EFFECT OF DIFFERENT SOURCES OF NUTRIENTS ON THE GROWTH AND YIELD OF BEETROOT (*Beta vulgaris* L.)

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CERTIFICATE

This is to certify that the thesis entitled ***"EFFECT OF DIFFERENT SOURCES OF NUTRIENTS ON THE GROWTH AND YIELD OF BEETROOT"*** *submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in HORTICULTURE****, embodies the result of a piece of authentic research work carried out by* ***AL HASIR GAJANFOR ALI,*** *Registration No.* ***14-06135*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

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- ***Author***

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ABSTRACT

A field experiment was accomplished in the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2020 to March, 2021 to study on the effect of different sources of nutrients on the growth and yield of beetroot. The experiment comprised of eleven levels of T_0: $N_0P_0K_0$ + No Organic Manure + No Biochar (Control); T_1: NPK 100% (RDF)/ha; T_2: Biochar 10 t/ha; T_3: Organic Manure 15 t/ha; T_4: NPK 50% (RDF)/ha + Biochar 10 t/ha; T_5: NPK 100% (RDF)/ha + Biochar 5 t/ha; T_6: Organic Manure 7.5 t/ha + Biochar 10 t/ha; T_7: Organic Manure 15 t/ha + Biochar 5 t/ha; T_8: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha; T_9: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha + Biochar 5 t/ha and T_{10}: NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha treatments were used in this experiment arranged in Randomized Complete Block Design (RCBD) with three replications. Data on different parameters were taken where all treatments showed significant variations. The maximum yield (41.21 t/ha) was recorded from T_{10} (NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha) and the lowest yield was (21.35 t/ha) obtained from T_0. The analyses revealed that (NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha) treatment was the best in terms of net return (8,75,100 Tk.) with a benefit cost ratio of (2.13), it was obvious from the above results that the treatment of (NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha) was more profitable than rest of treatments.

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ABBREVIATIONS

@	At the rate
AEZ	Agro-Ecological Zone
ANOVA	Analysis of variance
AFU	Agriculture and Forestry University
FYM	Farmyard Manure
CV%	Percentage of coefficient of variation
DAS	Days after sowing
FvA	Fulvic Acid
Et al	All and others
Etc	Etcetera
FAO	Food and Agricultural Organization
FYM	Farm Yard Manure
J.	Journal
LS	Least Significant Difference
RCBD	Randomized Complete Block Design
RFD	Recommended Fertilizer Dose
SOC	Soil Organic Carbon
%	Percent
^{0}C	Degree Celsius
m	Meter
m^3/fed.	Cubic meter per federal (US barrels)
cm	Centimeter
cfu ml^{-1}	Colony forming unit per milliliter
kg	Kilogram
Kg ha^{-1}	Kilograms per Hector
t ha^{-1}	Ton per Hectare
g	Gram
TSS	Total Soluble Solid
CEC	Cation Exchange Capacity
EC	Electrical Conductivity
DM	Dry Matter
SRDI	Soil Research Development Institute
TSP	Triple Super Phosphate
BARI	Bangladesh Agriculture Research Institute
DMRT	Duncan’s Multiple Range Test
PAPR	Partially Acidulated Phosphoric Rock
DW	Dry Weight

CHAPTER-I
INTRODUCTION

Beetroot (*Beta vulgaris* L.) belongs to the Chenopodiaceae family and is originally from temperate climate regions of Europe and North Africa. In Brazil, it is grown in the south and southeast regions (77% of total produce), and annual yield is 32-42 tons per hectare, which corresponds an average production of 280 tons. Beetroot is a rich source of minerals like magnesium, sodium, potassium, iron, manganese. It also consists a lot of antioxidants and vitamins like A, B and C. It is very good source of dietary fiber and natural dye. Beetroot has many healthful benefits, therefore in the recent years it has been considered as one of the most essential functional foods.

Beetroot (also known by its colloquial name, "beets" or beta vulgaris) is a sweet, healthy vegetable loaded with antioxidants. It's actually these antioxidants, packed inside beetroot's red pigments that contain cancer-preventing and heart-protecting properties. Beetroot is generally easy to grow and is consistently ranked as one of the top 10 vegetables grown in home gardens. All organic manures improve the behaviors of several elements in soils through that active group (fulvic and humic acids) which have the ability to retain the elements in complex and chelate form. These materials release the elements over a period of time and are broken down slowly by soil microorganisms. The extent of availability of such nutrients depends on the type of organic materials and microorganisms (Saha *et al*., 1998). Also, organic manure supplies the plants with many nutrients which improve the physical properties of the soil consequently improve the plant growth (Slawon *et al*., 1998) on radish plant and yield of both qualitatively and quantitatively.

However, Marculescu *et al*., (2002) revealed that, the soil with its content in macro and microelements, enhanced by the use of organic fertilizers, play an essential role in the plants growing and development, in biosynthesis of the organic substances. In the same respect, Shafeek *et al.,* (2003) on Japanese radish reported that increasing the rate of organic manure up to (40 m^3 / fed.) resulted in the highest total roots yield and the highest values of crude protein, N, P and K as well as the heaviest seed production. Also, it is very cheap and expressed cash money improving the income of farmer, in addition, uses these organic materials are safe for human health. However, Enteshari *et al.*, (2012) on turnip plants reported that using organic compost reduces the negative effects of chemical fertilizer and increase soil fertility.

The results showed that the germination, growth parameters (total chlorophyll content, fruit diameter, leaf number, leaf area, shoot fresh weight and dry weight) was significantly altered, especially with these roots of plants in 20% organic compost. Moreover, El-Sherbeny *et al.*, (2012) found that adding organic compost tea increased carbohydrate content of turnip roots. Also, Heba and Sherif (2014) found that compost manure as a soil drench alone or with yeast increased the %N and %P uptake rates, the values were 126%, 174% for N and 255%, 322% for P respectively. In addition, Aisha *et al.*, (2014) found that adding organic manure at high rates (20 m^3 /fed.) had a significant effect on growth characters, i.e., plant length, number of leaves/plants, fresh and dry weight/plant as well as root fresh and dry weight and its components (root length and diameter). Also, gave the highest percentage of protein, N, P, K and Fe ppm as well as total carbohydrate percentage of turnip plants. However, Marques *et al.*, (2010) evaluating rates (0 to 80 t ha^{-1}) of cow manure on production of beetroot, cultivar Early Wonder, obtained greatest yield values at the highest rate. On the other hand, Felipe *et al.*, (2015) reported that the rates of the organic manure does not affect the quality traits, but the rate of 49 t ha^{-1} resulted in the maximum root yield.

Organic manure has multiple benefits due to the balanced supply of nutrients, including micro nutrients, increased soil nutrient availability due to increased microbial activity, the decomposition of harmful elements, soil structure improvements and root development, and increased soil water availability. Chand *et al.*, (2006) has reported that the mixed use of nitrogen, phosphorus, potassium (NPK) chemical fertilizer and livestock organic manure increases the mean growth of mint (*Mentha arvensis*) and mustard (*Brassica juncea*) by 46% and the soil concentrations of nitrogen, phosphorus, potassium by 36%, 129% and 65% respectively.

Inorganic fertilizers are from non-living sources. Most elements are absorbed by plants as inorganic ions (electrically charged atoms). A plant does not distinguish between ions originating from inorganic or from organic sources. When nutrients are the main interest, inorganic fertilizes usually favored.

It is classified as a plant of high potassium (K) requiring crop (Johanson *et al.*, 1971). Fertilizer is considered as a limiting factor for obtaining high yield and quality (Ouda, 2002). Thus, application of suitable fertilizers, such as nitrogen (N) and potassium (K) may be one of the favorable factors for the production of beetroot. Many investigators have confirmed the role of N and K in increasing the yield and quality of beetroot by enhancing the biosynthesis of organic metabolites and improving nutritional status (Bondok, 1996; El-Shafai, 2000; O'shea *et al*., 2009). Ibrahim *et al*., (2002) found that the highest sucrose percentage and juice purity were achieved with K application up to 228.5 kg K_2O ha^{-1}. The beneficial effect of K fertilization on growth, yield and quality of beetroot was emphasized by previous studies (Abd El-Aziz *et al.*, 1992; Sobh *et al*., 1992; El-Maghraby *et al*., 1998; El-Shafai, 2000; Ouda, 2002). Beetroot yield and quality are dramatically influenced by the level of available N. Residual and fertilizer N levels allowing adequate top growth and maximize root growth and extractable sucrose concentration are desired. However, sucrose yield decreases by over-fertilizing beetroot with more N than needed for maximum sucrose production (Hassanin & Elayan, 2000).

An adequate supply of N is essential for optimum yield but excess N may result in an increase in yield of roots with lower sucrose content and juice purity. Yield increased with applied but TSS, sucrose%, purity% and recoverable sugar yield per ha were significantly decreased as N level increased (Lauer, 1995; Salama & Badawi, 1996; El-Hennawy *et al*., 1998).

Contrary to this, Horn and Fürstenfeld (2001) showed that the uptake of N by beetroot plants increased by increasing the application level of N, while the sugar content and juice purity decreased. The direct effect of K on yield is less marked than of N, which itself constitutes a part of the organic matter synthesized during growth. Also, K uptake is much affected by N level and in most cases, K is more effective at higher N level, which is the case especially to modern high yielding varieties (El-Shafai, 2000; Mäck *et al.,* 2007). The interaction between N and K were small at low rates, but became more important at high rates and the best returns from one nutrient were obtained at high rates of others. Root crops especially, have a high K requirement. It is commonly observed that root or tube enlargement is depressed relatively more than leaf development, when K is in short supply (Inal, 1997). In Egypt, many investigations revealed that 214-262 kg N ha^{-1} exhibited the highest root quality, technological characters, root and sugar yields and minimized sugar losses to molasses (Hassanin & Elayan, 2000; Moustafa & Darwish, 2001; Abo El-Wafa, 2002; Hilal, 2005). The aim of the present study was to determine the effect N, P and K fertilization on the yield of beetroot plant grown on a non-calcareous soil.

Biochar is a predominantly stable, recalcitrant organic carbon (C) compound that is produced from biomass via pyrolysis (Lehmann, 2009; Laird *et al*., 2008). Due to the potential to sequester C in the soil, biochar application is currently considered as a means to help mitigating greenhouse gas (GHG) emissions and climate change (Marris, 2006; Woolf *et al*., 2010). Plant root systems play an important role in plant growth and soil C sequestration (Matamala *et al*., 2003; Nie *et al*., 2013) because they not only take up soil nutrients and water to support plant production but also transport photosynthetically fixed C to soil organic matter pools (Jackson *et al*., 1997; Li *et al*., 2015; Peng *et al*., 2017). Biochar application may have significant effects on plant root morphology and functioning because biochar particles contact plant roots directly (Prendergast-Miller *et al*., 2014). Therefore, it is critical to determine how root traits respond to biochar application for sustainable biochar management (Laird, 2008; Jeffery *et al*., 2015).

However, soil amendment with biochar, produced by the combustion of biomass under oxygen-limited conditions, has attracted a fair amount of research interest due to its abundant usage and wide potential, which includes enhancing crop production by improving soil fertility, decreasing greenhouse gas emissions and increasing soil carbon sequestration (Gaskin *et. al.* 2008).

Numerous case studies have been conducted to examine how plant roots respond to biochar application (Rillig *et al*., 2010; Prendergast-Miller *et al*., 2011; Brennan *et al*., 2014; Vanek & Lehmann, 2015). Some root traits, including root biomass, morphology (Pren-dergast-Miller *et al*., 2011; Brennan *et al*., 2014; Keith *et al*., 2015), nutrient concentration, and root-associated microbes (Rondon *et al*., 2007; Rillig *et al*., 2010; Vanek & Lehmann, 2015), can be significantly influenced by biochar application.

Addition of biochar in the soil can be extremely useful to improve the soil quality, as well as to stimulate the plant growth, and thus, biochar can play an important role in developing a sustainable system of agriculture. Several uses and positive effects of biochar amendment have currently been considered as an effective method to reclaim the contaminated soil (Placek *et al*., 2016) and to achieve high crop yields without harming the natural environment. The positive influence of biochar on plant growth and soil quality suggests that using biochar is a good way to overcome nutrient deficiency, making it a suitable technique to improve farm-scale nutrient cycles. Therefore, this work aimed to evaluate the effect of biochar on the yield of beet root.

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To date, the effects of biochar application on root traits remain controversial and highly variable. For example, root biomass may increase (Prendergast-Miller *et al*., 2011; Varela Milla *et al*., 2013), under biochar application. These highly diverse results are not surprising because multiple factors and processes are involved in root responses (Prendergast-Miller *et al*., 2014). For instance, root establishment in the soils can be enhanced by biochar addition (Brennan *et al*., 2014). The choice of biochar type is also important as biochar generated from different materials or pyrolysis conditions varies significantly in structure, nutrient content, pH, and phenolic content (Novak *et al*., 2009; Lehmann *et al*., 2011). The characteristics of biochar, as well as its application rate and cumulative amount, may affect the soil environment and thereby alter root traits (Taghizadeh-Toosi *et al*., 2012). Biochar application promotes plant growth mainly by improving characteristics of the soil environment, such as nutrient status, pH and cation-exchange capacity (CEC) (Lehmann *et al*.,2011). In addition, biochar is often applied with fertilizer to the soil; this combined application may interactively regulate root growth (Alburquerque *et al*., 2015). However, to our knowledge, no synthesis has revealed any general patterns of responses of root traits to biochar application. The lack of a comprehensive synthesis significantly prevents biochar from being widely popularized as a highly efficient, sustainable soil management practice for food security under climate change (Jeffery *et al*., 2015).

Objectives of the study

i. To identify the effect of organic manure, inorganic fertilizer and biochar for beetroot production.
ii. To find out sustainable combination level of organic manure, inorganic fertilizer and biochar for maximum yield of beetroot.

CHAPTER-II
REVIEW OF LITERATURE

Beetroot is one of the most important and popular salad vegetable in Bangladesh as well as in many countries of the world. The crop has conventionally less concentration by the researchers on various aspects because it is newly introduced crop. Very few studies on the growth and yield of beetroot have been carried out in our country as well as many other countries of the world. Therefore, the research work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important informative works and research findings related to inorganic fertilizer, organic manure and biochar on beetroot so far been done at home and abroad have been reviewed in this Chapter under the following headings.

2.1 Effect of inorganic fertilizer on growth and yield of different crops including Beetroot

Sapkota *et al*. (2021) this study was conducted in the horticulture farm of the Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal from November 2018 to February 2019 to evaluate the effect of organic and inorganic sources of nitrogen (N) on growth, yield, and quality of beetroot (*Beta vulgaris* L.) varieties. The experiment was laid out in two factorial randomized complete block design with four replications consisting of two beetroot varieties, i.e., Madhur and Ruby Red, and five N source combinations, i.e., N_1: 100% poultry manure (PM), N_2: 50% PM + 50% urea, N_3: 100% farmyard manure (FYM), N_4: 50% FYM + 50% urea, and N_5: 100% urea (120:80:40 kg NPK ha^{-1}). Results of this study indicated a significant impact of N sources and varieties on the assessed parameters. During harvest, a significantly higher plant height (41.84 cm), number of leaves per plant (14.68), leaf length (34.56 cm), leaf width (11.38 cm), and beetroot diameter (72.15 mm) were observed in the N_2 treatment. Likewise, higher economic (49.78 t ha^{-1}) and biological yields (78.69 t ha^{-1}) were also recorded in the N_2 compared to other N sources. Out of the two varieties, the Madhur variety was significantly better in most growth and yield parameters. Similarly, the Madhur variety showed a significantly higher economic (44.49 t ha^{-1}) and biological yields (69.79 t ha^{-1}) compared to the Ruby Red variety. However, the physiological weight loss was higher in the Ruby Red variety. Therefore, the current study suggests that an integration of poultry manure along with the combination of N fertilizer and the Madhur variety is the best combination for quality beetroot production in the Terai region of Nepal.

Maurya and Goswami (1985) revealed that, nitrogen fertilizer application during growth stage of carrot increases plant height of carrot. Beside this it also increased the leaf number of carrot. After the application of over dose of nitrogen the length and diameter of carrot root was increased (Sarker, 1999; Batra and Kallo, 1990). Sarker (1999) showed that nitrogen treatments significantly increased yield of carrot per hectare.

Nitrogen had significant influence on the growth and yield of carrot. The tallest plants (47.36 cm), highest number of leaves (11.61), highest root length (16.17 cm), maximum fresh weight of leaves (145.1 g), maximum dry matter content of leaves (11.66%), maximum dry matter content of root (15.90%), maximum fresh weight of root (68.33g), maximum gross yield of root (22.55 t/ha) and maximum marketable yield of root (20.67 ton/ha) were found in 100 kg N per ha. Therefore, from the present study it maybe concluded that, 100 kg N per ha were suitable for optimum growth and yield of carrot (Moniruzzaman *et al*., 2013).

A review by Mozafar (1993) summarizes the effects of N fertilization on the vitamin content of plants, including carrot. Fertilization with N, especially at high rates, decreases the concentration of vitamin C and increases the concentration of carotenes. Musa et al. (2010) reported that the applied nitrogen significantly elevated ß-carotene content at maturity, while no significant variation was recorded at fruiting. Nitrate accumulation in carrot root was measured from the carrot root which were grown in the Central European region, the values range from 50 to 500 mg NO3kg-1 fresh weight FW) (Pokluda, 2006; Gutezeit, 1999; Mazur, 1992). Increasing fertilizer rates increased nitrate accumulation over control in carrot (John et al., 2003). With 180 kgNha-1 supply, a higher nitrate accumulation in carrot is possiblydue to a greater uptake of nitrate than its utilization in plant physiological processes.

(Cantliffe, 1973). Hartmann (1983) found increased soil nitrate concentrations and nitrate accumulation in plants under drought and inadequate watering conditions.

Similar results were obtained by Augustin *et al*. (1977), who reported a two-fold increase in nitrate contentdue to insufficient irrigation.

Allaire-Leung *et al*. (2001) found that nitrate leaching was positively correlated to soil NO3-N content but was not correlated to irrigation depth, irrigation uniformity, or deep percolation.

Kandil *et al.* (2020) two field experiments were conducted at the research farm of the Faculty of Agriculture, Saba Basha, Alexandria, Egypt, to study the effects of foliar application treatments and boron (B) fertilizer applications on monogerm sugar beet plants (cultivar classic) during the 2017/2018 and 2018/2019 seasons. The treatments were replicated three times in a split-plot design. Four foliar applications [fulvic acid (FvA), NPK nanoparticles (NPK NPs), FvA + NPK NPs, and a control (water)] were randomly allocated to the main plots. Different numbers of foliar spray applications of B [one application at 120 days after sowing or two applications at 120 and 150 days after sowing, as well as a control (water)] were assigned within the subplots. FvA + NPK NPs significantly increased the root length, root diameter, root weight, and root/shoot ratio of the sugar beet plants; the greatest values were obtained by spraying FvA + NPK NPs during both seasons. B significantly increased the root yield, shoot yield, and biological yield, and two applications of B resulted in the greatest values of root yield, shoot yield, biological yield, and quality of sugar beet. The interaction between FvA or NPK NPs and B significantly affected the yield and quality parameters of the sugar beet plants. However, the greatest mean values of these traits resulted from foliar applications of FvA + NPK NPs in conjunction with applications of B under the conditions at Alexandria, Egypt.

Wotchoko *et al.* (2019) this work aims to compare the effects of basalt dust, poultry manure and NPK 20-10-10, single and combined, on the growth and yield of beetroot (*Beta vulgaris*). Thus, fieldwork was preceded by land evaluation and standard laboratory soil analysis. A Randomized Complete Block Design (RCBD) on a 172.5 m^2 experimental plot was used to investigate the effects of nine treatments: control soil (T_0), T_1 (5 tons ha^{-1} basalt dust), T_2 (0.7 tons ha^{-1} NPK 20-10-10), T_3 (20 tons ha^{-1} poultry manure), T_4 (2.5 tons ha^{-1} basalt dust), T_5 (0.35 tons ha^{-1} NPK 20-10-10 + 10 tons ha^{-1} poultry manure), T_6 (10 tons ha^{-1} poultry manure + 2.5 tons ha^{-1} basalt dust),

T_7 (0.35 tons ha^{-1} NPK 20-10-10 + 2.5 tons ha^{-1} basalt dust) and T_8 (0.25 tons ha^{-1} NPK 20-10-10 + 6.5 tons ha^{-1} poultry manure + 2.5 tons ha^{-1} basalt dust) treatments. The main results showed that land limitation was severe (N_1), due to soil acidity, and potentially unsuitable for beetroot cultivation. The control (T_0) was acidic (pH = 4.8) but treatment raised the pH to 6.56, 6.76 and 4.91 for basalt dust, poultry manure and NPK 20-10-10, respectively. The yields were recorded in decreasing order as $T_3>T_8>T_6>T_5>T_7>T_2>T_4>T_1>T_0$. T_1 had the highest capacity to provide nutrients to soils and to balance nutrient availability to plants. T_3 alone boosted immediate productivity by improving soil acidity. The most economic treatment was T_8 suggesting a reduction in chemical fertilizer input and importation and popularization of local natural fertilizers.

Jibrin *et al*. (2018) research was carried out during 2017 dry season at Samaru College of Agriculture, A.B.U., Zaria. To determine the most appropriate rate of NPK fertilizer and weed control on beetroot production in Samaru. The experiment consisted of two factors: NPK fertilizer rates (NPK 80 40 40 kg ha^{-1}, NPK 100 80 80 kg ha^{-1}, NPK 150 75 75 kg ha^{-1}) and weed control (Weedy check, weeding at 3 WAS, weeding at 6 WAS and weeding at 3 and 6 WAS). The treatments were factorially combined and laid out in a randomized completely block design (RCBD). The results showed *Cyperus haspan* Linn. Was the weed species that recorded the highest infestation while absolute frequency while *Physalis angulata* Linn. recorded the lowest infestation at the experimental site. Application of NPK fertilizer at 100, 50, 50 kg ha^{-1} recorded the higher stand count, chlorophyll contents, root weight and root diameter, while NPK 80, 40, 40 kg ha^{-1} recorded the lowest. Likewise, plot grown to weeding at 3 and 6 WAS or weeding at 3 WAS recorded the highest value for stand count, chlorophyll content and root weight while plot grown to weedy check recorded the least values for the aforementioned characters. From the results of the study, it can be concluded that application of NPK 100, 50, 50 kg ha^{-1} produced the highest stand count, chlorophyll content, root diameter, root weight than NPK fertilizer at the rate of 80, 40, 40 kg ha^{-1} and NPK 150, 75, 75 kg ha^{-1}. Similarly, weeding at 3 and 6 WAS and weeding at 3 WAS gave the best weed control.

Mehanna *et al.* (2017) two field experiments were conducted in the Experimental farm of the National Research centre, El-Nobaria, El-Boheira Governorate, Egypt, during two seasons (2013-2014 & 2014-2015) to evaluate the growth of root and yield of sugar beet (*Beta vulgaris* L.). The experimental treatments were as following: (a) two sugar beet varieties (Samba and Farida), (b) three irrigation water regimes (2483, 1862 and 1241 m^3/fed./season) under drip irrigation system, and (c) four NPK fertilization rates (0, 0, 0) as control, (50, 75, 25), (75, 110, 35) and (100, 150, 50) as quantity of compound NPK fertilizers, respectively. The results were: Samba variety was the superior in root characters i.e., length, and diameter, and yield of roots and sugar/fed., water stress induced by irrigated sugar beet plants with the lowest water regime which depressed the root parameters as well as yield of roots and sugar/fed. Root diameter and yield of roots and sugar showed its higher values under the moderate water regime (1862 m^3/fed.). For water productivity of root yield, it was observed that the highest values were gained using the lowest quantity of water. Generally, it was obviously that Samba variety which irrigated by the moderate water regime (1862 m^3/fed./season), and fertilized by the highest amount of NPK (100, 150, 50) produced the economic root and sugar yield of sugar beet and saved 621 m^3/fed./season, which is the main concern now a days for the arid regions.

Agamy *et al.* (2013) this study evaluated the effect of soil amendment with three newly isolated yeast strains on the productivity and the external and internal structure of sugar beet to prove their application as bio-fertilizer. We conducted a two-year pot experiment to investigate the effects of *Kluyveromyces walti*, *Pachytrichospora transvaalensis* and *Sacharromycopsis cataegensis* on the growth and productivity of sugar beet. Soil was inoculated with three doses of each strain (0.0, 50.0- and 100.0-ml pot^{-1} with concentration of ~108 cfu ml^{-1}). Results showed that application of the yeasts significantly ($P<0.05$) increased the photosynthetic pigments, soluble sugars, sucrose, and total soluble proteins of sugar beet. *K. walti* showed the best results among the three yeasts. It increased the sucrose content by about 43% of the control. Anatomy of the leaf and the root showed an increase in thickness of the blade, midvein, dimensions of the vascular bundles, and number and diameter of xylem vessels as the result of application of yeasts. Gas chromatography – mass spectrometry (GC-MS) analysis of the culture filtrates of the yeasts detected some beneficial secondary metabolites that could enhance the plant vigor and the physical and chemical properties of the soil. We assume that application of *K. walti*, *P. transvaalensis* and *S. cataegensis* as bio-fertilizers is a good alternative of the chemicals in the sustainable and organic farming and safe for human and environment.

Barlog *et al.* (2013) the study was conducted to determine the effect of various levels of P, K under the background of constant N rate on dynamics of sugar beet root yield. The field trial, arranged as a factorial design, was consisted of eight treatments: $N_0P_0K_0$; $N_0P_1K_1$; $N_1P_0K_1$; $N_1P_1K_0$; $N_1P_{0.25}$ $K_{0.25}$; N_1 $P_{0.5}$ K_1; $N_1P_1K_1$ and $N_1P_1K_1$ +Ca; where 1 is recommended level of N, P, K application and Ca means that phosphorus applied as partially acidulated phosphoric rock (PAPR). The in-season yield sampling was conducted at 92, 113, 134, 155 and 175th day after sowing. The highest degree of yield potential realization revealed in the year with favourable weather conditions. The highest yield was harvested on the plot fertilized with $N_1P_1K_1$ + Ca. In years with extended drought, sugar beet achieved the maximum yield in the treatment $N_1P_{0.25}$ $K_{0.25}$. Phosphorus revealed as the key yield forming factors, i.e., limiting N unit productivity. The maximum productivity of N occurred in treatments with full P rate, especially when P fertilizer was applied as the PAPR. However, phosphorus yield forming action depended on weather conditions in the mead-season and P fertilizer rate. The first factor, affecting N and K supply to sugar beet during the mead-season, was responsible for the size of the beetroot, considered as the sugar storage. Any drought, negatively impacting its size, in turn decreases P yield forming action, which appears in the late-season. The maximal exploitation of sugar beet yielding potential is, therefore, possible provided water is not a factor limiting sugar beet growth in the mead-season and P in late-season. Nevertheless, in farming practice, the lack of favourable growth conditions should not be a reason for development a sugar beet fertilizing strategy, based on reduced P and K rates

Petek *et al*. (2012) a field trial (2003-2005) was set up in a hilly part of Croatia according to the Latin square method with four types of fertilization (control, 50 t ha^{-1} stable manure, 500 and 1000 kg ha^{-1} NPK 5-20-30), while treatments involved harvested fresh beetroot and stored fresh beetroot. The highest dry weight (DW) content was determined in climatologically favourable 2004 (average 14.8% DW) and in the treatment with 1000 kg ha^{-1} NPK 5-20-30 (15.6% DW) in harvested beetroot. In 2004 and 2005, the highest levels of nitrogen and crude proteins in harvested beetroot were determined in the treatment with 1000 kg ha^{-1} NPK 5-20-30 (2.41 and 2.43 g N

kg^{-1} in fresh weight and 15.07 and 15.21 g crude proteins kg^{-1} in fresh weight, respectively). Regardless of fertilization treatment or studied year, nitrogen and crude protein contents were higher in stored than in harvested beetroot, by 12% on average. The lowest crude protein content was determined in treatment with stable manure what confirmed that protein content decreased by organic fertilization.

Abdel-Motagally and Attia, *et al.* (2009) this study was conducted during two successive seasons (2004-2005 & 2005-2006) to study the effects of different rates of nitrogen (143, 214 & 285 kg N ha^{-1}) and potassium (0, 57 & 114 kg K_2O ha^{-1}) fertilization on yield, quality and nutrient contents of sugar beet grown on sandy calcareous soil. In this split plot design, the main plots were assigned to levels of N fertilizer and K levels were arranged to random as the sub-plots. The results showed that increasing N and K rates significantly increased root and foliage fresh and dry weight and sugar yield (ton ha^{-1}) of sugar beet plants. Adding the highest level of K (114 kg K_2O ha^{-1}) under different rates of N significantly increased sucrose contents, recoverable sugar yield (ton ha-1) and some quality traits. Adding the highest level of N (285 kg N ha^{-1}) under different rates of K significantly increased sugar loss (ton ha^{-1}) and increased content and uptake of N and K in both root and foliage of sugar beet over two seasons. Increasing N level up to 285 kg N ha^{-1} (under 0.0 kg K_2O ha^{-1}) significantly increased impurities (Na, K & α-amino-N) and sugar loss percentage. In crux, N fertilizer at a level of 285 kg N/fed accompanied with 114 kg K_2O ha^{-1} were the most effective in improving yield, quality and nutritional status of sugar beet grown in a sandy calcareous soil.

Custic *et al*. (2007) the obtained results allow the conclusion that the application of 5 kg stable manure m^{-2} or 100 g NPK m^{-2} ensured the highest values of researched parameters. In the dryness 2003, the highest content of phosphorus and potassium in soil were determined in the treatment with 100 g NPK m^{-2}. In 2004, the highest content of phosphorus and potassium in soil and red beetroot was obtained in the treatment with stable manure. The highest nitrogen, phosphorus and potassium content in red beetroot as well as yield were determined in 2003 in the treatment with stable manure. Regardless fertilization, the N content, dry weight and yield of red beetroot were strongly influenced by agro ecological conditions. The application of 5 kg stable manure m^{-2} or 100 g NPK 5-20-30 m^{-2} can be recommended for good nutritive quality of red beet as well as standard yield if the weather conditions are favourable.

2.2 Effect of organic manure

Shafeek *et al.* (2019) conducted a study in two field experiments were carried out during the two seasons of 2016 and 2017 at the experimental station of National Research Centre, Beheira Governorate (North of Egypt) to investigate the effect of organic cattle manure fertilizer at rates of (0, 10 and 20 m^3/fed.) as well as foliar application of potassium fertilizer at (0, 1 and 2 cm/L) for influence plant growth, roots physical and chemical quality of beet root plants c.v. Balady. The traits related to production evaluated were: 1-Adding cattle manure fertilizer at high levels (20 m^3/fed.) had a significant increase in growth characters, i.e., plant length, number of leaves/plants, fresh and dry weight/plant as well as root fresh and dry weight and its components (root length and diameter). Also, gave the highest percentage of total sugar, vitamin C and TSS contents. 2-By increasing concentration of potassium increased growth characters, root yield parameters and increment the percentage of total sugar, vitamin C and TSS contents of beet root tissues. 3-The highest values of the growth characters, roots parameters and the percentage of total sugar, vitamin C and TSS contents in beet root tissues were associated with those plants received higher cattle manure level (20 m^3/fed.) with higher concentration of potassium (2 cm/L).

Kisić *et al.* (2018) the effects of different rates of organic fertilizers upon the yield of dry chamomile flowers were studied in an exact field trial setup on Luvisols in Podravina region, Croatia. The trial was set up according to the randomized block design with four replications. During three years of research (2013/2014, 2014/2015, and 2015/2016), changes in the soil chemical complex were monitored. Organic fertilization rendered significantly higher yields of dry chamomile flower than the control treatment. Organic fertilizers did not significantly affect soil pH, soil organic matter, and plant available phosphorus and potassium. The optimum amount of fertilizer for chamomile on this type of soil is 70 kg of nitrogen and 35 kg of plant available phosphorus and potassium. The study has also shown that the most effective parameter in the process is the weather conditions during the year, i.e., precipitation intensity, especially in the last few weeks prior to harvest.

Behera *et al.* (2022) this review paper is based on organic fertilizer and the nutrient content of pea (*Pisum sativum* L.). Animal manure, compost and bio manure are used in making organic manure which forms the alternative service for mineral fertilizers. The nutrient supply from organic fertilizers such as manure, compost may not be necessary to the plant needs at any stage of growth but often needed in the crop growing period. With the availability of food, fruit, vegetables and plants are similar in organic and non- organic fertilizers in the long-term results of the testing. Similarly, the availability of nutrients like phosphorus, potassium and many trace elements are lower than the soil solution, as they are more concentrated in complex soils as insoluble forms. Foliar fertilizer is therefore often used to provide the nutrients needed by plants for adequate filtration, to develop the nutritional levels of plants and to increase the yield and quality of crop.

Assefa and Tadesse (2019) the use of organic fertilizers has advantage of being cheap, improving soil structure, texture and aeration increasing the soils water retention abilities and stimulating healthy root development. Organic fertilizer has many sources such as minerals, animal source, sewage sludge and plant. Vegetables, animals and residue materials had a contribution to improve soil organic matter content in soil. Therefore, it is recommended that, using integrated nutrient management is a continuous improvement of soil productivity on longer term basis through appropriate use of organic fertilizers (i.e., animal manure, plants residue and sewage sludge) and their scientific management for increments of optimum growth, yield and quality of different crops.

2.3 Effect of biochar

Rapid industrial development and human activities have caused a degradation of soil quality and fertility. There is increasing interest in recovering low fertility soils to progress crop yield and sustainability. Biochar, a carbonaceous material intentionally produced from biomass, is widely used as an amendment to improve soil fertility by retaining nutrients and potentially enhancing nutrient bioavailability (El-Naggar *et al*., 2019). But, biochar is not a simple carbon material with uniform properties, so appropriate biochar selection must consider soil type and target crop. In this respect, many recent studies have evaluated several modifications methods to maximize the effectiveness of biochar such as optimizing the pyrolysis process, mixing with other soil amendments, composting with other additives, activating by physicochemical processes and coating with other organic materials (*Sun et al.,* 2014).

The extensive problems of an ever-increasing global human population, shrinking food reserves and climate change (carbon abatement) are a growing concern (Lehmann and Joseph, 2009). It has been projected that over the next two decades, crop yields of principal foods such as corn (maize), rice and wheat will significantly decline as a result of warmer and drier climatic conditions predominantly in semi-arid areas (Brown and Funk, 2008). In addition to this, agricultural soil degradation and soil7 infertility are common problems (Chan and Xu, 2009). As a means of addressing these problems, the use of biochar to soil has been brought forward in an effort to sustainably amend low nutrient-holding soils (Laird, 2008).

Biochar is a stable carbon-rich by-product synthesized through pyrolysis /carbonization of plant- and animal-based biomass (Ahmad *et al*., 2014). Carbonization is a slow pyrolysis process in which biomass is converted into a highly carbonaceous, charcoal-like material. Typically, carbonization consists of heating the biomass in an oxygen-free or oxygen-limited environment, and reaction conditions are tailored to maximize the production of char (Ronsse *et al.,* 2015). Application of biochar to agriculture may have a significant effect on reducing global warming through the reduction of greenhouse gas (GHG) emissions and the sequestering of atmospheric carbon into soil. At the same time, biochar can help improve soil health and fertility and enhance agricultural productivity (Qambrani *et al*., 2017).

Biochars vary widely in pH, surface area, nutrient concentration, porosity, and metal binding capacity due to the assortment of feedstock materials and thermal conversion conditions under which it is formed (Novak *et al.,* 2016). The wide variety of chemical and physical characteristics have resulted in biochar being used as an amendment to rebuild soil health, improve crop yields, increase soil water storage, and restore soils/spoils impacted by mining (Yargicoglu *et al.,* 2015). In spite of the mixed crop yield reports, biochar have properties that can improve soil health characteristics, by increasing carbon (C) sequestration and nutrient and water retention. Biochars also have the ability to bind enteric microbes and enhance metal binding in soils impacted by mining. In this review, we present examples of both effective and ineffective uses of biochar to improve soil health for agricultural functions and reclamation of degraded mine spoils.

Mukherjee and Lal (2013), reported that biochar's physical properties like large surface area and presence of micro pores contribute to the adsorptive properties of biochar and potentially alters the soil's surface area, pore size distribution, bulk density, water holding capacity and penetration resistance.

In earlier studies, soils used to study the agricultural properties of biochar have mostly been highly weathered soils from humid tropic regions (Verheijen *et al*., 2009).

Only recent research has involved the investigation of biochar application on the performance of infertile, acidic soils with kaolinitic clays, low cation exchange capacity (CEC), and deteriorating soil organic carbon contents (Chan *et al.,* 2007; Chan and Xu,2009; Novak *et al*., 2009). Generally, the addition of biochar to soil has been stated to have a multitude of agricultural benefits. These include a high soil sorption capacity, reduced nutrient loss through surface and groundwater runoff, and a regular release of nutrients to the growing plant (Laird, 2008).

Nelissen *et al.*, (2015) established a field trial to inspect the influence of biochar application to a temperate agricultural soil on soil chemical, physical and biological properties, and on crop growth and nutrient uptake under field conditions. The biochar applied was produced from a mixture of hard and softwood at 480°C. The biochar dose was 0 (control) or 20 t ha−1 (on dry weight basis). Over two years, biochar addition to soil did not affect soil chemical properties, except for organic carbon content and C: N ratios. Effects on bulk density, porosity and soil water retention curves were non-consistent over time, possibly due to interaction with tillage operations. Biochar increased soil water content, although mostly not significantly. Soil temperature, as measured at a soil depth interval of 9 8–20 cm, was not changed by biochar addition. Furthermore, biochar addition to soil did only slightly influence soil microbiological community structure during the first year after biochar application. Hence, it was not surprising that biochar addition did not affect crop yield, N or P uptake during the first two years after biochar application.
Laird *et al*., (2010) elucidate that biochar amended soils retained more water at gravity drained equilibrium (up to 15%), had greater water retention at − 1 and −5 bars soil water matric potential, (13 and 10% greater, respectively), larger specific surface areas (up to 18%), higher cation exchange capacities (up to 20%), and pH values (up to 1 pH unit) relative to the un-amended controls. No effect of biochar on saturated hydraulic conductivity was detected. The biochar amendments significantly increased total N (up to 7%), organic C (up to 69%), and Mehlich III extractable P, K, Mg and Ca but had no effect on Mehlich III extractable S, Cu, and Zn.

Regardless of positive aspects, a few possible negative implications have been reported to be associated with biochar. The release of particulate from biochar is cause for concern because of the potentially harmful effects on health and the implications in terms of reduction of its mitigation potential (Genesio *et al*., 2016). Indeed, the production and post-production processes (packaging, storage, transport, and field application) can cause substantial losses of biochar, whose extent and destiny depends on many factors. A segment of the smallest biochar particles can be gone by percolation, runoff, and lateral migration or transported by turbulence into the atmosphere (Spokas *et al*., 2014). Anthropogenic Black Carbon aerosols (BCa), due to their shortwave absorption properties, are known to have both a direct and indirect climate warming effect, the release of particulate matter from biochar can lead to the formation of BCa, 10 potentially reversing the efficacy of biochar for climate change mitigation (Bond *et al*., 2013).

Kookana *et al*., (2011) found some negative impact associated with biochar these include i) further agronomic input costs, ii) the binding and deactivation of synthetic agrochemicals due to relations with herbicides and nutrients, iii) the deposit and transport of dangerous contaminants due to the release of toxicants such as heavy metals present in biochar, and iv) an unexpected increase in pH and electrical conductivity (EC). Although studies have emphasized that contaminants such as organic compounds, heavy metals, and dioxins may be present in biochar but there is a inadequate published research that proves that these contaminants are available (Smernik, 2009; Verheijen *et al*., 2009).

Anthropogenic amazonian dark earths (ADE) high fertile soils found in Brazil are mostly created between 500 and 2500 years ago by pre-Columbian populations called terra peta de Indio (Souza *et al*.,2017).

These rich black earths are highly fertile and produce large crop yields despite the fact that the surrounding soils are infertile (Renner, 2007). It is believed that the accumulation of charcoal in these soils is as a result of anthropogenic activities which consequently led to the formation of terra pretasoils (Glaser, 2007). Although most dark earths are as a result of long-term human habitation, studies show that chemical changes in the soil are central to the darkening of these soils. These chemical changes encourage soil biotic activity and downward development, and thus resulting in melanization. While these ADE have formed over several millennia, they have not formed at a constant rate. Several studies have found that the rate of formation can fall in the range of 0.015 cm to 1.0 cm per annum. In particular, dark brown to black soils are classified as terra peta de Indio based on similarities in texture and subsoil of the underlying and immediately surrounding soil (Woods and McCann, 1999).

Rudong *et al*. (2015). observed that biochar positively affects the soil acidity by reducing exchangeable Al^{3+} and exchangeable acidity as well as increasing pH and exchangeable bases. However, the effect declined to a certain extent when biochar went short term aging without soils. Wrobel-Tobiszewska *et al*. (2016). found that high rates of biochar application (50–100 t ha−1) increased soil pH from 4.0 to 4.8 in a Eucalyptus forestry plantation. Further, Rhoades *et al*. (2017) reported that the joint application of biochar (application rate of 20 t ha−1) and mulch (application rate of 37 t ha−1) increased soil pH from 5.7 to 6.4 in a pine (Pinus contorta) forest. There are two probable mechanism responsible for the observed rises in soil pH as a result of biochar application. First, biochar is alkaline and contains mineral carbonates with an abundance of basic-charged groups (Yuan and Xu, 2011). Thus, the observed increase in soil pH may be simply due to the addition of alkaline material.

Alternatively, biochar application decreases the exchangeable aluminum content of soils through binding Al^{3+} ion by oxygenated functional groups on its surface, thereby increasing the abundance of soil exchangeable base cations, increasing soil base saturation, and ultimately resulting in a soil pH increase (Yuan and Xu, 2011; Dai *et al*., 2017).

Zhang *et al.* (2020) this study was undertaken to determine whether biochar-based organic fertilizer could alleviate the negative effect of saline-alkaline soil on sugar beet yield and whether such an effect correlated with changes in nitrogen assimilation, antioxidant system, root activity, and photosynthesis. Three treatments were established: Chemical fertilizers were applied to neutral soil (CK), chemical fertilizers were applied to saline-alkaline soil (SA), and biochar-based organic fertilizer was applied to saline-alkaline soil (SA + B). Our results showed that saline-alkaline stress significantly inhibited the nitrogen assimilation and antioxidant enzymes activities in root, root activity, and photosynthesis, thus significantly reducing the yield and sugar content of sugar beet. Under saline-alkaline conditions, the application of biochar-based organic fertilizer improved the activities of nitrogen assimilation enzymes in the root; at the same time, the antioxidant enzymes activities of the root were significantly increased for improving root activity in this treatment. Moreover, the application of biochar-based organic fertilizer could improve the synthesis of photosynthetic pigments, PSII (Photosystem II) activity, stomatal opening, and photosynthesis of sugar beet under saline-alkaline conditions. Hence, the growth and yield of sugar beet were improved by applying biochar-based organic fertilizer to saline-alkaline soil. These results proved the significance of biochar-based organic fertilizer in alleviating the negative effect of saline-alkaline stress on sugar beet. The results obtained in the pot experiment may not be viable in field conditions. Therefore, in the future, we will verify whether biochar-based organic fertilizer could alleviate the adverse effects of saline-alkaline stress on sugar beets yield under field conditions.

The use of biochar as soil amendment is proposed as a new approach to mitigate man-induced climate change along with improving soil productivity. In previous studies, soils used to investigate the agricultural properties of biochar have mostly been highly weathered soils from humid tropic regions (Verheijen *et al.,* 2009). Only recent research has included the investigation of biochar application on the performance of infertile, acidic soils with kaolinitic clays, low cation exchange capacity (CEC), and deteriorating soil organic carbon contents (Chan *et al.,* 2007; Chan and Xu, 2009 and Novak *et al.*, 2009). Generally, the addition of biochar to soil has been reported to have a multitude of agricultural benefits. These include a high soil absorption capacity, reduced nutrient loss by surface and groundwater runoff, and a gradual release of nutrients to the growing plant (Laird, 2008). In order to sequester carbon, a material must have long residence time and should be resistant to chemical processes such as oxidation to CO_2 or reduction to methane.

The widespread problems of an escalating global human population, diminishing food reserves and climate change (carbon abatement) are a growing concern (Lehmann and Joseph, 2009). In agriculture use of biochar is not new; in ancient times farmers used it to enhance the production of agricultural crops. Where farmer uses this as ash not biochar, this type of ash now namely biochar which produce by some management method. In recent some practices have indicated that combined applications of biochar with organic or inorganic fertilizers could lead to enhanced soil physical, chemical, and biological properties, as well as plant growth and development. This is a matter that a few possible negative implications have been reported to be associated with biochar. Kookana *et al*. (2011) found that these include i) Biochar cost is additional agronomic input costs, ii) the binding and deactivation of synthetic agrochemicals due to an interaction with herbicides and nutrients, iii) Another negative implication is deposit and transport of hazardous contaminants due to the release of toxicants such as heavy metals present in biochar, and iv) Sometime this is causes immediate increase in pH and electrical conductivity (EC). Furthermore, although studies have highlighted that contaminants such as organic compounds, heavy metals, and dioxins may be present in biochar, there is limited published research that proves that these contaminants are available (Smernik, 2009 and Verheijen *et al.*, 2009).

2.4 Effect of biochar on plant growth

Plant growth and development depend on plant nutrient where biochar plays a great important role. Numerous and regular applications of biochar to soil are not necessary because biochar is not warranted as a fertilizer (Lehmann and Joseph, 2009). In a pot trial carried out by Chan *et al.* (2007) a significant increase in the dry matter (DM) production of radish resulted when N fertilizer was used together with biochar. The results showed that in the presence of N fertilizer, there was a 95 to 266 % variation in yield for soils with no biochar additions, in comparison to 10 those with the highest rate of 100 t ha^{-1}. Improved fertilizer-use efficiency, referring to crops giving rise to higher yield per unit of fertilizer applied (Chan and Xu, 2009), was thus shown as a major positive attribute of the application of biochar.

Major *et al.* (2010) conducted a study whereby a field trial demonstrated that a single dolomitic lime and wood biochar application on an acidic, infertile Oxisol was sufficient to increase crop yield and nutrition uptake of crops. In addition, inorganic fertilizers were equally applied to both the biochar-amended and control soils. The trial was carried over 4 years. It was found that no significant effect was observed during the first year of application. However, the maize yield gradually increased with an increase in the biochar application rate in the ensuing years. These yield increases were as a result of increases in pH and nutrient retention. It was found that there was a stark overall decline in yield in the fourth year of application due to the decreasing Ca and Mg soil stocks.

2.5 Biochar effect on crops

There are varied responses of crops to biochar (Chan *et al.*, 2008a). Van Zwieten *et al.* (2010a) tested two biochar produced from the slow pyrolysis of paper mill waste, in two agricultural soils in a glasshouse and found that they significantly increased biomass in wheat, soybean and radish in ferrosol soil but reduced wheat and radish biomass in calcaresol, amended with fertilizer in both soils. A significant decrease in dry matter content of radish was obtained when biochar was applied at 10 tons ha^{-1}.

Asai *et al.* (2009) showed that biochar increased rice grain yields at sites with low P availability, which might be due to improved saturated hydraulic conductivity of the top soil, xylem sap flow of the plant and response to N and NP chemical fertilizer treatments. Limiting soil N content by biochar application in N deficient soils could be due to the high C/N ratio, hence it might reduce crop productivity temporarily (Lehmann *et al.*, 2003). However, some biochar contains considerable amounts of micronutrients. For example, pecan-shelled biochar contained greater amount of copper (Cu), magnesium (Mg) and zinc (Zn) than the soil (Novak *et al.*, 2009). In a separate experiment, 10 concentrations of heavy metals including Cu and Zn increased in sewage sludge biochar but those of available heavy metals decreased (Liu *et al.*, 2014). Furthermore, poultry litter biochar was also rich with considerable amounts of Zn, Cu and manganese (Mn) (Inal *et al.*, 2015). Thus, it is essential to compare its effect solely and in combination with other nutrient sources. Some authors (Verheijen *et al.*, 2009 and Brandstaka *et al.*, 2010) have emphasized the need for further research on potential benefits of biochar as well as their economics. However, their interactions with other organic sources as well as microbes and release of nutrients from them are insufficiently assessed. In addition, biochar application in a nutrient-poor, slightly acidic loamy sand soil had little effect on wheat yield in the absence of mineral fertilization but when applied with the highest rate of mineral fertilization, it produced yield 20–30 % more than mineral fertilizer alone (Alburquerque *et al*., 2014).

In another work, biochar did not increase annual yield of winter wheat and summer maize but the cumulative yield over four growing season was significantly increased in a calcareous soil (Liang *et al.*, 2006). Biochar of maple was tested at different concentrations for root elongation of pea and wheat but no significant difference was observed (Borsari, 2011), possibly due to little effect of biochar in the short-term. The wood chip biochar produced at 290^{o}C and 700^{0}C had no effect on growth and yield of either rice or leaf beet (Lai *et al.,* 2013). A biochar significantly increased growth and yield of French bean as compared to no biochar (Saxena *et al.*, 2013). A rice-husk biochar tested in lettuce-cabbage-lettuce cycle increased final biomass, root biomass, plant height and number of leaves in comparison to no biochar treatments (Carter *et al.*, 2013).

CHAPTER-III
MATERIALS AND METHODS

This Chapter describes the materials and methods which were used in the field to conduct the experiment during the period from November 2020 to March, 2021. It includes a short description of experimental site, characteristics of soil, climate, materials used, data collection, statistical analysis and cost and return analysis. The details of these are described below.

3.1 Experimental site

The experiment was conducted at the Horticulture Farm of Sher-e- Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from November 2020 to March 2021. The experimental site was previously used as vegetable garden and recently developed for research work. The location of the site is 23° 74'N latitude and 90° 35' E longitude with an elevation of 8.2 meter from sea level (Anon, 1981).

3.2 Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during rest of the year (Rabi season). The total rainfall of the experimental site was 218 mm during the period of the experiment. The average maximum and the minimum temperatures were 29.45°C and 13.86° C respectively. Rabi season is characterized by plenty of sunshine. The maximum and minimum temperatures, humidity and rainfall during the study period were collected from the Bangladesh Meteorological Department (climate division) and have been presented in Appendix I.

3.3 Soil

The soil of the experimental area belongs to the Madhupur Tract. The analytical data of the soil sample collected from the experimental area were determined in SRDI, Soil Testing Laboratory, Dhaka and presented in appendix II.

The experimental site was a medium high land and pH of the soil was 5.6. The morphological characters of soil of the experimental plots as indicated by FAO (1988) are given below – AEZ No. 28, Soil series – Tejgaon, General soil- non-calcarious dark grey.

3.4 Plant materials

The test crop used in the experiment was beetroot variety Ruby red which is an Indian local variety and the seeds were collected from Benapole land port, Jashore. Because in Bangladesh, due to the hot and humid weather conditions, farmers are reluctant to cultivate beetroot commercially, so the seeds must be imported.

3.5 Treatment of the experiment

The experiment consisted of various single factor:

T_0: Control ($N_0P_0K_0$ + No Organic Manure + No Biochar)

T_1: NPK 100% (RDF)/ha.

T_2: Biochar 10 t/ha.

T_3: Organic Manure (Cow dung) 15 t/ha.

T_4: NPK 50% (RDF)/ha + Biochar 10 t/ha.

T_5: NPK 100% (RDF)/ha + Biochar 5 t/ha.

T_6: Organic Manure 7.5 t/ha + Biochar 10 t/ha.

T_7: Organic Manure 15 t/ha + Biochar 5 t/ha.

T_8: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha.

T_9: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha + Biochar 5 t/ha.

T_{10}: NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha.

*Biochar: Organic carbon compound that is produced from biomass via pyrolysis.

3.6 Design and layout of the experiment

The one factors experiment was laid out in Randomized complete block design (RCBD) with three replications. The total area of the experimental plot was 73.1 m^2 with length 17 m and width 4.3 m. The total area was divided into three equal blocks. Each block was divided into 11 plots where 11 treatments combination was allotted at randomly. There were 33 plots altogether in the experiment. The size of each plot was 1.4m × 1m. The distance maintained between two blocks and two plots were both 0.5m. The size of the main drain was 0.5m each.

3.7 Land preparation

The selected plot of the experiment was opened in the 1st week of November, 2020 with a power tiller, and left exposed to the sun for a week. Subsequently cross ploughing was done five times with a country plough followed by laddering to make the land suitable for sowing. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilth was achieved. The soil was treated with insecticides (Furadan 5G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.8 Seed sowing

Seeds were air-dried before sowing since water soaked to facilitate germination. The seeds of beetroot were sown on 22 November, 2020. The seeds were treated with Bavistin before sowing the seeds to control the seed borne disease. Seeds were sown in well-prepared plot by maintaining row to row distance of 30 cm and plant to plant distance within the rows 10 cm (approximately).

3.9 Application of manures and fertilizers

Manures and fertilizers were applied to the experimental plot considering the recommended fertilizer doses of BARI (2005).

Nutrient	Dose/ha (kg)	Dose/plot (plot size: 1.4 m^2)										
		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
N	70kg	0	10g	0	0	5.1g	10.3g	0	0	5.1g	5.1g	10g
P	60kg	0	10g	0	0	5g	10g	0	0	5g	5g	10g
K	110kg	0	15g	0	0	7.5g	15g	0	0	7.5g	7.5g	15g
OM (cow dung)	15t	0	0	0	2.2kg	0	0	1kg	2kg	1.1kg	1kg	2kg
Biochar	10t	0	0	1kg	0	1kg	750 g	1kg	750g	0	750g	1.5kg

3.10 Intercultural operation

3.10.1 Thinning

The optimum plant population was maintained by thinning out the excess plants. Seeds were germinated seven days after sowing (DAS). Thinning was done at 15 days after sowing (DAS) to maintain 10 cm distance between plant to plant to obtain proper plant population in each plot.

3.10.2 Weeding

The crop was infested with some weeds during the early stages of crop establishment. The crop was weeded thrice; first weeding was done at 15 DAS, second weeding was done at 30 DAS and the third one was done at 45 DAS.

3.10.3 Irrigation

Light irrigation was given just after establishment of the seedlings. Wherever the plants of a plot had shown the symptoms of wilting the plots were irrigated on the same day with a hosepipe until the entire plot was properly wet.

3.10.4 Drainage

Drainage channels between the plots were properly prepared to easy and quick drained out of excess water.

3.11 Insects, pests and diseases control

Few plants were damaged by cut worms after the seedlings were established in the experimental plots. Cut worms were controlled both mechanically and spraying Diazinon 60 EC @ 0.55 Kg per hectare. Some of the leaves of the plants were infected by *Cercospora beticola*, producing *Cercospora* leaf spot. To prevent the spread of the disease, Neem oil @ 2g /liter of water was sprayed in the field. Another problem for beetroot production is the attack of mongoose (*Herpestes javanicus*) at fruit development stage. It was almost impossible to control mongooses. They visited the field almost every day at 4.00 pm to whole night and ate up the upper surface of the beetroot or damaged the beetroot by puncturing. Several measures were taken such as- flooding the whole field, fencing the field by metal wire, traps etc. Among them, fencing and flooding were most effective in controlling mongooses.

Plate no. 01: Showing *Cercospora* leaf spot, cutworm and mongoose attack (Left to right)

3.12 Crop sampling and data collection

Five plants from each treatment were randomly selected and marked with tag for recording data of plant characters. The data of plant characters were recorded from 20 days of sowing to till harvest at 20 days interval. Yield and yield contributing parameters were recorded from the central part of the plots. A brief outline of the data recording on morpho-physiological and yield contributing characters are given below.

3.13 Harvesting

Five plants from each plot avoiding central 0.25 m^2 area were collected and tagged properly from which yield attributes data were recorded. For taking yield data, the matured beetroot was harvested from the central 0.25 m^2 area of each plot and tied into bundles.

3.14 Methods of data collection

The data pertaining to the following characters were recorded from five (5) plants randomly selected from each unit plot, except yield of beetroot which was recorded plot wise. Data on plant height was collected on 20, 40 and 60 days after sowing and also at harvest. All other parameters were recorded at harvest.

3.14.1 Plant height (cm)

Plant height was measured in centimeter (cm) by a meter scale at 20, 40, and 60 days after sowing (DAS) and at harvested from the ground level up to the tip of the longest leaf.

3.14.2 Number of leaves per plant

Number of leaves per plant of five randomly selected plants was counted at harvest. All the leaves of each plant were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from counting.

3.14.3 Number of branch root

Number of branch roots of five randomly selected plants was counted at harvest. All the branch root of each plant was counted separately. Only the smallest branch root at the growing point of the plant were excluded from counting.

3.14.4 Crack root percentage

Crack roots of five randomly selected plants were counted at harvest. Then it was calculated in percentage.

3.14.5 Root length

The root length of selected plants was measured with the help of a scale and the total length was recorded. Then the root length (cm) per plants was calculated by dividing the total length of roots by 5.

3.14.6 Beetroot diameter

Length and breadth of five randomly selected beetroot were measured in centimeter (cm) at harvest by using slide calipers. All the beetroots of each plant were measured separately.

3.14.7 Days required to first harvest

Each plant of the experimental plot was kept under close observation from growth to count days required for first harvesting. Total number of days from the date of sowing to respective maturity was recorded.

3.14.8 Total days required to harvest

Each plant of the experimental plot was kept under close observation from growth to count total days required for harvesting. Total number of days from the date of sowing to respective maturity was recorded.

3.14.9 Single root yield per plant

The Single root yield per plant was calculated by adding the weight of plants harvested and the yield was weighed in gram (g).

3.14.10 Total yield per plot

The total yield per plot was calculated by adding the weight of plants harvested and the yield was weighed in gram (g).

3.14.11 Marketable yield per unit plot

The Marketable yield per unit plot was calculated by adding the weight of plants. The total marketable yield per unit plot of all plants in each unit plot was recorded and was expressed in kilogram (kg).

3.14.12 Yield per hectare

The yield per hectare was calculated by converting the per plot yield data to per hectare and was expressed in ton (t).

3.15 Statistical analysis

The data obtained for different characters were statistically analyzed by using MSTAT-C computer package program to find out the effect of the difference level of fertilizer, organic manure and biochar on the yield of beetroot. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.16 Economic analysis

The cost of production was analyzed in order to find out the most economic analysis. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 13% in simple rate. The market price of beetroot was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al.* (1989).

3.16.1. Analysis for total cost of production of beetroot

All the material and non-material input cost, interest on fixed capital of land and miscellaneous cost were considered for calculating the total cost of production. Total cost of production (input cost, overhead cost), gross return, net return and BCR are presented in Appendix.

3.16.2. Gross income

Gross income was calculated on the basis of sale of branch and fruit. The price of fruit was assumed to be Tk. 42 kg^{-1} on the current market value of Kawran Bazar, Dhaka at the time of harvesting.

3.16.3. Net return

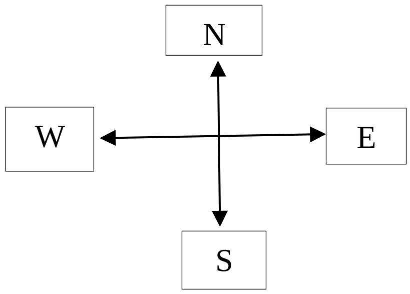
Net return was calculated by deducting the total production cost from gross income for each treatment combination.

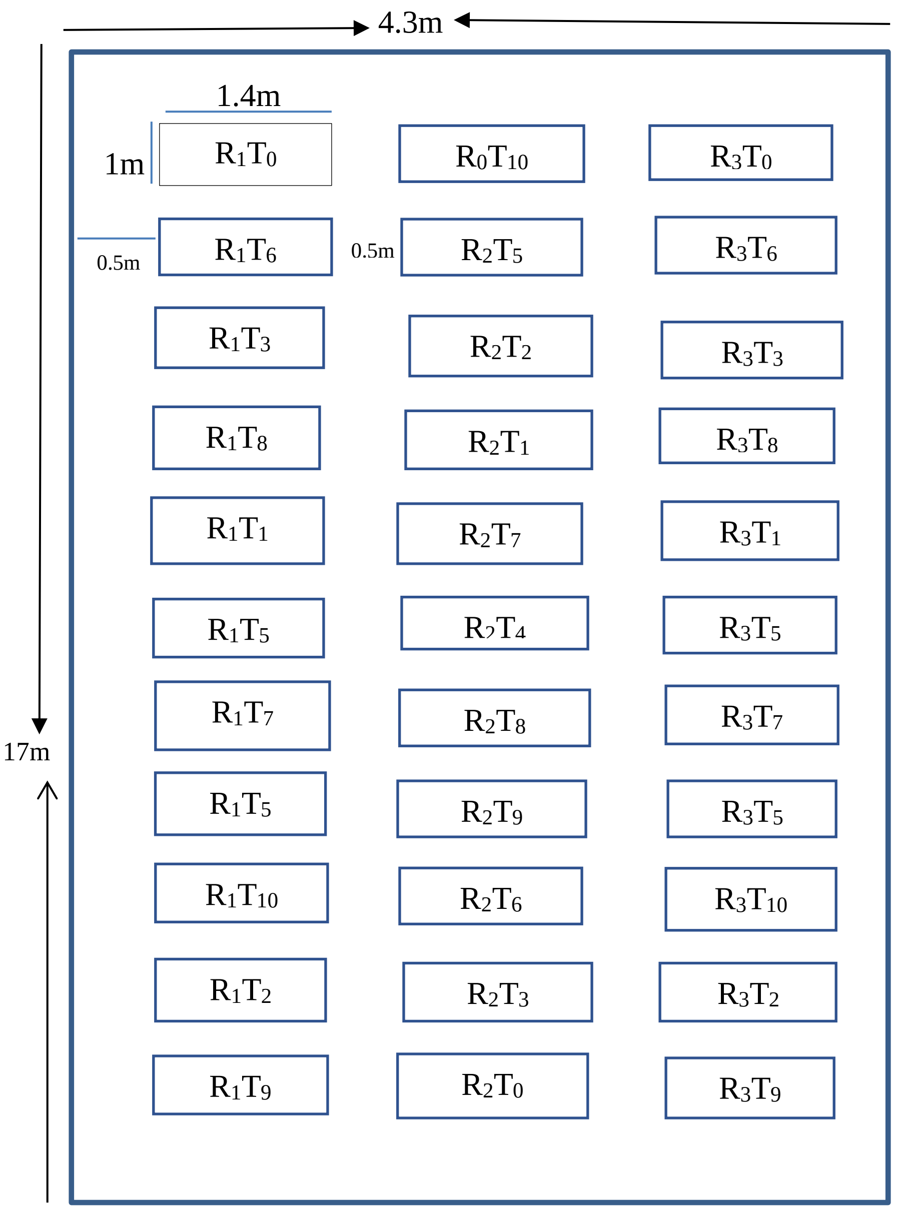
Net return = Gross return per hectare (Tk.) - Total cost of production per hectare (Tk.)

3.16.4. Benefit cost ratio (BCR)

The benefit cost ratio (BCR) was calculated as follows:

$$BCR = \frac{\text{Gross return per hectare (Tk)}}{\text{Total cost of production per hectare (Tk)}} \times 100$$





T_0: $N_0P_0K_0$+ No Organic Manure + No Biochar (Control).
T_1: NPK 100% (RDF)/ha.
T_2: Biochar 10 t/ha.
T_3: Organic Manure 15 t/ha.
T_4: NPK 50% (RDF)/ha + Biochar 10 t/ha.
T_5: NPK 100% (RDF)/ha + Biochar 5 t/ha.
T_6: Organic Manure 7.5 t/ha + Biochar 10 t/ha.
T_7: Organic Manure 15 t/ha + Biochar 5 t/ha.
T_8: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha.
T_9: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha + Biochar 5 t/ha.
T_{10}: NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha.

Experimental layout:
plot to plot distance =0.5 m
block to block distance =0.5m
plot size =1.4m x 1m 1
replication =3

Fig. 01: Field layout of the experiment in Randomized complete block design (RCBD)

RESULTS AND DISCUSSION

Results of the experiment entitled "Effect of the different sources of nutrients on the growth and yield of beetroot", conducted during Rabi season 2020-21 at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka are presented in this chapter. The observations pertaining to growth and yield attributes of beetroot recorded during the course of investigation were statistically analyzed and significance of results verified. The analyses of variance for all data have been presented in Appendices I to VII at the end. The results of all the main effects and only significant variation have been presented in succeeding paragraphs. Some of the characters have also been represented graphically to show the treatment effect wherever necessary to provide better understanding of the results.

4.1 Plant height

Plant height increased with the significantly increase different level of fertilizer, organic manure and biochar at 20, 40 and 60 DAS (Table 1). At 20 DAS, the maximum plant height (12.17 cm) was recorded from T_1 (NPK 100% RDF/ha) treatment which was statistically similar to T_5 (11.64 cm) and T_{10} (11.75 cm) treatments and minimum plant height (9.99 cm) was observed from T_0 (control) treatment (Table 1). At 40 DAS, the tallest plant (40.14 cm) was recorded from T_{10} (NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha) treatment. On the other hand, the lowest plant height (22.17 cm) was observed from T_0 (control) treatment. At 60 DAS, the tallest plant (52.58 cm) was recorded from T_{10} treatment followed by T_4, T_8 and T_9 treatment while the lowest plant height (31.71 cm) was observed from T_0 (control) treatment. The result of this study was supported by Maurya and Goswami et al., (1985).

Table 01: Effect of different sources of nutrients on the plant height of beetroot at different days after sowing

Treatments	Plant height (cm)		
	20 DAS	40 DAS	60 DAS
T_0	9.99 e	22.17 h	31.77 g
T_1	12.17 a	37.28 b	42.00 c
T_2	11.37 bc	27.75 g	32.39 g
T_3	11.11 bc	27.60 g	39.47 e
T_4	11.28 bc	35.23 cd	43.67 b
T_5	11.64 ab	36.31 bc	40.83 d
T_6	10.79 cd	31.03 f	33.88 f
T_7	10.03 de	32.19 ef	41.53 cd
T_8	10.61 cde	32.47 e	43.92 b
T_9	10.27 de	34.75 d	44.37 b
T_{10}	11.75 ab	40.14 a	52.58 a
$LSD_{(0.05)}$	0.7725	1.2149	0.7802
$CV_{(\%)}$	5.65	2.21	9.14

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Here, T_0: $N_0P_0K_0$+ No Organic Manure + No Biochar (Control); T_1: NPK 100% (RDF)/ha; T_2: Biochar 10 t/ha; T_3: Organic Manure 15 t/ha; T_4: NPK 50% (RDF)/ha + Biochar 10 t/ha; T_5: NPK 100% (RDF)/ha + Biochar 5 t/ha; T_6: Organic Manure 7.5 t/ha + Biochar 10 t/ha; T_7: Organic Manure 15 t/ha + Biochar 5 t/ha; T_8: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha; T_9: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha + Biochar 5 t/ha and T_{10}: NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha.

4.2 Number of leaves per plant

Number of leaves per plant is an important parameter for crop plant because of its physiological role in photosynthetic activities. Leaf number varied significantly with increasing amount of different level of fertilizer, organic manure and biochar at 20, 40 and 60 DAS (Table 2). At 20 DAS, the maximum number of leaves (5.95) was recorded from T_{10} treatment which was statistically identical to T_1 (5.80) treatment, while the minimum number of leaves (4.81) was obtained from T_0 (control) treatment. Again at 40 DAS, the highest number of leaves (10.21) was recorded from T_{10} treatment followed by T_1, T_6 and T_9 treatments and the minimum number of leaves (7.81) was obtained from T_0 (control) treatment. At 60 DAS, the maximum number of leaves (13.07) was recorded from T_{10} treatment which was statistically identical to T_1 (12.60) treatment. On the other hand, the minimum number of leaves (9.41) was obtained from T_0 (control) treatment.

Table 02: Effect of different sources of nutrients on the number of leaves/plants of beetroot at different days after sowing

Treatments	Number of leaves/plants		
	20 DAS	40 DAS	60 DAS
T_0	4.81 e	7.83 f	9.41 g
T_1	5.80 a	9.54 b	12.60 a
T_2	5.15 c	8.36 e	10.59 def
T_3	5.37 b	8.86 cd	10.34 f
T_4	4.96 de	8.91 cd	10.413 ef
T_5	5.02 cd	9.19 c	11.74 b
T_6	5.38 b	9.56 b	11.16 bcd
T_7	5.06 cd	9.14 c	11.04 cde
T_8	5.43 b	8.67 de	10.94 def
T_9	5.18 c	9.71 b	11.65 bc
T_{10}	5.95 a	10.21 a	13.07 a
$LSD_{(0.05)}$	0.1626	0.3382	0.6545
$CV_{(\%)}$	10.82	6.20	3.46

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Here, T_0: $N_0P_0K_0$+ No Organic Manure + No Biochar (Control); T_1: NPK 100% (RDF)/ha; T_2: Biochar 10 t/ha; T_3: Organic Manure 15 t/ha; T_4: NPK 50% (RDF)/ha + Biochar 10 t/ha; T_5: NPK 100% (RDF)/ha + Biochar 5 t/ha; T_6: Organic Manure 7.5 t/ha + Biochar 10 t/ha; T_7: Organic Manure 15 t/ha + Biochar 5 t/ha; T_8: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha; T_9: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha + Biochar 5 t/ha and T_{10}: NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha.

4.3 Number of branch root

The number of branch root was significantly influenced by the effect of different level of fertilizer, organic manure and biochar on the number of branch/plants of beetroot (Figure 02). The maximum number of branch (3.73) was observed in T_0 (control) treatment which was statistically identical to that of T_3 (3.14) while the minimum number of branch (0.33) was observed from T_7 treatments followed by T_{10} and T_5 (0.50 and 0.60) treatments.

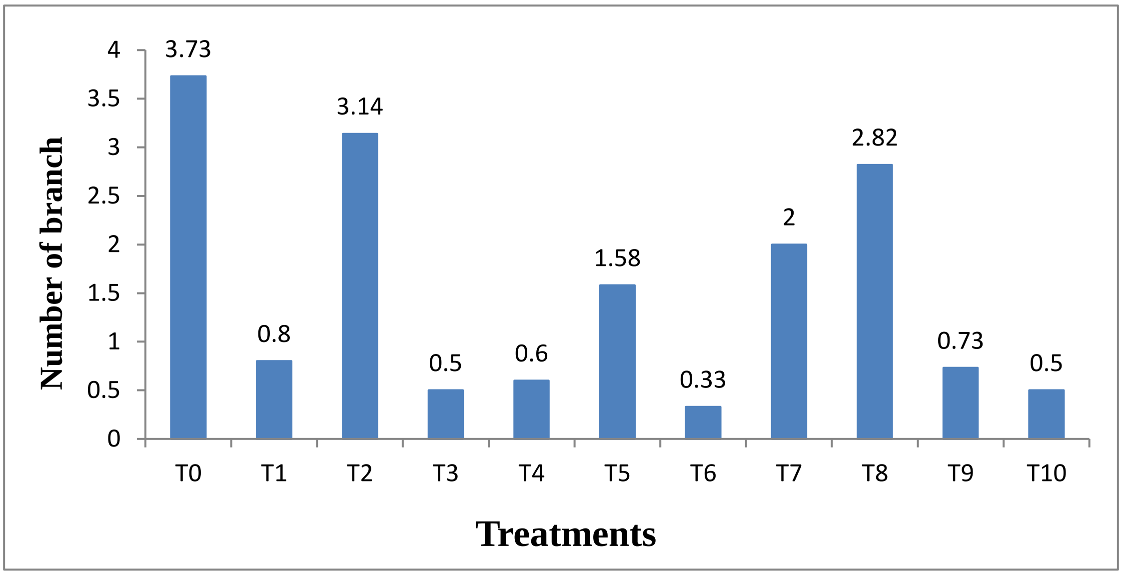


Figure 02: Effect of different sources of nutrients on number of branch of beetroot

4.4 Crack root percentage

Crack root of beetroot showed statistically significant differences for different level of fertilizer, organic manure and biochar application (Figure 03). The maximum crack root percentage (33.33%) was recorded from T_0 (control) treatment which was statistically identical with T_7 (33.33%), while the minimum crack root percentage (6.66%) was obtained from T_{10}, T_9, T_6 and T_2 treatments (Figure 03).

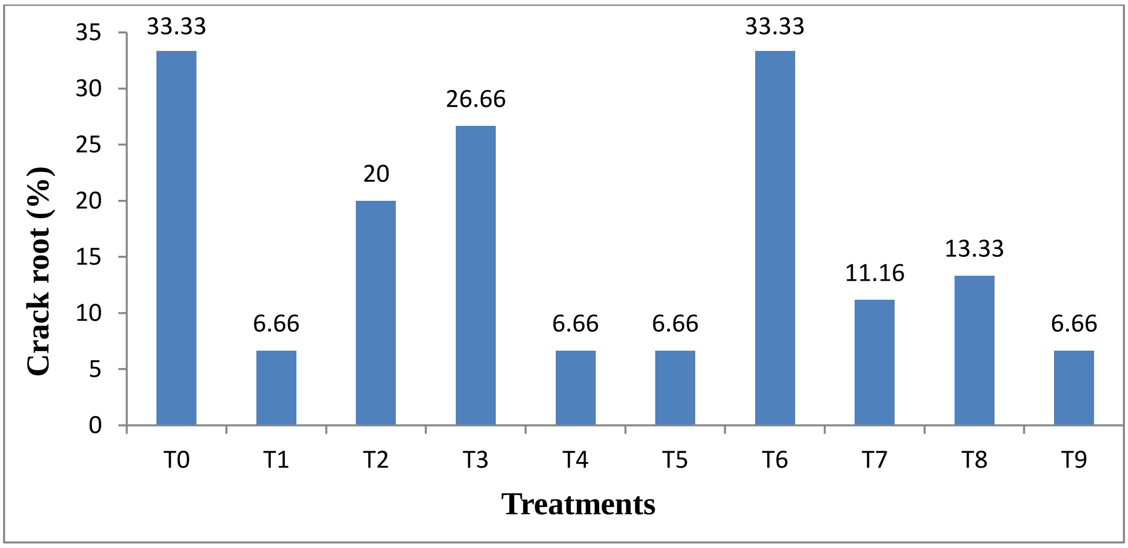


Figure 03: Effect of different sources of nutrients on the crack root percentage of beetroot

- Here, T_0: $N_0P_0K_0$+ No Organic Manure + No Biochar (Control); T_1: NPK 100% (RDF)/ha; T_2: Biochar 10 t/ha; T_3: Organic Manure 15 t/ha; T_4: NPK 50% (RDF)/ha + Biochar 10 t/ha; T_5: NPK 100% (RDF)/ha + Biochar 5 t/ha; T_6: Organic Manure 7.5 t/ha + Biochar 10 t/ha; T_7: Organic Manure 15 t/ha + Biochar 5 t/ha; T_8: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha; T_9: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha + Biochar 5 t/ha and T_{10}: NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha.

4.5 Root length

Root length of beetroot showed statistically significant differences for different level of fertilizer, organic manure and biochar application (Table 3). The maximum length of root (19.93 cm) per plant was recorded from T_5 treatment which was statistically identical with T_7 (18.96 cm), while the minimum length of root (11.71 cm) was obtained from T_0 (control) treatment (Table 3).

4.6 Beetroot diameter

The effect of different sources of nutrients on was significant influenced on beetroot diameter of beetroot plants (Table 3). T_{10} treatment produced the maximum beet root width (7.96 cm) which was statistically similar to T_4, and T_5 (6.83 and 6.80 cm) treatment and the minimum beet root width (4.16 cm) was measured in T_0 (control) treatment.

4.7 Days required to first harvest

The effect of treatments on days required for harvesting was found significant (Table 3). The results indicated that 95.12 days were needed to harvest T_0 (control) treatment whereas the statistically similar result was found in T_4 (91.85) and T_2 (91.81) (Table 3) and the lowest result was found in T_{10} (81.45) treatment.

4.8 Total days required to harvest

The effect of treatments on days required for first harvesting was found significant (Table 3). The results indicated that 78.85 days were needed to harvest T_0 (control) treatment whereas the statistically similar result was found in T_7 (75.35) and T_8 (75.01) (Table 3) and the lowest result was found in T_{10} (66.89) treatment.

Table 03: Effect of different sources of nutrients on the root length, diameter, days required to first harvest and total days required to harvest of beetroot at different days after sowing

Treatment	Root length	Beet root diameter (cm)	Days required to first harvest	Total days required to harvest
T_0	11.71 e	4.16 e	78.85 a	95.12 a
T_1	16.00 b	6.03 d	68.86 g	87.91 d
T_2	16.29 b	6.63 bc	72.52 cd	91.81 b
T_3	15.49 bc	6.83 b	70.62 f	89.81 c
T_4	19.93 a	6.80 b	72.37 de	91.85 b
T_5	16.25 b	6.56 bcd	70.66 ef	85.26 e
T_6	18.96 a	6.46 bcd	75.35 b	87.68 d
T_7	15.84 b	6.56 bcd	75.01 b	90.74 bc
T_8	16.08 b	6.13 cd	74.11 bc	87.11 d
T_9	14.31 cd	6.46 bcd	69.72 fg	86.64 d
T_{10}	13.17 d	7.96 a	66.89 h	81.45 f
$LSD_{(0.5)}$	1.2989	0.5917	1.7420	1.3219
$CV_{(\%)}$	4.85	5.44	11.42	9.88

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Here, T_0: $N_0P_0K_0$+ No Organic Manure + No Biochar (Control); T_1: NPK 100% (RDF)/ha; T_2: Biochar 10 t/ha; T_3: Organic Manure 15 t/ha; T_4: NPK 50% (RDF)/ha + Biochar 10 t/ha; T_5: NPK 100% (RDF)/ha + Biochar 5 t/ha; T_6: Organic Manure 7.5 t/ha + Biochar 10 t/ha; T_7: Organic Manure 15 t/ha + Biochar 5 t/ha; T_8: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha; T_9: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha + Biochar 5 t/ha and T_{10}: NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha.

4.9 Single root weight (g)

Significant variation was recorded total yield per plant of beetroot due to different level of fertilizer, organic manure and biochar application (Table 4). The highest total yield per plant (310.81 g) was recorded from T_{10} treatment which was statistically similar with T_9 (258.24 g) and T_5 (253.47 g) treatments whereas the lowest total yield per plant (157.14 g) was recorded from T_0 (control) treatment.

4.10 Yield per plot

Significant variation was recorded yield per plot of beetroot due to different level of fertilizer, organic manure and biochar application (Table 4). The highest yield per plot (5.77 g) was recorded from T_{10} treatment which was statistically similar with T_7 (4.67 g) treatment whereas the lowest yield per plot (2.99 g) was recorded from T_0 (control) treatment.

4.11 Marketable yield per plot

The Marketable Yield per plot (kg) of beetroot showed statistically significant variations with the different varietal treatment (Table 4). From the experiment it was observed that the treatment T_{10} produced the highest total marketable yield per plot (3.25 kg) which was statistically similar with T_9 and T_1 (2.57 and 2.53 kg) treatments whereas the lowest total marketable yield per plot (1.81 kg) was recorded from T_0 (control) treatment.

Table 04: Effect of different sources of nutrients on the yield contributing factor of beetroot at different days after sowing

Treatment	Single root weight (g)	Total marketable yield (kg) per plot	Total yield (g)per plot
T_0	157.14 g	1.81 f	2.99 i
T_1	250.83 bc	2.53 b	3.76 g
T_2	212.94 f	2.02 de	3.87 f
T_3	236.36 cd	2.07 d	3.99 e
T_4	214.08 ef	2.06 d	4.00 e
T_5	253.47 b	2.34 c	4.56 c
T_6	237.04 cd	2.31 c	4.67 b
T_7	226.99 def	2.26 c	4.26 d
T_8	228.36 de	1.97 e	3.98 e
T_9	258.24 b	2.57 b	3.59 h
T_{10}	310.81 a	3.25 a	5.77 a
LSD $_{(0.5)}$	15.049	0.0878	0.0923
CV $_{(\%)}$	3.78	12.26	11.32

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Here, T_0: $N_0P_0K_0$+ No Organic Manure + No Biochar (Control); T_1: NPK 100% (RDF)/ha; T_2: Biochar 10 t/ha; T_3: Organic Manure 15 t/ha; T_4: NPK 50% (RDF)/ha + Biochar 10 t/ha; T_5: NPK 100% (RDF)/ha + Biochar 5 t/ha; T_6: Organic Manure 7.5 t/ha + Biochar 10 t/ha; T_7: Organic Manure 15 t/ha + Biochar 5 t/ha; T_8: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha; T_9: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha + Biochar 5 t/ha and T_{10}: NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha.

4.12 Yield (t ha^{-1})

The total yield (ton/ha) of beetroot showed statistically significant variations with the different varietal treatment (Figure 04). From the experiment it was observed that the treatment T_{10} produced the highest yield (41.21 ton/ha) than to other treatments whereas the lowest yield per plot (21.35 ton/ha) was recorded from T_0 (control) treatment.

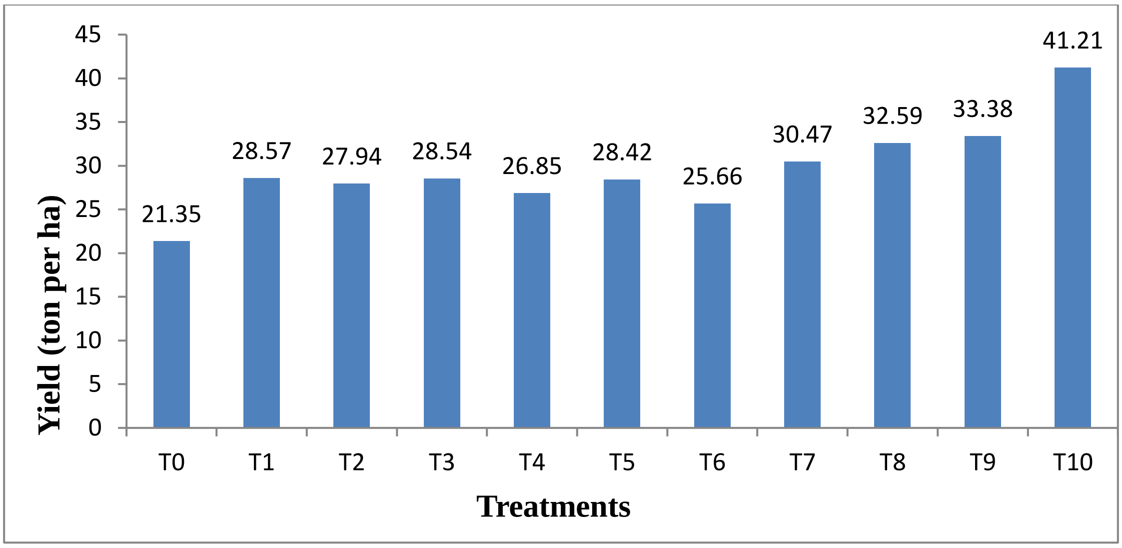


Figure 04: Effect of different sources of nutrients on the yield of beetroot

Here, T_0: $N_0P_0K_0$+ No Organic Manure + No Biochar (Control); T_1: NPK 100% (RDF)/ha; T_2: Biochar 10 t/ha; T_3: Organic Manure 15 t/ha; T_4: NPK 50% (RDF)/ha + Biochar 10 t/ha; T_5: NPK 100% (RDF)/ha + Biochar 5 t/ha; T_6: Organic Manure 7.5 t/ha + Biochar 10 t/ha; T_7: Organic Manure 15 t/ha + Biochar 5 t/ha; T_8: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha; T_9: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha + Biochar 5 t/ha and T_{10}: NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha.

4.16 Economic analysis

Input costs for land preparation, fertilizer, irrigation and manpower required for all the operations from seed sowing to harvesting of beetroot were calculated for unit plot and converted into cost per hectare (Appendix VI-VII). Price of beetroot was considered as per market rate. The economic analysis presented under the following headings.

4.16.1 Gross return

The effect different level of fertilizer, organic manure and biochar on the yield of beetroot showed different values in terms of gross return under the trial (Table 5 and Appendix VI-VII). The highest gross return (Tk. 1648400) was found from the treatment T_{10}. The lowest gross return (Tk. 854000) was obtained from T_0.

4.16.2 Net return

In case of net return, different treatment showed different levels of net return under the present trial (Table 5 and Appendix VI-VII). The highest net return (Tk. 875100) was obtained from the treatment T_{10}. The lowest (Tk. 306200) net return was found from T_0 treatment.

4.16.3 Benefit Cost Ratio

The effect of different level of fertilizer, organic manure and biochar on the yield of beetroot for benefit cost ratio was different in all treatments (Table 5). The highest benefit cost ratio (2.39) was found from the treatment T_{10} and the second highest benefit cost ratio (2.11) was found from T_1 treatment. The lowest benefit cost ratio (1.56) was found from the T_0 (control) treatment. From the economic point of view, it was apparent from the above results that the treatment T_{10} was more profitable than rest of treatments.

Table 05. Cost and return of beetroot cultivation as influenced by effect of different sources of nutrients on the yield of beetroot

Treatments	Cost of production (Tk /ha)	Yield (t/ha)	Gross return (Tk/ha)	Net return (Tk /ha)	BCR
T_0	547800	21.35	854000	306200	1.56
T_1	619225	32.59	1303600	684375	2.11
T_2	590400	27.94	1117600	527200	1.89
T_3	596300	28.54	1141600	545300	1.91
T_4	637600	26.85	1074000	436400	1.68
T_5	643500	28.42	1136800	493300	1.77
T_6	634060	25.66	1026400	392340	1.62
T_7	637600	30.47	1218800	581200	1.91
T_8	602200	28.57	1142800	540600	1.89
T_9	640450	33.38	1335200	694750	2.08
T_{10}	773300	41.21	1854450	1081150	2.39

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Total cost of production was done in details according to the procedure of Krishitattik Fasaler Upadan O Unnayan (in Bengali), 1988 by Alam *et al*., pp:231-239

Sale of marketable part @ Tk. 40000/ton

Net return =Gross return – Total cost of production

Benefit cost ratio = Gross return ÷ Total cost of production

CHAPTER V
SUMMARY AND CONCLUSION

A field experiment was conducted at the horticulture farm, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the period from November 2020 to March, 2021 to study the "Effect of different sources of nutrients on the growth and yield of beetroot (*Beta vulgaris* L.)." The experiment comprised of eleven different levels of fertilizer, organic manure and biochar viz., T_0: $N_0P_0K_0$ + No Organic Manure + No Biochar (Control); T_1: NPK 100% (RDF)/ha; T_2: Biochar 10 t/ha; T_3: Organic Manure 15 t/ha; T_4: NPK 50% (RDF)/ha + Biochar 10 t/ha; T_5: NPK 100% (RDF)/ha + Biochar 5 t/ha; T_6: Organic Manure 7.5 t/ha + Biochar 10 t/ha; T_7: Organic Manure 15 t/ha + Biochar 5 t/ha; T_8: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha; T_9: NPK 50% (RDF)/ha + Organic Manure 7.5 t/ha + Biochar 5 t/ha and T_{10}: NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha. Thus, there were eleven treatments and the experiment was laid out in randomized complete block design with three replications.

All the growth and yield contributing characters like plant height, number of leaves, crack root percentage, root length, beetroot diameter, beetroot breadth, days required for first harvesting, total days required for harvesting, single root yield per plant (g), total yield (g)-per plot, total marketable yield (kg)-per plot, and yield ton/ha varied significantly due to different levels of fertilizer, organic manure and biochar.

At 20 DAS, the maximum plant height (12.17 cm) was recorded from T_1 (NPK 100% (RDF)/ha) treatment and minimum plant height (9.99 cm) was observed from T_0 (control) treatment. At 40 DAS, the tallest plant (40.14 cm) was recorded from T_{10} (NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha) treatment. On the other hand, the lowest plant height (22.17 cm) was observed from T_0 (control) treatment. At 60 DAS, the tallest plant (52.58 cm) was recorded from T_{10} treatment, while the lowest plant height (31.71 cm) was observed from T0 (control) treatment.

At 20 DAS, the maximum number of leaves (5.95) was recorded from T_{10} treatment, while the minimum number of leaves (4.81) was obtained from T_0 (control) treatment. Again at 40 DAS, the highest number of leaves (10.21) was recorded from T_{10}

treatment and the minimum number of leaves (7.81) was obtained from T_0 (control) treatment. At 60 DAS, the maximum number of leaves (13.07) was recorded from T_{10} treatment. On the other hand, the minimum number of leaves (9.41) was obtained from T_0 (control) treatment.

T_{10} treatment produced the maximum beet root diameter (7.96 cm) treatment and the minimum beet root width (4.16 cm) was measured in T_0 (control) treatment. The maximum beet root breadth (7.40 cm) was measured from T_{10} treatment while the minimum beet root breadth (3.96 cm) was recorded from T_5 treatment. The results indicated that 95.12 days were needed to harvest T_0 (control) treatment and the lowest result was found in T_{10} (81.45) treatment.

The results indicated that 78.85 days were needed to harvest T_0 (control) treatment whereas the statistically similar result was found in T_7 (75.35) and T_8 (75.01) (Table 3) and the lowest result was found in T_{10} (66.89) treatment. The highest total marketable yield per plant (179.53 g) was recorded from T_{10} treatment g) treatment whereas the lowest total yield per plant (86.17 g) was recorded from T_0 (control) treatment.
The highest total yield per plant (310.81 g) was recorded from T_{10} treatment whereas the lowest total yield per plant (157.14 g) was recorded from T_0 (control) treatment. The highest yield per plot (5.77 g) was recorded from T_{10} treatment which was statistically similar with T_7 (4.67 g) treatment whereas the lowest yield per plot (2.99 g) was recorded from T_0 (control) treatment.

From the experiment it was observed that the treatment T_{10} produced the highest total marketable yield per plot (3.25 kg) whereas the lowest total marketable yield per plot (1.81 kg) was recorded from T_0 (control) treatment. From the experiment it was observed that the treatment T_{10} produced the highest yield (41.21 ton/ha) than to other treatments, whereas the lowest yield per plot (21.35 ton/ha) was recorded from T_0 (control) treatment.

The highest benefit cost ratio (2.39) was found from the treatment T_{10} and the second highest benefit cost ratio (2.11) was found from T_1 treatment. The lowest benefit cost ratio (1.56) was found from the T_0 (control) treatment. From the economic point of view, it was apparent from the above results that the treatment T_{10} was more profitable than rest of treatments.

CONCLUSION

Considering the above result of this experiment, the following conclusion and recommendation can be drawn:

1. NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha showed better performance for maximum parameters of beetroot.
2. NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha gave best results for both vegetative growth and yield of beetroot.
3. So, it can be concluded that combination of NPK 100% (RDF)/ha + Organic Manure 15 t/ha + Biochar 10 t/ha is suitable for beetroot cultivation.

Considering the situation of the present experiment, further study might be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performances. The experiment was however, conducted in one season only and hence the results should be considered as a tentative. It is imperative that similar experiment should be carried out with more variables to reconfirm the recommendation.

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APPENDICES

Appendix I. Monthly record of air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from November 2020 to March 2021

Year	Month	Air temperature (°c)			Relative humidity (%)	Rainfall (mm)
		Maximum	Minimum	Average		
2020	November	29.45	18.63	24.04	69.52	00
	December	26.85	16.23	21.54	70.61	00
2021	January	24.52	13.86	19.19	68.46	04
	February	28.88	17.98	23.43	61.04	06
	March	30.97	23.31	27.14	75.25	208

Source: Bangladesh Meteorological Department (climate division) Agargaon, Dhaka-1212.

Appendix II. Characteristics of Horticulture Farm soil as analyzed by Soil Resources Development Institute (SRDI), Khamar Bari, Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture Garden, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Fallow - Broccoli

Appendix II (contd.)

B. Physical and chemical properties of the initial soil

Characteristics	Value
Particle size analysis	
% Sand	27
% Silt	43
% Clay	30
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (mc/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI

Appendix III: Analysis of variance on germination percent, plant height and number of leaves per plant of beetroot

Source of variation	Degree of freedom	Mean Square of						
		Seed ger. %	PH 20 DAS	PH 40 DAS	PH 60 DAS	NL 20 DAS	NL 40 DAS	NL 60 DAS
Different nutrients	10	93.0348		79.1186	111.852	0.37079	1.32926	3.29876
Error	22	14.0866		0.5148	0.212	0.00922	0.03989	0.14939

Appendix IV: Analysis of variance on number of branch root, crack root, root length, beet root width– length, beet root breadth, days required for first harvesting and total days required for harvesting of beetroot

Source of variation	Degree of freedom	Mean Square of						
		Number of branch root	Crack root	Root length	Beet root width (cm) - length	Beet root breadth	Days required for first harvesting	Total days required for harvesting
Different nutrients	10	4.48196	358.371	16.0666	2.43285	3.86352	34.8468	41.7245
Error	22	0.28115	193.150	0.5884	0.12212	1.16000	1.0583	0.6094

Appendix V: Analysis of variance on total marketable yield per plant, total yield per plant, yield per plot, total marketable yield per plot and yield of beetroot

Source of variation	Degree of freedom	Mean Square of				
		Total Marketable Yield (g) per plant	Total Yield (g) per plant	Yield (g) per plot	Total Marketable Yield (kg) per plot	Yield (ton /ha)
Different nutrients	10	1534.09	4194.09	1.51161	0.47258	76.8269
Error	22	13.03	78.98	0.00297	0.00269	0.1835

Appendix VI: Cost of production of beetroot per hectare

Treatments	Labour cost (TK)	Ploughing cost (TK)	Seed cost (TK)	Fertilizer cost (TK)	Insecticide and Pesticide cost (TK)	Irrigation cost (TK)	Sub-Total (A)
T_0	30000	70000	40000	0	40000	10000	190000
T_1	50000	70000	40000	97500	40000	10000	307500
T_2	50000	70000	40000	70000	40000	10000	280000
T_3	50000	70000	40000	75000	40000	10000	285000
T_4	50000	70000	40000	110000	40000	10000	320000
T_5	50000	70000	40000	115000	40000	10000	325000
T_6	50000	70000	40000	107000	40000	10000	317000
T_7	50000	70000	40000	110000	40000	10000	320000
T_8	50000	70000	40000	80000	40000	10000	290000
T_9	50000	70000	40000	112500	40000	10000	322500
T_{10}	50000	70000	40000	225000	40000	10000	435000

Appendix VII: Overhead cost of beetroot per hectare

Treatments	Cost of lease of land for 6 months (13% of value of land Tk. 20,00,000/ year	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 months (Tk. 13% of cost per year)	Subtotal (Tk.) (B)	Total cost of production (Tk/ha) [Input cost (A) + overhead cost (B)]
T_0	260000	9500	27300	297800	486800
T_1	260000	14350	37375	311725	619225
T_2	260000	14000	36400	310400	590400
T_3	260000	14250	37050	311300	596300
T_4	260000	16000	41600	317600	637600
T_5	260000	16250	42250	318500	643500
T_6	260000	15850	41210	317060	634060
T_7	260000	16000	41600	317600	637600
T_8	260000	14500	37700	312200	602200
T_9	260000	16100	41860	317950	640450
T_{10}	260000	21750	56550	338300	773300

A

B

Plate 02: Pictorial presentation of different operations during land preparation, A. Land preparation with power tiller, B. Seed sowing

A

B

C

D

E

Plate 03: Some pictorial representation of intercultural operations, A. Weeding, B. Watering, C. Irrigation, D. Control measure, E. Data collection

Plate 04: Some pictorial representation of harvested beetroot