GROWTH AND YIELD PERFORMANCE OF STEM AMARANTH UNDER MORINGA BASED AGROFORESTRY SYSTEM

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ABSTRACT

A field experiment was conducted at the Agroforestry research field of Sher-e-Bangla Agricultural University Dhaka, to evaluation of the growth and yield performance of stem amaranth *(Amaranthus lividus)* under moringa *(Moringa oliefera)* based Agroforestry system during the period from January 2020 to April 2020. The experiment was consisted of six treatments *viz;* T_1 = 25 cm distance from the tree base, T_2 = 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 =125 cm distance from the tree base and T_6 = Open field referred to as control (Sole crop) treatment which were arranged by following Randomized Complete Block Design (RCBD). Data on different parameters were collected for assessing the results of this experiment and showed significant variation in respect of growth and yield of amaranth due to the effect of different treatments. In *M. oleifera and A. lividus* based agroforestry system, *M. oleifera* suppressed crop growth and productivity of *A. lividus* at closer distance from the tree row. Increasing distance from the *M. oleifera* trees gradually increasing the growth and yield characteristics of stem amaranth. Among different *M. oleifera and A. lividus* interactions, the highest yield (26.30 t ha^{-1}) of *A. lividus* was obtained in T_5 (125 cm distance from the tree base) treatment comparable to others treatments. The crop (*A. lividus)* growth and yield decreased under *M. oleifera* tree but due to the presence of *M. oleifera* tree economical returns obtained from *M. oleifera and A. lividus* based agroforestry system was higher than sole cropping. In moringa amaranth interaction, the highest gross return (613700 Tk), net return (548034 Tk) and benefit cost ratio (9.35) were observed in T_5 (125 cm distance from the tree base) treatment and on the other hand the lowest gross return (314800), net return (264648), and benefit cost ratio (6.28) was observed in sole cropping.

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ABBREVIATIONS

Full word	Abbreviations	Full word	Abbreviations
Agriculture	Agric.	Milliliter	mL
Agro-Ecological Zone	AEZ	Milliequivalents	Meqs
And others	et al.	Triple super phosphate	TSP
Applied	App.	Milligram(s)	mg
Asian Journal of Biotechnology and Genetic Engineering	AJBGE	Millimeter	mm
Bangladesh Agricultural Research Institute	BARI	Mean sea level	MSL
Bangladesh Bureau of Statistics	BBS	Metric ton	MT
Biology	Biol.	North	N
Biotechnology	Biotechnol.	Nutrition	Nutr.
Botany	Bot.	Pakistan	Pak.
Centimeter	Cm	Negative logarithm of hydrogen ion concentration (-log[H+])	pH
Completely randomized design	CRD	Plant Genetic Resource Centre	PGRC
Cultivar	Cv.	Regulation	Regul.
Degree Celsius	°C	Research and Resource	Res.
Department	Dept.	Review	Rev.
Development	Dev.	Science	Sci.
Dry Flowables	DF	Society	Soc.
East	E	Soil plant analysis development	SPAD
Editors	Eds.	Soil Resource Development Institute	SRDI
Emulsifiable concentrate	EC	Technology	Technol.
Entomology	Entomol.	Tropical	Trop.
Environmment	Environ.	Thailand	Thai.
Food and Agriculture Organization	FAO	United Kingdom	U.K.
Gram	g	University	Univ.
Horticulture	Hort.	United States of America	USA
International	Intl.	Wettable powder	WP
Journal	J.	Serial	Sl.
Kilogram	Kg	Percentage	%
Least Significant Difference	LSD	Number	No.
Liter	L	Microgram	µ

CHAPTER I

INTRODUCTION

Forests are of great importance to any country and mankind as they contribute significantly to the environmental, economic and social amelioration. In developing country like Bangladesh, there is a great demand for fuel wood and timber. This demand is mainly met out from trees outside forests and on the farms. Forests are very important in maintaining ecological balance, provides habitat for a large number of plant and animal species and act as natural obstruction of soil erosion (Hossain *et al.*, 2008). Recently, forests and trees have received an impetus in light of climate change scenario. Trees play an important role in climate change mitigation and adaptation. Bangladesh has 2.46 million ha of forestland covering about 17% of the country's area. Bangladesh Forest Department (FD) controls, manages and protects all state-owned forests except Unclassed Stated Forest (FD, 2012). More than 90% of the state-owned forest land is concentrated in 12 districts in the eastern and south-western regions of the country and out of 64 districts, 28 districts have no state-owned forest at all (GoB, 1990). The per capita land area is decreasing at an alarming rate due to increasing population (Hossain and Bari, 1996). This availability of land has been declined from 0.19 ha in 1961 to 0.101 ha in 1992 and now the country is claimed to have the lowest per capita arable land of 0.02 ha (Iqbal, *et al*., 2002). Henceforth to increase the forest cover, activities like afforestation, reforestation, enrichment planting and Agroforestry has to be carried out.

Agroforestry is a land-use systems that combine agricultural and silvicultural practices to produce food, wood, and other products (Brenda, 2010). Agroforestry has also been gaining recognition as a tool for reducing poverty, improving food self-sufficiency for farmers, and increasing the productivity and income for small scale farmers (Islam *et al*., 2021; Leakey, 2014). Likewise, Agroforestry unifies a method of producing trees and crops and/or livestock in a single system on the same piece or unit of land (Rahim and Hasnain, 2010). Cultivating trees and agricultural crops in intimate combination with one another is an ancient practice that farmers have used throughout the world.

Trees are known to bring about changes in edaphic, micro-climatic, floral, faunal and other components of the eco-system through bio-recycling of mineral elements, environmental modifications (including thermal and moisture regime) and changes in floral and faunal composition (Shukla, 2009). Trees can improve the nutrient balance of soil by reducing unproductive nutrient losses from erosion and leaching and by increasing nutrient inputs through nitrogen fixation and increase biological activities by providing biomass and suitable microclimate (Schroth and Sinclair, 2003). The fast growing, multipurpose and short rotation trees are generally used in agroforestry and other afforestation programmes. However, the species varies according to agroecological zone, the commonly used agroforestry species in Bangladesh are *Moringa oleifera, Acacia auriculiformis, Casuarina equisetifolia, Eucalyptus terticornis, Leucaena leucocephala, Melia composita, Populus deltoides, Tectona grandis, Michelia champaca* etc.

Moringa oleifera Lam commonly known byvarious name like drumstick, moringa, sahajan belongs to family Moringaceae. The name of tree varied according to its vicinity in varied province of country. Moringa is a wonder tree with its great medicinal, industrial, food, fodder, and fuel values for both human and their livestock. The origin of tree has to be believed in sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan (Mulugeta and Fekadu, 2014). The drought resistant, easy acquiescently in all type of soil and climate, makes it highly suitable in all parts of the world especially in semi-arid tropics. Moringa naturally found in tropical and sub-tropical forest of Asian reason or grow by farmers on bund of agricultural land. India has first rank in case of area and production of moringa. It is a suitable tree for traditional agroforestry in the homestead because of its versatility (Odee *et al.,* 2001; Palada and Chang, 2003; Nduwayezu *etal.*, 2007).

Moringa grown in homestead gardens, in between of agricultural crop/intercrop and on the boundaries of agricultural fields. The tree and its products are highly versatile in nature. The tree fulfills all the basic needs of human like food, health (medicinal properties) and wealth (by selling of its products). It is said to have known immune boosting ability (Ncube, 2006; Smith and Eyzaguirre, 2007). Every parts of tree has used in various manner by the human being (Kumar *et al*., 2017). The very most utilizable parts of tree are green pod, tender leaves, flowers and seed for food purpose. With Moringa tree parts, retaining high percentages of vital nutrients throughout the year (Melesse *et al.*, 2012). The leaves of moringa are rich source of many nutrients, vitamins and protein. Most of the products of tree are consumed by the local people itself and remaining are sold in market. The local people used the leaves and flower of moringa for vegetable purpose (Gopalakrishnan *et al*., 2016). The leaves and tender parts of tree also used as a fodder purpose. The wood produce from it are soft in nature so it is used as a fuel wood and sometime used for construction of local structures like hut, shed etc (Kumar *et al.*, 2017). The seed oil of moringa is edible used for cooking purpose by the local healers. Moringa seed can also be used as a water purifier both for the urban and rural inhabitants (Delelegn*et al.*, 2018).

Stem amaranth *(Amaranthus lividus)* belongs to the genus *Amaranthus*. *Amaranthus* is a core genus of the family Amaranthaceae, consists of 70 species of hardy, weedy, herbaceous, fast growing grains and vegetables, widely distributed in America, Africa, Australia, Asia, and Europe (Franssen *et al*., 2001). Among them only 17 species produce edible leaves and 3 produce food grains (Jansen, 2004). *Amaranthus* leaves and stems are rich sources of antioxidants, protein, carotenoids, vitamin C, dietary fiber, and minerals such as calcium, iron, zinc, and magnesium (Sarker *et al*., 2018a; 2018b; 2018c). Member of these genera are widely used as traditional medicinal plant, especially as antiviral, antimalarial, antidiabetic, antibacterial, antihelminthic, snake antidote (Kusumaningtyas *et al*., 2006; Vardhana, 2011; Kumar *et al*., 2010) and tolerant to drought and salinity (Sarker and Oba, 2018i, 2018j). *Amaranthus lividus* is an inexpensive vegetable whose stem and leaves are used as human food (Martin and Ruberte, 1989). Flashy succulent stems and leaves of *A. lividus* are very popular in Bangladesh including Asia, Africa and are becoming increasingly popular in the rest of the continent and elsewhere due to its attractive leaf and stem color, taste and nutritional value. It is one of the cheapest vegetables because of low production cost and high yield. Compared to lettuce, *Amaranthus* contains 18 times more vitamin A, 13 times more vitamin C, 20 times more calcium and 7 times more iron (Guillet, 2004). It has been rated equal or superior in taste to spinach and is considerably higher in carotenoids (90-200 mg kg^{-1}), protein (14-30% on dry weight basis) and ascorbic acid (about 28 mg $100g^{-1}$) (Wu-leung *et al*., 1968; Makus, 1990; Prakash and Pal, 1991; Shukla *et al*., 2006b). It is an under exploited plant with promising economic value, which has been recognized by the USA National Academy of Sciences (1984).

There are positive and negative interactions between tree and crop components of agroforestry systems (Pratap and Shalini, 2019). A positive interaction is a complementarity between woody and herbaceous components in resource acquisition. Competition between components for water, nutrients, light, allelopathy, damage caused by animals or pests, and disease transmission are negative interactions (Qin *et al*., 2018).

Although there are numerous studies on tree-crop interactions, still there is no literature to reveal the interactions between *Moringa oleifera* and *Amaranthus lividus*based agroforestry system. Therefore, the present investigation was carried out with the following objectives:

i. To investigate the effect of tree component on the growth and yield of stem amaranth;
ii. To quantify the effect of distance from the tree trunk on crop performance and
iii. To estimate the benefit-cost analysis of the system

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding to evaluation of growth and yield performance of stem amaranth (*Amaranthus lividus)* under moringa *(Moringa oliefera)* based Agroforestry system, to gather knowledge helpful in conducting the present piece of work.

2.1 Concept of agroforestry system

Agroforestry is a collective is an integrated land-use system in which woody perennials, along with trees, shrubs and bamboos are grown in association with herbaceous plants, including grass, pasture and/or livestock, in spatial or temporary arrangements where each ecological and financial relationship occurs between the system's tree and non-crop additives (Young, 1989). The key components of agroforestry systems are trees, plants, pastures, and livestock along with climate, soil, and land forms environmental factors. In essence there should be an interaction between the tree and non-tree portion. Agroforestry also covers biomass switch of biological material which include the incorporation of the leaf litter into the soil or feeding of such litter as browse to farm animals with next go back to the soil as manure (Young, 1988).

Vergara (1982) told that agroforestry as a "system of mixing diverse longevity of agricultural and tree vegetation (ranging from annual to biennial and perennial vegetation), arranged temporarily (crop rotation) or spatially intercropping to enhance and sustain agricultural production."

Agroforestry is an ideal land-use alternative because it optimizes production in increased agricultural productivity, alleviating poverty and protecting the environment (Izac, 2000). Agricultural forestry also mitigates wood demand and reduces the pressure on natural forests (Pandey, 2002). Bangladesh has 2.46 million ha of forestland covering about 17% of the country’s area. Bangladesh Forest Department (FD) controls, manages and protects all state-owned forests except Unclassed Stated Forest (FD, 2012). More than 90% of the state-owned forest land is concentrated in 12 districts in the eastern and south-western regions of the country and out of 64 districts, 28 districts have no state-owned forest at all (GoB, 1990).

Ajit *et al.*, (2010) reported that the agroforestry operations are very ancient in south asia, but the arrival story of prepared agroforestry research began in 1979 at Imphal, Manipur.

2.2 Advantages of agroforestry systems

Sharma (2012) reported that nutrient cycling is the highest prevalent among the numerous benefits obtained from agroforestry structures in phrases of soil quality. Plant nutrients are in a realm of continuous, revolutions within a soil-plant system. Plants take nutrients from the soil and use them for sporting metabolism. Such nutrients, in addition, are returned to the soil either naturally as the debris falls in and as pruning in certain agroforestry systems or by root senescence. Because of microbial activity, these plant parts are decomposed and release the nutrients held in them into the soil. Further nutrient these become available for plant uptake once more (Nair *et al.*, 1999). Therefore, the agroforestry land-use systems therefore play a first-rate role in influencing the nutrient flows and the ordinary quality of soil.

Bargali *et al.* (2009) demonstrated the botany, distribution, ecology, uses and effects of *Acacia nilotica* on soil and crops. They have to reported various aspects of *A. nilotica* and its future use in land reclamation.

Nair *et al.* (2009) noted that agroforestry because of its production and environmental benefits as an integrated approach to sustainable land use. They also implied its perceived potential, based on the idea of greater performance of integrated structures in useful resource conversion and use than single-species systems, leading to greater net carbon sequestration.

Kidanu *et al.* (2005) studied that *Eucalyptus globulus* planted along field boundaries has come to dominate Ethiopia's central highland landscape; Eucalyptus boundaries have great potential to meet increasing demand for wood, without needing a significant land-use transition on the Vertisols highlands. Higher wood supply would reduce demand for dung and crop residues for fuel, thereby leading to improved soil management on croplands while at the same time relieving the growing strain on indigenous forests and forests. The annual production of eucalyptus boundaries for wood ranged from 168 kg $ha^{-1}y^{-1}$ in four year plantations to 2901 kg $ha^{-1}y^{-1}$ at 12 years of age.

Viswanath *et al.* (2000) stated that time-tested, indigenous land-use systems can provide useful information for the design of agroforestry systems that are environmentally sustainable and socially acceptable. The farm trees supply a variety of products such as fuel wood (30 kg / tree), fencing brushwood (4 kg / tree), small timber for farm implements and furniture (0.2cu.m) and non-timber products including gum and seeds. It was calculated that the babul + rice method has a benefit / cost (B / C) ratio of 1.47 and an internal rate of return (IRR) of 33 per cent at an annual discount rate of 12 per cent over a ten-year period, even at a low income. Babul trees account for almost 10 per cent of smallholder farmers' annual farm production (<2 ha). By practising the agroforestry (rice + babul), farmers earn higher cash returns on a short-term (10-year) tree harvesting period, and the worker input (both family and hired) on farms has been spread more equally throughout the year than in rice monoculture. Inputs purchased are seldom used on the system.

A study on the role of agroforestry systems in enhancing microbial activity, organic soil status, and the availability of nitrogen to correctly regulate the fertility of relatively alkaline soil was conducted at Karnal by Kaur *et al.* (2000) in various frameworks, including rice-berseem crop rotation; Acacia farming system. Eucalyptus and Common rice-berseem and single-species tree plantations. They observed that microbial biomass carbon was low in rice-berseem (96.14 pg g^{-1} soil) and accelerated under tree plantations (109.12-143.40 pg g^{-1} soil) and agrisilvicultural systems (133.80-153.40 pg g^{-1} soil). Microbial biomass increased by 42% (microbial carbon) and 13% (microbial nitrogen) in a completely tree-based systems compared to monocropping. They also estimated that soil carbon increased by 11-52 percent, nitrogen by 8-74 percent, and nitrogen mineralization by 12-37 percent relative to monocropping in tree-based systems (Kaur *et al.,* 2000).

The benefits of agroforestry have been mentioned by various workers at diverse locations. Forest soils higher vegetation yields were calculated than in natural soils. Without fertilizer at Uttar Pradesh's Tarai site, toungya cultivators harvested higher vegetation yields along with maize, wheat, pulses, etc. About 20 percent better grain and timber yields have been reported within the Haryana and western Uttar Pradesh agroforestry areas than from pure agriculture (Dwivedi and Sharma, 1989). Experiments at Indian Grassland and Fodder Research Institute (IGFRI), Jhansi suggest that the entire yield of fodder is greater when fodder grasses were grown with fodder trees than the cultivation of pure fodder grass. Intercropped with agricultural plants and fodder grasses, *Leucaena leucocephala* expanded the entire yield of meal grains, fodder, and fuel (Pathak, 1989).

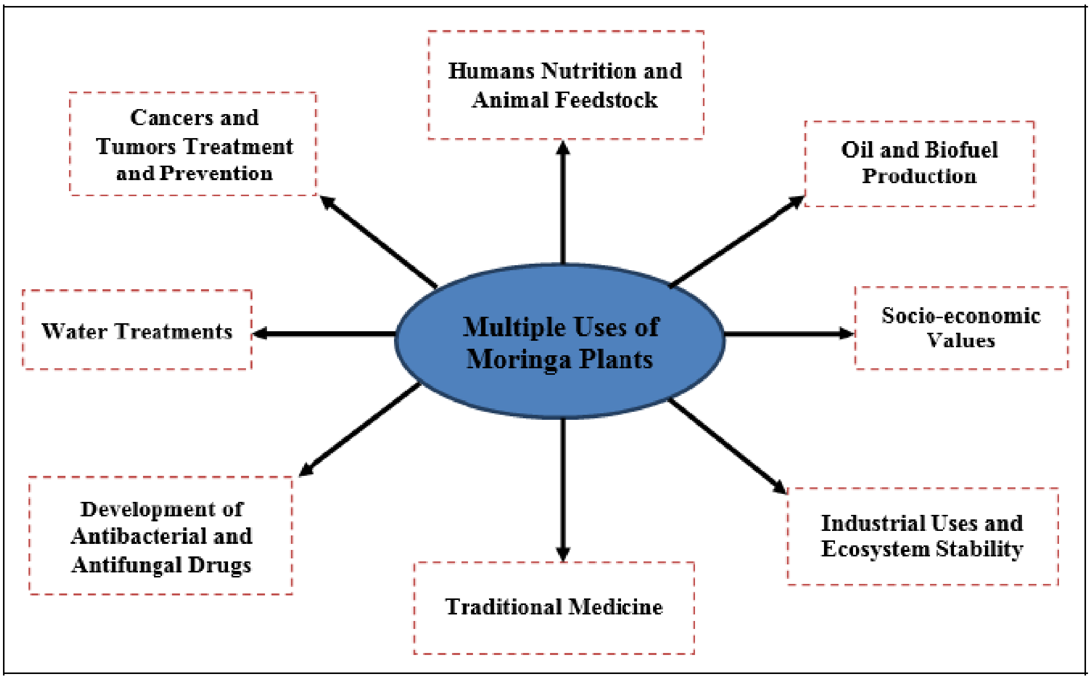
Sanchez (1987) has said that adequate agroforestry systems enhance soil, physical properties, conserve organic matter, and cycling of nutrients. Nitrogensolving timber is recognized as one of the most important agroforestry components. After decomposition the leaf litter forms humus releases nutrients and improves the various properties of the soil. It also reduces fertilizer requirements. Growing bushes and fodder crops, including fodder bushes, is extra-economic, especially on marginal lands. Observations taken in warm arid and semi-arid Rajasthan regions suggest that marginal lands are unable to support stable and competitive crop cultivation. Silvopasture consisting of rising trees along with the species such as *Prosopis, Albizia, Zizyphus* and *Acacia* may also provide extra yields consistent with unit of land than under certain conditions (Gupta and Mohan, 1982).

Poschen (1986) has reported that the growing *Acacia albida* as a permanent tree crop is an indigenous agroforestry method in the Hararghe highlands of Eastern Ethiopia, on farmland with cereals, vegetables and coffee below or between. Benefits of *A. albida* trees provide fuel wood and forage supplies. The study provides quantitative estimates of those results as well as their monetary values. However, to realise these benefits in a discernible way, higher tree densities are needed than at present.

2.3 Importance of moringa

Moringa has multiple benefits to society due to it's diversify nature of products. All parts of moringa are utilized in variety of purpose. The moringa is known worldwide for its nutritional and medicinal benefits and industrial uses and almost every part of the plant has nutritional value (Azeez *et al.,* 2013). Medicinal properties of moringa like anti-inflammatory, curing of skin cancer, diabetes, anemia and high blood pressure. Liver, kidney, stomach and thyroid problems. Almost all parts of the moringa have been utilized within traditional medicine practices (D'souza and Kulkarni, 1993). The highly medicinal properties of plant support the many pharmaceutical industries in the country. Flowers of moringa is a good source of nectar for honey producing bees which support the honey industries (Adeyemi *et al.,* 2012; Bashir *et al.,* 2016). Moringa seed oil (yield 30–40 % w/w), also known as

"Ben oil" is used for the production of biodiesel, because of the high content of monounsaturated fatty acids in the form of oleic acid (C18:1) (Azam *et al.*, 2005; Rashid *et al.*, 2008). Moringa seed oil is a potential candidate for biodiesel production, as it meets all the main specifications of the biodiesel standards of many countries in the world. Thus, it has great commercial and industrial importance in bio-energy sector. Beside these uses moringa seed used in water purifying and the barks, gums and pulp are used for mats, printing and paper making respectively. Pod shucks and seed kernel press cake can be used as mulch and enhances soil fertility when they decompose (Prat *et al.*, 2002). The moringa has vast potential and diversify nature of its products makes it as a source of subsistence life of farmers.



Source: Prat *et al.*, 2002

Figure 1. Multiple uses of *Moringa oleifera*.

2.4 Cultivation requirement of moringa

The moringa tree is grown mainly in semiarid, tropical, and subtropical areas. It tolerates a wide range of soil conditions, but prefers a neutral to slightly acidic (pH 6.3 to 7.0), well-drained sandy or loamy soil. In waterlogged soil the roots have a tendency to rot. Moringa is a sun- and heat-loving plant, thus does not tolerate freezing or frost. Moringa is particularly suitable for dry regions, as it can be grown using rainwater without expensive irrigation techniques.

2.5 Importance of stem amaranth

Amaranth is one of the cheapest leafy vegetables in tropical markets and is often described as the poor man's vegetable. The nutritional value of amaranth is excellent because of its high content of essential micro nutrients. The leaves and tender stem of amaranth are rich in protein, fat, calcium, phosphorus, iron, riboflavin, niacin sodium, β-carotene and ascorbic acid than any other common vegetables (Chowdhury, 1967 and FAO, 1972). The amaranth is being cultivated in an area 10463.56 ha with a total production 67358 tons and the average yield is only 6.88 t/ha (BBS, 2011).

2.6 Moringa amaranth interaction

Moringa trees are planted in gardens to provide support for climbing crops such as pole beans, although only mature trees should be used for this purpose since the vine growth can choke off the young tree. Moringa trees can be planted in gardens to provide shade to vegetables less tolerant to direct sunlight. Trees are planted in hedgerows forming wide alleys where vegetables are planted within. Choose vegetables that are adapted to alley cropping, such as shade-tolerant leafy vegetables and herbs, since moringa hedgerows are highly competitive and can reduce yields of companion plants significantly. From the second year onwards, moringa can be intercropped with maize, sunflower and other field crops. Sunflower is particularly recommended for helping to control weed growth. However, moringa trees are reported to be highly competitive with eggplant and sweet maize and can reduce their yields by up to 50%.

Ahmed (2017) conducted and experiment 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 lividus*) during the early establishment period of Moringa (*Moringa oliaferae*) trees. The study was conducted during the period from January to April, 2018 by following Randomized Complete Block Design (RCBD) comprising of four treatments with four replications. 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). Experiment result showed that at harvest (50DAS), the maximum plant height of stem amaranth (59 cm), number of leaf per plant (25 cm) was recorded in control condition (T0 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 root 1 g) and green yield (14 t/ha) were observed in open field condition (T0 treatment). The yield was reduced by 15% in T_1 treatment (12 t/ha) compared to open field condition. The fresh yield of stem amaranth under T_2 (10 t/ha) and T_3 (10 t/ha) 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. *oleifera* 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.

Sumona (2017) undertaken a study to find out the response of red amaranth in association with drumstick (*Moringa oleifera*) sapling. The experiment was conducted at agroforestry experimental field, Sher-e-Bangla Agricultural University, during February to March 2017. Four treatments namely, T_0= Open field referred to as control, T_1= 12 cm distance from the tree base, T_2= 24 cm distance from the tree base and T_3= 36 cm distance from the tree base were used in Randomized Complete Block Design (RCBD) with four replications. Yield contributing characteristics of red amaranth and growth perimeters of drumstick as influenced by the management practice were also determined. Experimental result revealed that best yield performance of red amaranth at treatment T_1 in association with Moringa sapling. So, farmer can easily cultivate Moringa tree in association with red amaranth maintaining 12 cm distance from tree base without much loss.

2.7 Effect of distance on crop performance

Zhang *et al.* (2017) conducted a field experiment at the Hetian oasis in southern Xinjiang Province to investigate the relationship between root distribution and interspecific interaction between the two intercropped species. The study included seven treatments: sole-cropped 5, 7, or 9-year-old jujube trees (treatments 1–3); 5, 7, or 9-year-old jujube trees intercropped with wheat (treatments 4–6); and sole-cropped wheat (treatment 7). To determine vertical root distribution, soil cores were collected in 20-cm increments from the 0 to 100-cm soil depth. The cores were collected at horizontal distances of 30, 60, 90, 120, and 150 cm from the jujube rows. They found the relationship between root length densities and root densities of the intercropped species. They concluded from the experiments that root growth, biomass accumulation and yield was significantly affected in the intercropped treatments.

Sanwal *et al.* (2016) conducted an experiment at Dr. Y S Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, India and reported net returns from *Andrographis paniculata* grown under chir pine. *Andrographis paniculata* had positive average annual returns even in understorey conditions which indicate its possible economic viability under chir pine plantations. The yield reduction 13.01% in understorey could be because of the lower values of crop plant height (40.42 cm), number of branches (12.52) than open conditions which could be attributed to adverse effect of tree canopy shade in understorey condition compared to the open conditions.

A study was conducted by (Srikrishnah and Sutharsan, 2015) on growth and development of turmeric under four different shade levels at crop farm, Faculty of Agriculture, Eastern University, Srilanka. Treatment consists of open field condition which was considered as T_1: 100% shade level, T_2: 50% shade level, T_3:70% shade level, T_4 :80% shade level. Results indicated that leaf area, biomass and yield were significantly higher in 50% shade level followed by 70% shade level. In the treatments 70% shade level of and 80% shade level, the amount of solar radiation received by the plants is not sufficient for optimum photosynthesis. Therefore, it was concluded that 50% shade level is suitable for the cultivation of turmeric in the Batticaloa district of Srilanka.

Shweta *et al.* (2015) investigated the effect of different types agriculture crops on growth performance of Guava under guavabased agroforestry system. The experiment was conducted in complete randomized block design with four treatments which were replicated five times. Treatments wereGuar + Guava (T1), Cowpea + Guava (T2), Mungbean+ Guava (T3) and Guava alone (T4). Initial soil pH 7.88 and EC 1.09 ds/m were recorded (1:2 ratio). Results show that intercropping with mungbean increased guava growth as compared to other crops (cowpea and guar) as well as mono cropping. Intercropping in general improved height and diameter of guava trees as well as improve the nutrient status of soil over mono-cropping.

Bhat (2015) conducted an experiment in *Melia composita* intercropped with Tomato and Capsicum at Dr. Y S Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, India and recorded decrease in growth and yield parameters of tomato like plant height, fruit yield per plant of crop under tree spacing within the system probably due to competition between trees and crops for critical resources like water, nutrients, photo synthetically active radiation.

Vikram and Hegde (2014) reported that due to shade loving nature of turmeric plants growth was significantly higher under cashew intercropping but the yield was recorded higher under open situation.

Solanki *et al.* (2014) observed that fresh weight of plant/plot (kg), dry weight of plant/plot (kg) and economic yield (kg/ha) was recorded higher under sole crop of Basil, Kalmegh and Mint as compared to intercrop with Sapota-Jatropha in both the years. While Basil (1.67), Kalmegh (1.46) and Mint (1.40) gave higher B:C ratio when grown as intercrop in the agroforestry system as compared to sole crop in 2011 and 2012.

Sarvade *et al.* (2014) conducted an experiment at Pantnagar, Uttrakhand, India in which *Populus deltoides, Eucalyptus camaeldulensis, Leucaena leucocephala* and *Melia azedarach* were intercropped with wheat and recorded maximum grain, straw and biological yield of wheat from control (3.6 Mg/ha), followed by Leucaena and Melia and Eucalyptus. The reduction in grain yield was in the range of 16 to 62% under agroforestry systems as compared to control. The maximum reduction in grain yield was with Eucalyptus (62%) followed by Melia (50%), Leucaena (27%) and Poplar (16%) respectively. Poplar based agrisilvicultural system performed better as compared to other systems.

Sarkar *et al.* (2014) showed that the growth and yield of radish and coriander in association with the Lohkat tree increased significantly with increasing distance from tree.

Chandra (2014) reported that the survival of *Curcuma longa* and *Amorphophallus paeoniifolius* was greater in intercrops than monocrop due to positive response to shade. The survival of plant increased by 5.74% and 13.18% respectively under guava than monocrops.

Palsaniya (2012) reported that grain yield of sole barley (5.6 Mg/ha) was 26.8% higher than the yield under guava based agrihorticulture system. The light interception by barley crop at harvest was higher in pure crop and reduced by 15.7%, when it was grown with guava.

Chauhan *et al.* (2012) conducted an experiment at Rajowal district, Ludhiana, India and studied the quantitative performance of wheat crop under 1.5-year-old poplar plantations in irrigated agro-ecosystem to ascertain the biological yield of tree and crop. Results revealed that growth and yield of wheat decreased significantly with the increase in poplar age. The per cent reduction in net grain yield was 17% under one-year-old poplar plantation, which increased to 52.15% under five-year-old plantation.

Bhuiyan (2012) reported that the yield of ginger rhizome was significantly influenced by different shade levels. The highest yield (32.88 Mg/ha) was obtained under partial shade condition of Coconut+Lemon based agroforestry system with 70-80% PAR and lowest yield (18.75 Mg/ha) was obtained from severe shade condition of Coconut+Lemon based agroforestry system with 25-30% PAR.

Sehgal (2011) showed that closely spaced (0.50 m) Leucaena hedgerows negatively influenced various growth and yield attributes like plant height, number of inflorescence and economic yield of the associated herb as compared to wider spaced hedgerows (0.75 m and 1.50 m). Irrespective of the tree spacing the growth of *O. basilicum* was suppressed to a greater extent at a distance closer to the hedgerows in all the treatments.

Das *et al.* (2011) indicated that the production of fruits in aonla significantly increased due to intercrops and it was maximum in aonla in association with turmeric (13.30 Mg/ha) followed by arbi (11.71 Mg/ha). On the other hand, reduction in yield of intercrops was 7.5-12.0% for turmeric, 12.2-19.3% for ginger and 15.7-25.3% for arbi compared to the yield in open area without trees.

Arya *et al.* (2011) observed immense variations in growth as well as yield performance of annual crops which were allowed to grow in combination with tree crops. They came up with the conclusion that plant growth and yield of associated crops were maximum as compared to sole cropping. Also, it was found that an overall increase in yield (84.60 to 86.52 q ha^{-1}) of ber was recorded over its sole cropping (56.32 q ha^{-1}).

Pandey *et al.* (2010) reported that the reduction in grain yield was 60%, 71% and 80% in 1997, 1998 and 1999, respectively under the tree canopy which indicated that tree canopy management of neem was required to enhance PAR and crop yield.

Malik and Butola (2010) revealed that maximum yield and growth was observed under open (sole cropping) which was at par with 2.5 m from trees and minimum was observed at 0.5 m from trees**.**

Hanif *et al.* (2010) conducted a field experiment to study the growth performance and selection of potential okra varieties under litchi based agroforestry system(hybrid okra, BARI-1 and local okra variety) under litchi based agroforestry system and reported that the yield was highest (10.24 Mg/ha) in monocropping of hybrid okra and the lowest yield (4.24 Mg/ha) was found in litchi+local okra variety.

Manceur *et al.* (2009) reported that soybean leaves were thicker as shade increased (increase by 6.2 × 10-4 to 1.2 × 10-3 mg cm^{-2}, per unit of crown volume), pointing to competitive interactions specific to tree-based intercrops.

Bargali *et al.* (2009) conducted a study in an age series of *Acacia nilotica* (L.) Willd. ex Del (6–28 years old) based traditional agroforestry system in the sub-humid region of Chhattisgarh, India. The experimental result revealed that with increase in tree age, crown diameter and diameter at breast height (DBH), rice productivity reduced by 4.7% (under 9 year old tree) to 28.8% (under 28 year old tree).

Thakur and Singh (2008) reported that in *Pisum sativum* the maximum plant height (52.5 cm) was in open condition followed by plants under 75% crown removal at 3 m distance 47.7 cm and 43.2 cm at 1 m distance from the tree trunk under no crown removal.

2.8 Economics of agroforestry system

Thakur *et al.* (2016) conducted an experiment in the experimental farm of ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, India in 2013- 2014 and reported the economics of three *Ocimum* species, namely *O.*

tenuiflorum, *O. gratissimum*and *O. basilicum*, which were grown under 18-year old teak (*Tectona grandis*) based silvi-medicinal agroforestry system (teak+*Ocimum* spp). Out of four Ocimum species, maximum values of fresh above ground (10.54 t/ha) and total herbage yield (12.05 t/ha) were attained by *O. tenuiflorum.* Whereas, maximum below ground fresh herbage yield (20.08 t/ha) was recorded for *O. basilicum.* Among intercrops, significantly maximum oil yield (61.32 kg/ha) was obtained for *O. tenuiflorum*. The study has found that herbage production of *O. gratissimum* provided highest net returns of Rs.38,018/ha with B:C ratio 1.85. The essential oil production from *O. basilicum* accrued the highest net returns of Rs.103327/ha with B:C ratio of 2.56. The study has revealed that the financial flow on account of oil production was higher as compared to herb production in terms of net returns and B:C ratio.

Prakash and Pant (2015) conducted an experiment at Dr. Y S Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, India and found that intercropping of flower crop *Godetia grandiflora* with *Grewia optiva* provides an excellent agroforestry system to enhance the socio-economic status of farmer as well as the socio-economic status of the country. The B:C ratio was 2.66 in agroforestry system, whereas it was 1.50 in pure plantation.

Rahangdale *et al.* (2014) studied intercropping in three-year-old plantation of *Bambusa arundinacea* and *Dendrocalamus strictus* planted at a spacing of 5x5 m during rainy season with 4 intercrops viz., green gram, soyabean, paddy and sesame at Jabalpur, Madhya Pradesh, India. The economic analysis of the system revealed that the bamboo based agroforestry system Rs.21,029/ha gave higher monetary return as compared to sole bamboo Rs.9,801/ha. Growing of green gram with bamboo species gave significantly higher net monetary return Rs.27,736/ha but was at par with sesame Rs.23,365/ha.

Chandra (2014) conducted an experiment at Bilaspur, Chattisgarh, India in which growth and economic parameters of two intercrops *Amorphophallus paeonifolius* (Variety-Gajendra-1) and *Curcuma longa* (Variety- Narendra haldi-1) were investigated under 11-year-old guava (Variety Allahabad Safeda) orchard. The net income was 18.86% and 17.54% higher from *Curcuma longa* and *Amorphophallus paeoniifolius* as intercrop with *Psidium gujava* compared to sole crop. The net income of guava+*Curcuma longa* was Rs.2.62 lakhand Rs.2.85 lakh for guava+*Amorphophallus paeoniifolius* against the net income of Rs.2.31 lakh and Rs.1.56 lakh in monocropping of intercrops at open field. The B:C ratio also improved from 2.78 to 3.31 for guava+*Curcuma longa* and 1.52 to 2.08 for guava+*Amorphophallus paeoniifolius* with intercropping system in orchard.

Patil *et al.* (2012) conducted a study on *Melia azadirach*-Soybean based agroforestry system at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, India. The plantation was 10 years old. The higher gross return was recorded in soybean with *Melia azadirach* Rs.10,502/ha/yr with B:C ratio 1.86 as compared to sole soybean Rs.6,410/ha/yr with B:C ratio 1.73.

Das *et al.* (2011) conducted an intercropping trial during 2007-2010 on 6-year-old aonla (*Emblica officinalis* Gaertn.; cv. NA-7) orchard planted at 6 × 6 m spacing and growing under rainfed soil at Central Soil and Water Conservation Research and Training Institute, Dehradun, India to identify the suitable and profitable intercrops. Economic analysis of the systems in terms of B:C revealed that „aonla + turmeric" gave a higher value (6.29) followed by „aonla + ginger" (3.44) and „aonla + arbi" (3.20).

Rani *et al.* (2011) conducted an experiment at the experimental area of the Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana, India during the year 2007-08 and 2008-09 with *Populus deltoides* intercropped with winter flower annuals *Coreopsis tinctoria*, *Coreopsis lanceolata*, *Phlox drumondii* and *Gaillardia pulchelia* showed better performance with flower for seed production under poplar canopy during the initial years with B:C of 1.86 to 5.71 and 1.72 to 5.62 in open condition. The B:C ratio of growing flowers for seed production ranged from 1.15 to 5.31 under three-year-old poplar canopy and 1.68 to 5.51 in open environment. The corresponding values were 1.12 to 5.17 and 1.40 to 5.37 for four-year-old poplar canopy and open environment.

Sujatha *et al.* (2010) studied intercropping of medicinal and aromatic plants (MAPs) in arecanut plantation at Central Plantation Crops Research Institute, Regional Station, Vittal, Karnataka, India. The results revealed that MAPs can be successfully grown as intercrops in arecanut plantation with increased productivity and net income per unit area. Intercropping of MAPs in arecanut was found economical and the B:C ratio was highest in *Cymbopogon flexuosus* (4.25) followed by *Bacopa monnieri* (3.64), *Ocimum basilicum* (3.46), *Artemisia pallens* (3.12) under arecanut and pure arecanut (1.85).

Kumar *et al.* (2008) conducted an experiment during 2004-05 in a five-year-old arecanut garden at Agricultural Research Station, Sirsi, Karnataka, India.Seven different medicinal plants viz., *Aloe vera*, *Alpinia galangal, Coleus forskholii*, *Stevia rebaudiana*, *Andrographis paniculata*, *Catharanthus roseus* and also *Ocimum sanctum*were grown as intercrops with arecanut. The results revealed that among the medicinal plants, the best performer was *Stevia rebaudiana* which gave a net return of Rs. 89,422.3/ha whereas under the shade of arecanut the best performer was *Catharanthus roseus* which gave returns of Rs. 11,507.3/ha. *Catharanthus roseus, Andrographis paniculata* and *Stevia rebaudiana* were found to be economical under arecanut giving economic returns of Rs.11,507, 5,226 and 3,897/ha respectively.

Lal *et al.* (2005) carried out field experiment during 1998-2003 to determine the economic viability of an agroforestry based system in Allahabad district, Uttar Pradesh, India. The Rabi (*Cicer arietinum* and *Vigna mungo*) and kharif (*Vigna radiata*) crops of were intercropped with papaya. They observed that the cultivation of papaya+crop was comparatively more profitable than the sole papaya and sole pulses crop. The B:C ratio was found to be highest in agroforestry system (3.79) compared to sole papaya (2.65).

Tomar and Bhatt (2004) studied the perfomance of, Assam lemon (citrus lemon [*Citrus limon*] and peach (*Prunus persica* cv. TA 170) and upland rice cultivars as intercrops in a 6-year-old existing plantation of guava (*Psidium gujava* cv. Allahabad safeda) at Dr. Y S Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, India during 2002 and 2003. The report showed that on an average, the maximum net monetary benefit per hectare was recorded from peach intercropped with rice Rs.48,044/ha followed by guava Rs.27,887/ha and Assam lemon Rs.20,991/ha irrespective of rice cultivars. Peach, guava and Assam lemon exhibited 5.09, 2.95 and 2.22 fold higher net return respectively, compared to the control.

Chauhan (2002) carried out an experiment at Dr. Y S Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, India to identify the performance of medicinal and aromatic plants for agroforestry system. The observation recorded in the system revealed that the income from the sole trees of poplar and eucalyptus was much lower than the income received from the intercropping system. On an average Rs.20,360/ha/yr from poplar trees and Rs.28,150/ha/yr from eucalyptus trees was obtained without any intercrops. Under poplar plantation, lemongrass gave the highest net returns Rs.42,840/ha/yr and palmarosa Rs.24,290/ha/yr gave lowest returns, while under eucalyptus palmarosa gave the highest net returns Rs.35,640/ha/yr, followed by lemongrass Rs.33,680/ha/yr in the agroforestry system.

Yaseen *et al.* (2001) studied the effect of cover crops on productivity of medicinal and aromatic plants and ascertained the monetary benefits from the system. The additional income from the clover was Rs.23,800/ha in addition to menthol mint yield. The total monetary benefit due to clover-mint system wasRs.89,900/ha, which was 1.5 times compared with that of sole menthol mint.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to evaluation ofgrowth and yield performance of stem amaranth (*Amaranthus lividus)* under moringa *(Moringa oliefera)*based Agroforestry system. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from January 2020 to April 2020.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted at Agroforestry research field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Ahmmed, 2018).

3.2.2 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 (Ahmmed, 2018). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.3 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-II .

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-III.

3.3 Plant materials

In this experiment, variety of *M. oleifera* were collected from Savar which were established three year ago. To observe the interaction with Moringa tree, a variety of stem amaranth (Bhutan data) was used. The seeds of stem amnaranth were collected from United Seed Company, Siddique Bazar, Gulisthan, Dhaka.

3.4 Experimental treatments

There were 6 treatment in this experiment viz,

T_1 = 25 cm distance from the tree base

T_2 = 50 cm distance from the tree base

T_3 = 75 cm distance from the tree base

T_4 =100 cm distance from the tree base

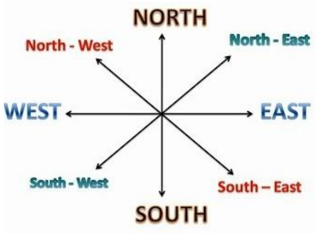
T_5 =125 cm distance from the tree base and

T_6 = Open field referred to as control (Sole crop).

3.5 Experimental design and lay out

Stem amaranth was planted according to treatment requirement followed Randomized Complete Block Design (RCBD) with single factorial arrangement having four replications. Field size was 1080 cm × 540 cm, block size was 300 cm × 540 cm and distance between block was 60 cm.A characteristic feature of the experiment layout is shown in the figure 1. Amaranth grown at different distance from the tree were treated as treatments and control condition was stem amaranth without tree.

T_6	T_1	T_3	T_3
T_1	T_6	T_5	T_6
T_3	T_2	T_1	T_4
T_4	T_4	T_6	T_1
T_2	T_5	T_2	T_5
T_5	T_3	T_4	T_2



Field size = 1080 cm × 540 cm
Block size = 300 cm × 540 cm
Plot size = 50 cm × 90 cm
Block to block distance = 60 cm

Figure 1.Layout of the experiment field

Here,

T_1 = 25 cm distance from the tree base

T_2 = 50 cm distance from the tree base

T_3 = 75 cm distance from the tree base

T_4 =100 cm distance from the tree base and

T_5 =125 cm distance from the tree base

T_6 = Open field referred to as control

3.6 Experimental details

3.6.1 Land preparation

The experimental land was first opened on 1 January 2020 and operation was done by spades. Then the land was kept fellow for one month. The field was cleared by removing all crop residues and weeds,broken stones and also bricks were sorted out then finally the land was properly leveled.

3.6.2 Fertilizer application

Fertilizer namely urea, muriate of potash, TSP and organic manure (cow dung) was applied into the experimental plot during the final land preparation. Sources of N, P and K were urea, triple super phosphate (TSP) and muriate of potash (MoP) respectively. The full dose of cow dung (10 t ha^{-1}), TSP (75 kg ha^{-1}) and MoP (100 kg ha^{-1}) were applied as basal dose during final land preparation. Urea (125 kg ha^{-1}) was applied in three equal installments as top dressing at 15, 25 and 35 days after sowing (DAS).

3.6.3 Sowing of seeds in the field

Stem amaranth seeds were sown in the experimental field on 20 February 2020. After Emergence of seedlings, various intercultural operations were done.

3.6.4 Intercultural operations

3.6.4.1Weeding

Weeding was done during the experimental period to keep the pot free from hazardous effect of weed during the growth and development of vegetables. Irrigation was done as per necessity for sufficient moisture by watering cane.

3.6.4.2 Thinning out

The emergence of Amaranth was started after 5-7 days of sowing respectively. Thinning was carried out three times. For stem Amaranth first, second and third thinning was done after 10 days, 20 days and 30 days of sowing respectively.

3.6.4.3 Pest and disease management

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

3.7 Methods of data collection

Stem amaranth was harvested at 50 days after sowing (DAS) when the crop reached at edible size. Plant samples of stem amaranth were collected randomly from each replication of the respective plots.

The data were recorded on the following parameters

i. Plant height (cm)
ii. Number of leaves per plant
iii. Leaf length (cm)
iv. Leaf width (cm)
v. Stem diameter (mm)
vi. Fresh shoot weight plant^{-1} (g)
vii. Fresh root weight plant^{-1} (g)
viii. Dry shoot weight plant^{-1} (g)
ix. Dry root weight plant^{-1} (g)
x. Yield plot^{-1}
xi. Yield ha^{-1}

3.8 Procedure of recording data

i) Plant height (cm)

The height of the selected plant was measured from the ground level to the tip of the plant at 10. 20, 30, 40 and 50 DAS. Mean plant height of red amaranth plant were calculated and expressed in cm.

ii) Number of leaves plant^{-1}

Total number of leaves plant^{-1} were counted at 10. 20, 30, 40 and 50 days after sowing. Randomly 2 plants were selected and measured, then the sum of number of leaf was divided by 2 to record number of leaf per plant.

iii) Leaf length (cm) and leaf width (cm)

The leaf length and leaf width of the upper 3rd leaf of each plant was measured against a centimetre scale at 50 DAS.

iv) Stem diameter

From each plot 2 plants were uprooted randomly. Then the diameter was taken from the base portion of each plant. Then average result was recorded in mm.

v) Fresh shoot weight plant^{-1} (g)

Randomly 2 plants were selected from the each replication and the sum of the fresh shoot weight of 2 plants was weighted and divided by 2, then it was recorded as weight of fresh shoot weight (g) at 50 DAS.

vi) Fresh root weight plant^{-1} (g)

Randomly 2 plants were selected from the each replication and the sum of the fresh root weight of 2 plants was weighted and divided by 2, then it was recorded as weight of fresh root weight (g) at 50 DAS.

vii) Dry shoot weight (g)

Randomly 2 plants were selected from the each replication and the sum of the dry shoot weight of 2 plants was weighted. The dry weight of the shoot from each plot was measured at 50 days after sowing. Dry weight was recorded by drying thefresh shoot sample in an oven at 70°C until attained a constant weight.

viii) Dry root weight (g)

Randomly 2 plants were selected from the each replication and the sum of the dry root weight of 2 plants was weighted. The dry weight of the root from each plot was measured at 50 days after sowing. Dry weight was recorded by drying thefresh root sample in an oven at 70℃ until attained a constant weight.

ix) Yield pot^{-1} (g)

The yield (g) of stem amaranth per pot was calculated by taking fresh weights of all the plants that grows in each pot at 50 DAS.

x) Yield ha^{-1}

The yield (t) of red amaranth per hectare was calculated by converting the total yield (kg) of stem amaranth per square meter.

3.9 Economic analysis of stem amaranth cultivation

In this research from the beginning to end of the experiment, individuals cost data of all the heads of expenditure in each treatment were recorded carefully and classified according to Mian and Bhuiya (1977) as well as posted under different heads of cost of production.

3.9.1Moringa tree establishment (Moringa was planted 3 years ago)

A 45×45 cm deep square size pit was dug maintaining at 5.4 m ×3 m distance in the experimental field. A total of 50 kg of cowdung was mixed well with the soil of the pit without any application of chemical fertilizer. All the cuttings were 1.5 m in length which was placed separately at the center of each pit. After planting, the above ground length of each sapling was 1 m. Irrigation was done as necessary by using watering cane.

Spacing :5.4 m ×3 m
Number of cutting ha^{-1} = 617
Cow dung requirement 50 kg pit^{-1}
Total number of pit = 617
Cow dung requirement = 31 t ha^{-1}
Cutting cost = 100 taka cutting^{-1}
Number of fruits plant^{-1} = 125
Per fruits weight = 65 g
Yield per plant = 8.13 kg (Re-calculate)
Yield ha^{-1} = 5.01 t ha^{-1}

3.9.2Amaranthus seed rate.

The seed rate is about 2 kg/ ha for direct sowing and 1 kg for transplanted crop. Amaranthus seeds are very small, so they should be sown shallow, about 1.5 cm deep, mixed with fine soil or sand for even distribution (Miah *et al*., 2013). The seeds of stem amaranth were collected from United Seed Company, Siddique Bazar, Gulisthan, Dhaka.

3.9.3Fertilizer requirement of amaranthus

Fertilizer namely urea, muriate of potash, TSP and organic manure (cow dung) was applied into the experimental plot during the final land preparation. Sources of N, P and K were urea, triple super phosphate (TSP) and muriate of potash (MoP) respectively. The full dose of cow dung (10 t ha^{-1}), TSP (75 kg ha^{-1}) and MoP (100 kg ha^{-1}) were applied as basal dose during final land preparation. Urea (125 kg ha^{-1}) was applied in three equal installments as top dressing at 15, 25 and 35 days after sowing (Krishijagran, 2022).

3.9.4.1 Input cost

Input costs were divided into two parts. These were as follows:

3.9.4.2Non-material cost

Non-material cost is all the labors cost. Human labors was obtained from adult male labors. In a day 8^{th} hours working of a labors was considered as a man day. The mechanical labor came from the tractor. A period of eight working hours of a tractor was taken to be tractor day.Individual labor wages 400 taka day^{-1}.

3.9.4.3 Material cost

Its included seeds rate ha^{-1}, fertilizers, pesticide application, irrigation application cost etc.

3.9.4.4 Overhead cost

Overhead cost is the land cost. The value of the land varies from place to place. In this research the value of land was taken Tk. 200000 per hectare. The interest on this cost was calculated for 6 months @ Tk. 12.5% per year based on the interest rate of the Bangladesh Krishi Bank.

3.9.4.5 Miscellaneous cost (common cost)

It was 5% of total input cost.

iv. Gross return from stem amaranth

Gross return from stem amaranth (Tk. ha^{-1}) = Value of yield of stem amaranth (Tk. ha^{-1})

3.9.4.6 Net return (NR)

Net return was calculated by using the following formula:

NR (Tk. ha^{-1}) = Gross return (Tk. ha^{-1}) – Total cost of production (Tk. ha^{-1}).

3.9.4.7 Benefit cost ratio (BCR)

Benefit cost ratio indicated whether the cultivation is profitable or not which was calculated as follows:

$$\text{BCR} = \frac{\text{Grossreturn (Tk/ha)}}{\text{Cost of production (Tk/ha)}}$$

3.10 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix 10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

Results obtained from the present study have been presented and discussed in this chapter with a view to evaluation of growth and yield performance of stem amaranth (*Amaranthus lividus)* under moringa *(Moringa oliefera)* based agroforestry system. The data are given in different tables and figures. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Influence of *Moringa oleifera* and *Amaranthus lividus* based agroforestry system on the growth and yield contributing characteristics of stem amaranth

4.1.1 Plant height (cm)

Plant height is an important morphological character that acts as a potential indicator of availability of growth resources in its approach. Experimental, result revealed that, plant height of stem amaranth showed significant variation due tree crop interaction at different days after sowing. (Table 1).The plant height was gradually increased with the advancement of crop growth up to final harvest. The highest plant height (3.57, 12.60, 26.20, 36.47 and 43.83 cm) at 10, 20, 30, 40 DAS, and at harvest, respectively was recorded in T_6 (Open field plantation considered as control) treatment which was statistically similar (33.50 cm) with T_5 (75 cm distance from the tree base) at 40 DAS. Whereas the lowest plant height (2.33, 8.23, 19.77, 25.70 and 31.07 cm) at 10, 20, 30, 40 DAS, and at harvest, respectively was recorded in T_1 (25 cm distance from the tree base) treatment which was statistically similar (2.50 and 8.27 cm) with T_2 (50 cm distance from the tree base) at 10 and 20 DAS. But under tree crop interaction, the best result on plant height was obtained from T_5 (125 cm distance from the tree base) treatment recorded plant height (3.23, 11.40, 23.57, 33.50 and 41.70 cm) at 10, 20, 30, 40 DAS, and at harvest, respectively. The variation of plant height may be due nutrient availability among different treatment. Open field plantation has no nutrient competition with other plant/Moringa. Whereas tree crop interaction increasing competition and plant nutrient uptake is increased with decreasing of plantation distance between tree and crop, hence influence plant height of stem amaranth. The result obtained from the present study was similar with the findings of Bhat (2015) decrease in plant height due to competition between trees and crops for critical resources like water, nutrients, photo synthetically active radiation. Sarkar *et al.* (2014) also reported that the growth of radish and coriander in association with the Lohakat tree increased significantly with increasing distance from tree.

Table 1. Effects of *Moringa oleifera* and *Amaranthus lividus* based agroforestry system on plant height (cm) of stem amaranth at different DAS

Treatments	Plant height at				
	10 DAS	**20 DAS**	**30 DAS**	**40 DAS**	**At harvest**
T_1	2.33 d	8.23 e	19.77 f	25.70 c	31.07 e
T_2	2.50 d	8.27 e	20.73 e	30.33 b	38.70 d
T_3	2.83 c	9.37 d	21.67 d	31.33 b	39.53 cd
T_4	3.10 bc	10.30 c	22.53 c	31.87 b	40.47 bc
T_5	3.23 b	11.40 b	23.57 b	33.50 ab	41.70 b
T_6	3.57 a	12.60 a	26.20 a	36.47 a	43.83 a
CV (%)	5.97	2.03	2.12	7.00	2.01

Here, T_1 = 25 cm distance from the tree base,T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

4.1.2 Number of leaves plant^{-1}

A leaf is the principal lateral appendage of the vascular plant stem, usually borne above ground and specialized for photosynthesis. In this experiment number of leaves plant^{-1} of stem amaranth was varied among the treatments at different DAS (Table 2). Experimental result revealed that, stem amaranth grown in control condition i.e., without interaction with moringa (T_6) recorded the highest number of leaves plant^{-1} (3.70, 8.20, 13.23, 18.83 and 22.83) at 10, 20, 30, 40 DAS, and at harvest, respectively which was statistically similar (21.50) with T_5 (75 cm distance from the tree base) treatment at harvest, respectively. But under tree crop interaction increasing distance from the tree base gradually increase leaf number comparable to close distance from tree base. Under tree-crop interaction, the best result was obtained in T_5 (125 cm distance from the tree base) treatment recorded number of leaves plant^{-1}(3.30, 7.10, 12.10, 17.30 and 21.50) at 10, 20, 30, 40 DAS, and at harvest, respectively.

Whereas the lowest number of leaves plant^{-1}(2.00, 4.80, 8.03, 12.93 and 16.60) at 10, 20, 30, 40 DAS, and at harvest, respectively was recorded in T_1 (25 cm distance from the tree base) treatment. The variation of number of leaves plant^{-1} may be due to competition of water, nutrients, photo synthetically active radiation etc between tree and crop.Sehgal (2011) also found similar result which supported the present finding and reported that closely spaced (0.50 m) Leucaena hedgerows negatively influenced various growth and yield attributes as compared to wider spaced hedgerows (0.75 m and 1.50 m). Irrespective of the tree spacing the growth of *O. basilicum* was suppressed to a greater extent at a distance closer to the hedgerows in all the treatments.

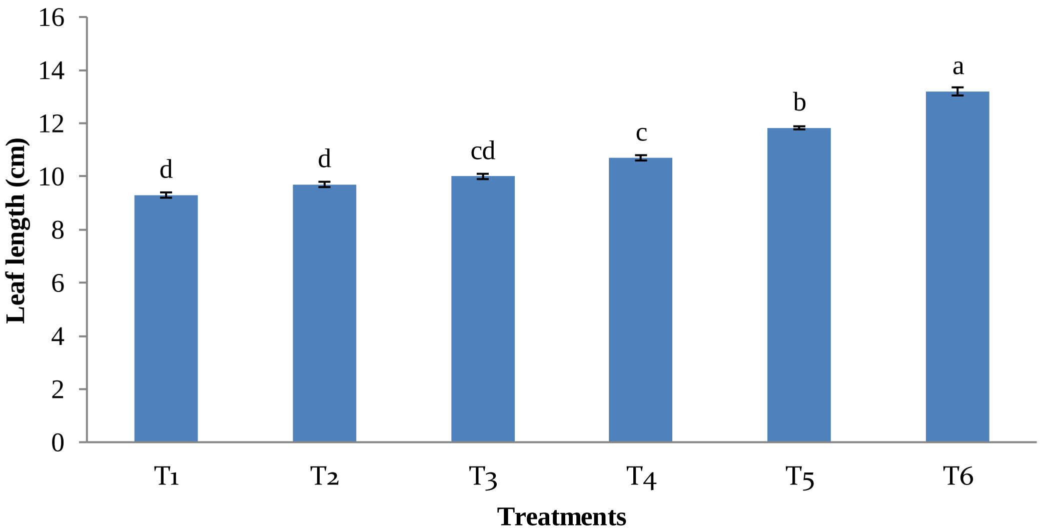
Table 2. Effects of *Moringa oleifera* and *Amaranthus lividus* based agroforestry system on number of leaves plant^{-1} of stem amaranth at different DAS

Treatments	Number of leaves plant^{-1}at				
	10 DAS	**20 DAS**	**30 DAS**	**40 DAS**	**At harvest**
T_1	2.00 f	4.80 f	8.03 f	12.93 e	16.60 d
T_2	2.33 e	5.30 e	9.30 e	14.37 d	18.20 c
T_3	2.60 d	5.90 d	10.40 d	15.60 c	18.73 c
T_4	2.83 c	6.60 c	11.37 c	16.60 b	20.40 b
T_5	3.30 b	7.10 b	12.10 b	17.30 b	21.50 ab
T_6	3.70 a	8.20 a	13.23 a	18.83 a	22.83 a
CV (%)	1.86	3.36	3.42	2.78	4.39

Here, T_1 = 25 cm distance from the tree base,T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

4.1.3 Leaf length (cm)

Leaf length of stem amaranth varied due to influenced of different treatment (Figure 2). At harvest, leaf length of stem amaranth ranged from 10 cm to 13.20 cm. Experimental result revealed that, stem amaranth grown in control condition i.e., without interaction with moringa (T_6) recorded the highest leaf length (13.20 cm), whereas stem amaranth grown in 25 cm distance from the moringa tree base (T_1)recorded the lowest leaf length (9.30 cm),which was statistically similar (9.70 cm) with T_2 (50 cm distance from the tree base) treatment at harvest. In case of tree-crop interaction, stem amaranth grown in 125 cm distance from the moringa tree base perform well and recorded leaf length (11.83 cm) comparable to others tree-crop interaction treatments. 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. Palsaniya (2012) reported that attributes of barley increased with increasing distance from tree base. The light interception by barley crop at harvest was higher in pure crop and reduced by 15.7%, when it was grown with guava.



Here, T_1 = 25 cm distance from the tree base, T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

Figure 2. Effect of different distance from the tree base on leaf length of stem amaranth at harvest

4.1.4 Leaf breadth (cm)

Leaf breadth of stem amaranth varied due to influenced of different treatment (Figure 3). At harvest, leaf breadth of stem amaranth ranged from 3.80 cm to 6.97 cm. Experimental result revealed that, stem amaranth grown in control condition i.e., without interaction with moringa (T_6) recorded the highest leaf breadth (6.97 cm), whereas stem amaranth grown in 25 cm distance from the moringa tree base (T_1)

recorded thelowest leaf breadth (3.80 cm), which was statistically similar (4.23 cm) with T_2 (50 cm distance from the tree base) treatment at harvest. In case of tree-crop interaction, stem amaranth grown in 125 cm distance from the moringa tree base perform well and recorded leaf length (6.03 cm) comparable to others tree-crop interaction treatments.

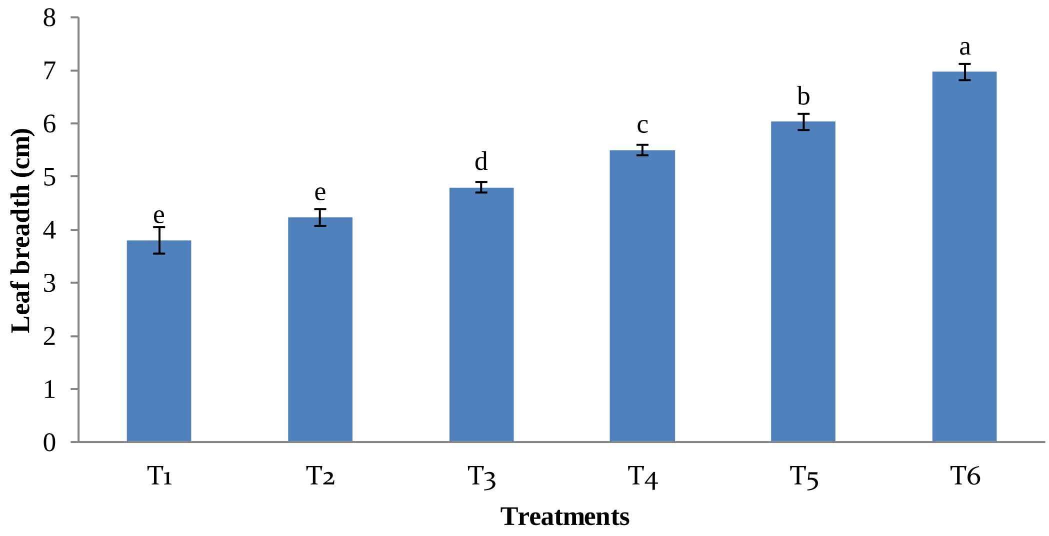


Figure 3. Effect of different distance from the tree base on leaf breadth of stem amaranth at harvest

Here, T_1 = 25 cm distance from the tree base,T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

4.1.5 Stem diameter (mm)

Stem diameter of stem amaranth was significantly influenced with increasing distance from tree base (Figure 4). Stem diameter varied 24.17-28.43 mm at harvest due to effect of different treatment, where the highest stem diameter (28.43 mm) was recorded in control treatment (T_6) which was statistically similar (27.30 mm) with T_5 (125 cm distance from the tree base) treatment at harvest. While the lowest stem diameter (24.17 mm) was recorded in T_1 (25 cm distance from the tree base) treatment.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.

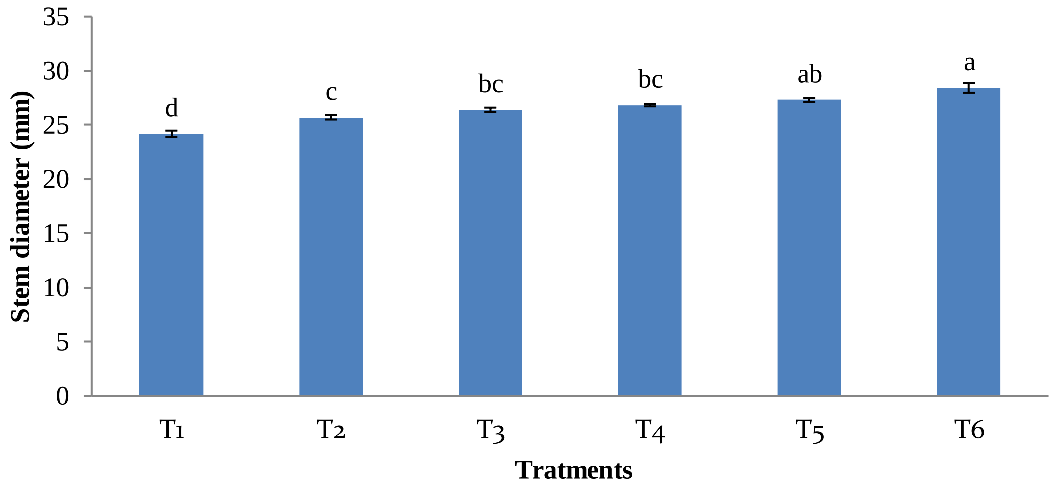


Figure 4. Effect of different distance from the tree base on stem diameter of stem amaranth at harvest

Here, T_1 = 25 cm distance from the tree base,T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

4.1.6 Shoot length (cm)

Shoot length of stem amaranth was significantly influenced with increasing distance from tree base (Figure 5). Shoot length of stem amaranth varied 45.13 -38.20 cm at harvest due to effect of different treatment. At harvest the highest shoot length (45.13) was recorded in control treatment (T_6) which was statistically similar (43.70 cm) with T_5 (125 cm distance from the tree base) treatment at harvest. While the lowest shoot length (38.20 cm) was recorded in T_1 (25 cm distance from the tree base) treatment.

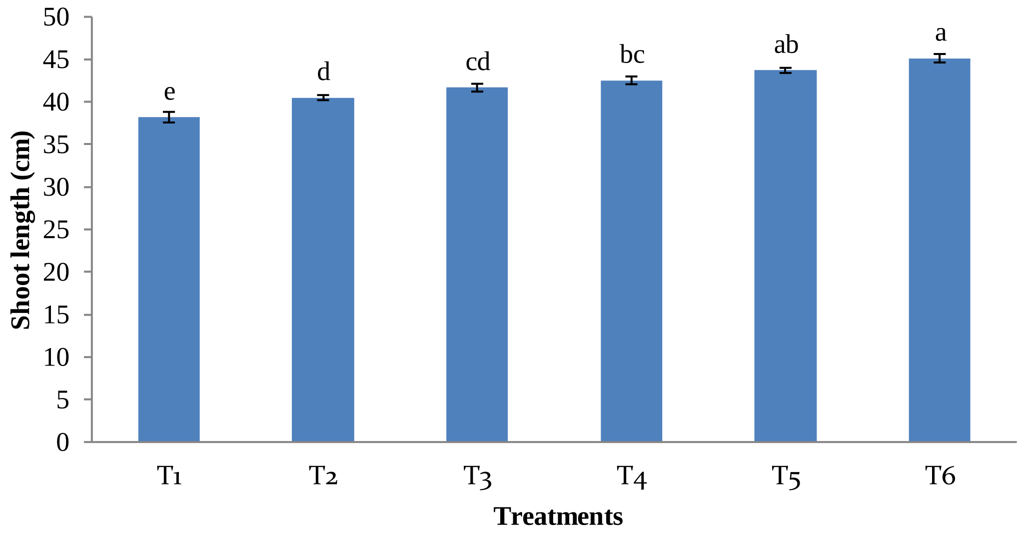


Figure 5. Effect of different distance from the tree base on shoot length of stem amaranth at harvest

Here, T_1 = 25 cm distance from the tree base,T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

4.1.7 Root length (cm)

Roots are important plant organs. The roots anchor the plant in place, resisting the forces of wind and running water or mud flow. The root system takes in oxygen, water and nutrients from the soil, to move them up through the plant to the stems, leaves and blooms. In this experiment root length of stem amaranth was significantly influenced with different treatment (Figure 6). Experimental result revealed that, the height root length (14.40 cm) was recorded in T_6 (Control) treatment whereas the lowest root length (11.17 cm) was recorded in T_1 (25 cm distance from the tree base) treatment which was statistically similar (11.17 cm) with T_1 (50 cm distance from the tree base) treatment. But under tree crop interaction T_5 (125 cm distance from the tree base) treatment perform well and recorded root length (13.33 cm) comparable to others interaction treatments. 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. Zhang *et al.* (2017) also found similar result with the present study and reported that root growth was significantly affected in the intercropped treatments.

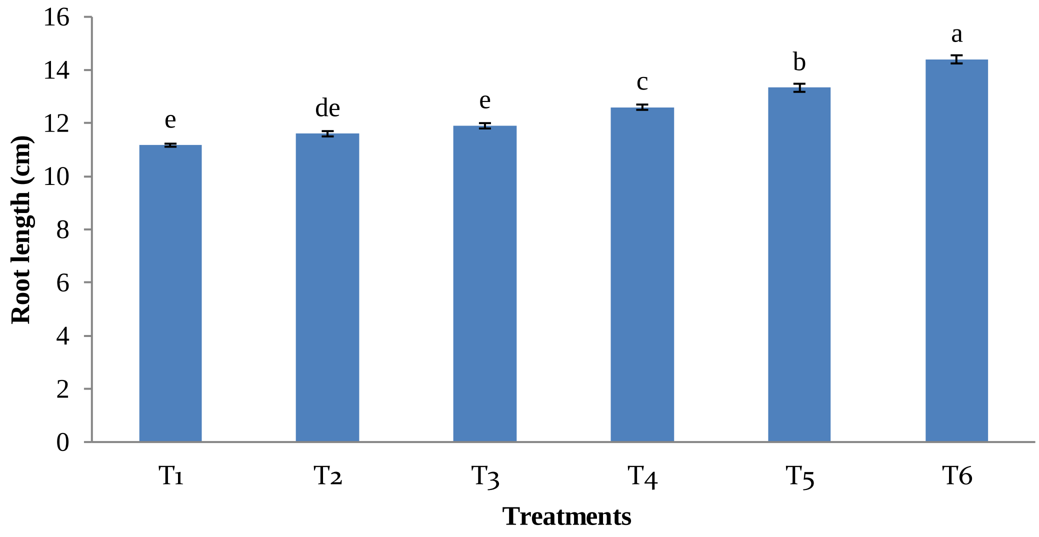


Figure 6. Effect of different distance from the tree base on root length of stem amaranth at harvest

Here, T_1 = 25 cm distance from the tree base, T_2 = 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

4.1.8 Fresh shoot weight (g)

Fresh shoot weight of stem amaranth was significantly influenced with increasing distance from tree base (Figure 7). Fresh shoot weight of stem amaranth varied 60.87-66.67 g at harvest due to effect of different treatment. At harvest the highest fresh shoot weight of stem amaranth (66.67 g) was recorded in control treatment (T_6). While the lowest fresh shoot weight of stem amaranth (60.87 g) was recorded in T_1 (25 cm distance from the tree base) treatment.But under tree crop interaction T_5 (125 cm distance from the tree base) treatment perform well and recorded fresh shoot weight of stem amaranth (64.70 g) which was statistically similar with T_4 (100 cm distance from the tree base) treatment recorded fresh shoot weight of stem amaranth (63.80 g).

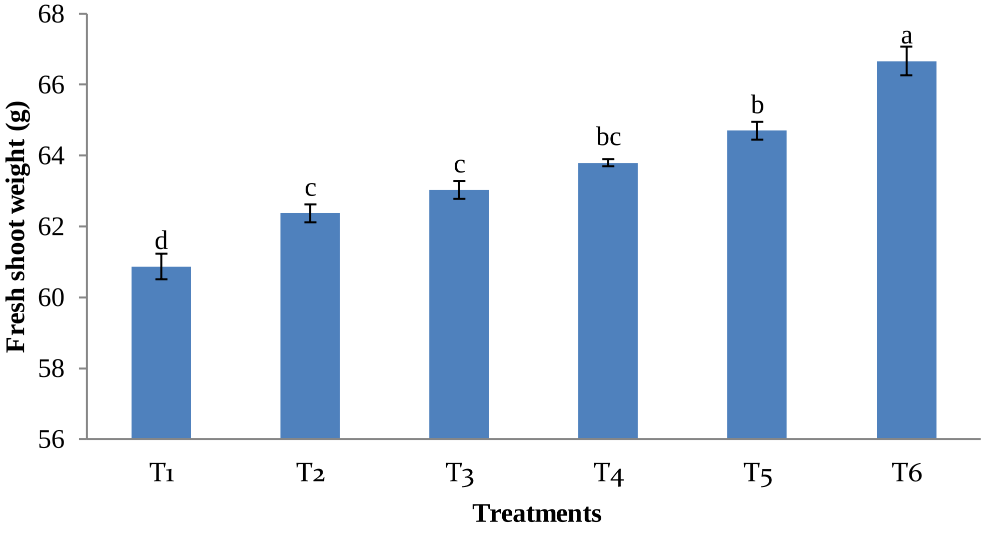


Figure 7. Effect of different distance from the tree base on fresh shoot weight of stem amaranth at harvest

Here, T_1 = 25 cm distance from the tree base,T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

4.1.8 Fresh root weight (g)

Fresh root weight of stem amaranth was significantly influenced with increasing distance from tree base (Figure 8). Fresh root weight of stem amaranth varied 7.10 - 10.73 g at harvest due to effect of different treatment. At harvest the highest fresh root weight of stem amaranth (10.73 g) was recorded in control treatment (T_6). While the lowest fresh root weight of stem amaranth (7.10 g) was recorded in T_1 (25 cm distance from the tree base) treatment. But under tree crop interaction T_5 (125 cm distance from the tree base) treatment perform well and recorded fresh root weight of stem amaranth (9.20 g) comparable to others interaction treatments.

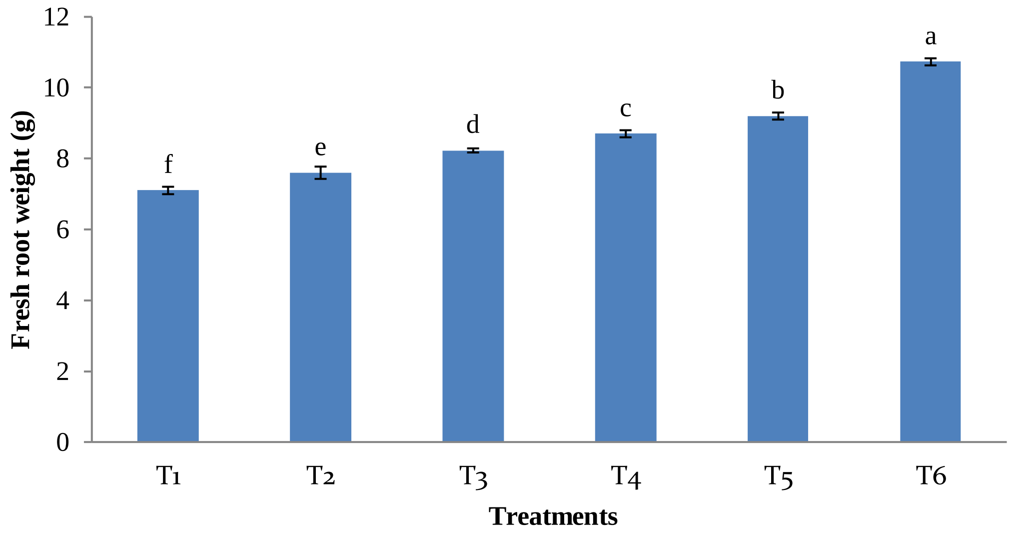


Figure 8. Effect of different distance from the tree base on fresh root weight of stem amaranth at harvest

Here, T_1 = 25 cm distance from the tree base,T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

4.1.9 Dry shoot weight (g)

Interaction of stem amaranth and moringa (with or without) showed significant variation on dry shoot weight (g) of stem amaranth (Figure 9).Dry shoot weight of stem amaranth varied 2.61-4.13 g at harvest due to effect of different treatment. At harvest the highest dry shoot weight of stem amaranth (4.13 g) was recorded in control treatment (T_6) which was statistically similar with T_5 (125 cm distance from the tree base) treatment recorded dry shoot weight of stem amaranth (3.64 g). While the lowest dry shoot weight of stem amaranth (2.61 g) was recorded in T_1 (25 cm distance from the tree base) treatment

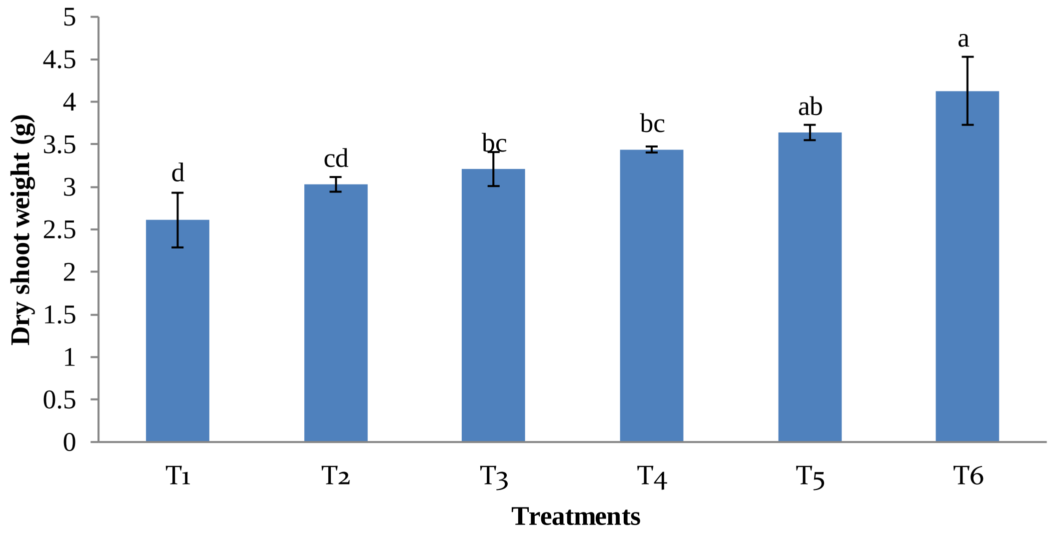


Figure 9. Effect of different distance from the tree base on dry shoot weight of stem amaranth at harvest

Here, T_1 = 25 cm distance from the tree base, T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

4.1.10 Dry root weight (g)

Interaction of stem amaranth and moringa (with or without) showed significant variation on dry root weight (g) of stem amaranth (Figure 10).Dry root weight of stem amaranth varied 0.71-1.02 g at harvest due to effect of different treatment. At harvest the highest dry root weight of stem amaranth (1.02 g) was recorded in control treatment (T_6) which was statistically similar with T_5 (125 cm distance from the tree base) treatment recorded dry root weight of stem amaranth (0.98 g). While the lowest dry root weight of stem amaranth (0.71 g) was recorded in T_1 (25 cm distance from the tree base) treatment. The variation of dry root weight may be due nutrient availability among different treatment.

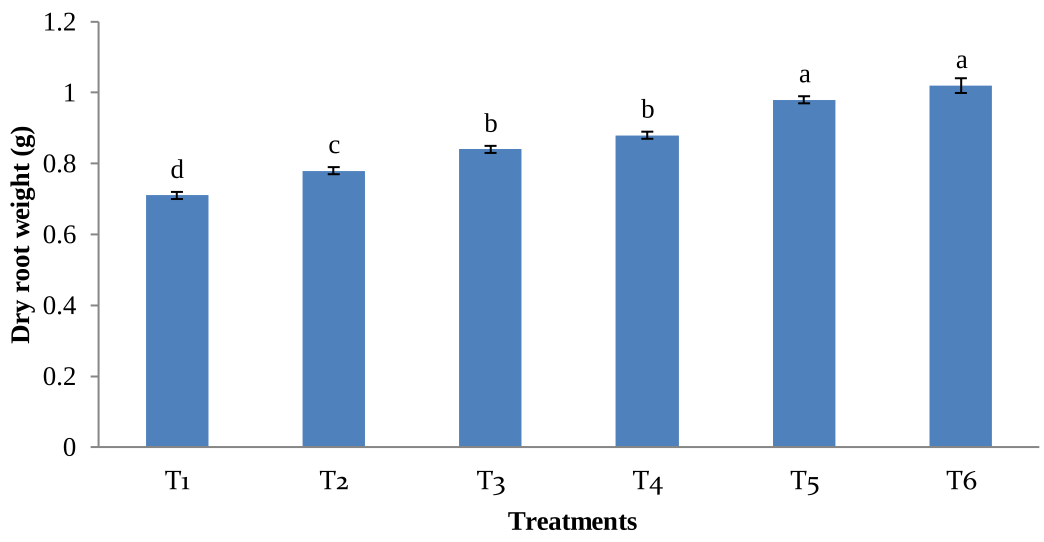


Figure 10. Effect of different distance from the tree base on dry root weight of stem amaranth at harvest

Here, T_1 = 25 cm distance from the tree base, T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

4.1.11 Yield plot^{-1} (kg)

Yield of stem amaranth was significantly influenced with increasing distance from tree base (Figure 11). Due to effect of different treatment stem amaranth yield varied 7.03 -14.17 kg plot^{-1} at harvest. Experimental result revealed that, at harvest the highest yield of stem amaranth (14.17 kg plot^{-1}) was recorded in control treatment (T_6). While the lowest yield of stem amaranth (7.03 kg plot^{-1}) was recorded in T_1 (25 cm distance from the tree base) treatment. But under tree crop interaction T_5 (125 cm distance from the tree base) treatment perform well and recorded yield plot^{-1} of stem amaranth (11.83 kg plot^{-1}) comparable to others interaction treatments.

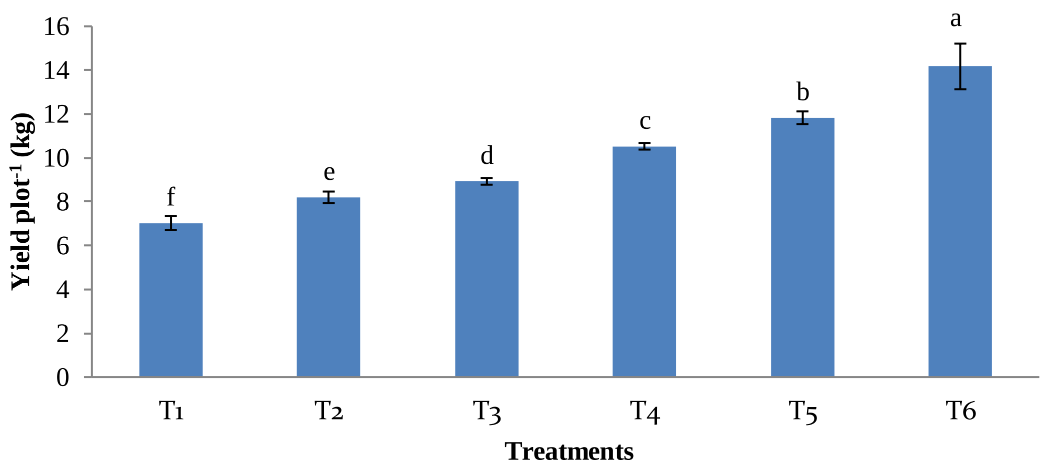


Figure 11. Effect of different distance from the tree base on yield plot^{-1}of stem amaranth at harvest

Here, T_1 = 25 cm distance from the tree base,T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

4.1.12 Yield (t ha^{-1})

Yield of stem amaranth was significantly influenced with increasing distance from tree base (Figure 12). Due to effect of different treatment stem amaranth yield varied 15.63-31.48 t ha^{-1} at harvest. Experimental result revealed that, at harvest the highest yield of stem amaranth (31.48 t ha^{-1}) was recorded in control treatment (T_6). While the lowest yield of stem amaranth (15.63 t ha^{-1}) was recorded in T_1 (25 cm distance from the tree base) treatment. But under tree crop interaction T_5 (125 cm distance from the tree base) treatment perform well and recorded yield of stem amaranth (26.30 t ha^{-1}) comparable to others interaction treatments. The result obtained from the present study was similar with the findings of Solanki *et al.* (2014) and reported that fresh weight of plant/plot (kg), dry weight of plant/plot (kg) and economic yield (kg/ha) was recorded higher under sole crop of Basil, Kalmegh and Mint as compared to intercrop with Sapota-Jatropha in both the years. Sarkar *et al.* (2014) reported that that the growth and yield of radish and coriander in association with the Lohkat tree increased significantly with increasing distance from tree. Sehgal (2011) reported that the growth of *O. basilicum* was suppressed to a greater extent at a distance closer to the hedgerows in all the treatments.

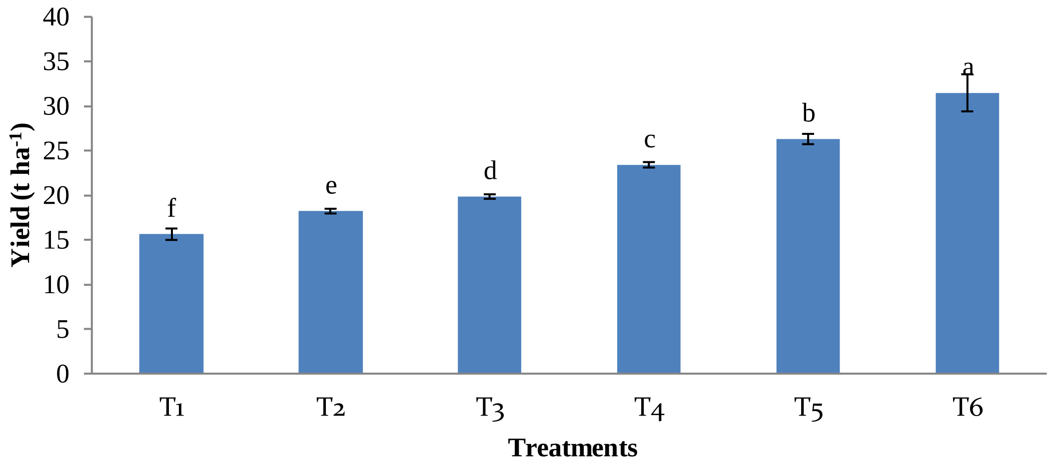


Figure 12. Effect of different distance from the tree base on yield ha^{-1}of stem amaranth at harvest

Here, T_1 = 25 cm distance from the tree base,T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

4.2. Economic analysis of *M.oleifera* and *A.lividus* based agroforestry system

The economic performance of different treatments were determined on per hectare area basis, which includes total cost of production, gross returns, net returns and benefit cost ratio under different treatments imposed (Table 3).

4.2.1 Total cost of production

Cost of production varied due to different treatment. The cost of production was varied mainly for the sole cropping and intercropping. In case of only stem amaranth cultivation, there was no involvement of cost for Moringa cultivation. In this experiment highest total cost of production (65666 Tk) was recorded in moringa amaranth based intercropping system and lowest (50152 Tk) in sole cropping of stem amaranth cultivation.

4.2.2 Gross return (Tk)

Gross return was influenced by different treatment. The highest gross return (613700 Tk) was recorded under tree crop interaction T_5 (125 cm distance from the tree base) treatment while the minimum (314800 Tk) insole cropping (T_6)of stem amaranth cultivation.

4.2.3 Net return (Tk)

Net return was varied by different treatment. The highest net return (548034 Tk) was recorded under tree crop interaction T_5 (125 cm distance from the tree base) treatment while the minimum (264648 Tk) insole cropping (T_6). The result obtained from the present study was similar with the findings of Rahangdale *et al.* (2014) and reported that the bamboo based agroforestry system Rs.21,029/ha gave higher monetary return as compared to sole bamboo Rs.9,801/ha. Yaseen *et al.* (2001) reported that additional income from the clover was Rs.23,800/ha in addition to menthol mint yield. The total monetary benefit due to clover-mint system wasRs.89,900/ha, which was 1.5 times compared with that of sole menthol mint.

4.2.4 Benefit cost ratio (BCR)

Benefit cost ratio varied in different treatment. The highest benefit cost ratio (9.35) was recorded under T_5 (125 cm distance from the tree base) treatment whereas the lowest benefit cost ratio (6.28) was recorded in sole cropping (T_6).

Table 3. Gross retrun, net return and BCR of of *Moringa oleifera* and *Amaranthus lividus* based agroforestry system

Treatment	Gross retrun (Tk)/ha	Total cost of production/ha	Net return/ha	BCR
T_1	507000	65666	441334	7.72
T_2	532900	65666	467234	8.11
T_3	549200	65666	483534	8.37
T_4	584800	65666	519134	8.91
T_5	613700	65666	548034	9.35
T_6	314800	50152	264648	6.28

Here, T_1 = 25 cm distance from the tree base,T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY

Bangladesh is struggling to provide the national demand of food, fuel as well as malnutrition due to overcrowded condition with geometrical population growth rate. Agroforestry system is one of the diversified systems that can balance this problem by maximum utilization of land. A field experiment was therefore conducted at Agroforestry research field of Sher-e-Bangla Agricultural University Dhaka,to evaluation of tree-crop interactions in *Moringa oleifera* and *Amaranthus lividus* based Agroforestry system during the period from January 2020 to April 2020.The experiment was consisted of 6 treatments *viz;* T_1 = 25 cm distance from the tree base, T_2 = 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 = 100 cm distance from the tree base ,T_5 =125 cm distance from the tree base and T_6 = Open field referred to as control (Sole crop) treatment that followed Randomized Complete Block Design (RCBD). Data on different parameters were collected for assessing results for this experiment and showed significant variation in respect of growth and yield of amaranth due to the effect of different treatments.

Experimental result showed that the growth and yield parameters; such as plant height, number of leaves plant^{-1}, leaf length, leaf breadth, weight plant^{-1} (fresh and dry), yield plot^{-1} and yield ha^{-1} of *Amaranthus lividus* were significantly influenced by the distance from the *Moringa oleifera* trees and the highest values of above said parameters were recorded in the plants growing in open field (T_6) and lowest at < 25 cm distance from the under canopy (T_1). Increasing distance from the *Moringa oleifera* trees gradually increasing the growth and yield characteristics of stem amaranth, and in case of *Moringa oleifera and Amaranthus lividus* interaction the highest leaf length (11.83 cm), leaf breadth (6.03), stem diameter (27.30 mm), root length (13.33 cm), shoot length (43.70 cm), fresh shoot weight (64.70 gm), fresh root weight (9.20 gm), dry shoot weight (3.64 gm), dry root weight (0.98 gm), yield plot (11.83 kg) and yield (26.30 t ha^{-1}) of *Amaranthus lividus* were obtained in T_5 (125 cm distance from the tree base) treatment and this treatment also recorded the highest gross return (613700 Tk), net return (548034 Tk) and benefit cost ratio (9.35) comparable to others interaction treatments.

CONCLUSION

Based on the results of the present experiment, the following conclusion can be drawn: *M.oleifera* suppressed crop growth and productivity of *A.lividus* at closer distance from the tree row. Increasing distance from the *M.oleifera* trees gradually increasing the growth and yield characteristics of stem amaranth. Among different *M.oleifera and A.lividus* interactions, the highest yield (26.30 t ha^{-1}) of *A.lividus* was obtained in T_5 (125 cm distance from the tree base) treatment comparable to others interaction treatments.The highest gross return (613700 Tk), net return (548034 Tk) and benefit cost ratio (9.35) were observed in T_5 (125 cm distance from the tree base) treatment comparable to sole cropping. So, farmer may cultivate moringa tree in association with stem amaranth maintaining 125 cm distance from tree base for gaining higher profitability.

RECOMMENDATION

Further studies need to be conducted throughout the year on tree-crop interactions between *M. oleifera and A. lividus* to evaluate the systems before recommended to farmer's to identify the better one level.

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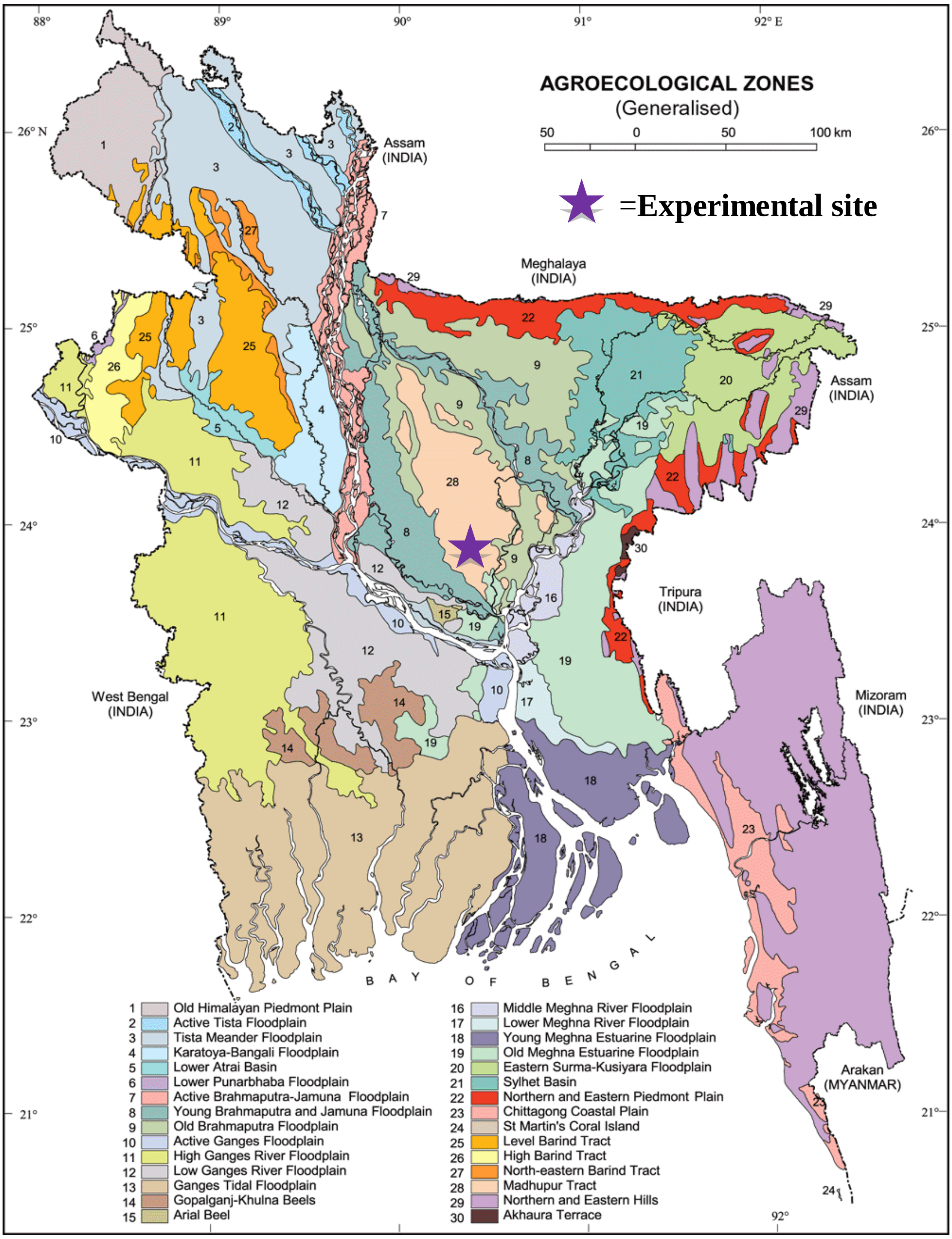
APPENDICES

Appendix I. Map showing the experimental location under study



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10

Appendix III.Monthly meteorological information during the period from January to April, 2020.

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2020	January	25.5	13.1	41	00
	February	25.9	14	34	7.7
	March	31.9	20.1	38	71
	April	33.7	23.9	74	168

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance of the data of plant height (cm) of stem amaranth at different DAS

		Mean square of				
Source	DF	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS
Replication	2	0.75036	1.39854	0.6226	9.3877	0.2955
Treatments	5	0.64589*	9.19922*	15.6409*	38.2947*	57.4997*
Error	10	0.03059	0.04129	0.2261	4.8754	0.6236
Total	17					

*: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data of number of leaves plant^{-1} of stem amaranth at different DAS

		Mean square of				
Source	DF	10 DAS	20 DAS	30 DAS	40 DAS	50 DAS
Replication	2	0.06313	0.10500	0.0779	0.0607	0.7853
Treatments	5	1.17522*	4.64900*	10.7846*	13.3726*	15.8049*
Error	10	0.00271	0.04500	0.1351	0.1959	0.7476
Total	17					

*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data of leaf length, leaf breadth and stem diameter of stem amaranth at harvest

Mean square of				
Source	DF	Leaf length	Leaf breadth	Stem diameter
Replication	2	0.28434	0.12887	0.57331
Treatments	5	6.56222*	4.17422*	6.34722*
Error	10	0.22313	0.05689	0.50134
Total	17			

*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of shoot length, root length and, fresh shoot weight of stem amaranth at harvest

Mean square of				
Source	DF	Shoot length	Root length (cm)	Fresh shoot weight
Replication	2	0.6103	0.12887	0.8855
Treatments	5	17.8689*	4.35733*	11.9779*
Error	10	1.0353	0.05689	0.6469
Total	17			

*: Significant at 0.05 level of probability.

Appendix VIII. Analysis of variance of the data of fresh root weight, dry shoot weight, dry root weight of stem amaranth at harvest

Mean square of				
Source	DF	Fresh root weight	Dry shoot weight	Dry root weight
Replication	2	0.16103	0.01069	0.00139
Treatments	5	4.98322*	0.82181*	0.04165*
Error	10	0.06113	0.08898	0.00058
Total	17			

*: Significant at 0.05 level of probability.

Appendix IX. Analysis of variance of the data of yield plot and yield ha^{-1} of amaranth at harvest

Source	DF	Mean square of	
		Yield plot (kg)	Yield (t ha^{-1})
Replication	2	0.8222	4.144
Treatments	5	20.4623*	101.049*
Error	10	0.1129	0.589
Total	17		

*: Significant at 0.05 level of probability.

Appendix X.Cost of production of moringa amaranth intercropping system

Input cost= Non material cost + Material cost

A. Non material cost

Items	No. of labor required	Amount taka
Harvesting and others works	20	8000
	Grand total= 8000	

(Individual labor wages 400 taka day^{-1}).

B. i. Material cost (Moringa)

Sl. No.	Quantity (ton/kg/ha)/times	Items Cost (Tk)	Cost (Tk/ha)
Fertilizers			
Cowdung	31 ton	400	12000
			Grand total= 12000 Tk

B . ii. Material cost (Amaranth)

Sl. No.	Quantity (ton/kg/ha)/times	Items Cost (Tk)	Cost (Tk/ha)
Seed rate ha^{-1}	2 kg	60	120
Fertilizers			
Cowdung	10 ton	400	4000
Urea	125 kg	16	2000
TSP	75 kg	22	990
MP	100 kg	15	1500
Gypsum	-	8	
Zinc sulphate	-	250	
Boron	-		
Irrigation	3 times	1000	3000
Tractor	1	3000	3000
			Grand total= 14610Tk

C. 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.

D. Miscellaneous cost (common cost)

It was 5% of total input cost

E. Total cost of production (Amaranth)

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)
		ii					
8000		14610	22610	1413	1130	25000	50152

F. Total cost of production (Moringa + Amaranth)

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					
8000	12000	14610	34610	4326	1730	25000	65666

G. Gross return from moringa amaranth cultivation

Moringa pods = 1 kg 70 taka so 1 ton = 70000 taka

Amaranth = 1 kg 10 taka so 1 ton = 10000 taka

Treatment	Moringa pods yield (t/ha)	Value	Amranth leaf yield (t/ha)	Value	Gross retrun (Tk)
T_1	5.01	350700	15.63	156300	507000
T_2	5.01	350700	18.22	182200	532900
T_3	5.01	350700	19.85	198500	549200
T_4	5.01	350700	23.41	234100	584800
T_5	5.01	350700	26.30	263000	613700
T_6	0	0	31.48	314800	314800

Here, T_1 = 25 cm distance from the tree base,T_2= 50 cm distance from the tree base, T_3 = 75 cm distance from the tree base, T_4 =100 cm distance from the tree base, T_5 = 125 cm distance from the tree base and T_6 = Control (Sole crop).

PLATES

Plate 1. Experimental field preparation for seed sowings

Plate 2. Seeds sowing to the experimental field

Plate 3. Stem amaranth seedling establishment in the experimental field