EFFECT OF INORGANIC FERTILIZER ON THE VEGETATIVE GROWTH OF DRUMSTICK (*Moringa oleifera)*

A THESIS

BY

PROTIMA RANI ROY

Student No. 1601403

Session: January-June, 2023

MASTER OF SCIENCE (M.S.)

IN

SOIL SCIENCE

DEPARTMENT OF SOIL SCIENCE

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY

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DECEMBER, 2023

DEDICATED

TO MY

BELOVED FAMILY

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The Authoress

ABSTRACT

A field experiment was carried out at the Soil Science research field in Hajee Mohammad Danesh Science and Technology University, Dinajpur during the rabi season of 2022. This study was done to examine the effects of inorganic fertilizer on the growth and yield of drumstick. The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. There were six treatment combinations viz. T_1: No fertilizer (control), T_2: RDF NPKS, T_3: $N_{10}P_{20}K_{20}$, T_4: $N_{20}P_{20}K_{20}$, T_5: $N_{30}P_{20}K_{20}$, T6: $N_{40}P_{20}K_{20}$, respectively. The result showed the yield contributing characteristics except plant height were not significantly influenced by different treatments used in the experiment. The highest value of plant height (at 15 DAT, 30 DAT and 60 DAT, 86.13 cm, 107.63 cm and 126.13 cm, respectively), number of leaves plant^{-1} (at 15 DAT, 30 DAT and 60 DAT, 9.33, 18.33 cm and 24.93 cm, respectively), diameter of the stem (at 15 DAT, 30 DAT and 60 DAT, 3.53 cm, 6.89 cm and 10.79 cm, respectively) was recorded in the treatment T_5 ($N_{30}P_{20}K_{20}$), among the combined application of inorganic fertilizer. Application of $N_{30}P_{20}K_{20}$ exerted beneficial effects on yield and yield contributing characteristics of drumstick compared to control. Analyses of post-harvest soil fertility status revealed that the application of inorganic fertilizer positively influenced the total N, available P, exchangeable K, and available S contents in soils. In post-harvest soil application of NPK gave positive result. It also increased soil fertility status.

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ABBREVIATION AND ACRONYMS

%	Percentage
@	At the rate
AEZ	Agro Ecological Zone
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
Conc.	Concentration
Contd	Continued
df	Degrees of freedom
DMRT	Duncan's Multiple Range Test
e.g.	Example
et al.	And others
Fig.	Figure
g	Gram
i.e.	That is
IRRI	International Rice Research Institute
J.	Journal
kg	Kilogram
kg^{-1}	Per kilogram
m^{-2}	Per meter square
mg	Milligram
MOC	Mustard oil cake
SOC	Sesame oil cake
FM	Fish meal
No.	Number
^{0}C	Degree Celsius
pH	Potential of H^{+} concentration
ppm	Parts per million
CBD	Complete Block Design
RFD	Recommended Fertilizer Dose
S	Standard error
$t\ ha^{-1}$	Ton(s) per hectare
T	Treatment
viz.	Such

CHAPTER 1
INTRODUCTION

Drumstick (*Moringa oleifera)* is a fast growing, drought resistant tree of the family Moringaceae, native to tropical and subtropical regions of South Asia. Almost all parts of Moringa are edible. M. oleifera is a plant that has been praised for its health benefits for thousands of years. It is very rich in healthy antioxidants and bioactive plant compounds. It is the most widely cultivated species in the genus Moringa and the only genus in the plant family Moringaceae (Olson, 2010). M. oleifera is cultivated for its leaves, pods, and/or its kernels for oil extraction and water purification. The yields vary widely depending on season, variety, fertilization, and irrigation regimen. Moringa yields best under warm, dry conditions with some supplemental fertilizer and irrigation (Ted, 2011). It is originated in the Indian subcontinent and then distributed into many different tropical and subtropical countries of the world (Alaklabi, 2015). Among the species, Moringa peregrine and M. Oleifera Lam are the most widely cultivated, which are indigenous to south Asia and were introduced and became naturalized in other parts of the world because of multifarious use and medicinal properties (El-Alfy *et al.,* 2011). Moringa has earned its name as the miracle tree due to its amazing healing abilities for various ailments and even some chronic diseases. Several investigations were carried out to isolate bioactive compounds from various parts of the plant due to its various applications (Guevara *et al.,* 1999). The Moringa's incredible medicinal usage which is claimed by many cultures and communities based on real-life experiences are now slowly being confirmed by science (Matic *et al.,* 2018). Through research, the Moringa was found to contain many essential nutrients, for instance, vitamins, minerals, amino acids, beta-carotene, antioxidants, anti-inflammatory nutrients and omega 3 and 6 fatty acids (Fahey, 2005; Hsu *et al.,* 2006; Kasolo *et al.,* 2010). Moringa oleifera L. is one of the most useful tropical trees; its leaves are highly valuable source of nutrition for people of all ages.

Nutritional analysis indicates that moringa leaves contain affluence of essential disease preventing nutrients. They even contain all of the essential amino acids which are not found in other plant source (Matic *et al.,* 2018). The young leaves are edible and are commonly cooked and eaten like spinach or used for making soups and salads. It is an exceptionally good source of antioxidant compounds such as flavonoids, ascorbic acid, carotenoids, phenolics and some mineral nutrients (in Particular, iron) and the Sulphur containing amino acids methionine as well as cystine. The composition of amino acids in the leaf protein is well balanced; they contain high amounts of many of these nutrients and total phenols also a very low source of fat (Abdull Razis *et al.,* 2014; Mishra *et al.,* 2012; Osman and Abohassan, 2012). 2 Stress in plants refers to external conditions that adversely affect growth, development or productivity of plants. Stresses trigger a wide range of plant responses like altered gene expression, cellular metabolism, changes in rates, crop yields, etc. (Verma *et al.,* 2013). Plants are subjected to a wide range of environmental stresses which reduces and limits the establishment and productivity of agricultural crops. Two types of environmental stresses are encountered to plants which can be categorized as abiotic stress and biotic stress. The abiotic stress causes the loss of major crop plants worldwide. Among a number of abiotic stresses, salinity is the one (Gull *et al.,* 2019). It is estimated that about approximately 7% of world land is affected by salinity and approximately 20% of 230 million ha irrigated land is salt- affected. This number could be increased in the future due to increased land salinization as a consequence of contaminated artificial irrigation, climate change, and unsuitable land management (Parihar *et al.,* 2015).

Nitrogen and phosphorus are essential elements required during the developmental stages of plants. Literature reports that nitrogen promotes vegetative growth while phosphorus improves root development in plants (Razaq *et al*., 2017. McDonald *et al*. 2011) reported that nitrogen increased crude protein and leaf biomass. Fodder crops are considered acceptable when crude protein is high, while neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents are relatively low (Janhi *et al.,* 2020). Crude protein above 8% with ADF and NDF ranging between 45 and 65% are highly recommended for good quality animal feed (Wangila *et al.,* 2021). Fertilizer research on moringa is scarce for the conditions of the Eastern Cape Province, and reports in the literature are inconsistent. Some researchers reported that the plant performs very well without fertilizer application (Pahla *et al*., 2014; Mashamaite *et al*., 2021). However, fertilizer use, especially during the seedling establishment period, was reported to improve nutritional quality and biomass yield of moringa (Mabapa *et al*., 2017). Moringa seedlings grown in a glasshouse did not require a high amount of fertilizer, but a minimal intake could potentially improve its quality and yield (Christophe *et al*., 2019). Similarly, (Pahla *et al.* 2014) reported that moringa seedlings planted in Zimbabwe without fertilizer application in soils with low nutrient status and poor drainage showed stunted growth and chlorosis of leaves, which resulted in a delayed growth rate and death of the plants. (Francis and Liogier, 1991) also reported that addition of fertilizer on moringa plants during the establishment phase resulted in increased foliage and seed yield. The contradictory results are possibly due to biomass and nutrient quality of moringa that are influenced by genetic background, climatic conditions, environment, and production practices (Brisibe *et al.,* 2009). It is therefore it is essential to evaluate moringa production under the Eastern Cape Province conditions.

There are limited studies conducted to evaluate the effects of inorganic fertilizer on moringa yield and nutrient content in Bangladesh. This inadequacy of information makes it challenging to recommend to farmers on the fertilizer quantity and type to apply. Therefore, this study aimed to examine the effects of inorganic fertilizer application rates on moringa plants' growth and leaf nutrient composition. The study hypothesis is that inorganic fertilizer application rates influence the growth and leaf nutrient composition of moringa. Therefore, the objective of the experiment is to investigate the-

i. To assess the effect of different levels of inorganic fertilizer on growth and yield of Moringa oleifera
ii. To study the post-harvest soil fertility status of soil after addition inorganic fertilizer.

CHAPTER II

REVIEW OF LITERATURE

This research has been undertaken to observe the effect of inorganic fertilizer on the vegetative growth of drumstick. Review is a required part of grant of research proposals and often a chapter in thesis. The reviews of literature of the past studies related to the present experiment collected through reviewing of journals, thesis, internet browsing, reports, newspapers, periodicals and other form of publications are presented and discussed in this chapter.

2.1 Effect of inorganic fertilizer on the growth and yield of drumstick

Vora *et al.* (2023) carried out an experiment at Lal Baugh Farm, College of Horticulture, Junagadh Agricultural University, in the year 2021-22. The results indicated that among three levels of nitrogen, N3 (80 g/plant) demonstrated maximum number of pods per plant (141.67), pod yield (11.32 kg/plant), pod yield (12.57 t/ha), fresh weight (79.46 g), dry weight (18.53 g), pod girth (4.68 cm), pod length (61.19 cm), number of seeds per pod (18.80) and nitrogen content of pod (2.05%). While, N1 (40 g/plant) gave fiber content of pod (46.40%). Regarding phosphorus, P_2 (30 g/plant) gave number of pods per plant (138.91), pod yield (10.49 kg/plant), pod yield (11.65 t/ha), fresh weight (74.54 g), dry weight (17.64 g), pod girth (4.55 cm), pod length (61.44 cm), number of seeds per pod (18.68), phosphorus content of pod (0.73%) and fiber content (45.15%). The results indicated that among three levels of potash, K3 (45 g/plant) gave maximum number of pods per plant (140.36), pod yield (10.84 kg/plant), pod yield (12.05 t/ha), fresh weight (76.33 g), dry weight (17.55 g), pod girth (4.56 cm), pod length (60.84 cm), number of seeds per pod (18.62), potassium content of pod (1.98%) and fiber content (45.17%).

Abdoun *et al.* (2023) This study was conducted to determine the combined effect of irrigation frequency and selenium (Se) fertilizer levels on the chemical composition of Moringa oleifera

(*M. oleifera*) and Moringa peregrina (*M. peregrina*), with the ultimate goal of incorporating *M. oleifera* and M. peregrina in livestock feed. The combined effect of irrigation frequency and selenium (Se) fertilizer levels were studied in a completely randomized split plot design. The experiment included two plant species (*M. oleifera* and *M. peregrina*), four irrigation frequencies (7, 10, 15, and 20 days), and three Se levels (0.0, 12.5 and 25 mg/L). The results of the study indicated that the irrigation frequency and the foliar spray with organic amino selenium fertilizer affected ($p < 0.05$) proximate analysis (crude protein, ether extract, crude fiber and ash contents), as well as the minerals contents (P, Ca, Mg and Se) of the dried leaves and upper fine stems of *M. oleifera* and *M. peregrina* in the different cutting periods. The effect of organic amino selenium fertilizer application and irrigation frequency on all studied traits allowed the classification of *M. oleifera* and *M. peregrina* vegetative plant parts as suitable for livestock feeding. Selenium foliar spray can be considered as a safe method to increase the selenium content of both *M. oleifera* and *M. peregrina* vegetative parts, which may contribute to increase the functional feeding quality of these plants.

Jan *et al.* (2022) carried out a field experiment entitled "Exogenous application of Moringa leaves extract influences growth, flowering and vase life of snapdragon cultivars". The experiment was laid out in Randomized Complete Block Design with a factorial arrangement having two factors i.e., Cultivars (Potomac and Rocket) and Moringa leaf Extract (MLE) concentrations (0%, 10%, 20%, 30%) replicated three times. Cultivars and MLE concentrations significantly affected the studied parameters. Statistical analysis showed that Rocket cultivar produced maximum numbers of leaves plant-1 (126.50), stem diameter (11mm), plant height (100cm), number of florets spike^{-1} (34), flowering duration (39days) and vase life (6days) as compared to Potomac cultivar. Similarly, the greatest number of leaves plant^{-1} (114), stem diameter (11mm), plant height (99cm), number of florets spike^{-1} (35), flowering duration (44 days), and vase life (8days) was recorded in plants treated with

30% MLE extract. It is concluded that 30% MLE for exogenous application and Rocket cultivar for commercial production is recommended in agro-climatic conditions of Peshawar valley.

Hoque *et al.* (2022) conducted a field study to evaluate the influence of MLE (Moringa Leaf Extract) on the growth, yield and nutritional improvement in two vegetable crops [Tomato (*Solanum lycopersicum*) and Indian Spinach (*Basella alba*)]. The extract was applied at two weeks interval with different frequencies. The crops were fertilized with chemical fertilizers and MLE application was done as per treatment @ 25 ml/plant. For each of the crops, this biostimulant had a significant boosting effect on growth, yield and nutrient uptake whereas the maximum frequency in the application i.e., T_4 (foliar application of MLE at 2 weeks after transplanting and application at every 2 weeks thereafter) showed the highest influence. Indian Spinach responded proportionally more to foliar-applied MLE in terms of plant growth and nutrient uptake compared to tomato. The effect of MLE on the yield parameters was more pronounced in tomato that showed a 25% (averaged across all the growth parameters) increase over control, but Indian Spinach showed >20% increase in yield parameters compared to control.

Sahoo *et al.* (2021) studied the effect of Different soil media, on seed germination, vegetative growth and survival percentage on transplanting of Annual drumstick (*Moringa oleifera*) cv. PKM-2" was undertaken in the Horticulture Research Farm, Department of Horticulture, Sam Higginbottom University of Agriculture Technology and Science, Prayagraj, 211007 during the rabi season of 2019- 2020. The Experiment was laid out in a Randomized Block Design with 10 treatments and 3 replications. Results concluded that the application of media's T_1 (Vermicompost+ sand) (3:1) responded with superior results in various parameters i.e. in germination percent (91.67%), minimum days taken to emergence (4.55 days), stem diameter (1.04 cm), plant height (45.66 cm), shoot fresh weight (22.50 gm), shoot dry weight

(5.47gm), root fresh weight (18.50 gm), root dry weight (4.60 g), total fresh weight (40.67 gm), total dry weight (10.23 gm), shown maximum survivability percent (75 percent), leaf vitamin-c percent (0.17 gm/100 gm) while soil media T_4 (Poultry manure + sand) (3:1) has highest leaf calcium percent (0.41 gm/100 gm), T_5 (Poultry manure + sand) (2:1) (0.17 gm/100 gm) has highest leaf iron percent.

Mehetre *et al.* (2021) conducted an experiment for two consecutive years of 2016-17 and 2017-18 at Research Farm, Post Graduate Institute, MPKV, Rahuri Maharashtra to assess the "Nutrient uptake and soil available nutrients of drumstick as influenced by fertilizer levels and pruning techniques". The experiment was laid out in Factorial RBD design with three replications. The treatments comprised of three fertilizer levels viz., 75% RDF plant^{-1}, 100% RDF plant^{-1} and 125% RDF plant^{-1} as main plot treatments and four pruning techniques viz., No pruning of main shoot, pruning of main shoot at 30 cm from ground level, pruning of main shoot at 60 cm from ground level and pruning of main shoot at 90 cm from ground level at 90 days after transplanting. Application of 125 per cent RDF plant^{-1} recorded significantly higher plant dry matter production and pod dry matter production (4070.67 and 2981.63 kg ha^{-1}), (4148.00 and 3055.42 kg ha^{-1}) and (4109.33 and 3018.57 kg ha^{-1}), uptake of nitrogen (58.68, 89.29, 147.97 kg ha^{-1}, respectively), phosphorous (24.98, 14.04, 38.85 kg ha^{-1} respectively) and potassium (54.62, 64.10, 119.02 kg ha^{-1} respectively) by pod, plant and in total and soil available nitrogen (217.14, 227.56 and 222.35 kg ha^{-1}), phosphorous (27.53, 29.69 and 28.61 kg ha^{-1}) and potassium (307.79, 315.54 and 311.67 kg ha^{-1}) after harvest of drumstick crop during 2016-17, 2017-18 and on pooled mean, respectively than rest of the fertilizer levels. The pruning of main shoot of drumstick at a height of 60 cm from the ground level at 90 days after transplanting recorded significantly higher plant dry matter production and pod dry matter production (4268.44 and 3464.72 kg ha^{-1}), (4293.33 and 3605.28 kg ha^{-1}) and (4280.89 and 3534.99 kg ha^{-1}), uptake of nitrogen (67.82, 91.70, 159.52 kg ha^{-1}, respectively), phosphorus (28.60, 14.13, 42.50 kg ha^{-1}, respectively) and potassium (63.63, 65.16, 128.79 kg ha^{-1}, respectively) by pod, plant and in total and higher nitrogen (222.28, 229.21 and 225.75 kg ha^{-1}, respectively), phosphorous (27.78, 30.85 and 29.31 kg ha^{-1}, respectively) and potassium (311.94, 319.19 and 315.56 kg ha^{-1}, respectively) during 2016-17, 2017-18 and on pooled mean, respectively than rest of the pruning techniques. Significant interaction effect of fertilizer levels and pruning techniques on plant dry matter production and pod dry matter production (4629.33 and 4373.33 kg ha^{-1}), (4704 and 4531.15 kg ha^{-1}) and (4666.67 and 4452.24 kg ha^{-1}), uptake of nitrogen (186.20, 192.81 kg ha^{-1}, respectively), phosphorus (51.17, 57.32, 54.24 kg ha^{-1}, respectively) and potassium (150.91, 161.12 kg ha^{-1}, respectively) by pod and in total, respectively and it was obtained with the treatment combination, fertilizer levels of 125 per cent RDF $plant^{-1}$ with pruning of main shoot at 60 cm from ground level at 90 days after transplanting and which was at par with fertilizer levels of 100 per cent RDF $plant^{-1}$ with pruning of main shoot at 60 cm from ground level at 90 days after transplanting.

Bopape-Mabapa *et al.* (2020) carried out an experiment was established as a randomized complete block design and replicated eight times. This study was conducted to evaluate the effect of planting density on biomass and nutritional composition of *M. oleifera* planted under the semi-arid conditions of the Limpopo Province. The study was conducted at Eiland (NBef Organic Farm) over two consecutive years, 2014–15 and 2015–16. The treatment combinations included planting densities of 5000, 2500, 1667, and 1250 plants ha^{-1}. The study showed that a population of 5000 plants ha^{-1} produced the highest biomass yield of more than 1.5 tons ha^{-1}.

Yaseen and Hajos (2020) reported that Moringa oleifera is the most nutritious tree that has ever been found. Almost all parts of the plant can be used as an eco-friendly nutrient supplement and natural bio-pesticide to improve crop growth and yields. Based in this fact this review 12 article aims to focus on the possible role of Moringa oleifera as an alternative source of the environmentally friendly product in organic vegetable production. It is evident that the plant is rich in antioxidants, antibiotics, nutrients, including vitamins and minerals, protein, and carotenoids. Due to the presence of high concentration of different hormones mainly zeatin, it can be used to improve the yield of many types of crops by 10-45 per cent apart from the lowest cost of production. Many research papers demonstrate the benefits of the tree in different aspects like livestock production, medicine, manufacturing, water purification, source of nutrients in poor nations, and food technology.

Mabapa *et al.* (2018) stududid on *M. oleifera* was conducted over twelve months during 2014-2015 to evaluate the impact of the growing season and varying planting densities on biomass yield and physiological at-tributes under dryland conditions. The trial was established 16 at densities of 5000, 2500, 1667, and 1250 plants ha^{-1}, with eight replicates. The increase in planting density led to an increase in biomass production.

Bashir *et al.* (2017) aimed to assess the potential benefit of *M. oleifera* leaf extract as a vegetative growth enhancer, the effect of different application level of *M. oleifera* leaf extract on the growth of sorghum. The extract was prepared by blending young Moringa leaves together with water (500 ml of distilled water per 100 kg of fresh leaves). A muslin cloth was used in sieving the decoction. A fine filtrate was obtained and the residue was discarded. From the stock, five concentrations were prepared. About 25 ml of the different percentage of the concentration was directly spread on each seedling. For plant height, 100 % concentration showed best growth with 43.00, 74.50, 88.75 and 105.7 cm at 1st, 2nd, 3rd, and 4th weeks respectively. The control had the least growth with 40.25, 60.25, 75.50 and 90.75 cm at1st, 2nd, 3rd and 4th weeks respectively. For number of leaves, the result at 100 % was 5.00, 6.00, 7.00 and 8.00 cm at 1st, 2nd, 3rd and 4th weeks respectively. The control had the least growth with 5.00, 5.00, 5.00 and 5.00 cm at 1st, 2nd, 3rd and 4th weeks respectively. Fresh and dry weight matter of the root was 1.50 and 0.20 g respectively for 100 %, with 0.55 and 0.05 g respectively for the control. Fresh and dry weight matter of the shoot was 12.73 and 1.33 g respectively for 100 %, with 6.21 and 0.76 g respectively for the control.

Hashem (2016) reported that the effect of different fertilizer doses on production performance of Moringa oleifera as fodder in autumn. A land size of 20×12 m with a plant density of 13,500/hectare, was equally divided into 18 sub-plots. Keeping randomly 6 of them as a control (F0), the rest 12 sub-plots were randomly grouped into two; one of them of 6 plots was fertilized with N:P:K at a ratio of 90:30:15,respectively considered as F1 treatment group; and the other 6 plots with a ratio of 160:60 :40, respectively considered as F2 treatment group. The experimental design was arranged in Completely Randomized Design (CRD). The BM, DM and CP yield were significantly ($P<0.001$) higher in 1st cutting than that of 2ndcutting. The BM & DM yield obtained with different treatment groups did not vary significantly ($p>0.05$) in both first and overall cutting. But in case of 2nd cutting, the average BM and DM yield were significantly ($P<0.05$) higher in control fertilizer doses (F_0) than F_1 and F_2 fertilizer doses, whereas the CP yield obtained with different treatments differed significantly ($P<0.05$) in both first & second cutting and did not differ significantly ($p>0.05$) in overall cutting. In case of 1st cutting, the increased CP yield was observed in F_1 fertilizer doses and in case of 2nd cutting, the CP yield increased in F_0 than other fertilizer doses. It could be concluded that medium doses of fertilizer are suitable for optimum production of Moringa oleifera during autumn in its decreasing temperature and humidity.

Roy et al. (2010) carried out an experiment at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh to study the effect of starter solution and GA3 on growth and yield of cabbage. The two-factor experiment consisted of four levels 17 of starter solution, viz., 0, 1.0, 1.5 and 2.0% of urea, and four concentrations of GA3, viz., 0, 25, 50 and 75 ppm. The highest yield (104.93 t/ha) was found from 1.5% starter solution which was significantly different from other solutions, and the lowest yield (66.86 t/ha) was found from the control. Significantly the highest yield (104.66 t/ha) was recorded from the treatment of 50 ppm GA3, while the lowest yield (66.56 t/ha) was found from control. In case of combined effect, the highest yield of cabbage (121.33 t/ha) was gained from the treatment combination of 1.5% starter solution + 50 ppm GA3 followed by 1.5% starter solution + 75 ppm GA3 (115.22 t/ha), while the lowest yield (57.11 t/ha) was produced by the control treatment. Economic analysis found that 1.5% starter solution + 50 ppm GA3 treatment was the best treatment combination in respect of net return (Tk. 173775/ha) with a benefit cost ratio of 3.52.

Amaglo *et al.* (2006) conducted an experiment was performed between 19 May 2004 and 21 March 2005. The spacing treatment combinations (5 x 5 cm, 5 x 10 cm, and 5 x 15 cm) were arranged in a 3 × 2 factorial Randomized Complete Block Design (RCBD). The results showed that the fresh and dry shoot yield per hectare was significantly different ($P < 0.05$) with the closest spacing giving the highest yields of 101.52 and 31.32 tons of fresh and dry shoots respectively. The medium spacing gave 55.84 tons of fresh shoots and 15.73 tons of dry shoots yield per hectare. The least shoot yield per hectare was from the widest spacing, which gave 38.47 and 11.71 tons of fresh and dry shoots yield respectively.

2.2 Effects of inorganic fertilizers on soil properties

Sardooi *et al.* (2019) was conducted an experiment to investigate germination and seedling growth response of Moringa peregrina toward different levels of salinity and drought stress at an optimum temperature. In the experiment, seed germination was assessed in four levels of salinity and drought with the osmotic potential of 0, -4, -8 and -12 bar. The results indicated that seed germination speed and percentage were decreased due to drought and salinity stress.

Generally, seed germination of Moringa peregrina was more sensitive to drought stress than to salinity stress.

El-Sayed *et al.* (2018) conducted Two main field trials to study the potential effects of moringa seed (MSE; 0.5%) extraction growth and yield, physio-biochemical components, antioxidant defense system, and contamination of pepper plants grown on heavy metals-contaminated saline soil. MSE was applied in two single treatments (i.e., with drip irrigation water; SA or as foliar spray; FS) or in integrative (i.e., MSESA + MSE-FS) treatment. The results showed that all single or integrative treatments significantly increased plant growth and yield, leaf contents of leaf photosynthetic pigments, free proline, total soluble sugars, N, P, and K+, ratio of K+/Na+, and activities of CAT, POX, APX, SOD and GR, while significantly reduced contaminants; Na+, Cd, Cu, Pb and Ni contents in plant leaves and fruits compared to the control (free from MSE). Additionally, the integrative MSE-SA + MSE-FS treatment significantly exceeded all single treatments in this concern. The integrative MSE-SA + MSEFS treatment was the best that it had been recommended for maximizing pepper fruits with minimizing contaminants on heavy metal-contaminated saline soils.

Kumar *et al.* (2017) investigated the adaptability of moringa in agroforestry system. The study has described that *Moringa oliefera* L. is a wonder tree grow in all type of soil and climate especially in semiarid tropics. The tree has fast-growing and drought resistant in nature. The versatile nature and diversify uses of tree open new dimension for fit in agroforestry system of cropping. Beside the domestic uses, ecosystem services, its highly marked for industrial uses. The industrial utility, positive interaction with crop, diversified products and low management practices, enhance the value of tree at large scale. In spite of immense benefit provided by tree, it is restricted or grows only by traditional farmers in country. The contracted recognition of tree is result of inadequate knowledge about the use of tree, market of its product and deficit scientific approach.

Sarhan *et al.* (2016) set up an experiment at nursery of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University during two successive seasons of 2014 and 2015. The study was conducted to investigate the effect of different soil types (sand, clay and sand + clay) and bio-fertilizers (microbine) and chemical fertilization (NPK at 6, 8 and 10 g/pot) and the interaction between them on vegetative growth parameters of Moringa oleifera plants. The obtained results revealed that the use of clay in combination with NPK at 8 g/pot gave the highest values of plant height and stem diameter. Also, the obtained highest values of fresh and dry weights of vegetative growth resulted due to using clay or sand + clay medium in combination with microbine + NPK at 10 g/pot and NPK at 8 g/pot. The best results of root fresh and dry weights, were obtained due to the use of clay in combination with microbine + NPK at 10 g/pot and NPK at 8 g/pot.

Badran *et al.* (2016) conducted a field experiment to explore the influence of three irrigation intervals and six organic and/or mineral NPK fertilization treatments on vegetative growth characters and chemical composition of Moringa oleifera plants. Obtained results showed that all studied vegetative growth characters, plant height, stem diameter, branch number and leaves number, fresh and dry weights were gradually increased parallel to the gradual shortening in irrigation intervals. On the contrary, the three photosynthetic pigments, chlorophyll a, chlorophyll b and carotenoids, as well as, the leaves % of nitrogen, phosphorus, potassium, calcium and magnesium were increased parallel to prolonging the irrigation intervals. Concerning organic/mineral NPK fertilization treatments, the highest vegetative growth characters and chemical constituents were given by the 100 % organic followed by 75 % organic + 25 % NPK treatments in comparison with all other treatments including control plants. In regard to the interaction between irrigation intervals and fertilization treatments, the best overall growth characters were obtained due to irrigation Moringa oleifera plants at the short interval (every 14 days) and supplied the plants with 100 % organic fertilizer (4 kg poultry manure/plant).

El-Dabh *et al.* (2011) conducted an experiment to evaluate salt tolerance of Moringa oleifera during its early growth stage. In the experiment, equal amounts of sodium chloride and calcium chloride (w:w, 1:1) were mixed with sandy loam soil at six rates: 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 %. Forty-day-old seedlings were planted and kept to grow for 18 months until recording the data. Young Moringa trees were affected by soil salinity at relatively high levels. Low salt concentrations slightly reduced growth, whereas increasing salinity decreased plant height, stem diameter, branch number, leaf number, and root length. High salinity had a detrimental effect on shoot and root dry weights, and pigment contents. Nitrogen, phosphorous, and potassium contents in all plant parts were greatly reduced under high salinity levels. Sodium content increased with increasing salinity and showed a higher accumulation in roots.

Santosa *et al*. (2011) carried out an experiment to evaluate the effect of pre-soaking on *M. oleifera* seeds as a way to overcome salinity stress at first stages of development aiming the planting in marginal areas subjected to salinity. For the test, two batches of seeds were used, with 0 and 3 months of storage. Both seed batches were treated for two times of pre-soaking in water (0 and 24 hours). After the treatment the seeds were placed on germination paper soaked 2.5 times with saline solutions (0, 25, 50, 100, 200 and 250 mol m^{-3}) and kept into germination chamber at 25°C and continuous light. The variables analyzed were percentage, speed of germination index, length and dry matter of seedlings. The 18 treatments with submersion in water for 24 hours was effective to promote higher average values for vigor on Moringa seeds.

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted during the period from November to January 2022 to find out the effect of inorganic fertilizer on the vegetative growth of drumstick. This chapter presents a brief description of the experimental site, soil, climate, experimental design, treatments, cultural operations, data collection, and analysis of different parameters under the following headings:

3.1 Description of the experimental site

3.1.1 Experimental site

The experiment was set up at the Soil Science field, Hajee Mohammad Danesh Science and Technology University, Dinajpur. The experimental site is situated under the Dinajpur Sadar Upazila and is located at 25.13 ^{0}N latitude, 88.23 ^{0}E longitude, and at an elevation of 37.5 m above the mean sea level (Appendix-1). The land belongs to the Old Himalayan Piedmont Plain (AEZ-1). The topography of the field was medium-high.

3.1.2 Climate and weather

The experimental area possesses a sub-tropical climate. 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), relative humidity (%) at the experiment site during the study period i.e., November to January 2022 (Appendix-II).

3.1.3 Soil

The land where 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 the soil are presented in (Table 3.1).

Table 3.1. Morphological, physical, and chemical characteristics of the research area

A. Morphological characteristics

Location	Soil Science 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 (%)	53.2
Silt (%)	34
Clay (%)	12.8
Textural class	Sandy loam

C. Chemical characteristics

pH	6.8
Organic matter (%)	0.76
Total N (%)	0.028
Available P (ppm)	34.76
Exchangeable K (meq100^{-1} g soil)	5.00
Available S (ppm)	9.08

3.2 Planting materials

Drumstick plant was used for the study purpose in the rabi season (November to January). It was collected from Metal Biotech Nursery, Dinajpur.

3.3 Experimental design and treatments

The experiment was laid out in randomized complete block design (RCBD) with 6 treatments and 3 replications. The whole area was divided into 3 blocks and each block was divided into

6 units. As each treatment was replicated 3 times, therefore the total number of plots was 18 (6×3). There was some combination of the treatments.

Treatment combinations will be as follows:

T_1: No fertilizer (control)

T_2: RDF NPKS

T_3: $N_{10}P_{20}K_{20}$

T_4: $N_{20}P_{20}K_{20}$

T_5: $N_{30}P_{20}K_{20}$

T6: $N_{40}P_{20}K_{20}$

Fertilizer doses used in the experiment are given below

Fertilizer	Doses (kg ha^{-1})
TSP	45
MoP	35

3.4 Application of fertilizer

Here, N, P, K fertilizers were used as urea, TSP and MoP. The NPK fertilizers were applied as per recommended doses which were TSP 45 kg ha^{-1}, MP 35 kg ha^{-1} and Urea were applied with different increasing rate. The NPK fertilizers were applied in two split applications.1^{st} dose were applied at final land preparation and 2^{nd} dose were applied after 15 days of transplant. Moreover, NPK fertilizers were applied according to the treatments to the plots. Immediately after inorganic fertilizer application, rotary cultivation and spade were mixed amendments properly with the soil.

3.5 Layout of the experimental plots

Total number of plants	: 18
Space between plant to plant	: 1m
Treatment	: 6
Replication	: 3

3.6 Land preparation

The land was burst opened on 10 November 2022 by a tractor and prepared thoroughly by plowing and cross plowing with a power tiller and country plow. Finally, each block was prepared by laddering. The experiment was laid out in a randomized complete block design (RCBD), with three blocks each block was divided into six-unit plots as treatments with raised bunds around. The distance between two blocks and two plants was 1m.

3.7 Transplanting

Drumstick saplings were transplant in the field at the 19 November. Drumstick saplings were transplant in the at rabi (November to January) season. Plant to Plant spacing was maintained 1m and row to row distance was also maintained 1m.

The layout of the experimental field is shown in the figure. 1

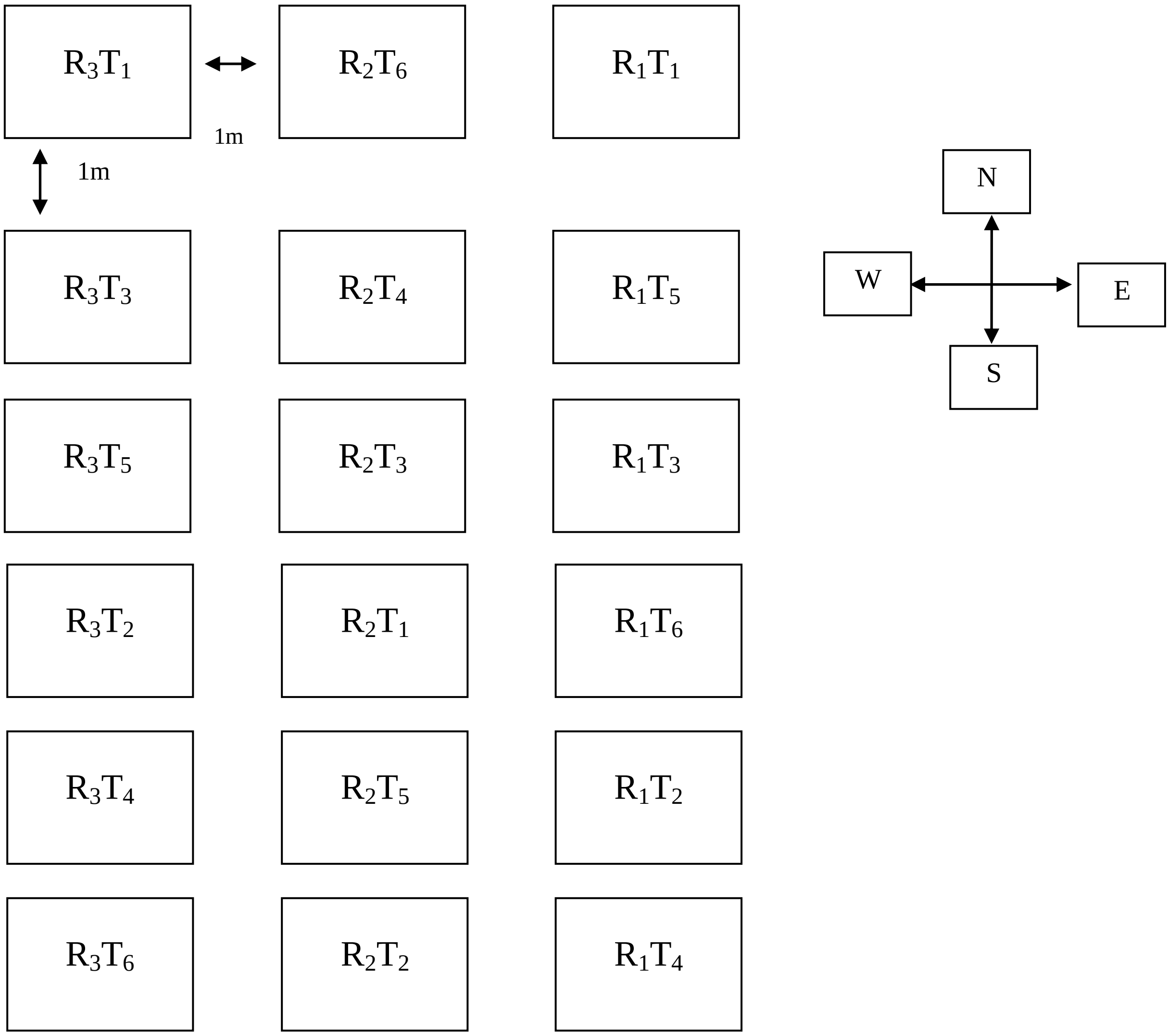

Fig. 1: Layout of the experiment

3.8 Intercultural operations

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

3.8.1 Weeding

Three-hand weeding was done at 15, 30, and 45 DAS of the seedlings.

3.8.2 Irrigation

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

3.8.3 Insect and pest control

There was no pest and disease in the field during the experimental period and hence no control measures were adopted.

3.9 Data collection

Final data were collected at 27 January 2023. For collecting data on several plant characters from each plant at different days after transplanting. The data were collected in the following head.

3.9.1. Plant height

Plant height was recorded manually from ground levels to top of the leaves from each plant at 15, 30 and 60 DAT.

3.9.2 Number of leaf plant^{-1}

Number of leaf plant^{-1} was recorded manually from each plant at 15, 30 and 60 DAT.

3.9.2 Stem Diameter

Stem diameter was recorded by the Slide Callipers from each plant at 15, 30 and 60 DAT.

3.10 Analysis of soil sample

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

- Total N content
- Available P
- Exchangeable K
- Available S

3.10.1 Collection and preparation of soil sample

3.10.1.1 Initial soil sample

The initial soil sample was collected from the plow depth layer (0-15 cm). Ten samples were taken by an auger from 10 locations covering the whole experimental plot and mixed thoroughly to make a composite sample. The composite sample was air-dried, grounded, sieved, and stored in a plastic bag for physical and chemical analyses.

3.10.1.2 Post-harvest soil sample

After harvesting the crop 5 soil samples were collected from each plot at 0 - 15 cm depth. The soil samples were air-dried, grounded, and sieved. Prepared soil samples were stored in plastic.

3.10.2 Particle size analysis

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

3.10.3 Determination of total nitrogen from soil samples

1g of oven-dry ground soil samples was taken in a micro-Kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se 100: 10: 1), 3 ml 30% H_2O_2, and 5 ml H_2SO_4 were taken into the flasks. The flasks were rotated and allowed to stand for about 10 minutes. Then it was heated at 380°C and continued until the digest was clear and colorless. The contents were taken into 100 ml volumetric flasks after cooling and the volumes were made up to the mark with distilled water. A reagent blank was prepared in the same way. These digests were used for nitrogen determination. 40% NaOH was added with the digests for distillation after the completion of digestion. The evolved ammonia was trapped in 4% Boric acid solution and 5 drops of the mixed indicator of bromocresol green and methyl red solution. At last, the distillates were titrated with the standard 0.01 N H_2SO_4 until the color changed from green to pink (Bremner and Mulvaney, 1982).

3.10.4 Available P

Available phosphorous (P) was extracted from the soil with 0.5 M sodium bicarbonate solution, pH 8.5 (Olsen *et al.*, 1954). P in the extract was then determined by developing blue color with $SnCl_2$ reduction of phosphomolybdate complex and the color intensity was measured calorimetrically at 660 nm wavelengths (Page *et al.*, 1982).

3.10.5 Exchangeable K

Exchangeable potassium (K) was determined from the ammonium acetate extraction method using a flame photometer as described by (Page *et al.*, 1982).

3.10.6 Available S

Available sulfur was measured by extracting the soil samples with CaC_{l2} solution (0.15%). The S content in the extract was estimated turbidimetrically with a spectrophotometer at 420 nm wavelength (Hunter, 1984).

3.11 Statistical analysis

The data were analyzed statistically (Gomez and Gomez, 1984) by F-test to examine whether the treatment effects were significant. The mean comparisons of the treatment were evaluated by DMRT (Duncan's Multiple Range Test). The analysis of variance (ANOVA) for different treatment parameters was done by a computer package program "SPSS".

CHAPTER IV
RESULTS AND DISCUSSION

The results of the present study have been presented in several tables and figures. Adequate discussion and possible interpretations whenever suitable have been provided in this chapter.

4.1 Plant height (PH)

A significant variation ($p < 0.01$) was observed in plant height of drumstick at 15, 30 and 60 DAT due to application of inorganic fertilizer (Table 4.1). At 15 DAT, the highest plant height (86.13 cm) was observed in treatment T_5 which was significantly parallel with T_6 (77.83 cm) and the lowest plant height (61.16 cm) was recorded in treatment T_1. At 30 DAT, the highest plant height (107.63 cm) was observed in treatment T_5 and the lowest plant height (83.66 cm) was recorded in treatment T_1. At 90 DAT, the highest plant height (126.13 cm) was observed in treatment T_5 which is similar to T_4 (97.23 cm) where $N_{30}P_{20}K_{20}$ were applied and the lowest plant height (109.16 cm) was recorded in treatment T_1 where no fertilizer was applied as control. At harvest 90 DAS, the treatments with respect to plant height were ranked in order of $T_5 > T_6 > T_4 > T_3 > T_2 > T_1$. Application of organic fertilizer (NPK @ 30,20,20 kg ha^{-1} respectively) might have improved the soil's physical properties, particularly soil porosity, structure, and water holding capacity, and supplied other plant growth promoting nutrients and substances. As a result, the increasing dose of NPK fertilizer rates increased plant height. This trend was supported by Vora *et al.* (2023) who reported that the plant height was significantly governed by the application of NPK containing fertilizer.

4.2 Number of leaves $plant^{-1}$

The number of leaves $plant^{-1}$ is an important yield-determining factor in drumstick plants. The number of leaves $plant^{-1}$ was not significantly different ($p > 0.05$) among the studied varieties indicating that varietal treatment had a consistent effect on this parameter. The number of leaves plant^{-1} was influenced by the application of different rates of inorganic fertilizers (Table 4.2).

Table 4.1: Effect of inorganic fertilizer on the plant height of drumstick at different days after transplanting (DAT)

Treatment	Plant height (cm)		
	15 DAT	30 DAT	60 DAT
T_1	61.16 c	83.66 c	109.16 c
T_2	64.66 bc	89.16 bc	113.66 bc
T_3	68.26 b	91.76 b	117.26 b
T_4	74.73 b	97.23 ab	119.73 ab
T_5	86.13 a	107.63 a	126.13 a
T_6	77.83 ab	93.33 b	119.83 ab
SEM	0.83	1.54	1.45
Significance level	**	**	**

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

Ph= plant height, * = 5% level of significance; ** = 1% level of significance; NS = Not significance; SEM = Standard error mean.

Treatment combinations will be as follows:

T_1: No fertilizer (control)

T_2: RDF NPKS

T_3: $N_{10}P_{20}K_{20}$

T_4: $N_{20}P_{20}K_{20}$

T_5: $N_{30}P_{20}K_{20}$

T6: $N_{40}P_{20}K_{20}$

Table 4.2: Effect of inorganic fertilizer on the number of leaves plant^{-1} of drumstick at different days after transplanting (DAT)

Treatment	Number of leaves plant^{-1}		
	15 DAT	30 DAT	60 DAT
T_1	6.25	14.27	20.61
T_2	7.66	15.89	20.78
T_3	7.36	16.33	22.33
T_4	8.23	16.33	23.33
T_5	9.33	18.33	24.93
T_6	7.41	16.33	22.33
SEM	0.15	0.51	0.62
Significance level	NS	NS	NS

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

* = 5% level of significance; ** = 1% level of significance; NS = Not significance; SEM = Standard error mean.

Treatment combinations will be as follows:

T_1: No fertilizer (control)

T_2: RDF NPKS

T_3: $N_{10}P_{20}K_{20}$

T_4: $N_{20}P_{20}K_{20}$

T_5: $N_{30}P_{20}K_{20}$

T6: $N_{40}P_{20}K_{20}$

At 15 DAT, the maximum number of leaves plant^{-1} (9.33) was found in treatment T_5 and the lowest number of leaves plant^{-1} (6.25) was found in treatment T_1. At 30 DAT, the maximum number of leaves plant^{-1} (18.33) was observed in the treatment T_5 and the lowest number of leaves plant^{-1} (14.27) was recorded in the treatment T_1. At 60 DAT the maximum number of leaves plant^{-1} (24.93) was noticed in treatment T_5 and the lowest number of leaves plant^{-1} (20.61) was found in treatment T_1 where no fertilizer was used. The treatment T_5 showed the highest number of leaves plant^{-1} due to more nutrient availability. The result of the present study is similar to the findings of Abdoun *et al.* (2023) who found that the application of inorganic fertilizer the best performance for the number of leaves plant^{-1}.

4.3 Diameter of the stem

No significant variation ($p > 0.05$) was observed in diameter of stem due to the application of different doses of inorganic fertilizer individually in different treatments. The diameter of the stem was influenced by the application of different levels of NPK fertilizer (Table 4.3). At 15 DAT, the maximum diameter of the stem of drumstick plants (3.53 cm) was found in treatment T_5 and the lowest diameter of the stem (3.20 cm) was recorded in treatment T_1. At 30 DAT, the highest diameter of the stem (6.89 cm) was found in treatment T_5 and the lowest diameter of the stem (6.56 cm) was found in treatment T_1. At 60 DAT, the maximum diameter of the stem (10.79 cm) was found in the treatment T_5 where $N_{30}P_{20}K_{20}$ were applied and the lowest diameter of the stem (10.46 cm) was found in the treatment T_1 where no fertilizer was used as control. The treatment showed the highest diameter of the stem due to more nutrient availability. The result of the present study is similar to the findings of Hoque *et al.* (2022) who found that the application of inorganic fertilizer showed no significant effect on diameter of the stem.

Table 4.3: Effect of inorganic fertilizer on the stem diameter of drumstick at different days after transplanting (DAT)

Treatment	Stem Diameter (cm)		
	15 DAT	30 DAT	60 DAT
T_1	3.20	6.56	10.46
T_2	3.46	6.82	10.72
T_3	3.43	6.79	10.69
T_4	3.27	6.62	10.52
T_5	3.53	6.89	10.79
T_6	3.30	6.66	10.56
SEM	0.011	0.012	0.015
Significance level	NS	NS	NS

In the figures having a similar letter (s) do not differ significantly at 5% level of significance. * = 5% level of significance; ** = 1% level of significance; NS = Not significance; SEM = Standard error mean.

Treatment combinations were as follows

T_1: No fertilizer (control)

T_2: RDF NPKS

T_3: $N_{10}P_{20}K_{20}$

T_4: $N_{20}P_{20}K_{20}$

T_5: $N_{30}P_{20}K_{20}$

T6: $N_{40}P_{20}K_{20}$

4.4 Chemical properties of post-harvest soil

4.4.1 Total N in soil

The total N content in the post-harvest soil varied significantly ($p > 0.01$) by different treatments (Table 4.4). The total N content of the post-harvest soils ranged from 0.026 to 0.037%. The highest total N content (0.037%) was obtained in the treatment T_6 which is statistically similar to T_4 (0.033%) and T_5 (0.030%) where $N_{40}P_{20}K_{20}$ were applied and the lowest total N content (0.026%) was noted in the T_1 treatment. The results indicated that application of chemical fertilizer exerted an increasing effect on the total N contents of the post-harvest soils. Drumstick cultivation with chemical fertilizers tended an increasing effect on the total N content of the soil. Sardooi *et al*. (2019) observed that the application of chemical fertilizer increased the total N content in soil.

4.4.2 Available P in soil

The available phosphorus content of the post-harvest soil varied significantly ($p < 0.01$) by different treatments of inorganic fertilizer application. Available P content varied from 32.31 ppm to 44.58 ppm (Table 4.4). The maximum (44.58 ppm) phosphorus content was observed in treatment T_6 which is similar to T_2 (37.69 ppm), T_3 (39.74 ppm), T_4 (43.55 ppm) and T_5 (43.00 ppm) where $N_{40}P_{20}K_{20}$ were applied. The lowest phosphorus content (32.31 ppm) was observed in the T_1 treatment. The value of the P showed that there was a significant difference among the different treatments of the post-harvest soil. The result of the present study was similar to the findings of Sardooi *et al.* (2019) and Kumar *et al.* (2017).

4.4.3 Exchangeable K in soil

There were significant differences in the exchangeable potassium (K) contents in post-harvest soil ($p < 0.01$). The exchangeable K content of the post-harvest soil was influenced considerably by the application of chemical fertilizer. The exchangeable K content of the post-harvest soil ranged from 3.75 to 5.40 meq.100 g^{-1}soil soil (Table 4.4). All the treatments caused an increasing effect on the exchangeable K contents against the initial value of 5.00 meq.100 g^{-1}soil soil. The highest value of exchangeable K was found (5.40 meq.100 g^{-1}soil) in treatments T_6 where $N_{40}P_{20}K_{20}$ were applied and which is similar to T_2 (4.80 meq.100 g^{-1}soil), T_3 (4.75 meq.100 g^{-1}soil), T_4 (5.00 meq.100 g^{-1}soil), and T_5 (5.12 meq.100 g^{-1}soil) and the lowest value of exchangeable K was found (3.75 meq.100 g^{-1}soil) in the T_1 treatments were no fertilizer applied as control. The result of the present study was similar to the findings of Sarhan *et al.* (2016) reported that application of inorganic fertilizer maximized the exchangeable K contents in soil.

4.4.4 Available S in soil

Significant ($p < 0.01$) effect of available S contents caused in the post-harvest soils due to application of P and S containing fertilizer by different rates. The available S content in the studied soil ranged from 13.56 ppm to 9.00 ppm. All the treatments caused an increasing effect on the available S contents against the initial value of 9.08 ppm. The highest S content (13.56 ppm) soil was found in the treatment T_6 treatment where $N_{40}P_{20}K_{20}$ were applied and which is similar to T_2 (9.79 ppm), T_3 (9.80 ppm), T_4 (10.81 ppm) and T_5 (12.00 ppm). The lowest S content (9.00 ppm) was observed in treatment T_1. This trend was not supported by Badran *et al.* (2016).

Table 4.4 Effect of chemical fertilizer on total N, available P, exchangeable K, and available S on the post-harvest soil

Treatments	Total N (%)	Available P (ppm)	Exchangeable K (meq.100 g^{-1}soil)	Available S (ppm)
T_1	0.026 c	32.31 c	3.75 c	9.00 c
T_2	0.025 bc	37.69 abc	4.80 abc	9.79 abc
T_3	0.027 bc	39.74 abc	4.75 abc	9.80 abc
T_4	0.030 ab	43.55 ab	5.00 ab	10.81 ab
T_5	0.033 ab	43.00 ab	5.12 ab	12.00 ab
T_6	0.037 a	44.58 a	5.40 a	13.56 a
Initial Soil	0.028	34.76	5	9.08
SEM	0.003	1.67	0.29	1.02
Significance level	**	**	**	**

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

* = 5% level of significance; ** = 1% level of significance; NS = Not significance; SEM = Standard error mean.

Treatment combinations will be as follows:

T_1: No fertilizer (control)

T_2: RDF NPKS

T_3: $N_{10}P_{20}K_{20}$

T_4: $N_{20}P_{20}K_{20}$

T_5: $N_{30}P_{20}K_{20}$

T6: $N_{40}P_{20}K_{20}$

CHAPTER V

SUMMARY AND CONCLUSIONS

The research work was conducted in the research field of the Department of soil science, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period from November to January 2022 in the Rabi season to study the effect of inorganic fertilizer on the vegetative growth of drumstick. The experimental soil belongs to the Old Himalayan Piedmont Plain (AEZ-1). Initially, the soil was sandy loam in texture having pH 6.8, organic matter content 0.76%, total N 0.028%, available P 34.76 ppm, exchangeable K 5.00 mg 100^{-1} g soil and available S 9.08 ppm. The experiment was laid out in a randomized complete block design (RCBD). There were six treatments with three replications in the experiment. So, the total numbers of plots were 18. The unit plot size was 1 m^2 (1 m × 1 m). Different doses of chemical fertilizer were used as treatment viz T_1: No fertilizer (control), T_2: RDF NPKS, T_3: $N_{10}P_{20}K_{20}$, T_4: $N_{20}P_{20}K_{20}$, T_5: $N_{30}P_{20}K_{20}$, T6: $N_{40}P_{20}K_{20}$. Saplings were sown on 19 November 2022. The final data were collected on 27 January 2023. Plot-wise and yield components were recorded. Soil samples were collected before fertilizers application and after harvest. Initial and post-harvest soil samples were analyzed for physical and chemical properties of soil using the standard methods. All the data were statistically analyzed by F-test and the mean differences were judged by Duncan's Multiple Range Test (DMRT).

The study revealed that all the yield contributing characteristics except plant height were not significantly influenced by different treatments used in the experiment. At The highest value of plant height (at 15 DAT, 30 DAT and 60 DAT, 86.13 cm, 107.63 cm and 126.13 cm, respectively), number of leaves $plant^{-1}$ (at 15 DAT, 30 DAT and 60 DAT, 9.33, 18.33 cm and 24.93 cm, respectively), diameter of the stem (at 15 DAT, 30 DAT and 60 DAT, 3.53 cm, 6.89 cm and 10.79 cm, respectively), was recorded in the treatment T_5. Oppositely, the lowest values of yield contributing traits were noted in the treatment T_1 (control). The results revealed that the application of NPK containing fertilizer ($N_{30}P_{20}K_{20}$) showed better performance on growth and yield of Drumstick.

Application of chemical fertilizer resulted in a considerable influence on the properties of the post-harvest soils such as total N, available P, exchangeable K and available S. In post-harvest soil application of NPK gave positive result. The total highest levels of N, P K and S (0.037%, 44.58 ppm, 5.40 mg 100^{-1}g and 13.56 ppm, respectively) were found in T_6 treatment where $N_{40}P_{20}K_{20}$ were applied and lowest (0.026%, 32.31 ppm, 3.75 mg 100^{-1}g and 9.00 ppm, respectively) was in T_1 treatment.

From the present study it may be concluded that drumstick plants responded better to the nutrients supplied when inorganic fertilizer ($N_{30}P_{20}K_{20}$) were applied. The utilization of inorganic fertilizer ($N_{40}P_{20}K_{20}$) resulted better effects in producing grain yields and improved the soil properties. The lower saplings yield of control plot might be due to the low availability of nutrients to the plants. So, application of NPK containing fertilizer in drumstick plants produced better yield and improved soil health. So, drumstick plants can be cultivated in this soil profitably and better growth and yield by the application of inorganic fertilizer $N_{40}P_{20}K_{20}$ for drumstick production and better soil health.

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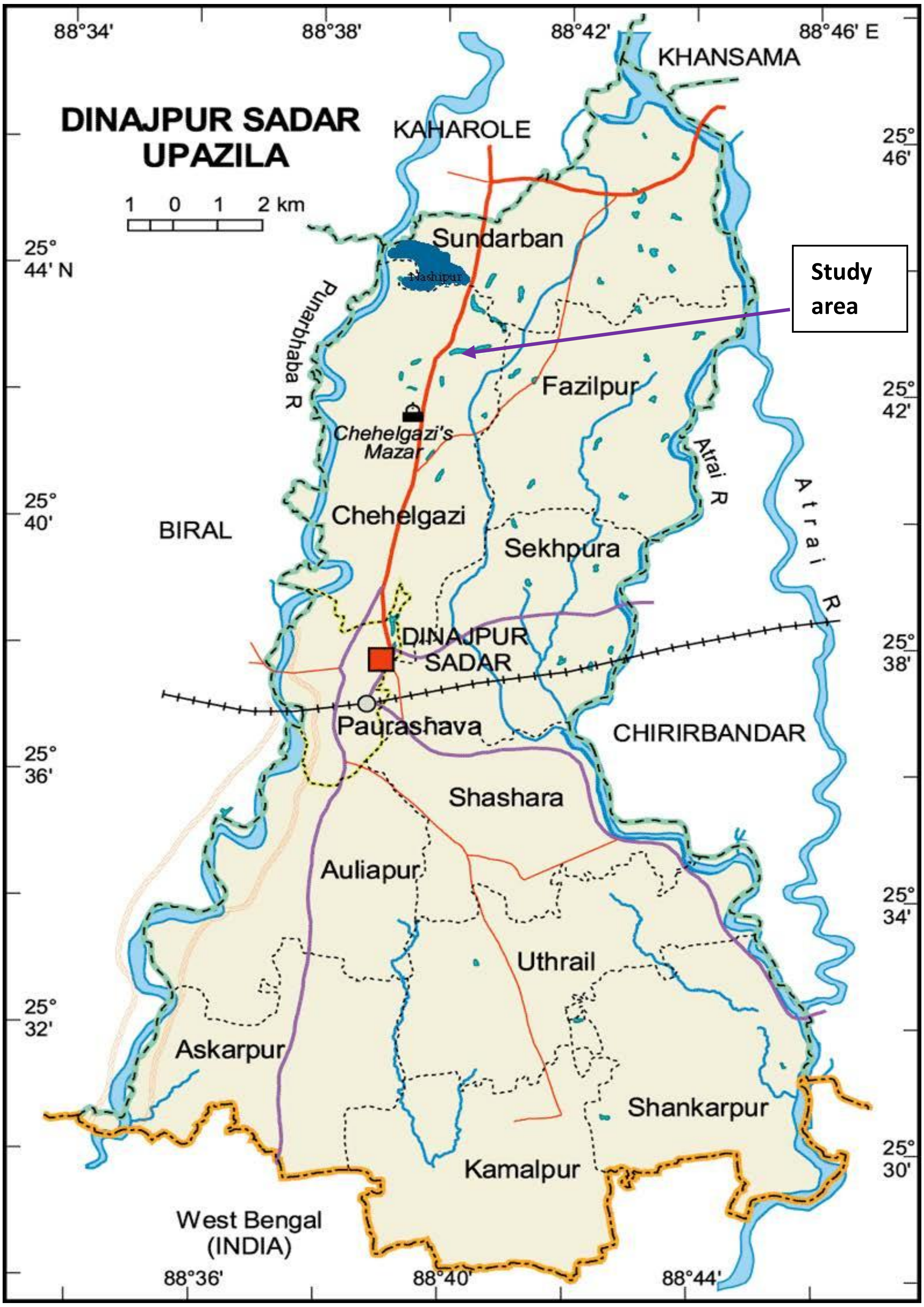
APPENDICES

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 August to December 2022)

Year	Month	**Temperature (^{0}C)		**Relative Humidity (%)	**Rainfall (mm)
		Minimum	Maximum		
2022	October	22.2	31.1	82	115.1
	November	16.5	28.9	78	7.0
	December	11.9	25.5	78	10.2
	January	10.4	23.4	79	12.3
	February	12.5	26.4	70	10.5

**Monthly average

Source: Bangladesh Meteorological Department.

Appendix III. Some picture of the experimental site

মেটাল বায়োটেক নার্সারি
Metal
মোবাইল: