EFFECT OF REDUCED DOSES OF CHEMICAL FERTILIZERS WITH VERMICOMPOST ON THE GROWTH AND YIELD OF OKRA (*Abelmoschus esculentus*)

A THESIS

BY

MST. KANIZ FATEMA

Student No. 2205086

Session: 2022-2023

Semester: July-December, 2022

MASTER OF SCIENCE (M.S.)

IN

SOIL SCIENCE

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Dedicated to

My

Beloved Parents

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ABSTRACT

An experiment was conducted in Soil Science research field, Hajee Mohammad Danesh Science and Technology University, Dinajpur, over the period of May 2023 to September 2023. The experiment was laid out in a Randomized Complete Block Design (RCBD) with six treatments and three replications. Six fertilizer treatments were used which were T_1= control, T_2 = 100% RDF, T_3 = 75% Recommended doses of NPK + 1 t ha^{-1} Vermicompost, T_4 = 50% Recommended doses of NPK + 2.5 t ha^{-1} Vermicompost, T_5 = 25% Recommended doses of NPK + 5.0 Vermicompost, T_6 = 7.5 t ha^{-1} Vermicompost. The fertilizers were distributed according to the treatment in individual plots. NPKS was applied as urea, TSP and MOP and gypsum at the rate of 150, 100, 150 and 40 kg per ha^{-1} respectively. Vermicompost was applied at the rate of 7.5 t ha^{-1}, respectively. The results of the experiment revealed that plant height, number of leaves $plant^{-1}$, fruit weight $plot^{-1}$, no. of fruits $plant^{-1}$, fruit length (cm) was significantly influenced by vermicompost and NPK fertilizers. The T_3 treatment (75% RDF + 1 t ha^{-1} vermicompost), produced the maximum result on plant height (96 cm), number of leaves $plant^{-1}$ (13.0), fruit weight $plot^{-1}$ (122.3 g), no. of fruits $plant^{-1}$ (18), fruit length (16.1 cm) The findings of the study showed that the performance of the treatment T_3 was the maximum among all other treatments in respect of While the minimum result on plant height (21.7 cm), number of leaves $plant^{-1}$ (7.6), fruit weight $plot^{-1}$ (44.3 g) , no. of fruits $plant^{-1}$ (11.3), fruit length (11.2cm) was recorded from T_1 treatment (control). Therefore, application of 75% recommended dose of NPKS combined with 1 t ha^{-1} vermicompost fertilizers was suggested for the better growth and yield of okra cultivation. The result of post-harvest soil properties revealed that combined application of chemical fertilizer and Vermicompost significantly increased the total N, available P, exchangeable K, available S, and organic in the soil when compared with the control or sole application of chemical fertilizers. The treatment T_6 (7.5 t ha^{-1} Vermicompost) showed superior in respect of post-harvest OC, PD, and NPKS content. The overall results suggested that application of 75% RDF + 1.0 t ha^{-1} vermicompost would be suitable for profitable okra cultivation in summer season.

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ABBREVIATION AND ACRONYMS

%	Percentage
@	At the rate of
AEZ	Agro-ecological zone
ANOVA	Analysis of Variance
BBS	Bangladesh Bureau of Statistics
Cm	Centimeter
Conc.	Concentration
Contd	Continued
CV	Co-efficient of Variation
DAS	Days after sowing
DMRT	Duncan's Multiple Range Test
e.g.	For example
et al.,	And others
FYM	Farm Yard Manure
g	Garm
NS	non-significant
No.	Number
MT	Metric Ton
pH	Potential of H^+ concentration
ppm	Parts per million
RCBD	Randomized Complete Block Design
RDF	Recommended doses fertilizer
SOM	Soil organic matter
SPSS	Statistical Package for social sciences
T	Treatment
t ha^{-1}	Ton(s) per hectare
VC	Vermicompost

CHAPTER I
INTRODUCTION

Okra (*Abelmoschus esculentus*) is a widely consumed vegetable in Bangladesh as well as other tropical and subtropical regions of the world (Shahriazzaman *et al.,* 2014). It is a member of the Malvaceae family (Maurya *et al.,* 2013). Okra may be cultivated up to an Altitude of 4000 ft and grow best under temperature ranges of 25 to 35°C. It is an annual crop that is primarily grown as fruits and vegetables in the world (Chowdhury *et al.,* 2014). When there are few vegetables available on the market, it is crucial to meet the nation's vegetable needs (Ahmed, 1995). Okra can be grown all year round, but in Bangladesh, it is most commonly grown in summer. It has a lot of vitamins and minerals and can help prevent many diseases (Gemede, 2015). The demand for food and the amount of available agricultural land has increased due to the expanding world population (El-Shaikh and Mohammed, 2009). Vegetables are the most significant food crop in terms of cultivation and consumption (Ali *et al.,* 2022a; Ali *et al.,* 2023b). In general, vegetables are grown all over the world utilizing a variety of inputs such as chemical fertilizers and pesticides, organic fertilizers, biofertilizers and biopesticides, etc. In recent years, the use of various organic fertilizers, biofertilizers, and biopesticides has been suggested not only to reduce the use of dangerous chemical inputs but also for sustainable crop production, notably in the cultivation of vegetables (Gandhi and Sundari, 2012). Fertilizers provide the nutrients required for a plant's healthy growth. Plant nutrients are divided into macronutrients and micronutrients, both of which are crucial to a plant's metabolism.

Between 1980 and 2010, Bangladesh produced more vegetables. In contrast to 5.7 t ha^{-1} in 1980, current yields are 5.8 t ha^{-1}. However, according to Weinberger and Genova (2005), the supply of domestic vegetables is still far from meeting domestic demand. In Bangladesh, the supply of vegetables is abundant in the winter and scarce in the summer. About 30% of the total vegetable production occurs during the Kharif season and about 70% during the Rabi season. Okra can therefore become important as a vegetable in our country's context during both the kharif and summer seasons (Firoz *et al.,* 2007). The total production of okra was 42,366 MT produced from 10,204 ha of land in the year 2009- 2010, and the average yield was 3.92 t ha^{-1} (BBS, 2011), which is very low compared to that of other developed countries where the yield was as high as 14.0-15.0 t ha^{-1} (Dash *et al.,* 2013, Anjali *et al.,* 2006). The daily requirement of vegetables for an adult person is approximately 285 g, whereas in

Bangladesh, people hardly can intake only 35g of vegetables per day. Therefore, there is a big gap between the requirement and per capita vegetable consumption in Bangladesh. As a result, malnutrition is very much evident in our country. Successful okra production may partially contribute to solving this vegetable scarcity during the summer season for the people of Bangladesh (Muqtadir *et al.*, 2019).

Vermicompost is one of the best organic manures for increasing crop yield. Besides, the biowastes for vermicompost production are readily available in large quantities, hence a cheap source of organic soil amendment. Its use in vegetable production not only improves the soil's physical properties but also results in eco-friendly vegetable production. The solid waste in Nigeria is generated at the rate of about 0.43 kg per head per day and is rich in organic matter of about 60 to 80% (Sridhar, 2006).

The role of organic manures in maintaining organic matter and raising crop yields has long been recognized (Karikari and Yayock, 1987; Sridhar, 2006). An increase in the number of fruits and fruit yield with an application of vermicompost in okra has been reported (Dhanalakshmi *et al.*, 2014). In a study on using sewage sludge in combination with NPK and *Azotobacter*, 2.5 t sewage NPK + *Azotobacter* significantly produced higher vegetative and yield attributes of okra Mishra and Singh (2005) observed.

Nitrogen plays an important role in building protoplasm and protein, which induce cell division and initiate meristematic activities when applied in optimum quantity. Nitrogen application significantly increased pod weight, diameter, number of fruits/plants, and number of seeds/pods in okra (Majanbu *et al.,* 1985). Phosphorus fertilization can influence the fruiting and fruit development of okra. Phosphorus is called the "Key to life" because it is directly involved in the most living process. It is a key constituent of ATP and has a significant role in energy transformation in plants and also in various physiological processes (Shivasankeb *et al.,* 1982). Phosphorus helps in nutrient uptake by promoting root growth, thereby ensuring a good pod yield through increasing total dry matter. Phosphorus deficiency results in poor root development and subsequently reduces yield. Many researchers reported the effect of phosphorus application on the green pod yield of okra.

Nitrogen is a part of chlorophyll molecule, amino acid, proteins, nucleic acid and pigments. Adequate supply of nitrogen favors the transformation of carbohydrate in to proteins while inadequate supply of N induces their deposition in the vegetative cells. Nitrogen promotes the formation of protoplasm, and since protoplasm is highly hydrated, the plant becomes more succulent. In all plants, N considerably influences the utilization of P and K and other plant nutrients. Nitrogen is mobile in plants and deficiency symptoms appear in the older leaves first (Haque and Jakhro, 1996). Potassium is considered essential in photosynthesis, sugar translocation, nitrogen metabolism, enzyme activation, stomata, opening, water relation and promotion of growth and instamatic tissues. It acts as a chemical traffic policeman, stalk strengthener, protein builder, breathing regulator, disease retarder and increase the plumpness and boldness of seeds but it is not effective without its co-nutrients as N and P (Chandra, 1989).

Sulfur is identified as a low acute toxic element in plant disease control (Singh *et al.*, 2012). Basically, it prevents fungal infections including powdery mildew, black spots, and rusts. Since sulfur has the ability to prevent spore germination, it would be advantageous in the application at seedling stage sulfur is available in the market in the form of powder, liquid and wettable powder (Bilal, 2008). The present study was focused on identification of the effect of sulfur spray on okra seedlings. The objective of this study is to study the effect of sulfur for ladies' fingers as a foliar spray. Some selected morphological characters of ladies' fingers under application of sulfur foliar spray were observed in this study.

Organic manures on the other hand are eco-friendly and cheaper source of nutrients. Application of vermicompost and vermiwash along with recommended dose of NPK inorganic fertilizers or alone has proven the significant increase in yield and yield contributing parameters of okra and reported by many researchers (Kulkarni *et al.*, 2004, Paramasivan *et al.*, 2006, Maithy and Tripathi, 2009 and Gorakhnath and Singh, 2009). During the last decade, fertilizer cost, soil health, sustainability and pollution have led to a renewed interest in the use of organic manures. The integrated use may help in improving productivity and quality of okra.

Considering this, the present experiment has been undertaken with the following objectives:

I. To determine the effect of chemical fertilizers and Vermicompost alone and their combination on the growth and yield of okra
II. To find the changes in soil properties of post-harvest soil after adding chemical fertilizers and Vermicompost

CHAPTER II

REVIEW OF LITERATURE

Okra, a significant summer vegetable crop in Bangladesh, is particularly prized for its tender and delectable edible pods. The important factor that significantly influences the growth, development, and yield of okra is the management of fertilizer, particularly nitrogen, phosphorus, and sulfur. For the best growth and yield of okra, it is crucial to evaluate the impact of nitrogen, phosphorus, sulfur, and vermicompost. However, only a limited amount of research has been done on how okra reacts to nitrogen, phosphorus, sulfur, and vermicompost in different parts of the world, including Bangladesh, and the work done there thus far is insufficient and inconclusive. However, some of the important and informative works conducted at home and abroad in these aspects are re-reviewed under the following headings:

2.1 Effect of organic manure on crop growth and yield

The irrational application of inorganic fertilizers has a significant impact on agricultural production. The common negative impact of inorganic fertilizers is degradation of soil nutrient content leading to reduced crop yield. On the other hand, inorganic fertilizers greatly harm the environment and the living things that inhabit it. Organic manures have been developed as a suitable and environmentally friendly replacement for the environment due to decreased soil fertility and rising fertilizer prices. The organic matter content of soil varies from 0-5% and it depends on several factors like origin of soil, climatic conditions, vegetation, microbial activities etc. The physical, chemical and biological properties of soil are greatly influenced by organic matter (Cardoso and Berni, 2012).

Abou El-Magd *et al.* (2006) reported that application of manures sustains cropping system through better nutrient recycling and provides all necessary nutrients, thereby improving soil’s physical and biological properties. Organic fertilizer released all type of micro and macro nutrients that help to plant elongation. Although, organic matter contains all the essential plant nutrients, but after application of organic manures required time to convert its available form to the plant. That is why the response of crops to organic manure is low. But due to the beneficial effects on soil properties, applications of organic manures are encouraged.

Adekiya *et al.* (2012) expressed that organic manures generally improve the soil physical, chemical and biological properties such as increased infiltration rate, reduced bulk density, aggregate stability, cation exchange capacity (CEC), and biological activities along with conserving the moisture holding capacity of soil and thus resulting in enhanced crop productivity along with maintaining the quality of crop produce. However, the organic manures contain plant nutrients in small quantities as compared to the fertilizers, the presence of growth promoting principles like enzymes and hormones, besides plant nutrients make them essential for improvement of soil fertility and productivity.

Muhammad *et al.* (2019) reported that, organic manure helps plants absorb micronutrients, acts as a slow-release reservoir for macronutrients, and promotes water and air infiltration. However, it has been argued that the mineralization of nutrients in organic manures is typically delayed. Although organic manure has many benefits for soil productivity, few studies have examined how it affects vegetable yield in the tropics.

Shahriazzaman *et al.*, (2014) also stated the roles of manures influencing many physicochemical and biological properties of the soil as well as increasing high yield of vegetables that have yet not been given the necessary attention. Very recently, attention is focused on the global environmental problems; utilization of organic wastes, vermicompost and poultry manures as the most effective measure. Application of vermicompost and poultry manure subsequently increase yield attributing characters and yield of okra.

Ali *et al.*, (2008) stated that cowdung is important organic manure in Bangladesh. It can be easily found in the village area and are frequently applied to the soil during the land preparation. The farmers of our country used it as a compulsory nutrient component for crop production. Cow dung manure may be bulky (nutrient contents are very low per unit volume) but it improves physical conditions of the soil and supplies N-P-K and other nutrients to plants. It also increases water-holding capacity of soil and balance the soil temperature. As it a good source of nitrogen, it supplemented nitrogen in the field thus reduce the pressure of applying extra amount of inorganic nitrogenous fertilizers. Cow dung helps to make the plant nutrients available in the soil solution and also make the good soil physical condition. Water holding capacity of the soil, root penetration capacity of the crop gets increased due to the application of the cow dung.

Muhammad *et al.*, (2019) observed the effect of cow dung and poultry manure on yield of okra varieties, and the results revealed that yield parameters such as number of pods per plant, mean pod weight, mean pod length, fresh pod weight per plant and pod yield were significantly increased when the nitrogen dose of 120 kg N ha^{-1} was applied using cow dung 6.6 t ha^{-1}. He also reported that cowdung manure application in addition to N and P fertilizers, significantly increased yield by 14-41% in comparison with plots that received the same amount of N and P but without manure.

Santos *et al.,* (2019) reported that, organic fertilization like cowdung did not influence the vegetative growth of okra, but was beneficial to the production of fruits with higher vitamin C content, 52% higher than the contents found in fruits produced without such input. Mona *et al.,* (2008) conducted a study to compare the impact of organic compost at 3 levels (6, 12 and 18 m^3/fed.) and mineral fertilization (150 kg ammonium sulphate, 150 kg ammonium sulphate, 150 kg calcium monophosphate and 50 kg potassium sulphate/fed), on growth and productivity of bitter fennel (*Foeniculum vulgare* var. vulgare Mill.) and Egyptian sage (*Salvia officinalis*). The results retrieved that all levels of compost significantly increased plant height, number of branches, fresh and dry weights of herb, oil (%) in fennel seeds and sage herb, as well as seed, herb and oil yield ml/plant and L/fed in fennel and sage, respectively, as compared to mineral fertilization.

Marschner (2012) observed that compost is the stable humus-like product resulting from the biological decomposition of organic matter under controlled conditions. It recycles nutrient elements such as nitrogen, sulfur, calcium, phosphorus, carbon, magnesium and trace minerals. These nutrients do not feed the plants directly, but sustain the natural life cycles of the soil by feeding the microorganisms that live there.

Chavan *et al.,* (2015) showed that the highest plant height, number of leaves $plant^{-1}$ and pods yield of okra were higher with the application of compost, followed by chemical fertilizers and as compared with control field.

Rady *et al.,* (2016) showed that addition of compost at a rate of 20 t ha^{-1} improved the soil chemical and physical properties besides growth characteristics viz., pods weight $plant^{-1}$, pod and seed yields of common bean.

Abou El-Hassan *et al.,* (2017) showed that all treatments of compost and vermicompost without mineral fertilizers decreased all vegetative characteristics, early and total yield of green bean plants and nitrate content of green bean pods.

Bucagu *et al.,* (2017) found that application of organic fertilizers significantly increased leaf area, plant height, number of leaves, pods, weight of pods and total pod yield of snap bean.

Chang *et al.,* (2017) indicated that compost addition up to 20% had a positive influence on plant emergence and plant growth index (shoot height, stem diameter, leaf area, root dry weight and plant biomass) of green bean.

Fouda *et al.,* (2017) showed that the best treatment that produced the highest values of vegetative growth parameter, pod length, pod diameter and yield of bean, and quality parameters of bean plant was NPK 100 % + compost, compared to control.

Sheela and Khimiya, (2013) observed that vermicompost is a nutrient-rich, microbiologically active organic amendment that results from the interactions between earthworms and microorganisms during the breakdown of the organic matter. It is a stabilized, finely divided peat-like material with a low C: N ratio, high porosity, and high water-holding capacity, in which most nutrients are present in forms that are readily taken up by plants. The most important benefit of vermicompost is its diverse and high microbial population. Its other benefits are as follows: good organic fertilizer, decreasing environmental pollution, and detoxifying some toxic chemicals. Recently, using vermicompost has increased because of these benefits and many researches are carried out to optimize them.

According to Chauhan *et al.,* (2010), worm waste frequently contains 5 to 11 times as much nitrogen, phosphorus, and potassium as bare soil. Islam *et al.,* (2016) reported that, vermicompost-fertilized bush bean (*Phaseolus vulgaris*) plants produced the highest levels of fresh biomass, pod weight, pods per plant^{-1}, pod dry weight, pod length, green pod yield, and pod protein content.

2.2 Effect of inorganic fertilizer on crop growth and yield

To determine how okra responded to organic and inorganic sources of nitrogen (N) fertilizer, Akanbi *et al.,* (2010) conducted both pot and field experiments. Okra variety NHAe 47-4 was fertilized with three N levels (0, 25 and 75 kg N ha^{-1}) and four compost rates in the field experiment as opposed to four N levels (0, 25, 50 and 75 kg N ha^{-1}) and five compost rates in the pot experiment. The highest okra fruit yield was achieved with an application of 75 kg N ha^{-1}.

Uwah *et al.,* (2010) conducted field experiments in 2007 and 2008 at Calabar in the south eastern rainforest zone of Nigeria to evaluate the response of okra due to the four rates of nitrogen (0, 40, 80 and 120 kg ha^{-1}) and three rates of lime. Nitrogen had significant effects on plant height, number of leaves and branches $plant^{-1}$, number of pods $plant^{-1}$, fresh pod weight and total fresh pod yield. Nitrogen 80 kg ha^{-1} maximized all the growth and yield attributes. Vermicompost essentially improves the quality of the fruits and pods of different crops. Crop quality tends to increase with the increasing doses of vermicompost.

Liza *et al.,* (2014) conducted a field experiment to evaluate the residual effects of organic manures and different level of recommended fertilizer dose (RFD) on the yield and nutrient uptake of BBRI dhan29. Results showed that, residual effects of organic manure with inorganic fertilizers significantly increased the yield attributes as well as grain and straw yields of rice. Treatment T_6 (50% RFD + residual effect of CD 2.5 t ha^{-1}, PM 1.5 t ha^{-1}, and Com. 2.5 t ha^{-1}) produced the highest grain yield (6.87 t ha^{-1}) and straw yield (7.24 t ha^{-1}). The lowest grain yield (3.22 t ha^{-1}) and straw yield (4.55 t ha^{-1}) were found in T_0 (Control) treatment. Arora *et al.,* (1991) compared growth and yield of new okra cultivar, Punjab Padmini, with that of cv. Pusa-Sawani grown under variable N (0, 30, 60 and 90 kg ha^{-1}) and P (0, 30 and 60 kg ha^{-1}) fertilizer applications. They stated that plant height, number of fruits, fruit size and total green fruit yield were significantly improved by the application of 90 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}.

2.3 Effect of vermicompost on the growth and yield of okra

Baliah and Muthulakshmi (2017) reported that microbially enriched vermicompost significantly impacted the growth of Okra (*Abelmoschus esculentus* (L.)). Plants amended with enriched vermicompost, growth traits like seed germination, seedling vigor index, shoot length; root length, plant fresh weight, and plant dry weight were significantly higher.

Sinha *et al.,* (2009) interviewed some farmers in India using vermicompost for agriculture. Most of them asserted to have switched over to organic farming by vermicompost, eliminating the use of chemical fertilizers in the last 3-4 years with very encouraging results, benefiting both their economy (reduced cost of inputs and significantly high outputs from good crop production, sale of vermicompost and worms) and the environment (reduced use of chemical pesticides, improved physical, chemical and biological properties of farm soil). Some of them asserted to have harvested three (3) different crops in a year (reaping 2-3 times more harvest) due to their rapid growth and maturity and reduced harvest cycle. Several villages have become ‘BIO-VILLAGE’ using only vermicompost in crop production and ultimately giving up chemical agriculture.

Suthar (2008) reported that vermicompost may be a potential source of nutrients for field crops if applied in suitable ratios with synthetic fertilizers. The earlier workers reported a positive effect of vermicompost application on the growth and productivity of cereals and legumes (Suthar, 2006). Phosphate solubilizing microorganisms (PSM) involve the different characteristics of micro-organisms which turn an insoluble organic compound of phosphorus into a soluble form (Raju and Reddy, 1999; Sundara *et al.,* 2002).

Gopinath *et al.,* (2009) showed that, plots amended with vermicompost had higher soil organic carbon levels than those treated with mineral fertilizer. However, plots with applied mineral fertilizer had higher levels of readily available N and P than did those with vermicompost. However, K levels were comparable between the plots treated with vermicompost and mineral fertilizer.

Reena *et al.,* (2017) reported that the application of NPK with Vermicompost was an excellent source for fertilization than fertilizers. The result that they obtained with treatment T_5- [NPK@ 50% + Vermicompost @ 100%] showed the highest yield regarding, gave the best results concerning plant height 115.69 cm, number of leaves per plant 49.33, Number of branches 48.50, Number of Fruit per plant 20.71, it gave highest yield, 199.21 q ha^{-1}. The maximum cost-benefit ratio was recorded 1: 8.55 and net profit. Rs. 37,154.6 ha^{-1} in treatment combination T_5-L1V2 [@ 50% N P K ha^{-1} + 100% Vermicompost ha^{-1}] combined use of N, P, and K resulted in a significant increase in enrichment of soil fertility status. Vermicompost in combination resulted in a slight increase in pH 7.40, EC 0.52 dSm^{-1}. In post soil of N, P, and K fertilizers observations have resulted in a significant increase in OC 0.84 %, particle density 2.73 M gm^{-3}, bulk density 1.46 M gm^{3}, pore space 53.06% and available N 229.48 kg ha^{-1}, P 24.03 kg ha^{-1}, K 147.87 kg ha^{-1}, the significant increase in case of nitrogen (kg ha^{-1}), phosphorus (kg ha^{-1}), potassium (kg ha^{-1}), vermicompost (t ha^{-1}) was found to be significant among other treatments in okra cultivation and soil quality improvement.

2.4 Effect of organic and inorganic fertilizers on the growth and yield of okra

Shampazuraini *et al.,* (2023) reported that application of inorganic fertilizer is very important to increase the productivity of the crop, but overuse of inorganic fertilizer can lead to soil acidification that can affect the plant growth. The purpose of this study is to determine the effectiveness combination rate of organic and inorganic fertilizer toward okra growth and yield performance. s. The study was used chicken dung as organic fertilizer. The treatments applied were T_0 (NPK), T_1 (NPK + 20 g chicken dung), T_2 (NPK + 40 g chicken dung), and

T_3 (NPK + 60 g chicken dung). NPK green was applied only one-time during 14 days after sowing (DAS) and was continued with NPK blue. T_3 showed an increasing in fresh pod yield. Thus, combination of organic fertilizer and inorganic fertilizer was showed the positive effect to the crop production. The combination of organic and inorganic fertilizer was proven to be the most effective in okra production.

Akinmutimi *et al.,* (2021) suggested that comparative effects of organic and inorganic fertilizer sources on the growth, yield and nutrient content of okra (*Abelmoschus esculentus*) in an ultisol at Umudike. The treatments were: 10-ton ha^{-1} chicken manure, 10-ton ha^{-1} pig manure, 400 kg ha^{-1} NPK 15:15:15 fertilizer, 1.0 kg ha^{-1}Agrolyser, 10-ton ha^{-1} chicken manure plus 400 kg ha^{-1} NPK 15:15:15 fertilizer, 10-ton ha^{-1} of pig manure plus 400 kg ha^{-1}of NPK 15:15:15 fertilizer and Control. The results showed that the test soil was moderately acidic, with a pH (6.0) and medium in percentage total nitrogen, low in percentage organic carbon (0.71) and low in available phosphorus and exchangeable bases. The okra variety SM 35 was used for the study. The results showed that10 ton ha^{-1} chicken manure significantly increased plant height, number of leaves of okra over the other treatments. However, at harvest, 1.0 kg ha^{-1}Agrolyserand10-tonha^{-1} chicken plus 400 kg ha^{-1} NPK 15:15:15 fertilizer and 10-ton ha^{-1} of pig manure plus 400 kg ha^{-1} of NPK 15:15:15 fertilizer, respectively gave the highest values of number of fruits and fresh fruit weight respectively. The N, P and K contents of okra was also investigated, but the result obtained could not be attributed to the effects of the treatments applied. 10-ton ha^{-1} chicken manure plus 400 kg ha^{-1} NPK 15:15:15 fertilizer, 10-ton ha^{-1} of pig manure plus 400 kg ha^{-1} of NPK 15:15:15 fertilizer and 1.0 kg ha^{-1}Agrolyser were therefore recommended for profitable okra production in the ultisols of Umudike.

Mishra *et al.,* (2020) observed that “impact of organic and inorganic fertilizers on growth, yield, nutrient uptake and soil fertility in okra” variety-Pusa A4. From the experiment it was observed that application of RDF (75%) + (25%) N through neem oil cake (T_7) produced maximum plant height (136.41cm), number of leavesplant^{-1} (20.98), leaf area (321.52cm2), minimum days to first flowering (36.1), minimum days to 50% flowering (45.2), minimum days to first harvest (41.2), number of fruits plant^{-1} (15.02) and maximum Yield (10.49 t ha^{-1}) followed by T_5 where RDF (75%) + (25%) N through vermicompost were applied. RDF was 110:50:80 NPK kg ha^{-1}. Highest uptake of nitrogen (68.48 kg ha^{-1}), Phosphorus (20.92 kg ha^{-1}), Potassium (64.82 kg ha^{-1}) were recorded in T_7 where RDF (75%) + (25%) N through neem oil cake were applied. Highest post-harvest available nitrogen (338 kg ha^{-1}), phosphorus (28.4

kg ha^{-1}), potassium (276 kg ha^{-1}) was found in T_{11} where 25% N through FYM + 25% N through vermicompost + 25% N through poultry manure + 25% N through neem oil cake were applied. Whereas, lowest post-harvest available nitrogen (298 kg ha^{-1}), phosphorus (14.4 kg ha^{-1}), potassium (227 kg ha^{-1}) was found was observed in T_7.

Mishra *et al.,* (2020) recorded that "Response of organic, inorganic fertilizers and integrated nutrient management on growth, yield and quality of okra" variety-Pusa A4. From the experiment it was observed that application of RDF (75%) + (25%) N through neem oil cake (T_7) produced maximum plant height (136.41 cm), internode length (8.20cm), fruit length (12.13 cm), maximum number of fruits per plant (15.02), individual fruit weight (15.11 g) and yield per ha. (10.49 ton) where RDF was 110:50:80 N P K kg ha^{-1}. Whereas, maximum number of nodes per plant (23.32), maximum fruit girth (5.87 cm) was found in (T_5) where RDF (75%) + (25%) N through vermicompost was applied. Application of RDF (75%) + (25%) N through neem oil cake (T_7) recorded high protein content (15.92%). Highest chlorophyll content in leaves (1.48mg/g) was found in T_2 (100% RDF + FYM 1.5 t ha^{-1}). High Ascorbic acid content (15.12mg/100g) was found in T_{12} (25% N through FYM + (25%) N through vermicompost + (25%) N through poultry manure + (25%) N through neem oil cake, sea weeds extract (15 kg ha^{-1}) which was at par with T_7 (14.66 mg/100g). Low crude fiber content (10.61%) was observed in T_1 (100% RDF) followed by T_7 (10.94%) and T_5 (11.12%). High TSS content (3.720 Brix) was found in T_2 receiving RDF (100%) and FYM (1.5 kg ha^{-1}).

Sharma *et al.*, (2015) expressed that effect of organic and inorganic fertilizers on the growth and seed yield of okra under sub-tropical areas during the spring- summer seasons of 2008 and 2009. Application of 60: 30: 30 kg NPK ha^{-1} significantly increased plant height (55.29 cm), stem diameter (5.71 cm), branches plant^{-1} (5.77), average fruit weight (15.55 g), marketable yield per plant (1.73 kg) and seed yield (12.78 q ha^{-1}) except than internodal length as compared to other treatments. *Azospirillum* inoculation produced significantly higher plant height (54.16 cm), stem diameter (4.83 cm), branches per plant (5.44), fruit weight (14.75 g), marketable yield per plant (1.67 kg) and seed yield (12.46 q ha^{-1}) over control. All the organics proved superior to control in respect of growth, yield attributes yield and net returns. The interaction between organic × inorganic fertilizers had significant beneficial effect on internodal length and yield of okra.

2.5 Effect of organic and inorganic fertilizers on the post-harvest soil properties

Vithursha and Premanandarajah (2023) conducted field experiment to study the impact of biochar with different nutrient sources on soil organic matter content and nitrogen content of soil and okra (Abelmoschus esculentus) grown in sandy regosol using variety Haritha. Soil analysis for available soil nitrogen and organic carbon were carried out at the time of harvest. Plant sample were analyzed for nitrogen content. Combination of biochar with nutrient sources favorably influenced nitrogen availability in soil. Among the nutrient sources, poultry manure had the greatest influence on soil available nitrogen plant nitrogen content and soil organic carbon content and pod yield.

Prity *et al.*, (2023) reported that compared among eight treatments: control (T_1), 6 t ha^{-1} vermicompost (T_2), 60 kg ha^{-1} N (T_3), 2 kg ha^{-1} Zn (T_4), 6 t ha^{-1} vermicompost + 60 kg ha^{-1} N (T_5), 60 kg ha^{-1} N + 2 kg ha^{-1} Zn (T_6), 6 ton ha^{-1} vermicompost + 2 kg ha^{-1} Zn (T_7), and 6 ton ha^{-1} vermicompost + 60 kg ha^{-1} N + 2 kg ha^{-1} Zn (T_8). Although there was no significant difference with the application of vermicompost 6 t ha^{-1} + N 60 kg ha^{-1} + Zn 2 kg ha^{-1} (T_8), the treated pot in vermicompost with 6 t ha^{-1} + N 60 kg ha^{-1} ($T_{5)}$ showed the best achievements of macro elements N (0.008%), P (6.70 ppm), K (0.08 cmol/kg), and S (18.22 ppm) of post-harvest soil compared to the control T_1. Mineral nutrients of fruits N-1.64%, P-0.27%, K-0.30%, S-0.10%, and Fe-0.02% and protein content 10.23% were found to be highest in the identical T_5 where Zn content was highest (0.28%) in T_8.

Yadav *et al.*, (2022) conducted field a study was conducted on the Effect of different levels of NPK and Vermicompost on Physico – Chemical properties of soil of Okra (*Abelmoschus esculentus* L.) Var. Kashi Kranti at the Soil Science and amp; Agricultural Chemistry Research farm of Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during summer season 2018. The result obtained with treatment T_5 = [NPK@ 50% + Vermicompost @ 100%] that showed the highest pH 7.38, EC 0.50 dSm $^{-1}$. In post soil of NPK fertilizers observations were resulted in significant increase in OC 0.82%, Particle density 2.71 g cm 3, Bulk density 1.44 g cm 3, Pore space 53.01% and available N 228.44 kg ha^{-1}, P 23.02 kg ha^{-1}, K 144.87 kg ha^{-1}, significant increase in case of Nitrogen (kg ha^{-1}), Phosphorus (kg $ha^{-1)}$, Potassium (kg ha^{-1}) was found to be significant among other treatments in Okra cultivation and soil quality improvement. It was also revealed that the application of NPK with Vermicompost were excellent source for fertilization than fertilizers. The treatment (T_5) also showed greater benefit cost ratio followed by other treatments.

Abbas *et al.,* (2019) showed that to examine the effect of different forms of fertilizers (organic and inorganic) on the yield and physiochemical attributes of okra Abelmoschus esculentus a field trial was conducted. For this purpose, organic form of fertilizers like kitchen waste, poultry manure and compost were used while the inorganic sources were NPK fertilizer. No significant increase was observed in the yield and growth of okra under control and full NPK fertilizer treatment. Application of organic fertilizers like poultry manure and compost as well as its mixture with full NPK considerably increase the growth and total yield attributes of Okra.

Ola *et al.,* (2017) conducted field experiment during Kharif (rainy) season of 2016 on Response of different levels of N P K and FYM on Soil Health and Yield of Okra (*Abelmoschus esculentus* L.) The best application of T_8 - (100% RDF @ N100 P60 K50 kg ha^{-1} + 100% FYM @ 25 t ha^{-1}) has effect on physical and chemical property of soil and yield of okra. The observed in post-harvest soil resulted were significantly increased maximum values of water holding capacity (63.42%), % pore space (62.17%), organic carbon (0.74 %), nitrogen (304.90 kg ha^{-1}), phosphorus (33.58 kg ha^{-1}) and potassium (186.03 kg ha^{-1}) was with treatment T_8 – (100% RDF @ N100 P60 K50 kg ha^{-1} + 100% FYM @ 25 t ha^{-1}).

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted from June to September 2023 to determine the effect of reduced doses of chemical fertilizers with vermicompost on the growth and yield of okra [*Abelmoschus esculentus* (L.)]. This chapter presents a brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, fruit collection in different DAS, and analysis of various soil parameters under the following headings:

3.1 Experimental site

The experiment was conducted at the Soil Science Research Field, Hajee Mohammad Danesh Science and Technology University, Dinajpur. The experimental site is under the Dinajpur Sadar Upazila and is located at 25.13 °N latitude, 88.23 °E longitude, and 37.5 m above the mean sea level (Appendix-1). The land belongs to the Old Himalayan Piedmont Plain (AEZ-1) (UNDP, 1988). The topography of the field was medium-high.

3.2 Climate and weather

The experimental area belongs to a sub-tropical climate zone. Usually, the rainfall is heavy during the kharif season (April-September) and scanty in the Rabi season (October-March). The temperature was moderate during the kharif season. Weather information regarding air temperature (°C), rainfall (mm), and relative humidity (%) at the experiment site during the study period is presented in Appendix-II.

3.3 Soil

The land of the experiment was conducted medium-high land belonging to the non-calcareous dark gray floodplain soil under Old Himalayan Piedmont Plain. The soil is sandy loam under the order Inceptisol. The general characteristics of soil are presented in Table

Table: 3.3.1 Morphological, physical, and chemical characteristics of the experimental soil

A. Morphological characteristics

Location	Soil Science Research Field, HSTU, Dinajpur
AEZ	Old Himalayan Piedmont Plain
General type of soil	Non-calcareous brown floodplain soil
Parent material	Piedmont alluvium
Drainage	Moderately well-drained
Topography	High land
Flood level	Above floodplain

B. Physical characteristics

Sand (%)	51.2
Silt (%)	36.0
Clay (%)	12.8
Textural class	Sandy Loam
Particle density (g/cm^3)	2.3

C. Chemical characteristics

pH	6.5
Organic matter (%)	0.7
Total N (%)	0.02
Available P (ppm)	21.4
Exchangeable K (m. eq./100 g soil)	0.1
Available S (ppm)	8.8
Particle density (g/ cm^3)	2.3
Organic carbon	0.4

3.4 Planting materials

BRAC seed Sufi Dherosh was used for the experiment. This variety was used during the Kharif-II (June to September). Seed was collected from the local market, Dinajpur Sadar.

3.5 Land preparation

The land was opened on 15 May 2023 by a tractor and prepared thoroughly by plowing and cross plowing with a power tiller and country plow. Finally, each plot was prepared by laddering. Each block was divided into six-unit plots as treatments with raised bunds around. The unit plot size was 1 m^2 (1m × 1m). The distances between the two blocks and two plots were 50 cm and 25 cm, respectively.

3.6 Seed sowing

Okra seeds were sowing in the field at mid-June. The seed rate of okra should be required 4-5 kg ha^{-1} (12-20 gm/decimal), plant to plant spacing was maintained at 40 cm and row to row distance was maintained 60 cm (Krishi-Projukti-Hatboi, 2019).

3.7 Application of Vermicompost and chemical fertilizers

The full dose of Vermicompost as per treatments was added 2 days before transplanting. The full doses of TSP, MOP, and Gypsum were applied during the final land preparation. Urea was applied in the three equal splits: the first split after 10 days of transplanting, the second split as top dressing after 30 days of transplanting while third one after 45 days of transplanting (before panicle initiation stage).

3.8 Nutrient composition of VC

The nutrient compositions of the VC used in this experiment were as follows:

Name of organic manure	Nutrient content (%)		
	N	P	K
VC	1.5	2.5	1.3

3.9 Experimental design and treatments

The experiment was laid out in the Randomized Complete Block Design (RCBD) and six treatment combinations were replicated three times. The treatment combinations were as follows:

T_1 = Control

T_2 = 100% recommended dose of fertilizer (RDF)

T_3 = 75% RDF + 1 t ha^{-1} Vermicompost

T_4 = 50% RDF + 2.5 t ha^{-1} Vermicompost

T_5 = 25% RDF + 5.0 t ha^{-1} Vermicompost

T_6 = 7.5 t ha^{-1} Vermicompost

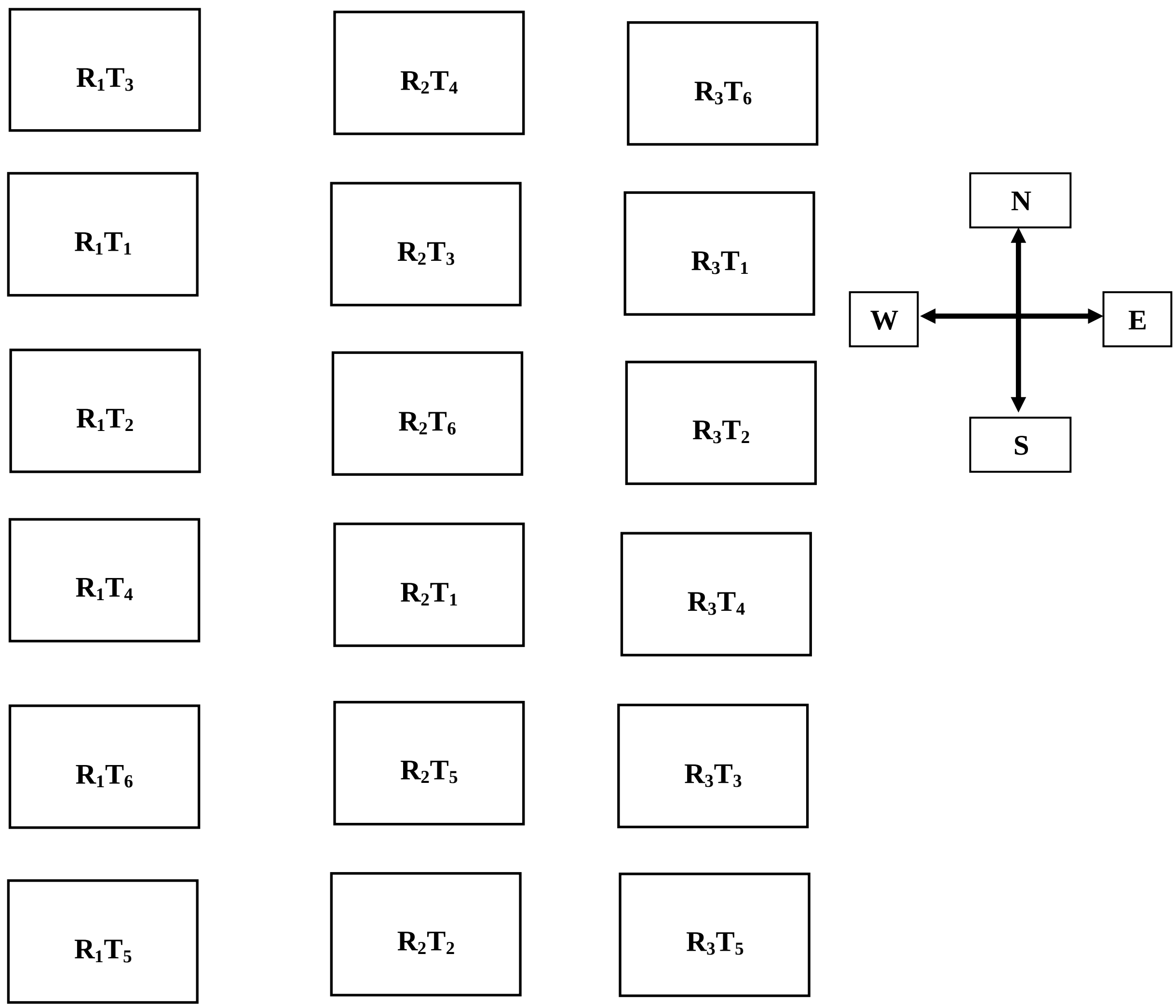
The recommended doses of fertilizer (RDF) for Dherosh cultivation in the experiment were as follows

Fertilizer	Doses (kg ha^{-1})
Urea	150
TSP	100
Mop	150
Gypsum	40

3.10 Layout of the experiment plots

Total number of plots	: 18
Individual plot size	: 1 m² (1 m × 1 m)
Space between row to row	: 60 cm
Space between plant to plant	: 40 cm
Treatment	: 6
Replication	: 3

The layout of the experiment field is shown in the figure



3.11 Intercultural operations

Intensive care was taken during the growing period to ensure adequate growth and development of the crop, which are given below:

3.11.1 Weeding

Weeding was done by nirani at 15, 30 and 45 days after sowing (DAS) of seeds to keep the plots free from any weeds.

3.11.2 Irrigation

The plots were irrigated from deep tube-well as needed during the growing period of the crop.

3.11.3 Insect and pest control

Insect infestation was a severe problem during the establishment of seedlings in the field. Although Setara 550 EC + Emamectin Benzoate 5 % SG was applied during final land preparation, few young plants were damaged due to mole cricket and cut worm attacks. Twenty-six cutworms were controlled mechanically and by spraying Darsban 29 EC @ 3%. Some discolored and yellowish diseased leaves were also collected from the plant and removed from the field.

3.12 Harvesting

Fruits were harvested at 3-4 days intervals based on eating and/or marketable quality. Harvesting was started on 26 July 2023 and was continued until18 September 2023.

3.13 Data collection

Three plants were selected randomly and tagged in each plot at different DAS to collect data on several growth and yield parameters. The following data were collected and presented in the subheading.

3.13.1 Plant height (cm)

Plant height was recorded manually from ground levels to the top of the leaves from the three tagged plants of each plot at 15, 30, 45, 60, 75 and 90 DAS, and the mean was calculated at different DAS.

3.13.2 Root length (cm)

Root length was recorded manually after harvesting from three selected plants, and the mean was calculated.

3.13.3 Number of fruits per plant

The number of pods per plant was counted from the total plants for the whole growing period, and the average number of pods produced per plant was recorded and expressed in pods per plant.

3.13.4 Fruit length (cm)

The length of the pod was measured with a meter scale from the neck of the fruit to the bottom of fruits each marketable fruit per plot and their average was taken and expressed in cm.

3.13.5 Weight of fruit

The weight of individual pods was measured with a digital weighing machine at 45, 47, 50, 53, 56, 59, 62, 65, 68, 71, 75, 80, 85 and 90 DAS from each marketable fruit from each plot, and their average was taken and expressed in grams.

3.13.6 Yield per plant

Yield of okra per pot was recorded as the whole fruit per pot by a digital weighing machine for the whole growing period and was expressed in gram.

3.14 Collection and preparation of soil sample

3.14.1 Initial soil sample

The initial soil sample was collected from the plow depth layer (0-15). Three samples were taken by auger from 9 locations covering the whole experimental plot and mixed thoroughly to make a composite sample. The composite sample was sun-dried, grounded, sieved, and stored in a plastic bag for physical and chemical analyses.

3.14.2 Post-harvest soil sample

After harvested the crop 6 soil samples were collected from each plot at 0-15 cm depth. The soil samples were sun-dried, grounded, and sieved. Prepared soil samples were stored in plastic.

3.15 Analysis of soil sample

Initial and post-harvest soil sample for physical and chemical properties were analyzed in the laboratory of the Department of Soil Science, HSTU, Dinajpur. The following analysis of the soil sample was done-

- Particle density
- Particle size analysis
- Soil pH
- Organic matter (OM)
- Total nitrogen (N)
- Available phosphorus (P)
- Exchangeable potassium (K)
- Available sulfur (S)

3.15.1 Particle density

Particle density was determined by volumetric flask method (Black, 1965). The particle density was determined by using following formula:

$$\text{Particle density} = \frac{\text{Weight of solid (g)}}{\text{Volume of soil solids (cm}^3\text{)}}$$

3.15.2 Particle size analysis

Particle size analysis was done by the hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the results for % sand, % silt, and % clay in the Marshall's Triangular Coordinate following the USDA system.

3.15.3 Soil pH

Soil pH was determined by using a glass electrode pH meter using 1:2.5 soil to water ratio. The suspension was allowed to stand for one hour after occasional shaking before determination (Jackson, 1967).

3.15.4 Organic matter (OM)

Soil organic carbon content was determined by wet oxidation method using $K_2Cr_2O_7$ and H_2SO_4 mixture and $FeSO_4$ solution was used for titration as outlined by Jackson (1967). The organic matter content was calculated by multiplying the percent organic carbon with the van Bemmelen factor of 1.724 (Piper, 1950).

3.15.5 Total nitrogen (N)

Total N content was determined by Micro-Kjeldahl method where soil was digested with 3 ml concentrated H_2SO_4 and 1:1 g catalyst mixture $K_2Cr_2O_7$:$CuSO_4.5H_2O$: Se) powder in the ratio of (100:10:1). Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of distillate trapped in H_3BO_3 with 0.01NH_2SO_4 (Page *et al.*,1989).

3.15.6 Available phosphorus (P)

Available P was extracted from the soil with 0.5 M sodium bicarbonate solution at pH 5.89 (Olsen, 1954). P in the extract was then determined by developing blue color with $SnCl_2$ reduction of phospho-molybdate complex and the color intensity was measured calorimetrically at 600 nm wavelengths (Page *et al.*, 1989).

3.15.7 Exchangeable potassium (K)

Exchangeable K was determined from the ammonium acetate extract using flame photometer as described by Page *et al.*, (1989).

3.15.8 Available sulfur (S)

Available S was determined by extracting the soil sample with $CaCl_2$ extraction method. The S content in the extract was estimated by turbidimetric method and the intensity of the turbid was measured by spectrophotometer at 420 nm wave length (Cihacek *et al.*, 2015).

3.16 Statistical analysis

Data obtained from the experiment were analyzed statistically following the ANOVA technique and the treatment means of different characters were compared following Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The effect of Vermicompost and chemical fertilizers on the growth and yield of okra was discussed in this chapter. The result has been discussed and possible explanations have been given under the following headings.

4.1 Growth and yield component characteristics

Growth and yield component characters such as plant height, number of leaves plant, number of fruits plant, fruit length, fruit weight, fresh shoot weight, and dry shoot weight were recorded in a trial.

4.1.1 Plant height

Application of chemical fertilizers and Vermicompost shows no signification in plant height of okra at 15 DAS transplantation. But significant variation was observed in plant height of okra at 30, 45, 60, 75, and 90 DAS due to application of chemical fertilizers and Vermicompost. At 15 DAS the highest plant height (26.8 cm) was observed in T_2 treatment when 100% RDF applied which was statistically similar to T_5 (23.5 cm), T_6 (23.5 cm), T_3 (23.3 cm), T_4 (23.0 cm), and T_1 (21.7 cm). The lowest plant height (21.7 cm) found in T_1 (control) treatment. At 30 DAS the minimum plant height (42.4 cm). The maximum plant height (53.3 cm) was found in T_3 treatment when 75% RDF and 1 t ha^{-1} vermicompost which was statistically identical to T_2 (53.1 cm), T_5 (49.7 cm), T_4 (48.5 cm) T_6 (47.3cm). At 45 DAS highest plant height (63.1 cm) was observed in T_3 treatment which is statistically similar to T_2 (60.4 cm), T_6 (58.8 cm), T_4 (58.2 cm), T_5 (58.2 cm). The lowest plant height (50.2 cm) was found in T_1 (control) treatment. At 60 DAS maximum plant height (78.0 cm) was recoded in T_3 treatment which is statistically identical to T_2 (73.6 cm), T_5 (72.9 cm), T_4 (68.9 cm), T_6 (68.3 cm). The minimum plant height (67.8 cm) was found in T_1 treatment. At 75 DAS lowest plant height (80.0 cm) observed in T_1 (control) treatment. The highest plant height (93.2 cm) was observed in T_3 treatment which is statistically similar to T_2 (92 cm), T_6 (58.8 cm), T_5 (88.7 cm), T_4 (82.5 cm). At 90 DAS the maximum plant height (96 cm) was recoded in T_3 treatment when 75% RDF and 1 t ha^{-1} vermicompost which was statistically identical to T_2 (94.7 cm), T_5 (90.2 cm), T_4 (89.8 cm), T_6 (83.1 cm). The minimum plant height (81.7 cm) found in T_1 (control) treatment. This result was similar to the findings of Bucagu *et al.*, (2017) found that application of organic fertilizers significantly increased plant height.

Table 4.1 Effect of vermicompost and inorganic fertilizer on plant height of okra

Treatments	Plant height (cm)					
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
T_1	21.7	42.4 d	50.2 b	67.8 d	80.0 b	81.7 c
T_2	26.8	53.1 ab	60.4 a	73.6 ab	92.0 a	94.7 a
T_3	23.3	53.3 a	63.1 a	78.0 a	93.2 a	96.0 a
T_4	23.0	48.5 c	58.2 a	68.9 bcd	82.5 b	89.8 b
T_5	23.5	49.7 bc	58.2 a	72.9 bc	88.7 a	90.2 b
T_6	23.5	47.3 c	58.8 a	68.3 cd	81.5 b	83.1 c
SEM	1.0	1.1	2.2	1.4	1.6	1.1
CV %	7.67	3.98	6.55	3.57	3.38	2.15
LS	NS	**	*	**	**	**

* = 5% level of significance; ** = 1% level of significance; SEM = Standard error of mean; CV (%) = Coefficient of variation; NS = Non significance; LS= Level of significant

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

Where:

T_1 = Control

T_2 = 100% recommended dose of fertilizer (RDF)

T_3 = 75% RDF + 1 t ha^{-1} Vermicompost

T_4 = 50% RDF + 2.5 t ha^{-1} Vermicompost

T_5 = 25% RDF + 5.0 t ha^{-1} Vermicompost

T_6 = 7.5 t ha^{-1} Vermicompost

4.1.2 Number of leaves plant^{-1}

Application of chemical fertilizers and vermicompost shows no signification variation in number of leaves plant^{-1} of okra at 20 DAS. At 20 DAS maximum number of leaves (6.0) was observed in T_5 treatment which is statistically similar to T_2 (5.6), T_4 (5.3 cm), T_6 (5.3 cm), T_3 (5.0). The minimum number of leaves (4) found in T_1 (control) treatment. Significant variation was found in number of leaves plant^{-1} of okra at 35 DAS. At 35 DAS the lowest number of leaves (7.6) found in T_1 (control) treatment. The highest number of leaves (13) was found in T_3 treatment which was statistically identical to T_2 (12.3), T_5 (11.4), T_4 (11.3) and T_6 (9.3). The finding was identical to Chavan *et al.*, (2015) showed that the number of leaves plant^{-1}.

Table 4.2 Effect of vermicompost and inorganic fertilizer on number of leaves plant^{-1}

Treatments	20 DAS	35 DAS
T_1	4.6	7.6 b
T_2	5.6	12.3 a
T_3	5.0	13.0 a
T_4	5.3	11.3 a
T_5	6.0	11.4 a
T_6	5.3	9.3 b
SEM	0.2	0.5
CV %	8.3	8.5
LS	NS	**

** = 1% level of significance; SEM = Standard error of mean; CV (%) = Coefficient of variation; NS = Non significance; LS= Level of significant

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

Where:

T_1 = Control

T_2 = 100% recommended dose of fertilizer (RDF)

T_3 = 75% RDF + 1 t ha^{-1} Vermicompost

T_4 = 50% RDF + 2.5 t ha^{-1} Vermicompost

T_5 = 25% RDF + 5.0 t ha^{-1} Vermicompost

T_6 = 7.5 t ha^{-1} Vermicompost

4.1.3 Fruit weight plot^{-1}

Significant variation was found in fruit weight plot^{-1} of okra at 42, 49, 56, 63, 69, 75, 80, 85, and 90 DAS due to application of chemical fertilizers and Vermicompost. At 42 DAS highest fruit weight plot^{-1} (76.3 g) was observed in T_3 treatment which is statistically similar to T_4 (75.3 g), T_2 (73.3 g), T_5 (63 g), T_6 (53.3 g). The lowest fruit weight plot^{-1} (44.3 g) found in T_1 (control) treatment. At 49 DAS lowest fruit weight plot^{-1} (129 g) found in T_1 (control) treatment. The highest fruit weight plot^{-1} (172.3 g) was found in T_2 treatment which is statistically identical to T_4 (168 g), T_3 (165.3 g), T_5 (149 g), and T_6 (140.6 g). At 56 DAS maximum fruit weight plot^{-1} (222.3 g) was observed in T_3 treatment which was statistically similar to T_4 (208.3 g), T_2 (193.6 g), T_5 (189.6 g), T_6 (150 g). The minimum fruit weight plot^{-1} (115 g) found in T_1 (control) treatment. At 63 DAS highest fruit weight plot^{-1} (355.6 g) was observed in T_3 treatment which is statistically similar to T_2 (337.6 g), T_4 (318.3 g), T_5 (296.3 g) and T_6 (222.3 g). The lowest fruit weight plot^{-1} (177.6 g) observed in T_1 (control) treatment. At 69 DAS minimum fruit weight plot^{-1} (124.3 g) found in T_1 (control) treatment. The maximum fruit weight plot^{-1} (243.6 g) was found T_3 treatment which is statistically identical to T_2 (240.6 g), T_4 (232.6 g), T_5 (210.3 g) and T_6 (185 g). At 75 DAS highest fruit weight plot^{-1} (129 g) was found in T_2 treatment which was statistically similar to T_3 (123.3 g), T_4 (122.6 g), T_5 (109 g) and T_6 (104 g). The lowest fruit weight plot^{-1} (83.3 g) observed in T_1 (control) treatment. At 80 DAS minimum fruit weight plot^{-1} (124.3 g) found in T_1 (control) treatment. The maximum fruit weight plot^{-1} (127.6 g) was found in T_3 treatment which was statistically identical to T_4 (232.6 g), T_2 (123.3 g), T_5 (115.6 g) and T_6 (112.3 g). At 85 DAS highest fruit weight plot^{-1} (122.6 g) was observed in T_3 treatment which is statistically similar to T_2 (122 g), T_4 (119.6 g), T_5 (119g) and T_6 (108.6 g). The lowest fruit weight plot^{-1} (93.3 g) observed in T_1 (control) treatment. At 90 DAS minimum fruit weight plot^{-1} (84.6 g) found in T_1 (control) treatment. The maximum fruit weight plot^{-1} (122.3 g) was found in T_3 treatment which was statistically identical to T_4 (122 g), T_5 (118.6 g), T_2 (111.6 g) and T_6 (108.6 g). The results revealed that Akinmutimi *et al*, (2021), gave the highest values of fresh fruit weight.

4.1.4 Total Fruit weight plot^{-1} (kg)

There was significant variation observed in total fruit weight plot^{-1} when chemical fertilizers and vermicompost was applied. The maximum total fruit weight plot^{-1} (1.5 kg) was found in T_3 treatment. The minimum total fruit weight plot^{-1} (0.9 kg) observed in T_1 (control) treatment.

Table 4.3 Effect of vermicompost and inorganic fertilizer on the fruit weight plot^{-1}, total fruit weight Plot^{-1} of okra

Treatments	Fruit weight plot^{-1}(g)									Total Fruit weight Plot^{-1} (kg)
	42 DAS	49 DAS	56 DAS	63 DAS	69 DAS	75 DAS	80 DAS	85 DAS	90 DAS	
T_1	44.3 d	129.0 e	115.0 e	177.6 f	124.3d	83.3 c	87.6 c	93.3 c	84.6 c	0.9 e
T_2	73.3 a	172.3 a	193.6 bc	337.6 b	240.67 a	129.0 a	123.3 a	122 a	111.6ab	1.5 b
T_3	76.3 a	165.3 b	222.3 a	355.6 a	243.6 a	123.3 a	127.6 a	122.6 a	122.3 a	1.5 a
T_4	75.3 a	168.0 ab	208.3 ab	318.3 c	232.6 a	122.6 a	125.6 a	119.6 ab	122.0 a	1.4 b
T_5	63.0 b	149.0 c	189.6 c	296.3 d	210.3b	109.0 b	115.6 b	119.0 ab	118.6 a	1.3 c
T_6	53.3 c	140.6 d	150.0 d	222.3 e	185 c	104 b	112.0 b	108.6 b	98.3 b	1.1 d
SEM	1.2	1.4	4.7	5.0	3.7	3.6	2.1	3.8	4.2	0.01
CV %	3.3	1.6	4.5	3.1	3.1	5.7	3.2	5.8	6.7	1.67
LS	**	**	**	**	**	**	**	**	**	**

** = 1% level of significance; SEM = Standard error of mean; CV (%) = Coefficient of variation; NS = Non significance; LS= Level of significant

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

Where:

T_1 = Control

T_2 = 100% recommended dose of fertilizer (RDF)

T_3 = 75% RDF + 1 t ha^{-1} Vermicompost

T_4 = 50% RDF + 2.5 t ha^{-1} Vermicompost

T_5 = 25% RDF + 5.0 t ha^{-1} Vermicompost

T_6 = 7.5 t ha^{-1} Vermicompost

4.2 Fruits yield of okra

4.2.1 Number of fruits plant^{-1}

Significant variation was observed in number of fruits plant^{-1} when chemical fertilizers and Vermicompost was applied. The maximum number of fruits plant^{-1} (18) was found in T_3 treatment which was statistically identical to T_2 (17), T_4 (16), T_5 (15), T_6 (14). The minimum number of fruits plant^{-1} (11) observed in T_1 (control) treatment. This result supported that Akinmutimi *et al.,* (2021), respectively gave the highest values of number of fruits plant^{-1}.

4.2.2 Individual fruit weight

Application of chemical fertilizers and vermicompost shows no signification variation in individual fruit weight of okra. The maximum individual fruit weight (14.9) was found in T_4 treatment which was statistically identical to T_5(14.9), T_2 (14.7), T_3 (14.4), T_6 (14.0). The minimum individual fruit weight (13.8) observed in T_1 (control) treatment.

4.2.3 Fruit length of okra

There was significant variation observed in fruit length of okra when chemical fertilizers and vermicompost was applied. The lowest fruit length of okra (13.8 cm) observed in T_1 (control) treatment. The highest fruit length of okra (14.9 cm) was found in T_4 50% RDF and 2.5 t ha^{-1} vermicompost was applied. Islam *et al.,* (2016) who observed the application vermicompost-fertilized bush bean (*Phaseolus vulgaris*) plants produced the highest levels of pod length.

Table 4.4 Effect of vermicompost and chemical fertilizer on Number of fruits plant^{-1}, Individual fruit weight (g), fruit length (cm) of okra

Treatments	No. of fruits plant^{-1}	Individual fruit weight (g)	Fruit length (cm) of okra
T_1	11 d	13.8	13.2 d
T_2	17 a	14.7	15.2 bc
T_3	18 a	14.4	16.1 a
T_4	16 ab	14.9	15.0 bc
T_5	15 bc	14.9	15.5 ab
T_6	14 c	14.0	14.6 c
SEM	0.43	0.44	0.24
CV%	4.8	5.2	2.7
LS	**	NS	**

* = 5% level of significance; ** = 1% level of significance; SEM = Standard error of mean; CV (%) = Coefficient of variation; NS = Non significance; LS= Level of significant

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

Where:

T_1 = Control

T_2 = 100% recommended dose of fertilizer (RDF)

T_3 = 75% RDF + 1 t ha^{-1} Vermicompost

T_4 = 50% RDF + 2.5 t ha^{-1} Vermicompost

T_5 = 25% RDF + 5.0 t ha^{-1} Vermicompost

T_6 = 7.5 t ha^{-1} Vermicompost

4.3 Root length

The treatment showed significant variation in the root length when chemical fertilizers and Vermicompost was applied. The maximum root length in (24.2 cm) found in T_3 treatment. The minimum root length (16.4 cm) observed in T_1 (control) treatment. This result supported Baliah and Muthulakshmi (2017) reported that microbially enriched Vermicompost significantly impacted the growth of Okra (*Abelmoschus esculentus* (L) root length were significantly higher.

4.4 Biomass production of okra

4.4.1 Fresh shoot biomass plant^{-1}

Significant variation was observed in fresh shoot biomass plant^{-1} when chemical fertilizers and Vermicompost was applied. The lowest fresh shoot biomass plant^{-1} (168.6 g) observed in T_1 (control) treatment. The highest fresh shoot biomass plant^{-1} in (233.3 g) found in T_3 treatment. The results revealed that Islam *et al.*, (2016) observed that application of vermicompost-fertilized bush bean (*Phaseolus vulgaris*) plants produced the highest levels of fresh biomass.

4.4.2 Dry shoot biomass plant^{-1}

Application of chemical fertilizers and Vermicompost shows signification variation in dry shoot biomass plant^{-1} of okra. The maximum dry shoot biomass plant^{-1} in (35 g) found in T_3 treatment. The minimum dry shoot biomass plant^{-1} (25.2 g) observed in T_1 (control) treatment.

Table 4.5 Effect of vermicompost and chemical fertilizer on root length, fresh shoot biomass plant^{-1}, dry shoot biomass plant^{-1} of okra

Treatments	Root length (cm)	Fresh shoot biomass plant^{-1} (g)	Dry shoot biomass plant^{-1} (g)
T_1	16.4 b	168.6 e	25.2 e
T_2	23.2 a	218.0 b	32.7 b
T_3	24.2 a	233.3 a	35.0 a
T_4	23.6 a	200.0 c	30.0 c
T_5	23.7 a	222.2 b	33.3 b
T_6	24.2 a	177.7 d	26.6 d
SEM	0.45	1.61	0.24
CV%	2.7	1.3	1.3
LS	**	**	**

** = 1% level of significance; SEM = Standard error of mean; CV (%) = Coefficient of variation; NS = Non significance; LS= Level of significant

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

Where:

T_1 = Control

T_2 = 100% recommended dose of fertilizer (RDF)

T_3 = 75% RDF + 1 t ha^{-1} Vermicompost

T_4 = 50% RDF + 2.5 t ha^{-1} Vermicompost

T_5 = 25% RDF + 5.0 t ha^{-1} Vermicompost

T_6 = 7.5 t ha^{-1} Vermicompost

4.5 Soil properties

4.5.1 Soil pH

In post-harvest soil, the highest amount of pH was found in T_1 (6.6) and lowest amount was observed in T_4 (6). This result Reena *et al.,* (2017) reported that the application of Vermicompost in combination resulted in a slight increase in pH 7.40.

4.5.2 Particle density

In post-harvest soil, the maximum amount of PD was found in T_2 (2.4) and minimum amount was observed in T_6 (2). Identical findings were also observed by Yadav *et al.,* (2022).

4.5.3 Organic carbon content

It was noted that the minimum amount of organic carbon content in treatment T_2 (0.4 %) was due to the application of vermicompost and the maximum amount of organic carbon content (0.7%) was recorded in treatment T_6. This result supported was Gopinath *et al.* (2009), plots amended with vermicompost had higher soil organic carbon levels than those treated with mineral fertilizer.

4.5.4 Organic matter content

It was observed that the highest amount of organic matter content in treatment T_6 (1.3%) was due to the application of vermicompost and the lowest amount of organic matter content (0.7%) was recorded in treatment T_2.

4.6 Post-harvest soil properties

4.6.1 Total Nitrogen

The highest amount of nitrogen was found in the treatment T_6 (0.067 %) and the lowest amount of nitrogen was found in T_1 (0.018%). This result was in agreement with Uwah *et al.* (2010) nitrogen had significant effects on plant height, number of leaves.

4.5.2 Available Phosphorus

The maximum amount of phosphorus was observed in T_6 (53.1 ppm). The minimum amount of available phosphorus was found in the treatment T_1 (14.8 ppm). This result was in agreement with Ola *et al.,* (2017) who experienced that organic fertilizer positive effect on available P in soil.

4.6.3 Exchangeable Potassium

The highest amount of available potassium was recorded in the treatment T_5 (0.16 m. eq. /100 g soil) and the lowest amount of potassium was found in T_1 (0.12 m. eq /100 g soil). Similar result was obtained by Yadav *et al.,* (2022).

4.6.4 Available Sulfur

The lowest amount of available sulfur was found in the treatment T_1 (8.4 ppm). The highest amount of sulfur was found in T_6 (13.7 ppm). Similar result was obtained by Prity *et al.,* (2023).

Table 4.6 Effect of vermicompost and inorganic fertilizer on Soil analysis after harvesting

Treatments	Particle density (g cm^{-3})	pH	Organic carbon (%)	Organic matter (%)	Total N (%)	Available P (ppm)	Exchangeable K (m. eq 100 g^{-1} soil)	Available S (ppm)
T_1	2.4 a	6.6 a	0.5 e	0.8 e	0.018 e	14.8 e	0.120 d	8.4 e
T_2	2.3 b	6.4 b	0.4 f	0.7 f	0.026d	33.8 d	0.125 c	9.7 d
T_3	2.2 c	6.3 c	0.5 d	0.9 d	0.033c	39.7 c	0.131 b	9.8 d
T_4	2.2 d	6.0 f	0.6 c	1.0 a	0.056b	40.5 c	0.132 b	10.2 c
T_5	2.1 e	6.2 d	0.6 b	1.1 b	0.056b	45.4 b	0.164 a	12.9 b
T_6	2.0 f	6.1 e	0.7 a	1.3 a	0.060a	53.1 a	0.165 a	13.7 a
Initial soil	2.3	6.5	0.4	0.7	0.02	21.4	0.14	8.8
SEM	0.003	0.009	0.006	0.0105	0.0013	0.415	0.0010	0.1207
CV %	0.3	0.2	1.7	1.7	5.4	1.9	1.2	1.9
LS	**	**	**	**	**	**	**	**

** = 1% level of significance; SEM = Standard error of mean; CV (%) = Coefficient of variation; NS = Non significance; LS= Level of significant

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

Where:

T_1 = Control

T_2 = 100% recommended dose of fertilizer (RDF)

T_3 = 75% RDF + 1 t ha^{-1} Vermicompost

T_4 = 50% RDF + 2.5 t ha^{-1} Vermicompost

T_5 = 25% RDF + 5.0 t ha^{-1} Vermicompost

T_6 = 7.5 t ha^{-1} Vermicompost

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Soil Science Research Field, Hajee Mohammad Danesh Science and Technology University, Dinajpur, from May 2023 to September 2023. The experiment was laid out in a Randomized Complete Block Design (RCBD) with six treatments and three replications. The size of the unit plot was 1m×1m ($1m^2$) the spacing between blocks was 50 cm and the plot to plot was 25 cm. Six fertilizer treatments were used which were T_1 = Control (No fertilizer application), T_2 = (100% RDF), T_3 = (75% RDF + 1 t ha^{-1} vermicompost), T_4 = (50% RDF + 2.5 t ha^{-1} vermicompost), T_5 = (25% RDF + 5.0 t ha^{-1} vermicompost), T_6 = (7.5 t ha^{-1} vermicompost). The fertilizers were distributed according to the treatment in individual plots. The total numbers of plots were 18 (6×3). NPK were applied as urea, TSP, and MoP, gypsum at the rate of 150, 100, 150 and 40 kg ha^{-1}, respectively. The okra seeds were sown in the main field on 18 June 2023. Intercultural operations such as weeding and irrigation were done whenever required to support the normal growth of the plant. Fruits harvesting was done from July to September. During the experiment observations were recorded on plant height, number of leaves $plant^{-1}$, fruit weight $plot^{-1}$, no. of fruits $plant^{-1}$, fruit length (cm). The data were analyzed by using the SPPS program for interpretation of the results.

The tallest plant height at 30, 45, 60, 75, and 90 DAS was obtained (53.3 63.1, 78.0, 93.2 and 96cm respectively) from T_3, whereas the shortest plant height (42.4, 50.2, 67.8, 80.0 and 81.7 cm, respectively) was obtained from T_1. The maximum number of leaves at 20, and 35, DAS were recorded (6 and 12, respectively) from T_5 and the minimum number of leaves (4.6, 7.6, respectively) were obtained from T_1. The highest fruit weight $plot^{-1}$ at 42, 56, 63, 69, 75, 80, 85, and 90 DAS (76.3, 172.3, 222.3, 355.6, 243.6, 129, 127.6, 122.6 and 122.3 g) was obtained from treatment T_3 and lowest (44.3, 115, 177.6, 124.3, 83.3, 124.3, 93.3. 84.6 g) were recorded from the treatment T_1. The maximum no. of fruits $plant^{-1}$ (18) was obtained from treatment T_3 and minimum (11) were obtained from T_1. The highest fruit length (14.9 cm) was obtained from treatment T_4 and minimum (13.8 cm) were obtained from T_1. The highest total fruit weight $plot^{-1}$ (1.5 kg) of fruit was obtained from treatment T_3, whereas the lowest fruit weight (0.9 kg) was observed from the control treatment (T_1).

The present study strongly agrees with the above results and it was concluded that the use of vermicompost will certainly enhance the yield of Okra. The results suggested that the effects of vermicompost were more efficient than chemical fertilizers for the production of okra. This research recommended show vermicompost is a new Technology, the environmentally-friendly process used to treat organic waste. The resulting vermicompost has been shown to have several positive impacts on plant growth and yield. This organic fertilizer is therefore increasingly considered in agriculture as a promising alternative to inorganic fertilizers. By this, the farmers can save money using vermicompost besides inorganic fertilizer being able to get more yield as well as economic solvency which has no health hazards and eco-friendly in national aspect. Based on the result of the present study it was found that the application of 75% RDF and 1 t ha^{-1} vermicompost doses performed the highest yield of Okra. The importance of vermicompost is to promote and increase the yield of Okra, on the other hand, it maintains the soil health and its ability to provide the crops with nutrients and also improves the chemical properties of soil. Vermicompost besides inorganic fertilizer produced more yield when compared to the inorganic fertilizer. Also combined application significantly increases the soil properties like total N, available P, exchangeable K, available S, organic carbon, organic matter in the soil and decrease in pH, particle density of soil to some extent. Which will significantly increase the yield contributing characteristics of next crops cultivation in a sustainable way.

5.1 Recommendations

- Combined application of 75% RDF and 1 t ha^{-1} vermicompost can significantly increase the growth and yield of okra and vermicompost doses performed the highest yield of okra.
- Further study is needed to be repeated in different agroecological zones (AEZ) of Bangladesh for the evaluation of regional adaptability.

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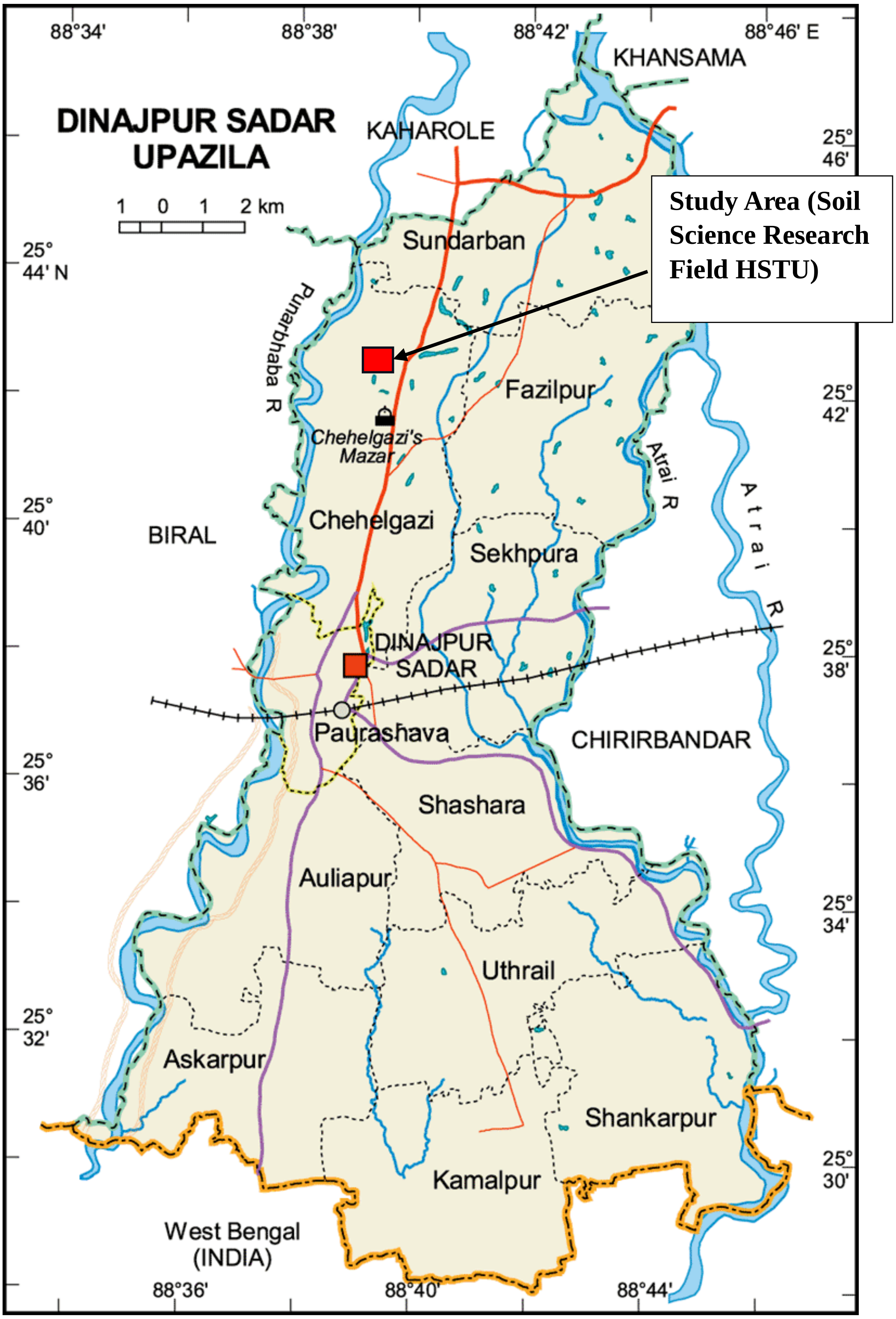
APPENDICES

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



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

Year	Month	**Air Temperature (0C)		**Relative Humidity (%)	**Rainfall (mm)
		Maximum	Minimum		
2023	May	32.6	23.0	76	232.5
	June	32.7	25.5	82	335.3
	July	31.8	25.5	84	433.6
	August	32.1	26.0	84	387.7
	September	31.5	25.1	85	383.8

** Monthly average

Source Bangladesh Meteorological Department

Appendix III. Some photographs during research period