IMPACT OF DIFFERENT SOIL MIXTURES ON THE GROWTH AND YIELD OF RED AMARANTH FOR ROOFTOP GARDENING

A THESIS

BY

SANJIDA TAMANNA

Student No. 1701207

Session: July-December, 2023

MASTER OF SCIENCE (M.S.)

in

SOIL SCIENCE

DEPARTMENT OF SOIL SCIENCE

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY

DINAJPUR-5200

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Submitted to the

Department of Soil Science

Hajee Mohammad Danesh Science and Technology University

Dinajpur

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (M.S.)

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DINAJPUR-5200

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DEDICATED

TO MY

BELOVED FAMILY

ACKNOWLEDGEMENTS

First of all, the authoress expresses her sincere gratitude to the Almighty the supreme ruler of the universe forever ending blessings for the successful completion of the present research work and to prepare the thesis.

I express my deepest sense of gratitude, love and ever indebtedness to my revered teacher and supervisor Professor Dr. Md. Shahadat Hossain Khan, Chairman, Department of Soil Science, Hajee Mohammad Danesh Science and Technology University, Dinajpur, for his ingenious suggestions, guidance, direction whenever I needed it to complete this study and also for his constructive criticism and meticulous review of the manuscript.

I sincerely express my heartiest respect, deepest gratitude and the profound appreciation to my co-supervisor Prof. Dr. A.K.M Mosharof Hossain, Department of Soil Science, Hajee Mohammad Danesh Science and Technology University, Dinajpur, for his co-operation and helpful suggestions to conduct the research work and in the preparation of this manuscript.

I also express my respect and thankfulness to all the teachers of the Department of Soil Science, HSTU, Dinajpur for their good advices and co-operation during the period of this study.

I wish to express deep sense to the senior laboratory technician Md. Nurul Amin, Department of Soil Science and other assistants for their cordial co-operation.

Finally, I express my most sincere gratitude to my beloved parents, husband, brothers, sisters, friends, well-wishers and relatives for their blessings, inspiration and co-operation throughout the period of my study.

The authoress

ABSTRACT

A pot experiment was conducted at the Soil Science laboratory-2 of Hajee Mohammad Danesh Science and Technology University, Dinajpur during the period of September 2023 to November 2023. The objective of the study was to determine the effect of different soil mixture combinations on the growth and yield of red amaranth. Seven (7) different treatments were: T_1 = control (only soil), T_2 = 50% soil + 40% vermicompost (VC) + 5% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder ,T_3 = 45% soil + 45% VC + 5% sand + 5% sawdust + 1.5 g kg^{-1} bone meal powder ,T_4 = 45% soil + 40% VC + 5% sand + 10% sawdust + 1.5 g kg^{-1} bone meal powder ,T_5 = 40% soil + 40% VC + 15% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder ,T_6 = 35% soil + 50% VC + 10% sand + 5% sawdust + 1.0 g kg^{-1} bone meal powder ,T_7 = 35% soil + 50% VC + 5% sand + 10% sawdust + 1.0 g kg^{-1} bone meal powder. The experiment was laid out in Completely Randomized Design (CRD) with three replications. The soil was sandy loam and the pH, organic matter, total N, available P, exchangeable K and available S were 6.44, 0.64%, 0.014%, 23.72 ppm, 0.128 meq $100g^{-1}$ soil and 13.81ppm, respectively. The results showed that the treatment T_7 had the highest growth and yield such as plant height (7.67, 20.77, and 51.94 cm at 25, 40, and 55 DAS, respectively), number of leaves per plant (4.74, 9.45, and 19.33 at 25, 40, and 55 DAS, respectively), fresh weight per plant (25.77 g) and total fresh weight per pot (644.25 g). On the other hand, T_1 treatment (only soil) had the lowest values of growth and yield characters of red amaranth. In post-harvest soil, different soil mixture combination also had an impact on OM, total N, available P, exchangeable K, and available S content. Therefore, the study reveals that the treatment T_7, i.e., application of 35% soil, 50% VC, 5% sand, 10% sawdust, and 1.0 g kg^{-1} bone meal powder in a mixture combination might be an efficient practice for red amaranth production in urban rooftop.

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ABBREVIATION AND ACRONYMS

%	=	Percent
AEZ	=	Agro- ecological zone
C.V.	=	Co-efficient of Variation
Cm	=	Centimeter
DAS	=	Days after sowing
et al.	=	And authors
G	=	Gram
kg	=	Kilogram
$Kgha^{-1}$	=	Kilogram $hectare^{-1}$
M.S.	=	Master of Science
mg	=	Milligram
MOP	=	Murate of Potash
t ha^{-1}	=	Ton $hectare^{-1}$
TSP	=	Triple Super Phosphate
VC	=	Vermicompost
Viz.	=	Namely
meq	=	milliequivalent
@	=	At the rate of
ppm	=	Parts Per Million
i.e.	=	That is
CRD	=	Completely Randomized Design
LSD	=	Least Significance Difference

CHAPTER I

INTRODUCTION

Red amaranth, belonging to the *Amaranthaceae* family, is a plant that can grow very quickly and offers a lot of nutritional value. It is seen as a prospective future auxiliary food crop (Rai and Yadav, 2005). It is a delicious leafy vegetable worldwide, including in south Asian and African countries, growing throughout the summer and rainy season (Grubben and Denton, 2004). Red amaranth is a significant and well-liked leafy vegetable in Bangladesh due to its low cost, quick growth, and better production potential (Islam *et al.,* 2023). Foods of animal origin, which are considered to be the main source of vitamins and proteins, are particularly expensive for impoverished households (Schonfeldt *et al.,* 2013). Due to their capacity to provide the proteins, vitamins, calories, and other elements required in a balanced diet, fruits and vegetables could instead play a significant role in easing issues related to malnutrition (Wehmeyer and Rose, 1983). So, it is one of the most affordable and nutritious vegetables in Bangladesh and is frequently referred to as a poor man's vegetable. As a result, it is thought to be a potential future subsidiary food crop that can be utilized as vegetables and salads in many countries (Teutonico and Knorr, 1985). Furthermore, red amaranth is a cheap source of nutritional components like vitamins, minerals, fat, calcium, phosphorus, riboflavin, niacin, salt, iron, and ascorbic acid, which are abundant in the leaves and stems (Ruth *et al.,* 2021). Besides those, amaranth grain, when rolled or popped, can be utilized in granola bars and muesli. Its seeds are used to make crepes, biscuits, crackers, and other baked goods (Mlakar *et al.,* 2009; Shanmugavelu, 1989).

Bangladesh is a densely populated country that has been increasing day by day, but the land is limited. The cropping lands have been shrinking to ensure the accommodation of the mass population in general and particularly in urban areas (Nath, 2015). In Bangladesh, amaranth is currently grown in an area of 8,647.77 hectares, producing a total of 58.095 tons, and its production is growing daily due to its high yield, simple cultivation method, and nutritional value (BBS, 2010). The average production is 4.79 tons per hectare, which is less than in other nations that also produce amaranth (Talukder, 1999). The daily recommended allowance for vegetables is 200 g per person, but we only consume 60 g per person each day in our country, including potatoes and sweet potatoes, it was 70 g day^{-1} $person^{-1}$. Vegetable output should be boosted to feed the country's growing population, as there is a severe scarcity in our country. Our nation produces roughly 1.879 million tons of vegetables annually, of which 61.9% are produced in the Rabi season and 38.09% in the Kharif season (BBS, 2010). It is obvious that Kharif has relatively little vegetable production. However, the months of November to April are when diverse vegetables are produced to their highest levels. Therefore, there is a severe lack of vegetables from May to September. So, the price of vegetables remained high at that time. As a result of the high price and vegetable shortage, malnutrition in Bangladesh is severe in the late summer.

In this critical condition, we should focus on alternative ways. Although we are aware that there is little potential to expand our arable land, we may enhance crop production by methodically growing vegetables, fruits, spices, medicinal plants, flowers, etc. on rooftops. A garden that is located on a building's roof is called a rooftop garden. In addition to being aesthetically pleasing, roof plantings may also offer a variety of other advantages, including food, temperature control, hydrological advantages, architectural embellishment, wildlife habitats or corridors, recreational activities, and in some cases, ecological advantages. An urban agricultural technique for ensuring food security is roof gardening. Food production will increase as a result of using an appropriate medium for growing vegetables in rooftop gardens, which will also help to minimize transportation costs for meals and boost the production of safe, healthy food. To meet the demand for vitamins, amaranths can be grown year-round. Given these facts, it is possible to significantly increase red amaranth production by using the appropriate combination of organic manure such as cowdung, vermicompost, cocodust, and bone meal along with soils and other ingredients by optimizing the physical, chemical, and fertility characteristics of the soil mixture (Russel, 1975). In this experiment, the soil combinations included soil, sand, cowdung, vermicompost, sawdust, bone meal, and additional chemical fertilizers such as urea, TSP, MoP, and gypsum. The drainage capacity is increased by adding sand to the potting mix to overcome the waterlogging conditions. The inclusion of cow dung enriches water holding capacity, loosening ability and aeration in the mixtures. Vermicompost has been acknowledged as having significant potential as a soil amendment from a variety of sources of organic matter (Norman *et al.*, 2005). Vermicompost is described as a finely divided peat-like material with high porosity, aeration, drainage, and water holding capacity by several researchers who have studied the physical and chemical features of vermicompost (Albanell *et al.*, 1988). Sawdust enhances water holding capacity (WHC), porosity, and promotes the growth of superior plants with great uniformity and long shelf lives. Phosphorus levels in soil are raised by using bone meal as an organic source, which releases the nutrients slowly and provides calcium as well.

So, pot culture is essential for year-round vegetable production, especially in urban areas because only a few vegetables like red amaranth can be grown all year round. As a result, we may grow red amaranth in pots with the right pot soil combination all year long in rooftop gardens to get on a daily or weekly basis along with other foods. Due to the low production costs, growers will be more motivated to cultivate red amaranth in rooftop gardens, which will be sufficient to supply demand as the population grows. Along with earning money by selling a sizeable portion of the goods in the market, one may guarantee the needs of their family. However, an appropriate pot soil mixture is very important, but managing it for plant growth is very difficult because of proper techniques, knowledge, ingredients, price and other factors that play a vital role in root growth, vegetative growth and quality production of vegetables. Though the investigation of appropriate pot soil mixtures for red amaranth practiced in the recent years but they couldn’t find any solution due to various factors. Keeping in view the importance of growing media, the current study will be conducted to find out the appropriate pot soil mixture for red amaranth for rooftop gardening.

Objectives: Considering the above circumstances, the research work was undertaken with the following objectives,

i. To know the effect of different soil mixtures on the growth and yield of red amaranth.
ii. To find out the proper combination of readily available soil mixture for rooftop red amaranth production.

CHAPTER II

REVIEW OF LITERATURE

Red amaranth is a distinctive amaranth variant with red leaves and vibrant red stems that is widely cultivated in Bangladesh. In this chapter, a brief and appropriate review of the literature has been included. The impact of various pot soil combinations on the amaranth yield and yield-contributing traits has received special interest.

Jahan *et al.* (2022) determined the significant amounts of vitamins, minerals, amino acids, phytochemicals, carotenes, antiradical activity, and antibacterial activity in every component of the red amaranth plant. The nutritional analysis of the entire portion of red amaranth revealed that there was a sizable amount of protein, carbohydrate, and fat. The most important trace element was potassium. There were 17 recognized amino acids in all, with glutamic acid being the most prevalent. The chosen vegetable also has a significant level of carotenoids. A little amount of bacterial growth inhibitory activity was present in plant extract. Red amaranth is a great source of minerals, acts as a natural antioxidant, and contains other bioactive substances.

In accordance with Munmun *et al.* (2022), the treatment of VC produced the largest yield of red amaranth (7.79 t ha^{-1}), followed by lime (5.79 t ha^{-1}), compost (5.52 t ha^{-1}), and cowdung (4.73 t ha^{-1}). In comparison to other management methods, the results indicated that the impacts of VC were more effective in terms of brisk production, nutrient contents, and soil pH maintenance for the prospective growth of red amaranth. In addition to these, the nutrients present in red amaranth were examined. It was discovered that all nutrients, with the exception of Zn and B, were significantly greater in VC for Ca, Mg, K, P, S, and Fe.

Solaiman *et al.* (2022) studied the manner in which red amaranth growing on amended soil (a combination of acid and calcareous soil) responded to the effects of cow dung and chicken manure on its development. Except for S and Mg, it was shown that 9 tons of cow dung per hactre had the maximum nutrient absorption. The highest dosages of cow dung and poultry manure treatments, with the exception of S, Cu, Mn, and Zn, enhanced the maximum nutrient levels in the post-harvest soil. The study's findings demonstrated that adding organic manures to the soil can enhance its health and that soil amendment (a combination of acid and calcareous soil) can be an effective restoration procedure.

According to Akamine *et al.* (2021), the NPK fertilizer at 30-40 gm^{-2} for red stem amaranth and 20-30 gm^{-2} for red leaf amaranth significantly boosted growth indices and yield. In contrast to those grown under control conditions, amaranths fertilized with NPK at 30-40 gm^{-2} had higher or similar mineral contents. The findings show that mixed NPK fertilizer at 30-40 gm^{-2} is efficient in raising amaranth production and quality in the red soil.

As stated by Islam *et al.* (2020), applying biochar to the soil could boost its fertility and productivity. Furthermore, red amaranth grown with charcoal had a more desirable appears than red amaranth grown with fertilizer. The study came to the result that biochar has the ability to enhance soil fertility and red amaranth plant productivity in Bangladesh.

Lestari and Dewi (2020) reported that humic acid applied at a concentration of 20 mg L^{-1} through the leaves considerably raised plant height, leaf number, fresh and dry weight of shoots, and betacyanin content. Humic acid implemented at a level of 20 mg L^{-1} by means of the soil surface also significantly increased leaf number, both fresh and dry weight of shoot and root, but reduced oxalate content. One of the foods that contains betacyanin, a rich source of antioxidants, is red amaranth (*Amaranthus tricolor* L.). However, oxalate is also present in the stem and leaves of red amaranth, which may prevent humans from absorbing calcium. Moreover, humic acid of 20 mg L^{-1} applied either through foliage spay or soil surface increased plant height, yield and betacyanin content but it reduced oxalate content of red amaranth.

Dehariya *et al.* (2019) designed an experiment with the aim of determining the ideal nitrogen dose for leafy Amaranthus (*Amaranthus tricolor* L.) plant growth and production. The plant height, number of leaves, leaf length, leaf width, stem diameter, leaf area, and yield were all considerably impacted by the usage of varied levels of nitrogen fertilizer. With an increase in N treatment, plant height, leaf length, leaf width, leaf area, and fresh weight increased. With a mean yield of 187.90 kg ha^{-1}, vegetables produced the highest output at 140 kg N ha^{-1}.

In accordance with Mondal *et al.* (2019), the highest yields of fresh vegetables were attained in the following order: NPK > CD > PM > MOC. MOC application is not economical since it costs 30 times more than CD and PM. Vegetable yield was better with PM added NPK fertilizer mixture (10.87 t ha^{-1}) than with CD added NPK fertilizer mixture (10.17 t ha^{-1}). The combination of NPK + CD fertilizer might be advised to farmers.

Pittelkow *et al.* (2019) reported that phosphorus supplied by the planting furrow boosts productivity and phosphorus content in the amaranth foliar tissue in succession to the soybean crop. Considering amounts that are close to the level of economic response to the application of the input, 98.7 kg ha^{-1} of P_2O_5 was used to produce the maximum estimated productivity of amaranth grains.

Sawatdee *et al.* (2019) investigated the effect of cationic nutrient (K, Mg and Ca) concentrations on the biosynthesis of antioxidants while also maintaining the dietary fiber content and mass productivity in *Amaranthus tricolor* L. was chosen as a model vegetable as it was reported to contain high antioxidants in the leaves. It was found that an increase in potassium enhanced the antioxidant activity and total phenolic productivity whereas the mass yield and dietary fiber were not negatively affected. The lowest Mg proportion (2.8 ppm) resulted in no mass productivity. High concentration of Ca (130.2 ppm) could increase the mass yield by up to 34%, compared with the control (70 ppm Ca). The results suggest that producing an antioxidant-rich vegetable, not lowering its original quality, could be achieved by optimization of these nutrient elements.

As reported by Peiretti (2018), amaranth (*Amaranthus* spp.) is commonly cultivated in Central America, Asia, and Africa to be consumed as a grain and as a leafy vegetable. In addition, it has been utilized as a grain, forage, or silage crop in numerous countries for several kinds of animals, including cattle, chickens, pigs, and rabbits. In order to gain a greater understanding of this plant and to enable its use in animal nutrition as a substitute source of protein and fiber as well as a bioactive component (essential fatty acids, flavonoids, stanols, tocotrienols, and squalene) source, the goal of this review was to highlight the potentialities of amaranth in animal nutrition.

Ghosh *et al.* (2017) found that the addition of arbuscular mycorrhiza (AM), cowdung (CD), and phosphorus (P) individually and in combination led to significant variances in growth and yield characters such as plant height, plant diameter, number of leaves per plant, shoot fresh and dry weights, and root fresh and dry weights of red amaranth and Indian spinach. Combining arbuscular mycorrhiza, CD, and phosphorus resulted in a much more intense response in the growth and yield of these crops.

In agreement with Oshiro *et al.* (2016), all amaranth lines grew and produced more in gray soil (pH 8.4) compared to dark red soil (pH 6.6) and red soil (pH 5.4). In all soil types, the combined NPK fertilizer produced amaranths with the best traits for growth and yield. In contrast to K and Mg in gray soil, Ca in gray and red soils, and Fe in dark red soil, amaranth lines exhibited greater levels of Na in dark red and red soils. It was found that gray soil performs best for amaranth production and that Okinawa's gray soil, when fertilized with a mixed NPK fertilizer, produces amaranth with higher yields as well as more nutrients.

Rani *et al.* (2016) carried out study on urban agriculture in a few of Hyderabad City's urban neighborhoods. For the purposes of the study, 50 respondents were chosen who were engaged in rooftop gardening. The most often planted plants in the rooftop gardens were fruits, flowers, and vegetables. According to the survey, the majority of the practitioners were cultivating these plants organically and were able to, with the exception of the summer, mostly satisfy their household's needs. However, there were other challenges in maintaining the practice, including limited access to technical assistance, lack of services and high-quality input materials at reasonable prices, possible leaks, a lack of training and follow-up, and others.

Sanni (2016) assessed the consequences of compost, cow dung, and NPK 15-15-15 fertilizer supplements on the growth and yield performances of *Amaranthus hybridus*. The obtained results suggested that, in contrast to the control, all treatments substantially boosted the morphological parameters (number of leaves, stem girth, leaf area, and plant height). Cow dung, compost, NPK 15-15-15, and control delivered the best outcomes in terms of these attributes.

In an experiment, Abayomi and Adebayo (2014) investigated the growth and yield of *Amaranthus caudatus* as well as the long-term impacts of compost, organomineral, and inorganic fertilizers. Compost Grade B (unamended compost), compost Grade A (compost amended with mineral fertilizer), NPK 15-15-15, and no fertilizer (control) were used to cultivate *Amaranthus*. All treatments aside from the control were administered at a rate of 100kg Nha^{-1}. According to the findings, the yield of 18.9 tha^{-1} generated by Grade A was substantially greater than the yield of 17.6 tha^{-1} obtained from NPK fertilizer. The residual effect of Grade A-grown Amaranthus growth characteristics, such as plant height, leaf count, and yield values, was also noticeably greater than those of NPK, compost, and control values.

Miah *et al.* (2013) carried out an experiment to boost the growth and yield of red amaranth (*Amaranthus tricolor* cv. BARI lal shak1) by modifying the proper doses of nitrogen fertilizer. The treatment combinations were T0 (0 kg N ha^{-1}), T1 (50 kg N ha^{-1}), T2 (75 kg N ha^{-1}), T3 (100 kg N ha^{-1}) and T4 (150 kg N ha^{-1}) in that order. Red amaranth's short-term growth and production were significantly impacted by the usage of urea at a rate of 150 kg N ha^{-1}, based on data on plant height, leaf number, root-shoot growth, dry weight, yield, and BCR (benefit cost ratio).

According to Malik *et al.* (2011), zinc has a substantial effect on the growth and production of rice and red amaranth. Red amaranth and rice roots, shoots, and grains all had increased zinc concentrations after receiving more zinc treatment. Red amaranth's output of fresh and dry matter, as well as the length of roots and shoots, reduced as zinc levels raised. In the case of rice, increasing zinc levels led to longer roots, shoots, and spikelets. The findings suggested that zinc had an impact on rice and red amaranth's growth and production.

Peyvast *et al.* (2008) performed studies to explore how Amaranth responded to the incorporation of various levels of vermicompost (0, 10, 20 and 30%) into sandy loam soil in terms of growth, yield, and chemical properties. The findings demonstrated that adding vermicompost to the soil may considerably enhance plant height and leaf count. Vermicompost fertilization resulted in the highest amaranth leaves and roots, whereas vermicompost deficiency resulted in the lowest amaranth growth. The plants produced considerably more leaf area, potassium, phosphorus, total nitrogen, calcium, magnesium, nitrate-N in petioles and leaves, total soluble solids, and microelements including iron, copper, manganese, and zinc when 10% vermicompost was given to the soil.

Alam *et al.* (2007) revealed that the incorporation of VC and NPKS has a profound impact on the growth and yield of red amaranth. In red amaranth, the 10 tha^{-1} VC indicated better growth and yield to 100% NPKS. Red amaranth's vegetative growth and production increased when various dosages of VC (2.5, 5, and 10 tha^{-1}) and NPKS fertilizers (50 and 100 percent) were added. Red amaranth production was highly associated with plant height, total dry matter, leaf length, and stem length. The outcomes shown that VC impacts are more effective for the strong growth of red amaranth. It is also suggested that VC (10 tha^{-1}) + NPKS (50%) is more favorable for vigorous production of red amaranth and maintenance of soil environment but VC (5 t ha^{-1}) + NPKS (100%) can be economically and environmentally suitable.

Materechera and Mukwevho (2007) reported that especially for rural households in South Africa, leaf amaranth, a widespread indigenous food plant, has a significant potential to increase nutritional security. The growth and dry matter yield of edible leaves were dramatically enhanced over the control by increasing the rate of manure N application. At the beginning of the harvesting period, differences in manure rates were minimal, but they grew more pronounced towards the conclusion, suggesting larger N release because of the mineralization of the manure. Weekly defoliation of amaranth resulted in considerably lower cumulative leaf dry matter yields than every two weeks defoliation. The study confirms that chicken manure is an important resource that can be used by resource poor farmers to supply nutrients and improve productivity of this less conventional crop.

Kamron (2006) published an article naming "Adoption of roof gardening at Mirpur-10 area under Dhaka city". She revealed the preferred distinctiveness of the respondents, family size, roof gardening knowledge, approach towards roof gardening, use of information sources, and familiarities of rooftop gardening had encouraging consequence of relationship with their acceptance of rooftop gardening. There were other characteristics, namely: age, family education and family earnings did not show any significant relationship with the respondent's adoption of rooftop gardening.

Freeze *et al.* (1993) found that the application of cow dung and poultry manure drastically decreased the toxic metals Cr, Co, Cd, and Pb in red amaranth. Manure's value as an amendment for improving the productivity of slightly unfertile land is enough to allow manure to be carried farther than would be the case in unfertile land. Application of the relevant manures significantly decreased the absorption of heavy metals, which was followed by improved crop growth.

Nuruzzaman *et al.* (1993) revealed that the use of cow dung has been shown to be an effective way to mitigate the hazardous effects of heavy metals. The hazardous metals Cr, Co, Cd, and Pb in red amaranth were dramatically reduced by the use of cow dung and poultry manure.

Makus (1992) showed that amaranth's biomass production responded best to increasing doses of additional P (up to 90 kg ha^{-1}) and least effectively to rising levels of supplemental K (up to 180 kg ha^{-1}). N, K, and P showed average production increases of 1.15, 1.27, and 14.5 times, respectively. P addition enhanced the proportion of non-edible stem tissue and the number of leaves per plant. K and P boosted the water content of plants. The mineral soil had 59 kg N, 14 kg P, and 84 kg K ha^{-1}, while the vegetable amaranth demanded the most P.

Singh and Whitehead (1992) studied the impact of soil pH and moisture on amaranth's vegetative growth in the greenhouse during 1990-1991. The treatments for the two trials consisted of soil pH values of 4.5, 5.3, and 6.4 and soil water levels of 3, 6, and 18%. Compared to plants growing in pH 5.3 or 4.7 soil, those cultivated in pH 6.4 soil were significantly taller and had more branches, leaves, and leaf area. In accordance with the study, amaranth is a vegetable that can grow in soil with a pH of 6.4 and produce high yields. Amaranth showed its best vegetative growth when irrigated with 6% soil water in Dothan sandy loam soil.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out in front of soil science laboratory-2 of Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, from September 2023 to November 2023. The experimental site, soil properties, climate, planting materials, soil collection, preparation of pots and sowing of seeds, experimental design, treatments, fertilizer dosages at different treatments, intercultural operations, harvesting, data collection, preparation of soil samples, soil analysis, and statistical analysis are all presented in this chapter.

3.1 Experimental site

The experiment was performed in front of the soil science laboratory-2 at Hajee Mohammad Danesh Science and Technology University, located in Dinajpur, 5200, from September to November 2023. The study site was positioned at 25°13' N latitude and 88°23' E longitude, 37.5 meters above mean sea level. It belongs to the Agro-Ecological Zone (AEZ-1) of the Old Himalayan Piedmont Plain.

3.2 Characteristics of Soil

This medium-high terrain is part of the non-calcareous brown floodplain soils of the Old Himalayan Piedmont (AEZ 1) (UNDP and FAO, 1988). Tables 3.1 to 3.3 provide the general properties of the soil.

3.3 Climate

The experimental area is located in a subtropical climate zone. During the Kharif season (April- September), there is a lot of rainfall, high humidity, high temperature, and a relatively long day period. During the Rabi season (October- March), there is little rainfall, low humidity, low temperature, and a short-day period. The experiment was carried out in September through November of 2023, during the last of kharif season.

Table 3.1 Morphological characteristics of the soil of Soil Science Research Field of HSTU

Morphology	Characteristics
Location	Soil Science Research Field, Department of Soil Science, HSTU
AEZ	Old Himalayan Piedmont Plain (AEZ-1)
General soil type	Non-calcareous brown floodplain soil
Parent material	Piedmont alluvium
Drainage	Well drained
Flood level	Above flood level

Table 3.2 Physical characteristics of the soil of Soil Science Research Field of HSTU

Characteristics	Value
Sand (%)	53.20
Silt (%)	29.60
Clay (%)	17.20
Textural class	Sandy loam

Table 3.3 Chemical characteristics of the initial soil sample

Characteristics	Content
pH	6.44
OM (%)	0.64
Total N (%)	0.014
Available P (ppm)	23.72
Exchangeable K (meq 100 g^{-1} soil)	0.128
Available S (ppm)	13.81

3.4 Planting material

Red amaranth (*Amaranthus tricolor* L. cv. Altapeti) was the plant material used in the experiment. This annual plant grows rapidly, attaining 1.2 meters in height and 0.8 meters in width within 4 to 5 months. Red amaranth is self-pollinating and monoecious, as it possesses male and female flowers. It prefers soil that drains properly and profound sunshine. Seedlings sown immediately into the soil will grow into mature plants in two to three months. The plant normally dies in about four to five months.

3.5 Soil collection, soil and pot preparation and seed sowing

At a depth of 0 to 15 cm, soil was collected from the Soil Science Research Field at HSTU, Dinajpur. Collected soil was air-dried. The stubbles and weeds in the soil were pulled out carefully. Then, the treatments components i.e., soil, sand, vermicompost, sawdust, bone meal, and other chemical fertilizers like urea, TSP, MP, and gypsum were thoroughly combined for each pot. The total weight of the soil mixture for one pot was 6 kg. For incubation, the pots were then kept for ten days. On September 11, 2023, the seeds collected from seed distributing shop, Station Road, Dinajpur were sown in the pots.

Figure 1. Picture showing the preparation soil mixture treatments

3.6 Experimental design

The experiment was laid out Completely Randomized Design (CRD) with 7 treatments and 3 replications. A total of 21 experimental pots were used.

3.7 Treatments

There were seven (7) treatments as follows:

T_1 = control (only soil)

T_2 = 50% soil+ 40% VC+ 5% sand+ 5% sawdust+ 2.0 g kg^{-1} bone meal powder

T_3 = 45% soil+ 45% VC+ 5% sand+ 5% sawdust+ 1.5 g kg^{-1} bone meal powder

T_4 = 45% soil+ 40% VC + 5% sand + 10% sawdust + 1.5 g kg^{-1} bone meal powder

T_5 = 40% soil+ 40% VC + 15% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder

T_6 = 35% soil+ 50% VC + 10% sand + 5% sawdust + 1.0 g kg^{-1} bone meal powder

T_7 = 35% soil+ 50% VC + 5% sand + 10% sawdust + 1.0 g kg^{-1} bone meal powder

Where, VC means vermicompost

3.8 Fertilizer doses at different treatment

During soil preparation, chemical fertilizers such as urea, TSP, MP, and gypsum were also combined with each treatment mixture in accordance with 2.45 g kg^{-1}, 0.85 g kg^{-1}, 1.25 g kg^{-1}, and 490 mg kg^{-1} of material, respectively.

3.9 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. The following intercultural operations were followed:

3.9.1 Weeding

The experimental pots were kept under observation, and weeds were routinely pulled out of them.

3.9.2 Irrigation

The experimental pots were monitored regularly and plants were watered whenever necessary.

3.9.3 Thinning

To improve growth, the plants were thinned from the remaining ones that were chosen for the experiment's outcome.

3.9.4 Insect and pest control

The crop was mainly protected from ant’s attack by applying Dursban-20 EC. The leaves and shoots were attacked by some sap-sucking insects i.e., Aphid, Thrips during the vegetative stage. For pest control, Imitaf 20SL (Imidachloropid) was applied at appropriate doses whenever necessary.

Figure 2. Picture showing the treatment pots with tagging

3.10 Harvesting

Harvesting of red amaranth was done when the plants were at their peak growth for vegetable use on November 1, 2023.

3.11 Data collection

On October 31, data collection was completed following harvest. According to the study's objectives, the following information was gathered from three randomly chosen plants:

i. Plant height (cm)

ii. Number of leaves per plant

iii. Fresh plant weight (g)

iv. Total fresh weight per pot (g)

3.11.1 Plant height (cm)

Three randomly chosen sample plants were used to measure the height of the plants in centimeters and averaged, starting from the base and ending at the top leaf.

3.11.2 Number leaves per plant

The number of leaves plant per were counted from the randomly selected 3 plants and mean value was calculated.

Figure 3. Photo captured during the data collection

3.11.3 Fresh plant weight (g)

Following harvest, the fresh weight of three plants from each pot was recorded in grams (g) and averaged.

3.11.4 Total fresh weight per pot (g)

Total fresh weight of each pot was measured with an electrical balance and calculated at gram (g).

Figure 4. Weighing of plant fresh weight by balance in Laboratory of Soil Science-1

3.12 Physico-chemical properties measurement of treatment mixtures

The following electro-chemical traits of different soil mixture treatments were measured:

i. pH
ii. Moisture content (%)
iii. Electrical conductivity (EC) (µS cm^{-1})
iv. Temperature (^{0}C)

3.12.1 pH of the soil mixtures

The pH of each soil mixture treatment pots was measured by using pH meter at 7 days of interval from first day of sowing for 4 times.

3.12.2 Moisture content (%)

Moisture content of the treatment pots was monitored by moisture meter and the data were recorded properly for 4 times from the first day of seed sowing at 7 days of interval.

3.12.3 Electrical conductivity (EC) (µS cm^{-1})

Each treatment pot was measured for EC in µS cm^{-1} through using electrical conductivity meter from first day of sowing to 21 DAS for 4 times at 7 days of interval.

3.12.4 Temperature (^0C)

Soil mixtures temperature from first day of sowing to 21 DAS at 7 days of interval for 4 times was recorded by using the electrical conductivity cum temperature meter.

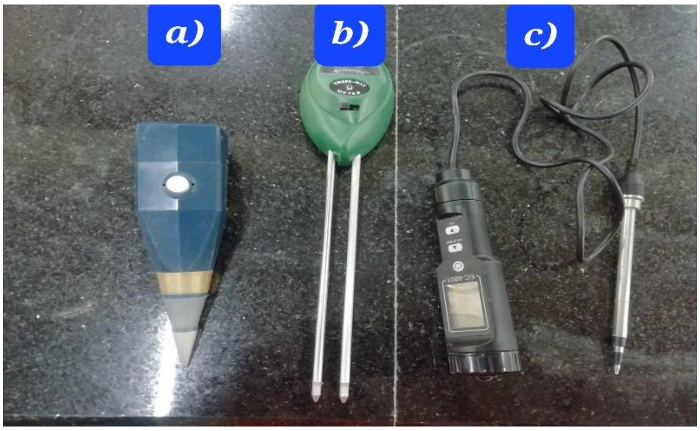


Figure 5. Picture showing the instruments used for data collection a) pH meter; b) Moisture meter and c) Electrical conductivity cum temperature meter

3.13 Soil sample preparation

Soil samples for subsequent chemical analysis were taken from each pot after harvesting. The samples were then dried and sieved using a 2 mm (10 mesh) sieve. A clean plastic container held the soil until it was time for analysis.

3.14 Analysis of soil sample

At the Soil Science Laboratory-1, Department of Soil Science, HSTU Dinajpur, the chemical characteristics of every soil sample were examined. The soil samples were analyzed as follows:

i. Organic matter (OM) content
ii. Total Nitrogen content (N)
iii. Available phosphorus (P)
iv. Exchangeable potassium (K)
v. Available sulphur (S)

3.14.1 Organic matter (OM) content

The amount of organic carbon in the post-harvest soil was measured volumetrically using the wet oxidation method with a mixture of K_2Cr2O_7 and H_2SO_4, and titration was performed using $FeSO_4$ solution (Jackson, 1967). By multiplying the percentage of organic carbon by the Benmmelen factor of 1.724, the organic matter content was determined (Piper, 1950).

3.14.2 Total nitrogen content (N)

The Micro-Kjeldahl method was used to determine soil total N (Bremner and Mulvancey, 1982). Three milliliters of concentrated H_2SO_4 and one kilogram of a K_2SO_4:$CuSO_4.5H_2O$: Se powder catalyst mixture was used to digest the 1.0 g soil sample. Total N was calculated using the following method of titration distillate trapped in H_2B0_3 indicator solution with 0.01 N, followed by distillation with 40% NaOH (Page *et al.,* 1989).

3.14.3 Available phosphorus (P)

With a 0.5 M sodium bicarbonate solution at pH 8.5, available P was extracted from the soil (Olsen, 1954). The amount of P in the extract was then determined by using $SnCl_2$ reduction of phosphomolybdate complex to develop blue color, and color intensity was measured colorimetrically at 660 nm wavelength (Page *et al.*, 1989).

3.14.4 Exchangeable potassium (K)

Exchangeable K was determined by the ammonium acetate extraction method using a flame photometer as described by Page *et al*. (1989).

3.14.5 Available sulphur (S)

A soil sample was extracted using 0.01 M Ca $(H_2PO_4)_2$ in order to calculate the available S (Piper, 1950). The extract's S content was calculated and its level of turbidity assessed using a spectrophotometer set at 420 nm wavelength.

3.15 Statistical analysis

The statistical software Statistix version 10.0 was used to analyze the collected data statistically in order to determine the level of significance using a Completely Randomized Design (CRD). According to Gomez and Gomez (1984), the Least Significant Difference (LSD) test and standard deviation (SD) was used to compare the mean differences at a 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

The performance of red amaranth grown in various soil mixtures is shown in through tables and figures. Furthermore, the study's observations and their interpretation are presented and discussed in this chapter under the following sub-headings in order to achieve the objectives of the study. These sections include growth, yield contributing characteristics, yield of red amaranth, physico-chemical traits of the treatment combinations and post-harvest soil analysis as well.

4.1. Effect of different soil mixtures on growth and yield of red amaranth

4.1.1 Plant height (cm)

One of the most crucial factors is plant height, which has a positive correlation with red amaranth yield. A statistically significant influence on plant height was demonstrated by the combined effects of various soil mixtures (Table 4.1). The T_7 treatment was recorded with the highest average plant height of three selected plants per pot at 25 DAS, measuring 7.67 cm, which was statistically similar to T_6 (7.11 cm), T_5 (7.04 cm), T_4 (7.58 cm), T_3 (6.87 cm) and T_2 (6.19 cm) except treatment T_1. The T_1 treatment was recorded the lowest average plant height (3.24 cm) at 25 DAS. Afterwards, T_7 treatment was recorded with the highest plant height at 40 DAS with the value of 20.77 cm, which was found statistically identical to T_6 (18.50 cm), T_5 (18.50 cm), T_4 (15.59 cm), T_3 (17.74 cm), and T_2 (17.44 cm), respectively. The shortest plant was found in T_1 (only soil) treatment having the plant height of 8.04 cm at 40 DAS. At 40 DAS, except T_1 treatment, every treatment was statistically similar regarding plant height. Furthermore, the T_7 treatment was observed with the highest plant height at 55 DAS of 51.94 cm, which was statistically exact as T_6

(47.74 cm), T_5 (41.84 cm), T_3 (43.96 cm) and T_2 (43.53 cm) except T_4 and T_1. The T_1 treatment yielded the lowest plant height of 23.35 cm at 55 DAS.

The release of nutrients that encouraged vigorous plant growth through effective photosynthesis is most likely what caused the red amaranth plants amended with organic matter to grow taller plant (Sanni, 2016). Additionally, N is involved in plant cell division and elongation, nitrogen fertilization has the potential to increase plant height (Mazumder *et al.,* 2019). Furthermore, studies comparing the combined effects of 25% NPKS and 75% vermicompost have shown increased yields of tomatoes, cabbage, and okra when compared to full doses of NPKS and control (Farzana *et al.,* 2019; Islam *et al.,* 2007).

Table 4.1 Effect of different soil mixtures on plant height of red amaranth at different DAS

Treatments	Plant height (cm)		
	At 25 DAS	At 40 DAS	At 55 DAS
T_1	3.24 b	8.04 b	23.35 c
T_2	6.19 a	17.44 a	43.53 ab
T_3	6.97 a	17.74 a	43.96 ab
T_4	7.58 a	15.59 a	35.06 b
T_5	7.04 a	18.50 a	41.84 ab
T_6	7.11 a	18.50 a	47.74 a
T_7	7.67 a	20.77 a	51.94 a
LSD	1.881	4.880	10.279
CV (%)	28.70	29.30	25.03

In the column, figures having similar letter(s) do not differ significantly at 5% level of probability.

Where, T_1 = control (only soil), T_2 = 50% soil + 40% VC + 5% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_3 = 45% soil + 45% VC + 5% sand + 5% sawdust + 1.5 g kg^{-1} bone meal powder, T_4 = 45% soil + 40% VC + 5% sand + 10% sawdust + 1.5 g kg^{-1} bone meal powder, T_5 = 40% soil + 40% VC + 15% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_6 = 35% soil + 50% VC + 10% sand + 5% sawdust + 1.0 g kg^{-1} bone meal powder, T_7 = 35% soil + 50% VC + 5% sand + 10% sawdust + 1.0 g kg^{-1} bone meal powder, VC = vermicompost.

4.1.2 Number of leaves per plant

As Table 4.2 showed, the different combinations of soil mixtures had negligible effect on the average number of leaves per plant (three selected plants) at 25 DAS but significant effect at 40 DAS and 55 DAS, respectively. At 25 DAS, treatment T_7 produced the highest number of leaves per plant (4.74), which was similar to treatment T_6, T_5, T_4, T_3, T_2, and T_1. The treatment T_1 (control) had the lowest value of 3.67 regarding number leaves per plant. Here, the results varied insignificantly. Alternatively, the treatment T_7 provided the greatest number of leaves at 40 DAS (9.45), whereas treatment T_1 produced the lowest number of leaves (7.23). Results for T_2, T_3, T_4, T_5, and T_6 were statistically similar. Afterwards, at 55 DAS, treatment T_7 was recorded with the most leaves (19.33), which was found statistically similar to T_2 (16.34) and T_6 (15.23). On the contrary, control treatment T_1 had the fewest leaves (10.11).

Since the leaves are the plant's primary organ for photosynthetic processes, variations in their quantity will inevitably impact amaranth's overall performance (Miah *et al.*, 2013). The availability of nitrogen, which encouraged leaf area during vegetative development and also assisted in maintaining functional leaf area during the growth period, is likely responsible for the increased leaf number in soil amended with organic fertilizer (Padmavathiamma *et al.*, 2008). The current results were agreed with numerous studies applying CD, CM, or MOC in conjunction with chemical fertilizers increased plant height and leaf number in leafy vegetable crops (Sanni, 2016; Noor *et al.*, 2007; Islam *et al.*, 2007).

Table 4.2 Effect of different soil mixtures on number of leaves per plant at different DAS

Treatments	Number of leaves/ plant		
	At 25 DAS	At 40 DAS	At 55 DAS
T_1	3.67	7.23 b	10.11 c
T_2	4.00	8.56 ab	16.34 ab
T_3	3.78	8.11 ab	13.56 bc
T_4	4.00	8.23 ab	11.67 bc
T_5	4.23	8.11 ab	13.34 bc
T_6	4.23	8.89 ab	15.23 ab
T_7	4.74	9.45 a	19.33 a
LSD	0.68	1.144	3.756
CV (%)	16.61	13.68	26.40

In the column, figures having similar letter(s) do not differ significantly at 5% level of probability.

Heere, T_1 = control (only soil), T_2 = 50% soil + 40% VC + 5% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_3 = 45% soil + 45% VC + 5% sand + 5% sawdust + 1.5 g kg^{-1} bone meal powder, T_4 = 45% soil + 40% VC + 5% sand + 10% sawdust + 1.5 g kg^{-1} bone meal powder, T_5 = 40% soil + 40% VC + 15% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_6 = 35% soil + 50% VC + 10% sand + 5% sawdust + 1.0 g kg^{-1} bone meal powder, T_7 = 35% soil + 50% VC + 5% sand + 10% sawdust + 1.0 g kg^{-1} bone meal powder, VC = vermicompost.

4.1.3 Fresh weight per plant (g)

The fresh weight of the red amaranth plant statistically varied due to the combined impact of distinct soil mixtures (Figure 6). Treatment T_7 was found with the highest fresh weight per plant (25.77 g) of the averaged value of randomly selected plants, which was statistically different from all other treatments. A statistical similarity was found with other treatments like T_6 (16.49 g), T_5 (13.11 g), T_4 (8.82 g), T_3 (12.65 g), and T_2 (12.81 g) except T_1 in regard to fresh weight per plant. Conversely, treatment T_1 (only soil) was recorded the lowest plant fresh weight, which was 2.98 g.

Consistent findings were also found by some researchers that the application of organic fertilizers most likely increased the amount of nitrogen in the soil, which in turn positively affected the fresh weight and quality of the leaves because nitrogen increases leaf area and stimulates plant vegetative growth (Noor *et al.*, 2007; Islam *et al.*, 2007). The poor performance of red amaranth grown in the control treatment revealed that plants tend to grow at their optimum potential when nutrients are available in adequate amounts; these deficiencies were most likely the factor limiting plant growth and productivity in the control treatment (Sanni, 2016).

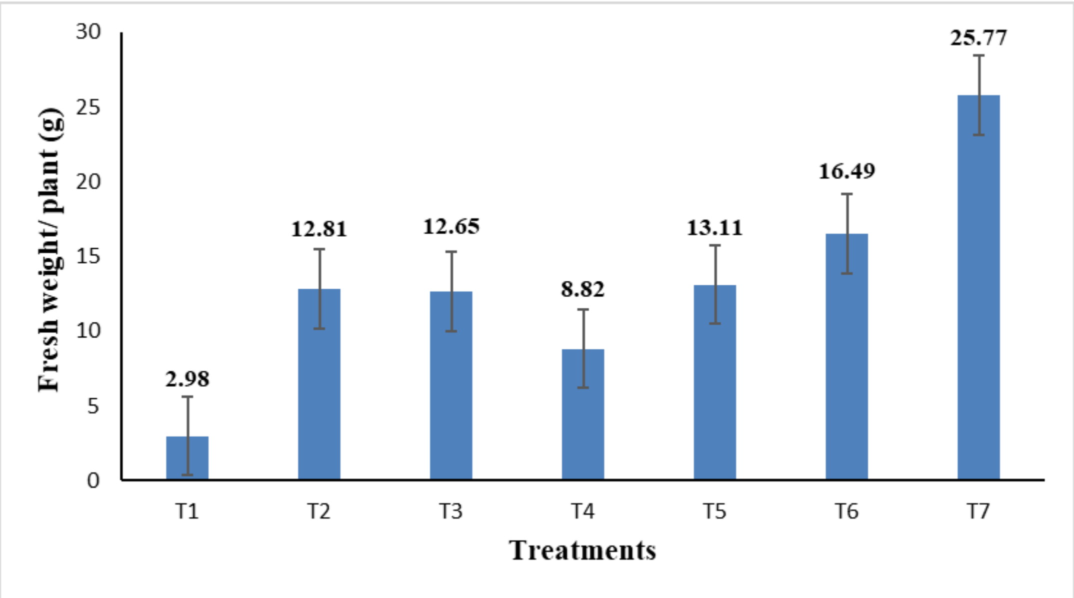


Figure 6. Effect of different soil mixtures on fresh weight per plant (g) of red amaranth

4.1.4 Total fresh weight per pot (g)

Red amaranth fresh weight was strongly influenced by seed rates, variety, and the combinations of various soil mixtures (Figure 7). However, in this study, treatment T_7 produced the highest yield (fresh weight) of red amaranth (644.25 g) at harvesting, which was statistically superior to all other treatments. Except T_1 treatment, other treatments like T_2 (320.17 g), T_3 (316.25 g), T_4 (220.58 g), T_5 (327.75 g) and T_6 (412.33 g) are statistically shown as similar values in terms of total fresh weight per pot. Conversely, treatment T_1 had the lowest fresh weight of 74.42 g, where the treatment comprised of soil only.

Red amaranth yield as leafy vegetable was strongly influenced by the addition of organic matter and/or combinations of organic manures in the growth medium (Saha *et al.*, 2022). Almost similar results were also observed by Raksun *et al.* 2022, where vermicompost was applied with other chemical fertilizers increased the yield of red amaranth.

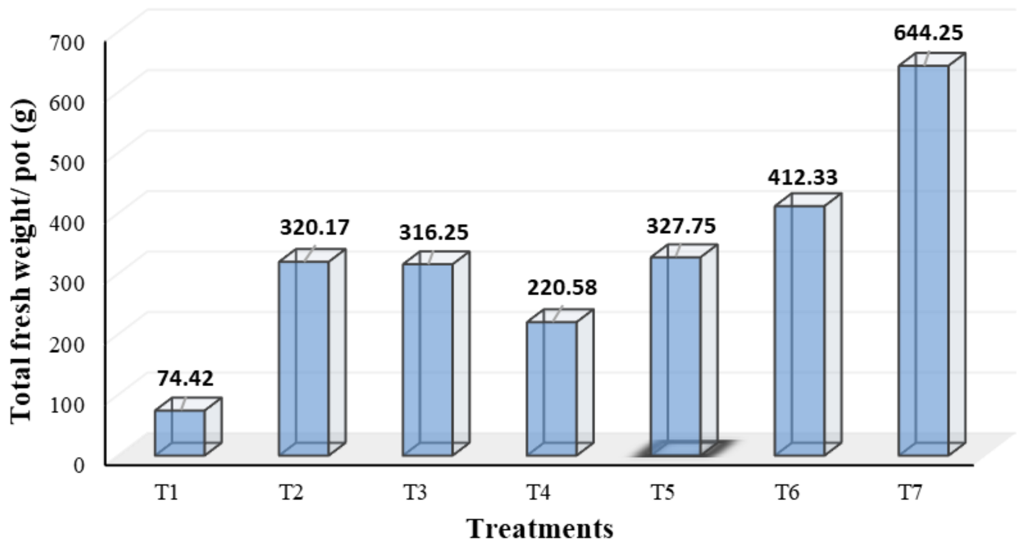


Figure 7. Effect of different soil mixtures on total fresh weight per pot (g) of red amaranth

4.2 Effect of soil mixtures on physico-chemical properties of treatment combinations

4.2.1 Soil pH

The pH of different treatment combinations was found with statistically significant differences due to the distinct soil mixtures which was recorded at 7 days of interval for 4 times, except at 1st day of sowing (Table 4.3). This differences of pH in treatment combinations may happen due to the variations of components in the mixtures. Initially, T_6 (6.17) treatments had the highest pH value and T_2 (5.73) was the lowest value. Every treatment's value was comparable on the first day, indicating that there was little variation in the values but not statistically varied. Afterwards, treatment T_5 and T_3 had the highest pH value of 5.73 at 7 DAS, which was statistically identical to treatment T_7, T_6, T_4 and T_1, whereas treatment T_2 had the lowest pH value (5.30). Furthermore, the highest pH value among the treatment combinations was 5.67 in both T_7 and T_5 at 14 DAS, while the lowest pH value was 5.13 in treatment T_2. Consistently, Treatment T_6 and T_4 was statistically similar to T_7 and T_5. Additionally, the highest pH value was treatment T_4 (5.87) which was statistically similar to treatment T_3, T_5, T_6 and T_7 at 21 DAS and lowest pH value was in treatment T_2 (5.20). The pH of the treatment combinations was moderately acidic and in a decreasing manner after first day of sowing and slightly increased at 21 DAS.

Soil physico-chemical properties like pH was greatly influenced by the ratio of organic amendments applying in the soil (Esmaeilzadeh and Ahangar, 2014). Similar results were also found that soil mixture combinations differed the soil pH at greater extent and sometimes turned into slightly acidic conditions and returned to the neutralized conditions due to their buffer capacity (Meng *et al.,* 2020; Barzegar *et al.,* 2002).

Table 4.3 Impact of different soil mixtures on pH of the treatment combinations at 7 days interval

Treatments	pH			
	At first Day	**At 7 DAS**	**At 14 DAS**	**At 21 DAS**
T_1	5.80	5.53 ab	5.33 bc	5.23 b
T_2	5.73	5.30 b	5.13 c	5.20 b
T_3	6.13	5.73 a	5.33 bc	5.60 ab
T_4	6.10	5.70 a	5.60 ab	5.87 a
T_5	6.10	5.73 a	5.67 a	5.77 a
T_6	6.17	5.70 a	5.47 ab	5.73 a
T_7	6.03	5.67 a	5.67 a	5.80 a
LSD	0.296	0.221	0.246	0.327
CV (%)	4.93	3.93	4.51	5.84

In the column, figures having similar letter(s) do not differ significantly at 5% level of probability.

Here, T_1 = control (only soil), T_2 = 50% soil + 40% VC + 5% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_3 = 45% soil + 45% VC + 5% sand + 5% sawdust + 1.5 g kg^{-1} bone meal powder, T_4 = 45% soil + 40% VC + 5% sand + 10% sawdust + 1.5 g kg^{-1} bone meal powder, T_5 = 40% soil + 40% VC + 15% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_6 = 35% soil + 50% VC + 10% sand + 5% sawdust + 1.0 g kg^{-1} bone meal powder, T_7 = 35% soil + 50% VC + 5% sand + 10% sawdust + 1.0 g kg^{-1} bone meal powder, VC = vermicompost.

4.2.2 Soil Moisture (%)

The moisture of the treatment combinations was affected due to the different soil mixtures. the moisture content of the treatment combinations was gradually decreased from the first day of sowing to 21 DAS which was recorded at 7 days of interval for 4 times. There was no statistically significant difference among the treatment combinations at first day of sowing, 7 DAS and 14 DAS, except 21 DAS (Table 4.4). At 1st day of sowing, moisture content was highest in treatment T_7 (8.50%) and lowest in treatment T_5 (7.33%). Here, the results vary slightly regarding the moisture content of the treatment combinations. Furthermore, at 7 DAS, the moisture level was highest in treatment T_7 (7.50%) and lowest in T_5 (6.33%). Additionally, at 14 DAS, treatment T_7 (7.00%) had the highest moisture content, while the treatment T_5 (5.97%) was recorded with the lowest content. Afterwards, the highest moisture content was found in treatment T_1 (5.63%) which was statistically similar to almost all other treatments except T_5 (4.50%) and T_6 (4.63%) at 21 DAS. Meanwhile, the lowest moisture content was observed in T_5 treatment (4.50%) at 21 DAS. This variation in moisture content among the treatment combinations at different days after sowing may occur due the climatic conditions like rainfall, temperature and humidity during the experiment and other intercultural operations was done as need of experiment. Similar kinds of observations were also found that the different mixture of organic amendments influenced the moisture or water content of the soil (Malkawi *et al.*, 1999).

Table 4.4 Impact of different soil mixtures on soil moisture content (%) at 7 days interval

Treatments	Moisture content (%)			
	At first Day	At 7 DAS	At 14 DAS	At 21 DAS
T_1	8.17	7.17	6.67	5.63 a
T_2	7.83	6.83	6.40	5.17 ab
T_3	7.50	6.50	6.33	4.87 ab
T_4	8.33	7.33	7.00	5.30 ab
T_5	7.33	6.33	5.97	4.50 b
T_6	7.50	6.67	6.47	4.63 b
T_7	8.50	7.50	7.00	5.33 ab
LSD	0.934	0.785	0.661	0.558
CV (%)	11.85	11.36	10.10	11.03

In the column, figures having similar letter(s) do not differ significantly at 5% level of probability.

Here, T_1 = control (only soil), T_2 = 50% soil + 40% VC + 5% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_3 = 45% soil + 45% VC + 5% sand + 5% sawdust + 1.5 g kg^{-1} bone meal powder, T_4 = 45% soil + 40% VC + 5% sand + 10% sawdust + 1.5 g kg^{-1} bone meal powder, T_5 = 40% soil + 40% VC + 15% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_6 = 35% soil + 50% VC + 10% sand + 5% sawdust + 1.0 g kg^{-1} bone meal powder, T_7 = 35% soil + 50% VC + 5% sand + 10% sawdust + 1.0 g kg^{-1} bone meal powder, VC = vermicompost.

4.2.3 Electrical conductivity (EC) of soil (µS cm^{-1})

There was a significance differences in electrical conductivity among the soil mixture combinations which was measured from the 1st day of sowing to 21 DAS at 7 days of interval (Table 4.5). At 1st day the recorded highest electrical conductivity was in T_6 treatment (2.80 µS cm^{-1}), which was statistically similar to T_3 (2.76 µS cm^{-1}) and T_5 (2.50 µS cm^{-1}). The lowest recorded value of electrical conductivity was in treatment T_7 (1.58 µS cm^{-1}) which was also statistically similar to T_1 (1.69 µS cm^{-1}). Furthermore, the highest recorded value was in treatment T_3 (2.67 µS cm^{-1}) which was found with a statistical similarity with T_6, T_5 and T_2 at 7 DAS, whereas and the lowest recorded regarding electrical conductivity value was in T1 (1.24 µS cm^{-1}). Additionally, at 14 DAS, the recorded highest value was in treatment T_3 (2.30 µS cm^{-1}) which was similar with T_2 (2.05 µS cm^{-1}), T_5 (2.05 µS cm^{-1}), T_6 (2.29 µS cm^{-1}) and T_7 (1.71 µS cm^{-1}) as well, while the lowest recorded was treatment T_1 (1.11 µS cm^{-1}) which was statistically similar with T_4 treatment (1.33 µS cm^{-1}). At 21 DAS, the recorded highest electrical conductivity was in treatment T_5 (1.87 µS cm^{-1}), which was found with statistically similarity with T_2 (1.57 µS cm^{-1}), T_3 (1.85 µS cm^{-1}), T_4 (1.16 µS cm^{-1}) and T_6 (1.79 µS cm^{-1}) except T_1. Meanwhile, treatment T_1 (0.79 µS cm^{-1}) was found with the lowest electrical conductivity at 21 DAS where only soil as control treatment was provided for growing red amaranth. Almost similar observations were also revealed by some researchers earlier (Esmaeilzadeh and Ahangar, 2014; Barzegar *et al.*, 2002).

Table 4.5 Impact of different soil mixtures on Electrical conductivity (µS cm^{-1}) of soil at 7 days interval

Treatments	Electrical conductivity (EC) (µS cm^{-1})			
	At first Day	**At 7 DAS**	**At 14 DAS**	**At 21 DAS**
T_1	1.69 c	1.24 c	1.11 b	0.79 b
T_2	1.99 bc	2.30 ab	2.05 a	1.57 ab
T_3	2.76 a	2.67 a	2.30 a	1.85 a
T_4	1.84 bc	1.76 bc	1.33 b	1.16 ab
T_5	2.50 ab	2.29 ab	2.05 a	1.87 a
T_6	2.80 a	2.60 a	2.29 a	1.79 a
T_7	1.58 c	1.89 b	1.71 ab	1.69 ab
LSD	0.588	0.550	0.548	0.588
CV (%)	27.14	26.10	29.87	38.56

In the column, figures having similar letter(s) do not differ significantly at 5% level of probability.

Here, T_1 = control (only soil), T_2 = 50% soil + 40% VC + 5% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_3 = 45% soil + 45% VC + 5% sand + 5% sawdust + 1.5 g kg^{-1} bone meal powder, T_4 = 45% soil + 40% VC + 5% sand + 10% sawdust + 1.5 g kg^{-1} bone meal powder, T_5 = 40% soil + 40% VC + 15% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_6 = 35% soil + 50% VC + 10% sand + 5% sawdust + 1.0 g kg^{-1} bone meal powder, T_7 = 35% soil + 50% VC + 5% sand + 10% sawdust + 1.0 g kg^{-1} bone meal powder, VC = vermicompost.

4.2.4 Soil temperature (°C)

The temperature of the treatment combination was not statistically significant due to the impact of distinct soil mixtures. The temperature of different treatments was found with variations in terms of value, which was recorded from 1st day of sowing to 21 DAS at 7 days of interval (Table 4.6). This variations in temperature may occur due to the weather, climatic condition and intercultural operation during the present study. At 1st day of sowing the recorded highest temperature was in treatment T_5 (34.20 ^{0}C) and lowest temperature in treatment T_1 (32.97 ^{0}C) where only soil was provided as a growing medium. At 7 DAS, the highest recorded temperature was 29.20 ^{0}C in both treatment T_1 and T_7 and the lowest temperature was in treatment T_3 (28.63 ^{0}C). Furthermore, at 14 DAS, the highest recorded temperature was in treatment T6 (28.50 ^{0}C) and lowest one was treatment T_2 (28.17 ^{0}C). At 21 DAS, the highest temperature was in treatment T_1 (29.47 ^{0}C) and lowest one was found in treatment T_3 (29.10 ^{0}C). In all cases, there were no statistical variations in the temperatures among the treatment combinations differed from each other in terms of distinct soil mixtures.

Table 4.6 Impact of different soil mixtures on soil temperature (^{0}C) at 7 days interval

Treatments	Temperature (^{0}C)			
	At first Day	**At 7 DAS**	**At 14 DAS**	**At 21 DAS**
T_1	32.97	29.20	28.33	29.47
T_2	33.53	28.87	28.17	29.40
T_3	33.73	28.63	28.33	29.10
T_4	34.03	28.67	28.20	29.13
T_5	34.20	28.70	28.43	29.33
T_6	33.53	29.03	28.50	29.37
T_7	33.30	29.20	28.33	29.40
LSD	0.777	0.400	0.382	0.241
CV (%)	2.32	1.38	1.35	0.824

In the column, figures having similar letter(s) do not differ significantly at 5% level of probability.

Here, T_1 = control (only soil), T_2 = 50% soil + 40% VC + 5% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_3 = 45% soil + 45% VC + 5% sand + 5% sawdust + 1.5 g kg^{-1} bone meal powder, T_4 = 45% soil + 40% VC + 5% sand + 10% sawdust + 1.5 g kg^{-1} bone meal powder, T_5 = 40% soil + 40% VC + 15% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_6 = 35% soil + 50% VC + 10% sand + 5% sawdust + 1.0 g kg^{-1} bone meal powder, T_7 = 35% soil + 50% VC + 5% sand + 10% sawdust + 1.0 g kg^{-1} bone meal powder, VC = vermicompost.

4.3 Impact of different soil mixtures on chemical properties of the post-harvest soil

4.3.1 Organic matter (%)

There were strong significant differences in the post-harvest soil's OM content due to different soil mixture combinations (Table 4.7). The T_2 treatment had the highest OM content (6.17 %), while the T_1 treatment had the lowest OM percentage (1.18 %). The organic matter values varied statistically significant across all the treatments. In the initial soil, the percentage of OM was 0.64 % (Table 3.3). According to the study, using a combination of organic fertilizers, such as vermicompost, sawdust and bone meal powder, increased the content of OM in post-harvest soil when compared to the initial soil.

4.3.2 Total nitrogen (N) in soil

There were statistically significant differences among the treatments regarding the total N content of the post-harvest soil, which might be happened due to the distinct combinations of soil mixtures used as the growth medium of red amaranth. The post-harvest soil had a total N content that varied from 0.08% to 0.32% (Table 4.7). The post-harvest soil in T_7 treatment had the highest total N content (0.32%), while T_1 treatment, which possessed only soil, had the lowest total N content (0.08%). The treatment T_5 (0.14 %) and T_2 (0.15 %) were statistically similar. The post-harvest soil had a higher soil N content than the initial soil. According to Sreelatha *et al.* (2006), organic manures also improved the total and available N content in the soil.

4.3.3 Available phosphorus (P) in soil

Available P content in the post-harvest soil differed statistically depending on the treatments used. Each treatment was greatly varied from each other. The range of the available P content in the collected post-harvest soil was 100.10 ppm to 284.26 ppm (Table 4.7). In treatment T_7, the highest available P content (284.26 ppm) was recorded, while the least amount of available P content (100.10 ppm) was found in T_1 treatment. Meanwhile, the available P content of initial soil was 23.72 ppm (Table 3.3), which was much lower than any treatment combinations in regards to available P content.

4.3.4 Exchangeable potassium (K) in soil

The distinct soil mixtures had a significant impact on the exchangeable potassium (K) content of the post-harvest soil (Table 4.7). Initial soil had an exchangeable K content of 0.128 meq $100g^{-1}$ soil (Table 3.3), while post-harvest soil had values ranging from 0.38 to 0.87 meq $100g^{-1}$ soil. Treatment T_7 had the highest exchangeable K (0.87 meq $100g^{-1}$ soil), while treatment T_1 had the lowest exchangeable K content (0.38 meq $100g^{-1}$ soil). Treatments T_2 (0.83 meq $100g^{-1}$ soil) and T_6 (0.84 meq $100g^{-1}$ soil) were statistically identical, whereas, treatment T_3 (0.76 meq $100g^{-1}$ soil) and T_4 (0.77 meq $100g^{-1}$ soil) were statistically similar as well.

4.3.5 Available sulphur (S) in soil

The available S content in the analyzed soil varied statistically, ranging from 113.30 ppm to 193.43 ppm (Table 4.7). There was strong statistical variation across all the treatments due to different combinations in the treatments. Treatment T_2 was found with the highest S content (193.43 ppm), while treatment T_4 had the lowest available S content (113.30 ppm) in post-harvest soil. The initial soil's available S content was 13.81 ppm (Table 3.3).

Table 4.7 Effect of different soil mixtures on the total N, available P, exchangeable K and available S content of the post-harvest soil

Treatments	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (meq $100g^{-1}$ soil)	Available S (ppm)
T_1	1.18 g	0.08 e	100.10 g	0.38 e	119.63 f
T_2	6.17 a	0.15 d	199.35 f	0.83 b	193.43 a
T_3	4.68 f	0.22 b	264.97 b	0.76 c	192.87 b
T_4	5.93 d	0.17 c	242.47 e	0.77 c	113.30 g
T_5	6.11 b	0.14 d	250.67 c	0.72 d	157.28 d
T_6	5.99 c	0.17 c	245.40 d	0.84 b	186.41 c
T_7	5.88 e	0.32 a	284.26 a	0.87 a	124.65 e
LSD	1.722	0.071	58.385	0.159	34.234
CV %	33.53	39.37	25.75	21.54	22.03
Initial soil	0.64	0.014	23.72	0.128	13.81

In the column, figures having similar letter(s) do not differ significantly at 5% level of probability.

Here, T_1 = control (only soil), T_2 = 50% soil + 40% VC + 5% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_3 = 45% soil + 45% VC + 5% sand + 5% sawdust + 1.5 g kg^{-1} bone meal powder, T_4 = 45% soil + 40% VC + 5% sand + 10% sawdust + 1.5 g kg^{-1} bone meal powder, T_5 = 40% soil + 40% VC + 15% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder, T_6 = 35% soil + 50% VC + 10% sand + 5% sawdust + 1.0 g kg^{-1} bone meal powder, T_7 = 35% soil + 50% VC + 5% sand + 10% sawdust + 1.0 g kg^{-1} bone meal powder, VC = vermicompost.

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

From September 2023 to November 2023, an experiment was carried out in front of the soil science laboratory-2 at Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200 to assess how red amaranth performed under various soil combination treatments. The experiment soil belonged to the Agro- Ecological Zone (AEZ-1) namely Old Himalayan Piedmont Plain. The texture of the studied soil was sandy loam, and its pH, organic matter, total nitrogen, exchangeable potassium, available phosphorus, and available sulfur contents were 6.44, 0.64%, 0.014%, 23.72 ppm, 0.128 meq $100g^{-1}$ soil, and 13.81 ppm, respectively.

The experiment was laid out in a Completely Randomized Design (CRD) having seven (7) treatments with three (3) replications. Therefore, the total number of pots was 21. The seven different treatments were T_1 = control (only soil), T_2 = 50% soil + 40% VC + 5% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder ,T_3 = 45% soil + 45% VC + 5% sand + 5% sawdust + 1.5 g kg^{-1} bone meal powder ,T_4 = 45% soil + 40% VC + 5% sand + 10% sawdust + 1.5 g kg^{-1} bone meal powder ,T_5 = 40% soil + 40% VC + 15% sand + 5% sawdust + 2.0 g kg^{-1} bone meal powder ,T_6 = 35% soil + 50% VC + 10% sand + 5% sawdust + 1.0 g kg^{-1} bone meal powder ,T_7 = 35% soil + 50% VC + 5% sand + 10% sawdust + 1.0 g kg^{-1} bone meal powder. Here, VC stands for vermicompost, and the total amount of soil mixture was 6 kg in each pot. All manures and fertilizers were applied during the soil preparation phase. Chemical fertilizers such as urea, TSP, MP, and gypsum were applied with each treatment mixture in accordance with 2.45 g kg^{-1}, 0.85 g kg^{-1}, 1.25 g kg^{-1}, and 490 mg kg^{-1} of total amount of soil mixture, respectively. On September 11, 2023, seeds were sown, and the crop was allowed to grow until maturity. Intercultural activities, such as weeding, thinning, irrigation, and pesticide application, were carried out as needed to support the plant's normal growth and development. Vegetative yields of each pot were noted. Soil samples were taken both before and after harvesting of applying treatment combinations and fertilizers. After the data were recorded, the Least Significance Difference test (LSD test) was used at a 5% level of significance to compare the mean differences. The application of sand, vermicompost, sawdust, and bone meal powder along with other chemical fertilizers at varying doses in the form of pot soil mixtures significantly responded to the growth and yield characteristics of red amaranth, including plant height, number of leaves per plant, fresh weight per plant and total fresh weight per pot. The physico-chemical properties like soil pH, soil moisture, EC, and temperature of the distinct soil treatment combinations were also measured for four times at seven days of interval. The physico-chemical properties of the treatment combinations were statistically significant in some extent at different stages of growth of red amaranth. Different mixtures of organic manures and inorganic fertilizers were applied, and the results were considerable changes in various traits of red amaranth. The T_7 treatment produced the highest plant height of 7.67 cm, 20.77 cm, and 51.94 cm at 25, 40, and 55 DAS, respectively, while the T_1 treatment produced the lowest plant height of 3.24 cm, 8.04 cm, and 23.35 cm at 25, 40, and 55 DAS. Average number of leaves of three randomly selected plants from each pot yielded the highest value of 4.74, 9.45, and 19.33 in T_7 treatment at 25, 40, and 55 DAS, respectively. On the other hand, the T_1 treatment produced the lowest average number of leaves per pot which were 3.67, 7.23, and 10.11 at 25, 40, and 55 DAS, respectively. Furthermore, T_7 treatment produced the highest fresh weight per plant (25.77 g) and total fresh weight per pot (644.25 g), whereas the T_1 treatment produced the lowest fresh weight per plant (2.98 g) and total fresh weight per pot as well.

5.2 Conclusion

Based on the findings of the present study, it can be concluded that the different soil mixture combinations influenced the growth and yield characteristics of red amaranth. While red amaranth growth and yield were improved by all treatments, one treatment performed relatively better than the others in terms of growth and yield of red amaranth and the physico-chemical traits of the soil mixtures as well. The overall results showed that the soil mixtures of 35% soil, 50% VC, 5% sand, 10% sawdust, and 1.0 g kg^{-1} bone meal powder in T_7 treatment, produced the maximum growth and fresh weight of red amaranth regarding as a leafy vegetable in pot culture for rooftop gardening.

5.3 Recommendations

i. The application of the soil mixtures of 35% soil, 50% VC, 5% sand, 10% sawdust, and 1.0 g kg^{-1} bone meal powder was found optimum which should be tested to a narrower extent of mixture.

ii. These findings should be replicated with other vegetables of Amaranthaceae family for rooftop cultivation in urban areas.

REFERENCES

Abayomi OA and Adebayo OJ. 2014. Effect of fertilizer types on the growth and yield of *Amaranthus caudatus* in Ilorin, Southern Guinea, Savanna zone of Nigeria. Advances in Agriculture. 2014: 1-5.

Akamine H, Ohshiro M and Hossain MA. 2021. Effects of N, P and K fertilizers on edible *Amaranths* spp. grown on the red soil of Okinawa. Applied Ecology and Environmental Research. 19(3): 2333- 2346.

Alam MN, Jahan MS, Ali MK, Islam MS and Khandakar SMAT. 2007. Effect of vermicompost and NPKS fertilizers on growth, yield and yield components of red amaranth. Australian Journal of Basic and Applied Science. 1(4): 706-716.

Albanell E, Plaixats J and Cabrero T. 1988. Chemical changes during vermicomposting (*Eisenia fetida*) of sheep manure mixed with cotton industrial wastes. Biology and Fertility of Soils. 6: 266-269.

Barzegar AR, Yousefi A and Daryashenas A. 2002. The effect of addition of different amounts and types of organic materials on soil physical properties and yield of wheat. Plant and Soil. 247(2): 295-301.

BBS, 2010. Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Bangladesh. Dhaka. Bangladesh. pp. 100-109.

Bremner JM and Mulvaney CS. 1982. Methods of soil analysis. Nitrogen-Total. Part-2 (2nd edition). Agronomy Monographs. 9. ASA and SSSA, Madison. pp. 595-624.

Dehariya P, Mishra DK, Dhakad R and Kumar A. 2019. Studies on different levels of nitrogen application on growth and yield of Amaranthus (*Amaranthus tricolor*

L.). International Journal of Current Microbiology and Applied Sciences. 8(4): 1423-1427.

Esmaeilzadeh J and Ahangar AG. 2014. Influence of soil organic matter content on soil physical, chemical and biological properties. International Journal of Plant, Animal and Environmental Sciences. 4(4): 244-52.

Farjana S, Islam MA and Haque T. 2019. Effects of organic and inorganic fertilizers, and mulching on growth and yield of cabbage (Brassica oleraceavar. capitata L.). Journal of Horticulture & Postharvest Research. 2(2): 1-10.

Freeze BS, Webber C, Landwill CW and Domar JF. 1993. Risk simulation of the economics of manure application to restore eroded wheat crop land. Canadian Journal of Soil Science. 73: 267-274.

Ghosh A, Arif MTU, Chamely SG, Haque MR, Rahman MM and Bhuiyan MAH. 2017. Comparative effect of arbuscular mycorrhiza, cowdung and phosphorus on growth and yield contributing characters of red amaranth (*Amaranthus tricolor* L.) and Indian spinach *(Basella alba* L). Tropical Plant Research. 4(2): 254-263.

Gomez KA and Gomez AA. 1984. Statistical procedure for agricultural research (2nd Edition). John Wiley and Sons, New York. pp. 188-206.

Grubben GJH and Denton OA. 2004. Plant Genetic Resources of Tropical Africa 2: Vegetable. Wageningen, Netherlands: PROTA Foundation.

Islam MM, Jalal MS, Islam MS, Hossain MM, Isik M and Iqbal MT. 2020. Akha biochar enhances soil fertility and productivity of red amaranth plant. Net Journal of Agricultural Science. 8(1): 1-7.

Islam MT, Islam MZ, Alam MM, Hossain MS and Islam MA. 2007. Effect of manures and chemical fertilizers on nutrient concentration and quality of red amaranth. Bangladesh Journal of Environmental Science. 12: 237-241.

Islam SS, Nasrin S, Rupanty NJ, Hossain MZ, Akter F, Adhikary N, Islam MT. 2023. Effect of faecal sludge compost on growth, yield and quality of red amaranth (*Amaranthus cruentus*). Khulna University Studies. 2023 Aug 24.

Jackson ML. 1967. Soil Chemical Analysis. Prentice Hall of India (Pvt.) Limited, New Delhi, India. pp: 41-55.

Jahan F, Bhuiyan MNH, Islam MJ, Ahmed S, Hasan MS, Bashera MN, Waliullah M, Chowdhury AN, Islam MB, Saha BK and Moulick SP. 2022. *Amaranthus tricolor* an indigenous source of nutrients, minerals, amino acids, phytochemicals and assessment of its antibacterial activity. Journal of Agricultural and Food Research. 10: 100419.

Kamron NN. 2006. Adoption of roof gardening at Mirpur-10 area under Dhaka city. (Doctoral dissertation, Dept. of Agricultural extension & information system).

Lestari F and Dewi K. 2020. Effect of humic acid on vegetative growth, yield, oxalic acid and betacyanin content of red amaranth (*Amaranthus tricolor* L.). AIP conference proceedings. 2260: 030011.

Makus DJ. 1992. Fertility requirement of vegetable Amaranth (A*maranthus tricolor* L.) in an upland mineral soil of the Mid – South. Acta Horticulture. 318, 291- 298.

Malik NJ, Chamon AS, Mondol MN, Elahi SF and Faiz SMA. 2011. Effects of different levels of zinc on growth and yield of red amaranth (*Amaranthus* sp.) and rice *(Oryza sativa*, variety BR- 49). Journal of Bangladesh Association of Young Researchers. 1(1): 79- 91.

Malkawi AI, Alawneh AS and Abu-Safaqah OT. 1999. Effects of organic matter on the physical and the physicochemical properties of an illitic soil. Applied clay science. 14(5-6): 257-78.

Materechera SA and Mukwevho TN. 2007. Response of leaf Amaranth (*Amaranthus cruentus*) to nitrogen from chicken manure and defoliation frequency in a semi-arid environment of South Africa Crop Science Department, North West University (Mafikeng campus), Mmabatho, South Africa. Acta-Horticulture. 752: 499- 504.

Mazumder N, Sultana T, Paul P, Noor MM. 2019. Influence of NPK fertilizer and spacing on growth parameters of onion (Allium cepa L. Var. BARI piaz-1). Research in Agriculture, Livestock and Fisheries, 6(1): 19-25.

Meng Q, Zou H, Zhang C, Zhu B, Wang N, Yang X, Gai Z and Han Y. 2020. Soil mixing with organic matter amendment improves Albic soil physicochemical properties and crop yield in Heilongjiang province, China. Plos one. 15(10): e0239788.

Miah MY, Monira US, Fazal KI and Roy PK. 2013. Nutrient accumulation and their uptake by red amaranth as influenced by different levels of N. Journal of the Bangladesh Agricultural University. 11(1): 29-32.

Mlakar SG, Turinek M, Jakop M, Bavec M and Bavec F. 2009. Nutrition value and use of grain amaranth: potential future application in bread making. Agricultura. 6(4): 43-53.

Mondal MM, Akter MB, Rahman MH and Puteh AB. 2019. Influence of micronutrients and manures on growth and yield of garlic (*Allium sativum* L.) in sandy loam soil. International Journal of Plant & Soil Science. 13(4): 1-8.

Munmun S, Mousomi KN, Maukeeb ARM and Mondal S. 2022. Vermicompost enhances the yield and quality of red amaranth subjected to acidic Soil. American journal of Agricultural, Science, Engineering and Technology. 6 (2). 74-81.

Nath NC. 2015. Food security of Bangladesh: Status, challenges and strategic policy options. Bangladesh Journal of Political Economy. 31(2): 189-250.

Noor S, Shil NC and Farid AT. 2007. Integrated nutrient management for radish-tomato-red amaranth-Indian spinach cropping pattern in a homestead area. Bangladesh Journal of Agricultural Research. 32: 17-28.

Norman Q, Arancon NQ, Edwards CA, Bierman P, James D, Metzger JD and Lucht C. 2005. Effect of vermicompost produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. Pedobiologia. 49: 297-306.

Nuruzzaman M, Ullah SM, Islam A, Rahman S and Rashid H. 1993. Effect of industrial waste on soil properties and crop growth. Regional workshop on Environmental impacts from fertilizers, agrochemicals and industrial wastes. Under the project Chemical Research Need (REN)."

Olsen SR. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). US Department of Agriculture.

Oshiro M, Hossain MA, Nakamura I, Akamine H, Tamaki M, Bhoumik PC and Nose A. 2016. Effects of soil types and fertilizers on growth, yield and quality of edible *Amaranthus tricolor* lines in Okinawa, Japan. Plant Production Science. 19(1): 61-72.

Padmavathiamma PK, Li LY and Kumari UR. 2008. An experimental study of vermi-biowaste composting for agricultural soil improvement. Bioresource technology. 99(6):1672-81.

Page AL, Miller RH and Keeney DR. 1989. Methods of soil analysis: Part 2 (2nd edition). American Society of Agronomy, Wisconsin, USA.

Peiretti PG. 2018. Amaranth in animal nutrition. Livestock Research for Rural Development. Vol.30.

Peyvast GH, Olfati JA, Madeni S, Forghani A. 2008. Effect of vermicompost on the growth and yield of amaranth. Journal of Food, Agriculture & Environment. 6(1): 110-113.

Piper CS. 1950. Soil and Plant Analysis. Adelaide University Press, Adelaide, Australia.

Pittelkow FK, Bianchini A, Pereira PSX, Belufi LMR, Bianchini MDGA and Rosa RP. 2019. Phosphate fertilization in Amaranth Cultivar cv. BRS Alegria in second harvest in the Cerrado. Journal of Experimental Agriculture International. 39(4): 1-9.

Rai N and Yadav DS. 2005. Advances in Vegetable Production. Published by Research co Book Center 25-B/2, New Rohtak Road Karol Bagh, New Delhi-110005 India, pp. 550 -558.

Raksun A, Merta IW, Mertha IG and Ilhamdi ML. 2022. The effect of vermicompost and NPK fertilizer on the growth of Spinach (Amaranthus tricolor). Jurnal Pijar Mipa. 17(5): 691-5.

Rani KU, Reddy TN and Shah S. 2016. Urban Agriculture: Experiences of Practitioners of Rooftop Gardening. Journal of Agricultural Extension. 17(1): 1-11.

Russel EW. 1975. Opening address on soil physical condition and crop production. Tech, Bul, 29. Her. Majistry's Stationary Office, London.

Ruth ON, Unathi K, Nomali N and Chinsamy M. 2021. Underutilization versus nutritional-nutraceutical potential of the Amaranthus food plant: A mini-review. Applied Sciences.11(15): 6879.

Saha M, Mousomi KN, Maukeeb AR and Mondal S. 2022. Vermicompost Enhances the Yield and Quality of Red Amaranth Subjected to Acidic Soil. American Journal of Agricultural Science, Engineering and Technology. 6(2): 74-81.

Sanni KO. 2016. Effect of compost, cowdung and NPK 15-15-15 fertilizer on growth and yield performance of Amaranth (*Amaranthus hybridus*). International Journal of Advances in Scientific Research. 2(03): 076- 082.

Sawatdee S, Prommuak C, Jarunglumlert T, Pavasant P and Flood AE. 2019. Enhancement of antioxidants contents in *Amaranthus tricolor* L. by adjustment of cationic ions in fertilizer. Journal of Advanced Agricultural Technologies. 6(2).

Schonfeldt HC, Pretorius B and Hall N. 2013. The impact of animal source food products on human nutrition and health. South African Journal of Animal Science. 43(3): 394-412.

Shanmugavelu KG. 1989. Amaranthus. In: production Technology of vegetables Crops. Oxford and IBH Publishing Co Pvt. Res. Cent. USDA. Albary, Calilhrnia, USA.

Singh BP and Whitehead WF. 1992. Response of vegetable Amaranth to different soil pH and moisture regimes. Acta Horticulture. 318, 225- 230.

Solaiman SB, Hossain MB, Saha MK, Mandal R and Khan MHR. 2022. Impacts of cowdung and poultry manure on the mineral nutrient uptake of red amaranth grown in a mixture of acid calcareous soil. Dhaka University Journal of Biological Science. 31(2): 329- 342.

Sreelatha T, Raju AS and Raju AP. 2006. Effect of different doses of farm yard manure and poultry manure and their interaction with fertilizer nitrogen on yield and nutrient uptake in mesta-rice cropping system. Journal of Crop Research. 34: 42-47.

Talukder MSA. 1999. Effect of plant density on green yield and seed production in different thesis. BSMRAL1, Salna. Ciazipur.

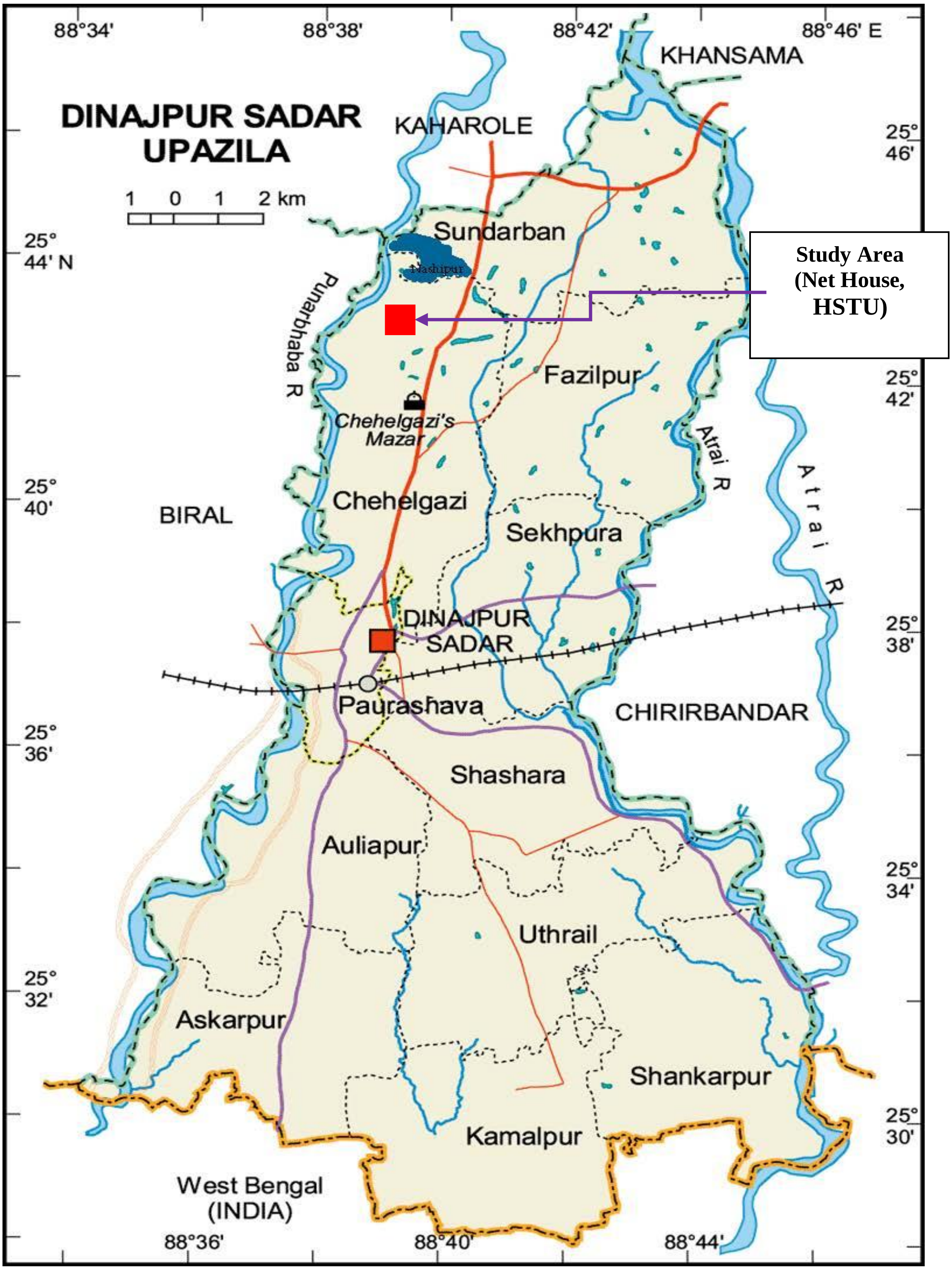
Teutonico RA and Knorr D. 1985. Amaranth composition, Properties and application of a reddish covered food crop: Food technology. 39: 49-61.

UNDP and FAO. 1988. Land resources appraisal of Bangladesh regions of Bangladesh United Nations Development Programme and Food and Agricultural Organization. pp. 212- 221.

Wehmeyer AS and Rose EF. 1983. Important indigenous plants in the Transkei as food supplements. Bothalia, 14: 613 - 615.

APPENDICES

Appendix I. Location of the experimental site (map of Dinajpur Sadar Upazila showing the research area)



Appendix II. Monthly recorded air temperature, relative humidity, and rainfall during the research period (From September 2023 to November 2023)

Year	Month	**Temperature (^{0}F)			**Relative Humidity (%)	**Rainfall (in)
		Minimum	Maximum	Average		
2023	September	96.4	68.8	78.6	95	41.61
	October	90.4	63.8	76.6	94	32.56
	November	85.8	56.1	70.0	88	0

**Monthly average

Source: Personal Weather Station Dashboard.

Appendix III. Some photographs during my research work


Shot on Y50
AI Quad camera


Shot on Y50
AI Quad camera


Dept.of Soil Science
Shot on Y50
AI Quad camera