	2	1.9676	0.9838		
Factor A	2	6.9601	3.4801	22.85	0.0000
Factor B	3	70.0552	23.3517	153.32	0.0000
A×B	6	0.5471	0.0912	0.60	0.7283
Error	22	3.3507	0.1523		
Total	35	82.8808			

Source	DF	SS	MS	F-Value	Pr(>F)
11. Outer leaf width (cm) at 60 DAT					
Replication	2	0.161	0.0807		
Factor A	2	18.725	9.3624	10.50	0.0006
Factor B	3	258.024	86.0081	96.47	0.0000
A×B	6	2.566	0.4276	0.48	0.8162
Error	22	19.613	0.8915		
Total	35	299.090			
12. Outer leaf width (cm) at 75 DAT					
Replication	2	1.543	0.772		
Factor A	2	18.581	9.290	14.73	0.0001
Factor B	3	321.447	107.149	169.89	0.0000
A×B	6	0.957	0.160	0.25	0.9528
Error	22	13.875	0.631		
Total	35	356.404			
13. Curd weight without leaf/plant (g)					
Replication	2	1022	510.8		
Factor A	2	5324	2662.1	12.70	0.0002
Factor B	3	251762	83920.8	400.34	0.0000
A×B	6	11365	1894.1	9.04	0.0000
Error	22	4612	209.6		
Total	35	274085			
14. Yield of curd without leaf (kg/ha)					
Replication	2	997397	498699		
Factor A	2	2.421E+08	1.211E+08	455.25	0.0000
Factor B	3	4.403E+08	1.468E+08	551.88	0.0000
A×B	6	5692864	948811	3.57	0.0127
Error	22	5849980	265908		
Total	35	6.949E+08			
15. Yield of curd without leaf (t/ha)					
Replication	2	0.995	0.498		
Factor A	2	242.077	121.039	456.52	0.0000
Factor B	3	440.103	146.701	553.31	0.0000
A×B	6	5.694	0.949	3.58	0.0126
Error	22	5.833	0.265		
Total	35	694.702			

Appendix- IV: Production cost analysis of cauliflower cultivation under mango based agroforestry systems

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)											
	Mango tree	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)		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)	
S_1F_0	25000	26000	42000	26666	0	8000	3260	6850	68626	113402	155402	12432	24000	7720	199554
S_1F_1	25000	26000	42000	26666	10860	8000	3260	6850	75681	131317	173317	13865	24000	8615	219797
S_1F_2	25000	26000	42000	26666	7055	8000	3260	6850	71876	123707	165707	13256	24000	8235	211198
S_1F_3	25000	26000	42000	26666	3250	8000	3260	6850	79486	127512	169512	13561	24000	8425	215498
S_2F_0	25000	32000	48000	37037	0	8000	3260	6850	78997	134144	182144	14571	24000	9057	229772
S_2F_1	25000	32000	48000	37037	10860	8000	3260	6850	86052	152059	200059	16004	24000	10002	250065
S_2F_2	25000	32000	48000	37037	7055	8000	3260	6850	82247	144449	192449	15395	24000	9622	241466
S_2F_3	25000	32000	48000	37037	3250	8000	3260	6850	89857	148254	196254	15700	24000	9812	245766
S_3F_0	25000	45000	61000	50000	0	8000	3260	6850	91960	160070	221070	17685	24000	11053	273808
S_3F_1	25000	45000	61000	50000	10860	8000	3260	6850	99015	177985	238985	19118	24000	11949	294052
S_3F_2	25000	45000	61000	50000	7055	8000	3260	6850	95210	170375	231375	18510	24000	11568	285453
S_3F_3	25000	45000	61000	50000	3250	8000	3260	6850	102820	174180	235180	18814	24000	11759	289753

Here, S_1F_0 = Broader spacing + No fertilizer; S_1F_1 = Broader spacing + Cow-dung; S_1F_2 = Broader spacing + Poultry manure; S_1F_3 = Broader spacing + Chemical fertilizer; S_2F_0 = Intermediate spacing + No fertilizer; S_2F_1 = Intermediate spacing + Cow-dung; S_2F_2 = Intermediate spacing + Poultry manure; S_2F_3 = Intermediate spacing + Chemical fertilizer; S_3F_0 = Closer spacing + No fertilizer; S_3F_1 = Closer spacing + Cow-dung; S_3F_2 = Closer spacing + Poultry manure and S_3F_3 = Closer spacing + Chemical fertilizer

Appendix- V: Some plates of the experiment

Land preparation

Planting time


Field investigation time


Full field structure