PRODUCTIVITY AND PROFITABILITY OF *MORINGA*-RED AMARANTH BASED AGRISILVICULTURAL FARMING SYSTEM

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CERTIFICATE

This is to certify that the thesis entitled **"PRODUCTIVITY AND PROFITABILITY OF *MORINGA*-RED AMARANTH BASED AGRISILVICULTURAL FARMING SYSTEM"** submitted to the Department of Agroforestry And Environmental Science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **AGROFORESTRY AND ENVIRONMENTAL SCIENCE**, embodies the result of a piece of bona fide research work carried out by **KANIJ FATEMA, Registration No. 14-06268** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2021
Dhaka, Bangladesh

……………………………………….
Dr. Md. Kausar Hossain
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THIS THESIS IS LOVINGLY DEDICATED TO MY PARENTS

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PRODUCTIVITY AND PROFITABILITY OF *MORINGA*-RED AMARANTH BASED AGRISILVICULTURAL FARMING SYSTEM

ABSTRACT

An experiment was conducted to assess the productivity and profitability of *Moringa*-Red Amaranth based agrisilvicultural farming system at the Agroforestry Field under the Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University during the period from 1st December 2020 to January 2021. Four treatments namely, T_1= 30 cm distance from the tree base, T_2= 50 cm distance from the tree base, T_3= 75 cm distance from the tree base and T_4= Open field referred to as control, were used in Randomized Complete Block Design (RCBD). The highest leaf length (9.30 cm) and breadth (6.17 cm) were found in T_4 treatment. The maximum yield of red amaranth (14.25 t/ha) was observed in T_4 treatment. Apart from control, the highest fresh weight (37.00 g), dry weight (1.13 g) and yield (12.69 ton ha^{-1}) were also obtained in T_3 treatment. Thus, it revealed that in association with *Moringa* sapling the best yield performance of red-amaranth was found at the plants belong to treatment T_3. In *Moriga* based agroforestry system calculated BCR was 6.48 found in T_3 treatment.

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ABBREVIATIONS

Abbreviations	Full word
BBS	Bangladesh Bureau of Statistics
etc.	Etcetera
e.g.	Exempli gratia (L), for example
SAU	Sher-e-Bangla Agricultural University
et al.	And others
DAS	Days After Sowing
RCBD	Randomized Complete Block Design
DMRT	Duncan's Multiple Range Test
BCR	Benefit Cost Ratio
TSP	Triple Super Phosphate
MP	Muriate of Potash
M.S.	Master of Science
%	Percentage
WHO	World Health Organization
IPCC	Standard Deviation
IVs	Indigenous Vegetables
FAO	Food and Agricultural Organization
BARI	Bangladesh Agricultural Research Institute
SRDI	Soil Research and Development Institute

CHAPTER I

INTRODUCTION

Bangladesh is one of the world's most densely populated country, with over 166 million people battling to find food. In the last 30 years, the population has doubled, resulting in a density of 1125 people per square kilometer (BBS, 2021). Around 85% of the population lives in rural areas and relies on agriculture for a living. Due to intense cropping and the adoption of high-input technology, our land's potential is diminishing day by day (BBS, 2021). Some strategies, such as agro-forestry, have recently been proposed as a means of overcoming future issues. Agroforestry or the integration of tree, agricultural, and vegetable production on the same piece of land, is a potential production technique for increasing productivity and maintaining a healthy environment (Nair, 2012). Farmers have traditionally grown various types of trees and vegetables in tandem at their homesteads, with low vegetable output due to a lack of optimal pairings. Vegetable crops excluding potato occupy only 2.08% of the total cropped area with a gross production of 1.95 million tons (BBS, 2021). This limited land resource is engaged in producing minimum vegetables requirements for the people. Therefore, much emphasis was not given on vegetable and fruit production, which are important sources of nutrition. The minimum dietary requirement of vegetables per day per capita is 85 g, whereas the availability is only 30-35 g (Siddique, 2015). The per capita consumption of vegetable in Bangladesh is only 53 g, which is pretty below the recommended daily requirement of 200 g/head/day. The low consumption of vegetables creates a tremendous pressure over cereals and also causes malnutrition leading to several kinds of health hazards. To provide balance diet there would be no alternative to produce vegetable, as this would also provide vitamins and minerals. On the other hand, there is little scope to increase cultivation area. Hence we need to find out other alternatives.

Red Amaranth (*Amaranthus tricolor*) and drumstick (*Moringa oleifera*) are such promising plants which have both a medicinal and a functional property. Drumstick leaves contain cytokinins in the form of zeatin as well as other beneficial phytochemicals such as vanillin, beta-sitosterol, caffeoylquinic acids, kaempferol, quercetin and carotenes (Andrews and Andrews, 2009). Amarnath leaves contain dietary fibre, folic acid and perhaps other bioactive nutrients such as bioflavonoids.

M. oleifera is a multi-purpose tropical tree belonging to Moringaceae family, commonly referred to as the 'drumstick tree' (describing the shape of its pods) or 'horseradish tree' (Anwar and Rashid, 2003). All parts of *M. oleifera* are economically viable as food and nutrition, animal fodder, natural coagulants, forestry products and fertilizer (Fahey, 2005; Afolabi *et al.*, 2013; Ahmad *et al.*, 2014). In addition, the leaves and the seeds are nutritionally rich containing high concentrations of crude protein, calcium, iron, potassium, manganese, essential vitamins (thiamine, riboflavin, niacin, ascorbic acid), the sulphur-containing amino acids methionine and cystine (Foidl *et al.*, 2001); antioxidants and anti-inflammatory compounds (Adisakwattana and Chanathong, 2011 and Adejumo *et al.*, 2012).

Red amaranth (*Amaranthus gangeticus* L.) is a common leafy vegetable throughout the Bangladesh (Monira, 2007) and grows plenty in warm temperate regions of tropical and subtropical Asia (Alonge *et al.,* 2007) during summer and rainy season. Total red amaranth production in Bangladesh is 50139 MT covering 27055 acres amaranth producing area (BBS, 2015).Red amaranth is a heat-loving C_4 crop (Baral *et al.*, 2011). C_4 plants exhibit higher photosynthetic and growth rates due to gains in the water, carbon and nitrogen efficiency uses. The leaves and stems of amaranth are rich in protein, fat, calcium, phosphorus, riboflavin, niacin, sodium, iron and ascorbic acid (Makinde *et al.*, 2010). Additionally, it contains 43 food caloric which is higher than any other vegetables except potato and tomato (Yadav *et al.*, 2013).

Further, red amaranth leaves contain magnesium, an antimuta-gen and chlorophyllin, a proven efficient antimutagen andantioxidants (Anilakumar *et al.*, 2006). Red amaranth leaves tended to be associated with high total polyphenol andantioxidant activity. The high amount of betacyanin in red amaranth, which gives its deep red hue, enhances antioxidant activity along with phenolic compounds (Khandaker *et al.*, 2008).

Considering the above facts the present experiment was undertaken to evaluate the performance of red amaranth in association with *Moringa* with the following objectives

- To determine the optimum distance from the tree base for intercropping red amaranth with *Moringa* trees;
- To evaluate the yield characteristics of red amaranth in association with the *Moringa t*ree;
- To determine the cost benefit ratio of the *Moringa*-Red amaranth Agroforestry system.

CHAPTER II

REVIEW OF LITERUARE

The review of literature from previous research connected to the current experiment is offered, which was compiled by looking through journals, theses, internet surfing, reports, periodicals, and other types of publications.

2.1 Concept of Agroforestry

Agroforestry refers to land-use systems and technologies in which woody perennials (trees, shrubs, palms, bamboos and so on) are intentionally planted alongside agricultural crops and/or animals on the same land-management units in some sort of spatial arrangement or temporal sequence. There are both ecological and economic linkages between many components of Agroforestry systems. Agroforestry is also a dynamic, ecologically oriented natural resource management system that diversifies and sustains output for improved social, economic, and environmental advantages for land users at all levels through the integration of trees on farms and in the agricultural landscape. Agroforestry is especially important for smallholder farmers and other rural residents since it can improve their food supply, income, and health. Agroforestry systems are multifunctional systems that offer a variety of economic, societal, and environmental benefits.

Agroforestry systems can be divided into three categories

- Agrisilvicultural systems, such as alley cropping or home gardens, combine crops and trees.
- On pastures, rangelands, or on-farm, silvopastoral systems combine forestry and grazing of domesticated animals.
- The three elements, trees, animals, and crops, can be combined in agrosylvopastoral systems, which are exemplified by home gardens with animals and scattered trees on croplands utilized for grazing after harvests.

Agroforestry, the integration of tree and crop or vegetables on the same area of land is a promising production system for maximizing yield and maintaining friendly environment. According to IPCC (2000) it has been shown that agroforestry systems have 3-4 times more biomass than traditional treeless cropping systems and in Africa they constitute the third largest carbon sink after primary forests and long term fallows.

Albrecht *et al.* (2003) reported that the agroforestry practices are based on a variety of management approaches and have potential positive implication for climate change mitigation.

Rahim *et al.* (2007) reported that traditionally, multilayer tree garden or multistoried cropping is practiced in and around the homestead of Bangladesh in an unsystematic manner. An initiative was taken to develop systematic multistoried cropping system. In multistoried cropping system, indigenous vegetables and medicinal plants grow very well as compared to the sole cropping. In this system natural resources were utilized properly. Income per unit area increased substantially with this system. This approach ultimately helps to remove nutritional problems as well as poverty alleviation of developing countries like Bangladesh.

Bayala *et al*. (2008) reported that Agroforestry has potentiality to improve soil fertility. This is mainly based on the increase of soil organic matter and biological nitrogen fixation by leguminous trees. Trees on farms also facilitate more nutrient cycling than mono culture systems, and enrich the soil with nutrients and organic matter, while improving soil structural properties. Hence, through water tapping and prevention of nutrient leaching, tree help recover nutrients, conserve soil moisture and improve soil organic matter.

Lott (2009) stated that some studies suggest that smallholder farmers in developing countries may combat climate change by reverting to more natural productive systems, which provide improved ecological and social functions, while meeting adaptation needs and building resilient agro- ecological systems that actively sequester carbon.

According to Kumar (2012) Agroforestry could be a win-win solution to the seemingly difficult choice between reforestation and agricultural land use, because it increases the storage of carbon and may also enhance agricultural productivity.

According to FAO (2013) currently, there is a growing interest in investing in Agroforestry systems for these multiple benefits and also as a set of innovative practices that strengthen the system's ability to cope with adverse impacts of a changing climate.

2.2 Agroforestry's Desirable Qualities

The following desirable properties should be considered while choosing tree species for Agroforestry systems. Despite the fact that all desirable features are not found in a single species, their many applications are addressed.

Tree species chosen for Agroforestry should not interfere with soil moisture

- Tree species chosen for Agroforestry should have a low water requirement;
- Tree species chosen for Agroforestry should not compete for water with key agricultural crops.
- Tree species should have deep tap roots, allowing them to collect water from the soil's deep layers.

Tree species should not compete for plant nutrients

- Tree species should not consume additional plant nutrients; and
- They should aid in soil fertility building.
- Preference should be given to leguminous tree species that fix

atmospheric nitrogen in their roots.

- Ideally, the root system and root growth characteristics should lead to the investigation of soil layers other than those trapped by agricultural crops.

Tree species should not compete for sunlight

- Tree species should not block sunlight from reaching crops; and
- Tree species should have a light branching habit.
- Trees allow light to penetrate the earth, promoting improved crop, pasture, and yield growth.
- Tree species with a dense canopy can endure pruning operations.

Tree species should have a high rate of survival and be easy to establish

- Tree species should have a high survival rate;
- After transplantation, leave few or no gaps.
- Hardy tree species are simple to plant.
- They have a lower death rate because they can easily withstand transplant shocks.
- After transplantation, trees should be able to grow lateral roots in a short amount of time.

Tree species should have a quick growth rate and be easy to maintain

- Tree species for an Agroforestry system should primarily be fast-growing;
- Rapid growth, particularly in the early years;
- The tree should rotate in a short amount of time (the period between planting and final harvesting)
- Fast-growing plants like as Poplar, Casuriana, and Leucaena leucocephala, among others, are significant species that can be planted in AFS.

Tree species should be able to adapt to a wider range of conditions

- The tree species chosen for Agroforestry combinations must be adaptable.

The majority of Indian farmers rear cattle separately

- The cut-and-carry method of fodder production is extremely common.
- As a result, farmers must choose tree species that are attractive to cattle and have a high digestibility in Agroforestry.

Tree species should have the ability to provide shelter as well as soil stabilization

- Some tree species are especially beneficial in providing protection for soils, crops, and livestock due to their natural growth habits and flexibility. Because of their vast root systems and capacity to grow in water-logged soils, poplars (*Populus* spp.), willows (*Salix* spp.), *Casurina equisetifolia*, and other trees have been widely utilized in soil erosion management.

Tree species should be capable of nutrient cycle and nitrogen fixing

- Trees can play an essential role in recycling nutrients leached down through the soil profile and minerals released from weathering parent material such as rocks and sediments in an Agroforestry system.
- These nutrients are consumed by the tree during its growth and development, with many of them returning to the topsoil in the form of dead leaves, twigs, blossoms, and seeds that disintegrate on the surface or are eaten by animals.
- Although all trees contribute to maintaining the soil's nutrient status through recycling,
- Deciduous trees lose the majority of their leaves in the autumn, creating a dense mat of leaves on the ground, whereas most evergreen species have some litter fall throughout the year.

- Another major issue is that many tree species can exploit a complicated symbiotic relationship between Rhizobium bacteria and their fine roots to transform atmospheric nitrogen into organic nitrogen for their own use.
- The bacteria develop nodules on the roots that can convert nitrogen gas from the atmosphere into plant-available nitrogen.
- Most leguminous and some non-leguminous trees, such as Acacia, Leucaena, and Prosopis, as well as Casuarina spp., fix atmospheric nitrogen, and their litter is generally high in nitrogen, enhancing the nitrogen status of the soil.

2.3 Agricultural Crops Characteristics for Agroforestry

- Agricultural crops should have a short life cycle and grow quickly.
- They should be tolerant of shadow to some extent.
- The leguminosae family should account for the majority of them.
- They should respond well to tree planting at a high density.
- They must withstand adverse conditions like as water stress and/or overwatering;
- Crops should return sufficient organic matter to the soil through fallen leaves, root systems, stumps, and other means.
- Crops should be used wisely in intensive or multiple cropping cuisines, and their individual flavor should be recognized.

2.4 *Moringa*

Moringa oleifera Lam. belonging to the family Moringaceae is a softwood tree, native of India, occurring wild in the sub- Himalayan regions of Northern India and now grown world wide in the tropics and sub-tropics. In India it is grown all over the subcontinent for its tender pods and also for its leaves and flowers. The pod of *Moringa* is a very popular vegetable in South Indian cuisine and valued for their distinctly inviting flavour.

Moringa is well-known for its medicinal properties and a long list of health benefits. Antifungal, antiviral, anti-depressant, and anti-inflammatory properties all work together to prevent recurrence of the illness. The tree is native to India, but it may also be found in other parts of the world, including Asia, Africa, and South America. *Moringa c*ontains a wide range of proteins, vitamins, and minerals. *Moringa oleifera* few documented side effects are generally benign. It has a high nutritional value as well as promising medicinal potential. There are many different minerals present, and they are a good source of protein, vitamins, and antioxidants. *M. oleifera* is even more significant because of its considerable medicinal capabilities, which are especially vital due to the high nutritional content of *M. oleifera* sap. The leaves, roots, seed, bark, fruit, flowers, and immature pods of this plant are employed in the traditional medicinal system to cure a variety of ailments, including the in South Asia.

Importance of *Moringa*

The medicinal qualities of the *Moringa* tree are well-known. Because all parts of the *Moringa* tree are edible, humans have traditionally consumed them all. It is commonly recognized as a vegetable, a medicinal plant, and a source of vegetable oil in the developing countries. *Moringa* is a plant that is high in vitamins and minerals. The leaves have seven times the amount of vitamin C as oranges and fifteen times the amount of potassium as bananas. Calcium, protein, iron, and amino acids are also present, all of which contribute in the healing process. *Moringa oleifera* leaves, fruits, immature pods, and flowers are blended into a traditional human diet. *Moringa oleifera* is used as a food. Dried *Moringa* leaves and fresh *Moringa* leaves, for example, are used in Indian cuisine (Stevens et al., 2013))

Species type (www.healingmoringatree.com.

- *Moringa* arborea Verdc. (indigenous to Kenya)
- *Moringa* borziana Mattei (indigenous to Somalia)

- *Moringa* concanensis [sv] Nimmo (indigenous to northern India)
- *Moringa* drouhardii Jum. – bottle tree (indigenous to southwestern Madagascar)
- *Moringa* hildebrandtii Engl. – Hildebrandt's moringa (indigenous to southwestern Madagascar) Moringa longituba Engl. (indigenous to Ethiopia and Somalia)
- *Moringa oleifera* Lam. (syn. M. pterygosperma) – horseradish tree (indigenous to northwestern India. Moringa ovalifolia Dinter & Berger (indigenous to Namibia and Angola)
- *Moringa peregrina* (Forssk.) Fiori indigenous to Arabian Peninsula Horn of Africa and in the Southern Sinai, Egypt *Moringa* pygmaea Verdc. (indigenous to Somalia)
- *Moringa rivae* Chiov. (indigenous to Kenya and Ethiopia)
- *Moringa ruspoliana* Engl. (indigenous to Ethiopia)
- *Moringa stenopetala* (Baker f.) Cufod. (indigenous to Kenya and Ethiopia)

Morphological Description

It's a fast-growing deciduous tree. It can reach a height of 10–12 m (32–40 ft) and a trunk diameter of 45 cm (1.5 ft). The bark has a whitish-grey hue to it and is surrounded by thick cork. Young shoots have purple or greenish-white bark that is hairy (Kuikman *et al.,* 2015).

Propagation

Moringa can be grown from seeds or cuttings. Direct seeding is likely with *M.oleifera d*ue to its high germination rate. *Moringa* seeds can be sprouted all year in well-draining soil. For vegetative development, cuttings with a length of 1 m and a diameter of at least 4 cm can be used (Khan *et al.*, 2016 and Kar *et al.*,2020).

Medicinal Properties (Farooq *et al.*, 2012)

- Skin and hair protection and benefits
- *Moringa* seed oil keeps hair healthy and fresh by protecting it from free radicals.
- *Moringa's* anti-inflammatory properties may aid in the prevention of edema maturation.
- *Moringa* appears to protect the liver from the side effects of antitubercular medications and may hasten the healing process.
- Extracts possess properties that may aid in cancer prevention. It also contains niazimicin, a substance that prevents malignant cells from multiplying.
- *Moringa's* antibiotic and antibacterial properties may aid in the prevention of pathogen formation, and its high vitamin B concentration aids digestion.
- *Moringa* extracts may aid in the treatment of gastrointestinal issues such as constipation, gastritis, and ulcerative colitis.
- *Moringa c*ontains calcium and phosphorus, which help to keep bones healthy and strong. *Moringa* extract may help with the treatment of ailments including arthritis and the repair of fractured bones, in addition to its anti-inflammatory properties.
- *Moringa* extract includes significant antioxidants that have been demonstrated to help prevent cardiac damage and maintain a healthy heart, and it has been proved to help with melancholy, worry, and weariness.
- *Moringa* extract has been shown to aid in wound healing and scar reduction, as well as lowering blood glucose levels and sugar and protein levels in the urine. As a result, the hemoglobin levels and total protein content of the people who were tested improved.
- *Moringa* has been demonstrated to help prevent bronchial constriction and reduce the intensity of asthma attacks. It has also long been known to aid lung function and respiration in general.

- People who ingest *Moringa* extract may have a lower risk of developing kidney, bladder, or uterine stones. *Moringa* is high in antioxidants, which may aid to reduce kidney damage.
- The compounds isothiocyanate and niaziminin contained in *Moringa* help to prevent arterial hardening, which can raise blood pressure.
- *Moringa* has the ability to improve vision due to its high antioxidant content. *Moringa* has been proven to suppress retinal dysfunction by reducing retinal artery dilation, capillary membrane thickening, and retinal artery dilation.
- *Moringa* may help with iron absorption, resulting in a higher red blood cell count. The plant extract is thought to help with anemia and sickle cell disease therapy and prevention.

Fertilizer

In comparison to other treatments with more protein, Sarwar *et al.* (2002) found that 120 kg ha^{-1} (NPK) generated plants with greater height stem girth, number of leaves, and maximum number of branches at week 8. In comparison to the others, the carbohydrate content of 50 + 50 percent (NPK + Compost) was considerable. Inorganic ions such as nitrogen (N), phosphorus (P), and potassium (K) play important roles in plant activities.

Deep root system

Moringa has a deep tap root system with very less or few lateral roots, which will not compete for nutrients with the crops and also tree bring nutrients from deeper layer of soil to the surface. it will also added nutrients infield through leaf and litter fall. Tree leaves are very good as reclaiming, marginal land (Fuglie, 1999).

Diversified uses

Tree has multiple benefits to society due to it's diversify nature of products. All parts of tree are utilized in variety of purpose. The tree 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 tree like anti-inflammatory, curing of skin cancer, diabetes, anemia and high blood pressure. Liver, kidney, stomach and thyroid problems. Almost all parts of the tree 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 tree 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 tree 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).

Food security potential

Almost all parts of tree (leaves, flower pod for vegetable purpose seed oil for cooking purpose wood for fuel purpose) are consumed in various manners by human and their livestock. Tree has the potential of improving nutrition, boost food security, and foster rural development by enhancing and sustaining rural households as well as supporting sustainable land use and care (Adedokum *et al.,* 2010; Odedode *et al.,* 2010). Each products/parts of tree are rich source of vitamin and iron. Every part of the tree can be eaten especially the leaves, young shoots, young pods, flowers, roots and the bark (Adeyemi *et al.,* 2012). Tree has long been considered a panacea for improving the nutrition of poor communities in the tropics and sub tropics (Agbogidi and Ilondu, 2012). Now a day plant are grow commercially at many parts of the world. prevalent in different parts of the country will mitigate the impacts of climate change. Many other ecosystem services provide tree like, Improvement of soil fertility, act as barrier for Air, Water, Soil erosion, Biodiversity and habitat conservation are very essential for equilibrium between human and nature.

Climate mitigate potential of tree

All trees in nature have tangible and intangible benefits to societies. Intangible benefits include ecosystem services provide through tree or nature, essential for survival ship of human kinds. Tree improve moisture regime of soil by reducing interception losses, excess run-off and by increasing infiltration/ recharge rate and also has potential not only to arrest fast depletion of ground water table but also to reverse the trend in raising. Tree sequester aboveground and belowground carbon and thus contribute in mitigation of climate change in the long run. According to one study, the rate of *Moringa* tree to absorb carbon dioxide (CO_2) is fifty times (50x) higher when compared to the Japanese cedar tree and also twenty times (20x) higher than that of general vegetation (Villafuerte et al., 2009).

Economics of *Moringa* tree

Socio- economic consideration is very important aspects of each component in all type of farming. Unless a system is proven economical in the context of on-farm situations, it will not be adopted by the farming community. As pressure on agriculture land increased and fragmentation of farm will start very rapidly in such type of situation, poly-culture or vertical farming is the only option for subsistence of life. Rural and urban populations are becoming increasingly reliant on farm and non-farm income in order to meet their food and other needs. Products of farm trees can be important sources of farm income (Arnold *et al.,* 1995; Ajayi *et al.,* 2013). As stated above, the tree has fast growing and produces in a very short duration, are a good source of income. Almost all products of tree consumed by people and their livestock remaining products are brought in market for selling. However seedlings of *Moringa* are prepared in nursery and put on the market which fetch reasonable price and a source for generating income. These products obtained from tree not only source of food to society but also generate income even in harass condition when agriculture crop has failure. So the tree has multiple benefits to society and act as source of subsistence for life of poor people.

Management practices of tree in Agroforestry field

Proper management of tree can increased the yield of agriculture crop as well as yield of tree itself. A time to time pruning, lopping and pollarding increase the yield of agricultural crop and lopping and pruning also facilitate the sprouting of leaves. The tree *Moringa oleifera* open new dimension in field of agroforestry due its easily established, fast growing/ Short rotation habit, diversify nature of its products, multiple benefits to people and their livestock and several other direct and indirect benefit to societies across the world. The trees are planted between the crops or on the bund by the farmers. The yield of crop increase in the field where *Moringa* integrated with agricultural crop because it is rich source of nutrient and withdraw the subsurface nutrient from the soil through its deep root system. Many earlier study across the world show that the growth and yield of agricultural or horticulture crop increase when this tree incorporate in field (Anjorin *et al.,* 2010; Phiri and Mbewe, 2010; Ali *et al*., 2011; Yasmeen *et al.,* 2013) crops such as wheat (Yasmeen *et al.,* 2012 and 2013). Other than positive effect on agriculture crops, the tree has source of income to poor or small scale farmers in country. Many country across the world where population increase at the rapid rate and agricultural land fragmentation is more common (Arnold *et al*., 1995; Ajayi *et al*., 2013). The trees are very rich source of nutrients, mineral, vitamins and protein which are essential for balance diets of human kind. In the many parts of world specially rural area where nutrient deficiency in human population are more common due to unavailability of appropriate foods, low purchasing power and improper food processing, *Moringa* play important role in improving nutrition, boost food security through its highly nutrients rich products for poor people or societies lives in interiors. (Folkard and Sutherland, 1996).

Now a day *Moringa* tree popularized among the farmers across the world and adopted by them on their field as a tree component in Agroforestry system. In recent decades *Moringa* tree is an important component of silvo- aquaculture system due to its foliage and fruits which are very good feed for fish (Richter *et al.*, 2003). The multiple uses and wide range of adoptability makes it as an ideal crop for sustainable food production, subsistence of life and climate resilience. These tremendous characteristic of a tree open new dimension in field of Agroforestry. However there are several constraints which hamper the actual economics of these miracle trees like, lack of markets, lack of appropriate knowledge about cultivation practices, lack of planting material and Competition for land with other food crops (Mudyiwa *et al.*, 2013).

The *Moringa* tree can be used for medicines, human food, water purification, animal feed, alley cropping, fertilizer, living fence, domestic cleaning agent, fuel wood, and other uses. *Moringa* boosts physical energy - Give your body a boost with naturally occurring nutrients to help your energy last longer. Several studies have demonstrated that various parts of the *Moringa* plant can be used in different ways. *Moringa oleifera* seed and leaves are a good source of nutrients, pharmaceuticals, and clean contaminated water since they contain a lot of leafy material. It can also be used to crop alleys. *Moringa oleifera's* nutritional, industrial, medicinal, and agricultural benefits have all been demonstrated by Fahey. *Moringa oleifera* has a lot of potential for avoiding diseases such as vitamin deficiency, cancer, and anemia, as well as purifying contaminated water. *Moringa* powder is high in vitamins, minerals, and chemical compounds. As a result, the tree can be utilized to treat a wide range of health problems. *Moringa oleifera* has also been recommended by the World Health Organization (WHO) as an alternative to imported food sources for addressing malnutrition (Agrawal *et al.*, 2008 and Kar *et al.*, 2020).

2.5 Biodiversity of *Moringa*

The sub-Himalayan ranges of India, Sri Lanka, North Eastern and South Western Africa, Madagascar, and Arabia are home to 13 species of *Moringa. Moringa pterygosperma Gaerthn* is the most well-known and widely spread species (syn. *Moringa oleifera Lam*). The white or pink flowered *Moringa* Peregrina comes in second.

Moringa pterygosperma Gaerthn, *Moringa arabica*, and *Moringa zeylanica Sieb* are all species of *Moringa.* These are native species to North Eastern tropical Africa, Syria, Palestine, and the driest parts of Arabia.

2.6 Botany of *Moringa*

Moringa oleifera is found in all countries in the tropics, despite being endemic to a small area in the southern foothills of the Himalayas.

Botanical classification of *Moringa*

Kingdom	-	Plantae
Division	-	Magnoliophyta
Class	-	Magnoliopsida
Order	-	Brassicales
Family	-	Moringaceae
Genus	-	*Moringa*
Species	-	*oleifera*

Moringa is a member of the Moringaceae family. *Moringa oleifera* Lam is the botanical name for the tree, which belongs to the genus *Moringa.* The parietal placentation, three-valved fruit, elongated, non-dehiscent berry, and winged seeds define this family. Pax (1936) and Puri (1942) identified ten species belonging to the Old World Tropics, while Philips (1951) listed four. The family was classified as Rheoadales by Bessey (1915). It was more closely linked to the Violaceae of the Violales, according to Datta and Mitra (1942). *M.*

oleifera and *M. concanensis* are the two most prevalent species. The leaves of *M. oleifera* are normally tripinnate, with leaflets 12-18 mm long, yellow or white petioles without red streaks, and a medium-sized tree. Bipinnate leaves, leaflets 15-30 mm long, flowers with crimson streaks or reddish at base, and a huge tree describe *M. concanensis*.

2.7 *Moringa* Industrial Applications

Moringa oleifera Lam, a beautiful softwood tree native to India, grows wild in the sub-Himalayan regions of Northern India, and is currently planted all over the world in the tropics and sub-tropics. It is planted throughout India for its soft pods, leaves, and flowers, as well as for its tender pods. *Moringa* pods are a popular vegetable that are prized for their distinctive flavor. This is a common garden tree in South India, with over two million homesteads. *Moringa* is mentioned in ancient Indian literature as a fascinating plant because of its vast application in agriculture, medicine, and industry. Rajangam *et al.* (2001).

***Moringa* oil**

De-hulled seed (kernel) contains about 42% oil. The oil has a bright yellow color to it. Because it has a low tendency to decay and become rancid and sticky, it's utilized as a lubricant for fine machinery such as watches (Ferrao and Ferrao, 1970 and Ramachandran *et al.,* 1980).

It can also be used as cooking oil for vegetables. Because of its ability to absorb and hold volatile chemicals, the oil is useful in the perfume business for smell stabilization. The quantity of free fatty acids ranges from 0.5 to 3%. *Moringa* seed oil has 13 percent saturated fatty acid content and an 82 percent unsaturated fatty acid content. It has a large amount of oleic acid (70 percent) other vegetable oils typically only contain about 40% oleic acid.

Water purification

Moringa seeds contain 30-42 percent oil, and the press cake produced as a by-product of the oil extraction process has a significant protein content. Approximately 1% of these proteins are active cationic polyelectrolytes with molecular weights ranging from 7 to 17 K Dalton. Because the majority of the colloids in muddy or dirty water have a negative electrical charge, the cationic polyelectrolytes neutralize them. As a result, this protein can be employed as a non-toxic natural polypeptide for sedimenting mineral particles and organics in drinking water purification, cleaning vegetable oil, and sedimenting fibers in the juice and beer sectors (Foidl *et al.,* 2001).

This protein can therefore be used as a non-toxic natural polypeptide for sedimenting mineral particles and organics in the purification of drinking water, for cleaning vegetable oil, or for sedimenting fibers in the juice and beer industries (Foidl *et al.,* 2001).

There has recently been a growing movement to assess various indigenous, less expensive materials for wastewater treatment. Because the traditional wastewater treatment technique has some drawbacks, such as partial metal removal, high cost, and high energy needs, biological materials have been identified as low-cost wastewater treatment alternatives. *Moringa* seeds and pots have been found to be efficient sorbets for removing heavy metals and volatile organic chemicals from aqueous systems in recent investigations (Akhtar *et al.,* 2006 and Sharma *et al.,* 2006).

Nutritional potential

M. oleifera contains more than 90 nutritional chemical compounds, including proteins, lipids, carbohydrates and dietary fibers. It is used in the tropics as a food source to overcome malnutrition, especially in children and infants (Fahey, 2005 and Fuglie, 2001). Among the several nutrients found in different parts of *M. oleifera*, proteins are the most abundant, accounting for approximately 25% of dry weight (Anwar et *al.*, 2007), and at least 19 amino acids have been identified in this plant. Furthermore, *M. oleifera* also contains several minerals and vitamins. Lipids are abundant in seeds, mainly stearic acid, saturated palmitic acid and oleic acid, representing about 30% of dry weight (Abdulkarim *et al.,* 2005). The lipidic compounds linolenic acid and palmitic acid are the main constituents of *M. oleifera* leaves. In addition, the high nutritional content found in dried leaves is an indicator of the usefulness of the plant as a food resource (Moyo *et al*., 2011).

Applications of *M. oleifera* in aquaculture

Aquaculture in many countries is under strong political and social pressure to reduce environmental damage caused by intensive production systems, as a result of the use of chemicals and antibiotics for water treatment and disease prevention and control. The use of antimicrobial drugs poses a risk to human and animal health, as an intensive selective pressure for microbial communities, and favors environmental contamination by chemical residues (Makkar *et al.,* 2007). In this context, *M. oleifera* potentially represents an alternative for aquaculture, since this plant is a source of coagulant, antioxidant, and antimicrobial agents (Fahey, 2005 and Anwar *et al.*, 2007). Suspensions obtained from *M. oleifera* crushed seeds reduce organic matter and turbidity, due to the activity of the protein of the seed extract, which eliminates humic acids from water, improving water quality. In addition, as previously described, these seeds promote sedimentation or suspension and reduce bacterial load in contaminated water (Ferreira *et al.,* 2011). Some studies have reported the potential use of crude, ethanol and aqueous extracts of *M. oleifera* for water treatment and reduction of microbial load in fish and shrimp farming (Anwar *et al.,* 2007). Antimicrobial effects of *M. oleifera* seed extracts have been demonstrated against S. aureus, E. coli and *V. cholerae* isolated from tilapia *(Oreochromis niloticus*) and the shrimp Litopenaeus vannamei farming (Viera *et al*., 2010). Moreover, ethanol extract of leaves, pods and seeds, and chloroform extract of flowers have shown antimicrobial activity against microorganisms recovered from Macrobrachium amazonicum prawn farming, such as *V. cholerae serogroups* non-O1, non-O139, *V. mimicus* and *V. vulnificus,* as well as Candida spp. (*C. ciferri, C. famata*, C. *guilliermondii, C. parapsilosis and C. tropicalis*), and the dematiaceous filamentous fungus *H. werneckii* (Das *et al*., 2012 and Brilhante *et al*., 2015).

2.8 Red Amaranth

Because of its rapid growth and high output potential, red amaranth (Amaranthus gangeticus) is one of the most significant and popular vegetables in Bangladesh. The seeds can be used in a variety of baked goods. Red amaranth has the potential to improve Bangladesh's nutritional status, particularly in terms of vitamins and minerals (Hossain, 1995).

Classification

Amaranthus spp. is the scientific name for this plant.
Amaranthaceae is a family of plants.

Pigweed (English), Hanekam (Afrikaans), Thepe (Sesotho), Imbuya (isiZulu) and Vowa (isiZulu) are some of the common names for this plant (Tshivenda)

Origin and distribution

Amaranth is a food crop that originated in America and is one of the world's oldest, with evidence of cultivation dating back to 6700 BC. There are over 60 species of Amaranth, some of which are farmed as leaf vegetables, grains, or decorative plants, and others of which are weeds. Various species of grain amaranth have been important in different parts of the world and at different times over the last few thousand years.

Amaranth is now widely grown as a green, leafy food in a variety of temperate and tropical climates. During the height of the Aztec civilization in Mexico in the 1400s, the world's largest acreage was grown. Amaranth practically vanished as a crop in the Americas after the advent of the Spanish conquistadors in Mexico in the early 1500s, until study on it began in the 1970s in the United States. Meanwhile, amaranth had expanded around the world and had established itself as a food crop (grain or leaves) in regions like Africa, India, and Nepal. Grain amaranth has been grown in a variety of locations during the last two centuries, including Mexico, Central America, India, and Nepal. Although it can be eaten as a grain, Amaranth is more commonly used as a pot herb, providing a significant amount of protein, minerals, and vitamins in some cases. This makes it a simple crop to grow and domesticate.

In an Agroforestry system, how well do different crops perform?

Studies from Burkina Faso have revealed that yields of pearl millet and sorghum as sole crops were lower when grown under *P. biglobosa* and *Vitellaria paradoxa* than when grown in the open field. Yields varied with different pruning levels as well as distances from trunk (Kessler, 1992; Bayala *et al.*, 2002). Bayala *et al.* (2002) reported that crop yield increased after pruning of trees in the short term, while fruiting of trees was delayed two years following pruning. Intercropping of pearl millet with cowpea could be another way of improving the crop production under the trees without increasing input levels.

These influences of trees on crops reported in the literature mainly revolve in shading effects. Plant emergence took place two weeks earlier in tree-adapted species than in plants found outside, while flowering stages started earlier, lasted a shorter time and had a lower success rate in the open than under tree canopies (Akpo and Grouzis, 1993 and Boffa, 1999). Duration of the vegetative plant development was longer in sorghum, plant height of both sorghum and pearl millet was negatively affected under *P. biglobosa* canopies and thus maturity was retarded (Kessler, 1992).

Plant height at high light intensities has distinct leaf morphology than plants produced at low light intensities, Miah (2001). Different crops, such as cabbage, carrot, radish, and tomato plants, increased their leaf size (length and breadth) when grown in the shade.

Without tree shade, plant height, root length, girth, dry weight, and total chlorophyll content were higher, but under tree shadow root length, girth, dry weight, and yield were lower, according to Reddy *et al.* (2002).

Taleb (2003) when light levels decreased, plant height and length of leaves of vegetables grew progressively.

Harrison (2004) conducted a study to determine the suitability of two vegetables (tomato and radish) for use in an Agroforestry system. He demonstrated that when the shade level increased, the vegetable output reduced steadily.

Except for plant height, Rahman *et al.* (2004) found that in open field conditions, all other morphological parameters of three vegetables (tomato, brinjal, and chilli) were highest, including number of branches/plant, number of fruits/plant, fruit length, fruit diameter, and fruit weight. The Horitoki + lemon + vegetable based Agroforestry system produced the best yield of all the Agroforestry systems.

Chipungahelo *et al.* (2007) leaf morphological traits revealed that light intensity had a significant impact on sweet potato growth and development. In full sunshine, specific leaf area values were less than in deep shade. Cowpea seed increased significantly when light intensity increased, and the interaction between seasons (year) light regimes was significant. Pineapples blossomed earlier and yielded more in low intensity than in high intensity.

Rahim *et al.* (2007) multilayer tree gardens or multistoried cropping is traditionally conducted in and around Bangladesh homesteads in an ad hoc way. A project to build a systematic multistoried cropping system was launched. When compared to solitary cropping, indigenous vegetables (IVs) and medicinal plants thrive in multistoried cropping systems. Natural resources were properly exploited in this system. The amount of money earned per square foot rose.

Hamamoto *et al.* (2000) conducted an experiment on tomato plants grown in the shade using black gauze and found that the shaded plants reduced dry weight by about 30% in flower buds, 30-40% in stems and leaves, and by about 50% in roots found to represent 1 hours. 70-80% shade compared to less shaded plants by 4 weeks.

Onwveme and Johnston (2000) studied the impact of shading on stomatal density, leaf length, leaf dry remember and leaf lamina thickness within side the most important tropical root and tuber crops; Tannic (*Xanthosoma sagitifolium*), candy potato (*Ipomea batatas*), yam (*Dioscorea esculenta*) and Taro (*Colocasia esculenta*). They determined that shading reduced stomatal density withinside the decrease dermis of tannic, candy potato, yam and cassava. Taro below colour had an expanded stomatal density in each the top and decrease dermis shading usually resulted withinside the manufacturing of large length of leaves however thinner leaves in taro, candy potato and yam.

Verchot *et al.* (2007) discovered that multistrata Agroforestry systems with varying tree spacing had a substantial impact on carrot root yield. Sole cropping produced the highest carrot root yields (29.87 t ha^{-1} in 2005 and 29.24 t ha^{-1} in 2006), followed by sissoo + lemon based multistrata Agroforestry systems with broader and intermediate spacing. Closer spacing of multistrata Agroforestry systems resulted in a greater drop in carrot output compared to sole cropping.

Islam *et al.* (2008) tested the performance of winter vegetables grown in a multistrata system based on guava and coconut. The results showed that reduced light levels resulted in considerably different plant growth as well as the tallest plants, whereas full sunshine produced the highest yield plot^{-1} and yield ha^{-1}.

Nsabimana *et al.* (2008) the morphological properties of winter vegetables, such as leaf length, leaf diameter, stem girth, fresh and dry weight, reduced as the distance from the tree decreased. All three winter vegetables had a substantial impact on the growth parameters of posur (*Hopea odorata*) (red amaranth, stem amaranth and coriander).

Basak *et al*. (2009) vegetable yield contributing properties grew progressively with increasing planting distance from the tree, and pine tree growth characters are higher in association with soybean than tomato and radish.

In the early years of growth, both density and intercrop affected tree growth, according to Farooq *et al.* (2009). With higher densities, the photosynthetic photon flux density (PPFD) accessible to intercrops decreased.

Sayed *et al.* (2009), the highest vegetable output was found in the control condition (without tree), which was considerably similar with 3 and 4 feet distance from the tree base, and the lowest was reported at 1 foot distance, which was almost similar with 2 feet distance. The vegetables had a big impact on telsur's growth.

According to Duguma *et al.* (2011), monoculture produces the maximum yield of individual crops, whereas all intercropped and treatments involving red amaranth, spinach, and coriander were shown to be agronomically practical and economically profitable.

CHAPTER III
MATERIALS AND METHODS

The purpose of the experiment was to assess the response of red amaranth in association with drumstick (*M.oleifera*) saplings in order to determine the optimal tree crop interaction, its scope, and importance in an Agroforestry system. The materials employed, the methods used, and the relevant work done throughout the experimental period is all presented in this chapter. This section includes a brief description of the experimental site and season, as well as soil, climate, and weather, plant materials, land preparation, fertilizer application, experimental design, and treatment combinations, seed sowing, intercultural operation, harvest, data collection, statistical analysis, and so on. The following are the products that are currently in use:

3.1 Experimental Site

Sher-e-Bangla Agricultural University's Agroforestry Field Laboratory is located in Sher-e-Bangla Nagar, Dhaka during the period from 1 December 2020 to January 2021. The experimental site was previously used as vegetable garden and recently developed for research work. The location of the site is 23° 74'N latitude and 90° 35' E longitude with an elevation of 8.2 meter from sea level (Anon, 1981).

3.2 Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from April to September and scanty rainfall during rest of the year. The total rainfall of the experimental site was 218 mm during the period of the experiment. The average maximum and the minimum temperatures were 29.45°C and 13.86° C respectively. Rabi season is characterized by plenty of sunshine. The maximum and minimum temperatures, humidity and rainfall during the study period were collected from the Bangladesh Meteorological Department and have been presented in Appendix I.

3.3 Soil

The soil of the experimental area belongs to the Madhupur Tract. The analytical data of the soil sample collected from the experimental area were determined in SRDI, Soil Testing Laboratory, Dhaka and presented in appendix II.

The soil of the experimental field belongs to the Tejgaon series under the Agro Ecological Zone, Madhupur Tract (AEZ- 28) and the soil is general type (These information was collected from department of soil science, SAU Dhaka).

3.4 Treatment

For the various treatments, *Moringa* trees of similar ages (3 years) were chosen. *Moringa* trees were left as an upper-story component, while red amaranth was planted as a lower-story crop. There were four different treatments in the trial.

T_1 = 30cm distance from tree base
T_2 = 50cm distance from tree base
T_3 = 75cm distance from tree base
T_4 = Open field referred to as control

3.5 Land Preparation

The experimental land was first opened on December 1, 2020, with spades being used to operate it. The ground was then left alone for a week. All crop wastes and weeds were removed from the ground at this time, broken stones and bricks were sorted, and the area was completely leveled.

3.6 Establishment and Maintenance of Crops

The experiment was done during 3 years period of *M. oleifera* tree. Distance from *M. olifera* to 1st treatment (T_1) of red amaranth was 30cm, then 2nd treatment (T_2) to *Moringa* plant distance 50cm, then 3rd treatment (T_3) distance 75cm from *Moringa* tree and open field (T_4) referred to control condition. Above these distance properly maintenance and on December 10, 2020, red amaranth seeds were sown in the experimental field. Seedlings were pruned out after emergence.

Spacing: 6 m ×10 m

Cow dung requirement 50 kg pit^{-1}

Cow dung requirement = 35 t ha^{-1}

Cutting cost = 100 taka cutting^{-1}

Per fruits weight = 65 g

Yield ha^{-1} = 5.01 t ha^{-1}

3.7 Fertilizer Application

For this experiment, chemical fertilizers were applied. Urea, TSP and MoP are among the ingredients, with urea being used twice. During the first land preparation and second growth period, cow dung (20kg) was applied to the experimental field, and during the final land preparation, cowdung was applied to the experimental field. Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses of BARI (2005).

Fertilizer application

Items	*Moringa* (Fertilizer dose ha^{-1})	Amaranthus (Fertilizer dose ha^{-1})
Cowdung	35 ton	10 ton
Urea	250 kg	125 kg
TSP	125 kg	75 kg
MoP	250 kg	100 kg

3.8 Intercultural Operation

3.8.1 Weeding

Weeding was done in several times in each plot because of experiment field remain fellow condition upto one years. Vast weeds were growing and which root was gone to deep soil to maintain it free of weeds that could harm the red amaranth growth and development.

3.8.2 Irrigation

During the experimental period, the field was irrigated frequently in everyday to because of experiment field was heavily dry and weed affected field condition. Irrigation was carried out in accordance with the guidelines.

3.8.3 Thinning

After 5 days of seeding, the emergence of Amaranth began. Three times thinning was done, after 10, 15 and 20 DAS.

3.8.4 Pest and disease control

Because the crops were free of pests and diseases, no pesticides or insecticides were used.

3.9 Data Collection

Red amaranth was started to harvest 40 days after sowing (DAS). Red amaranth (15 plant samples) was randomly picked from each replication of the various plots. A total of 45 red amaranth plants (15 from each replication) were chosen for data collection from each plot.

The following parameters were recorded.

a) plant height (cm)
b) Number of leaves per plant
c) Leaf length (cm)
d) Leaf breadth (cm)

e) Shoot weight (g)
f) Root weight (g)
g) Fresh weight (g)
h) dry weight (g)
i) Yield per hectare (t/ha)

3.9.1. Plant height

From the point of ground level to the tip of the plant leaf, plant height was measured in centimeters (cm) using a scale 10, 20, 30 and 40 DAS.

3.9.2 No. of leaves per plant

At 10, 20, 30 and 40 DAS, the total number of leaves per plant was counted. Five plants were chosen at random and measured and then the total number of leaves was divided by five to get the number of leaves per plant.

3.9.3 Leaf width and length

Using a centimeter scale, the length and breadth of each plant's upper third leaf were measured.

3.9.4 Stem length

Stem length was measured from the base of the bottom to the tip after harvest. A meter scale was used to measure the stem length of plant and expressed in centimeter (cm).

3.9.5 Stem girth

Five plants were chosen at random and each stem was measured against cm scale roller, then the sum of stem girth was divided by 5 to get the plant's stem girth.

3.9.6 Shoot weight

The weight of the shoot was measured at the point where the central shoot was cut off. Shoot weight was recorded in three dimensions with weight machine and the average of the three values was taken in kg.

3.9.7 Root weight

All root of selected plant were collected. Then these were placed on the digital balance for the calculation of weights.

3.9.8 Fresh weight

Five plants were chosen at random from each replication and the weight of all 5 plants was divided by 5 to get the weight of a single plant (g).

3.9.9 Dry weight per plant

Plants were kept for drying as a natural condition and after sun drying; Sundry weight of plants was measured from each treatment and then weighted which expressed as g. Ten plants of each plot were cut down and oven dried at temperature of 60°C for 72 hours and was weighed in gram by an electrical balance and the weights were converted into gram plant.

3.9.10 Yield t ha^{-1}

The yield t ha^{-1}was calculated by converting the per plot yield data to per hectare and was expressed in ton (t).

3.10 Economic Analysis

i. Input cost

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

A. Non-material cost

Non-material cost is all the labors cost. Human labors were obtained from adult male labors. In a day 8th 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}.

B. Material cost

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

ii. 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.

iii. 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})

v. Net returns (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}).

vi. Benefit cost ratio of rice (BCR)

Analyses were done according to the procedure of Alam *et al.* (1989). The benefit cost ratio (BCR) was calculated as follows

$$\text{BCR} = \frac{\text{Gross return t ha}^{-1}\text{ (Tk)}}{\text{Total cost of production t ha}^{-1}\text{(Tk)}}$$

3.11 Statistical Analysis

The data obtained for different characters were statistically analyzed by using MSTAT-C computer package program to find out the significance of the difference for proper distance on yield and yield contributing characters of *Moringa*. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER-IV

RESULTS AND DISCUSSION

Results of the present experiment are presented in this chapter. The observations pertaining to growth and yield attributes of *Moringa*-Red amaranth recorded during the course of investigation were statistically analyzed and significance of results verified. The results of all the main effects and only significant have been presented in succeeding paragraphs. Some of the characters have also been represented graphically to show the treatment effect wherever necessary to provide better understanding of the results.

4.1 Plant Height (cm)

Different spacing from tree base exhibited significant differences in plant height at different sampling dates (Table 1). The plant height was increased gradually with the advancement of crop growth up to harvest. At 10 days after sowing (DAS) red amaranth plant heights were not significantly different in between the treatments. However, at 20 DAS significantly the maximum plant height (6.56 cm) was observed in control (T_4) which was statistically similar with T_3 treatment (5.47 cm). The plants belong to T_2 treatments appeared as intermediate height (4.78 cm). Consistently, the lowest plant height (3.68 cm) was observed in T_1 treatment. At 30 DAS significantly maximum plant height (24.13 cm) were observed in T_4 treatment which was statistically similar (21.17) with T_3 treatment and the lowest plant height (17.00 cm) was observed in treatment T_1which was statistically similar (20.00) with T_2 treatment. At harvest, the plant height ranged from 36.00 cm to 26.67 cm. At harvest significantly variation was observed, the maximum plant height (36.00 cm) were in T4 treatment which was statistically similar with T_3 treatment (31.67) and the lowest plant height (26.67 cm) was observed in treatment T_1 which was statistically similar (26.67) with T_2 treatment. This result was in line with the result of Wadud et al. (2005) who conducted an experiment with red amaranth at different light condition. They found decreased plant height (22.98 cm) at 50% reduced light condition than that of control environment (30.57 cm).

Table 1. Effect of planting distance from *Moringa* cuttings base on plant height (cm) of red amaranth at different days after sowing (DAS)

Factor	10 DAS	20 DAS	30 DAS	40 DAS
T_1	2.79	3.68 c	17.20 c	26.67 d
T_2	3.20	4.78 bc	20.00 b	29.83 c
T_3	3.10	5.47 ab	21.17 ab	31.67 b
T_4	3.90	6.56 a	24.13 a	36.00 a
$LSD_{(0.05)}$	1.45	0.87	2.30	2.03
$CV_{(\%)}$	17.67	19.77	18.24	9.80
Sig. level	-	*	*	**

Different alphabetical letters within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.01$, $P<0.05$)

Remarks: T_1 = 30 cm distance from tree base; T_2 = 50 cm distance from tree base; T_3 = 75 cm distance from tree base; T_4 = Open field referred to as control

4.2 Number of Leaves per Plant

Number of leaves per plant is an important parameter for plant because of its physiological role in photosynthetic activities. A good number of leaves indicate better growth and development of plants. No. of leaves/plant is positively related to the yield of red amaranth. Leaf number varied significantly with increasing distance of the red amaranth at10, 20, 30 and 40 DAS. At 10 DAS significantly the maximum number of leaves (5.58) was observed in (T_4) treatment which was statistically similar (4.00 and 3.83) with T_2 and T_3 treatments and lowest number of leaves (3.50) was observed in T_1treatments. At 20 DAS significantly the maximum number of leaves (6.75) was observed in (T_4) treatment which was statistically similar (5.67 and 5.33) with T_3 and T_1treatment and lowest number of leaves (4.00) was observed in T_2 treatment which was statistically different from other treatments. At 30 DAS significantly the maximum number of leaves (14.00) was observed in T_4 treatment which was statistically similar (11.00 and 10.00) with T_3 and T_2treatment and the lowest number of leaves (8.33) was observed in treatment T_1. At harvest 40 DAS number of leaves ranged from 9.33 to 19.67 where highest number of leaves (19.67) was recorded in (T_4) and lowest number of leaves (9.33) was in T_1 treatment which was statistically similar with T_2.

Table 2. Effect of planting distance from *Moringa* cuttings base on number of leaves per plant of red amaranth at different days after sowing (DAS)

Factor	Number of leaves per plant			
	10 DAS	20 DAS	30 DAS	40 DAS
T_1	3.50 b	5.33 ab	8.33 c	9.33 c
T_2	4.00 ab	4.00 b	10.00 bc	11.33 bc
T_3	3.83 ab	5.67 ab	11.00 b	12.33 b
T_4	5.58 a	6.75 a	14.00 a	19.67 a
$LSD_{(0.05)}$	2.005	2.53	1.60	2.23
$CV_{(\%)}$	25.18	24.72	17.15	15.09
Sig. level	*	*	**	**

Different alphabetical letters within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.01$, $P<0.05$)

Remarks: T_1 = 30 cm distance from tree base; T_2 = 50 cm distance from tree base; T_3 = 75 cm distance from tree base; T_4 = Open field referred to as control

4.3 Leaf Length (cm) and Leaf Breadth (cm)

Leaf length and leaf breadth per plant of red amaranth showed statistically significant differences for distance at 10, 20, 30 and 40 DAT (Table 3). Different treatments differed significantly on leaf length of red amaranth. The highest leaf length (9.30 cm) was recorded in T_4 treatment. The second highest leaf length (7.50 cm) was found both in T_3 treatment and the lowest plant leaf length (5.33 cm) was recorded in T_1 treatment. The maximum leaf breadth (6.17 cm) was observed in T_4 treatment which was statistically similar with (4.86 cm) was found in T_3 treatment which was statistically similar with T_1 and the shortest leaf breadth (3.01 cm) was recorded in T_2 treatment. This result was analogous with the result of Ara et al. (2005) who conducted an experiment with spinach at different nitrogen level.

Table 3. Effect of planting distance from *Moringa* cuttings base on leaf length (cm) and leaf breadth (cm) of red amaranth at the time of harvest

Factor	Leaf length (cm)	Leaf breadth (cm)
T_1	5.53 d	4.41 bc
T_2	6.33 c	3.01 c
T_3	7.50 b	4.86 b
T_4	9.30 a	6.17 a
LSD $_{(0.05)}$	1.12	1.60
CV $_{(\%)}$	13.34	9.21
Sig. level	**	*

Different alphabetical letters within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.01$, $P<0.05$)

Remarks: T_1 = 30 cm distance from tree base; T_2 = 50 cm distance from tree base; T_3 = 75 cm distance from tree base; T_4 = Open field referred to as control

4.4 Stem Length (cm) and Stem Girth (cm)

The effect of different distance was significant on stem length of red amaranth plants at 10, 20, 30 and 40 DAS (Table 4). The maximum stem length (13.00 cm) was recorded in T_4 which was statistically similar (11.50) withT_3 treatments and the minimum stem length (9.00 cm) were observed in T_1 treatment which was statistically identical (9.33) with T_2 treatments.

The variation due to different treatment of the red amaranth was significant on stem girth of red amaranth plant at 10, 20, 30 and 40 DAS (Table 4). The maximum stem girth (3.18 cm) was recorded in T_4 which was statistically similar with T_3 treatments and the minimum stem length (2.21 cm) was observed in T_2 treatment which was statistically identical (2.25) with T_1 treatments. This result was consistent with the result of Miah et al. (2001) who conducted an experiment with red amaranth with different N level. They found upto 50% reduced stem girth at N deficient soil than that of control environment.

Table 4: Effects of *Moringa* based Agroforestry system on stem length (cm) and stem girth (cm) of red amaranth at the time of harvest

Factor	Stem length (cm)	Stem girth (cm)
T_1	9.00 c	2.25 b
T_2	9.33 c	2.21 b
T_3	11.50 ab	2.58 ab
T_4	13.00 a	3.18 a
$LSD_{(0.05)}$	1.24	0.81
$CV_{(\%)}$	16.78	16.83
Sig. level	**	*

Different alphabetical letters within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.01$, $P<0.05$)

Remarks: T_1 = 30 cm distance from tree base; T_2 = 50 cm distance from tree base; T_3 = 75 cm distance from tree base; T_4 = Open field referred to as control

4.5 Shoot and Root Weight (g)

Shoot weight of red amaranth was affected significantly due to distance orientation from the tree base (Table 5). At harvest, shoot weight varied from 12.33 g to 26.67 g. The highest shoot weight (26.67 g) was recorded in T_4 closely followed by treatment T_3, whilst the lowest shoot weight (12.33 g) was recorded in treatment T_1 followed by treatment T_2. Shoot weights of red amaranth at T_2 and T_3 treatments were statistically similar.

Significant root weight of red amaranth was recorded from the different level of treatments. The root weight varied from 4.50 g to 1.63 g. The highest root weight (4.50 g) was recorded in control treatment followed by treatment T_3, whilst the lowest root weight (1.63 g) was recorded in treatment T_1 followed by treatment T_2.

Organic manure is an eco-friendly, economically viable and ecologically sound compound that played a significant role in improving physical, chemical and biological properties of soil. It improves soil structure, water holding capacity, enhanced soil micro flora and fauna activity, which results in availability of plants micronutrients, resulting in more extensive shoot and root development that contribute to increased shoot and root weight.

Table 5: Effect of *Moringa* based Agroforestry system on shoot weight (g) and root weight (g) of red amaranth at the time of harvest

Treatments	Shoot weight (g)	Root weight (g)
T_1	12.33 c	1.63 c
T_2	19.00 bc	2.46 bc
T_3	20.67 ab	2.93 b
T_4	26.67 a	4.50 a
LSD	7.16	0.83
CV (%)	19.36	15.41
Significance level	**	**

Different alphabetical letters within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.01$, $P<0.05$)

Remarks: T_1 = 30 cm distance from tree base; T_2 = 50 cm distance from tree base; T_3 = 75 cm distance from tree base; T_4 = Open field referred to as control

4.6 Fresh Weight (g) and Dry Weight (g)

Fresh weight of red amaranth was affected significantly by the distance from the tree and root growth (Table 6). At harvest, fresh weight varied from 50.00 g to 23.33 g. The highest fresh weight (50.00 g) was recorded in T_4 followed by treatment T_3 (37.00 g), whilst the lowest fresh weight was found in T_1 (23.33 g) treatment followed by treatment T_2 (33.33 g).

Dry weight of red amaranth differed significantly due to various distance orientation from the tree base (Table 6). The dry weight varied from 1.40 g to 0.60 g, whilst the highest dry weight (1.40 g) was observed in without tree condition followed by treatment T_3, and the lowest dry weight (0.60 g) was observed in T_1 treatment followed by treatment T_2.

Water, comprising 90% of the biomass of plants, is the central molecule in all physiological processes of plants by being the major medium for transporting metabolites and nutrients. Proper irrigation management is required to maintain the adequate soil moisture in the crop root zone for healthy plant growth, weight and optimum yield. Water deficit inhibits the accumulation of fresh plant mass in greater extent than dry biomass. Leaf area is an important factor in determining fresh weight, dry weight and biomass production of plant. Water deficiency reduce leaf expansion rate is usually associated with reduction of photosynthesis and consequent decrease in above-ground biomass, fresh weight, dry weight and yield of crops (Schurr *et al.,* 2006, Vanova *et al.,* 2006).

Table 6: Effects of *Moringa* based Agroforestry system on fresh weight (g), dry weight (g) of red amaranth at the time of harvest

Factor	Fresh weight (g)	Dry weight (g)
T_1	23.33 d	0.60 b
T_2	33.33 c	1.00 ab
T_3	37.00 b	1.13 a
T_4	50.00 a	1.40 a
LSD $_{(0.05)}$	2.30	0.43
CV $_{(\%)}$	12.11	9.35
Significance level	**	*

Different alphabetical letters within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.01$, $P<0.05$)

Remarks: T_1 = 30 cm distance from tree base; T_2 = 50 cm distance from tree base; T_3 = 75 cm distance from tree base; T_4 = Open field referred to as control

4.7 Yield (t/ha)

Significant variation was recorded yield (ton/ha) of red amaranth due to different distance. Yield of red amaranth was significantly influenced with increasing distance from tree base of *Moringa* (Table 7). The maximum yield of red amaranth (14.25 t/ha) was observed in T_4 treatment which was not statistically similar with T_3 treatment and the lowest yield (9.90 t/ha) was obtained in T_1 treatment which was statistically identical (10.80 t/ha) with T_3treatments. Organic fertilizer apart from releasing nutrient elements to the soil has also been shown to improve other soil chemical and physical properties which enhance crop growth and development (Ogbonna, 2008). Not only the pattern of biomass allocation, but also differences in the rates of uptake and loss of carbon and water of the different plant organs will contribute to variation in growth and yield of crops (Ogbonna, 2008).

Table 7. Effects of *Moringa* based Agroforestry system on yield (t/ha) performance of red amaranth at the time of harvest

Treatments	Yield (t/ha)
T_1	9.90 c
T_2	10.80 c
T_3	12.69 b
T_4	14.25 a
LSD	1.01
CV (%)	11.34
Significance level	**

Different alphabetical letters within the same column indicate significant differences among various treatments according to a least significant difference test (LSD) ($P < 0.01$, $P<0.05$)

Remarks: T_1 = 30 cm distance from tree base; T_2 = 50 cm distance from tree base; T_3 = 75 cm distance from tree base; T_4 = Open field referred to as control

4.8 Cost of *Moringa* based Agroforestry System

In *Moringa* based Agroforestry system cost includes all the activities from field preparation to production, harvesting and marketing. Different types of costs have been presented in (Table 8, 9, 10, 10, 11, 12, 13 and 14). The cost for seedling, land preparation during orchard establishment was Tk 28600. Other costs were fertilization, land use cost, intercultural operational cost, and pesticide, harvesting and marketing. The total cost per hectare of *Moringa* based Agroforestry system were Tk. 45930, 97199, 97199 and 97199 respectively.

8. Non material cost

Items	No. of labor required	Amount taka
Harvesting & others works	27	14850
	Grand total= 14850	

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

9. Material cost (*Moringa*)

Sl. No.	Quantity (ton/kg/ha)/times	Items Cost (Tk)	Cost (Tk/ha)
Fertilizers			
Cowdung	35 ton	400	14000
Urea	250 kg	16	4000
TSP	125 kg	22	2750
MP	250 kg	15	3700
Gypsum	25 kg	8	200

Zinc sulphate	25 kg	250	6250
Boron	25 kg	110	2750
Irrigation	3 times	1000	3000
			Grand total= 35650 Tk

10. Material cost (Amaranth)

Sl. No.	Quantity (ton/kg/ha)/times	Items Cost (Tk)	Cost (Tk/ha)
Seed rate ha^{-1}	2 kg	700	1400
Fertilizers			
Cowdung	10 ton	400	4000
Urea	125 kg	16	2000
TSP	75 kg	22	990
MP	100 kg	15	1500
Irrigation	3 times	1000	3000
Tractor	1	3000	3000
			Grand total= 15890

11. 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)
	i	ii					
14850		15890	30740	1921	769	12500	45930

12. Total cost of production (Interaction)

Non-material cost	Material cost		Total input cost (A)	Interest on input cost @ 12.5% for 6 month (B)	Miscellaneous cost is 5% of total input cost (C)	Overhead cost (1 year) (D)	Total cost of production (A+B+C+D)
	i	ii					
14850	35650	15890	66390	4149	1660	25000	97199

Gross returns from *Moringa* cultivation

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

Amaranth = 1 kg 20 taka so 1 ton = 20000 taka

13. Gross returns from *Moringa* cultivation

Treatment	***Moringa* pods yield (t/ha)**	**Value**	**Amaranth yield (t/ha)**	**Value**	**Gross return (Tk)**
T_4	0	0	21.45	429000	429000
T_3	5.05	252500	18.85	377000	629500
T_2	5.05	252500	18.22	364400	616900
T_1	5.05	252500	14.63	292600	545100

14. Profitability of *Moringa* amaranth intercropping

Treatment	Gross return (Tk)	Total cost of production	Net return	BCR
T_4	429000	45930	383070	9.34
T_3	629500	97199	532301	6.48
T_2	616900	97199	519701	6.37
T_1	545100	97199	447901	5.61

Remarks: T_1 = 30 cm distance from tree base; T_2 = 50 cm distance from tree base; T_3 = 75 cm distance from tree base; T_4 = Open field referred to as control

4.9 Gross Return

In case of gross return, different treatment showed different levels of gross return under the present trial. The highest gross return (Tk. 629500) was found from the treatment T_3 and the second highest gross return (Tk. 616900) was obtained from T_2 treatment combination. The lowest gross return (Tk. 429000) was obtained from T_4.

4.10 Net Return

In case of net return, different treatment showed different levels of net return under the present trial. The highest net return (Tk. 532301) was obtained from the treatment T_3 and the second highest netreturn (Tk. 519701) was found from the T_2. The lowest (Tk. 383070) net return was found from T_4 treatment.

4.11 Benefit Cost Ratio

The distance of different tree for benefit cost ratio was different in all treatment. The highest benefit cost ratio (9.34) was found from the treatment T_4 and the second highest benefit cost ratio (6.48) was found from T_3 treatment. The lowest benefit cost ratio (5.61) was found from the T_1 treatment. From the economic point of view, it was apparent from the above results that the treatment T_4 was more profitable than rest of treatment.

In this experiment, T_4 was the most promising treatment in terms of morpho-physiological traits. Treatment T_3 performed very close to control treatment (T_4) with regards to yield and yield contributing characters. Leaf number, plant height, and height growth rate are considered as the most desirable characters for red amaranth. At harvest, plant height, its growth rate, and leaf number varied widely among the treatment. It confirmed the below ground tree-crop competitions for resource sharing among the treatments were minimum in the early growing period which gradually increased with the advancement of crop growth (Zamora *et al.,* 2007).

Agroforestry has potentiality to improve soil fertility. This is mainly based on the increase of soil organic matter and biological nitrogen fixation by leguminous trees. Trees on farms also facilitate more nutrient cycling than mono culture systems, and enrich the soil with nutrients and organic matter, while improving soil structural properties. Hence, through water tapping and prevention of nutrient leaching, tree help recover nutrients, conserve soil moisture and improve soil organic matter (Sanou *et al.,* 2011).

Moringa trees do not need much water and can germinate and grow without irrigation if sown during the rainy season. The roots will develop in about twenty days and allows young plants to endure drought (Saint Sauveur and Broin, 2010; Fugli and Sreeja, 2011). Adisakwattana and Chanathong (2011) discovered tuberous roots of *M. oleifera,* which have the ability to storage of water and/or sugar during long drought periods. *Moringa* leaf contributes organic matter to the soil, improve soil structural properties and *Moringa* root conserve soil moisture.

CHAPTER-V
SUMMARY AND CONCLUSION, RECOMMENDATIONS

Summary

An experiment was conducted to assess the performance of red amaranth in association with *Moringa* tree at the Agroforestry Field under the Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka−1207, Bangladesh during the period from 1stDecember 2020 to January 2021, Dhaka. Four treatments namely, T_1= 30 cm distance from the tree base, T_2= 50 cm distance from the tree base, T_3= 75 cm distance from the tree base and T_4= Open field referred to as control, were used in Randomized Complete Block Design (RCBD) with three replications. The observations pertaining to growth and yield attributes of *Moringa* recorded during the course of investigation were statistically analyzed and significance of results verified.

All the growth and yield contributing characters like plant height, number of leaves, leaf length, leaf breadth, stem length, stem girth, stem diameter, diameter of primary curd, shoot weight, root weight, dry weight, fresh weight, thirty cm place weight and yield per hectare varied significantly due to distance.

At 10 days after sowing (DAS) red amaranth plant heights were not significantly different in between the treatments. However, at 20 DAS significantly the highest plant height (6.56 cm) was observed in control conditions (T_4) which were statistically similar with the plants of T_3 treatment (5.47 cm). The plants belong to T_2 treatments appeared as intermediate height (4.78 cm). Consistently, the least plant height (3.68 cm) was observed in T_1 treatment. At 30 DAS significantly highest plant height (24.13 cm) were observed in control condition and the lowest plant height (17.00 cm) was obtained in treatment T_1. At harvest 40 DAS plant height ranged from 36.00 cm to 26.67 cm where plants belong to control treatment appeared as the tallest

followed by the plants belong to T_4, while T_1 was the shortest in height closely followed by the plants belong to T_2 treatment.

At 10 DAS significantly the highest number of leaves (5.58) was observed in control condition (T_4) and lowest number of leaves (3.50) was observed in T_1 treatments which were statistically different from other treatments. At 20 DAS significantly the highest number of leaves (6.75) was observed in control condition (T_4) and lowest number of leaves (4.00) was observed in T_2 treatment which was statistically different from other treatments. As expectation, at 30 DAS significantly the highest number of leaves (14.00) was observed under control treatment and the lowest number of leaves (8.33) was observed in treatment T_1, followed by treatments T_2 and T_3 where treatments T_3, and T_2 are statistically similar. At harvest 40 DAS number of leaves ranged from 9.33 to 19.67 where maximum number of leaves (19.67) was recorded in control treatment (T_4) and minimum (9.33) were recorded in T_1 treatment. Treatments T_2 and T_3 were statistically similar and treatments T_1, and T_2 were also statistically similar.

The highest leaf length (9.30 cm) was recorded in T_4 treatment. The second highest leaf length (7.50 cm) was found both in T_3 treatment and the lowest plant leaf length (5.33 cm) was recorded in T_1 treatment. The highest leaf breadth (6.17 cm) was recorded in T_4 treatment. The second highest leaf breadth (4.86 cm) was found in T_3 treatment which was statistically similar with T_1 and the lowest plant leaf breadth (3.50 cm) was recorded in T_2 treatment.

The highest stem length (13.00 cm) was recorded in T_4 which was statistically similar with T_3 treatments and the lowest stem length (9.00 cm) was observed in T_1 treatment which was statistically identical with T_2 treatments.

The highest stem girth (3.18 cm) was recorded in T_4 which was statistically similar with T_3 treatments and the lowest stem length (2.21 cm) was observed under T_2 treatment which was statistically identical with T_1 treatments.

At harvest, shoot weight varied from 12.33 g to 26.67 g. The highest shoot weight (26.67 g) was recorded in T_4 closely followed by treatment T_3, whilst the lowest shoot weight (12.33 g) was recorded in treatment T_1 followed by treatment T_2. Shoot weights of red amaranth at T_2 and T_3 treatments were statistically similar.

The root weight varied from 4.50 g to 1.63 g. The highest root weight (4.50 g) was recorded in control treatment followed by treatment T_3, whilst the lowest root weight (1.63 g) was recorded in treatment T_1 followed by treatment T_2.

At harvest, fresh weight varied from 50.00 g to 23.33 g. The highest fresh weight (50.00 g) was recorded in T_4 followed by treatment T_3 (37.00 g), whilst the lowest fresh weight was found in T_1 (23.33 g) treatment followed by treatment T_2 (33.33 g).

The dry weight varied from 1.40 g to 0.60 g, whilst the highest dry weight (1.40 g) was observed in without tree condition followed by treatment T_3, and the lowest dry weight (0.60 g) was observed in T_1 treatment followed by treatment T_2.

The highest yield of red amaranth (14.25 t/ha) was obtained in control treatment without any competition and shading effect and the lowest yield (9.90 t/ha) was obtained in T_1 treatment followed by the plants belong to T_3 and T_2 treatments, respectively.

Conclusion

➢The optimum distance from tree base was 75 cm.

➢Among the Agroforestry system, almost all the yield characters were the highest in treatment T_3.

➢The highest benefit cost ratio (9.34) was found in treatment T_4 and the second highest benefit cost ratio (6.48) was found from T_3 treatment. The lowest benefit cost ratio (5.61) was found from the T_1 treatment.

➢From the economic point of view, it was apparent from the above results that the treatment T_4 was more profitable than rest of treatment.

Recommendation

- In our experiment examined only *Moringa*-red amaranth in association.
- So, others vegetables seasonal and annual crops should be successfully grown in *Moringa* –based Agroforestry system &
- Farmers might be encourage to practice these system for higher production, income generation & land use maximization.

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APPENDICES

Appendix I. Monthly record of air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from December 2020 to January 2021

Year	Month	Air temperature (°c)			Relative humidity (%)	Rainfall (mm)
		Maximum	Minimum	Average		
2021	December	24.52	13.86	19.19	68.46	04

Source: Bangladesh Meteorological Department (climate division) Agargoan, Dhaka-1212.

Appendix II. Characteristics of Horticulture Farm soil as analyzed by Soil Resources Development Institute (SRDI), Khamar Bari, Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture Garden, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Fallow - Broccoli

Appendix II (contd.)

B. Physical and chemical properties of the initial soil

Characteristics	Value
Particle size analysis	
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (mc/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI

Appendix III. Factorial ANOVA for plant height

Source of variation	Degree of freedom	Mean square			
		Plant height (cm) at			
		10 DAS	20 DAS	30 DAS	40 DAS
Factor A	3	0.50	0.47*	26.12*	45.57*
Error	8	5.71	17.59	14.08	9.25

*means significant at 5%

Appendix IV. Factorial ANOVA for leaves number

Source of variation	Degree of freedom	Mean square			
		Leaves number at			
		10 DAS	20 DAS	30 DAS	40 DAS
Factor A	3	0.84	3.85*	16.11*	67.22**
Error	8	0.23	1.80	3.66	3.75

*means significant at 5%

Appendix V. Factorial ANOVA for Leaf length, fresh weight, root weight and shoot weight

Source of variation	Degree of freedom	Leaf length	Fresh weight	Stem length	Root weight	Shoot weight
Factor A	3	8.70*	0.33**	4.59*	22.04**	7.19**
Error	8	2.75	0.05	2.43	0.19	14.50

*means significant at 5%

Appendix VI. Factorial ANOVA for leaf breadth, Stem girth,dry weight, 30 cm place weight and yield

Source of variation	Degree of freedom	leaf breadth	Stem girth	Dry weight	Yield
Factor A	3	3.69*	0.59*	13.89*	72.68*
Error	8	1.91	0.08	1.00	4.87

*means significant at 5%

Appendix VII. Pictorial view of experiment

1st Replication

2nd Replication

Data Collection of 5 Selected Plants

Harvesting

Data collection Sample

Weeds Collection

Control Condition


Final Experiment Field