PERFORMANCE OF SUNFLOWER UNDER MORINGA BASED AGROFORESTRY SYSTEM

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CERTIFICATE

*This is to certify that thesis entitled, "**PERFORMANCE OF SUNFLOWER UNDER MORINGA BASED AGROFORESTRY SYSTEM**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE in AGROFORESTRY AND ENVIRRONMENTAL SCIENCE**, embodies the result of a piece of bona-fide research work carried out by **SABRENA AJMERY ZINNIA,** Registration no.**14-05871** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:

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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

The experiment was conducted to performance of sunflower under moringa based agroforestry system as well as to find out the best tree crop interactions in the Agroforestry Field under the Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka, during the period from December 2020 to March 2021. Four treatments, D_1=50 cm distance from the tree base, D_2=100 cm distance from the tree base, D_3=150 cm distance from the tree base, D_4=Open field referred to as control were used in Randomized Complete Block Design (RCBD) with four replications. The observations pertaining to growth and yield attributes of moringa recorded during the course of investigation were statistically analyzed and significance of results was verified. All the growth and yield contributing characters like plant height, leaf length, leaf breadth, number of internode plant^{-1}, internode length, fresh weight of shoot (g), fresh weight of root (g), dry weight of shoot (g), dry weight of root (g), number of seed plant^{-1}, weight of seed plant^{-1}(g), and yield per hectare varied significantly due to distance. Among the intercropping patterns, the highest sunflower equivalent yields 3.17 t/ha and 2.97 t/ha were obtained with open field referred to as control followed by 150 cm distance from the tree base. The benefit cost ratio was different in all the treatments. The highest benefit cost ratio (4.27) was found from the treatment 150 cm distance from the tree base. The lowest benefit cost ratio (1.15) was found from control.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF APPENDICES

LIST OF PLATE

LIST OF ABBREVIATIONS

Abbreviations		Full meanings
%	=	Percent
^0C	=	Degree Celsius
AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
CV%	=	Percentage of Coefficient of Variance
DAT	=	Days after Transplanting
et al.,	=	And others
FAO	=	Food and Agricultural Organization
g	=	gram (s)
ha^{-1}	=	Per hectare
kg	=	Kilogram
LSD	=	Least Significant Difference
Max	=	Maximum
Min	=	Minimum
MOP	=	Muirate of Potash
N	=	Nitrogen
NPK	=	Nitrogen, Phosphorus and Potassium
NS	=	Not significant
RCBD	=	Randomized Complete Block Design
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
TSP	=	Triple Super Phosphate

CHAPTER I

INTRODUCTION

Bangladesh is one of the most vulnerable countries to climatic catastrophes due to its geographical position near to the Bay of Bengal. (Abdullah and Rahman, 2015; Naser *et al.,* 2019) having a population of 163 million, which is predicted to increase 192.6 million by 2050 (BBS, 2018; UN, 2019). Agriculture is the key factor of the country's economy but it is extremely impeded by climate and human-induced hazards (Miah *et al.,* 2016; Rahman *et al.,* 2018). Despite these hazards, Bangladesh has witnessed substantial improvement in agriculture over the past decades, although almost 24.2 million people remain in food-scarce situation (Hassan *et al.,* 2019; Molla, 2019). Contrarily, rapid industrialization and urbanization provoke transforming of 69,000 hectares of agricultural lands to non-agricultural practices annually, and the rate is gradually increasing thereby threatening the upcoming cultivable land in the country (Rahman *et al.,* 2018; Muhsin *et al.,* 2018; Khan, 2019). Additionally, cereal crops including rice occupy more than 75% of the country's total arable land (Ahmad, 2017). Various challenges such as climate uncertainty, improper management, land scarcity, lack of quality planting materials etc. are found in farming systems. Consequently, sustainable agricultural practices need to be developed to overwhelm the aforementioned restraints in crop production.

Agroforestry is a dynamic ecologically based natural resources management system that through the integration of sustains production for increased social, economic and environmental benefits for land users at all levels (Hanif *et al*., 2010). Agroforestry practices offer practical ways of applying various specialized knowledge and skills to the development of rural production systems. Agroforestry among other benefits strive to optimize the use of land for agricultural production on a sustainable basis and at the same time meeting other needs from forestry. 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 life. Indeed the advantage of agroforestry is all encompassing is a sustainable system.

In Bangladesh, Moringa is a common tree growing mainly in homestead areas. Moringa is a multipurpose vegetable tree with a variety of potential uses, of which the nutritional and medicinal properties are initially considered the most interesting. In total there are 13 species in the genus Moringa, belonging to the family *Moringaceae*, of which *Moringa oleifera*, commonly referred to as the drumstick tree (describing the shape of its pods) or horseradish tree (the roots can be used as a substitute for horseradish), is the most commonly cultivated species. This multipurpose tree is characterized by high biomass yield and tolerance to unfavorable environmental conditions (Foidl *et al*., 2001). Moringa is said to provide 7 times more vitamin C than oranges, 10 times more vitamin A than carrots, 17 times more calcium than milk, 9 times more protein than yoghurt, 15 times more potassium than bananas and 25 times more iron than spinach. Among these Moringa has gained a lot of attraction in the scientific name *M. oleifera* L. is widely distributed in the Pacific region, sub- tropical regions. Moringa has also been reported to significantly improve soil fertility if used as a green manure (Phiri, 2010). It has been reported that improvements in crop growth and yield results from the influence of zeatin which is a plant growth hormone from the Cytokinins group (Phiri and Mbewe, 2010). Moringa is increasingly becoming popular among communities in the world for uses such as a food supplement, as a weaning food in children and for medicinal purposes (Makkar and Becker, 1996).

Sunflower is one of the important oilseed crops grown throughout the world as a source of premium oil and dietary fiber that significantly contributes to human health (Khan *et al*., 2015). Sunflower is a short season plant classified into family *Asteraceae* and genus *Helianthus* with more than 70 species known worldwide. Sunflower has been recognized as a major source of high-quality edible oil importantly used for culinary purposes (Pal *et al*., 2015). Due to the continuous increase in the human population, the demand for edible sunflower seeds, oil, and by-products has also increased, and to meet the demand, there is a need to intensify efforts to expand sunflower output (Taher *et al*., 2017). Although, the use of sunflower meals in the human diet is limited due to the presence of anti-nutrients (saponins, protease inhibitor, and arginase inhibitor), insoluble fiber and presence of a trace of residue solvents in the meal after extraction (Grasso *et al*., 2019).

Conversely, adequate processing of sunflower seeds has caused a reduction in its anti-nutritional contents, thus making it importantly safe for human consumption (Adesina, 2018).As a promising protein source, sunflower seeds in food preparation can be made as a substitute to soybean, where its production is limited. The supply of essential micronutrients like potassium increases crop productivity as well as crop tolerance to drought and environmental stress (Enebe and Babalola, 2018). Growing and survival of sunflower plants under different soil conditions make them compete favorably as an alternative to other cereal grains such as maize, sorghum, or cowpea.

In comparison to other cereal grains, sunflowers grow maximally under high temperatures and drought. Moisture conservation due to long, deep taproot system enables the plant to recover rapidly from moisture loss, and for survival under stress conditions (Hussain *et al*., 2018). Better still, the current awareness about the continuous use of synthetic pharmaceuticals in phytomedicines and extraction natural functional oil from plants as an alternative could help in proffering curable solutions to various diseases affecting humans (Maqsood *et al*., 2020). During the year 2019-2020, sunflower occupied an area of 3330.47 acres of land of Bangladesh with a total production of 1448.70 metric ton (BBS, 2020). But this production of sunflower is not sufficient to meet up the demand of our huge population. Due to limitation of land in Bangladesh, it is very hard to expand the cultivable land area under sunflower cultivation.

Bangladesh has no scope to expand forest and agricultural areas. So, combined production system integrating trees and crops together need to be developed. In these circumstances, the practice of agroforestry is an authentic solution. But management has always been extremely poor in agroforestry system. Selection of plants, planting techniques, and also their management in most cases is poorly done. A few crops has been intercropped in association of Moringa (Kumar *et al*., 2017). To best of our knowledge sunflower has not been cultivated as understory crop in Moringa based agroforestry system.

Therefore in this study we are going to use sunflower in Moringa based agroforestry system as understory crop. Hence this study has been undertaken with the following objectives:

i To know about the vegetative growth stage of sunflower at different distances from Moringa tree base,

ii To determine the yield performance of sunflower at different distances from Moringa tree base and

iii To determine the cost benefit ratio of the Moringa-Sunflower agroforestry system.

CHAPTER II

REVIEW OF LITERATURE

The aim of this chapter is to describe the review of the past research conducted in line of the major focus of the study. The literature review chapter consists of three sections. The first section illustrates the role and importance of agriculture. Literatures related of this thesis which were collected through reviewing of journals, thesis, internet browsing, reports, newspapers, periodicals and other form of publications are presented in this chapter under the following headings

Bangladesh has a land area of only 14.39 million hectares, but due to the over increasing population, per capita land area is decreasing at an average rate of 0.005 ha/cap/year since 1989. Our forest resource is also shrinking with increasing population pressure. To maintain the environmental equilibrium and rate of socio-economic development at least 25% area of a country should be covered with forest. Whereas in Bangladesh the actual tree coverage is only 9.4% which is decreasing at an alarming rate (BBS, 2010). Out of 64 districts, 28 districts have no public forest land. So, the effective area of forest (9.4%) in Bangladesh is neither in a position to fulfill the requirements of the peoples demand for fuel, fodder and timber nor to stabilize the climatic condition. Under these alarming situations, agricultural production as well as forest resources must be increased by using sustainable farming system. Recently, agroforestry farming system have already been appeared as a sustainable technique to overcome therefore mention challenges. Agroforestry is the combination of forestry and agriculture with attributes of productivity, sustainability and adoptability.

Once heavily forested Bangladesh is now almost devoid of forest vegetation, resulting from high population pressure, extensive urbanization, and industrialization. Forest cover was reduced from 15% in 1971 to 9% in 1996 (FAO, 2000), and created a huge gap between demand and supply of forest products and services. Restoring tree cover on forestlands is not possible because the boundary of country's remaining forests has already been demarcated. Thus, needs for forest products are fulfilled by non-forest sources. Agroforestry farming system deliberately integrates trees into crop, and mixed agricultural systems at nested scales where trees contribute to improving food and nutrition security, livelihoods and the delivery of multiple ecosystem services simultaneously in a sustainable way.

2.1 Characteristics of tree species in Agroforestry

In Agroforestry systems, people plants trees for fruit, fodder, fuel, shade, conservation purpose and various other purposes. Since large varieties of tree are available which could grow in different edaphic climatic condition, People can select trees of their choice very easily. While selecting tree species for agroforestry systems, the following desirable characteristics should be taken into consideration (Swieter *et al*., 2021). Though all desirable characters are not found in a single species, but their multiple uses are taken care of

- Tree species selected should not interfere with soil moisture.
- Tree species selected for agroforestry have very less water requirement.
- Should not compete with main agricultural crops for water.
- Tree species must be deep tap rooted so that they can draw water from deep.
- Tree species should not compete for plant nutrients.
- Tree species should not utilize more plant nutrients.
- They should help in building soil fertility.
- Tree species should not compete for sunlight.
- Tree species can withstand pruning operation if it possess dense canopy.
- Tree species should have high survival rate and easy establishment.
- Trees species should have high survival percentage.
- Tree species should have fast growing habit and easy management.
- Tree species should have wider adaptability.
- Tree species should have high palatability as a fodder.
- Tree species should have shelter conferring and soil stabilization attributes.
- Tree species should have capability to withstand management practices.
- Tree species should have nutrient cycling and nitrogen fixation attributes.
- Tree species should be free from chemical exudations.
- Tree species should have easily decomposable leaves.

- ❖ Tree species should have their multiple uses.
- ❖ The tree should yield more than one of the main produce like Fuel wood, leaf fodder, edible fruit, edible flower and fiber.
- ❖ Tree species should have high yield potential.

Hegde and Mac Dicken (1990) pointed out some criteria of suitable trees that should be planted under the agroforestry system

- Non-interference with arable crops
- Easy establishment
- Fast growth and short gestation period
- No allelopathic effects on arable crops
- Atmospheric nitrogen fixation ability
- Easy decomposition of liter
- High returns and multiple uses
- Ability to withstand frequent lopping
- Employment generation ability

As it is not possible to select having all the above mentioned criteria, therefore researcher should select suitable species having most of the characters and adaptive to local environmental conditions (Swieter *et al*., 2021).

2.1. Importance of Moringa in Agroforestry

Moringa is a multipurpose vegetable tree with a variety of potential uses, of which the nutritional and medicinal properties are initially considered the most interesting. The tree ranges in height from 5 to 10 m (Morton, 1991). It was found wild and cultivated throughout the plains, especially in hedges and in house yards, thrives best under the tropical insular climate, and is plentiful near the sandy beds of rivers and streams (Qaiser, 1973). Moringa trees do not need much water and can germinate and grow without irrigation if sown during the rainy season. The roots will develop in about twenty days and allows young plants to tolerate drought (Saint Sauveur and Broin, 2010; Fugli and Sreeja, 2011).

The Moringa tree has many potential uses, and as a result a great deal of research and development has been done. It provides different foods and other profitable uses with minimum growing and harvesting input. The tree can also be used to combat deforestation and to beautify streets and informal settlements. The leaves, fruit, flowers and immature pods are used as highly nutritive vegetable in many countries, particularly in India, Pakistan, Philippines, Hawaii and many parts of Africa (Anwar and Bhanger, 2003; Anwar *et al*., 2007).

Trees on farms also facilitate more nutrient cycling than monoculture systems, and enrich the soil with nutrients and organic matter, while improving soil structural properties. Hence, through water tapping and prevention of nutrient leaching, tree help recover nutrients, conserve soil moisture and improve soil organic matter (Sanou *et al*., 2011). Moringa trees do not need much water and can germinate and grow without irrigation if sown during the rainy season. The roots will develop in about twenty days and allows young plants to endure drought (Saint Sauveur and Broin, 2010; Fugli and Sreeja, 2011). Adisakwattana and Chanathong (2011) discovered tuberous roots of *M. oleifera*, which have the ability to storage of water and sugar during long drought periods. Moringa leaf contributes organic matter to the soil, improve soil structural properties and Moringa root conserve soil moisture.

Moringa leaves contain more beta-carotene than carrots, more protein than peas, more vitamin C than oranges, more calcium than milk, more potassium than bananas, and more iron than spinach. Crushed seed of *M. oleifera* has been shown to be an effective natural coagulant for the treatment of river waters exhibiting relatively high levels of suspended solids (Fuglie, 2001). Moringa responds well to pruning and the leaves intercept less light than other agroforestry species (Immanuel and Ganapathy, 2010). Regular pruning and leaf harvesting, therefore, would likely result in sufficient light below the canopy to allow for intercropping. Palada *et al*., 2008 studied the competitive effects of Moringa intercropped with medicinal plants and culinary herbs and found that Moringa, with its rapid growth, was competitive against many herbaceous plants, however, lemon grass (*Cymbopogon citratus*) and basil (*Ocimum basilicum*) could be grown with Moringa during the early establishment phase.

Data gathered from the Bangladesh Bureau of Statistics (BBS, 2014) shows that *M. oleifera* is mainly cultivated in gardens and homesteads. Commercially cultivated Moringa trees account for an estimated annual harvest of 10 tons of pods, while another estimated 2860 metric tons of Moringa pods are being harvested in homestead gardens. The Bangladesh Bureau of Statistics (BBS) does not have estimations for the cumulative area of Moringa that is grown in homestead gardens. The data of the BBS confirm the main findings of the farmer survey. Commercial cultivation of *M. oleifera* is rare in Southern Bangladesh.

In the Barisal and Patuakhali Regions Moringa is not cultivated at all on agricultural lands. The average harvest per tree is higher in Jessore than in Khulna. However, the data are not exhaustive and conclusive, e.g. there were no data available for the estimated area under cultivation in Jessore nor are there data available for homestead gardening (BBS, 2014).

2.2 Moringa cultivation

Moringa tolerates a wide range of environmental conditions. It grows best between 25 to 35^0C, but can tolerate up to 48^0C in the shade and survive a light frost (Palada and Change, 2003). It is a drought-tolerant tree that grows well in areas receiving annual rainfall amounts that range from 250 to 1500 mm, prefers a well-drained sandy loam or loam soil, also tolerates clay, but cannot survive under prolonged flooding and poor drainage (Palada and Change, 2003). Soil pH should range between 5.0−9.0. Altitudes below 600 m are best for Moringa, but this adaptable tree can grow in altitudes up to 1200 m in the tropics.

The germination rate of Moringa seeds is high (Saint Sauveur and Broin, 2010). Furthermore, Moringa seeds have no dormancy period, so they can be planted as soon as they are mature. Seeds may be sown in seedbeds (for transplanting) or directly in the main field. Moringa seeds germinate 5 to 12 days after seeding (DAS) (Saint Sauveur and Broin, 2010). For intensive (commercial) leaf production the spacing of the plants should be 15×15 cm or 20×10 cm, with conveniently spaced alleys to facilitate plantation management and harvests (Saint Sauveur and Broin, 2010). This intensive system requires careful crop management. For semi-intensive leaf production plants are spaced 50 cm to 1 m apart. This is more appropriate for small-scale farmers and gives good results with less maintenance.

For fruit or seed production the spacing must be at least 2.5×2.5 meter in order to achieve good yields. For intensive production the land should be prepared by means of ploughing and harrowing to a maximum depth of 30 cm (Saint Sauveur and Broin, 2010). In case of semi-intensive production, it is better to dig planting pits (30-50 cm deep, 20-40 cm wide), which ensures good root system penetration and retains soil moisture, without causing too much land erosion (Fugli and Sreeja, 2011).

Compost or manure can be mixed with the fresh topsoil around the pit and used to fill the pit. Moringa trees flower and fruit annually. During its first year, a Moringa tree will grow up to five meters in height and produce flowers and fruits; when left alone, the tree can eventually reach 12 meters in height with a trunk 30 cm wide (Fugli and Sreeja, 2011). If the trees are left to grow naturally yields will be low.

Pinching the terminal bud on the central stem is necessary when the tree attains a height of 50 cm to 1 m (Saint Sauveur and Broin, 2010). This will trigger the growth of lateral branches which need to be pinched too. Regular pinching will encourage the tree to become bushy and produce many leafs and pods within easy reach and helps the tree develop a strong production frame for maximizing the yield (Fugli and Sreeja, 2011). In fruit and seed producing farms, pruning induces more fruits, as well as larger fruits (Saint Sauveur and Broin, 2010).

The roots of Moringa develop in about twenty days and allows young plants to endure drought (Saint Sauveur and Broin, 2010; Fugli and Sreeja, 2011). It is however advisable to irrigate regularly to ensure optimal growth and continuous yield, especially in arid conditions. Moringa trees will generally grow well without adding very much fertilizer, but in order to achieve good yields the soil needs to provide enough nitrogen and minerals to the plant. Before seeding / planting, manure or compost can be mixed with the soil used to fill the planting pits. After wards it is important to apply manure or compost at least once a year, for instance before the rainy season, when the trees are about to start an intense growth period (Saint Sauveur and Broin, 2010).

Weeding must be done regularly to avoid competition for nutrients, especially for nitrogen. Weeding must be more frequent when the plant is young and small. Mulching can be applied (covering the soil with crop or weed residues) in order to reduce the loss of soil moisture, minimize irrigation needs and reducing weed growth. Moringa is fairly resistant to pests and diseases since its relatively fast vegetative growth allows it to regenerate quickly from any disturbance. The most common pests and diseases are grasshoppers, crickets, caterpillars, termites and fungal disease. Preventive measures and timely detection of pests and diseases are important in the pest and disease management strategy (Gongalez *et al*., 2015).

For human consumption, harvested pod should be young (about 1 cm in diameter) and snap easily. In seed producing farms (for planting or oil extraction), pods should be harvested when they reach maturity, i.e. when they turn brown and dry. Harvest the pods before they split open and seeds fall to the ground. Seeds should be extracted from the pods, bagged, and stored in a dry shady place. Harvesting of the leaves can be done by cutting shoots and leaves or by only removing the leaves, picking them directly off the tree. In this case it was advisable to apply pruning after the harvest of the leaves in order to ensure again a vigorous growth (Gongalez *et al*., 2015).

2.3. Response of crops in Agroforestry System

In agroforestry systems the responses of different crops was different. Under shaded condition the size of the leaf increased in different vegetables such as tomato, brinjal and coriander (Miah, 2001). Martin and Rhodes (1983) studied variability of 95 associations of *Abelmuscus esculentus* and *Abelmuscus tetraphylous.* Significant differences were found among the association of all the characters studied viz. plant height, plant spread, number of primary braches, days to flowering, nodes when the first flower appeared, number of leaves per plant, leaf size, petiole length, number of pod per plant, pod weight and total yield.

Miah *et al.* (1995) recorded the reduced light availability on crop rows as they approached the tree rows across the alleys. The rate of decrease was greater in unpruned than in pruned alleys. The yield of Rice and Mungbean was decreased more in pruned (13kg/ha) than in unpruned (9kg/ha) condition. Hossain *and* Bari, (1996) stated that the different in primary branching in plant due to shading is important because it contributes towards the yield of grain legumes.

Ali (1998) reported that red amaranth and okra could be grown successfully under drumstick tree although 10-15 percent yield was reduced compared to open field condition. Ventimiglia *et al.,* (1999) reported that soybean was sown at row spacing of 20 cm and 40 cm. Yield was higher in 20cm row spacing than 40 cm row spacing. Compensation points of photosynthesis were lower in shaded plants than in less shaded plants.

Miah (2000) observed that plant height at high light intensity has different leaf morphology from those grown at low light intensities, leaf size increased under shaded condition in different vegetables like radish, carrot, cabbage and tomato plants.

An experiment was conducted to study the effects of three levels of Irradiance (25, 60 and 100% of full sunlight) at early flowering, peak flowering and late flowering stages on the photosynthetic activity and yield of tomato (Liu *et al.,* 2002).

Moringa has proved to be a potential bio-source for research as scientists have moved their focus to this Miracle tree. Various parts of Moringa plant are known to possess diverse medicinal and biological activity on human and animals, little is known scientifically about its potential effect as a growth enhancer in major crops because very few published literature are available that clearly explain the effects of Moringa leaf extract in plants (Jhilik *et al*., 2017). Therefore, the findings derived from the proposed study will provide fundamentals to understand the multiple mechanisms of Moringa leaf extract on plant growth promotion mechanism which will ultimately increase the yield and quality of cauliflower. Thus, the study will result in improved decision-making tool for cauliflower cultivation using Moringa leaf extract more precisely.

2.4 Tree-crop Interaction

Tree-crop interaction refers to the influence of one component of a system on the performance of other component. Various interactions take place between the trees and herbaceous plants which is referred to as tree-crop interaction. Agroforestry is an ecologically sustainable land use system that maintains increase total yield by combining food crops with tree crops and/or livestock on the same unit of land. It plays a crucial role in climate change mitigation especially due to its tree component. Growing trees with crops (agroforestry) has been observed to enhance crop yields and improve soil quality.

A field experiment was conducted at the Agroforestry Farm of Bangladesh Agricultural University, Mymensingh during the period from November 2009 to March 2010 to find out the performance (growth and yield) of tomato, radish, soybean and lettuce under different distance from the *Xylia dolabriformis* tree also under pruned and unpruned condition of the tree. Different treatments of the experiment were T_0 (open field), T_1 (3 feet distance from tree), T_2 (6 feet distance from tree) and T_3 (9 feet distance from tree) under pruned and unpruned conditions of the tree Lohakat. In radish, the highest value of yield (20.97 t/ha^{-1}) was found under open field which was statistically similar to treatment T_3 under pruned condition. In tomato, it was also found that open field produced highest yield (52.08 t/ha^{-1}). In soybean, the highest grain yield (4.2 t/ha^{-1}) was recorded in open field which was also statistically similar to treatment T_3 under pruned condition. In lettuce, it was observed that open field produced highest yield (18.5 t/ha^{-1}). In case of all crops, lowest yield was found in 3 feet distance from the tree under unpruned condition of *X. dolabriformis*. The growth characters such as height, number of leaves and stem girth of Lohakat tree are not satisfactory in association with tomato but growth characters of Lohakat tree are found higher in association with soybean so we may recommended that growing of soybean at 9 feet distance from Lohakat under pruned condition of tree is the best tree-crop combination in Agroforestry system (Tanni *et al*., 2010).

Another field experiment was conducted at the Agroforestry Farm of Bangladesh Agricultural University, Mymensingh, during the period from September 2012 to March 2013 with the aim of evaluating effect of five years old Lohakat tree (*Xylia dolabriformis*) on the growth and yield of Carrot (*Daucus carota*). Different distances from tree base viz. 1.0-1.5m, 0.5-1.0m and 0-0.5m were treatments of this study. The individual plot size was 6m x 2m and each plot contains two Lohakat trees maintaining 3m distance from one to another. The result showed that plant characteristics viz. plant height (cm), no. of leaves plant^{-1}, leaf size (cm^2), leaf weight plant^{-1}(g), root length (cm), root girth (cm), root weight plant^{-1}(g) of Carrot was less vigorous near the Lohakat tree base. Individual root weight was highest (47.18 t/ha^{-1}) in open field condition which almost identical with the yield produced in the 1.0-1.5m distance area (46.65 t/ha^{-1}) from Lohakat tree base. It was found that yield of Carrot remarkably reduced with reducing distance from Lohakat tree base where 21.05 t/ha^{-1} and 13.21 t/ha^{-1} yield obtained from 0.51.0m and 0-0.5m distance area from Lohakat tree base respectively which were 55.38 and 72.00 % lower compare to open field condition. Thus it appears that yield performance of Carrot was better beyond 1m distance from Lohakat tree base without significant yield loss (Akter *et al*., 2013).

To maximize the production in agroforestry system it was needed to explore the best possible tree-crop interactions. Therefore, an experiment was conducted at the Char Kalibari which was situated by the side of Brahmaputra River Sadar Upazila, Mymensingh, during the period from November 2012 to March 2013, under the Department of Agroforestry, Bangladesh Agricultural University, Mymensingh. Four treatments of this study were viz., T_0 (open field condition referred as control), T_1 (0-1.5 feet distance from the tree base), T_2 (1.5-3.0 feet distance from the tree base) and T_3 (3.0-4.5 feet distance from the tree base). One tree species viz., Akashmoni (*Acacia auriculiformis*), which is 3 years old was used as test species in this experiment. The result showed that morphological characteristics viz. plant height, no. of leaves per plant, leaf size, leaf area (cm^2), number of flower per plant, number of fruit per plant, fruit length (cm), fruit girth (cm), fruit weight (g) of bottle gourd was less vigorous near the Akashmoni tree base. The results also showed that in association with Akashmoni, tree both fresh and dry yield of bottle gourd was gradually increased with increasing distance from the tree base; while it were 29.83 t/ha and 3.59 t/ha, respectively in open field condition. Fruit yield of bottle gourd in association with Akashmoni tree reduced 64.93%, 48.43% and 15.47% in 0-1.5 feet, 1.5-3.0 feet and 3.0-4.5 feet distant area, respectively. It comes into the point that the yield performance of bottle gourd was better in open field condition comparing to Akashmoni (Anwar *et al*., 2013).

Another field experiment was conducted to evaluate the effect of Karanja (*Pongamia pinnata*) on the growth and yield of Kangkong (*Ipomoea reptans*) as vegetables grown in association with Karanja. It located Char Kalibari, Mymensingh, during February 2013 to May 2013, under the Department of Agroforesty, Bangladesh Agricultural University, Mymensingh. So the four treatments of this study were T_0 (open field condition referred as control), T_1 (2.5ft distance from the tree base), T_2 (5ft distance from the tree base) and T_3 (7.5ft distance from the tree base). The results showed that Kangkong yield was gradually increased with increasing distance from the Karanja tree base. In T_0 T_1, T_2 and T_3 the yield were 58.6 t/ha, 40.71 t/ha, 48.23 t/ha and 57.19 t/ha respectively. The yield produced in open field (T_0) and T_3 (5-7ft distance from tree base) were statistically similar and there was no significant variation. Therefore, Karanja tree base was suitable for cultivation of Kangkong without significant yield loss compared to that of control (Hossain *et al*., 2013).

This experiment also carried out in Char Kalibari of Old Brahmaputra River adjacent to Bangladesh Agricultural University, Mymensingh during the period from October 2013 to March 2014 to observe the performance of four different winter vegetables in association with four years old Akashmoni tree for ‘Char’ based farming system. Factor A: tree species were Akashmoni (*Acacia auriculiformis*). Factor B: four winter vegetables and these were sweet potato (*Ipomoea batatus*), radish (*Raphanus sativus*), carrot (*Daucus carota*) and coriander (*Coriandrum sativum*). Almost all tested vegetable species were slightly taller (215%) in open field condition. Number of leaves per plant, leaf size and individual plant/root weight was partially increased (10-20%) without Akashmoni tree association or open field condition. The morphological performance of akashmoni significantly influenced by the interaction of four winter vegetables such as sweet potato, radish, carrot and coriander. Yield of sweet potato, radish, carrot and coriander were 9.03, 8.08, 8.99 and 4.59% lower along with Akashmoni combination as compared to open field condition (Nasir and Kamrul, 2015).

The experiment was conducted at the Field Laboratory of the Department of Agroforestry of Bangladesh Agricultural University, Mymensingh during the period from November 2013 to March 2014 to observe the performance of mustard grown in association with Kalo koroi (*Albizia lebbeck*), a timber yielding tree species in crop based Agroforestry system. Different treatments in association with Kalo koroi tree were T_1 = 0-1.5m distance from the tree base, T_2=1.5-3.0m distance from the tree base, T_3=3.0-4.5m distance from the tree base and T_4=open field condition referred as control. It was found that growth parameters viz. plant height (cm), number of leaves per plant, leaf size including length (cm) and breadth (cm), length of floral rachis, no. of branches/rachis, no. of flower/branch, no. of siliqua/plant, length of silique (cm), no. of seed/siliqua, weight of 1000 seeds (g) of mustard varied almost similar pattern in all treatments when grown combindly with Kalo koroi tree. The highest values of all growth parameters were found in treatment T_4 i.e. without tree condition (control treatment) while the lowest data regarding above parameters were drastically reduced very near the tree base (0-1.5m from the tree base). As evident from the result it was found that yield of mustard gradually increased with increasing distance from Kalo koroi tree base. Yield of mustard remarkably reduced compare to control condition towards the base of Kalo koroi tree. Yield of mustard was highest (0.945 t/ha) in control condition which was statistically similar with the yield obtained from the treatment T_3 (0.94 t/ha) followed by treatment T_2 (0.635 t/ha) and lowest (0.425 t/ha) yield was obtained from treatment T_1 in association with kalo koroi tree. Yield reduction of mustard with kalo koroi tree in treatments T_1, T_2 and T_3 was 55.03, 32.80 and 0.53%, respectively compared to treatment T_4 i.e. open field condition (Pervin *et al*., 2015).

The influence of Grewia on the wheat produce varied according to the distance of the tree. Competition for growth and yield was more pronounced in close vicinity of the tree at 1 and 2 m. The more negative effect in close vicinity of trees can be discribed to more competition for moisture, nutrients and light, which is also evident from the present study. Reductions in yield of wheat below the tree crown due to resource competition were also reported by Puri and Bangarwa (1992) and Dhillon *et al*., (1998). An agrisilviculture system (Wheat + Grewia) was established and it was reported that integration of *Grewia optiva* (tree density 666 trees/ha) with wheat pollarded at 1m height reduces the wheat grain yield by 24 per cent only as compared to 50 per cent in natural agroforestry system in this paper. This indicates that reduction in the wheat yield due to natural growing Grewia trees on farmland can be reduced by about 50 percent of the yield obtained in present studies by adopting tree management practices of pollarding (Verma *et al.*, 2002).

Competition for moisture in agroforestry systems is common occurring phenomenon, which can affect the system adversely (Ong *et al*., 1991; Rao *et al.,* 1991). Higher moisture in subsurface layer as compared to surface layer may be attributed to more sorption of moisture by crop and tree roots from upper layer since both the species are having shallow root system in general. Further, majority of roots of Grewia remains confined to 60 cm soil depth. Below canopy, lower soil temperature was maintained at 1m and 2m distances at the time of milking and harvesting. A similar effect of tree canopy on soil temperature was observed. Beneath canopy temperature also showed more reduction at 1 and 2m, which again can be ascribed to direct shading effect of Grewia on wheat. Reduced temperature below trees has also been reported by Monteith *et al*., (1991), Hazra and Patil (1996), and Thakur and Kaur (2001).

In recent decades, integrating trees with crops for food and wood production has received considerable attention in both tropical and temperate regions (Palma *et al*., 2007). Agroforestry has shown potential to increase and sustain food production per unit area in systems like the parklands of the Sahel (Bayala *et al*., 2012), through the use of fertilizer trees intercropped or in fallow rotations with crops throughout sub Saharan Africa (Sileshi *et al.,* 2008) and through integrating trees with crops on sloping land (Tiwari *et al*., 2009).

Agroforestry is increasingly seen as a promising approach to improving food security (Glover *et al.,* 2012), largely because the trees are associated with enhancing and sustaining soil health and hence crop yield (Barrios *et al*., 2012). Trees also produce fodder, fuel and construction materials, which are in high demand in many rural areas and if produced on farm may reduce the costs of obtaining them off-farm. Through production of high value timber, farmers can often generate substantial additional revenue in both temperate and tropical contexts (Bertomeu, 2006; Santos-Martin and van Noordwijk, 2009). Fruits obtained from trees can enhance both income (Mithöfer and Waibel, 2003) and human nutrition (Goenster *et al.,* 2009; Kehlenbeck *et al.,* 2013).

Agroforestry practices are often part of strategies to improve natural resource management (Ong and Kho, 2015), and they are often more effective than other land uses in providing regulating, supporting and cultural ecosystem services (Pagella and

Sinclair, 2014), such as microclimatic buffering, amelioration of soil structure and water infiltration, reduction of overland flow, regulation of the water cycle and provision of habitat for wild species (Bayala *et al.*, 2014).

The potential of agroforestry practices to sequester carbon in wood and soil has been widely demonstrated (Luedeling *et al.*, 2011; Kuyah *et al*., 2013).Agroforestry may also affect emissions of other greenhouse gases either positively or negatively (Verchot *et al*., 2008; Rosenstock *et al.*, 2014) and is expected to help farmers adapt to climate change through the risk-mitigating effects of additional farm products derived from trees, positive microclimatic effects through shading and enhanced farm productivity through tighter nutrient and water cycles (Garrity *et al*., 2010).

The magnitude of all documented or assumed benefits of agroforestry depends on site specific responses by trees, crops or other components of the system, with strong variation between locations and farming contexts (Coe *et al*., 2014). Benefits also vary over time, because many effects of trees on soils are slow to materialize (Barrios *et al*., 2012).

Trees can also compete with crops for water and nutrients and reduce the land area available for crops, so that the net effect of agroforestry on crop yields over time will depend on attributes and interactions of the trees, crops, soil, climate, and management (Bayala *et al.*, 2012). For instance, the beneficial effects of *Faidherbia albida* on crop yields have been reported to start only after the trees reach 20 to 40 years of age (Ong and Kho, 2015).

2.5 Performance of crops in association with Moringa

An experiment was conducted at the Char Kalibari at bank of Brahmaputra River adjacent to the Bangladesh Agricultural University, Mymensingh, during the period from August 2018 to December 2018 with the aim of evaluating the growth performance of chilli grown in combination with drumstick tree (*Moringa oleifera*) saplings. Different treatments of this study were T_0 (open field referred as control), T_1 (50 cm from tree base), T_2 (100 cm from tree base) and T_3 (150 cm from tree base). As evident from results, the highest yield of fresh chilli (4.36 t/ha) was obtained from treatment T_0 (open field as control) which was statistically similar with the second nearly value (4.27 t/ha) produced under T_3 followed by treatment T_2 (4.12 t/ha) and T_1 (3.97 t/ha). It was found that on an average 4.62% yield of chilli was decreased in T_1 compare to open field condition. From this study it was clear that chilli cultivation in association with drumstick tree during the establishment period without significant yield loss in char land ecosystem of Bangladesh (Noman *et al*., 2018).

An experiment was conducted in Agroforestry Field Laboratory at Sher-e-Bangla Agricultural University, Dhaka to find out the effect of planting distances on growth, yield and yield attributing characters of stem amaranth (*Amaranthus oleraceus*) during the early establishment period of Moringa (*Moringa oliaferae*) trees. Four treatments were T_0 (open field condition as control), T_1 (6 inches distance from tree base), T_2 (12 inches distance from tree base), T_3 (18 inches distance from tree base). At harvest, the maximum plant height of stem amaranth (59 cm), number of leaf per plant (25 cm) was recorded in control condition (T_0 treatment) and minimum plant height (49 cm), number of leaf per plant (20) was recorded in T_3 treatment. The highest leaf length (10 cm) and leaf breadth (5 cm), stem girth (6 cm), stem length (61 cm), root length(16 cm), shoot and root fresh weight (74 g and 16 g), shoot and root dry weight (4 g and 1 g) and green yield (14 t ha^{1}) were observed in open field condition (T_0 treatment). The yield was reduced by 15% in T_1 treatment (12 t ha^{-1}) compared to open field condition. The fresh yield of stem amaranth under T_2 (10 t ha^{-1}) and T_3 (10 t ha^{-1}) treatment with association of Moringa was recorded 26 % lower than the plants which were grown under control condition (T_0 treatment). The growth characters of *M. oliaferae* were also enhanced in association with stem amaranth. At harvest of stem amaranth, maximum bud length(8cm) and bud number (4) of Moringa sapling were also recorded in T_1 treatment thus showing its potential to be used in Moringa based agroforestry farming system in large-scale (Arif ahmed., 2018).

An experiment was conducted at the Agroforestry Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2018 to May 2019 to study brinjal growth and yield performance interaction with early establishment period of Moringa. Brinjal was grown under two different levels with four treatments *viz*., (i) T_0 (open field plantation considered as control), (ii) T_1 (30 cm distance from the tree base), (iii) T_2 (40 cm distance from the tree base) and (iv) T_3 (50 cm distance from the tree base).Results indicated that T_0 (open field plantation considered as control) treatment showed highest results on plant height, leaves plant1, branches plant^{-1}, plant spreading, number of fruits plant^{-1}, fruit weight plant1, single fruit weight and yield ha^{-1}. But under brinjal-moringa interaction, the highest results on respected parameters were found from T_3 (50 cm distance from the tree base) treatment. The highest fruit weight plant^{-1} (1923.90 g), single fruit weight (72.60 g) and fruit yield ha^{-1} (34.20 t) were found from T_0 (open field plantation considered as control) treatment and the second highest fruit weight plant^{-1} (1592.53 g), single fruit weight (67.48 g) and fruit yield ha^{-1} (28.31 t) were found from T_3 (50 cm distance from the tree base) treatment. The lowest fruit weight plant1 (758.11 g), single fruit weight (59.60 g) and fruit yield ha^{-1}(13.48 t) were found from T_1 (30 cm distance from the tree base) treatment (Manashi Roy., 2019).

2.6 Sunflower (*Helianthus annuus*)

2.6.1Origin and distribution

Sunflower (*Helianthus annuus* L.) is one of the few crop species that originated in North America (most originated in the Fertile Crescent, South Asia or Central America). It was probably a “camp flower” of several of the western native American tribes (North American Indians) who domesticated the crop (possibly 1000 BC) and then carried it eastward and south-ward in North America. The first Europeans observed sunflower cultivation in many places from southern Canada to Mexico and Spain.

Sunflower was probably first introduced to Europe through Spain, and spread through Europe until it reached Russia, where it was adapted readily. Selection for high oil in Russia began in 1860 and was largely responsible for increasing the oil content from 28% to almost 50%. The high-oil lines from Russia were reintroduced into the U.S. after World War II, which rekindled interest in the crop. However, it was the discovery of the male-sterile and restorer gene system that made hybrids feasible and increased the commercial interest in the crop. (Pleskachev *et al*., 2021).

2.6.2 Cultivars

Proper cultivar choice is one method of ensuring higher profits at no extra costs. Because sunflower is not prone to major diseases and pests, cultivar selection is generally based on yield and yield reliability. Performance of varieties tested over several environments is the best basis for selecting sunflower hybrids. The choice should consider yield, oil percentage, maturity, seed size (for non-oilseed markets), and lodging and bird resistance. Farmers should select cultivars best suited to their production area. It was important to realize that cultivars are updated on a regular basis and therefore could change over time (Pleskachev *et al*., 2021).

2.6.3 Climatic requirement

- The crop requires a cool climate during germination and seedling stage.
- Warm weather from seedling up to flowering.
- Non cloudy sunny days from flowering to maturity.
- High humidity together with cloudy weather and rainfall at the time of flowering results in poor seed set.
- The amount of linoleic acid decreases with high temperature at maturity.
- The seasonal rainfall requirement for a good crop of sunflower is about 500 mm.
- Sunflower is a photo insensitive crop, so it can be grown in any season.
- The ideal conditions for best sunflower production are that Kharif. Flowering period should not coincide with continuous rains/drizzle.

Summer : Temperature during flowering should not exceed 38 to 40ºC. Optimum temperature during growing period 20 to 25º C (Pleskachev *et al*., 2021).

2.6.4 Soil requirement

- Sunflower performs well on a wide range of soils such as sandy loams, black soils and alluviums. Never the less, it does best in fertile, well drained neutral soils.
- Sunflower is more susceptible to high moistness and soil compaction.
- During rabi season it is grown in moisture retentive soils of vertisols.
- PH of 6.5 to 8.0 is ideal for its cultivation.
- It can tolerate slight alkaline conditions but not acidity.
- Water logging areas should be avoided, adequate drainage is a must.

❖ Poor drainage conditions are unsuited because it increases susceptibility to fungal diseases.

An Exchangeable sodium percentage of more than 16 cause delayed germination and less development of flower heads (Pleskachev *et al*., 2021).

2.6. 5 CULTIVATION PRACTICES

Propagation

Sunflower is propagated by seed.

Soil preparation

Many different tillage systems can be used effectively for sunflower production. Soil preparation should be focused on decreasing runoff, especially in the case of soils with a low infiltration rate. These losses can be limited to a great extent by applying the correct soil cultivation practices. Conventional systems of seedbed preparation consist of mould board plowing or chisel plowing. The aim of the cultivation is to break up limiting layers, destroy weeds, provide a suitable seedbed and to break the soil surface and at the same time to ensure maximum rainfall infiltration, as well as to prevent wind and water erosion. Both germination percentage and lodging have been shown to increase in ridge-till systems vs. level plantings. Several till-age systems have been used with some success in specific environments.

Major considerations are

- Firm placement of seed near moist soil
- Absence of green vegetation during emergence
- Maintaining an option to cultivate
- Reducing the risk of soil erosion

Planting

The planting density for sunflower ranges from 25000 to 35000 plants per hectare, depending on the yield potential of the area. Row width has little influence on grain yield.

It can range from 90 to 100 cm however wider rows such as 1.5 m to 2.1 m can also be used, particularly to accommodate other farm implements.

Fertilization

Compared to grain crops, sunflower utilizes soil nutrients exceptionally well. The main reason for this is the finely branched and extensive root system. The roots come into contact with nutrients which cannot be utilized by other crops.

Weed control

Efficient weed control is a prerequisite for high sunflower yields. It is achieved by a combination of mechanical and chemical practices. Young plants are highly sensitive to strong weed competition and cannot develop fast enough to form a full shade covering which can suppress weed seed-lings. Therefore, the first 6 weeks after planting are a critical period for the crop. Yields can be increased significantly by keeping fields free of weeds during this time.

Harvesting

Harvesting should commence as soon as 80% of the sunflower heads are brown in order to minimize losses caused by birds, lodging and shattering. The leaves turn yellowish during harvesting maturity. Sunflower is generally mature long before it is dry enough for combining. The sunflower plant is physiologically mature when the back of the head has turned from green to yellow and the bracts are turning brown, about 30 to 45 days after bloom, and seed moisture is about 35%. The total growing period (from seeding to harvesting) for sunflower ranges from 125 to 130 days.

2.6.6Performance of crops in association with Sunflower

To investigate the interactive effect of different concentration levels and times of application of Moringa leaf extract as a foliar spray on sunflower a field experiment was conducted at Agronomic Research Area, University of Agriculture Faisalabad, during spring season of 2011. The experimental design was Randomized Complete Block Design (RCBD) with split plot arrangements. Different concentrations of Moringa leaf extract (0%, 5%, 10%, 15% and 20%) were sprayed at different times (25, 40 and 55 days after sowing (DAS) and a control treatment was kept for comparison. The results indicated that 20% Moringa leaf extract (B) 4 sprayed at 40 DAS (A_2), improved all agronomic parameters and finally gave the highest economic yield (2.96 t ha^{-1}). The same treatment also significantly increased the achene protein contents (29.48%) as well as 1achene oil contents (41%). Thus a foliar spray of 20% Moringa leaf extractat 40 DAS not only increased the economic yield but protein and oil content of achene were increased.

Singh (2007) carried out a field experiment in Kashmir, India, during the rainy (kharif) season of 2002 and 2003, to study the response of sunflower (*Helianthus annuus*), French bean (*Phaseolus vulgaris*) intercropping to different row ratios (1:1 and 2:2) and nitrogen levels (0. 40, 80 and 120 kg ha^{-1}) under rainfed conditions. Intercropping reduced the values of growth parameters, yield attributes and seed yield of both sunflower and French bean compared with their sole crops. Both the intercropping recorded significantly higher sunflower-equivalent yield (SEY), net income and benefit:cost ratio than their sole stands. Intercropping of sunflower + French bean under 2:2 row ratio recorded significantly higher SEY (1231 kg ha^{-1}), land-equivalent ratio (1.25), net income (Rs.13138 ha^{-1}) and benefit:cost ratio (1.95), and also indicated a modest competitive ratio (2.10 : 0.48), followed by sunflower + French bean in 1:1 ratio. Both sunflower and French bean in sole and intercropping responded favorably up to 80 kg N ha^{-1} only for higher leaf area index, dry matter accumulation, yield attributes, seed yield, N uptake, net income and benefit: cost ratio. The interaction effects of the factors showed that mean SEY responded to N application up to 80 kg ha in 2:2 row ratio of sunflower + French bean.

Wondirnu *et al.* (2007) conducted an experiment to find out the productivity of tef-sunflower intercropping, with or without fertilizer, was assessed by field trials in Northeast Ethiopia. Mixed planting of 10-50% of sunflower with tef had yield advantages of 20-39% and 58-77% at two different sites. The crop proportions giving the greatest yield benefit varied between the sites. The greatest net income benefits were USS 515 ha' and USS 69 ha at the two sites.

Morales *et al*. (2006) conducted an experiment to evaluate the biomass, yield and water and radiation use efficiency in the agrosystem of sunflower and commonbean. The treatments were monocropping and intercropping of common bean cultivars Canario 107, Bayomex (determinate type), Michoacan (indeterminate type) and sunflower cv. Victoria. The combination of the Victoria sunflower and the Michoacan bean showed higher water use efficiency and radiation use and resulted greater production of biomass and yield. Land equivalent ratio obtained with the combination of Victoria and Canario 107, Victoria and Michoacan and Victoria and Bayomex was 1.6. 1.9 and 3.0 respectively. This shows the yield advantage of combined crops over monocrops by 60, 90, and 200%, respectively.

Khan *et al.* (2006) conducted a field experiment to study the effect of intercropping on the soil fertility and economics of sunflower and companion legumes viz. moong, rajmash, soybean and cowpea. There was considerable improvement in the residual soil nitrogen as a result of sunflower + legume combinations. All intercropped treatments had made better use of available soil phosphorus and potassium as compared to their sole treatments. Intercropping of sunflower + soybean (1:1) produced the highest net returns (Rs/.14865/ha) and benefit-cost ratio (1.41) followed by sunflower + cowpea (1:1) and sunflower + moong (1:1).

Thakur *et al*. (2004) conducted a field experiment during 1994-95 and 1995-96 in Chhindwara. Madhya Pradesh, India, to select the most compatible intercrop with sunflower under varying row proportions for increased and economical productivity. The treatments comprised: 50 cm sole sunflower; 25 cm sole chickpea; 25 cm sole pea; 25 cm sole linseed; 25 cm sole niger; sunflower + chickpea (1:1 and 1:2); sunflower + pea (1:1 and 1:2); sunflower + linseed (1:1 and 1:2); sunflower + niger (1:1 and 1:2). Sunflower + chickpea (1:1) gave the maximum plant height (100 cm) of wheat and land equivalent ratio (1.27). Sunflower + linseed (1:1) gave the highest head size (12.5 cm) and grain yield (1525 kg ha^{-1}) of sunflower. Sunflower + niger (1:1) had the highest number of seeds per head (279) and relative crowding coefficient (3.33). Sunflower + pea

(1:1) and (1:2) and sunflower + linseed (1:2) gave the highest seed chaffiness (9.2%), sunflower equivalent yield (1101 kg ha^{-1} and stem girth (5.0 cm), respectively.

Maity and Gajendra (2003) conducted a field experiment to study the performance of groundnut (cv.SG-84) sunflower (hybrid MSFH-8) intercropping in relation to P and S fertilizer application. The treatments comprised of 3 cropping systems, i.e. sole groundnut, groundnut intercropped with simultaneously-sown sunflower and groundnut intercropped with sunflower sown one-month later; 0. 40 and 80 kg P/ha; and 0, 30 and 60 kg S/ha. Sole groundnut, 40 kg P/ha and 30 kg S/ha gave the best total productivity and oil yield. The highest gross and net returns, and benefit-cost ratio were obtained with sole groundnut along with 40 kg P/ha and 30 kg S/ha. The highest sustainable yield index was obtained with sole groundnut 0 kg P/ha and 30 kg S/ha. The highest P and S uptake was obtained with groundnut simultaneously intercropped with sunflower@ 40 kg P/ha and 30 kg S/ha.

Bheeniaiah and Subrahmanyam (2003) conducted an experiment to study the performance of sunflower intercropped with *Tamarindus indica* (cv. PKM 1) under various N:P fertilizer rates (0:0, 40:20. 40:40, 40:60, 80:20. 80:40 or 80:60 kg/ha). The cropping fertilizer rate had significant effects on dry matter production crop growth rate (CGR) and seed yield. Sole cropping registered higher mean dry matter production (7740 kg/ha), CGR (7.9 g m^{-2} day) and seed yield (662 kg/ha) than intercropping (4965 kg/ha, 6.3 g m^{-2} day t and 470 kg/ha). A higher benefit cost ratio was recorded for intercropping (1.26) than for sole cropping (0.76). The highest dry matter production (9221 kg/ha). CGR (10.7 g m^{-2} day') and seed yield (778 kg/ha) were obtained with sole cropping and 80:60 kg N:P/ha, whereas the highest benefit cost ratio (1.59) was obtained with intercropping and 80:60 kg N:P/ha.

Guriqbal and Sekhon (2002) conducted a field experiment to study the intercropping of mungbean cv. SML 32 and spring-planted sunflower cv. MSFH 8. Five cropping systems were established 1:4, 1:6 and 2:6 sunflower:mungbean row ratio and sole sunflower and mungbean. Sole crops of both species produced higher yields than intercrops. The land equivalent ratio was highest in 1:4 ratio in all the years except in 1994. In terms of mungbean equivalent yield. 1:4 sunflower:mungbean ratio produced the highest, while sole mungbean the lowest.

Patil *et al*. (2002) conducted a field experiment to optimize the total nutrient requirement in soybean-sunflower intercropping system. The highest soybean yield was obtained with the application of 100% of the recommended dose of fertilizer (RDF; 30:75:30 kg NPK/ha) to the main crop (soybean). The highest total productivity in terms of soybean equivalent yield (1939 kg ha^{-1}), land equivalent ratio (1.33) benefit-cost ratio (2.91) and maximum gross returns (Rs/.19981 ha^{-1}) were also obtained with the same treatment.

Rajvir (2002) conducted a field experiment to study the effect of' intercropping with mungbean on the performance of sunflower under various planting patterns. The treatments consisted of sole sunflower and mungbean. sunflower + mungbean at 1:1 and also at different paired row and skip row. Sunflower had the highest leaf area index (5.39) when planted as a sole crop. The skip row planting of sunflower resulted in the highest dry matter production (195.56 g per plant). The highest sunflower seed yields were obtained under sole sunflower (1651 kg/ha) and sunflower + mungbean at 1:1 (1502 kg/ha). Mungbean had the highest dry matter content (12.8 g per plant), leaf area index (2.92) and seed yield (1324 kg/ha) when planted as a sole crop.

Maloy (2001) conducted an experiment to find out the yield optimization through sunflower based intercropping system. Sunflower, greengram, blackgram and sesame were planted singly and sunflower (paired row) was intercropped with greengram, blackgram or sesame (single or paired rows). They observed that plant height and total dry matter were maximum when sunflower was grown singly followed by intercropping with greengram or blackgram. Dry matter accumulation was higher in sunflower intercropped with greengrani or blackgram than with sesame. The highest total productivity in terms of sunflower equivalent yield has been recorded through two rows of sunflower intercropped with one row of greengram (27.6 q/ha), followed by sunflower intercropped with two rows of greengram (26.33 q/ha).

Lopez *et al*. (2001) carried out an experiment to investigate the effect of three levels of maize:sunflower intercropping row ratios (25:75. 50:50 and 75:25) in comparison with the pure-stand of two varieties each of sunflower (20 GN and Black Rekord) and maize

(Matuba and Manica). Both Maize cullivar's yield/plant decreased in relation to density. The intercropping 75:25 maize: sunflower ratio showed the highest seed yield/ha (5195 kg/ha).

Chellaiah *et al*., (2001) carried out an experiment to investigate the performance of sunflower with intercrops under various planting pattern. These are three planting patterns (2:1, 3:1 and 4:1 ratio) and three intercrop (Red gram, Sesame and Bengal gram). Planting of component crops at 3:1 ratio was optimum for better growth. Increase sunflower grain-yield equivalent (1019 kg/ha) and higher net income (Rs/. 6392/ha) with higher BCR (2.69). The yield of intercrops was reduced by 17.7% and 33.8% and 3:1 ratio and 4:1 ratio compared to 2:1 ratio, Among the intercropping systems, sunflower + sesame recorded the highest mean grain yield equivalent (1082.6 kg/ha), mean net income (Rs/.6942/ha) coupled with maximum benefit-cost ratio (2.87) compared to other intercropping systems.

CHAPTER III

MATERIALS AND METHOD

The experiment was conducted to the response of sunflower in association with drumstick (*Moringa oleifera*) as well as to find out the best tree crop interactions in Agroforestry system. The materials, followed methodologies and other relevant activities during the experimental period are elaborately presented in this chapter. A brief description on the experimental site, season, soil, weather and climate, land preparation, fertilizer application, experimental design and treatment combination, planting materials, intercultural operations, data collection, statistical analysis etc. are included here.

3.1. Location and time

The experiment was carried out at the Agroforestry Field Laboratory under the Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2020 to March 2021. The location of the site is 23º74′/N latitude and 90º35′/E longitude with an elevation of 8.2 meter from sea level.

3.2. Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.3. Weather and climate

The experimental area has sub-tropical climate characterized by high temperature, heavy rainfall during May to September and scanty rainfall during rest of the year. The annual precipitation of the site is 2052 mm and potential evapotranspiration is 1286 mm, the average maximum temperature is 30-35^{0}C, average minimum temperature is 14-21^{0}C and the average mean temperature is 12-25^{0}C (BBS, 2021). Appendix-II

3.4. Soil

The soil texture was silty clay with pH 6.1. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix-III.

3.5. Planting materials

In this experiment, *M. oleifera* was collected from Rajshahi were established three year ago. Three moringa trees were selected and tagged properly. The seeds of sunflower, variety BARI Surjamukhi-3 collected from Bangladesh Agricultural Research Institute, Gazipur-1701, Dhaka.

3.6. Experimental design and treatment combination

The crop sunflower in association of three year old Moringa tree were cultivated by following the Randomized Complete Block Design (RCBD). Each of the four treatments was replicated four times. Field size: 1080 cm × 540 cm, Block size: 300 cm × 540 cm, Plot size: 50 cm × 90 cm and Block to Block distance: 60 cm. Four treatments which were used in this study are as follows: -

1. D_1= 50 cm distance from the tree base
2. D_2= 100 cm distance from the tree base
3. D_3= 150 cm distance from the tree base
4. D_4= Open field referred to as control (sole crop)

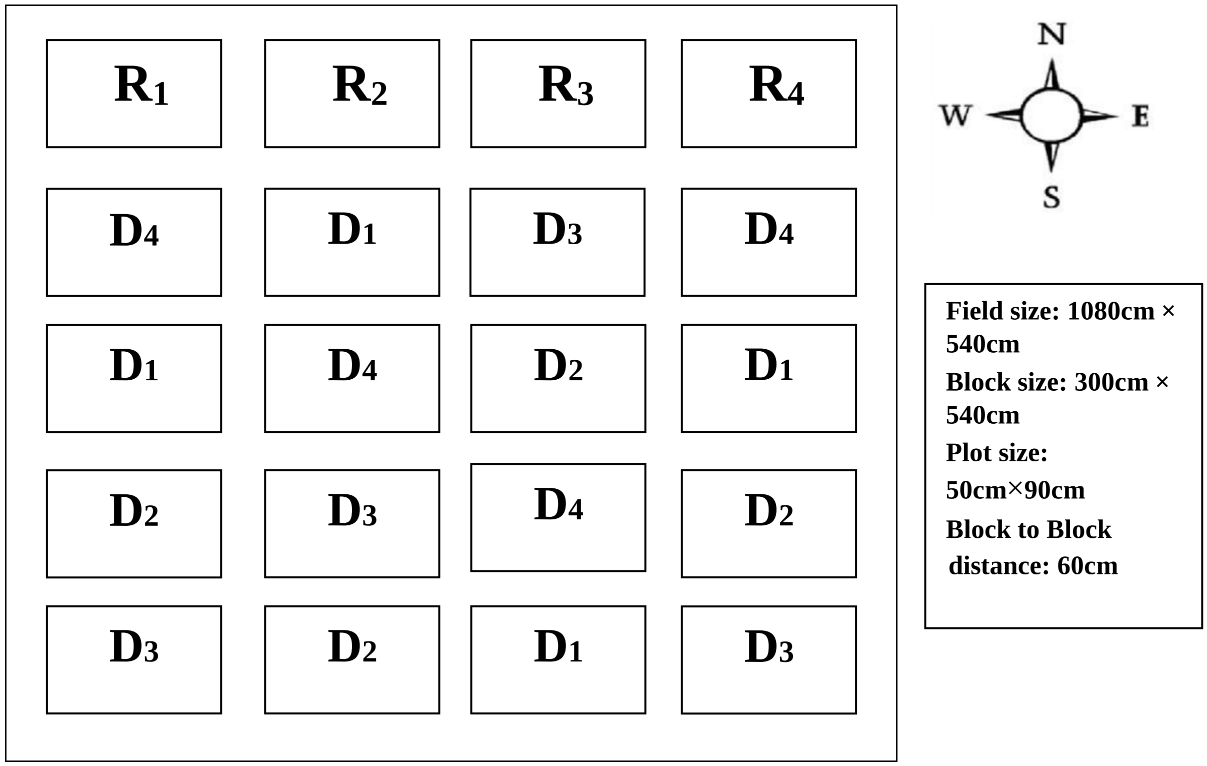


Figure 1. Layout of the Experiment Field

3.7. Land Preparation

The experimental field preparation was started on 26thNovember 2020 and all operations were done by spades. Then 27thNovember 10 kg cowdung was added and land was left fellow for twenty day. During this time all crop residues and weeds were removed from the land, broken stones and bricks were sorted out and finally 20 cm raised bed was leveled properly.

3.8. Crop Establishment and Management

Sunflower seed were planted in the experimental plot on 19thDecember 2020 by line sowing method at a spacing of plant to plant distance 25 cm and row to row distance 50 cm.

3.9. Management Practices

3.9.1. Fertilizer application

Urea (200 kg/ha), TSP (180 kg/ha), MP (170kg/ha), Boron (12 kg/ha) chemical fertilizers were used for this experiment and cow dung (10 t/ha) was applied into the experimental field during final land preparation.

3.9.2. Weeding and irrigation

Weeding was done as necessary to keep the field free from weed during the experimental period. To maintain optimum soil moisture all plots were irrigated as necessary by using watering cane.

3.9.3. Thinning out

First emergence of sunflower was observed at day four after sowing. Thinning was done 20 days after sowing.

3.9.4. Pest and Disease Management

No pesticide and insecticide were applied as the crops were not infected by any pest and disease.

3.10. Data Collection

The following data on growth and yield of sunflower were collected

1. Plant height (cm)
2. Leaf length
3. Leaf breadth (cm)
4. Number of internode plant^{-1}
5. Internode length (cm)
6. Fresh weight of shoot (g)
7. Fresh weight of root (g)
8. Dry weight shoot (g)
9. Dry weight of root (g)
10. Number of seed plant^{-1}

11. Weight of seed plant^{-1} (g)
12. Seed yield ha^{-1} (t)

Procedure of recording data

3.10.1. Plant Height (cm)

Plant height was measured in centimeter (cm) by using a scale at 15, 30, 60, 75, and 90 DAS (days after sowing) from the ground level to the tip of the plant leaf.

3.10.2. Leaf length

Fifteen plants from each plot were randomly selected and then the length of the leaves were measured against a centimeter scale. .

3.10.3. Leaf breadth

Fifteen plants from each plot were randomly selected and then the breadth of the leaves were measured against a centimeter scale.

3.10.4. Number of internode per plant

Fifteen plants from each plot were selected randomly and tagged properly. The internode number was counted precisely for each plant.

3.10.5. Internode length (cm)

Fifteen plants from each plot were randomly selected and then the length of the internode were measured against a centimeter scale.

3.10.6. Stem Diameter (cm)

Stem diameter was measured in centimeter (cm) by using a scale at 15, 30, 60, 75, and 90 DAS (days after sowing) from the ground level.

3.10.7. Fresh weight of shoot (g)

After harvest randomly 10 plants were selected from each plot. Then shoot weight was weighted separately by balance. The sum of the fresh weight of 10 plants was divided by

10 then it was recorded as fresh weight of single plant. Fresh weight of shoot was expressed in gram (g).

3.10.8. Dry weight of shoot (g)

After harvesting selected plant shoots were put into paper packet and placed in oven and dried at 60^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken. Average weight was measured in gram (g) and expressed as dry weight per plant.

3.10.9. Fresh weight of root (g)

After harvest randomly 10 plants were selected from each plot and root was separated. Then root weight was weighted separately by balance. The sum of the fresh weight of 10 plant roots was divided by 10 then it was recorded as fresh weight of root per plant. Fresh weight of root was expressed in gram (g).

3.10.10 Dry weight of root (g)

After harvesting selected plant roots were put into paper packet and placed in oven and dried at 60^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken. Average weight was measured in gram (g) and expressed as dry root weight per plant.

3.10.11 Number of seed plant^{-1}

Total numbers of seeds were counted of harvest from the selected plants and average value was expressed as number of seeds per plant.

3.10.12. Weight of seeds plant^{-1} (g)

Total weight of seeds (g) of five plants was recorded and weight of seeds per plant was calculated.

3.10.13. Seed yield ha^{-1} (t)

It was measured by the following formula,

$$\text{Seed yield (t ha}^{-1}\text{)} = \frac{\text{Seed yield per plot (kg)} \times 10000}{\text{Area of plot in square meter} \times 1000}$$

3.11 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of moringa. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 10% in simple rate. The market price of moringa and sunflower was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al*., (1989). The benefit cost ratio (BCR) was calculated as follows

$$\text{Benefit Cost Ratio} = \frac{\text{Gross return per hectare (tk)}}{\text{Total cost of production per hecttare (tk.)}}$$

3.12 Analysis of data

The recorded data on various parameters were statistically analyzed by using MSTAT statistical package programmed. The mean for all the treatments was calculated and analysis of variance for all the characters was performed by F-test. Difference between treatment means were determined by Duncan`s new Multiple Range Test (DMRT) according to Gomez and Gomes, (1984).

CHAPTER IV

RESULTS AND DISCUSSION

Results of the experiment entitled “performance of sunflower yield under moringa based agroforestry system”, conducted at the Agroforestry Field under the Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2020 to March 2021, Dhaka are presented in this chapter. The observations pertaining to growth and yield attributes of moringa recorded during the course of investigation were statistically analyzed and significance of results verified. The results of all the main effects and only significant have been presented in succeeding paragraphs. Some of the characters have also been represented tables to show the treatment effect wherever necessary to provide better understanding of the results.

4.1 Plant Height (cm)

The sunflower plant exhibited significant differences in plant height at all sampling dates (Table 1). The plant height increased with the plant age. At harvest, plant height ranged from 90 to 95 cm. Plants under D_4 treatment were the tallest whereas the plants under D_1 treatment were the shortest in structure. In 15 DAS the highest (15 cm) was found in the plants belong to treatment D_4 which was closely followed by the plants under treatment D_3 and D_2 with the value of 13.0 and 10.6 respectively. The highest plant height was observed in D_4 throughout the experiment. In 90 DAS the highest plant height (95.0 cm) was recorded in D_4 treatment and the lowest plant height (90 cm) was recorded in D_1 treatment which was 50 cm away from tree base. Among the Moringa sunflower interaction, D_3 appeared as the best treatment. At harvest, the highest plant height of sunflower was recorded in D_3 treatment with the value of 93.1 cm which was only 2% less than that of control treatment. (Akter *et al*., 2013) reported that plant height of carrot significantly improved by increasing tree and crop distance.

Table 1. Effect of Moringa tree on plant height of Sunflower as influenced by distance from tree base

Treatment	Plant Height(cm)					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
D_1	10.0 d	25.0 d	54.6 d	65.1 d	78.1 d	90.0 d
D_2	10.6 c	27.0 c	55.6 c	66.0 c	79.2 c	91.0 c
D_3	13.0 b	28.3 b	57.0 b	68.1 b	80.0 b	93.1 b
D_4	15.0 a	30.3 a	58.0 a	69.3 a	82.0 a	95.0 a
$LSD_{0.05}$	0.57	0.66	0.88	0.23	0.21	0.11
CV(%)	2.37	1.20	0.78	0.17	0.13	0.06

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, D_1=50 cm distance from the tree base, D_2=100 cm distance from the tree base, D_3=150 cm distance from the tree base, D_4=Open field plantation considered as control

4.2 Leaf Length (cm)

The results on effects of various distance from tree base showed that had significant effect on length of leaves at 15, 30, 45, 60, 75 and 90 different days after sowing (DAS). The treatment (D_4) gave the maximum length of leaves (8.40, 15.3, 20.0, 22.1, 24.0 and 24.2 cm at 15, 30, 45, 60, 75 and 90 DAS, respectively). Then the treatment (D_1) gave minimum (5.96, 12.0, 17.0, 20.0, 22.0 and 22.1 cm at 15, 30, 45, 60, 75 and 90 DAS, respectively) length of leaves (Table 2). In tree-crop interaction, D_3 appeared as the best treatment because there are not significantly difference with D_4.Variation in the leaf size and shape has been shown to be correlated with climatic factors. In addition, other environmental factors, such as light intensity and nutrient availability, can influence leaf size and shape. The variation of leaf length may be due to the tree shading and tree crop nutrient competition. As tree shading effect on solar radiation received by the amaranth plants result in poor photosynthesis. As photosynthesis rate was highly correlated with vegetative growth and yield attributes of the crop. As a result its impact on leaf length of stem amaranth. While increasing distance reduces tree shading and tree crop nutrient competition effect. Anwar *et al*. (2013) reported that attributes of bottle gourd increased with increasing distance from Akashmoni tree base.

Table 2. Effect of different distance on leaves length (cm) of sunflower plant at different days after sowing (DAS)

Treatment	Leaf Length (cm)					
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
D_1	5.96 d	12.0 d	17.0 d	20.0 d	22.0 c	22.1 d
D_2	6.20 c	13.6 c	17.8 c	20.8 c	22.6 b	22.5 c
D_3	8.00 b	13.1 b	18.6 b	21.6 b	23.6 a	23.5 b
D_4	8.40 a	15.3 a	20.0 a	22.1 a	24.0 a	24.2 a
$LSD_{0.05}$	0.20	0.33	0.31	0.34	0.56	0.17
CV(%)	1.45	1.23	0.84	0.81	1.21	0.37

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, D_1=50 cm distance from the tree base, D_2=100 cm distance from the tree base, D_3=150 cm distance from the tree base, D_4=Open field plantation considered as control.

4.3 Leaf Breath (cm)

The effect of different distance was significant in this regard. Control (D_4) treatment produced the widest leaves (1.16, 8.16, 13.3, 16.0, 20.0 and 20.0 cm at 15, 30, 45, 60, 75 and 90 DAS, respectively) and (D_1) treatment produced narrowest leaves (2.00, 6.00, 10.0, 13.0, 17.0 and 17.5 cm at 15, 30, 45, 60, 75 and 90 DAS, respectively) (Table 3). D_3 treatment found the similar result leaves breadth of sunflower. Leaves breadth essentially varies for different distance of tree base.

Table 3. Effect of different distance on leaves breadth (cm) of sunflower at different days after sowing (DAS)

Treatment	Leaf Breath (cm)					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
D_1	2.00 d	6.00 d	10.0 c	13.0 d	17.0 d	17.5 d
D_2	3.00 c	6.60 c	10.2 c	14.7 c	18.0 c	18.1 c
D_3	4.20 b	7.06 b	12.0 b	15.0 b	18.6 b	18.8 b
D_4	5.16 a	8.16 a	13.3 a	16.0 a	20.0 a	20.0 a
$LSD_{0.05}$	0.32	0.27	0.32	0.07	0.28	0.11
CV(%)	4.47	1.96	1.42	0.25	0.78	0.30

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, D_1=50 cm distance from the tree base, D_2=100 cm distance from the tree base, D_3=150 cm distance from the tree base, D_4=Open field plantation considered as control.

4.4 Number of internode

The sunflower plant exhibited significant differences in internodes number at 15, 30, 45, 60, 75 and 90 DAS. The maximum internode number (4.00, 5.66, 8.00, 9.00, 10.3 and 11.6 at15, 30, 45, 60, 75 and 90 DAS, respectively) was produced by (D_4) treatment and the minimum (2.00, 3.00, 5.00, 7.00, 8.00 and 9.00 at 30, 45, 60, 75 and 90 DAS, respectively) was produced by D_1 treatment (Table 4). D_3 gave the highest number of leaves per plant compare to D_1 condition. Shading by the trees, reducing light intensity at the crop level result in poor growth and development of crops at closer distance. While increasing distance reduces competition and increasing photosynthesis of crops.

Table 4. Effects on number of internode per plant of sunflower at different days after sowing (DAS) in tree-crop intercropping system

Treatment	Internode number					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
D_1	2.00 d	3.00 d	5.00 d	7.00 b	8.00 c	9.00 d
D_2	2.66 c	3.66 c	6.00 c	7.66 b	8.66 bc	9.66 c
D_3	3.33 b	5.00 b	7.00 b	8.66 a	9.33 ab	11.0 b
D_4	4.00 a	5.66 a	8.00 a	9.00 a	10.3 a	11.6 a
LSD0.05	0.13	0.32	0.59	0.88	1.10	0.66
CV(%)	2.82	4.63	5.71	5.45	6.08	3.22

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, D_1= 50 cm distance from the tree base, D_2 = 100 cm distance from the tree base, D_3 = 150 cm distance from the tree base, D_4 = Open field plantation considered as control.

4.5 Internode length

The results on effects of various distance from tree base showed that had significant effect on length of internode at 15, 30, 45, 60, 75 and 90 different days after sowing. The treatment (D_4) gave the maximum length of internode (3.33, 4.33, 7.33, 8.33, 10.3 and 10.3 cm at 15, 30, 45, 60, 75 and 90 DAS, respectively). Then the treatment (D_1) gave minimum (1.93, 3.13, 5.06, 5.66, 7.66 and 8.16 cm at 15, 30, 45, 60, 75 and 90 DAS, respectively) length of internode (Table 5). In moringa crop interaction, D_3 appeared as the best treatment because there are not significantly difference with D_4.

Table 5. Effect of different distance on internode length (cm) of sunflower plant at different days after sowing (DAS)

Treatment	Internode Length(cm)					
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
D_1	1.93 d	3.13 c	5.06 c	5.66 c	7.66 d	8.16 d
D_2	2.30 c	3.66 b	5.46 c	5.93 b	8.66 c	9.00 c
D_3	3.03 b	4.16 a	6.50 b	8.16 a	9.33 b	9.66 b
D_4	3.33 a	4.33 a	7.33 a	8.33 a	10.3 a	10.3 a
$LSD_{0.05}$	0.17	0.28	0.47	0.21	0.66	0.51
CV(%)	3.26	3.72	3.89	1.49	3.70	2.75

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, D_1= 50 cm distance from the tree base, D_2 = 100 cm distance from the tree base, D_3 = 150 cm distance from the tree base, D_4 = Open field plantation considered as control.

4.6 Canopy area

The results on effects of various distance showed that had significant effect on canopy area at 15, 30, 45, 60, 75 and 90 different days after sowing. The control (D_4) gave the maximum canopy area (10.3, 18.3, 35.0, 40.0, 42.0 and 44.0 cm^2 at 15, 30, 45, 60, 75 and 90 DAS, respectively). The treatment (D_1) gave minimum (6.00, 14.0, 30.0, 36.0, 38.6, and 40.0 cm^2 at 15, 30, 45, 60, 75 and 90 DAS, respectively) canopy area (Table 6). The canopy area was increased with the increasing of days after sowing.

Table 6: Effect of different distance from tree base on canopy area (cm) of sunflower at different days after sowing (DAS)

Treatment	Canopy area (cm^2)					
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
D_1	6.00 d	14.0 d	30.00 d	36.00 c	38.60 c	40.00 c
D_2	7.33 c	15.3 c	32.00 c	37.00 bc	40.00 bc	41.00 c
D_3	9.00 b	17.0 b	33.00 b	38.00 b	40.60 ab	42.30 b
D_4	10.3 a	18.3 a	35.00 a	40.00 a	42.00 a	44.00 a
$LSD_{0.05}$	0.66	0.66	0.73	1.05	1.99	1.01
CV(%)	4.08	2.06	1.40	1.74	3.09	1.52

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, D_1= 50 cm distance from the tree base, D_2 = 100 cm distance from the tree base, D_3 = 150 cm distance from the tree base, D_4 = Open field plantation considered as control.

4.7 Stem diameter of sunflower

Diameter of sunflower was affected significantly by the different distance from the tree base (Table 7). The lowest diameter in D_1 (3.10cm) was noted in 90 DAS (50 cm distance from the tree) and highest diameter was noted in D_4 (Open field referred as control).

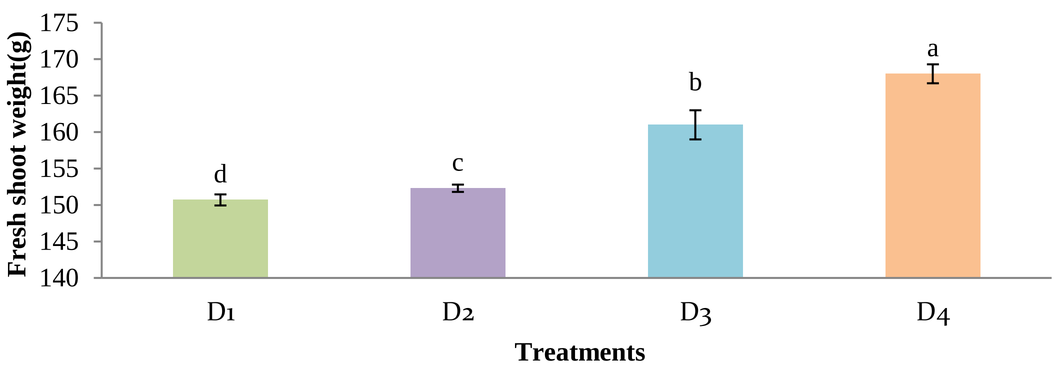
Table 7: Effect of different distance from tree base on diameter (cm) of sunflower at different days after sowing (DAS)

Treatment	Diameter (cm)					
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
D_1	0.23 d	0.40 d	1.16 d	1.86 d	2.60 d	3.10 d
D_2	0.33 c	0.53 c	1.40 c	2.16 c	3.06 c	3.33 c
D_3	0.43 b	0.70 b	1.76 b	2.60 b	3.23 b	3.70 b
D_4	0.53 a	0.80 a	2.06 a	2.90 a	3.50 a	4.10 a
$LSD_{0.05}$	0.02	0.05	0.17	0.24	0.15	0.12
CV(%)	3.22	5.12	5.41	5.04	2.57	1.81

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, D_1= 50 cm distance from the tree base, D_2 = 100 cm distance from the tree base, D_3 = 150 cm distance from the tree base, D_4 = Open field plantation considered as control.

4.8 Fresh weight of shoot (g)

The results on effects of various distance had showed significant effect on fresh weight of shoot at harvest (90 DAS). The control (D_4) gave the maximum fresh weight of shoot (168 g) at harvest respectively. The treatment (D_1) gave minimum (150.7 g) fresh weight of shoot at harvest respectively (Figure 1). The Fresh weight of shoot was increased with the increasing of days after sowing. Competition for moisture in agroforestry systems is common occurring phenomenon, which can affect the fresh shoot weight of sunflower adversely. Closer distance cause higher competition while increasing distance gradually decreasing competition.

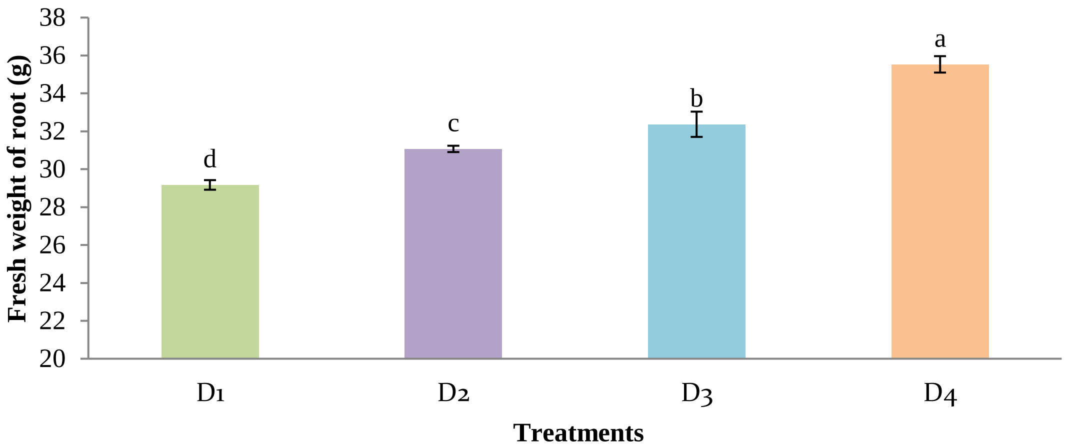


In the graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here D_1= 50 cm distance from the tree base, D_2 = 100 cm distance from the tree base, D_3 = 150 cm distance from the tree base, D_4 = Open field plantation considered as control.

Figure 1.Effect of different distance from tree base on fresh shoot weight of sunflower at harvest ($LSD_{0.05}$= 0.94).

4.9 Fresh weight of root (g)

Fresh weight of root was significantly varied by various distance at harvest (90 DAS). The maximum fresh weight of root (35.53 g) at harvest was observed from control (D_4). The treatment (D_1) gave minimum (29.17 g) fresh weight of shoot at harvest (Figure 2). The Fresh weight of shoot was increased with the increasing of days after sowing. Root competition between tree and crop for water and/or nutrients in the topsoil. Tree root are likely to compete more with the crop for scarce nutrients, while deep tree roots can act as a 'nutrient pump' or 'safety net' , where nutrients are so deep that they are out of reach for the crop roots, result in poor growth and development.

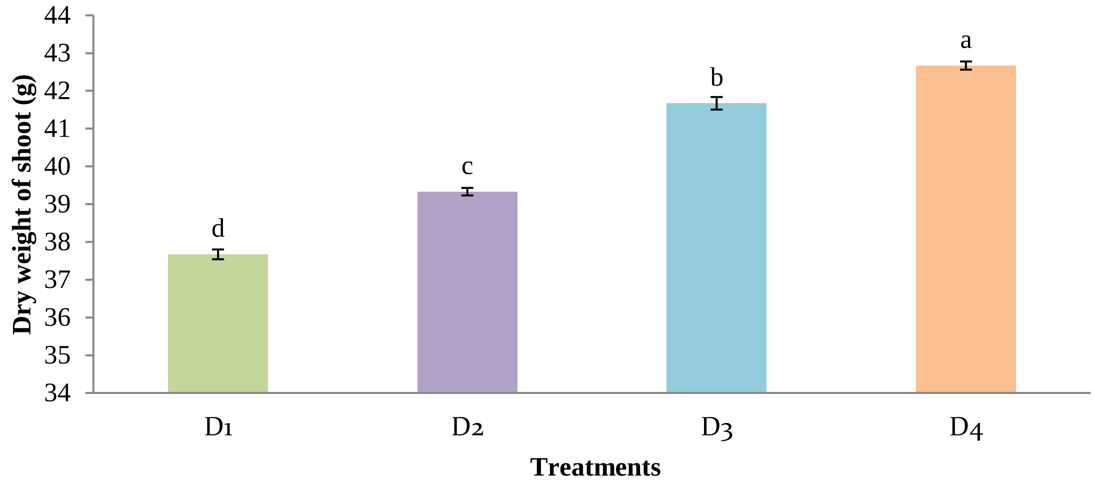


In the graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here D_1= 50 cm distance from the tree base, D_2 = 100 cm distance from the tree base, D_3 = 150 cm distance from the tree base, D_4 = Open field plantation considered as control.

Figure 2. Effect of different distance from tree base on fresh root weight of sunflower at harvest ($LSD_{0.05}$= 0.29).

4.10 Dry weight of shoot (g)

The results on effects of various distance showed that had significant effect on dry weight of shoot at harvest (90 DAS). The control (D_4) gave the maximum dry weight of shoot (42.67 g) at harvest. The treatment (D_1) gave minimum (37.67 g) dry weight of shoot at harvest (Figure 3). The dry weight of shoot was increased with the increasing of days after sowing.

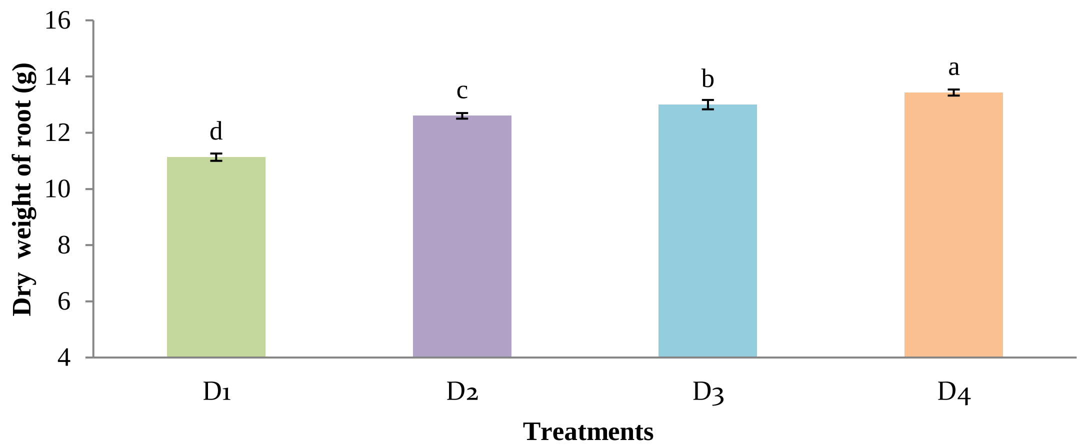


In the graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here D_1= 50 cm distance from the tree base, D_2 = 100 cm distance from the tree base, D_3 = 150 cm distance from the tree base, D_4 = Open field plantation considered as control.

Figure 3. Effect of different distance from tree base on dry shoot weight of sunflower at harvest ($LSD_{0.05}$= 0.99).

4.11 Dry weight of root (g)

Dry weight of root was significantly varied by various distance at harvest (90 DAS). The maximum dry weight of root (13.43 g) at harvest was observed from control (D_4). The treatment D_1 gave minimum (11.13 g) dry weight of shoot at harvest (Figure 4). The dry weight of shoot was increased with the increasing of days after sowing.



In the graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here D_1= 50 cm distance from the tree base, D_2 = 100 cm distance from the tree base, D_3 = 150 cm distance from the tree base, D_4 = Open field plantation considered as control.

Figure 4. Effect of different distance from tree base on dry root weight of sunflower at harvest ($LSD_{0.05}$= 0.99).

4.12 Total number of seeds plant^{-1}

The total number of seeds per plant was significantly affected by various distance. The highest total number of seeds per plant (451.7) was recorded in D_4 and the minimum (356.30) in D_1 treatment (Table 8). The total number of seeds per plant was increased with the increasing plant to plant distance.

4.13 Number of filled seed per plant

Number of filled seed per plant was significantly influenced by various distance (Table 8). The highest number of filled seed per plant (320.00) and lowest (175.30) of filled seed per plant was obtained with D_4 and D_1 treatment, respectively.

4.14Number of unfilled seed per plant

Among the traits made, number of unfilled seed per plant plays a vital role in yield reduction. Results showed that various distance had significant effect in respect of the number of unfilled seed per plant (Table 8). The control treatment produced minimum number (11.8) of unfilled seed per plant and D_1treatment produced maximum number (181.00) of unfilled seed per plant.

4.15 1000-seed weight

Different distance had significant effect on 1000-seed weight (Table 8). From the Table 5, it was revealed that 1000-seed weight of D_4 treatment much heavier (115 g) than that of D_1 (100.00 g), which is attributed to bold and larger seed size of this treatment.

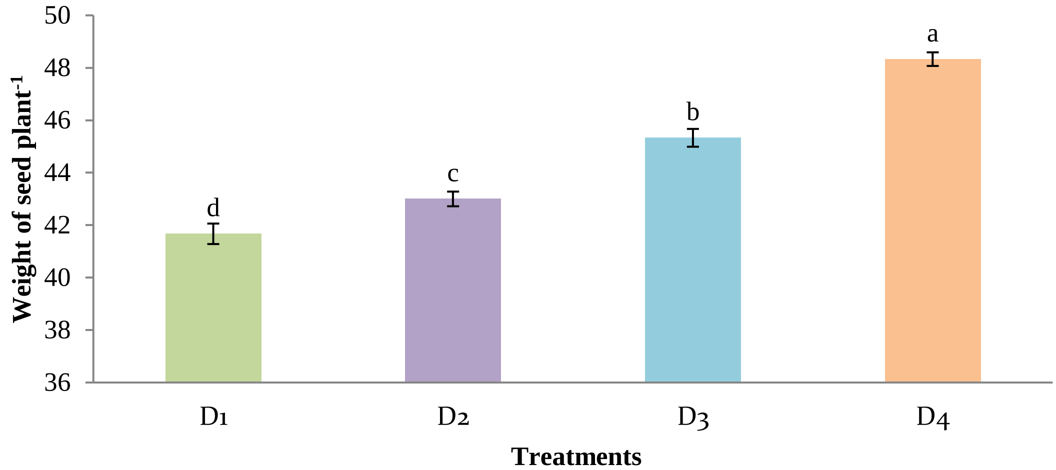
Table 8: Effect of different distance from tree base on yield contributing character of sunflower

Treatment	Total number of seed plant^{-1}	Number of filed Seed plant^{-1}	Number of unfiled Seed plant^{-1}	1000 seed weight (g)
D_1	356.3d	175.3d	181a	100.00c
D_2	380.7c	216.3c	164.3b	109.00b
D_3	424.7b	270b	154.7c	110.00b
D_4	451.7a	320a	131.7d	115.00a
$LSD_{0.05}$	10.31	19.95	7.03	2.71
CV(%)	1.60	5.08	2.78	1.57

In the graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here D_1= 50 cm distance from the tree base, D_2 = 100 cm distance from the tree base, D_3 = 150 cm distance from the tree base, D_4 = Open field plantation considered as control.

4.16 Weight of seed per plant

Seed weight per plant is a function of interplay of various yield components such as seed per plant and 1000-seed weight. In present experiment various distance had significant effect on Seed weight per plant (Figure 5). It was evident from Table 12 that D_4 produced higher (48.33 g) seed weight per plant and the minimum seed weight per plant D_1 (41.67g).

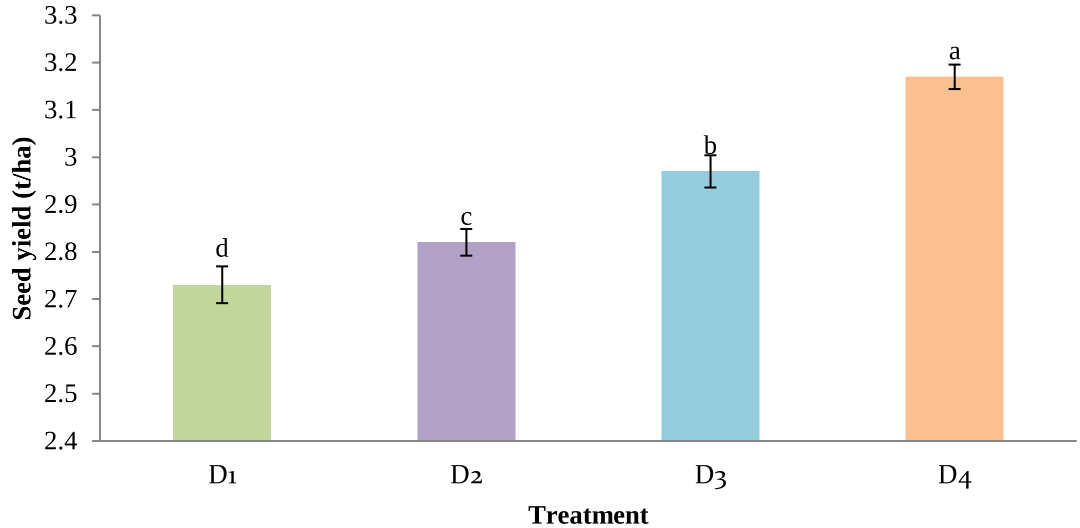


In the graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here D_1= 50 cm distance from the tree base, D_2 = 100 cm distance from the tree base, D_3 = 150 cm distance from the tree base, D_4 = Open field plantation considered as control.

Figure 5. Effect of different distance from tree base on weight of seed plant^{-1} of sunflower ($LSD_{0.05}$= 0.84).

4.17 Seed yield (t/ha)

Seed yield is a function of interplay of various yield components such as seed per plant and 1000-seed weight. In present experiment various distance had significant effect on Seed yield (t/ha) (Figure 6). It was evident from Fig.1 that D_4 produced highest seed yield (3.17 t/ha) and the minimum seed yield (2.73 t/ha) was obtained from D_1 (50 cm distance from the tree base). Tanni *et al*. (2010) reported that in radish, the highest value of yield (20.97 t/ha^{-1}) was found under open field condition while decreasing distance distance from the *Xylia dolabriformis* tree gradually decreasing the yield.



In the graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here D_1= 50 cm distance from the tree base, D_2 = 100 cm distance from the tree base, D_3 = 150 cm distance from the tree base, D_4 = Open field plantation considered as control.

Figure 6. Effect of different distance from tree base on seed yield of sunflower ($LSD_{0.05}$= 0.04).

4.18 Cost of moringa based agroforestry system

Moringa based agroforestry system cost includes all the activities from field preparation to production, harvesting and marketing. Different types of costs have been presented in (Table 13, 14, 15, 17, 18, and 19). Moringa produces an average of 166 fruits per tree with an average yield of 11 tones/ha. The pods were harvested in 3 months from January to march and pods were, about 20-40 cm long with a girth of 6.40 cm and an average weight about 280 g. They are fleshy (70% flesh), with lower fiber and good cooking quality.

Dig pits of size 45 cm × 45 cm × 45 cm

Spacing: 6 × 10 m^2

Number of plants ha^{-1} = 166

Yield per $plant^{-1}$ = 67 kg

Overhead cost

Land value ha^{-1} was 200000 taka. Land cost at 12.5 % interest for 6 month was 12500 taka. For 1 years 25000 taka.

Miscellaneous cost (common cost)

It was 5% of total input cost

Input cost=Non material cost + Material cost

Moringa

It produces an average of 240 fruits per tree with an average yield of 11 ton/ha. The pods were harvested in 3 months from January to march and pods were, about 20-40 cm long with a girth of 6.40 cm and an average weight about 280 g. They are fleshy (70% flesh), with lower fiber and good cooking quality.

Dig pits of size 45 cm × 45 cm × 45 cm

Spacing**:** 6 × 10 m^2

Number of plants ha^{-1}= 166

Yield per $plant^{-1}$ = 67 kg

Input cost=Non material cost + Material cost

4.18.1Non material cost

Items	No. of labor required	amount
Harvesting and other work	30	16500
	Grand total=	16500

(Individual labor wages 550 taka day^{-1}).

4.18.2 Material cost (Moringa)

SL No.	Quantity (ton/kg/ha/times	Item cost (TK)	Cost (Tk/ha)
Fertilizers			
Cowdung	60 ton	400	24000
Urea	250 kg	16	4000
TSP	125 kg	22	2750
MoP	250 kg	15	3750
Gypsum	25 kg	8	200
Zinc sulphate	25 kg	250	6250
Boron	25 kg	110	2750
Irrigation	3 times	1000	3000
		Grand total	46700

4.18.3 Material cost (sunflower)

SL No.	Quantity (ton/kg/ha/times	item cost(TK)	Cost (Tk/ha)
Seed rate ha^{-1}	166	75	12450
Fertilizers			
Cowdung	10 ton	400	4000
Urea	200 kg	16	3200
TSP	180 kg	22	3960
MoP	170 kg	15	2550
Boron	12 kg	110	1320
Irrigation	3 times	1000	3000
Tractor	1	3000	3000
		Grand total	33480

4.18.4 Total cost of production (sunflower)

Non-material cost	Material cost		Total input cost (A)	Interest on input cost @ 12.5% for 6 month (B)	Miscellaneous cost is 5% of total input cost (C)	Overhead cost (6 month) (D)	Total cost of production (A+B+C+D)
	i	ii					
16500		33480	49980	3124	2499	12500	68103

4.18.5 Total cost of production (Interaction)

Non-material cost	Material cost		Total input cost (A)	Interest on input cost @ 12.5% for 6 month (B)	Miscellaneous cost is 5% of total input cost (C)	Overhead cost (6 month) (D)	Total cost of production (A+B+C+D)
	i	ii					
16500	46700	33480	96680	6043	4834	12500	120057

4.18.5 Gross return from sunflower cultivation

Moringa pods = 1 kg 50 taka so 1 ton = 50000 taka

Sunflower = 1 kg 80 taka so 1 ton = 80000 taka

Treatment	Moringa pods yield (t/ha)	Value	Sunflower yield (t/ha)	Value	Gross retrun (Tk)
D_1	11	550000	2.73	218400	768400
D_2	11	550000	2.82	225600	775600
D_3	11	550000	2.97	237600	787600
D_4	0	0	3.17	253600	253600

4.18.7 Profitability of moringa-sunflower intercropping

Treatment	Gross retrun (Tk)	Total cost of production	Net return	BCR
D_1	768400	120057	648343	6.40
D_2	775600	120057	655543	6.46
D_3	787600	120057	667543	6.56
D_4	253600	68103	185497	3.72

4.19 Gross return

In case of gross return, different treatment showed different levels of gross return under the present trial. The highest gross return (Tk.787600) was found from the treatment D_3 and the second highest gross return (Tk.775600) was obtained from D_2 treatment combination. The lowest gross return (Tk.253600) was obtained from D_4.

4.20 Net return

In case of net return, different treatment showed different levels of net return under the present trial. The highest net return (Tk. 667543) was obtained from the treatment D_3 and the second highest net return (Tk. 655543) was found from the D_2. The lowest (Tk. 185497) net return was found from D_4 treatment.

4.21 Benefit Cost Ratio

The distance of different tree for benefit cost ratio was different in all treatment. The highest benefit cost ratio (6.56) was found from the treatment D_3 and the second highest benefit cost ratio (6.46) was found from D_2 treatment. The lowest benefit cost ratio (3.72) was found from the D_4 treatment. From the economic point of view, it was apparent from the above results that the treatment D_3 was more profitable than rest of treatment. All the four treatments evaluated in this experiment varied significantly for all studied parameters. In this experiment, $D_3$was the most promising treatment in terms of morpho-physiological traits. Control treatment (D_4) with regards to yield and yield contributing characters. Leaf number, plant height, and height growth rate are considered as the most desirable characters for sunflower. At harvest, plant height, its growth rate, and leaf number varied widely among the treatment. It confirmed the belowground tree-crop competitions for resource sharing among the treatments were minimum in the early growing period gradually increased with the advancement of crop growth (Zamora *et al*., 2007).

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY

The experiment was conducted to performance of sunflower under moringa based agroforestry system as well as to find out the best tree crop interactions in Agroforestry system at the Agroforestry Field under the Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2020 to March 2021. An experiment was conducted to assess the performance of sunflower in association with moringa tree. Four treatments namely, D_1=50 cm distance from the tree base, D_2=100 cm distance from the tree base, D_3=150 cm distance from the tree base, D_4=Open field referred to as control (plant to plant distance 25 cm) were used in Randomized Complete Block Design (RCBD) with four replications. The observations pertaining to growth and yield attributes of moringa recorded during the course of investigation were statistically analyzed and significance of results verified. All the growth and yield contributing characters like plant height, leaf length, leaf breadth, number of internode plant^{-1}, internode length, fresh weight of shoot (g), fresh weight of root (g), dry weight shoot (g), dry weight of root (g), number of seed plant^{-1}, weight of seed plant^{-1} (g), and yield per hectare varied significantly due to distance. In 15 DAS the highest height (cm) was found in the plants belong to treatment D_4. The highest plant height was observed in D_4 throughout the experiment. In 90 DAS the highest plant height (95.0 cm) was recorded in D_4 treatment. The treatment (D_4) gave the maximum length of leaves (8.40, 15.3, 20.0, 22.1, 24.0 and 24.2 cm at 15, 30, 45, 60, 75 and 90 DAS, respectively). Control (D_4) treatment produced the widest leaves (1.16, 8.16, 13.3, 16.0, 20.0 and 20.0 cm at 15, 30, 45, 60, 75 and 90 DAS, respectively). The maximum internode number (4.00, 5.66, 8.00, 9.00, 10.3 and 11.6 at15, 30, 45, 60, 75 and 90 DAS, respectively) was produced by (D_4) treatment. The treatment (D_4) gave the maximum length of internode (3.33, 4.33, 7.33, 8.33, 10.3 and 10.3 cm at 15, 30, 45, 60, 75 and 90 DAS, respectively). The control (D_4) gave 44.0 cm at 15, 30, 45, 60, 75 and 90 DAS, respectively) highest diameter. The control (D_4) gave the maximum fresh weight of shoot (168 g) fresh weight of root (35.53 g), dry weight of shoot (42.67 g), dry weight of root (13.43g), total number of seeds plant^{-1}(451.7), filled seeds plant^{-1} (320.00) and seed yield (3.17 t/ha). Whereas the minimum seed yield (2.73 t/ha) was obtained from D_1 (50 cm distance from the tree base).

In case of gross return, different treatment showed different levels of gross return under the present trial. The highest gross return (Tk. 787600) was found from the treatment D_3. The lowest gross return (Tk. 253600) was obtained from D_4.

In case of net return, different treatment showed different levels of net return under the present trial. The highest net return (Tk. 667543) was obtained from the treatment D_3. The lowest (Tk.185497) net return was found from D_4 treatment.

The distance of different tree for benefit cost ratio was different in all treatment. The highest benefit cost ratio (6.56) was found from the treatment D_3. The lowest benefit cost ratio (3.72) was found from the D_4 treatment.

CONCLUSION

The yield performance of sunflower affected significantly due to different distance from Moringa tree base. The highest yield of sunflower was observed in control condition. Apart from control, the second highest yield was found under D_3 treatment, which was 6.30% less than that of control condition. The yield decline continued up to 11.04% for treatment D_2 and13.88% for treatment D_1 compared to that of control condition. Therefore observed best yield performance of sunflower at treatment D_3 was 150 cm distance from the tree base in association with Moringa sapling. The highest benefit cost ratio (6.56) was found from the treatment D_3 and the second highest benefit cost ratio (6.46) was found from D_2 treatment. The lowest benefit cost ratio (3.72) was found from the D_1 treatment. From the economic point of view, it was apparent from the above results that the treatment D_3 was more profitable than rest of treatment.

RECOMMENDATIONS

This experiment sunflower in association with Moringa sapling was examined. So, more robi and kharif vegetables and other crop should cultivate with Moringa tree to find out suitable vegetables and crop for Moringa based agroforestry system. Light interception should the actual reason of growth and yield variation.

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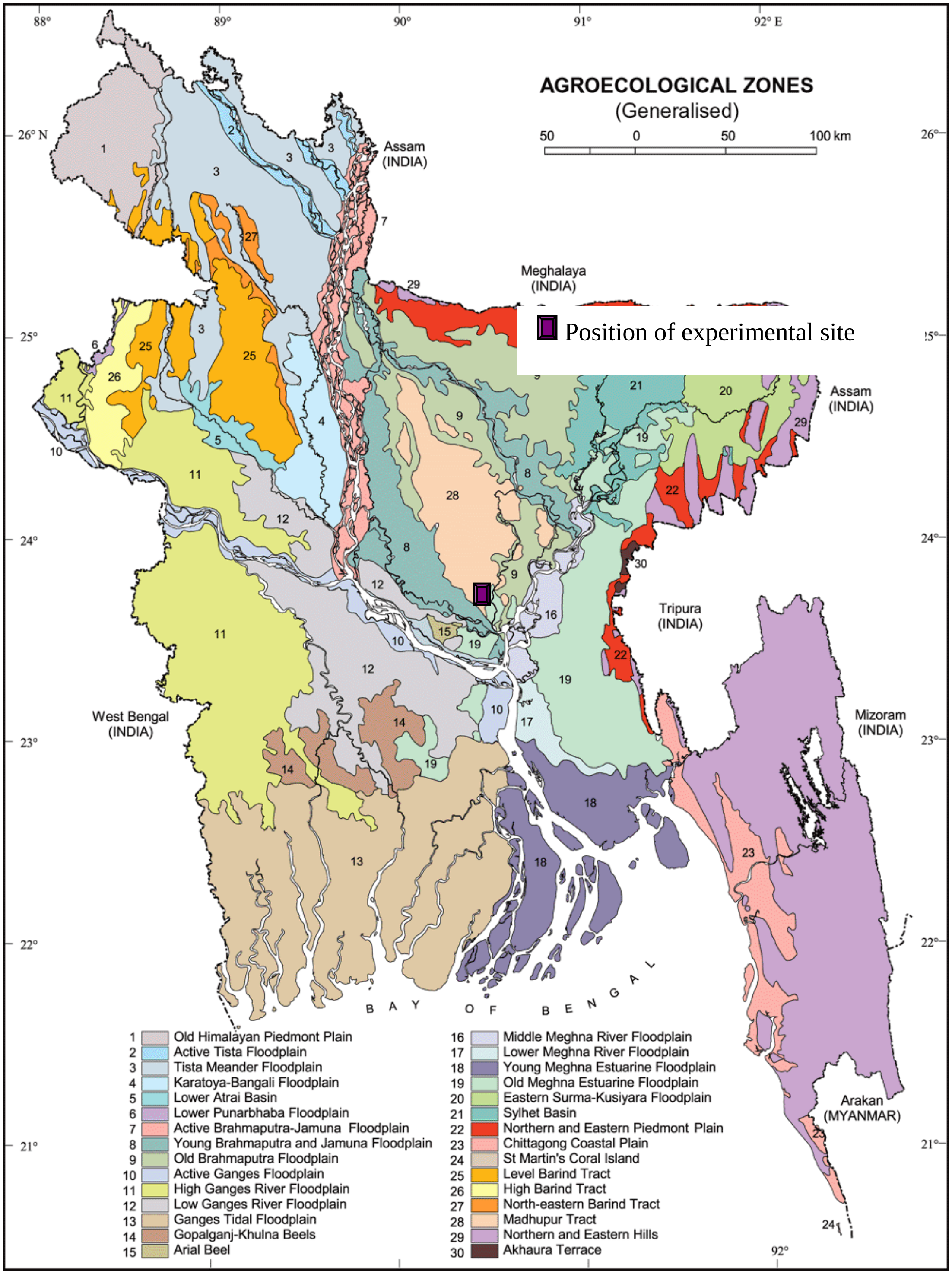
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Monthly air temperature, rainfall and relative humidity of the experimental site during the study period (November, 2020 to March, 2021)

Year	Month	Air temperature (^{0}C)			Rainfall (mm)	Relative humidity (%)
		Max.	Min.	Mean		
2019	November	28.6	20.0	24.3	34.4	76.0
	December	27.6	14.4	21.00	12.8	68
2020	January	24.4	12.5	18.45	7.7	67.00
	February	28.1	15.5	21.8	28.9	59
	March	29.1	16.5	22.8	28.8	65

Source: The Meteorological Department (Weather division) of Bangladesh, Agargoan, Dhaka

Appendix III. Physiochemical properties of the initial soil

Characteristics	**Value**
Partical size analysis.	
% Sand	26
% Silt	45
% Clay	29
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI), Dhaka-1207

Appendix IV. Analysis of variance of the data on plant height of sunflower as influenced by various distance of Moringa based agroforestry system.

Source	DF	Means square					
		Plant height					
		15 DAS	30 DAS	45 DAS	60DAS	75 DAS	90 DAS
Replication	2	0.0833	0.3333	0.08333	0.0808	0.04083	0.0058
Treatment	3	15.6667	15.1111	6.44444	10.9033	8.33861	14.8786
Error	6	0.0833	0.1111	0.19444	0.0142	0.01194	0.0036

Appendix V. Analysis of variance of the data on Leaf number of sunflower as influenced by various distance of Moringa based agroforestry system

Source	DF	Means square					
		Leaf number					
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Replication	2	1.18	1.04E+0	3.49	0.08333	0.08333	0.58333
Treatment	3	11	33	33	2.33333	5.41667	6.55556
Error	6	1.43	2.44E+0	2.05	0.08333	0.08333	0.13889

Appendix VI. Analysis of variance of the data on Leaf Length of sunflower as influenced by various distance of Moringa based agroforestry system

Source	DF	Means square					
		Leaf length					
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Replication	2	0.05083	0.10583	0.04083	0.1075	0.13	0.02083
Treatment	3	4.5875	5.76889	4.87417	2.65889	2.51639	2.60083
Error	6	0.01083	0.02806	0.02417	0.02972	0.07889	0.0075

Appendix VII. Analysis of variance of the data on leaf breath of sunflower as influenced by various distance of Moringa based agroforestry system

Source	DF	Means square					
		Leaf breath					
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Replication	2	0.07583	0.06083	0.04083	0.00583	0.02083	0.03
Treatment	3	5.73417	2.51861	7.42556	4.73639	4.75	3.27667
Error	6	0.02583	0.01861	0.02639	0.00139	0.02083	0.00333

Appendix VIII. Analysis of variance of the data on Number of internode of sunflower as influenced by various distance of Moringa based agroforestry system

Source	DF	Means Square					
		Number of internode					
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Replication	2	0.25	0.08333	1.5	0.08333	2.08333	0.33333
Treatment	3	2.22222	4.44444	15	2.52778	2.97222	4.44444
Error	6	0.13889	0.19444	4.19	0.19444	0.30556	0.11111

Appendix IX. Analysis of variance of the data on Internode Length of sunflower as influenced by various distance of Moringa based agroforestry system

Source	DF	Means Square					
		Internode Length					
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Replication	2	0.0675	0.1425	0.01083	3.24	3	0.05083
Treatment	3	1.25	0.87861	3.14972	6.05194	3.77778	4.5875
Error	6	0.0075	0.02028	0.05639	0.01111	0.11111	0.01083

Appendix X. Analysis of variance of the data on Canopy Area of sunflower as influenced by various distance of Moringa based agroforestry system

Source	DF	Means Square					
		Canopy Area					
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Replication	2	0.3333	0.3333	5.74	0.0025	0.33333	0.24333
Treatment	3	10.7778	10.7778	39	8.66972	5.77778	2.57639
Error	6	0.1111	0.1111	2.49	0.00139	0.11111	0.06556

Appendix XI. Analysis of variance of the data on diameter of sunflower of sunflower as influenced by various distance of Moringa based agroforestry system

Source	DF	Means square					
		Diameter of sunflower					
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Replication	2	0.00583	0.00583	0.0175	0.02333	0.0175	0.04083
Treatment	3	0.05	0.09417	0.47333	0.62778	0.42889	0.57417
Error	6	0.0025	0.0025	0.0075	0.01444	0.00639	0.00417

Appendix XII. Analysis of variance of the data on Fresh weight of shoot of sunflower as influenced by various distance of Moringa based agroforestry system

Source	DF	Means Square
		Fresh weight of shoot
		90DAS
Replication	2	1
Treatment	3	194.889
Error	6	0.222

Appendix XIII. Analysis of variance of the data on Fresh Root Weight of sunflower as influenced by various distance of Moringa based agroforestry system

Source	DF	Means square
		Fresh Root Weight (g)
		90DAS
Replication	2	0.0908
Treatment	3	21.5133
Error	6	0.0208

Appendix XIV. Analysis of variance of the data on Fresh Shoot Weight of sunflower as influenced by various distance of Moringa based agroforestry system

Source	DF	Means Square
		Dry shoot weight(g)
		90DAS
Replicati	2	0.5833
Treatment	3	15.3333
Error	6	0.25

Appendix XV. Analysis of variance of the data on Dry Root Weight of sunflower as influenced by various distance of Moringa based agroforestry system

Source	DF	Means Square
		Dry Root Weight (g)
		90 DAS
Replication	2	0.03083
Treatment	3	2.99194
Error	6	0.02194

Appendix XVI. Analysis of variance of the data on yield and yield contribution character of sunflower as influenced by various distance of Moringa based agroforestry system

Source	DF	Means Square				
		Number of Filed Seed Per Plant	Number of Unfiled Seed Per Plant	1000 seed weight (g)	Seed weight per plant	Seed yield (t/ha)
Replication	2	0.73	0.00043	2.54	0.0833	0.0908
Treatment	3	8403.14	0.33876	117	25.6389	27.0067
Error	6	0.27	0.00026	2.51	0.3056	0.0342

PLATE

Plate1. Layout of the experimental field

Plate2. Seedling of sunflower plant

Plate3. Experimental plot

Plate 4. Data collection