EFFECT OF DIFFERENT ORGANIC FERTILIZERS ON THE GROWTH OF SPINACH (*Spinacia oleracea* L.)

A THESIS

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PROGGA ASHRABI

Student No. 1601401

Session: 2021-2022

Thesis Semester: January - June, 2023

MASTER OF SCIENCE (M.S.)

IN

SOIL SCIENCE

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DEPARTMENT OF SOIL SCIENCE

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR, BANGLADESH

DECEMBER 2023

DEDICATED

TO MY

BELOVED PARENTS

AND HUSBAND

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The Authoress

EFFECT OF DIFFERENT ORGANIC FERTILIZERS ON THE GROWTH OF SPINACH (*Spinacia oleracea* L.)

ABSTRACT

A field experiment was conducted at Soil Science Research Field, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh December 2022 to February 2023 aimed to evaluate the impact of various organic fertilizers on Spinach. The experiment comprises six (6) treatments, T_1 = Control, T_2 = Compost (2.5 t ha^{-1}), T_3 = Cow dung (5 t ha^{-1}), T_4 = Vermicompost (1 t ha^{-1}), T_5 = Bone meal (0.5 t ha^{-1}) and T_6 = Poultry manure (5 t ha^{-1}). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications, and the total plot number was 18. The data was collected on different growth parameters such as, plant height (cm), number of leaves per plant, shoot weight per plant (g), root weight per plant (g), and post-harvest soil analysis e.g., available S (ppm), available P (ppm), exchangeable K (meq 100 g^{-1} soil), total N (%), pH, electrical conductivity (dS m^{-1}). The findings indicated that T_6 exhibited the tallest plant height, measuring 7.83 cm and 57.66 cm at 30 DAS and 45 DAS respectively. Additionally, T_6 also displayed the highest number of leaves (20.90), as well as the greatest shoot and root weight (22.75 g and 1.07 g, respectively). T_6 also had the highest levels of available S (26.62 ppm) and exchangeable K (0.22 meq 100 g^{-1} soil), as well as the highest total N content (0.11%). Furthermore, T_6 had the highest pH (6.52) and EC (0.15 dS m^{-1}). Furthermore, the maximum concentration of P was 75.86 ppm, which was achieved from T_5. In contrast, the T_1 treatments exhibited the lowest values for all parameters. This included the shortest plant height, measuring 5 cm and 36.66 cm at 30 and 45 DAS respectively. Additionally, T_1 had the lowest number of leaves per plant (11.1), as well as the lowest shoot and root weight per plant (7.59 g and 0.31 g, respectively). T_1 also had the lowest levels of available S (13.28 ppm), available P (61.21 ppm), exchangeable K (0.14 meq 100 g^{-1} soil), total N (0.056 %), pH (6.1), and electrical conductivity (0.08 dS m^{-1}). PM 5 t ha^{-1} may be recommended for famers' field and further investigation for different AEZ need to be conducted.

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LIST OF ABBREVIATIONS AND ACRONYMS

et al.	and others
%	Percent
g	Gram
N	Nitrogen
P	Phosphorus
K	Potassium
pH	Potential of hydrogen
S	S
m^2	Square
BBS	Bangladesh Bureau of Statistics
TSP	Tripple super phosphate
MOP	Muriate of potash
OC	Organic Carbon
OM	Organic Matter
RCBD	Randomized Complete Block Design
AEZ	Agroecological zone
@	At the rate
HSTU	Hajee Mohammad Danesh Science and Technology University
DAS	Days after sowing
FAO	Food and Agriculture Organization
UNDP	United Nations Development Program
°C	Degree Celsius
LSD	Least Significant Difference
AEZ	Agroecological Zone
CV	Co-efficient of variance
t ha^{-1}	Ton per hector

CHAPTER I

INTRODUCTION

Spinach (*Spinacia oleracea*) is an edible flowering plant in the family Amaranthaceae native to central and western Asia. Its leaves are eaten as vegetables (Patel *et al.*, 2017). Raw spinach is 91% water, 4% carbohydrates, 3% protein, and contains negligible fat. In a 100 g (3.5 oz) serving providing only 23 calories, spinach has a high nutritional value, especially when fresh, frozen, steamed, or quickly boiled. It is a rich source (20% or more of the Daily Value) of vitamin A, vitamin C, vitamin K, magnesium, manganese, iron and folate. Spinach is a moderate source (10–19% of DV) of the B vitamins, riboflavin and vitamin B_6, vitamin E, calcium, K, and dietary fiber and many phytochemicals that maintain good health (Patel *et al.,* 2017). Green spinach was grown in Bangladesh in 1986–90 on an average area of 9123.40 acres with average production of 16766.40 MT and yield was 1.83 MT per acres. In the recent year 2012–2016 the green spinach average area, production and yield were increased to 20541 acres with an annual production of 45309.4 t and yield 2.20 MT per acres. Statistics shows that, the average production and total cultivable land of spinach in Bangladesh is increasing day by day which indicates its popularity (Sharmin *et al.*, 2018).

Soil fertility is one of the key factors that have a direct effect on the yield of horticultural crops (Sherchan and Karki, 2006), and low soil fertility is considered as one of the main factors responsible for the low productivity of vegetables (Hamden and Fadni, 2010). Spinach due to its shallow root system is more susceptible to nutrient deficiency than any other crops. Heavy feeder Spinach demands high nutrients N in particular, to grow rapidly and to ensure a high and profitable yield (Zaman *et al.*, 2018; Darshan *et al.*, 2019).

Moreover, there is evidence that crop yields have significantly decreased due to improper and less availability of nutrients with increasing aridity under changing climate (Du *et al.*, 2020; Ali *et al.*, 2022). Worldwide reduction in cultivable land by urbanization and industrialization is also leading to a food crisis. The Food and Agriculture Organization estimated that by 2050, feeding a world population of 9.1 billion would require approximately 70% more food than available at present (Béné *et al.*, 2015). Thus, for ensuring food security, there is a dire need for advanced technologies, modern cultural practices, and more productive cultivars (Fiaz *et al.*, 2018). Furthermore, the importance of N, P and K for spinach plant growth and metabolism has been investigated. So, excessive application of chemical fertilizers, to enhance growth rates and yield of crops, is a common agricultural practice in developing countries. But this extreme fertilizer application often leads to the accumulation of high levels of nitrates in plant tissue (Farrag *et al.*, 2009). Under such a scenario, N-containing organic substances could be utilized as an effective and economic alternative to expensive synthetic N fertilizers, with a documented potential to improve crop yields and soil properties (Naher *et al.*, 2020; Elkhlifi *et al.*, 2023).

Organic farming has become popular due to consumer concern with human health and the environment. However, organic fertilizer is a broad concept that includes agricultural residue, animal manure, compost, cow dung (Patra *et al.*, 2022), vermicompost (Joshi *et al.*, 2015), bone meal (Nogalska *et al.*, 2012) and PM (Farhad *et al.*, 2009). Compost is the product of fermentation of solid organic waste, used as fertilizer in agricultural farming, which is becoming a hot trend in the organic agricultural study (Hoang *et al.*, 2019). The addition of organic compost not only increases the quality and yield of agricultural products, but also enriches soil fertility, improves the physical and chemical property and microecological structure of the soil, and increases microbial diversity (Parwada *et al.*, 2020). The use of organic manure like PM was found useful in increasing crop production (Yılmaz *et al.*, 2020).

In recent times, PM has gained attention as a potential source of organic fertilizer due to its high nutrient content and relatively low cost, readily available at all times, environmentally friendly, and also has a residual effect and ability to improve soil structure compared with chemical fertilizers (Singh *et al.*, 2020). N is the major growth hampering mineral nutrient for agricultural crops across the globe (Mutale-Joan *et al.*, 2020). PM, which is rich in N, P, K, and other essential nutrients, has been shown to improve soil fertility, increase crop yield, and enhance the quality of agricultural products (Jansson and Hofmockel, 2020; Adekiya *et al.*, 2019).

Some researchers observed that the application of PM improved the availability of some minerals in the soil, and especially the transfer of nutrients from rangeland to the crop plant. Recently, Izunobi *et al.* (2002) reported that PM, especially those produced in deep litter or battery cage houses are the richest known farmyard manure supplying greater amounts of absorbable plant nutrients. Another researcher Amujoyegbe *et al.*, (2007) reported that PM increased the leaf area, total chlorophyll content and grain yield of maize and sorghum. According to Rayne and Aula (2020), PM mineralizes faster than other animal manure such as cattle or pig dung; hence it releases its nutrients for plant uptake and utilization rapidly and PM contains basic nutrients required for enhancing growth and yield of crops. Application of

PM increases carbon content, water holding capacity, aggregation of soil, and decreases bulk density (Cayci *et al.*, 2017). It also increases the water soluble and exchangeable K and magnesium which enhance crop yield (Dikinya and Mufwanzala, 2010). PM application increases soil N by more than 53%, while exchangeable cations are also increased significantly upon application (Adekiya *et al.*, 2019). The rate of PM applied may also influence the amount of nutrient released (soil chemical properties), growth, and yield of plant.

Judicious application of organic fertilizer is necessary for good growth of spinach. But a little information is available on the effect of different organic fertilizers on the growth of spinach. The present study was carried out to investigate the influence of different organic fertilizers on the growth of spinach. Considering the facts mentioned above, the present research has been undertaken with the following objectives:

1. To compare the effect of different organic fertilizer for spinach successful growth
2. To find out the effective organic fertilizer to grow organic spinach

CHAPTER II

REVIEW OF LITERATURE

2.1 Effect of compost

A greenhouse experiment was conducted by Machado *et al.* (2020) in a greenhouse located at University of Evora, Portugal to evaluate the effect of the addition of organic compost in combination with the inorganic N fertigation on growth, phytochemical accumulation, and antioxidant activity of spinach (*Spinacia oleracea* L. cv. Manatee). Soil blocked spinach seedlings (six seedlings per block), three blocks per pot (316 plants m^{-2}) were transplanted 18 days after emergence into 12 L pots. The treatments were: unfertilized soil, organic compost, organic compost +75 kg of N ha^{-1}, applied as ammonium sulfate; and organic compost +75 kg N ha^{-1}, applied as ammonium nitrate. The addition of organic compost to unfertilized soil increased the fresh yield. The application of inorganic N from the two sources in relation to organic compost treatment increased spinach fresh yield from 2.3 to 4.81 kg m^{-2} and shoot dry weight from 0.60 to 1,31 g $plant^{-1}$.

Jakhro *et al.* (2017) conducted a field to examine the production of spinach under varying levels of organic and inorganic fertilizers in a three replicated Randomized Complete Block Design at Sindh Agriculture University. The treatments included: T_1 = Control, T_2 = 50 kg N ha^{-1}, T_3 = 50 kg N + 4 t FYM ha^{-1}, T_4 = 50 kg N + 6 t FYM ha^{-1}, T_5 = 75 kg N ha^{-1}, T_6 = 75 kg N + 4 t FYM ha^{-1} and T_7 = 75 kg N + 6 t FYM ha^{-1} (FYM = Farmyard manure). The results revealed that spinach plantation nourished with 75 kg N + 6 t ha^{-1} FYM produced the plants of 37.42 cm height on average, produced 18.05 leaves $plant^{-1}$, 43.31 g fresh weight, took 23.33 days to first cutting, 23.47 cm leaf length and so on. The values for almost all the characters declined with decreasing N and FYM levels and spinach crop given 50 kg N ha^{-1} + 6 t ha^{-1} FYM. The treatment 50 kg N ha^{-1} + 4 t ha^{-1} FYM, 50 kg ha^{-1} N (without FYM) as well as control resulted in decline in value for all the traits investigated, minimum being in control. It was concluded that the spinach growth and yield as substantially higher under combined application of organic manures (FYM) in addition to inorganic N (as urea); and 75 kg N + 6 t ha^{-1} FYM resulted in optimum crop performance; while decrease in N, FYM or N application without FYM showed adverse impact on spinach yields.

Rahman *et al.* (2012) conducted the experiment to investigate the effects of bio compost, cow dung compost and NPK fertilizers on growth, yield and yield components of chili was randomized block design with three replications at Botanical Garden of Rajshahi University Campus, Bangladesh. There were 15 treatments viz. T_1 = bio compost (3 kg pot^{-1}) + NPK, T_2 = bio compost (2 kg pot^{-1}) + NPK, T_3 = bio compost (1.5 kg pot^{-1}) + NPK, T_4 = bio compost (3 kg pot^{-1}), T_5 = bio compost (2 kgpot^{-1}), T_6 = bio compost (1.5 kg pot^{-1}), T_7 = cow dung compost 3 kg pot^{-1} + NPK, T_8 = cow dung compost (2 kg pot^{-1}) + NPK, T_9 = cow dung compost (1.5 kg pot^{-1}) + NPK, T_{10} = cow dung compost (3 kg pot^{-1}), T_{11} = cow dung compost (2 kg pot^{-1}), T_{12} = cow dung compost (1.5 kg pot^{-1}), T_{13}= NPK, T_{14}= bacterial suspension, T_{15}= control (only soil). Bio compost and NPK significantly (p = 0.05) influenced the growth and yield of chili. The treatment bio compost (3 kg pot^{-1}) +NPK (T_1) produced the highest germination (%), vigor index, growth and yield of chili and the lowest yield and yield contributing parameters were recorded in control (T_{15}). The correlation matrix showed that yield per plant of chili had significant and positive correlation with plant height (r = 0.929**), leaf number (r = 0.808**), number of primary branch (r = 0.918**), secondary branch (r = 0.985**), root number (r = 0.953**), root length (r = 0.947**), total number of flower at maximum flowering time(r = 0.981**), total number of fruit (r = 0.966**), fruit length (r = 0.917**), fresh fruit weight (r = 0.990**), dry fruit weight (r = 0.800**), number of seed fruit^{-1} (r = 0.861**) and hundred seed weight (r = 0.954**) and yield was significant and negative correlation (r = -0.906**) with number of days required for first flower initiation. The results suggest that inorganic fertilizers (NPK) with bio compost (3 kg pot^{-1}) are suitable for better production of chili that may increase soil fertility and this integrated approach could contribute to improve crop production.

Akinfasoye *et al.* (2008) carried out experiment at National Horticultural Research Institute (NIHORT), Ibadan to investigate the effects of maize-stover compost fertilizer and plant spacing on the growth and shoot yield of *Celosia argentea* L. var. TLV8. Plants were spaced 15× 15 cm; 20 × 20 cm and 25 × 25 cm and the compost fertilizer were applied at 2, 4, and 6 t ha^{-1}. Each experiment was arranged in a split-plot design with three replications, and a control where compost was not applied was set up for each spacing treatment. All data were reported as means and analyzed combined across the two experiments. Spacing had no significant effect on plant height, stem, girth, number of leaves and cumulative shoot yield but leaf area, number of off shoots and dry matter yield were significantly affected. 25 × 25 cm spacing produced the highest number of offshoots whereas the largest leaf area and highest dry matter yield were obtained at 20 × 20 cm spacing. Compost rates significantly increased growth and yield of the crop. Plant height and stem girth increased with compost rate up to 6 t ha^{-1}. But plant performance at 6 t ha^{-1} was not statistically difference from that obtained with 4 t ha^{-1}; dry matter accumulated most, at 4 t ha^{-1}. Hence, 4 t ha^{-1} was most outstanding in supporting the production of the crop. Interactive effects of spacing and compost were significant for both growth and yield. The highest plant height was obtained with 15 × 15 cm × 6 t ha^{-1}. 20 × 20 cm × 6 t ha^{-1} produced highest leaf area and 20 × 20 cm × 4 t ha^{-1} produced the highest dry matter and cumulative fresh shoot yield.

Maftoun *et al.* (2005) conducted an experiment in a greenhouse to evaluate the impact of two organic wastes and P on the growth, and elemental composition of spinach (*Spinacia oleracea* L.) and soil chemical properties. Treatments consisted of four levels of municipal waste compost (MWC) (0, 1, 2 and 4%), five rates of PM (0, 1, 2, 3 and 4%), and three P levels (0, 25 and 50 mg kg^{-1} as KH_2PO_4). Application of P and MWC alone or in combination significantly increased the top dry weight of spinach.

2.2 Effect of cow dung

Ama *et al.* (2022) conducted an experiment to study the effects of three different rates of application of cattle dung on growth parameters, proximate and mineral composition, weight loss and shelf life of *Amaranthus cruentus* and *Corchorus olitorius*. The treatments were cattle dung manure at rates of 0, 0.5. 0.8 and 1.1 t ha^{-1}. Application of 1.1 t ha^{-1} in *Amaranthus cruentus* resulted in the highest plant height on the 20th day after transplanting. The 0.8 t ha^{-1} rate of application gave the highest number of leaves and shoots of *Amaranthus cruentus*. Higher rates of application produced bigger stem girths which varied significantly from those without manure application. On the effects of the different rates of application on *Corchorus olitorius*, the results showed that, generally, there was no significant difference ($P > 0.05$) from those without manure application. Increased rates of application resulted in a decline in the growth parameters. The results on shelf life for both *Amaranthus cruentus* and *Corchorus olitorius* showed that both wilted and dried on the 24th hour and 48th hour after harvesting respectively. In conclusion, the study showed that increased application of cattle dung produced positive outcomes on the growth parameters of *Amaranthus cruentus*.

Pohan *et al.* (2021) conducted the study about the effect of organic fertilizers on the growth and yield of water spinach (*Ipomoea reptans* Poir) in the Green House of Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan. A Completely Randomized Factorial Design was designed for the experiment with two factors and three repetitions. The first factor is the type of fertilizer (chicken manure, cow manure, and compost), and the second factor is the dose of the fertilizer (1:1, 2:1 and 3:1). The parameters such as plant height, number of shoots, number of leaves, fresh weight, dry weight, leaf's total chlorophyll content, and water content were measured to evaluate plant growth and yield. The General Linear Model used SPSS 21 programs was applied to analyze the collected data. Study results revealed that cow manure increased plant growth and yield significantly with dose 2:1 as the finest treatment, followed by dose 3:1. Cow manure also increased total chlorophyll content (8.0574 c mg. L^{-1}), with the most suitable dose was 2:1 (8.2807 mg. L^{-1}). The plant's water content tended to be high in chicken manure (93%), and the lower water content was in cow manure with dose 3:1 (87.5%).

Tonoya (2014) investigated the effect of different levels of N fertilizer applied as urea in combination with cow dung (CD) on the growth and yield of green amaranth cv. BARI Data-I was at Sher-e-Bangla Agricultural University Farm. The experiment consisted of four levels of N (N_0= 0, N_1 = 75, N_2 = 100 and N_3= 125 kg N ha^{-1}) and four levels of cow dung (C_0 = 0, C_1 = 2.5, C_2 = 5 and C_3 = 7.5 t CD ha^{-1}. The experiment was laid out in a randomized complete block design with three replications. The results showed that N, cow dung and their interaction significantly influenced most of the growth and yield contributing characteristics such as plant height, number of leaves, stem diameter, leaf greenness, fresh and dry weight of leaf, stem and root along with the individual yield of leaf and stem or summation of them as green yield. All parameters studied in this experiment were increased with the increasing N levels i.e.,125 kg N ha^{-1}, gave the highest which showed statistically similar with 100 kg N ha^{-1} in case of final plant height, number of leaves, stem diameter and stem-leaf ratio. The growth and yield contributing parameters were increased with the increasing cow dung levels up to 5 t ha^{-1}. The highest green yield (69.74 t ha^{-1}) was obtained from the interaction of N_3C_1 (125 kg N ha^{-1} and 2.5 t CD ha^{-1}) treatment which is statistically similar with N_2C_2 (100 kg N ha^{-1} and 5 t CD ha^{-1}) in respect of highest plant height, maximum number of leaves $plant^{-1}$ and widest stem diameter. The N_0C_0 showed the lowest values in the case of all parameters. Therefore 100 kg N hi' were compatible to 5 t CD ha^{-1} for better as well as eco-friendly production of green amaranth.

2.3 Effect of vermicompost

Kumar and Gupta (2018) an experiment was conducted to study the effect of vermicompost and chemical fertilizers on growth and yield of Radish (*Raphanus sativus*). From this experiment it is clear that vermicompost is a better fertilizer than other fertilizers due to the availability of nutrients in vermicompost and also helps in sustainability of agriculture sector. The sustain abilities of agriculture are more important for food security of peoples of a country. The plant heights were found to be 50 cm in vermicompost, 41 cm in cow dung, 39 cm in urea and 17 cm in control treatment. The weight of the tuber was observed to be 152 g in vermicompost, 133 g in cow dung, 120 g in urea, and 49 g in control treatment. The number of fruits plant^{-1} was found to be 44 in vermicompost, 36 in cow dung, 25 in urea and 15 in control treatment. The stem diameters were observed to be 1.40cm in vermicompost, 1.16 cm in cow dung, 0.96 cm in urea and 0.76cm in control treatment. The dry matters yield was 41.36 g in vermicompost, 39.92 g in cow dung, 35.25 g in urea and 21.50 g control treatment.

Ali and Kashem (2018) conducted this field experiment was at the South Surma upazila, Sylhet during the period from November 2017 to March 2018 to evaluate the effect of different levels of fertilizers, cow dung and vermicompost on the growth and yield of cabbage. The experiment comprised four treatments viz. T_1= 392-330-150-133-8-5 kg ha^{-1} of urea-TSP-MoP-Gypsum-Zinc sulphate-Solubor boron (BFRG-2012), T_2= T_1 + Cow dung (5 t ha^{-1}), T_3= T_1 + Vermicompost (5 t ha^{-1}) and T_4 = Vermicompost (10 t ha^{-1}). The experiment was laid out in a randomized complete block design (RCBD) with three replications. Significant variation was observed in different growth and yield contributing characters with treatments except spreading area of plant. The tallest plant (14.03 cm) was observed in T_3 at 30 DAT whereas the shortest plant (9.01 cm) was observed in T_4. At 15 DAT, T_3 treatment gave the highest number of loose leaves per plant (4.87) and T_4 gave the lowest number of loose leaves per plant (3.67). At 45 DAT, the highest leaf length and leaf breadth (11.40 cm and 7.73 cm, respectively) was found in T_3 treatment. The highest length and weight of root (25.75 cm and 30.97 g) were indicated with the treatment of T_3. The highest fresh weight of stem (14.17 g) was indicated with the treatment of T_3. The highest head yield was recorded from T_3 (42.12 t ha^{-1}). The result revealed that vermicompost gave a better performance with recommended doses of chemical fertilizers than applying chemical fertilizers alone.

Ahirwar and Hossain (2015) conducted a study to evaluate the transplant quality and field performance of vegetable transplants grown in vermicompost. Tomato (*Lycopersicon esculentum* Mill.), Eggplant (*Solanum melongena* L.), Pepper (*Capsicum annuum* L.), Potato, Sweet corn hybrids, Pak choi, Spinach and Turnip. Growth of vegetable transplants was positively affected by addition of vermicompost, perhaps by altering the nutritional balance of the medium. Transplant quality was improved in peppers and eggplants while tomato transplant quality was slightly reduced. There were no significant differences in field performance. Hence, vermicomposting is a sustainable technique for solid waste disposal. Vermicomposting is the science of producing compost from biodegradable OM through earthworms. Vermicompost contains significant quantities of nutrients, a large beneficial microbial population and biologically active metabolites, particularly gibberellins, cytokines, auxins and group B vitamins which can be applied alone or in combination with organic or inorganic fertilizers so as to get better yield and quality of diverse crops.

Sharma and Agarwal (2014) conducted a pot experiment to assess the performance of organic fertilizers on growth, yield and quality of Spinach (*Spinacea oleracea* Linn) with treatments FYM (T_1), vermicompost (T_2), chemical fertilizer (T_3), Vermiculture + cattle dung (as feed) (T_4) and control (T_5) were organized in kitchen garden. The experiment was a completely randomized design, repeated three times, with four replications. Nutrient analysis of the spinach grown in kitchen garden was also done to ascertain the impact of organic fertilizers on its quality. The selected methods for nutritive analysis were β carotene- calorimetrically, Vitamin C- Titration method and Calcium- Titration method. After repeated use of vermiculture in the same soil, β carotene, Vitamin C and Calcium were observed better in organically grown spinach.

Hernández *et al.* (2010) conducted a greenhouse study to evaluate the effect on total growth and leaf nutritional content in lettuce (*Lactuca sativa* L.) in the Agrotechnology Sciences Department of the Universidad Autonoma de Chihuahua, Mexico. Three types of fertilization treatments were analyzed: two organic and one conventional or inorganic. Both vermicompost and compost were produced from cattle manure in a 25-week process. The study included 12 experimental units made up of lettuce plantlets var. Great Lakes a linear model was fitted for statistical analysis using a completely randomized experimental design. ANOVA was performed and means were compared by orthogonal contrasts. Results showed differences in weight and leaf content for the N and K variables, and the highest mean values for these variables were in the urea treatment. Leaf content of Ca, Mg, and Mn showed higher values in organic fertilization treatments. The vermicompost treatment showed a higher contribution of Mg, Fe, Zn, and Cu, and lower Na in lettuce leaf content when compared to compost usage.

2.4 Effect of bone meal

Atemni *et al.* (2023) conducted a pot experiment to examine the effect of bone meal application on soil properties, growth, and accumulation of macronutrients and heavy metals in aerial parts of *Pelargonium graveolens*. Treatments included six rates of bone meal (1, 5, 10, 15, 20, 40 g kg^{-1} dry soil), mineral fertilizer 15:30:15 NPK (15 kg N ha^{-1}, 30 kg P_2O_5 ha^{-1}, 15 kg K_2O ha^{-1}), and unamended control. The application of BM treatments significantly improved the yield and growth as well as the photosynthetic pigments of *P. graveolens*. Also, greater increases in soil pH, electrical conductivity (EC), Olsen-P, and other soil mineral elements were recorded with higher doses of BM, compared to the control. Furthermore, BM treatments significantly increased the concentrations of the elements N and calcium (Ca) but significantly decreased the concentrations of zinc (Zn), copper (Cu), lead (Pb), and manganese (Mn) in the aerial parts of *P. graveolens*. Correlation analysis shows that soil pH had negative relationships with heavy metal concentrations and positive relationships with N and Ca concentrations in the *P. graveolens*. The study suggests that bone meal can be used as a potentially inexpensive and eco-friendly amendment to enhance soil properties and promote crop growth and yield with low metal content.

Gyewali *et al.* (2020) conducted an experiment to evaluate the influence of different organic manures on growth, yield, and quality of radish (*Raphanus sativus*) at Institute of Agriculture and Animal Science (IAAS), Rupandehi, Nepal. The experiment was laid in Randomized Complete Block Design single factorial with seven treatments and three replications. The treatments were consisted as farmyard manure (FYM) (30 t ha^{-1}), PM (30 t ha^{-1}), FYM(15 t ha^{-1}) + PM (15 t ha^{-1}), FYM (15 t ha^{-1}) + vermicompost (2.5 t ha^{-1}) + phosphate solubilizing bacteria (PSB) (10 kg ha^{-1}), FYM (15 t ha^{-1}) + bone meal (5 t ha^{-1}) + PSB (10 kg ha^{-1}), PM (15 t ha^{-1}) + vermicompost (2.5 t ha^{-1}) + PSB (10 kg ha^{-1}), PM (15 t ha^{-1}) + bone meal (5 t ha^{-1}) + PSB (10 kg ha^{-1}). A significant variation was observed among the treatments. The PMs combined with bone meal and PSB significantly increased the growth and yield attributes viz., plant height (43.43 cm), number of leaves (20.9), shoot length (44.49 cm), root length (21.68 cm), root diameter (3.77 cm), root weight (211.3 g $plant^{-1}$), shoot weight (170.9 g $plant^{-1}$), biological yield (82.28 g $plant^{-1}$), dry root weight (46.89 g $plant^{-1}$), dry shoot weight (50.33 g $plant^{-1}$), total dry weight (97.22 g $plant^{-1}$), root yield (49.31 t ha^{-1}), shoot yield (939.87 t ha^{-1}) and biological yield (89.19 t ha^{-1}) at 70 days after sowing. However, the total soluble solid remains unchanged among the treatments. In total, the results suggested that PM combined with bone meal and PSB is suitable to cultivate radish.

Załuszniewska and Nogalska (2020) conducted a two-year field experiment in north-eastern (NE) Poland was to evaluate the effect of meat and bone meal (MBM) applied without or with mineral N on seed yield, thousand seed weight (TSW), protein yield, fat yield, fatty acid profile and glucosinolate (GLS) concentrations in winter oilseed rape. Five treatments were compared: MBM applied at 1.0, 1.5, 2.0 Mg ha^{-1}, inorganic NPK, and a zero-N check. The first two MBM plots and the NPK plots received supplemental inorganic N to provide a total of 158 kg N ha^{-1}. The yields of winter oilseed rape were highest in the treatment with mineral (NPK) fertilization. All plots receiving MBM yielded equally to each other but greater than the unfertilized check. Winter oilseed rape accumulated significantly more protein in seeds in the NPK treatment than in the 1.5 Mg ha^{-1} MBM + 40 kg N ha^{-1} treatment. The crude fat content of seeds was significantly higher in the 1.5 Mg MBM ha^{-1} + 40 kg N ha^{-1} treatment, compared with the NPK treatment and the 1.0 Mg MBM ha^{-1} + 79 kg N ha^{-1} treatment. Oleic, linoleic, and α-linolenic acids accounted for nearly 90% of total fatty acids in rapeseed oil, and the average ratio of linoleic acid to α-linolenic acid was 1.81:1. Fertilization had a minor influence on the proportions of fatty acids, which were considerably affected by adverse weather conditions.

Jeng *et al.* (2007) Meat and bone meal (MBM) contains appreciable amounts of total N (~8%), P (~5%) and calcium (~10%). It may therefore be a useful fertilizer for various crops. This paper shows results from both pot and field experiments on the N and P effects of MBM. In two field experiments with spring wheat, increasing amounts of MBM (500, 1000, 2000 kg MBM ha^{-1}) showed a linear yield increase related to the N-supply. A similar experiment with barley gave a positive yield increase for 500 kg MBM ha^{-1} and no further yield increase for larger amounts of MBM. Supply of extra mineral P gave no yield increase when 500 kg MBM ha^{-1} or more was applied. Meat and bone meal as P fertilizer was studied in greenhouse experiments using spring barley and rye grass as test crops. N applications were 100 N kg ha^{-1} to barley and 200 kg N ha^{-1} to rye grass, either from mineral fertilizer or assuming that 80% of total N in MBM was effective. Four different P deficient soils were given increasing doses of MBM and compared with compound NPK fertilizer 11-5-18, mineral N fertilizer (0 kg P ha^{-1}) and a control (0 kg N ha^{-1}, 0 kg P ha^{-1}). In barley there was no significant yield difference between the NPK treatment and MBM treatment with equal N supply, and both had significantly higher yield than the treatment receiving the same amount of mineral N without P-supply. The positive yield response of MBM was even larger in rye grass. Both in barley and rye grass a significant residual effect of P from MBM applied the year before was found when the treatments received the same amount of mineral N fertilizer (0 kg P ha^{-1}). The pot experiments confirmed the assumed N effect of MBM. When MBM is used according to the N demand of the crops, the P supply will be more than sufficient and residual P will be left in the soil. Since a part of this residual P was utilized by the crops of the following year, it is not recommended to apply P-fertilizer the year after MBM application.

2.5 Effect of poultry manure (PM)

Chowdhury *et al.* (2020) conducted research to find out the integrated effects of inorganic fertilizer (IF) and PM on the growth and leaf biomass yield of Aloe vera and post-harvest soil fertility along with the economics of Aloevera cultivation. Different combinations of IF and PM exerted significant influence on the growth, yield attributes and leaf biomass yield of Aloe vera. The highest fresh leaf weight (4864 g $plant^{-1}$), fresh gel weight (2956 g $plant^{-1}$) and dry leaf weight (420.70 g $plant^{-1}$) at harvest were obtained from the plant treated with 25% IF and 75% PM whereas the tallest plant (57.14 cm) and highest number of leaves $plant^{-1}$ (18.33) were identified from the pot treated with $IF_{100}PM_0$. About 153% yield increase over control was noticed from $IF_{25}PM_{75}$ which was statistically identical with the yield increase of the treatment $IF_{100}PM_0$. Correlation studies revealed that fresh gel weight was significantly and positively correlated with plant height, number of leaves, leaf area and fresh leaf weight. The pH, OM, total N, available P, exchangeable K, Ca, Mg and available S, Zn, B contents of post-harvest soil were significantly increased with the increased levels of PM. Based on BCR (Benefit Cost Ratio) value (1.72), $IF_{25}PM_{75}$ was the best profitable treatment. Farmers belonging to the agro-climatic conditions of the study area may be advised to cultivate Aloe vera in acid soil applying 75% PM along with 25% inorganic fertilizer for getting maximum leaf biomass yield and benefit maintaining soil fertility and productivity.

Parwada *et al.* (2020) done a 3-year field experiment at the Seke Teachers College research farm, Zimbabwe to evaluate the response of baby spinach to different types of organic manure sources, days after fertilizer application (DAS), and growing season. A 3×2 factorial in a completely randomized block design (CRBD) with three replicates was used. Baby spinach cultivar, Dash, was grown on three organic manures (goat applied at 14.894 t ha^{-1}, cattle at 17.789 t ha^{-1}, and poultry at 13.807 t ha^{-1}) in winter 2018, 2019, and 2020. Compound D (7% N, 14% P, and 7% K) at 300 kg ha^{-1} was included as a control. Crop growth rate, leaf area index, leaf area ratio, net assimilation rate, total dry matter production, and harvest index were measured on 7-day intervals from 14 to 35 days after transplanting. Results showed that PM had significantly the highest influence on baby spinach growth in the early developmental stages (14 and 21 days after application). Relatively high (C/N) organic manure (cattle and goat manure) had lower effects than low (C/N) manure (PM) at the early growth stages of baby spinach. Cattle and goat manure had a gradually increasing effect on the growth of the baby spinach from 14 to 35 days after application.

Mishra *et al.* (2020) conducted a study to evaluate the performance of cow or sheep manure, or chicken litter, on growth and yield of broccoli, cvs. Balimo, Green majic, and Zone. The number of leaves and branches, plant weight, time to 50% emergence of heads, broccoli head weight and diameter, contents of protein and sulfur in heads, and total yield were determined. The cv. Balimo treated with sheep manure produced more leavesplant^{-1} (~61). Plants treated with chicken litter had the widest heads (22 cm) and highest protein content (32.2%). The chicken litter produced more sulfur in heads than cow manure and sheep manure was intermediate. Chicken litter produced a higher yield than sheep manure, and cow manure produced a yield that was intermediate. The cv. Balimo had heavier plants than did “Zone,” and those of “Green majic” were intermediate. The cv. Zone had the most branchesplant^{-1} (~12), heaviest heads (589.16 g), least time to 50% heading (~81 days), and most total yield (23.57 t ha^{-1}). The cv. Zone had wider heads than ‘Green majic’ and those of cv. Balimo were intermediate. The cv. Balimo had the highest head protein content (32.2%). Chicken litter can be used to improve vegetative growth, and yield quality and quantity, and the broccoli cv. Zone appears to be the best of the cultivars tested.

Shaheen *et al.* (2014) conducted a 2-year pot experiment using loamy textured soil to study the effect of organic manure and complex chemical fertilizer (NPK) with or without effective microorganism (EM) on the agronomic performance of spinach crop, at Gomal University D.I. Khan. A commercial product called Bio-Aab was used as a source of EM. Organic manure was first mixed with Bio-Aab, left for 7 to 15 days at room temperature (20^{0}C) and then applied to appropriate pots. The treatments of farmyard manure (FYM) @ 10 t ha^{-1}, press mud @ 20 t ha^{-1}, compost @ 0.7 t ha^{-1} and PM @ 5 t ha^{-1} were applied with half of the recommended dose of NPK @ (75:60:30 kg ha^{-1}) with or without EM. In the first year, the application of EM with Press mud @ 20 t ha^{-1} significantly enhanced spinach growth by exhibiting higher average spinach plant height (35 cm), number of leaves (16.4), fresh foliage yields (330 g pot^{-1}), dry foliage yields (32 g pot^{-1}), leaf length (40.5 cm) and leaf area (238.4 mm^{2}) relative to PM, compost or FYM treatments. A similar trend was observed at the next year. Overall, press mud with EM was more effective in improving soil quality and enhancing spinach growth and quality followed by FYM and PM.

Uka *et al.* (2013) conducted a greenhouse experiment to study the relative effect of organic and inorganic fertilizers on the growth of okra (*Abelmoschus esculentus*). The experiment consisted of four treatments. Cow dung and poultry droppings were applied at the rates of 2.5 kg per 10 kg of soil one week before sowing, while NPK fertilizer (15:15:15) was applied at the rate of 6 g per 10 kg of soil three weeks after sowing. The treatments were laid in a completely randomized design with three replications. Plant growth was assessed using plant height, fresh weight, leaf area and dry weight. The application of cow dung, poultry droppings and NPK fertilizer had significant effects on all the parameters assessed. The data obtained from these treatments were significantly higher than the data obtained from the control. However, the application of poultry droppings gave plants with the greatest plant height, leaf area and fresh weight, while cow dung application gave the greatest dry weight.

Hasan and Solaiman (2012) carried out this study to evaluate the performance of fertilizers (organic and inorganic) on the growth of cabbage. The experiment comprised of two different factors such as three varieties: V_1 (Atlas 70), V_2 (Keifu 65) and V_3 (Autumn 60) and four different fertilizers: F_0 (control), F_1 (cow dung), F_2 (PM), and F_3 (inorganic fertilizer) and also their combined effects were tested. The experiment was set up in Randomized Complete Block Design (factorial) with three replications. There were 12 treatment combinations. The experimental plot was fertilized as per treatment with organic and inorganic fertilizers. Among the varieties, Atlas 70 (V_1) achieved the highest results of Plant height (31.94 cm), Leaf length with petiole (32.00 cm), stem length (4.194 cm), diameter of head (20.24 cm), weight of whole plant (2.23 kg plant^{-1}), gross yield (46.67 t ha^{-1}), marketable yield (45.29 t ha^{-1}) and Economic production (1.576 kg plant^{-1}) at the time of harvest. But the highest number of leaves plant–1 (22.75) and Root length (22.62 cm) were obtained with Autumn 60 (V_3) and leaf breadth (22.39 cm) were maximum in Keifu 65 (V_2) cultivars. On the contrary, inorganic fertilizer (F_3) treatment showed the highest results on plant height (32.55 cm), number of leaves plant^{-1} (22.02), leaf length with petiole (31.48 cm), leaf breadth (22.59 cm), root length (20.79 cm), stem length (4.043 cm) at the time of harvest. With the interaction effect of variety and fertilizer; V_1F_2 (Atlas 70 × PM) represented the highest weight of whole plant (2.56 kg plant^{-1}), gross yield (62.14 t ha^{-1}), marketable yield (61.52 t ha^{-1}) and economic production (1.85 kg plant^{-1}). The highest net return (Tk. 214789.00) and benefit cost ratio (3.31) were obtained from the combination of V_1F_2 (Variety: Atlas 70 with PM application @ 15 t ha^{-1}).

Lim *et al.* (2012) conducted an experiment to evaluate the growth and yield responses of four leafy vegetables to organic fertilizer. Four leafy vegetables, namely, leaf mustard (*Brassica juncea*), kangkung (*Ipomoea reptans*), chinese spinach (*Amaranthus* sp.) and lettuce (*Latuca sativa*), were grown on a clay loam soil with increasing rates of PM (0, 10, 20, 30 and 40 tha^{-1}), with and without inorganic fertilizer. There were altogether ten treatments. The rate of inorganic fertilizer (N: P_2O_5: K_2O: MgO = 12:12:17:2) applied was 1 tha^{-1}. The mean plant height of leaf mustard increased from 19.6 cm at 24 days after sowing (DAS) to 39.2 cm at 32 DAS and the mean leaf number was 6.7 and 9.7 respectively. The mean yield was 5.5 kg $plot^{-1}$ and 337.7 g $plant^{-1}$. For kangkung, the mean plant height was 33.1 cm at 22 DAS and 46.7 cm at 29 DAS, and the mean yield was 6.2 kg $plot^{-1}$ and 156.2 g $plant^{-1}$. Height of chinese spinach at 22 DAS and 29 DAS was 36.8 cm and 66.7 cm respectively with a mean yield of 7.2 kg $plot^{-1}$ and 188.2 $gplant^{-1}$. Lettuce gave a mean height of 20.8 cm for both 48 DAS and 54 DAS. Its mean leaf number was 11.0 at 38 DAS, 31.2 at 48 DAS and 32.1 at 54 DAS, with a mean yield of 6.6 kg $plot^{-1}$ and 164.0 $gplant^{-1}$. For most of the vegetables, application of 10 t ha^{-1} PM gave lower yields than inorganic fertilizer alone. Generally, 20 t ha^{-1} PM gave comparable yields to inorganic fertilizer alone. The optimum yields obtained for leaf mustard, kangkung, Chinese spinach and lettuce were 19.9, 24.1, 29.6 and 24.0 t ha^{-1} respectively.

Islam *et al.* (2011) studied in a homestead area of Gazipur district to find out the effect of organic manure and chemical fertilizers on vegetable crops and soil properties in the radish-stem amaranth-Indian spinach cropping pattern in Bangladesh. There were eight treatments - PM 5 t ha^{-1} (T_1), cow dung (CD) 10 t ha^{-1} (T_2), household waste (HW) 10 t ha^{-1} (T_3), PM 2.5 t ha^{-1} + reduced RDF (recommended dose of fertilizer) (T_4), CD 5 t ha^{-1} + reduced RDF (T_5), HW 5 t ha^{-1} + reduced RDF (T_6), 100% RDF (T_7) and Control (T_8). The 100% RDF treatment (T_7) gave the highest radish yield, however identical yield was obtained with T_5 and T_6 treatments. The maximum yield of stem amaranth and Indian spinach was obtained with T_4 and T_6 treatments, respectively. The highest N, P, K and S uptake was found in T_7 for radish, T_4 for stem amaranth and T_6 for Indian spinach. Soil bulk density and organic carbon were improved due to the application of organic manure. The highest nutrient availability was recorded with T_4 treatment that was followed by T_6. Among the treatments, the PM 2.5 t ha^{-1}

+ reduced dose of recommended fertilizer and household waste 5 t ha^{-1} + reduced dose of recommended fertilizer was found suitable for achieving sustainable vegetable crop yield.

An experiment was conducted by Uddain *et al.* (2010) at Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2006 to December 2006 to study the effect of different levels of cow dung manure on growth and yield of radish. Four levels of cow dung manure viz. M_1= control (no organic manure), M_2 = cow dung manure (40 t ha^{-1}), M_3 = vermicompost (20 t ha^{-1}) and M4 = PM (25 t ha^{-1}) were used in the experiment. The experiment was conducted in Randomized Complete Block Design (RCBD) with six replications. The maximum values of plants height (59.97 cm), number of leaves per plant (21.67), leaf size (37.26 cm long & 9.69 cm width), leaves weight per plant (151.81 g), leaves yield (13.36 t ha^{-1}), root size (22.76cm long and 5.72cm in diameter), individual root weight (349.75 g), root yield (31.07 t ha^{-1}), dry matter (11.03 g in leaves and 14.10g in root) were found in PM application at 75 DAS. On the other hand, the minimum plant height (39.12 cm), number of leaves per plant (13.01), leaf size (29.11 cm long & 7.19 cm width), leaves weight per plant (62.78 g), leaves yield (5.33 t ha^{-1}), root size (10.02 cm long and 3.30 cm in diameter), individual root weight (74.11 g), root yield (6.46 t ha^{-1}), dry matter (4.38 g in leaves and 3.52 g in root) were recorded from control treatment at 45 DAS.

Ewulo *et al.* (2008) studied the effect of PM additions on nutrient availability, soil physical and chemical properties and yield of tomato, five levels of the manure, namely 0, 10, 25, 40 and 50 t ha^{-1} were applied at Akure, Southwest Nigeria. The soil at the two experimental sites were slightly acidic, low in OM, N, P, and Ca. PM increased soil OM, N and P. Soil bulk density were reduced and moisture content increased with levels of manure. Manure applications increased leaf N, P, K, Ca and Mg concentrations of tomato, plant height, number of branches, root length, number and weight of fruits. The 25 t ha^{-1} PM gave highest leaf P, K, Ca and Mg and yield relative to control. The 10, 25, 40 and 50 t ha^{-1} manure level increased average fruit weight by 58, 102, 37 and 31% respectively.

CHAPTER III

MATERIALS AND METHODS

The field experiment was conducted during the period from December 2022 to February 2023 to evaluate the role of different organic fertilizers in improving growth of spinach. A brief of soil, climate, materials and methods used for conducting the experiment is presented below.

3.1 Location and duration

The experiment was conducted at Soil Science Research field (beside the Central Masjid) of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh. The geographical position of the area is between 25.69º N; 88.65º E and 40 m above sea level. The Agro Ecological Zone (AEZ) of the area is the Old Himalayan Piedmont Plain (AEZ-1) (Appendix I).

3.2 Soil

The soil of the experimental field belongs to the Old Himalayan Piedmont Plain (AEZ-1). The soil of the experimental plot was sandy loam with good drainage capacity. The experimental plot was medium high land with a pH value was 6.05. The soils of the experimental sites were analyzed before sowing spinach. The morphological, physical and chemical characteristics of the initial soil of the experimental field is described in table 1.

3.3 Climate

The experimental area is located in a subtropical climate zone with two distinct seasons, Kharif (April–September) and Rabi (October–March), which are marked by heavy rainfall, high humidity, high temperatures, and relatively long daytime hours. The experiment was carried out between December 2022 to February 2023, during the Rabi season when the highest temperature was 25^0C, and the lowest temperature was 13^0C.The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the BWMRI, Dinajpur for the period of experimentation have been presented in Appendix II.

Table 1. Morphological, physical and chemical characteristics of the initial soil of the experimental field

A. Morphological characteristics of the initial soil sample

Characteristics	Value
General Soil type	Non – calcareous Brown Floodplain Soil
Parent Material	Piedmont alluvium
Drainage	Moderately well drained
Topography	High land
Flood level	Above flood level

B. Physical characteristics of the initial soil sample

Characteristics	Value
Sand	56.00 %
Silt	34.00 %
Clay	10.00
Textural class	Sandy loam

C. Chemical characteristics of the initial soil sample

Characteristics	Value
pH	6.05
Electrical conductivity	0.06
Total N (%)	0.028
Available P(ppm)	57.78
Exchangeable K (meq $100g^{-1}$ soil)	0.12
Available S (ppm)	12.04

3.4 Planting Materials

The plant material of the experiment was spinach (*Spinacia oleracea*). The seeds were collected from the local market in front of HSTU, Dinajpur.

3.5 Treatments

The experiment contains 6 treatments. These are-

T_1 = Control

T_2 = Compost = 2.5 t ha^{-1}

T_3 = Cow dung = 5 t ha^{-1}

T_4 = Vermicompost = 1 t ha^{-1}

T_5 = Bone meal = 0.5 t ha^{-1}

T_6 = Poultry manure = 5 t ha^{-1}

3.6 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The six (6) treatments of the experiment were assigned at random into 18 plots of each replication. The size of each unit plot 1m × 1m. The spacing between blocks and plots were 50 cm and 25 cm, respectively.

R_1	R_2	R_3
T_4	T_3	T_2
T_5	T_1	T_4
T_6	T_6	T_5
T_1	T_5	T_3
T_2	T_2	T_1
T_3	T_4	T_6

Figure 1: Layout of the experimental plot

3.7. Details of the field operations

3.7.1. Preparation of the main field

The selected plot for the experiment was opened on the 1^{st} week of December 2022 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for seed sowing.

3.7.2 Application of fertilizers and manures

All manures were applied during final land preparation according to treatments.

3.7.3 Sowing of seed

The healthy seeds were selected for better germination and growth. Then the seeds were soaked in water for 24 hour and after that seeds were sown in line sowing by hand.

3.7.4 Intercultural operation

After the establishment of seedlings, various intercultural operations were accomplished for better growth and development of the crop.

Irrigation and drainage

The experimental plots required three irrigations during the crop growth and then when needed, and sometimes drainage was done due to remove the excess water.

Thinning

First thinning was done for all of the plots at 10 days after sowing (DAS).

Weeding

Three weeding were done to keep the plots free from weeds, which ultimately ensured better growth and development. The first weeding was done at 15 days after sowing (DAS) and 2nd weeding were done at 30 DAS.

Plant protection

At the early stage of growth few Leaf miners and aphid attacked plants during the crop production. Leaf miners and aphid were successfully controlled by the application of Mancozeb and Imitaf.

3.8 Data collection

A. **Growth parameter**
    1. Plant height (cm)
    2. Number of leaves per plant
    3. Shoot weight per plant (g)
    4. Root weight per plant (g)
B. **Post Harvest Soil Analysis**
    5. Available S (ppm)
    6. Available P (ppm)
    7. Exchangeable K (meq100g^{-1} soil)
    8. Total N (%)
    9. pH
    10. Electrical conductivity (dSm^{-1})

3.9. Data collection procedure

3.9.1. Plant height (cm)

The height of plant was recorded in centimeter (cm) at 30 and 45 DAS. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the leaves.

3.9.2. Number of leaves per plant

The number of leaves per plant was counted at 45 DAS. Leaves number per plant were recorded by counting all leaves from each plant of each plot and mean was calculated.

3.9.3 Shoot weight per plant (g)

At 45 DAS, selected plants were collected from the field and weight of plants were measured in g unit and average mean was recorded.

3.9.4 Root weight per plant (g)

The root weight of individual plant was weighed by electrical balance at 45 DAS and average mean was recorded in g unit.

3.10 Post Harvest Soil Analysis

Soil sample preparation

After harvesting, soil samples were collected from all the pots and sun-dried. Then the dried samples were sieved through a 2mm (10 mesh) sieve. The soil was stored in a clean plastic container for analysis.

Analysis of soil sample

Chemical properties of all soil samples were analyzed at the Soil Science Laboratory-1, Department of Soil Science, HSTU, Dinajpur. The soil samples were analyzed by the following standard methods as follows:

Available S

Available S was determined by extraction of the soil sample with 0.01 M $Ca(H_2PO_4)_2$. The S content in the extract was estimated and the intensity of turbid was measured by spectrophotometer at 420 nm wavelength (Page *et al.*1982).

Available P

Available P was extracted from soil by shaking with 0.5 M $NaHCO_3$ solution of pH 8.5 (Olsen *et al.,* 1954). The P in the extract was then determined by developing blue color using $SnCl_2$ reduction of phosphomolybdate complex. The absorbance of molybdophosphate blue color was measured at 660 nm wavelength by spectrophotometer and available P was calculated with the help of standard P curve (Page *et al.*1982).

Exchangeable K

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al.* 1982).

Total N

Total N of the soil was determined by Micro kjeldahl method where soil was digested by 30% H_2O_2, conc. H_2SO_4 and catalyst mixture (K_2SO_4:$CuSO_4.5H_2O$: Se powder in the ratio of

100:10:1). The digested N was estimated by distillation with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with 0.01N H_2SO_4 (Page *et al.*1982).

The amount of N was calculated by using the following formula:

$$\text{N (\%)} = \frac{(T-B)\times N \times 0.014 \times D}{W} \times 100$$

Here,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

W = Oven dry weight of supplied soil sample

D = Dilution factor

Soil pH

The pH of the soil was determined with the help of a glass electrode pH meter using soil: water ratio being 1:2.5 (Jackson, 1973).

Electrical conductivity (EC) (dSm^{-1})

Electrical conductivity indicates the amount of soluble (salt) ions in soil. The determination of electrical conductivity (EC) is made with a conductivity cell by measuring the electrical resistance of a 1:5 soil: water suspension described by Craze (1990). EC is measured by using the following formula:

$$\text{EC (dS m}^{-1}) = \frac{S \times 1.413}{K}$$

Here,

S = Measured EC of suspension

K = Measured EC of KCl solution

3.11 Statistical analysis

Collected data were tested statistically by using the Statistix 10 software. Mean for each treatment were calculated and analysis of variance and difference between treatments were assessed by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present study was undertaken to determine the effect of different organic fertilizers on the growth of spinach. Data on different morphological characters as well as post-harvest soil were recorded to find out the effective organic fertilizers on spinach growth. The results of the experiment have been presented and discussed in this chapter.

4.1 Plant height (cm)

The plant height of spinach is an important characteristic that can influence the overall growth, health, and yield of the spinach plant.

Significant variation was observed on plant height of spinach at different days after sowing (DAS) due to the application of different organic fertilizers (Table 2). At 30 DAS, the highest plant height (7.83 cm) was obtained from T_6 treatment, which was statistically similar with T_2 and T_3 while the lowest plant height (5.00 cm) was obtained due to T_1 (control) treatment. Moving to 45 DAS, again T_6 showed the maximum plant height (57.66 cm), which is statistically similar with T_3. On the other hand, the lowest plant height (36.66 cm) was recorded from T_1 (control) treatment. It was observed that different organic fertilizers have a positive effect than the control treatment, and T_6 showed the maximum plant height over the period. Overall, T_6 demonstrates the most favorable conditions for plant development, as indicated by its significantly taller height. Conversely, T_1 shows the poorest growth, with the shortest plants.

PM is a rich source of essential plant nutrients, including N, P and K. These nutrients are present in a form that is easily accessible to plants. N, for instance, is a crucial element for the growth of leafy green vegetables like spinach. The readily available nutrients in PM promote vigorous vegetative growth and improvement of soil fertility, structure, and microbial activity which contributes to increased plant height. The result obtained from the present study on plant height agreed with the findings of Lima and Vimala (2012) and Uka *et al.* (2013).

Table 2. Effect of different organic fertilizers on plant height of spinach

Treatment	Plant height (cm)	
	30 DAS	**45 DAS**
T_1	5.00 c	36.66 c
T_2	6.16 ab	40.66 b
T_3	6.50 ab	47.66 ab
T_4	5.66 b	40.16 b
T_5	5.50 b	39.50 b
T_6	7.83 a	57.66 a
LSD	1.74	13.53
CV	10.09	10.93

Here, in the figures having a similar letter(s) do not differ significantly at 5% level of significance.

T_1 = Control

T_2 = Compost = 2.5 t ha^{-1}

T_3 = Cow dung = 5 t ha^{-1}

T_4 = Vermicompost = 1 t ha^{-1}

T_5 = Bone meal = 0.5 t ha^{-1}

T_6 = Poultry manure = 5 t ha^{-1}

LSD = Least significant difference

CV = Coefficient of variance

4.2 Number of leaves plant^{-1}

The number of leaves is directly correlated with the leaf yield of the spinach plant. A greater number of leaves typically mean a larger harvest, which is important for both fresh market and processing purposes.

The effect of different organic fertilizers on the number of leaves per plant of spinach was significant (Figure 2). The highest number of leaves (20.90) was produced from T_6 treatment. On the other hand, the lowest number of leaves (11.1) was observed in control (T_1) treatment, indicating slower growth compared to other treatments. From this study it was observed that the highest number of leaves per plant of spinach increased due to their increase in vegetative growth of plants. This result also indicated that T_6 leads to an increase in the number of leaves per plant. Similar result was also observed by Shaheen *et al.* (2014) and Hasan and Solaiman (2012).

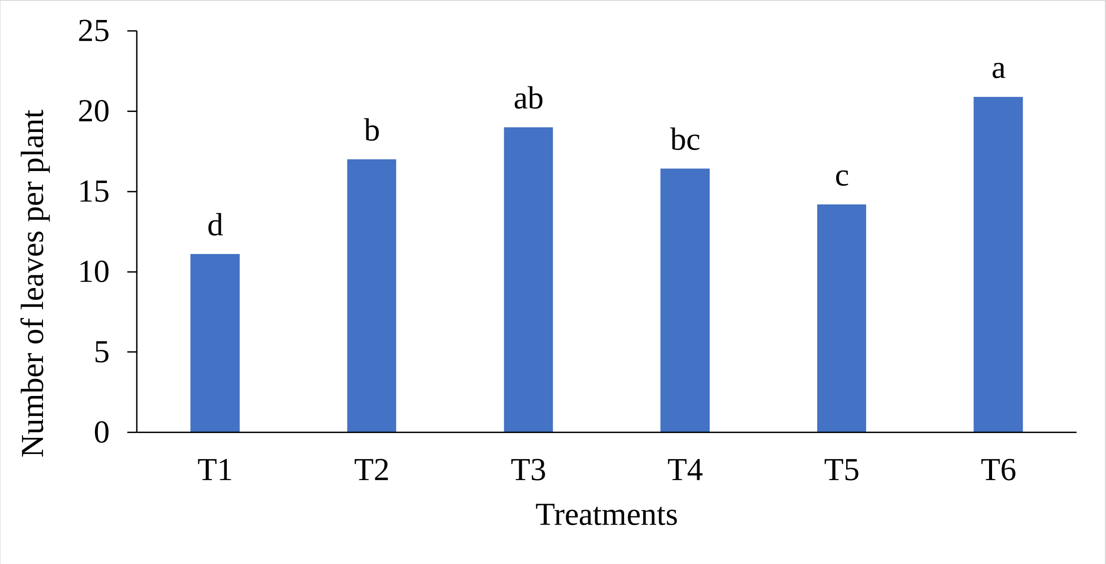

Figure 2: Effect of different organic fertilizers on number of leaves per plant of spinach

Here, In the figures having a similar letter (s) do not differ significantly at 5% level of significance. Treatment combinations were as follows:

T_1 = Control
T_2 = Compost = 2.5 ton/ha

T_3 = Cow dung = 5 ton/ha

T_4 = Vermicompost = 1 ton/ha

T_5 = Bone meal = 0.5 ton/ha

T_6 = Poultry manure = 5 ton/ha

4.3 Shoot weight (g)

The shoot weight of spinach is an important parameter to consider when assessing the growth and health of spinach plants. It is a valuable indicator of several factors that can impact the overall yield and quality of spinach crops.

The shoot weight of spinach differed significantly due to the different levels of organic fertilizers application (Table 3). Among the treatments, T_6 exhibited the highest shoot weight (22.75 g), indicating robust plant growth and biomass accumulation, which was statistically similar with T_3 (15.31 g) while the lowest (7.59 g) shoot weight in control treatment that means the plants in T_1 experienced relatively slower growth that impacted their biomass accumulation.T_6 showed the highest shoot weight, indicating favorable conditions that promote plant growth. On the other hand, T_1 exhibits the lowest weight, suggesting limitations in growth or suboptimal conditions.

Table 3. Effect of different organic fertilizers on number of shoot and root weight of spinach

Treatment	Weight (g)	
	Shoot	Root
T_1	7.59 c	0.31 c
T_2	11.45 b	0.64 ab
T_3	15.31 ab	0.63 ab
T_4	12.77 b	0.50 ab
T_5	10.81 b	0.48 b
T_6	22.75 a	1.07 a
LSD	9.37	0.68
CV	14.62	9.81

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

T_1 = Control

T_2 = Compost = 2.5 t ha^{-1}

T_3 = Cow dung = 5 t ha^{-1}

T_4 = Vermicompost = 1 t ha^{-1}

T_5 = Bone meal = 0.5 t ha^{-1}

T_6 = Poultry manure = 5 t ha^{-1}

LSD = Least significant difference

CV = Coefficient of variance

4.4 Root weight (g)

The root system of spinach plays a crucial role in absorbing essential nutrients and water from the soil. A healthy and well-developed root system can ensure that the plant has access to the resources it needs for optimal growth.

A significant variation was recorded in the case of root weight due to the various organic fertilizers (Table 3). The results showed that the maximum root weight (1.07 g) was observed owing to the application of T_6, which was statistically similar with T_2, T_3 and T_4 with the value of 0.64 g, 0.63 g and 0.50 g respectively. Alternatively, the minimum shoot weight (0.31 g) was found due to the effect of control (T_1) treatment condition, suggesting a comparatively lesser amount of root biomass. It suggests that T_6 indicates a remarkable accumulation of root biomass, indicating favorable growth conditions that promote robust root development. T_1 hinders the root biomass accumulation.

PM contains nutrients in organic forms, and these nutrients are released gradually as the OM in the manure decomposes. This slow-release characteristic ensures a sustained supply of nutrients, supporting continuous root development. Uddin *et al.* (2010) found a positive effect of PM on the root weight.

4.5 Available S (ppm)

Sulfur (S) is one of the essential macronutrients required by plants. It is a critical component of amino acids, vitamins, and enzymes, and it plays a vital role in photosynthesis, root development, and overall plant growth.

There was a positive impact on S availability in post-harvest soil for different treatments (Table 4). The initial soil sulfur content was listed as 12.04 ppm. After applying treatments, T_6 exhibits the highest sulfur content of 26.63 ppm, indicating a significant increase in sulfur levels, which was statistically similar with T_3 treatment. Conversely, T_1 displays a sulfur content of 13.28 ppm. Othe treatment T_2, T_4, T_5 showed sulfur contents ranging from 19.84 ppm to 15.04 ppm. These values indicate a slight increase in soil sulfur compared to the initial content, suggesting a minimal impact of the treatments on sulfur enrichment. Overall, T_6 treatment displays the most substantial sulfur enrichment in the soil among all the treatments and this increased sulfur availability in the soil can potentially benefit plant growth, as sulfur is an essential nutrient involved in various physiological processes and T_1 is vice versa.

Table 4: Effect of different organic fertilizers on available S, available P and exchangeable K of post-harvest soil of spinach

Treatment	Available S (ppm)	Available P (ppm)	Exchangeable K (meq/100g soil)
Initial soil	12.04	57.78	0.12
T_1	13.28 c	61.21 c	0.14 c
T_2	18.55 b	64.21 b	0.17 b
T_3	22.11 ab	72.54 a	0.19 a
T_4	19.84 b	63.34 b	0.17 b
T_5	15.04bc	75.86 a	0.14 c
T_6	26.63 a	73.21 a	0.22 a
LSD	2.54	13.2	2.01
CV (%)	11.38	2.09	10.8

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

T_1 = Control

T_2 = Compost = 2.5 t ha^{-1}

T_3 = Cow dung = 5 t ha^{-1}

T_4 = Vermicompost = 1 t ha^{-1}

T_5 = Bone meal = 0.5 t ha^{-1}

T_6 = Poultry manure = 5 t ha^{-1}

LSD = Least significant difference

CV = Coefficient of variance

PM introduces a diverse community of beneficial microorganisms to the soil. Some of these microbes are involved in nutrient cycling, including sulfur. They can help transform organic sulfur compounds in the manure into inorganic forms, such as sulfate ions ($SO4^{2-}$), which are readily available for plant uptake. Mishra *et al.* (2020) found a similar result that the PM produced more sulfur in heads of Broccoli.

4.6 Available P (ppm)

Phosphorus (P) plays a crucial role in root development and helps plants establish a strong and healthy root system. A lack of P in the soil can result in poor root growth, which can limit a plant's ability to access water and other nutrients in the soil.

The variations of available P were observed for different treatments (Table 4). Here, before any treatment application, the initial soil P content was 57.78 ppm. After applying treatment, T_5 exhibits the highest P content of 75.86 ppm, indicating a significant increase in P levels due to the applied treatment, which was statistically similar with T_6 (73.21 ppm) and T_3 (72.54 ppm). On the contrary, T_1 displays the lowest P content of 61.21 ppm. This result suggests that T_6 exhibiting the highest P enrichment in the soil and T_1 had a minimal effect on altering the post soil P levels.

Bone meal is rich in P, typically in the form of calcium phosphate. This P content is naturally present in bone meal, making it a valuable source of this essential nutrient for plants. Over time, the P in bone meal undergoes chemical reactions with soil components, gradually becoming more soluble. This solubilization process increases the availability of P to plant roots. The present study was similar with the findings of Ylivainio *et al.* (2008).

4.7 Exchangeable K (meq 100 g^{-1} soil)

Potassium (K) availability in the soil can affect the uptake of other nutrients by plants. It plays a role in nutrient transport within the plant. Inadequate K levels can lead to deficiencies in other nutrients, even if they are present in the soil.

The values of exchangeable K varied significantly using different treatments (Table 4). The initial soil K content was 0.12 meq100g^{-1} soil. Among the treatments, T_6 exhibited the highest K content of 0.22 meq100g^{-1} soil, which was statistically similar with T_3 (0.19 meq100g^{-1} soil). On the other hand, $T_1$and T_5showed the lowest K content of 0.14 meq100g^{-1} soil, which is higher than the initial soil content but lower than some of the other treatments.

PM contains a certain amount of K, as it is derived from the feed and metabolic processes of poultry. When PM is added to the soil, it serves as an additional source of K for the soil. The result obtained from the present study agreed with the findings of Ewulo *et al.* (2008).

4.8 Total N (%)

Nitrogen (N) is a key element which promotes leaf and stem growth. It encourages the development of new foliage, which is important for photosynthesis and overall plant health. Adequate N levels can lead to lush, green foliage.

There is a significant difference of total N (%) between the treatments (Table 5). The initial soil N percentage was 0.028. The results revealed that T_3 and T_6 have the highest N content, both measuring 0.11%, which was statistically similar with both T_2 and T_4 with the value of 0.084%. Conversely, T_1 showed the lowest N content at 0.056%, indicating a relatively lower level of N compared to the other treatments.

PM introduces a diverse community of beneficial soil microorganisms to the soil. These microbes play a crucial role in nutrient cycling, including N. During this process, organic N compounds in OM are broken down into inorganic forms, such as ammonium (NH_4^+) and nitrate (NO_3^-). These inorganic forms are readily available to plants and contribute to the total N content in the soil. The result obtained from Chowdhury *et al.* (2020) agreed with the findings of the present study.

Table 5: Effect of different organic fertilizers on total N, pH and electrical conductivity of post-harvest soil of spinach

Treatment	Total N (%)	pH	Electrical conductivity (dS/m)
Initial soil	0.028	6.05	0.06
T_1	0.056 c	6.1 c	0.08 b
T_2	0.084 ab	6.18bc	0.12 a
T_3	0.11 a	6.24 ab	0.14 a
T_4	0.084 ab	6.17bc	0.12 a
T_5	0.074bc	6.15bc	0.1 a
T_6	0.11 a	6.52 a	0.15 a
LSD	0.056	0.123	0.33
CV (%)	7.44	2.51	2.2

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

T_1 = Control

T_2 = Compost = 2.5 t ha^{-1}

T_3 = Cow dung = 5 t ha^{-1}

T_4 = Vermicompost = 1 t ha^{-1}

T_5 = Bone meal = 0.5 t ha^{-1}

T_6 = Poultry manure = 5 t ha^{-1}

LSD = Least significant difference

CV = Coefficient of variance

4.9 pH

Soil pH affects the availability of essential nutrients to plants. Different nutrients become more or less available to plants depending on the pH of the soil.

The pH varied significantly due to the application of different organic fertilizers (Table 5). The initial soil pH is recorded as 6.05. After applying treatment, T_6 exhibited the maximum pH value of 6.52, indicating a relatively more alkaline soil condition, which is statistically similar with T_3 (6.24). On the contrary, T_1 displayed the lowest pH value of 6.1.

Poultry manure (PM) has the ability to buffer soil pH. It can help stabilize pH levels and prevent extreme fluctuations. In alkaline soils, it can mitigate the rise in pH, while in acidic soils, it can help neutralize excess acidity, bringing the pH closer to a neutral range. This buffering effect contributes to a more stable and favorable pH for plant growth. Chowdhury *et al.* (2020) reported that the pH of post-harvest soil was significantly increased with the increased levels of PM.

4.10 Electrical conductivity (dSm^{-1})

Electrical conductivity (EC) can be correlated with the concentration of certain nutrients in the soil. In some cases, high EC values may indicate high nutrient levels, which can be beneficial for plant growth.

Application of different organic fertilizers positively affects the EC of the post-harvest soil (Table 4). The initial soil EC was recorded as 0.06 dSm^{-1}. Treatment T_2 to T_6 showed EC ranging from 0.15 to 0.08 dSm^{-1}. These values indicate a slight increase in soil EC compared to the initial content, suggesting a minimal impact of the treatments on improvement of EC. However, T_6showed the numerical highest value (0.15 dSm^{-1}) while T_1 experienced the lowest value (0.08), indicating a slight increase than the initial but lower than the other treatments.

PM is a valuable soil amendment for improving soil fertility and nutrient content, it does not directly contribute to a significant change in soil EC. The present study was similar with the findings of Chowdhury *et al.* (2020) in mungbean crop.

CHAPTER V

SUMMERY AND CONCLUSION

Summary

To assess the role of different organic fertilizers on growth of spinach was conducted a field experiment was conducted during December 2022 to February 2023 at the research field of the Department of Soil Science, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur-5200. The experiment comprises six (6) treatments, T_1 = Control, T_2 = Compost (2.5 t ha^{-1}), T_3 = Cow dung (5 t ha^{-1}), T_4 = Vermicompost (1 t ha^{-1}), T_5 = Bone meal (0.5 t ha^{-1}) and T_6 = Poultry manure (5 t ha^{-1}). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications, and the total plot number was 18. The data was collected on different growth parameters such as, plant height (cm), number of leaves per plant, shoot weight per plant (g), root weight per plant (g), and post-harvest soil analysis e.g., available S (ppm), available P (ppm), exchangeable K (meq100g^{-1} soil), total N (%), pH, electrical conductivity (dSm^{-1}). Statistix 10 software used for data analysis, and difference between treatments were assessed by Least Significant Difference (LSD) test at 5% level of significance.

The result revealed that the tallest plant (7.83 cm and 57.66 cm at 30 DAS and 45 DAS respectively) and the maximum number of leaves (20.90), the highest shoot and root weight (22.75 g and 1.07 g respectively), highest available S (26.62 ppm), the highest exchangeable K (0.22 meq100 g^{-1} soil), the highest total N (0.11%) and highest pH and EC (6.52 and 0.15 dSm^{-1}, respectively) was recorded from T_6. Additionally, the highest available P was 75.86 ppm obtained from T_5. On the other hand, the lowest value was observed in T_1 treatments regarding all parameters i.e., the shortest plant height (5 cm and 36.66 cm at 30 and 45 DAS respectively), the lowest number of leaves $plant^{-1}$ (11.1), lowest shoot and root weight $plant^{-1}$ (7.59 g and 0.31 g respectively), lowest available S (13.28 ppm), lowest available P (61.21 ppm), lowest exchangeable K (0.14 meq 100g^{-1} soil), the lowest total N (0.056 %), the lowest pH (6.1) and the lowest electrical conductivity (0.08 dSm^{-1}).

Conclusions

Based on the findings above, it may be concluded that:

First of all, different organic fertilizers can positively enhance the growth of spinach. The overall results showed that T_6 fertilizer (PM = 5 t ha^{-1}) produced the maximum growth of spinach.

Recommendations

Considering the above observation of the experiment further studies in the following may be suggested:

1. Considering the observation farmers may be suggested the apply PM to the field for spinach cultivation.
2. This study also needed to conduct in different agro ecological zone (AEZ) of Bangladesh for regional adaptability.

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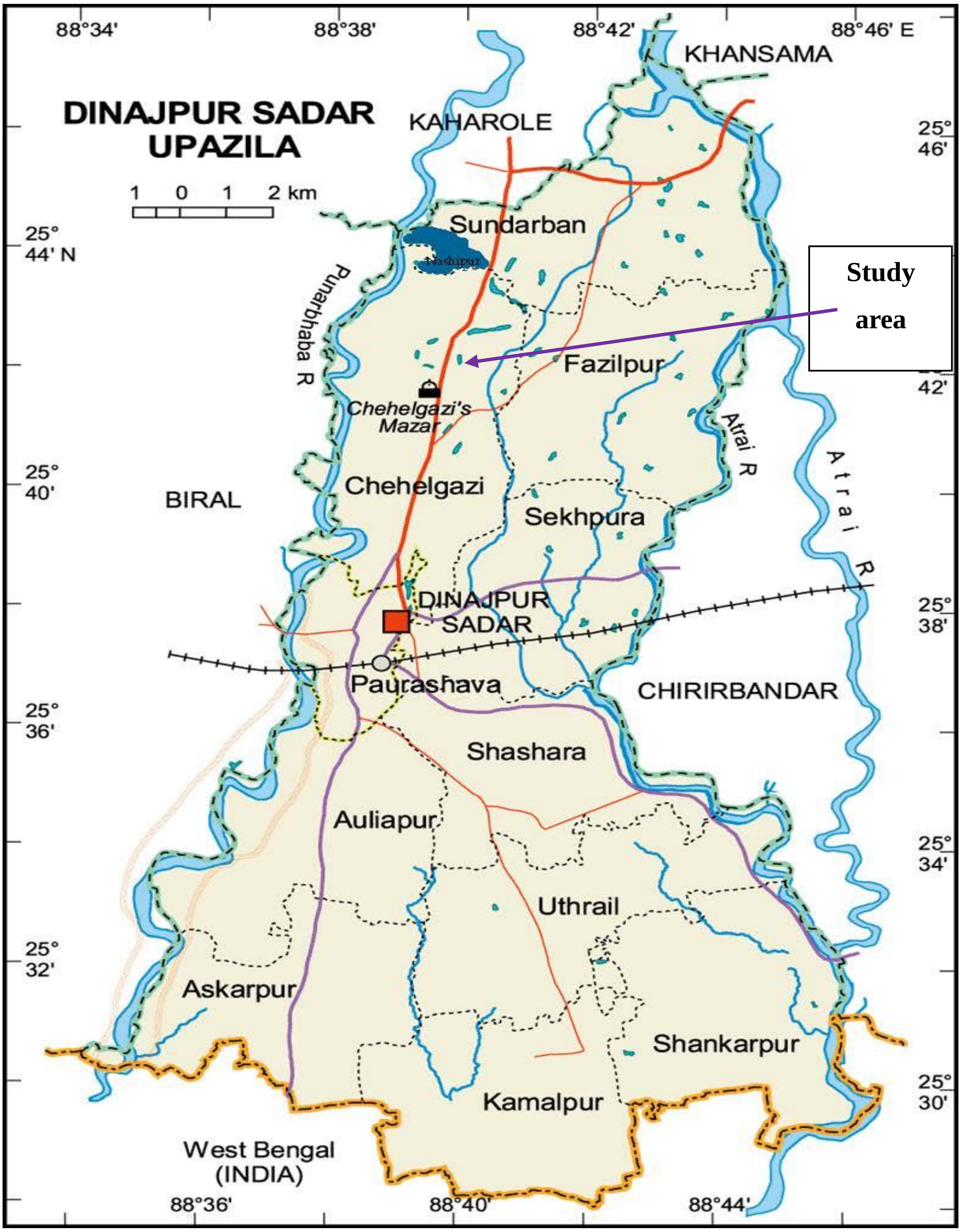
APPENDICES

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 December 2022 to March 2023)

Year	Month	**Temperature (^{0}C)			** Humidity (%)	**Rainfall (mm)
		Maximum	Minimum	Average (^{0}C)		
2022	December	25	13	19	82	0.0
2023	January	22	12	17	82	7.2
	February	26	15	20	72	17
	March	31	19	25	65	7.6

**Monthly average

Source: Bangladesh Wheat and Maize Research Institute, Nashipur, Dinajpur.

Appendix III. Some photographs of experimental site