AGROFORESTRY PRACTICES WITH RED AMARANTH DURING THE EARLY ESTABLISHMENT PERIOD OF MORINGA PLANTATION

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CERTIFICATE

This is to certify that the thesis entitled, **"AGROFORESTRY PRACTICES WITH RED AMARANTH DURING THE EARLY ESTABLISHMENT PERIOD OF MORINGA PLANTATION"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGROFORESTRY AND ENVIRONMENTAL SCIENCE,** embodies the results of a piece of bona fide research work carried out by **SINTHIA RAHMAN SUMONA, Registration no. 17-08202** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any other institute.

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

Dated: December, 2017
Dhaka, Bangladesh

Dr. Md. Kausar Hossain
Professor
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

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AGROFORESTRY PRACTICES WITH RED AMARANTH DURING THE EARLY ESTABLISHMENT PERIOD OF MORINGA PLANTATION

ABSTRACT

A study was undertaken 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. At the time of harvest, the highest plant height among the treatments was observed in T_3, which was 9% less than that of control condition and 22% less stem girth was observed in T_1 compared to control. The highest no. of leaves were observed in T_2 treatment, which was 15% less than that of control condition. In case of yield contributing characteristics of red amaranth, 20% less shoot length and 18% less root length were observed in treatment T_2 and T_1 respectively than that of control condition. Apart from control, the highest fresh weight, dry weight and yield were performed under T_1 treatment. Therefore, at treatment T_1, 16% less fresh weight, 13% less dry weight and 16% less yield were observed compared to that of control condition. But the moisture content of red amaranth (94.27%) was the highest in T_2 treatment and dry matter content of red amaranth (6.38%) was the highest in T_1 treatment. In case of drumstick, at the harvest of red amaranth the highest no of buds were found in T_3 treatment and lowest no. of buds were found in T_2 treatment, but the highest bud length was found in T_1 treatment. Therefore, it was observed 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.

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LIST OF ABBREVIATION AND ACRONYMS

AGB	:	Above-ground biomass
BGB	:	Below-ground biomass
C	:	Carbon
CO_2	:	Carbon dioxide
O_2	:	Oxygen
DW	:	Dry weight
FW	:	Fresh weight
e.g	:	For example
g	:	Gram
Ha	:	Hectare
IPCC	:	Intergovernmental Panel on Climate Change
et al.	:	And others
^{0}C	:	Degree Celsius
cm	:	Centimeter
m^2	:	Square meter
%	:	Percent
t	:	Ton
AEZ	:	Agro-Ecological Zone

CHAPTER I

INTRODUCTION

Bangladesh is one of the most densely populated country in the world with limited natural resources. To meet the food and nutritional demand of the ever-increasing population multilayered agroforestry system should be developed to maximize production within limited natural resources (Chakraborty *et al.*, 2015). Agroforestry, the integration of trees and crops, vegetables, live stocks, fisheries on the same area of land is a promising production system for maximizing yield and maintaining friendly environment (Alao *et al.*, 2011). Although the fertility of our land is decreasing rapidly due to intensive cropping, use of extensive amount of chemical fertilizers and use of high input technologies, but in case of agroforestry system the fertility of our land is increasing through integrated nutrient management system such as mixing of organic manure to the soil, increase activity of beneficial microorganisms (Kuntashula *et al.*, 2004). Total production of agroforestry system is several times higher than that of an annual cropping system or forestry alone because light, nutrients, water, minerals are used efficiently in this system (Roy *et al.*, 2008; Alao *et al*., 2011).

Drumstick (*Moringa 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; Adejumo *et al*., 2012)

Moringa can grow well in the humid tropics or hot dry lands and in all types of soil, from acid to alkaline (Oliveira *et al*., 2009; Fernandes *et al*., 2015), tolerate a wide range of rainfall (Palada and Chang, 2003). Although *M. oleifera* is fast growing, multi-purpose and one of the most useful tree due to its medicinal and nutritional properties but it is considered as neglected and underutilized species (NUS) in some parts of the world (Padulosi *et al.,* 2013a; Rudebjer *et al*., 2013) including Bangladesh. The neglect probably due to little or no research attention from researchers and policy makers, loss of local knowledge and lack of established varieties (Padulosi *et al*., 2011; Padulosi *et al*., 2013b).

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). 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)

Due to increasing demand of vegetables farmers now growing red amaranth commercially in the field as it requires less space and it is a short duration crop, tolerance of many biotic and abiotic stresses, so it can grow easily in association with Moringa sapling. Therefore, it would be wise to conduct experiments during the early establishment period of tree plantation in association with red amaranth at different spacing in terms of their growth and yield performance for identifying the best tree vegetable combination.

The present study was undertaken with the following objectives:

1. To observe the growth and yield performance of red amaranth grown in association with *M. oleifera* seedling at different spacing and
2. To observe the management effect of red amaranth on Moringa sapling in agroforestry system.

CHAPTER-II

REVIEW OF LITERATURE

The review of literature of the past studies related to the present experiment collected through reviewing of journals, thesis, internet browsing, reports, periodicals and other forms of publications are presented.

2.1 Concepts of Agroforestry

Agroforestry is an old system or concept, but the term is definitely new. The concept of Agroforestry probably originated from the realization that trees play an important role in protecting the long range interests of agriculture and in making agriculture economically viable.

Agroforestry is one of the most conspicuous land use systems across landscapes and agro ecological zones. With food shortages and increased threats of climate change, interest in agroforestry is gathering for its potential to address various on-farm adaptation needs, and fulfill many roles in AFOLU- related mitigation pathways. Agroforestry provides assets and income from carbon, wood energy, improved soil fertility and enhancement of local climate conditions. It provides ecosystem services and reduces human impacts on natural forests. Most of these benefits have direct benefits for local adaptation while contributing to global efforts to control atmospheric greenhouse gas concentrations.

Agroforestry is a sustainable land management system which increase the overall yield, utilize land, combine the production of crops (including tree crops) and forest plant and/or animals simultaneously or sequentially the same unit of land and applies management practices of the local population.

The emergence of agroforestry was mainly influenced by the need to maximize the utilization of soil resources through the "marriage of forestry and agriculture". Agriculture and forestry were considered before as two distinct areas but these practices are now considered as complementary. This was brought about by the increasing realization that agroforestry can become an important component of ecological, social and economic development efforts.

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 Characteristics of tree species in Agroforestry system

One of the important decision in agroforestry is the selection of species. In Agroforestry system, people plants trees for fruit, fodder, fuel shade, conservation purpose and various other purposes. The most appropriate species for this system remains an open question for research.

The characteristics at tree species that should be grown with agricultural crops

- They should tolerate relatively high incidence of pruning.
- They should have a low crown diameter to bole diameter ratio.
- They should be light branching in their habit.
- They should be tolerant of side shade.
- Their phytotoxic should permit penetration of the light of the ground.
- Their phenology, particularly with reference to leaf flushing and leaf all should be advantageous to the growth of the annual crop in conjunction with which their being raised.
- The rate of litter fall and litter decompositions should have positive effect on the soil.
- The above ground changes over time in structure and morphology should be such that they retain or improve those characteristics, which reduce competition for solar energy, nutrient and water.
- Their root system and root growth characteristics should ideally result in exploration of soil layers that are different to those being tapped by agricultural crop.

The following factors should be considered during the selection of woody legumes for intercropping with annuals in the low land tropics:

- Ease of establishment from seeds or seedlings
- Rapid growth and high productivity of foliage and wood
- Limited maximum size (may be optimum in small trees) Good cropping ability
- Effective nutrient recycling abilities specially N_2 fixation
- Multiple uses: food, feed, fire wood, construction materials and other products and services (shade, shelter etc.).
- Minimal competition with shallow rooted annual crops.
- Small leaflets readily detached when dried and quickly decomposed when used as fertilizer.
- Good tolerance for drought, low fertility and others.
- Freedom from pests and diseases and
- Ease to control of eventual elimination

2.3 Response of different crops in Agroforestry systems

Hamamoto *et al*. (2000) carried out an experiment in tomato plants, grow under shade condition using black cheesecloth and found that shaded plants showed a reduced dry weight at about 30% of flower tress, 30-40% of stem and leaves and about 50% of roots after 1 to 4 weeks of 70-80% shading compared with shade less plants.

Onwveme and Johnston (2000) studied the effect of shading on stomatal density, leaf size, leaf dry matter and leaf lamina thickness in the major tropical root and tuber crops; Tannic (*Xanthosoma sagitifolium),* sweet potato (*Ipomea batatas*), yam (*Dioscorea esculenta*) and

Taro (*Colocasia esculenta*). They found that shading decreased stomatal density in the lower epidermis of tannic, sweet potato, yam and cassava. Taro under shade had an increased stomatal density in both the upper and lower epidermis shading generally resulted in the production of larger size of leaves but thinner leaves in taro, sweet potato and yam.

Adams *et al.* (2001) reported that the effect of different fruit removal and lighting/ shading treatments on the pattern of tomato. While the removal of flowering trusses resulted in a yield loss about eight weeks later. There was litter loss in cumulative yield as assimilates were distributed of neighboring trusses. Increased photosynthetic photon flux (PPFD) for one week resulted in a period of increased yield from 4-6 weeks after the start of the treatments followed by suppressed yields due to smaller fruits on subsequent trees. Fruit size remained fairly consistent (except when fruit removal treatments where applied), where as the number of fruits picked pen week exhibited much greater variability.

Miah (2001) showed that plant height at high light intensity have a different leaf morphology from those grown at low light intensities. Leaf size (length and breadth) increased under shaded condition in different vegetables such cabbage, carrot, radish and tomato plants.

Reddy *et al.* (2002) studied without tree shade plant height and root length, girth, dry weight and total chlorophyll content were higher and under tree shade root length, girth, dry weight and yield were lower.

Taleb (2003) studied that plant height and length of leaves of the vegetables increased gradually with the decrease of light levels.

Harrison (2004) conducted an experiment to select the suitability of the two vegetables (tomato and radish) for agroforestry system. He showed that yield of the vegetables decreased gradually with the increase of the shade levels.

Rahman *et al.* (2004) reported that except plant height all others morphological characters viz., no. of branches/plant, no. of fruit/plant, fruit length, fruit diameter and fruit weight of three vegetables (tomato, brinjal and chilli) were highest in open field condition. Among the different agroforestry system, highest yield was obtained in Horitoki + lemon + vegetable based agroforestry system.

Chipungahelo *et al.* (2007) reported that leaf morphological characteristics showed light intensity strongly influenced growth and development of sweet potato. Specific leaf area values in full light were smaller than those in under heavy shade. The light intensity increased the cowpea seed yield significantly and the interaction between seasons (year) × light regimes was significant. In low intensity, pineapple flowered earlier and yielded more than in high intensity. These results have provided useful information in planning intercropping models in coconut based- farming systems.

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 (IVs) and medicinal plants grow very well as compared to 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.

Verchot *et al*. (2007) found that multistrata agroforestry systems with different tree spacing were found to significant influence on the root yield of carrot. The highest carrot root yield (29.87 t ha^{-1} in 2005 and 29.24 t ha^{-1} in 2006) was recorded under sole cropping which was followed by the wider and intermediate spacing of sissoo + lemon based multistrata agroforestry systems. The reduction in yield of carrot compared to sole cropping was more at closer spacing of multistrata agroforestry systems.

Islam *et al*. (2008) conducted an experiment to evaluate the performance of winter vegetables under Guava-Coconut based multistrata system. Result revealed that significantly various plant growth as well as tallest plants were found under reduced light level whereas maximum yield $plot^{-1}$ and yield ha^{-1} were recorded under full sunlight condition.

Nsabimana *et al.* (2008) reported that morphological characteristics of winter vegetables, leaf length, leaf diameter, stem girth, fresh and dry weight decreased consistently with the decrease of distance from the tree. The growth characteristics of posur (*Hopea odorata*) was significantly influenced by all the three winter vegetables (red amaranth, stem amaranth and coriander).

Basak *et al*. (2009) reported that the yield contributing characters of the vegetables increased gradually with the increase of planting distance from the tree and the growth characters of pine tree are higher in association with soybean than tomato and radish.

Farooq *et al*. (2009) studied that tree growth was affected by both density and intercrop in the initial years of growth. Photosynthetic photon flux density (PPFD) available to the intercrops reduced with increasing densities. Transpiration rate and stomatal conductance in intercrops decreased due to the presence of tress. No significant changes in leaf temperature were observed till the fifth year of the growing season. Yield was significantly higher in pure crop in comparison with all the densities in mustard. Soybean yield under 200 trees ha^{-1} was comparable to that of the pure crop. Trees at the density of 200 trees ha^{-1} provided a conducive microenvironment to the intercrops.

Mutua *et al.* (2009) studied that grain yield of arable crops was higher in 20 m alley of teak + papaya rows as compared to 10 m alley of teak and papaya. Among the four crops, average grain yields were obtained in the order of sorghum> groundnut> ragi> chilli with teak. Net returns were in order of groundnut> sorghum> ragi> chilli and sorghum> groundnut> ragi> chilli. Groundnut and sorghum crops realized stable yields and returns as compared to chilli or ragi. Grain yields were significantly higher in teak + papaya as compared to teak + papaya + grass.

Sayed *et al.* (2009) showed that highest production of vegetables was recorded in control condition (without tree) which was significantly similar with 3 and 4 feet distance from the tree base and the lowest was observed under 1 feet distance which was almost similar with 2 feet distance. The growth characteristics of telsur significantly influenced by the vegetables.

Duguma *et al.* (2011) reported that monoculture produce the highest yield of individual crops, all the intercropped and treatments involve i.e. red amaranth, spinach, coriander were found agronomically feasible and economically profitable for intercropping .

2.4 Cultivation technique of Moringa

Cultivation requirements

According to Palada and Change (2003) Moringa tolerates a wide range of environmental conditions. It grows best between 25 to 35ºC, but will tolerate up to 48ºC in the shade and can survive a light frost. It is a drought-tolerant tree that grows well in areas receiving annual rainfall amounts that range from 250 to 1500 mm, prefers a well-drained sandy loam or loam soil, also tolerates clay, but will not survive under prolonged flooding and poor drainage. Soil pH should range between 5- 9. Altitudes below 600m are best for Moringa, but this adaptable tree can grow in altitudes up to 1200m in the tropics.

Cultivation practices

According to Saint Sauveur and Broin (2010) the germination rate of Moringa seeds is high. Furthermore, Moringa seeds have no dormancy period, so they can be planted as soon as they are mature. Seeds may be sown in seedbeds (for transplanting) or directly in the main field. Moringa seeds germinate 5 to 12 days after seeding.

For intensive (commercial) leaf production the spacing of the plants should be 15×15 cm or 20 × 10 cm, with conveniently spaced alleys to facilitate plantation management and harvests. This intensive system requires careful crop management. For semi-intensive leaf production plants are spaced 50 cm to 1 m apart. This is more appropriate for small-scale farmers and gives good results with less maintenance. For fruit or seed production the spacing must be at least 2.5 × 2.5 meter in order to achieve good yields.

Fugli (2011) stated that for intensive production the land should be prepared by means of ploughing and harrowing to a maximum depth of 30 cm. In case of semi-intensive production, it is better to dig planting pits (30-50 cm deep, 20-40 cm wide), which ensures good root system penetration and retains soil moisture, without causing too much land erosion Compost or manure can be mixed with the fresh topsoil around the pit and used to fill the pit. Moringa trees will at least flower and fruit annually. During its first year, a Moringa tree will grow up to five meters in height and produce flowers and fruits; when left alone, the tree can eventually reach 12 meters in height with a trunk 30 cm wide. If the trees are left to grow naturally, yields will be low.

According to Saint Sauveur and Broin (2010) pinching the terminal bud on the central stem is necessary when the tree attains a height of 50 cm to 1 m. This will trigger the growth of lateral branches which need to be pinched too. Regular pinching will encourage the tree to become bushy and produce many leafs and pods within easy reach and helps the tree develop a strong production frame for maximizing the yield. Maintenance pruning is also required. This can be done at each harvest (i.e. if the leaves are removed). In fruit and seed producing farms, pruning helps induce more fruits, as well as larger fruits.

Fugli (2011) stated that 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. It is however advisable to irrigate regularly to ensure optimal growth and continuous yield, especially in arid conditions. Moringa trees will generally grow well without adding very much fertilizer, but in order to achieve good yields the soil needs to provide enough nitrogen and minerals to the plant. Before seeding / planting, manure or compost can be mixed with the soil used to fill the planting pits. Afterwards it is important to apply manure or compost at least once a year, for instance before the rainy season, when the trees are about to start an intense growth period.

Weeding must be done frequently to avoid competition for nutrients, when the plant is young and the trees are small. Mulching can be applied in order to reduce the loss of soil moisture, minimize irrigation needs and also reducing weed growth.

According to Afolabi *et al.* (2013) Moringa is fairly resistant to pests and diseases since its relatively fast vegetative growth allows it to regenerate quickly from any disturbance. The most common pests and diseases are grasshoppers, crickets, caterpillars, termites and fungal disease. Preventive measures and timely detection of pests and diseases are important in the pest and disease management strategy. When harvesting pods for human consumption, harvest when the pods are still young (about 1 cm in diameter) and snap easily. In seed producing farms (for planting or oil extraction), pods should be harvested when they reach maturity, i.e. when they turn brown and dry. Harvesting of the leaves can be done by cutting shoots and leaves or by removing the leaves, picking them directly off the tree. In this case it is advisable to apply pruning after the harvest of the leaves in order to ensure again a vigorous growth.

2.5 Multipurpose uses of Moringa

The Moringa plant is known worldwide for its nutritional and medicinal benefits and industrial uses. Almost every part of the Moringa plant has nutritional value.

1. Human consumption

According to Dash and Gupta (2009) the pods of the Moringa can be cooked as a vegetable and can be used in soups, stews or curries. The very young pods are very tasty, fibreless, and can be cooked and eaten like green beans. The leaves can be eaten as greens, boiled, fried, in soups and stews or for seasoning. Even the buds and the flowers of Moringa can be eaten and can be added and processed in various dishes

2. Nutritious value of Moringa

Foidl *et al.* (2001) stated that Moringa leaves are an exceptionally good source of vitamins A, B, and C, minerals (in particular iron and calcium), and the sulphur-containing amino acids methionine and cystine. Moringa leaves also acts as a good source of natural antioxidant due to the presence of various types of antioxidant compounds such as ascorbic acid, flavonoids, phenolics and carotenoids

3. Oil

Anwar and Rashid (2003) stated that the oil content of de-hulled Moringa seeds is about 42%. The clear, sweet and odorless oil is of excellent quality for cooking, can be used as a lubricant for fine machinery (e.g. watches).

4. Water purification

According to Foidl *et al.* (2001) the properties of the natural polypeptides produced from the seeds can also be used for water purification in the form of powder (grounded dry seeds). Up to 99 % of colloids can be removed and only one seed is required per litre for slightly contaminated water, two seeds for very dirty water.

5. Biofuel

Fahey (2005) stated that biodiesel derived from Moringa oil is an acceptable substitute for petro-diesel when compared to biodiesel fuels derived from other vegetable oils. A survey conducted on 75 indigenous (India) plant derived non-traditional oils concluded that *M. oleifera* oil, among others, has good potential for biodiesel production

6. Medical use

According to Anwar and Rashid (2003) almost all the parts of this plant: root, leaf, bark, gum, leaf, flowers, seed and fruit (pods) have been used for various ailments in the indigenous medicine of South Asia.

7. Agricultural uses

Reyes-Sánchez *et al*. (2006) stated that Moringa leaves can be used as a foliar spray (leaf extract) to increase plant growth and as a green manure to improve soil fertility. Moringa has also been reported to have the potential to be used as bio-pesticide. They have also been shown to produce more and larger fruit, consequently having a higher yield at harvest time. Foidl *et al.* (2001) also stated that feeding animals Moringa increased milk production, increased nutrient uptake, and faster weight gain than with other feeds.

Various uses of Moringa

Apart from the above discussed uses for Moringa, there are also some various other uses reported:

- Domestic cleaning agent (crushed leaves);
- Blue dye (wood);

• Gum (from tree trunks);

• Honey (flower nectar);

• Pulp for paper (wood);

• Rope (bark);

• Tannin for tanning hides into leather (bark and gum).

2.6 Importance of Moringa in Agroforestry system

Drumstick *(M. oleifera*) is one of the important, nutritious and palatable minor vegetable grown in most of the tropical and subtropical countries of the world (Abdulkarim *et al.*, 2005). It is the only tree type popular vegetable of Bangladesh and found in most of the homestead gardens. Drumstick is cultivated in almost all districts of Bangladesh. It is extensively cultivated in middle and western regions of Bangladesh specially in the division of Khulna, Rajshahi and Dhaka. It can survive without any type of fertilizer, manures, pesticides even watering and weeding, which is very important for the protection of our environment (Fahey, 2005). All parts of *M. oleifera* are economically viable as food and nutrition, animal fodder, natural coagulants, forestry products and fertilizer (Afolabi *et al*., 2013; Ahmad *et al*., 2014). Immature fruits, flowers and young leaves of drumstick are used as vegetables separately (Kekuda *et al.*, 2010). 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), antioxidants and anti-inflammatory compounds (Anwar *et al*., 2007; Adisakwattana and Chanathong, 2011; Adejumo *et al*., 2012). The medicinal uses, safety and efficacy of *M. oleifera* have been widely reported by several authors (Popoola *et al.*, 2013; Hussain, 2014). The seed oil as raw material for production of biodiesel is gaining attention globally as possible replacement for petro diesel fuel in unmodified engines (Fernandes *et al.*, 2015). Even oil extracted from the seeds is used in salads. The wood of drumstick is suitable for pulp, paper, cellophane and textile production (Popoola *et al*., 2013; Hussain, 2014).

Drumstick is grown as crop system, marginal/ hedgerow planting, agrosilvopastoral systems or multipurpose forest tree production system at different agro climatic zone in India (Fahey, 2005; Afolabi *et al*., 2013).

Ahmad *et al.* (2014) stated that drumstick tree produces a myriad of valuable products for local communities. Its green pods, leaves, flowers and roasted seeds are highly nutritious and consumed in many parts of the world. It provides many services that are always taken into consideration when trees are being selected for agroforestry systems. The tree provides semi- shade, useful in intercropping systems where intense direct sunlight can damage crops. It can be grown even in poor soils. It withstands long periods of drought and grows well in semi- arid and arid conditions.

Thilza *et al.* (2010) reported that aqueous leaf and bark extracts of some agroforestry tree crops were tested for their phytotoxic (allelopathic) effects on germination and radical extension of leguminous food crops (i.e., *Dolichos biflorus*, *Glycine max*, *Phaseolus linatus* and *P. mungo*). The phytotoxic effects of tree crops were specific where *M. oleifera* had more phytotoxic effect than *Celtis australis* or *Ougeinia oojeinensis*. Radicle extension of all four test crops was significantly reduced by all the tree crops except *O. oojeinensis* and *C. australis*.

Adisakwattana and Chanathong (2011) described the presence of tuberous roots on numerous drumstick species located in the environments of Ouagadougou, Burkina Faso in the context of species importance to Agroforestry systems. They discovered tuberous roots of *M. oleifera*, which have the ability to storage of water and/or sugar during long drought periods.

Fernandes (2015) suggested to select thin crowned tree species/ porous canopy trees which can transmit sufficient light for growth of alley crops. Since drumstick trees are light crowned with thin, small and tri-pinnate leaves so this tree will be suitable for sustainable agroforestry

However, *M. oleifera*, as a vegetable, is considered neglected and underutilized species in some parts of the world (Padulosi *et al.*, 2013a; Rudebjer *et al.*, 2013). The neglect may be probably due to little or no research attention from agronomic researchers and policy makers, loss of local knowledge and lack of established varieties (Padulosi *et al.*, 2011; Padulosi *et al.*, 2013b). Usually, neglected and underutilized species are not traded as commodities; however, the economic importance of *M. oleifera* has elicited utilization in different parts of Africa

2.7 Importance of red amaranth

Red amaranth is the most common leafy vegetable grown during summer and rainy seasons. However, during winter, its growth and development is slow than summer and rainy season (National Research Council, 2006). Red amaranth is a heat-loving C_4 crop (Baral *et al.*, 2011). The plants that perform C_4 dicarboxylic acid pathway of photosynthesis are called C_4 plants. C_4 species have evolved in a high CO_2 environment.

This increases both their nitrogen and water use efficiency compared to C_3 species. C_4 plants have greater rates of CO_2 assimilation than C_3 species for a given leaf nitrogen when both parameters are expressed either on a mass or an area basis. The C_4 photosynthesis is an adaptation of the C_3 pathway that overcomes the limitation of the photorespiration, improving photosynthetic efficiency and minimizing the water loss in hot, dry environments. C_4 plants exhibit higher photosynthetic and growth rates due to gains in the water, carbon and nitrogen efficiency uses. In C_4 plants, the photorespiration is suppressed by elevating the CO_2 concentration at the site of Rubisco though suppressing the oxygenase activity of the enzyme. This is achieved by a biochemical CO_2 pump and relies on a spatial separation of the CO_2 fixation and assimilation. In general, these species have a particular anatomy (Kranz anatomy), where mesophyll and bundle sheath cells cooperate to fix CO_2. Differentiation of these two cell types is essential for the operation of C_4 photosynthesis, although special cases for the operation of the C_4 cycle within only one type of photosynthetic cell have been found (Lara *et al.*, 2002; Edwards *et al*., 2004; Lara and Andreo, 2005). However, C_4 plants are less likely to die of dehydration compared to C_3 plants in dry conditions. Thus, being a heat loving C_4 plant, it’s quick growing and higher yield potential characteristics, red amaranth is one of the most important popular vegetables in Bangladesh. Normally plants are harvested at 20 to 30 days after sowing to consume as tender greens (Makinde *et al*., 2010). Consumption of plants within 15 to 20 days as well as at the mature stages of 35 to 40 days after sowing is also not uncommon. Khanda (2003) reported that the optimum stage of harvest in red amaranth could be fixed at the 25th to 30th days after sowing, as this stage the performance of the types was found to be superior with increase in leaf weight, stem weight, leaf length, leaf breadth, stem diameter and plant height. The fresh tender leaves and stem of red amaranth are delicious when cooked like other fresh vegetables. It is relished as vegetable soup cooked by boiling and mixing with condiments. The seeds have various bakery uses. Therefore, red amaranth can play a vital role in elevating the nutritional status especially vitamins and minerals of Bangladeshi people (Rauf *et al*., 2009). It can easily fit well in a crop rotation because of it's very short duration life cycle and large yield of edible matter per unit area. Usually it grows in kitchen, commercial gardens and high lands but it can grow well as mixed crops along with cereals, pulses and vegetables (Roy, 2008).

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out to evaluate the response of red amaranth in association with drumstick (*M. oleifera*) sapling to find out the best tree crop interaction, it's scope and importance in Agroforestry system. In this chapter the materials used, the methodologies followed and the related works done during the experimental period are presented. A brief description on the experimental site and season, soil, climate and weather, plant materials, land preparation, fertilizer application, experimental design and treatments combination, seed sowing, intercultural operation, harvest, data collection, statistical analysis etc. are included here. The working products are given below:

3.1 Location and time of the experiment

The present research work was carried out at the agroforestry experimental field of the department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from February 2017 to March 2017. The place is geographically located at 23°77'N latitude and 90°33'E longitude at an altitude of 8.6 meter above the sea level.

3.2 Climate

The experimental area has sub-tropical climate characterized by high temperature, heavy rainfall during May to September and scanty rainfall during rest of the year. The annual precipitation of the site is 2052 mm and potential evapo-transpiration is 1286 mm, the average maximum temperature is 30-35^{0}C, average minimum temperature is 14-21^{0}C and the average mean temperature is 12-25^{0}C (BBS, 2015). The experiment was carried out during kharif -1 season (February-March), 2017.

3.3 Soil characteristics

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).

Table 1. Morphological feature of the soil sample analyzed at Soil Resources Development Institute (SRDI), 2014, Farmgate, Dhaka (For 0-14 cm depth).

Morphological feature	Characteristics
Location	Sher-e-Bangla Agricultural University Farm,Dhaka
AEZ	AEZ- 28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Soil Series	Tejgaon
Topography	Fairly leveled
Depth of inundation	Above flood level
Drainage condition	Well drained
Land type	High land

3.4 Plant materials

In this study the saplings of *M. oleifera* tree were collected from Savar, which used as tree components. The seeds of red amaranth was purchased from United Seed Company, Siddique Bazar, Gulisthan, Dhaka.

Plate 1: Moringa stem cutting used as planting material

3.5 Tree establishment and study

The experiment was done during the early establishment period of *M. oleifera* tree from cutting as planting materials. Each cutting was 120 cm in length. At first 35 cm deep, 30 cm wide square size pits were dug maintaining 120 cm distance in the experimental field and then the pit was filled with surrounding soils. Then the cuttings were placed into the central portion of the pits. The above ground height of 80 cm was similar for all of the cuttings used as planting materials for tree. Irrigation was done after the plantation of the tree. Irrigation was done when necessary through watering cane.

3.6 Experimental design and treatment combination

Red amaranth was laid out following the Randomized Complete Block Design (RCBD) with single factorial arrangement with four replications. Field size was 900cm × 660 cm, block size was 150 cm × 540 cm and individual plot size was 150 cm × 90 cm. Each treatment was replicated 4 times

Four treatments were used in this study which are follows-

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

T_3= 36 cm distance from the tree base

A characteristic feature of the experiment layout is shown in the figure 1. Red amaranth grown at different distance from the tree were treated as treatments and control condition was red amaranth without tree.

Design of the Field

Field size = 900cm × 660 cm

Block size = 150 cm × 540 cm

Plot size = 150 cm × 90 cm

Block to block distance = 60 cm

Plot to plot distance= 60 cm

Total no. of plants = 12

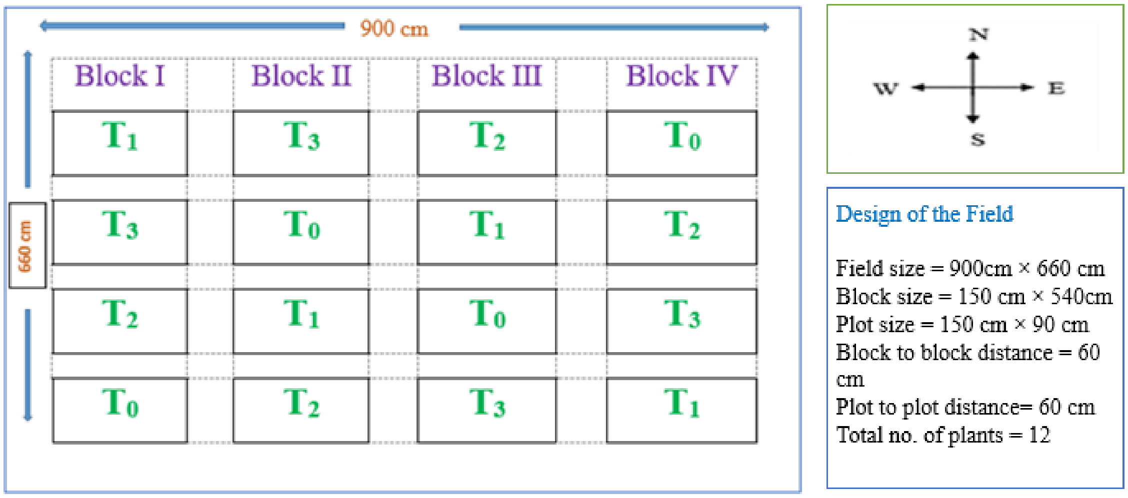

Figure 1. Layout of the experimental plot

3.7 Land preparation

The experimental land was first opened on 1 January 2017 and operation was done by spades. Then the land was left fellow for one month. During this time all crop residues and weeds were removed from the land, broken stones and bricks were sorted out and finally the land was properly leveled.

Plate 2: Picture taken at the time of final land preparation

3.8 Crop establishment and management

Red amaranth seeds were sown in the experimental plot on 20 February 2017. After emergence seedlings were thinned out.

Plate 3: Red amaranth in association with Moringa sapling

3.9 Management practices

3.9.1 Fertilizer application

No chemical fertilizers were used for this experiment but only cow dung was applied into the experimental field during the final land preparation.

3.9.2 Weeding, earthing up and irrigation

Weeding was done four times during the experimental period to keep the field 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.

3.9.3 Thinning out

The emergence of Amaranth was started after 5 days of sowing respectively. Thinning was carried out three times. For red Amaranth first, second and third thinning was done after 10 days, 15 days and 20 days of sowing respectively.

3.9.4 Pest and disease management

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

3.10 Methods of data collection

Red amaranth was harvested at 30 days after sowing (DAS) when the crop reached at edible size. Plant samples of red amaanth were collected randomly from each replication of the respective plots. A total of 60 (5 from each replication) plants of red amaranth were selected from each plot for data collection.

The data were recorded for the following parameters.

a) Height of the plant (cm)

b) No. of leaves per plant

c) Leaf length (cm)

d) Leaf breadth (cm)

e) Stem diameter of the plant (cm)

f) Weight of single plant (g)

Plate 4: Samples taken for measurement and data collection

g) Growth rate in stem diameter (mm/day)

h) Growth rate in height (cm/day)

i) Growth rate in weight (g/day)

j) Yield (t/ha)

k) Moisture content (%)

l) Dry matter content (%)

3.10.1. Plant height (cm)

Plant height was measured in centimeter (cm) by using a scale 10, 15, 20, 25, and 30 days after sowing from the point of ground level to the tip of the plant leaf.

10.2 No. of leaves per plant

Total no. of leaves per plant were counted at 10, 15, 20, 25 and 30 days after sowing. Randomly 5 plants were selected and measured, then the sum of number of leaf was divided by 5 to record number of leaf per plant.

3.10.3 Leaf length (cm) and leaf breadth (cm)

The leaf length and leaf breadth of the upper 3rd leaf of each plant was measured against a centimeter scale.

3.10.4 Stem diameter of plant (cm)

Randomly 5 plants were selected and measured each stem of the plant against a roller having mm scale, then the sum of stem diameter was divided by 5 to record stem diameter of plant.

3.10.5 Weight of single plant (g)

Randomly 5 plants were selected from the each replication and the sum of the weight of 5 plants was divided by 5, then it was recorded as weight of single plant (g).

3.10.6 Growth rate of stem diameter (mm/day)

At the date of harvesting, the stem diameter of randomly selected 5 plants from each replication was measured against a roller having mm scale and the diameter was divided by total growing period (30 days). The growth rate was calculated by using the following formula.

$$\text{Growth rate of stem diameter} = \frac{\text{Diameter of the stem (mm) at harvest}}{\text{Total growing period (30 days)}}$$

3.10.7 Growth rate of height (cm/day)

At the harvesting date the average weight was counted from randomly selected 5 plants of each replication and the weight was divided by the total growing period (30 days) and finally recorded as growth rate in height (cm/ day). The formula is as follows:

$$\text{Growth rate of height} = \frac{\text{Height of a plant (cm) at harvest}}{\text{Total growing period (30 days)}}$$

3.10.8 Growth rate of weight (g/day)

At the date of harvesting, 5 plants were selected randomly from each replication, then the average weight of 5 plants was divided by the total growing period and recorded as growth rate in weight (g/day). It was calculated by using the following formula.

$$\text{Growth rate of weight} = \frac{\text{Weight of single plant (g) at harvest}}{\text{Total growing period (30 days)}}$$

3.10.9 Yield (t/ha)

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

3.10.10 Moisture content (%)

Immediately after harvest, plants were cut to small pieces and weighted quantity of the samples was taken in by electrical balance. Then the samples were placed in an over maintained at 100^0C for 72 hours. The final weights of plants were taken by electrical balance. Percent moisture accumulation was computed using the following formula on fresh weight basis moisture content (%)

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight - Oven dry weight}}{\text{Fresh weight}} \times 100$$

3.10.11 Dry matter content (%)

Dry matter content (%) of the red amaranth was calculated from the data obtained during moisture estimation using the following formula

% Dry matter content= 100 – moisture content (%)

3.11 Analysis of data

All the data were subjected to analysis of variance (ANOVA) and tested for significance by Least Significant Difference (LSD) using R-3.5.1 software (R Core Team, 2013).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results from the experiment carried out to study the influence of Moringa sapling on the growth and yield of red amaranth. Results obtained from this experiment with discussion are presented below:

4.1 Influence of Moringa (*M. oleifera*) saplings on the growth and yield contributing characteristics of red amaranth

4.1.1 Plant height (cm)

Different spacing from tree base exhibited significant differences in plant height at different sampling dates (Table 2). The plant height was increased gradually with the advancement of crop growth up to harvest. At 10 DAS and 20 DAS, plant heights were not significantly different. At 15 DAS significantly highest plant heights were observed in control conditions which were statistically at par with the plants of T_3 treatment. Consistently, the least plant height was observed in T_2 treatment. The plants belong to T_1 treatment appeared as intermediate height. At 25 DAS significantly highest plant heights were observed in control conditions and the lowest plant height was obtained in treatment T_1. At harvest, plant height ranged from 27.6 cm to 20.7cm where plants belong to control treatment appeared as the tallest in stature followed by the plants belong to T_3, whilst T_2 was the shortest in height closely followed by the plants belong to T_1 treatment. At early growth stage (10 DAS), T_1 was the fastest growing and performed better than T_0 in height gain but at later stages plants belong to the control treatment exhibited the higher growth rate and plants belong to T_3 treatment exhibited the 2nd higher growth rate.

At harvest, the height of red amaranth under Moringa based agroforestry system was decreased by 25% at treatment T_2 relative to that of control condition. This might be due to the fact that water with organic manure provided the optimum growth conditions i.e., availability of macro and micro nutrients to the root zone of red amaranth as irrigation was provided regularly at control condition. This is consistent with the theoretical expectation as growth is accomplished through cell division, cell enlargement and differentiation which involve genetic, physiological, ecological and morphological events and their complex interactions. 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).

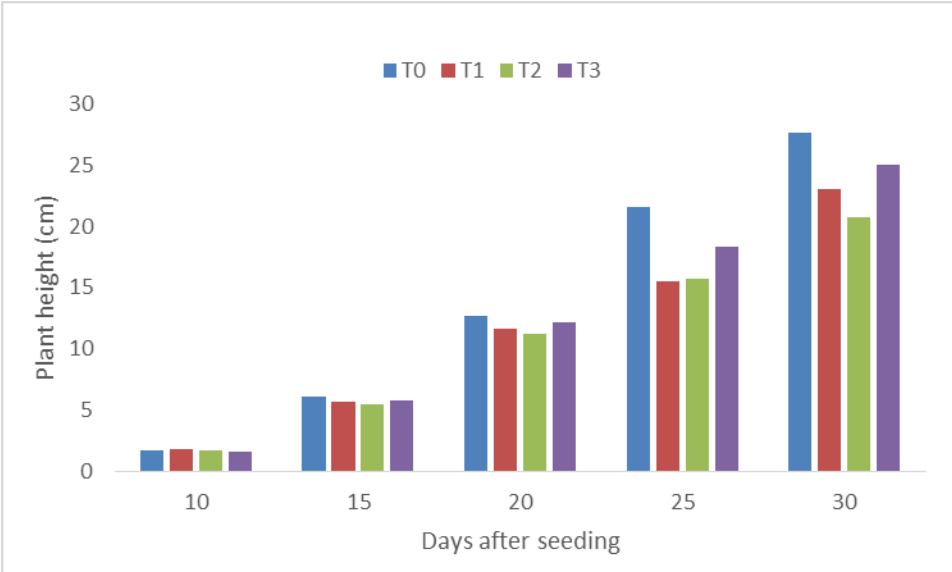

Fig.2. Effect of different plant spacing on plant height (cm) of red amaranth at different days after sowing

Remarks:
T_0 = Control;
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base

Table 2. Effects of Moringa based agroforestry system on plant height (cm) of red amaranth at different days after showing (DAS)

Treatments	Plant height (cm)				
	10 DAS	**15 DAS**	**20 DAS**	**25 DAS**	**30 DAS**
T_0	1.75	6.1a	12.7	21.6a	27.6a
T_1	1.77	5.7b	11.6	15.5c	23bc
T_2	1.7	5.5b	11.2	15.7c	20.7c
T_3	1.65	5.8ab	12.2	18.3b	25ab
LSD	NS	0.38	NS	2.1	2.6
CV(%)	4.9	4.1	5.5	7.6	6.8
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_0 = Control
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base.

4.1.2 No. of leaves/plant

A good number of leaves indicates better growth and development of plants. It is positively related to the yield of red amaranth. No. of leaves/plant were significantly influenced by different distance orientation from the base (Table 3). At 10 DAS and 20 DAS, different no. of leaves per plant were not significantly identified. At 15 DAS significantly highest no of leaves were observed in control condition and lowest no. of leaves were observed in T_3 treatment which were statistically different from other treatments. At 25 DAS significantly the highest no. of leaves were observed in control condition and the lowest no. of leaves were observed in treatment T_1, followed by treatments T_3 and T_2, where treatments T_1, T_2 and T_3 are statistically similar. At harvest, no of leaves ranged from 14.63 to 11.25 where maximum no. of leaves (14.63) were recorded in control treatment and minimum no. of leaves (11.25) were recorded in T_3 treatment. Treatment T_0 and T_2 were statistically comparable and treatment T_1, T_2 and T_3 are also statistically comparable.

Nitrogen from organic matter is a key element in plant growth which helps to secrete hormones in plant cells, in plant proteins. Hormones such as auxin, cytokinin are powerful chemical messengers that result in physiological changes of plants. Auxin a powerful root, shoot and leaf regulator, involved in buds and new leaf formation (Zahoor *et al.*, 2011). A high concentration of cytokinin in organs or tissues stimulate the transport of sugars to those organs or tissues which leads to a greater number of leaves development (Hopkins *et al.*, 2004). The leaf number of red amaranth thereby decreased in 23% at treatment T3 relative to that of control. This result was consistent with the result of Miah *et al.*, 2001 who conducted an experiment with red amaranth at different N level. They found upto 41% reduced no. of leaves in N deficient soil than that of control environment.

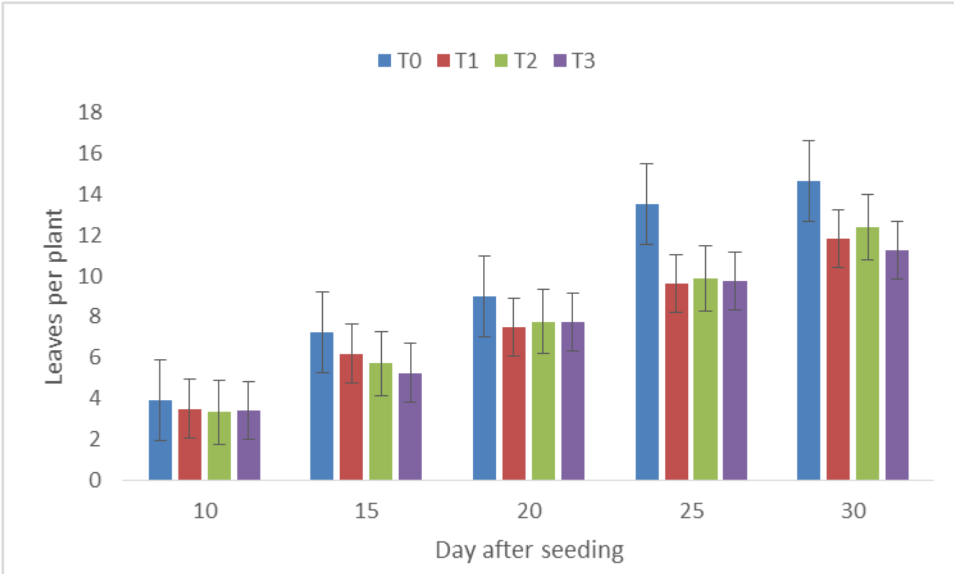

Fig. 3: Effect of different spacing on no. of leaves/ plant of red amaranth at different days after sowing

Remarks:

T_0 = Control
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base

Table 3. Effects of Moringa based agroforestry system on no. of leaves/plant of red amaranth at different days after sowing (DAS)

Treatments	No. of leaves/plant				
	10 DAS	**15 DAS**	**20 DAS**	**25 DAS**	**30 DAS**
T_0	3.92	7.25a	9	13.5a	14.63a
T_1	3.5	6.2b	7.5	9.63b	11.8b
T_2	3.33	5.71c	7.75	9.87b	12.38ab
T_3	3.42	5.25d	7.75	9.75b	11.25b
LSD	NS	0.38	NS	2.1	2.6
CV (%)	4.1	3.9	5.5	12.6	13.2
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_0 = Control;
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base.

4.1.3 Leaf area (length × breadth)

Leaves are photosynthetic organs; thus, the length and breadth of leaves are very important factors influencing the success of plants. Different treatments effect significantly on leaf length and breadth of red amaranth (Table 4). At harvest leaf length ranged from 5.77 cm to 4.47 cm. The best plant leaf length (5.77 cm) was recorded in without seedling treatment. The second highest plant leaf length (4.52 cm) was produced under both T_1 and T_2 treatments and the lowest plant leaf length (4.47cm) was observed under T_3 treatment. Leaf length of red amaranth at T_1, T_2 and T_3 treatments were statistically similar. Therefore, leaf breadth ranged from 3.75 cm to 2.97 cm. The best plant leaf breadth (3.75 cm) was recorded in control treatment. The second (3.32cm) and the third (3.17cm) highest leaf breadth were found under T_1 and T_3 treatments and the lowest leaf breadth (2.97cm) was observed under T_2 treatment. Leaf breadth of red amaranth at T_1, T_2 and T_3 treatments were statistically similar.

Leaf area growth and leaf area insertion changes are strongly modified by temperature, radiation and shading as well as photoperiod, air humidity, water supply and nutrition (Tardieu *et al.*, 2005). Leaf growth rate raises with increasing temperature until the optimum temperature is reached, but reversely further raise of temperature could reduce leaf growth (Tamaki *et al.*, 2002). Therefore, leaf size development rate is more closely associated with soil temperature near soil surface than air temperature during early stages of optimal leaf size and shape. Our research result was analogous with the result of Wadud *et al*. (2005) who conducted an experiment with red amaranth with different light condition. They found 23% decreased leaf length and 33% decreased leaf breath at 25% reduced light condition than that of control environment.

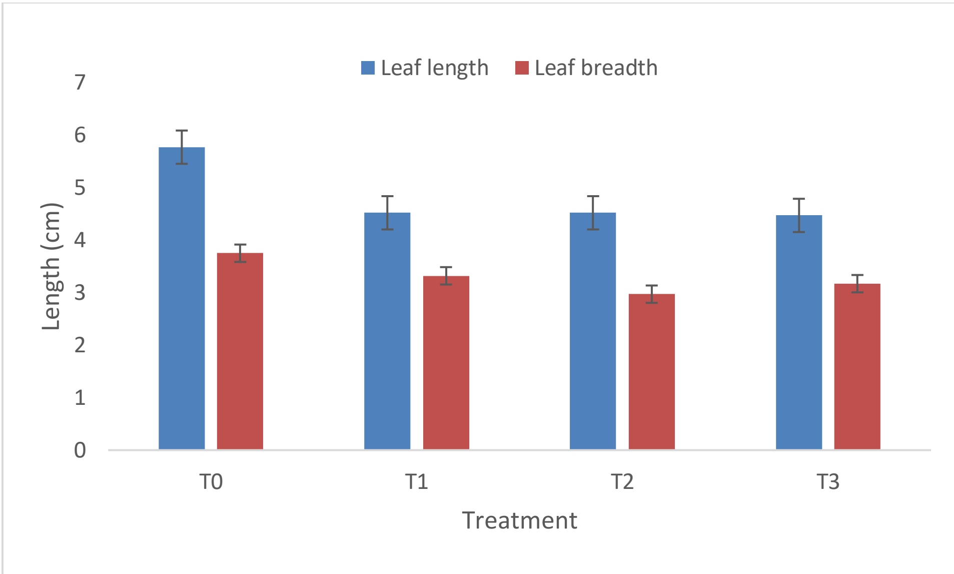

Fig. 4: Effects of different spacing on leaf length (cm) and leaf breadth (cm) of red amaranth at the time of harvest.

Remarks:
T_0 = Control
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base

Table 4. Effects of Moringa based agroforestry system on leaf length (cm) and leaf breadth (cm) of red amaranth at the time of harvest.

Treatments	Leaf length (cm)	Leaf breadth (cm)
T_0	5.77a	3.75a
T_1	4.52b	3.32b
T_2	4.52b	2.97b
T_3	4.47b	3.17b
LSD	0.51	0.35
CV (%)	6.6	6.6
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_0 = Control;

T_1 = 12 cm distance from the tree base

T_2 = 24 cm distance from the tree base

T_3 = 36 cm distance from the tree base.

4.1.4 Shem girth (cm)

Stem girth of red amaranth was significantly influenced with increasing distance from tree base (Table 5). Stem girth varied from 2.81 cm to 1.9 cm, where the highest stem girth (2.81 cm) was recorded under control condition and the lowest stem girth (1.9 cm) was recorded at treatment T_3. Stem girth was statistically similar at T_1 and T_2 treatments and also analogous with treatments T_2 and T_3. Stem girth was 32.3% lower at treatment T_3 than control treatment.

Organic manure contain N, P, S, K, N increases cytokinin production, which subsequently affects cell wall elasticity, number of meristematic cells, and cell growth. Calcium plays an essential role in plant development and overall plant health because it is a structural component of cell wall and it is necessary for cell growth and division. 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 5: Effects of Moringa based agroforestry system on stem girth (cm) of red amaranth at the time of harvest

Treatments	Stem girth (cm)
T_0	2.81a
T_1	2.17b
T_2	2.12bc
T_3	1.9c
LSD	0.23
CV (%)	6.5
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_0 = Control;
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base.

4.1.5 Shoot length (cm)

Shoot length of red amaranth was significantly influenced with increasing distance from tree base (Table 6). Shoot length varied from 28.7 cm to 22.8 cm, where highest shoot length was recorded under control condition (28.7 cm) and lowest shoot length (22.8 cm) was recorded at treatment T_2. Shoot length of red amaranth at T_1, T_2 and T_3 were statistically similar.

Root length (cm)

Roots are important plant organs. They absorb water and nutrients from the soil and translocate them to plant tops. Root length of red amaranth varied significantly at different level of treatments. Root length varied from 9.3 cm to 7.6 cm, where highest root length was recorded under control condition (9.3 cm) and lowest root length (7.6 cm) was recorded at T_1. Root length of red amaranth at T_1, T_2 and T_3 were statistically similar.

Total length (cm)

Significant shoot and root length of red amaranth was recorded from different level of distance orientation. Shoot and root length varied from 38 cm to 31 cm, where highest shoot and root length (38 cm) was recorded under control condition and lowest shoot and root length (31 cm) was recorded at T_2. Shoot and root length of red amaranth at T_1, T_2 and T_3 were statistically similar.

Nutrient availability have profound impact on shoot and root system architecture by altering the length of shoot and number, length, angle, and diameter of roots and root hairs. N is a major constituent of chlorophyll, carbohydrate utilization, root growth, and development, above ground vegetative growth and stimulation of uptake and utilization of other nutrient elements. The combined application of N and P increases shoot length, root surface area, root length, and root-shoot mass. This result was analogous with the result of Ara *et al.* (2005) who conducted an experiment with spinach at different nitrogen level. They found 33% decreased shoot and root length in spinach in N deficient soil than that of control environment.

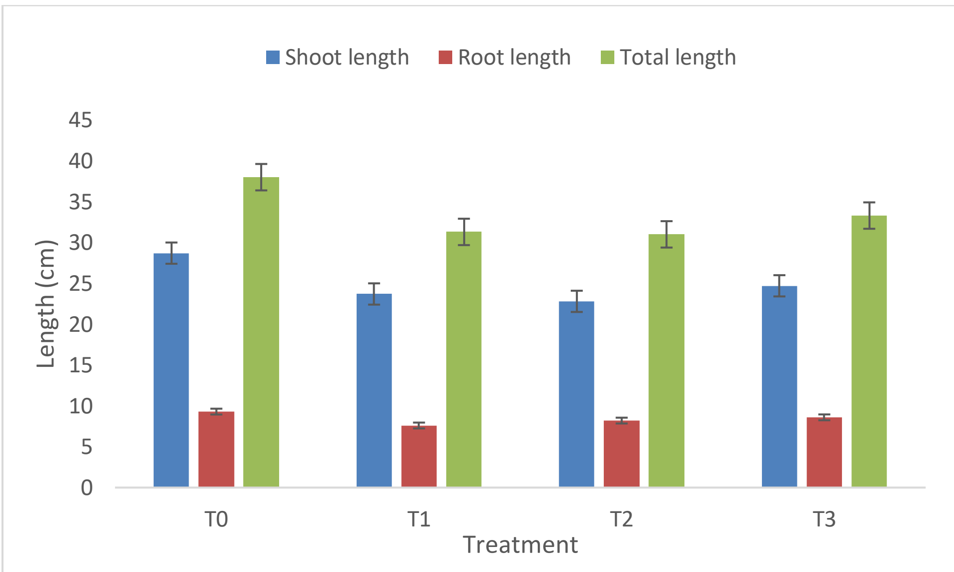

Fig.5. Effect of different spacing on shoot and root length (cm) of red amaranth at the time of final harvest

Remarks:

T_0 = Control

T_1 = 12 cm distance from the tree base

T_2 = 24 cm distance from the tree base

T_3 = 36 cm distance from the tree base

Table 6: Effects of Moringa based agroforestry system on shoot length (cm) and root length (cm) of red amaranth at the time of harvest

Treatments	Shoot length(cm)	Root length(cm)	Total length(cm)
T_0	28.7a	9.3a	38a
T_1	23.7b	7.6b	31.3b
T_2	22.8b	8.1b	31b
T_3	24.7b	8.6b	33.4b
LSD	2.81	0.79	2.1
CV (%)	7.03	7.05	6.9
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_0 = Control;
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base.

4.1.6 Shoot and Root weight (g)

Shoot weight of red amaranth was affected significantly due to distance orientation from the tree base (Table 7). At harvest shoot weight varied from 16.5 g to 12 g. The highest shoot weight (16.5 g) was recorded in control treatment followed by treatment T_1, whilst the lowest shoot weight (12 g) was recorded in treatment T_2 followed by treatment T_3. Shoot weight of red amaranth at T_2 and T_3 treatments were statistically similar.

Significant root weight of red amaranth were recorded from the different level of treatments. The root weight varied from 1.55 g to 1.07 g. The highest root weight (1.55 g) was recorded in control treatment followed by treatment T_3 , whilst the lowest root weight (1.07 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 7: 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)	Total weight (g)
T_0	16.5a	1.55a	18.05a
T_1	14b	1.07c	15.07b
T_2	12c	1.3b	13.3c
T_3	12.7c	1.41ab	14.11c
LSD	0.16	1.01	0.83
CV (%)	7.9	4.5	7.2
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_0 = Control;
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base.

4.1.7 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 8). At harvest, fresh weight varied from 18.05 g to 13.32 g. The highest fresh weight (18.05 g) was recorded in control treatment followed by treatment T_1 (15.05 g), whilst the lowest fresh weight was found in T_2 (13.3 g) treatment followed by treatment T_3 (14.1 g).

Dry weight of red amaranth differed significantly due to various distance orientation from the tree base (Table 8). The dry weight varied from 1.1 g to 0.75 g, whilst the highest dry weight (1.1 g) was observed in without tree condition followed by treatment T_1, and the lowest dry weight (0.75 g) was observed in T_2 treatment followed by treatment T_3.

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).

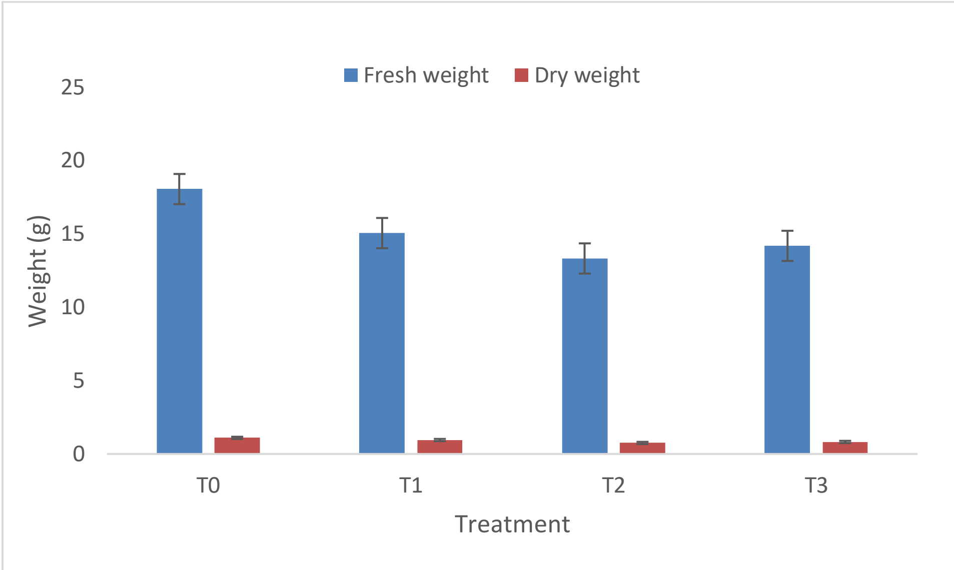

Fig.6. Effect of different spacing on fresh weight (g) and dry weight (g) of red amaranth at the time of final harvest

Remarks:

T_0 = Control
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base

Table 8: Effects of Moringa based agroforestry system on fresh weight (g) and dry weight (g) of red amaranth at the time of harvest

Treatments	Fresh weight (g)	Dry weight (g)
T_0	18.05a	1.1a
T_1	15.05b	0.95b
T_2	13.32c	0.75c
T_3	14.18bc	0.82bc
LSD	0.13	1.01
CV (%)	9.09	4.1
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_0 = Control;
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base.

4.1.8 Growth rate of stem diameter (mm/day), height (cm/day) and weight (g/day) of red amaranth

Growth rate of stem diameter, height and weight of red amaranth measured at 30 DAS in different spacing which were statistically significant (Table 9). It was observed that the highest growth rate of stem diameter (0.94 mm/day), height (0.92cm/day) and weight (0.60 g/day) of red amaranth were found in control treatment. The lowest growth rate of stem diameter (0.63 mm/day) was observed in treatment T_3, followed by treatment T_2. Again the lowest growth rate of height (0.69 cm/day) was observed in treatment T_2, followed by treatment T_1. Furthermore, the lowest growth rate of weight (0.44g/day) was observed in treatment T_2, followed by treatment T_3.

Table 9: Effect of different spacing on growth rate of stem diameter (mm/day), growth rate of height (cm/day) and growth rate of weight (g/day) of red amaranth in association with Moringa sapling

Treatments	Growth rate of stem diameter (mm/day)	Growth rate of height (cm/day)	Growth rate of weight (g/day)
T_0	0.94a	0.92a	0.60a
T_1	0.73b	0.77bc	0.50b
T_2	0.71bc	0.69c	0.44c
T_3	0.63c	0.84ab	0.47bc
LSD	0.078	0.08	0.03
CV (%)	6.57	6.8	3.9
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_0 = Control;
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base.

4.1.9 Yield (t/ha)

Yield of red amaranth was significantly influenced with increasing distance from tree base (Table 10). The highest yield of red amaranth (13.75 t/ha) was obtained in control without any competition and shading effect and the lowest yield (10.58 t/ha) was obtained in T_2 treatment followed by the plants belong to T_3 and T_1 treatments. Yield (t/ha) of red amaranth at T_1, T_2 and T_3 treatments were statistically similar.

Water deficit is one of most important environmental factors inhibiting photosynthesis and decreasing growth and productivity of plants. It is one of the major causes of crop loss worldwide, reducing average yields for most major crop plants by more than 50% (Wang *et al.,* 2003). Boutraa and Sanders (2001) established that mild water deficit causes upto 25% yield loss in crops. 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).

Therefore, total yield of red amaranth declined about 23% at treatment T_2 relative to that of control. This result was in accordance with the result of Miah *et al.* (2001) who conducted an experiment with red amaranth with different N level. They found upto 41% yield reduction in N deficient soil than that of control environment.

Table 10. Effects of Moringa based agroforestry system on yield (t/ha) performance of red amaranth at the time of harvest

Treatments	Yield (t/ha)
T_0	13.75a
T_1	11.5b
T_2	10.58b
T_3	10.95b
LSD	0.93
CV (%)	5
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_0 = Control;
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base.

4.1.10 Moisture content (%)

The moisture content reflects the amount of water present in the ingredient. Moisture content in red amaranth was not significantly varied among the treatments (Table 11). The maximum moisture content (94.27%) was recorded in treatment T_2 and the minimum moisture content (93.63%) was recorded in treatment T_1.

4.1.11 Dry matter content (%)

Dry matter refers to material remaining after removal of water. Results in table 11 clearly stated that dry matter content was not significantly varied among different treatments. The maximum dry matter content (6.38%) of red amaranth was obtained in T_1 treatment, followed by T_0 and the minimum dry matter content (5.73%) was recorded in treatment T_2, followed by T_3.

Competition for moisture in agroforestry systems is common occurring phenomenon, which can affect the system adversely (Verma *et al.*, 2002). Further, active growth stages/ phenophase of field crop/tree species coincided temporally, which might also have created competition for soil moisture at these stages. Alterations in the dry matter accumulation and partitioning achieved under drought conditions are strongly regulated through plant growth regulators and nutrient uptake. Roy *et al.* (2008) reported that increase in nitrogen level had a significant influence on the increase in plant dry matter content.

Table 11: Effect of different spacing on Moisture content (%) and dry matter content (%) of red amaranth in association with Moringa sapling

Treatments	Moisture content (%)	Dry matter content (%)
T_0	93.77	6.2
T_1	93.63	6.38
T_2	94.27	5.73
T_3	94.1	5.9
LSD	NS	NS
CV (%)	5.5	4.9
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_0 = Control;
T_1 = 12 cm distance from the tree base
T_2 = 24 cm distance from the tree base
T_3 = 36 cm distance from the tree base.

4.2 Influence of red amaranth on the growth characteristics of Moringa (*M. oleifera*) saplings

The growth characteristics of Moringa was not influenced by the interaction effect of red amaranth during three months after plantation. The growth characteristics of Moringa are shown below:

4.2.1 No. of buds

In case of Moringa sapling no. of buds were not differed significantly at 6 days after planting (Table 12). At 12 days highest no. of buds were observed at treatment T_1 and the lowest no of buds were observed at treatment T_2. At 18 days highest no. of buds were observed at T_3 treatment and it was followed upto 30 days. At 18 days lowest no. of buds were observed at T_2 treatment and it was followed upto 30 days.

Table 12: No. of buds of Moringa at different DAT as influenced by different treatments

Treatments	No. of buds				
	6 DAT	**12 DAT**	**18 DAT**	**24 DAT**	**30 DAT**
T_1	1.75	2.5a	2.5ab	2.5b	3.25a
T_2	0.75	1.75b	2.25b	2.5b	2.75b
T_3	1.75	2.25a	2.75a	3a	3.5a
LSD	NS	0.37	0.27	0.31	0.37
CV (%)	4.8	5.5	5.8	5.5	5.6
Significance level		*	*	*	*

4.2.2 Average bud length (cm)

In case of Moringa sapling average bud length differed significantly at 18 days after planting (Table 13). At 18 days average bud length was highest at treatment T_1, lowest at treatment T_3 and T_2 obtained intermediate bud length average which followed upto 30 days, at the time of harvest of red amaranth.

Table 13: Bud length average (cm) of Moringa at different DAT as influenced by different treatments

Treatments	Bud length average (cm)		
	18 DAS	24 DAS	30 DAS
T_1	5a	7.37a	9.55a
T_2	3.3a	4.11b	5.3b
T_3	1.22b	2b	2.87b
LSD	1.9	2.7	3.34
CV (%)	5.5	5.8	5.7
Significance level	*	*	*

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 (Bayala *et al.*, 2008; Duguma *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, 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 contribute organic matter to the soil, improve soil structural properties and Moringa root conserve soil moisture. Although red amaranth is a short duration crop, have lower volume in shoot and root systems, so it can easily cultivate under Moringa based agroforestry system. In the early growth stage of Moringa plantation no. of buds and bud length of Moringa was very poor. There was little shade effect of Moringa tree on growth and development of red amaranth and no competition was found between Moringa and red amaranth for food, nutrients, light, temperature and water. Therefore, we found no or very little tree crop interaction during the first month of Moringa plantation because there was very poor shoot and root development in Moringa sapling. But in case of red amaranth, the highest plant height, no of leaves, stem girth, shoot and root weight, fresh and dry weight, moisture and dry matter content were observed in control treatment though application of organic manure was done at the time of final land preparation and water was supplied at regular basis. More experiment should set up to find out the effect of Moringa tree on other crops upto one year and to find out the best tree crop interaction

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATION

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 to investigate the performance of Red amaranth under Moringa based agroforestry system at the agroforestry experimental field of the department of Agroforestry and Environmental Science, Sher-e- Bangla Agricultural University, during the period from February to March, 2017. The treatment were 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, T_3= 36 cm distance from the tree base. Moringa trees were grown following Randomize Complete Block Design (RCBD) with four replications. Field size was 900 cm × 660 cm, block size was 150 cm × 540 cm and individual plot size was 150 cm × 90 cm. 60 cm gap were maintained between block to block and plot to plot. The experiments plots were fertilized with cow-dung during final land preparation.

Data were collected on morphological behaviors, yield and yield contributing characters of red amaranth from randomly selected five plants and were analyzed for evaluation of the treatment effects. The highest plant height of red amaranth was observed in control condition. At the time of harvest, the highest plant height among other treatments was observed in T_3, which was 9% less than that of control condition, where, T_1 obtained 16% and T_2 obtained 25% less plant height than that of control condition.

Leaf number directly affect the yield performance of red amaranth. Here, the highest number of leaves were found in control condition. Except control, highest no. of leaves were observed in T_2 treatment, which was 15% less than that of control condition. Therefore, T_1 confined 19% and T_3 confined 23% less number of leaves relative to that of control condition.

The best stem girth was observed in control condition. Apart from this, the highest stem girth was observed in treatment T_1, which was 22% less than that of control condition and lowest stem girth was obtained by treatment T_3, which was 32% less than that of control condition.

In case of fresh weight of red amaranth, highest weight was observed in control condition. But among other treatments the highest fresh weight was observed in treatment T_1, which was 16% less than that of control condition. Thus, treatment T_3 contained 21% and T_2 contained 26% less fresh weight relative to that of control condition.

In case of dry weight, the highest dry weight was observed in control condition. The second highest dry weight was found in treatment T_1, which was 13% less than that of control condition. The third and the fourth positions were obtained by treatments T_3 and T_2 which obtained respectively 25% and 31% less dry weight relative to that of control condition.

CONCLUSION

The yield performance of red amaranth effected significantly due to different distance orientation from Moringa sapling base. The highest yield of red amaranth was observed in control condition. Apart from control, the highest yield was performed under T_1 treatment, which was 16% less than that of control condition. The yield loss followed upto 20% for treatment T_3 and 23% for treatment T_2 relative to that of control condition. Therefore, we observed best yield performance of red amaranth at treatment T_1 (12 cm distance from tree base) 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.

RECOMMENDATION

The experiment was conducted during one to three months of Moringa sapling plantation. Repeated experiment should set up from three to six months, six to twelve months or more to find out best tree crop interaction. In our experiment we examined only red amaranth in association with Moringa sapling. So, more robi and kharif vegetables should cultivate with Moringa tree to find out suitable vegetables for Moringa based agroforestry system. Regular soil analysis at one month interval and light interception should measure to find out the actual reason of growth and yield variation.

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APPENDICES

Appendix I: Soil characteristics of Agroforestry experimental field of Sher-e-Bangla Agricultural University are analyzed by Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Physical and chemical properties of the initial soil

Characteristics	Value
Practical size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
pH	5.56
Organic matter (%)	0.25
Total N (%)	0.02
Available P (µgm/gm soil)	53.64
Available K (me/100g soil)	0.13
Available S (µgm/gm soil)	9.40
Available B (µgm/gm soil)	0.13
Available Zn (µgm/gm soil)	0.94
Available Cu (µgm/gm soil)	1.93
Available Fe (µgm/gm soil)	240.9
Available Mn (µgm/gm soil)	50.6

Source: Dept. of Soil Science, SAU, Dhaka.

Appendix II: Analysis of variance of the data on plant height of red amaranth as influenced by different spacing

Sources of variation	Degrees of freedom	Mean Square				
		Plant height				
		10 DAS	15 DAS	20 DAS	25 DAS	30 DAS
Replication	3	0.05	0.048	2.54	0.521	1.09
Treatment	3	0.01	0.241*	1.76	32.6**	34.22**
Error	9	0.02	0.056	0.65	1.84	2.73

*indicate significant at 5% probability level and ** indicates significant at 1% probability level

Appendix III: Analysis of variance of the data on number of leaves per plant of red amaranth as influenced by different distance

Sources of variation	Degrees of freedom	Mean Square				
		Number of leaves per plant				
		10DAS	15 DAS	20 DAS	25 DAS	30 DAS
Replication	3	0.05	0.048	2.54	0.52	1.09
Treatment	3	0.012	0.241*	1.76	32.6**	34.22**
Error	9	0.023	0.056	0.65	1.84	2.73

*indicate significant at 5% probability level and ** indicates significant at 1% probability level

Appendix IV: Analysis of variance of the data on stem girth of red amaranth as influenced by different distance

Sources of variation	Degrees of freedom	Mean Square
		Stem girth
Replication	3	0.116*
Treatment	3	0.613**
Error	9	0.02

*indicate significant at 5% probability level and ** indicates significant at 1% probability level

Appendix V: Analysis of variance of the data on fresh weight, dry weight and yield of red amaranth as influenced by different distance

Sources of variation	Degrees of freedom	Mean Square		
		Fresh weight	Dry weight	Yield
Replication	3	7.1**	0.0084	4.6**
Treatment	3	16.9**	0.0944**	8.09**
Error	9	0.40	0.0068	0.342

*indicate significant at 5% probability level and ** indicates significant at 1% probability level