

**EFFECTS OF FARMYARD MANURE AND NITROGEN  
FERTILIZER ON GROWTH, YIELD COMPONENTS AND YIELD  
OF BEETROOT (*Beta vulgaris* L.) AT HARAMAYA, EAST ETHIOPIA**

**MSc THESIS**

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**JANUARY 2025  
HARAMAYA UNIVERSITY, HARAMAYA**

**Effects of Farmyard Manure and Nitrogen Fertilizer on Growth, Yield  
Components and Yield of Beetroot (*Beta vulgaris* L.) at Haramaya, East  
Ethiopia**

**A Thesis Submitted to the School of Plant Sciences,  
Post graduate Program Directorate  
HARAMAYA UNIVERSITY**

**In Partial Fulfillment of the Requirement for the Degree of  
MASTER OF SCIENCE IN AGRICULTURE (HORTICULTURE)**

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**January 2025**

**Haramaya University, Haramaya**



## **DEDICATION**

This thesis is dedicated to my mother Ashrefa Ibrahim whose strength supported me in whole my educational journey.

## STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this Thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analyses and compilation of this Thesis. Any scholarly matter that is included in the Thesis has been given recognitions through citations.

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## **BIOGRAPHICAL SKETCH**

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## ACKNOWLEDGMENTS

I would like to thank and praise the almighty God who opens the path for me and make me lucky to utilize my potential and reach this level by passing through a lot of challenges.

My deepest thanks to Prof. Kebede Woldetsadik, my major research advisor, and Prof. Wassu Mohammed, co- advisor for their well sustained and unique guidance, unreserved advice and enthusiastic collaboration. Their constructive criticism and insightful discussion with professional engagements immensely contributed to the accomplishment of this research and write up of the Thesis.

Also, I thank Haramaya University Research Office for financial support, especially Mr. Ibsa Aliye research facility directorate director for his support and facilitation of every instrument required during my field works. Additionally, I extend my gratitude to Haramaya University Soil Chemistry Laboratory Staff for their invaluable cooperation during Soil and Manure sample analysis.

I would also like to thank all my colleagues and brothers for helping and guiding me during data collections. I am also grateful to my father, Mr. Yehaya Ahmed, for encouraging and providing me all what I need, including research field and labor along with his partners and also I thank all members of my family for their all rounded support, love, and prayer to complete my studies.

**ACRONYMS AND ABBREVIATIONS**

ANOVA	Analysis of Variance
CEC	Cation Exchange Capacity
CIMMYT	Center for International Maize and Wheat Improvement
CM	Cow Manure
CSA	Central Statistical Agency
CU	Cow Urine
DAP	Days after Planting
DAT	Days after Transplanting
FAO	Food and Agriculture Organization
FYM	Farm yard manure
IFPRI	International Food and Policy Research Institute
LSD	Least Significant Difference
N	Nitrogen
NPK	Nitrogen, Phosphorous and Potassium
NPS	Nitrogen, Phosphorous and Sulfur
NPSZnB	Nitrogen, Phosphorous, Sulfur, Zinc and Boron
NRCS	Natural resource conservation service
MRR	Marginal Rate of Return
PM	Poultry Manure
RDF	Recommended Dose of Fertilizer
RDN	Recommended Dose of Nitrogen
TSP	Triple Super Phosphate

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## Effects of Farmyard Manure and Nitrogen Fertilizer on Growth, Yield Components and Yield of Beetroot (*Beta vulgaris* L.) at Haramaya, East Ethiopia

### ABSTRACT

*Beetroot is one of the most widely grown root vegetables in eastern part of Ethiopia due to its economic importance besides nutritional value and health benefits. However, the productivity of the crop is low due to poor soil fertility and management. This research was conducted to assess the effect of farmyard manure and nitrogen fertilizer rates on growth, yield component and yield of beetroot at Haramaya from February to May, 2024. Detroit Dark Red variety was evaluated with the application of 4x4 rates of farmyard manure (0, 7.5, 15 and 22.5 ton ha<sup>-1</sup>) and nitrogen fertilizer (0, 50, 100 and 150 kg ha<sup>-1</sup>) in factorial combinations in a randomized complete block design with three replications. The research results demonstrated that the main effects of FYM and N as well as their interaction had significant effects on plant height, leaf number, and leaf area. Plant height, leaf number, and leaf area, each at 35 DAP, 50 DAP, and at harvest were positively affected by the main effect of FYM and N. The root length, leaf and root dry matter were significantly influenced by the main effect of FYM and N; however, root diameter was responded only to FYM application. Similarly, leaf and root fresh weights, marketable and nonmarketable root yield were highly influenced by the main effect of FYM and N fertilizer along with their interaction, but total root yields was affected only by main effect of FYM and N fertilizers. The maximum marketable root yield (29.14 ton ha<sup>-1</sup>) was obtained with application of 22.5 ton ha<sup>-1</sup> of FYM plus 100 kg ha<sup>-1</sup> of N fertilizers. On the other hand, the highest total root yields of 29.68 and 29.32 ton ha<sup>-1</sup> were obtained from individual application of 22.5 ton ha<sup>-1</sup> of FYM and 150 kg ha<sup>-1</sup> of N fertilizer, respectively. The partial budget analysis also revealed that the highest net benefit (698289.9 Birr ha<sup>-1</sup>) with acceptable marginal rate of return (787.29%) was obtained from the combined application of 22.5 ton ha<sup>-1</sup> FYM and 100 kg ha<sup>-1</sup> of N fertilizer. Therefore, it could be suggested that integrated application of the two fertilizers at rates of 22.5 ton ha<sup>-1</sup> of FYM and 100 kg ha<sup>-1</sup> of N fertilizer could be used to maximize yield of beetroot and optimize the net benefit to beetroot producers in the study area.*

**Keyword:** *Detroit dark red variety, Integrated nutrient management, Marketable root, Net benefit, and Marginal rate of return.*



## 1. INTRODUCTION

Beetroot (*Beta vulgaris* L.) is one of the major root vegetables grown throughout the world and is mainly consumed as a salad vegetable, though the leaves can also be eaten as spinach (Lock *et al.*, 2004). Beetroot belongs to Chenopodiaceae family and is originated in the Mediterranean Region. The crop is grown on about seven million hectares around the world, with a total production of 240 million tones. It is grown in more than 120 countries, among which Germany and France are the largest producers (Jasmitha *et al.*, 2018), and in lesser amounts in other European countries, Africa and South America. It is ranked among the ten most potent vegetables with respect to antioxidant property. It has been used for centuries due to nutritional and health benefits (Babarykin *et al.*, 2019). Nowadays, the crop is a popular salad vegetable and used as root vegetables as well as leafy vegetables.

Beetroot is a biennial crop that grows as annual for its tap root production. It is mainly cool weather crop and short day plant. It is easy to cultivate in the field, highly productive, and is usually free of pests and diseases (Nottingham, 2004). Beetroots are consumed fresh, cooked or as a processed product (Rana, 2018). A large proportion of commercial production is processed into boiled and sterilized beetroot or pickles. It has also been widely used industrially as food colorant due to its red color from the pigment betalain (Singh *et al.*, 2017). Betanin, is used to improve the color and flavor of tomato paste, sauces, desserts, jams and jellies, ice cream, candy, and breakfast cereals (Grubben, 2004).

Beetroot is among the root crops that its production and consumption has been increasing in Africa. The production from 1970 to 2019 has increased from 1.21 to 14.3 million tons in Africa, expanding at a yearly rate of 6 percent (Enock, 2022). Ethiopia is amongst the major producers in Africa and the production of the crop has shown slight increases. In the 2014/15 main season, a total of 18.2 thousand tons of beetroot were produced from an area of 1.9 thousand ha with an average productivity of 9.3 ton ha<sup>-1</sup>. In the 2021/2022 main season, a total of 26451.6 tons of beetroot were produced from 3149 ha of land with 8.4 ton ha<sup>-1</sup> average productivity (CSA, 2014; 2021).

Ethiopia is endowed with different agro-ecologies that are appropriate for the production of tropical, subtropical, and temperate vegetables (Zerihun and Gezaheng, 2021). In Ethiopia

beetroot is mainly grown in altitude ranges of 500-3000 m.a.s.l, however the most suitable regions are located between 1100 m and 2400 m above sea level (Girma, 2008). The major beetroot production areas in Ethiopia are concentrated close to major cities and towns, including Addis Ababa, Bahir Dar, Debre Zeit, Jimma, Harar and Dire Dewa (CSA, 2008). Currently, Oromia region is the leading producer of beetroot compared to other parts of the country (CSA, 2021). In Haramaya watershed, out of land favorable for vegetable production, large proportion of land is allotted to beetroot cultivation during the main cropping seasons. The crop is becoming a popular vegetable in the area due to high demand from local and abroad markets like Djibouti and Somaliland, beside its importance for home use and health benefits.

Despite the importance of beetroot in the area, its productivity remains very low. The low productivity is attributed to a number of factors including limited choice of adaptable and high yielding variety, moisture stresses, poor soil fertility, and agronomic practices (Girma, 2008). Of these constraints, soil fertility management represents a crucial factor influencing the final yield and quality. Among the possible options for increasing the productivity of beetroot, optimal application of inorganic nutrients (mainly N) is the most important practice (Sapkota *et al.*, 2021). Nitrogen is important nutrient in determining plant growth and crop yield (Mampa *et al.*, 2017). The optimum application of N fertilizers promotes growth and in turn increases both yield and quality of roots; however, application of excessive amount of Nitrogen fertilizer negatively impacts the soil ecosystem and can reduce yield.

Soil fertility decline is one of a major constrains to increasing crop production in Ethiopia, mainly in vegetable cultivation. The primary cause of soil fertility decline includes loss of organic matter (OM), macro and micronutrient depletion, soil acidity, topsoil erosion and deterioration of physical soil properties (IFPRI, 2010). Ethiopia is one of the 14 sub-Saharan countries with highest rates of nutrient depletion (Negassa *et al.*, 2005). In eastern part, particularly at the study area, most of the farmers are engaged in repeated use of land without addition of any organic fertilizer. In addition, the plant residues are removed for use as animal feed and fuel. For this reasons, the fertility of the land is declining from time to time. In order to maintain fertility and productivity of the soil as well as maximize yield of crops, the soil has to be restored to meet crop nutrient requirements. This depleted nutrient

could be substituted through either application of inorganic or organic fertilizer. However, chemical fertilizers are expensive to purchase for most small-scale farmers and may not contain all nutrients required by the plants (Gete *et al.*, 2010). Amendment with organic manure may help to meet crop nutrient requirement, which are missing in the type of inorganic fertilizer formulations in use.

Organic fertilizer provides a stable supply of both macro and micronutrient, improves the soil physical, chemical and biological properties, and consequently supports the maximum plant growth and yield (Belay *et al.*, 2001). Application of manure can contribute to increase soil fertility, nutrient availability, soil aggregation, and also nutrient retention by elevating CEC of the soil while reducing the dependence on chemical fertilizer. In addition to reducing cost of inorganic nutrient, it is important for root crops like beetroot which needs loose and smooth soil during root initiation and enlargement. Therefore, the use farmyard manure (FYM) which is easily available at lower cost along with inorganic fertilizers is invaluable for crop productions.

Furthermore, the substitution of inorganic fertilizers with organic manure or a reduction in chemical fertilizer usage is necessary for the sustainability of agricultural production. Hence, the objectives of this research were:

- To assess the effect of different levels of nitrogen fertilizer and cattle manure on growth, yield components, and yield of beetroot; and
- To estimate the cost benefit of the rates of N and cattle manure for optimum yield of beetroot crop.

## 2. LITRETURE REVIEW

### 2.1. Origin and Botanical Description of the Crop

Beetroot belongs to the Chenopodiaceae family, which includes nearly 1,400 species (Nottingham, 2004; Paciulli, 2016). The family included silver beet (spinach and chard for edible leaves), sugar beet (cultivated for sugar production), and fodder beet (grow for animal feeding). There are nine species in the beta genus and all of them have the common name beet, although *Beta vulgaris* is the most well-known and commercially important (NRCS, 2006).

Beetroot (*Beta vulgaris* L.) which is also commonly known as red beet, garden beet or table beet is one of the most popular vegetable crops grown in many parts of the world (Stintzing and Carle, 2004; Rana, 2018). It is indigenous to Asia Minor and Europe. It has been known and cultivated since 1000 BC in the Roman Empire; its leaf was used as food, while its root was used as medicine (Ninfali and Angelino, 2013). The ancestor of all beet cultivars that are grown today, including beetroots, is *Beta maritima*. Sea beet was first domesticated in the eastern Mediterranean and the Middle East (Nottingham, 2004). The earliest form of domesticated beet was leaf beet and the crop was cultivated with long root like that of carrots. The table beet leaves are also widely consumed, particularly as immature leaf for a salad greens (Goldman and Janick, 2021).

The beetroot plant is biennial, requiring a period of intense cold to go through the reproductive stage of the cycle (Sediyama *et al.*, 2011). It produces fleshy elongated hypocotyls and a rosette leaf during the first year and flower in second year. But as a biennial, it requires a photo thermal induction to facilitate the process from vegetative to reproduction phase. Vernalisation is the first element in the induction; this requires low temperature during the rosette stage for the induction of flowering (Abo-Elwafa *et al.*, 2006; Salimi and Boelt, 2019). Stem elongation, which is also known as bolting, is initiated by the completion of vernalisation and the bolter is the main stem in beets (Salimi and Boelt, 2019).

The beetroot is the taproot portion of the beet plant. The plant has a root system composed of a main root and smaller roots with lateral branching. It also possesses a tuberous, purplish-red

part, globular in shape, with a sweet taste, which develops almost on the surface of the soil (Ravichandran *et al.*, 2013).

Beetroot leaves colour varies from light green to dark red depending on the cultivar. The foliage, size, colour and shape are also highly influenced by temperature, season, spacing and soil moisture (Rubatzky and Yamaguchi, 1997; Rana, 2018). The rosette leaves develop in a close spiral with the oldest ones outside. Angular, branching soft stem develops in the second year on which a clumpy inflorescence is located. The inflorescence is botanically a large spike. Flowering is initiated in the second growing season after a prolonged period of cold weather (Rana, 2018).

## **2.2. Nutritional Importance of the Crop and its Health Benefit**

The beetroot is nutritionally one of the most popular vegetable in many parts of the world due to its health benefit. It has long been used for medicinal purposes, primarily for disorders of the liver as it helps to stimulate the liver's detoxification processes and it has been considered beneficial to the blood, the heart, and the digestive system (Nottingham, 2004). Additionally, beetroot leaves are packed with several antioxidants such as betalains, flavonoids and polyphenols which are capable of counteracting dangerous reactive species (ROS) (Lee *et al.*, 2009). The crop product consumption provides a significant effect on nearly all organs of the digestive tract: pancreas, liver, colon. It is well known as an “internal cleansing” substance and provides a mild laxative effect. As a result, the demand for healthy food has also increased consumer interest in red beetroot and this has been reflected in various cuisines (Clifford *et al.*, 2015).

Red beetroots are becoming more and more important vegetable nowadays due to their many positive nutritional and physiological properties. Apart from raw consumption, salads, soups, vegetable dishes, roasting and olive oil dishes of red beetroot have become widespread in all cuisine (Akan *et al.*, 2019). It is especially rich in fiber as well as in sugars, but has a moderate caloric value. Beetroots are highly nutritive as they are packed with several vitamins, proteins, carbohydrates, minerals and antioxidants which have some anticarcinogenic, antibacterial and antiviral properties (Kanner, *et al.*, 2001; Akan *et al.*, 2019). Beetroot leaves are a good source of Vitamins A, B1, B2 and C (Rana, 2017). In addition to its significant

potassium and magnesium content, it is associated with low sodium concentrations, which have a beneficial effect on the ionic balance of the human body. The betacyanins in crops reduce oxidative stress and the harmful effects of free radicals, have antibacterial and antiviral properties, inhibit the proliferation of cancer cells, and are involved in the prevention of cardiovascular disease (Kujala *et al.*, 2002).

In recent years, the pigments of red beetroot have also been used as a natural colorant for the food industry and additive in food products (Slavov *et al.*, 2013; Chhikara *et al.*, 2019). The plant pigment that gives beetroot its rich, purple-crimson color is betacyanin; a powerful agent, thought to suppress the development of some types of cancer (Dwivedi, 2017).

### **2.3. Ecological Requirement of the Crop**

Beetroot thrives under a wide range of climatic and soil condition. It has been grown best under cool climatic condition and can be grown successfully almost all year round. Also it can grow well in warm weather but attain best color, texture and quality in cool condition, though slows growth under prolonged cool condition. It has a fair tolerance to moderate frost at all growth stages (Nottingham, 2004).

The ideal temperatures for cultivation of table beet are between 15 and 19°C. Temperatures below 10°C cause a physiological shift from vegetative to reproductive growth, with the storage root shrinking and nutrients being diverted to reproductive structures. Temperatures above 25°C can adversely affect the growth, color, and development of beetroot. Furthermore, sugar accumulation in beets is greatly affected by temperature. Any temperature above 30°C results in reduced sugar accumulation (Rana, 2017). At higher than optimal temperatures, the storage of nutrients in the roots is reduced, leading to smaller root size, and impaired texture and flavor (Nottingham, 2004). Additionally, beets which have been grown under high temperature conditions have less red colour and distinct zoning inside the flesh. Moreover, for good quality of roots, continuous cool weather conditions for two weeks is good for the development of good colour and texture as fluctuating temperatures cause zoning. In Ethiopia, the crop grows from 500-3000 m.a.s.l; however, the most suitable regions are located between 1100 m and 2400 m above sea level (Girma, 2008).

Beetroots can be classified as plants with medium water requirements. During germination and in the initial developmental stage of the plant, it requires a higher amount of continuous soil moisture, which is important for even germination and initial development. Except for this period, beetroots are less sensitive to water shortages compared to other root vegetables. After seed emergence, dry conditions can negatively affect growth and yield (Hoffmann, 2010). For optimum yield, beetroot requires an average of 300 mm of rainfall in a growing season (Rana, 2017). Keeping soil moisture at optimum levels will improve growth, yield and quality in root vegetables such as beetroot (Nottingham, 2004).

Soil conditions highly influence beetroot yield and quality. A wide range of soil types have been proven to favour for beetroot cultivation. However, beets prefer deep, friable, well drained, deep sandy soil rich in organic matter for better growth. High organic matter in the soil is desirable and helps to ensure an adequate moisture supply (Kumar, 2015). Particularly deep sandy loams are ideal for beetroot, especially those with a high organic content, which supplies natural fertilizer and retains its moisture but heavy clay is avoided due to restriction of tap root growth and undesirable shape. The crop can grow in a soil pH between 6 and 8 (Drost and Bitne, 2004), though very high pH levels have been found to promote scab, a soil borne disease. On the other hand, any pH below 5.8 has been associated with yield losses (Rana, 2017).

Nutrient requirement has been considerable and essential factor to optimum yield of the crops. Beetroot belongs to a group of vegetables considered to be heavy feeders and requires an optimum amount of major plant nutrients (N, P, K) to maximize yield (Dos Santos *et al.*, 2017). Apart from major plant nutrients, beets require optimum levels of boron, zinc and sodium and sometimes these are applied to meet the needs for minor plant nutrients (Rubatzky and Yamaguchi, 1997).

#### **2.4. Effect of Nitrogen Fertilizer on Growth and Yield of Beetroot**

Nitrogen is the most limiting nutrient in crop production and is needed in higher concentration than all other mineral nutrients in most plants. It comprises up 1 to 4 percent of dry matter of the plants (Ellis and Foth, 1996). Nitrogen forms a major component of proteins, enzymes, vitamins and is responsible for chlorophyll and amino acid formation in plant cells and it is

involved in all major process of plant development and yield formation (Petek *et al.*, 2012). A good supply of nitrogen stimulates root growth and development as well as the uptake of other nutrients (Brady and Weil, 2002). Beetroot at the beginning of its growth requires a lot of available nitrogen. Insufficient supply of nitrogen can decrease plant nitrogen content, reducing photosynthate production (Boussadia *et al.*, 2010) and thus, reduce plant growth and quality of harvestable materials (Mikkelsen and Hartz, 2008). On the other hand, an overdose nitrogen application does not always lead to increased yield, and it might actually result in reduced growth and yield as well as delay in maturity and also limits the formation of storage organs, especially for crops where roots and tubers are harvested (Najm *et al.*, 2013). In addition, the plant's resistance to disease is reduced by excess nitrogen. Thus, optimizing crop-specific fertilization regime is required to increase yield as well as improve quality of the produce (Kazimierczak *et al.* 2021).

An optimal rate of application of fertilizer is extremely important to improve yield and quality. However, many authors recommended different rate of nitrogen fertilizer on beet crop, which are site specific. Birhanu and Dawit (2020) reported the highest marketable root yield, which was 163% more than unfertilized plot, of *Detroit* dark red variety at the rate of 100 kg ha<sup>-1</sup> of N while further increase of N from 100 to 150 kg ha<sup>-1</sup> showed 46% yield decline in Wolaita Zone, Southern Ethiopia. Similarly, a study undertaken by Zerihun and Gezahegn (2021) at Arba Minch University on the response of beetroot to nitrogen rate and plant density showed the highest root yield at 92 kg ha<sup>-1</sup> of N with planting density ranging from 66,666, to 100,000 plants ha<sup>-1</sup>. In a different environment, beetroot yields were found to increase as the nitrogen application rate increased from 2.99 ton ha<sup>-1</sup> in the control treatments to 14.37 ton ha<sup>-1</sup> in the treatments that received 200 kg ha<sup>-1</sup> of N fertilizer (Rantao, 2013).

According to several researchers, application of nitrogen has significant effect on growth parameters of beetroot crop. An increment in plant growth characteristics such as plant height, shoot dry matter, and leaf area index were reported due to N application (Najm *et al.*, 2013). Idris *et al.* (2021) showed that application of 120 kg ha<sup>-1</sup> of N increase leaf number, leaf area index, leaf dry weight, root diameter and root fresh weight at University of Bahri, the Sudan. Fikru *et al.* (2017) stated that application of urea significantly increase leaf area and underground dry weight but not other parameters. The study conducted by Birhanu and Dawit

(2020) have also indicated that root length and root width were significantly affected by rates of nitrogen fertilizer, thus the longest root length (117.17 mm) was attained by variety Samba at 150 kg ha<sup>-1</sup> of N whereas; the shortest root length (80.90 mm) was attained from variety Farida with 0 kg ha<sup>-1</sup> of N fertilizer applications. Also the author confirmed that the highest root width (19.60 mm) was from variety Samba at 100 kg ha<sup>-1</sup> of N while the narrowest root width (9.37 mm) was obtained from Crimson globe at 0 kg ha<sup>-1</sup> of N fertilizer.

Similarly, Ouda (2007) found that root diameter, root length, root fresh weights and root yield were increase by raising N levels. Khalil *et al.*(2010) and Abdou *et al.*(2014) also found that increasing N levels significantly increased root length, root diameter, root fresh weight, and root yield plant<sup>-1</sup>. Likewise, Hellal *et al.* (2009) reported that increase root diameter and length were observed with an increase in N application. The report by Nemeat Alla *et al.* (2002) also show that increasing nitrogen rate to 100 kg ha<sup>-1</sup> of N resulted in about 74% increase in root width compared to no nitrogen rate treatment. On other hand, Fikru *et al.*(2017) found that urea has no significant effect on yield, leaf length, leaf number, plant height, above ground fresh weight, underground fresh weight, above ground dry weight, root length and root diameter.

Research results of different authors reported that increasing nitrogen fertilizer increased dry matter yield and yield components of beetroot. According to El-Hosary *et al.*(2010), and Seadh *et al.*(2012) increasing N fertilizer levels caused significant differences in yield, yield components, and quality of beet crop. Mampa *et al.* (2017) reported that N application of 120 kg ha<sup>-1</sup> resulted in increase yield and quality of beetroot leaves and roots. Albayrak and Yüksel (2010) also showed that nitrogen applications increase root yield, dry matter yield, root diameter, and root length at the rate of 150 kg ha<sup>-1</sup> of nitrogen. Similarly, Leilah *et al.*(2005) reported root yield increase by high N levels due to N playing an important role in enhancing growth, chlorophyll formation, the photosynthesis process, and other variables contributing to yield improvement. As numerous studies shows, application of nitrogen different effects on yield and yield related traits of beet crops, which could be differences in varieties used, soil and climatic conditions under which the experiments were undertaken.

## 2.5. Effect of Farmyard Manure on Growth and Yield of Beetroot

Farmyard manure is principal source of organic matter and it is a source of primary, secondary and micronutrient to plant growth. It is one of the components of integrated nutrient management as it is a cheap and easily available source of organic nutrients. It is prepared from mixture of dung and urine of farm animals along with litter and fodder fed to the cattle. It improves soil physical, chemical and biological properties, and thereby helps in making soils highly productive and sustainable (Ahmad *et al.*, 2006; Naeem *et al.*, 2009). It is highly used organic manure that supplies some essential plant nutrients (N, P, and K) and other macronutrients and micronutrients (Duncan *et al.*, 2005). Farmyard manure helps in increasing microbes' population and their activities, which play an important role in availability of complex nutrients to the plants as well as improving moisture retention capacity of soils. Being a popular source of organic matter, it contains beneficial microorganism that secretes substances that act as growth regulator which improve plant growth and also reduces nitrogen (N) losses by increasing Cation Exchange Capacity (CEC) of the soil, improves soil structure by adding organic matter and also minimizes phosphorus (P) and Potassium (K) fixation in all types of soils (Gill *et al.*, 1998). On the average, well decomposed farmyard manure contains 0.5 per cent Nitrogen (N), 0.2 per cent Phosphate ( $P_2O_5$ ) and 0.5 per cent Potassium ( $K_2O$ ) (Reddy and Bandopadhyay, 2018). A field experiment conducted in South India showed that application of farmyard manure at 17.5 ton  $ha^{-1}$  provided 200  $kg\ ha^{-1}$  of nitrogen, 32.5  $kg\ ha^{-1}$  of phosphorous and 297.5  $kg\ ha^{-1}$  of potassium over unfertilized plots (Jeyaseeli *et al.*, 2018). The study conducted by Lehrs *et al.* (2015) showed that root yield resulting from the application of manure or compost was equivalent to that resulting from urea application. Similarly, Murmu *et al.* (2013) pointed out that the application of organic manures increase crop yield and soil fertility more than chemical fertilizer.

According to Jagadeesh *et al.* (2018), application of FYM had significant effect on root length of beetroot. The highest root length (13.35 cm) was recorded in with FYM (50%) + poultry manure (50%) and FYM (100%). Similarly, Abd El-Lateef *et al.* (2019) revealed that the application of farmyard manure to beet plant significantly surpassed both the compost and chicken manure in root length, root, shoot and biological yields per plant and per hectare.

Also Aisha *et al.* (2014) found that adding organic manure at high rates (20 m<sup>3</sup>) had a significant effect on growth characters including plant length, number of leaves per plant, fresh and dry weight per plant as well as root fresh and dry weight and its components (root length and diameter). Furthermore, the authors indicated that applying organic manure at high rates gave the highest percentage of protein, N, P, K and Fe as well as total carbohydrate percentage of the plant.

An experiment conducted by Gazia (2001) found that application of farmyard manure significantly affected the root and shoot yields of beet crop. Also, sugar yield was shown to significantly increase due to FYM application at the rate of 20 ton. Similarly, Marques *et al.* (2010) evaluating rates (0 to 80 ton ha<sup>-1</sup>) of cow manure on production of beetroot, cultivar Early Wonder, found that the greatest yield was obtained at the highest rate of application. On the other hand, Felipe *et al.* (2015) reported that the rates of the organic manure do not affect the quality traits, but the rate of 49 ton ha<sup>-1</sup> resulted in the maximum root yield. Likewise, Shafeek *et al.* (2019) conducted experiment in Egypt for two years on enhancing the productivity and quality of beetroot (*Beta vulgaris*) by using organic manure and potassium foliar application. The result showed that all addition of organic cattle manure significantly increased total root yield and physical root quality compared with control.

According to the study conducted on beetroot by Hlisnikovsky *et al.* (2021) reported that the highest beetroot yield (61.2 ton ha<sup>-1</sup>) was obtained from FYM (21 ton ha<sup>-1</sup>), whereas the lowest yield (52.9 ton ha<sup>-1</sup>) was from the control plot. Also Amiri *et al.* (2009) showed that the effect of manure application on improving the crop yield was due to supply of some nutrients required by the plant, improvement of soil physical and chemical properties, elevation of soil water holding capacity and enhancement of micronutrient uptake. As aforementioned, farmyard manure application has positive effect on improving yield of beet plant by providing macro as well as micronutrient and changing physico-chemical property of the soil, although its application alone does not meet the desire of crops. So, combined use FYM with mineral nutrients would be much vital to find out maximum yield of crops. John *et al.* (2004) also advocated an integral use of organic manure and inorganic fertilizer to sustain maximum crop productivity and profitability, while minimizing environmental impact from nutrient use.

## 2.6. Integrated Use of Organic and Inorganic Fertilizers on Growth and Yield of Beetroot

It is notable that the integration of organic and inorganic nutrient sources is the best option to maintain soil health and meet the total crop nutrient demand in sustainable way. Organic nutrient sources are known to restore soil physical environment and enhance nutrient use efficiency by a crop, in such a way that they influence growth, yield and quality of crops (Taye *et al.*, 2011). Inorganic fertilizers are good for the rapid growth of plants, their effect on plant is usually immediate and fast, contain necessary nutrients that are ready to use and also quite high in specific nutrient content. On the other hand, manure is a natural source of slow-release fertilizer because it breaks down and decomposes in the soil, releasing nutrients gradually. Thus, complementary use of chemical fertilizer and organic manure has assumed great importance nowadays to maintain as well as sustain a higher level of soil fertility and crop productivity (Shalini *et al.*, 2002).

Several investigations revealed that application of organic fertilizer with inorganic ones improve soil fertility as well as growth and yield of plants. Shalini *et al.* (2002) stated that application of organic manure with inorganic fertilizer significantly increase growth and vigor of the plants over application of inorganic fertilizer alone. Tolanur *et al.* (2002) also reported that cation exchange capacity, exchangeable calcium, available nutrient N, P, K and Zn were increased significantly with organic material in conjunction with inorganic material.

The result of a large number of experiment on manure and inorganic fertilizer conducted in several countries reveal that neither chemical fertilizer alone nor organic sources used exclusively can sustain the productivity of the soil under highly intensive cropping system (Singh and Yadav, 1992). Han *et al.* (2016) also indicated that NPK fertilizer treatment leads to soil acidification, whereas organic manure + NPK treatments significantly increase soil pH. Similar finding by Walia *et al.*(2010) also reported that the incorporated nutrient management system results in rising organic carbon content, available nitrogen, phosphorus, and potassium increasing from 0.390% to 0.543%, 171.7 to 219.3 kg ha<sup>-1</sup>, 20.5 to 43.3 kg ha<sup>-1</sup> and 124.6 to 148.9 kg ha<sup>-1</sup>, respectively. For sustainable productivity, mixed use of chemical with organic fertilizer has proved to be highly beneficial in terms of balanced nutrient supply (Chen *et al.*, 2008).

An experiment conducted in Nepal on effect of organic and inorganic source of nitrogen on growth, yield, and quality of beetroot varieties revealed that all of the vegetative parameters of beetroot were significantly enhanced with the combined use of urea and organic manure, which were attributed to rapid cell division, multiplication, and elongation in the meristematic region of plants that promoted vegetative growth (Naik and Sreedhar, 2018). Also Sapkota *et al.* (2021) pointed out that significantly higher root diameter and length were produced by either organic manure alone or in combination with urea. This was associated to organic manure that helps soil microorganisms to produce polysaccharides and thus lead to better soil structure useful for root growth. According to Gajewski *et al.* (2010), the application of manure allows for easy root penetration, erosion resistance, and good soil moisture properties such as available water holding capacity and permeability, combined with adequate aeration. Also, significantly higher root diameter in manure plus urea-treated plots might be due to the sufficient availability of phosphorous from manure affecting the root diameter of root crops. It could also be due to the adequate supply of macro and micronutrients for the metabolic activities of the plants.

According to Heidarian *et al.* (2018) the highest root diameter was obtained by combined application of nitrogen fertilizer and cow manure treatment, resulting in increased root diameter by 21 and 24% compared to individual application of nitrogen fertilizer and cow manure, respectively. Also the authors confirmed that the integrated treatment (N+FYM) produced the highest dry weight of leaves both under stress and well watered conditions. An experiment conducted by Kebede *et al.* (2016) on determination of appropriate fertilizer rate for forage and seed yields of fodder beet (*Beta vulgaris*) in the central highland areas of Ethiopia indicated that application of fertilizers mixture at a rate of 10/23 kg ha<sup>-1</sup> of N/P<sub>2</sub>O<sub>5</sub> + 9 ton ha<sup>-1</sup> of FYM ha<sup>-1</sup> gave the highest (30.3 cm) plant height while minimum plant height of 19.3 cm was recorded from control treatment (no fertilizer). Also the researcher indicated that plant height was increased by 57% over the control treatment.

According to Faraji *et al.* (2015) application of chemical fertilizers combined with cow manure improved qualitative and quantitative traits of beet plant. Also Heidarian *et al.* (2018) reported that the combined application of 50% nitrogen fertilizer and 50% farmyard manure increased root yield by 28 and 32% compared with single application of nitrogen and

farmyard manure fertilizers, respectively. Similarly, Hlisnikovský *et al.* (2021) revealed that over the entire evaluated period (2016–2018), the combined application of the FYM with mineral NPK fertilizers increased beetroot yield by about 25% compared with the control treatment

The study conducted by Felczynski and Elkner (2008) on effect of long-term organic and mineral fertilization on the yield and quality of red beet (*Beta vulgaris*. L), reported that the highest total yields of whole red beet plants (roots 76.8 ton ha<sup>-1</sup> + leaves 73.7 ton ha<sup>-1</sup>) were obtained from the treatment in which manure was applied at 60 ton ha + N at 60 kg ha<sup>-1</sup>. In this combination, the additional mineral fertilization with nitrogen increased the share of the leaves in the total yield of whole plants compared to fertilization with manure only. However, the marketable yield of red beets was lower than from the treatment with manure alone at 60 ton ha<sup>-1</sup>. The author also confirmed that the highest increase in yield was obtained from the treatment with 20 ton ha<sup>-1</sup> of manure + 180 kg ha<sup>-1</sup> of N fertilizer. On other hand, the treatment with manure at the rate of 40 ton ha<sup>-1</sup>, the additional mineral fertilization with nitrogen at 120 kg ha<sup>-1</sup> of N did not have any significant effect on the marketable yield. Therefore, it shows that fertilization of beetroot crop with integration of both organic and inorganic fertilizer has an advantage if both fertilizers are applied at appropriate level.

### 3. MATERIALS AND METHODS

#### 3.1. Description of Study Site

The experiment was undertaken in 2024 under irrigated condition on farmer's field at Haji village, Haramaya sub city in Maya city, Oromia Regional State. The site is close to Haramaya University and located about 510 km far from Addis Ababa and 18 km from Harar town at 9° 24'N and 42° 1'E in the easterly direction. The altitude of study site is about 2047 meters above sea level. The location has a bimodal rainfall distribution and is a representative of a sub humid mid latitude agro-climatic zone. The short rainy seasons usually start in March and extend to May, whereas the long rainy seasons stretches from end of June to September (Kibebew, 2014). The site has annual rainfall of about 790 mm; mean temperature of 16.8° C with mean minimum and maximum temperature of 10.4° C and 23.4° C, respectively.

#### 3.2. Description of Experimental Materials

*Detroit* dark red variety of beetroot which is widely cultivated in the study area has been used as a test crop. The variety is well adapted to most environments, even in area that experience a lot of heat. It considered a multi-purpose cultivar and has been used for fresh market, processing, and market garden production. The storage roots of the variety are perfectly smooth and uniform, the flesh is generally red with light red zoning while the skin has a deep red colour. *Detroit* dark red leaves are generally medium to tall, and dark green leaves (Goldman *et al.*, 2008). The variety takes about 2 to 3 months to mature. Additionally, it is relatively tolerant to bolting and resistant to several diseases such as *Cercospora* leaf spot and other beetroot diseases. Seed of this variety was obtained from Haramaya Farmers' Union at Haramaya sub city.

TSP [(Triple Super phosphate (46% P<sub>2</sub>O<sub>5</sub>)] was used as fertilizer form of phosphorous and urea (46% N) also used as source of nitrogen fertilizer. A well decomposed FYM had been used as a source of organic fertilizer. It was prepared by gathering fresh dung from surrounding farmers under pit method in a hole with a size of 1.5 m x 1.5 m area and 1 m depth for 4 months to make it well decomposed.

### 3.3. Treatments and Experimental Design

The treatment consisted farmyard manure at four level (0, 7.5, 15 and 22.5 ton ha<sup>-1</sup>) as organic fertilizer and also mineral nitrogen at four level (0, 50, 100 and 150kg ha<sup>-1</sup>) as inorganic fertilizer. The rate of phosphorous fertilizer (80 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub>) for beetroot crop production had been used uniformly over all experimental plots as TSP form of fertilizer. The experiment was laid out as a randomized complete block design (RCBD) in a 4 x 4 factorial arrangement, and it was replicated three times. The experiment had contained 48 total plots. Each plot had the size of 1.50 m width x 3.00 m length with a total of 4.5 m<sup>2</sup> plot area. A plot had consisted five rows, and each row contained twenty plants.

### 3.4. Soil Sampling and Analysis

Prior to land preparation, the soil sample was taken in zigzag pattern randomly from the experimental site at 0-25 cm depth using auger at the interval of 4-8 meter. The sample was mixed thoroughly to produce one representative composite sample. Around one kilogram of the composite sample was stored in a clean plastic bag and sent to Haramaya university soil laboratory. The composite sample was analyzed for selected physiochemical properties like soil texture, soil pH, total nitrogen(N), available phosphorous(P), exchangeable potassium(K), electrical conductivity, and cations exchange capacity (CEC)(c mol kg<sup>-1</sup>) using appropriate laboratory procedures.

The total nitrogen in the soil was determined by the Kjeldahl method (Dewis and Freitas, 1975). Organic carbon content of the soil was determined by reduction of potassium dichromate by oxidation reduction titration with ferrous ammonium sulphate (Walkley and Black,1934). Particle size distribution was determined by hydrometer method (FAO,2008). Available phosphorous was determined by the Olsen' method using spectro photometer (Olsen *et al.*,1954). Cation exchange capacity (CEC) was determined after saturating the soil with 1N ammonium acetate (NH<sub>4</sub>OAc) and displacing it with 1N NH<sub>4</sub>OAc (Chapman, 1965). The PH of the soil was determined using 1:2 (weight volume -1) soil to CaCl<sub>2</sub> solution ratio and a glass electrode attached to digital pH meter (FAO,2008).

### **3.5. Experimental Procedures and Managements**

The land was cultivated three times manually to a depth of 20 to 25 cm and exposed to the sun for some days to make soil loose and clear of plant debris. It was leveled and flattened with a rake and plots were prepared. The prepared farmyard manure was applied by broadcasting at specified doses on the plots and incorporated into the soil at 15 to 20 cm depth two weeks before planting. The phosphorous fertilizer was applied uniformly in all experimental plots before planting.

The seed bed was prepared with ridges 30 cm apart for furrow irrigation. The treatments were assigned to each plot randomly. Then two seeds were sown 15 cm apart at 2 cm depth and covered with good crumbed light soil (February five). After the seeds were germinated, they were thinned out into single seedling at the spacing of 15 cm. The spacing between plot and adjacent block was 0.5 m and 1 m respectively. The gross size of experimental area was 384m<sup>2</sup>.

The nitrogen rates were applied in two split, with half done at seed sowing time by band placement and the remaining applied one month after seedling by side dressing. Immediately after seed sowing, watering was done at intervals of 3 days to maintain adequate moisture until the seedlings were fully emerged, then irrigation interval was adjusted based on weather condition and local practice and was done uniformly. Weeds were controlled two times; one at early seedling stage and the second one month later. All other agronomic practices were done uniformly as per recommendation to the crop. After the crop matured, it was harvested by hand pulling when majority of the plants attained globular shaped roots with market required size and when plants showed partial drying and yellowing of lower leaves at about 80 days after planting (end of April).

### **3.6. Data Collected**

The data collection was made by random sampling of ten plants on shoot growth and root parameters while yield was assessed on net plot basis as follows:

### 3.6.1. Growth Parameters

**Plant Height (cm):** refers to the length from the ground to the tip of the plant. It was determined by measuring the height of the randomly taken plants using a ruler from three central rows at 35, 50 and 65 DAP and at harvesting time.

**Leaf Number:** number of leaves from ten sample plants in the plot was counted and recorded at 35, 50 and 65 DAP and at harvesting, then their mean was worked out.

**Leaf Area (cm<sup>2</sup>):** the leaf area of randomly selected ten plants from the plots was marked and its length and width was measured at 35, 50 and 65 DAP and at harvesting time. The leaf area was calculated using the formula developed by (Yeshitila and Taye, 2016).

**Leaf Fresh Weight (g):** refers to the weight of plant leaf which was recorded immediately after detached. It was determined after leaves were separated from top of swollen root, and then weighed on electronic balance and the average was recorded in grams.

**Leaf Dry Weight (g):** is the weight of plant part after its water content has been removed by drying process. It was measured by taking fresh leaf of sample plants from the plots and placed in oven for 48 hours and dried at 70 °c (Mampa *et al.*,2017) and then dry weight was measured as:

$$\text{DMC (\%)} = \frac{\text{Weight of dried leaf sample (g)} \times 100}{\text{Fresh weight of the sample (g)}}$$

### 3.6.2. Yield Components and Yield

**Root Length (cm):** the length of root was measured from ten randomly selected plants on middle row at harvest from a base to the apex of the root using ruler and its average was calculated.

**Root Diameter (cm):** it had been determined by measuring the diameter of root with help of calipers and the average was expressed in centimeters.

**Root Fresh Weight (g per plant):** after harvesting the roots were washed to ensure it were free of soil particles and other extraneous material and, then the cleaned root portion was weighed on electronic balance and their fresh weight was recorded in grams.

**Root Dry Weight (g):** after fresh weight of root was recorded, the root was sliced into small pieces to facilitate for drying, and placed in an oven dry at 75°C till constant weight was occurred (Dlamini *et al.*, 2020) and then dry weight was calculated as:

$$\text{DMC (\%)} = \frac{\text{Weight of dried root sample (g)} \times 100}{\text{Fresh weight of the sample (g)}}$$

Fresh weight of the sample (g)

**Marketable Root Yield (ton ha<sup>-1</sup>):** the marketable yield was determined by sorting roots according to color, shape, size and freedom of any mechanical or disease injuries and acceptable by the market (Birhanu and Dawit, 2020). Root diameter between 4.5-8.6 cm was considered marketable size (Nure Abdukarem, exporter of vegetables, Haramaya). Also, commercial yield encompassed roots with an equatorial diameter greater than 5 cm and no evident lesions or deformations (HORTBRASIL, 2006).

**Unmarketable Root Yield (ton ha<sup>-1</sup>):** the roots which were undesired in color, size and shape, diseased and insect pest injured, and not preferred at market were weighed and converted to ton per hectare.

**Total Root Yield (ton ha<sup>-1</sup>):** it was recorded as the sum of marketable and unmarketable root yield. The total root yield of plants was measured and the yields obtained from plots were converted to hectare.

### 3.7. Partial Budget Analysis

Partial budget analysis was carried out as per the methodology described in CIMMYT (1988). The data like, cost incurred for preparation of farmyard manure and buying urea fertilizers, labor cost for application of fertilizer and the price of the marketable yield of beetroot after harvest were taken in to account to undertake cost-benefit analysis. Accordingly, the market price of marketable root yield of beetroot was determined based on average of open market price which was 28.00 Birr kg<sup>-1</sup>. To determine the total costs, the average price of fertilizer (Urea) in that period was 50 Birr kg<sup>-1</sup> and the estimated cost for FYM preparation was 1000 Birr ton<sup>-1</sup>. Additionally, labor cost for application of FYM fertilizer was estimated as 20

persons and for N also 15 persons and one person's cost was 75 Birr per day. The analysis was done on the basis of the formula developed by CIMMYT (1988) as follows:

**Gross marketable root yield (kg ha<sup>-1</sup>) (MRY):-** is marketable root yield of each treatment per hectare.

**Adjusted yield (AjY):-** is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers.

$$AjY = AvY - (AvY * 0.1)$$

**Gross field benefit (GFB):-** was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield.

$$GFB = AjY * \text{field/farm gate price for the crop}$$

**Total cost:** - is cost of fertilizers and FYM preparation used for experiment. The cost of other inputs and production practices such as labor cost for land preparation, planting, weeding, crop protection, and harvesting was considered to remain the same or considered among treatments.

**Net benefit (NB):-** was calculated by subtracting the total costs from gross field benefit for each treatment.

$$NB = GFB - \text{Total cost}$$

**Marginal rate of return (MRR%):** was calculated by dividing change in net benefit by change in cost.

$$MRR = \frac{\Delta NB}{\Delta TC} \times 100$$

Where; MRR is Marginal rate return in percent,  $\Delta NB$  and  $\Delta TC$  is change in net benefit and change in total cost, respectively.

### **3.8. Data Analysis**

All measured parameter were subjected to analysis variance (ANOVA) of RCBD in factorial arrangement according to the general linear model (GLM) of Gen Stat 18th edition (GenStat, 2018) and interpretation was made following procedure described by Gomez and Gomez (1984). Least significance difference's (LSD) test at 5% probability level had been used for mean comparison following the significance differences result from the ANOVA.

## 4. RESULTS AND DISCUSSION

### 4.1. Soil Physico-chemical Property of Experimental Site

The composite soil sample of the experimental site was analyzed for some selected soil physical and chemical properties before planting. The soil textural class of the study area was determined as sandy loam soil (Table 1). The pH of the soil was 7.50, which could be classified as moderate alkaline (Tekalign, 1991). The total nitrogen content of the soil is 0.16%, which was within a low category (Landon, 1991), also the soil of the experimental site had 1.21% of organic carbon content (OC), which could be classified as low according to the rating by Tekalign (1991). This exhibit that the soil of experimental site required the supply of additional organic fertilizer to increased soil fertility and promote healthy and vigorous plant growth.

The available phosphorous in the soil have been rated as high, which is  $36.73 \text{ mg kg}^{-1}$  (Olsen *et al.*, 1954). According to the classification by Tekalign (1991), the soil of the experimental site had  $1.01 \text{ cmol}(+)\text{kg soil}^{-1}$ , which is categorized under high exchangeable potassium(K). Likewise, the electrical conductivity (Ec) of experimental site had  $0.128 \text{ ms/cm}$  which is low according to Hazelton and Murphy (2007).

The soil of experimental site had  $23.2 \text{ meq/100 g}$  cation exchange capacities (CEC) which is moderate according to Egel *et al.* (2014). Cation exchange capacity (CEC) is the ability of a soil to attract and retain cations such as potassium (K),sodium (Na), calcium (Ca), magnesium (Mg), and ammonium ( $\text{NH}_4$ ). It shows the soil of experimental site had ability to retain and hold nutrient to plants at some extent.

Similarly, the FYM sample applied to the study area was analyzed for some selected chemical properties before planting. The analyzed sample of farmyard manure (Table 1) had pH (8.49), organic carbon (9.7%), total nitrogen content (0.89%), available phosphorous (3333.33 ppm), exchangeable potassium (1.18%) and electrical conductivity ( $2.27 \text{ ms/cm}$ ).

Table 1. Some selected physical and chemical properties of soil before planting and chemical properties of FYM before applications.

Parameters	Value		References
	Soil	Rating	
<b>Chemical properties</b>			
PH	7.50	Moderately alkaline	8.49 Tekalign (1991)
OC%	1.21	Low	9.17 Tekalign (1991).
TN%	0.16	Low	0.89 Landon (1991)
Av.P(mgkg <sup>-1</sup> & ppm)	36.73	High	3333.33 Olsen <i>et al.</i> (1954)
Exch.K (cmol(+) kg soil <sup>-1</sup> & %)	1.01	High	1.18 Tekalign (1991)
EC (ms/cm)	0.128	Low	2.27 Hazelton and Murphy(2007)
OM%	2.09	Medium	Hazelton and Murphy(2007)
CEC	23.2	Medium	Egel <i>et al.</i> (2014)
<b>Physical properties</b>		<b>Textural class</b>	
Sand	68%		Hazelton and Murphy(2007)
Clay	16%	Sandy loam	
Silt	16%		

OC=Organic Carbon, TN=Total Nitrogen, AP=Available Phosphorous, EK= Exchangeable Potassium, EC=Electrical Conductivity, CEC=Cation Exchange Capacity, OM=Organic Matter.

## 4.2. Growth Variables

### 4.2.1. Plant Height

The main effect of FYM and N fertilizer had significant ( $P < 0.05$ ) effects on plant height of beetroot at 50 DAP and at harvesting (Appendix Table 1); however, it had non-significant effect at 35 DAP. The tallest plant height at 50 DAP (20 cm) and harvesting (29.10 cm) were recorded from the application of 22.5 ton ha<sup>-1</sup> and 15 ton ha<sup>-1</sup> of farmyard manure, respectively, which were statistically similar with application of 15 ton ha<sup>-1</sup> at 50 DAP and 22.5 ton ha<sup>-1</sup> of FYM at harvesting. On the other hand, the shortest plant height at 50 DAP (15.40 cm) and at harvesting (24.23 cm) were obtained from the control treatment, which however, were at par with the application of 7.5 ton ha<sup>-1</sup> FYM (Table 2).

In the same way, the tallest plant at 50 DAP (19.85 cm) and harvesting (28.68 cm) were observed from the application of 150 kg ha<sup>-1</sup> of nitrogen, which were statistically similar with the application of 100 kg ha<sup>-1</sup> of N, whereas the shortest plant height at 50 DAP (15.46 cm) and harvesting (24.46 cm) were obtained from the control treatment (Table 2).

Table 2. Plant height and leaf numbers as affected by main effect of FYM and N fertilizer rates at various growth stages of beetroot plant in 2024 under irrigations.

Treatments	Plant Height(cm)			Leaf Numbers(No)		
	at			at		
Rate of FYM (ton ha <sup>-1</sup> )	35 DAP	50 DAP	Harvest	35 DAP	50 DAP	Harvest
0	11.71	15.40 <sup>a</sup>	24.23 <sup>a</sup>	5.750 <sup>a</sup>	7.922 <sup>a</sup>	13.15 <sup>a</sup>
7.5	12.58	16.89 <sup>a</sup>	25.89 <sup>a</sup>	5.833 <sup>a</sup>	8.445 <sup>ab</sup>	13.77 <sup>a</sup>
15	13.25	19.76 <sup>b</sup>	29.10 <sup>b</sup>	6.417 <sup>a</sup>	9.132 <sup>bc</sup>	14.79 <sup>b</sup>
22.5	13.17	20.00 <sup>b</sup>	28.67 <sup>b</sup>	7.250 <sup>b</sup>	9.404 <sup>c</sup>	15.28 <sup>b</sup>
LSD(0.05)	NS	2.295	2.433	0.778	0.836	0.785
Rate of N (Kg ha <sup>-1</sup> )						
0	12.17	15.46 <sup>a</sup>	24.46 <sup>a</sup>	5.667 <sup>a</sup>	8.049 <sup>a</sup>	13.87 <sup>a</sup>
50	13.08	17.19 <sup>a</sup>	26.19 <sup>ab</sup>	6.167 <sup>a</sup>	8.433 <sup>ab</sup>	13.82 <sup>a</sup>
100	12.83	19.55 <sup>b</sup>	28.55 <sup>bc</sup>	6.333 <sup>ab</sup>	8.965 <sup>bc</sup>	14.42 <sup>ab</sup>
150	12.62	19.85 <sup>b</sup>	28.68 <sup>c</sup>	7.083 <sup>b</sup>	9.455 <sup>c</sup>	14.88 <sup>b</sup>
LSD(0.05)	NS	2.295	2.433	0.778	0.836	0.785
CV%	17.2	15.3	10.8	14.8	11.5	6.6

CV: Coefficient of variations; LSD: Least significant difference; FYM: farmyard manure ;NS: Non-significant; means sharing common letter(s) are not significantly different at 5% level of significance

Generally application of 22.5 and 15 ton ha<sup>-1</sup> of FYM at 50 DAP and at harvesting increased plant height by 30%, and 20%, respectively, over that of control. Similarly, application of nitrogen (150 kg) at 50 DAP and harvesting increased plant height by 28%, and 17.3%, over that of the control treatment. This may be due to application of farmyard manure that improves soil structure and moisture retention capacity that facilitated better root growth, and thus plant height. Furthermore, the manure could have promoted soil fertility and increased uptake as well as availability of essential nutrient around of root zone. This could have led to increased vegetative growth. Application of FYM in the soil increases microbial activity, biomass and mineralization of C and N that improve moisture conservation in the soil (Naeem *et al.*, 2009).

The result of this study is in agreement with the finding of Shafeek *et al.* (2019) who reported the highest value of the growth character of beetroot plant by adding high level of cattle manures. Similarly, Kumar *et al.* (2022) stated that integrated application of FYM, Vermicompost, and PSB(Phosphorus solubilizing bacteria) had significant effect on plant

height at 50 DAS (28.10 cm) of beetroot Red express cultivar. Additionally, Gerba *et al.* (2018) on carrot indicated the highest plant height at 18 tons ha<sup>-1</sup> cattle manure application was obtained probably because of organic matter that improves soil structure and encourages root growth which intern promote plant growth. Also, Shivani and Kumar (2023) have reported that significantly the maximum plant height of beetroot crop at harvesting (27 cm) were recorded from the applied treatment of NPK (160:110:70). Similarly, Gayathri *et al.* (2021) on beetroot indicated that highest plant height at 75 DAS (38.47 cm) was registered in application of nitrogen at 122.5 Kg ha<sup>-1</sup> and lowest plant height (35.38 cm) was recorded in nitrogen level of 70 Kg ha<sup>-1</sup>.

Report by Afework *et al.* (2022) also showed that the main effect of NPS had significant effect on plant height of beetroot, with the tallest plant obtained by application of 242 kg ha<sup>-1</sup> of NPS fertilizer, while the shortest height was recorded with control plots.

The interaction effects of FYM and N fertilizer had significant ( $P < 0.05$ ) effect on plant height of beetroot at 65 DAP; however, it had non-significant effect at 35 DAP, 50 DAP and at harvesting (Appendix Table 1). The tallest plant height (26.55 cm) at 65 DAP was recorded from the combined application of 22.5 ton ha<sup>-1</sup> of FYM with 100 kg ha<sup>-1</sup> N fertilizer, which had non-significant difference from application of 22.5 ton ha<sup>-1</sup> of FYM with 150 kg ha<sup>-1</sup> of N and 15 ton ha<sup>-1</sup> of FYM with 100 and 150 kg ha<sup>-1</sup> of N fertilizer. On other hand, the shortest plant height (18.25 cm) was obtained at 0 ton ha<sup>-1</sup> of FYM and 0 kg ha<sup>-1</sup> of N fertilizer application (Table 3).

Application of 22.5 ton ha<sup>-1</sup> farmyard manure combined with 100 kg ha<sup>-1</sup> of N fertilizer increased plant height of beetroot by 45.5% over that of the control. The highest plant height obtained by the combined application of FYM with N could be attributed to the nitrogen from both fertilizers that enhanced vegetative growth, which has led to tall plants. The uptake of nitrogen stimulated cell division and enlargement, which would be responsible for promoting plant height (Tygi *et al.*, 2016).

The finding aligns with that of Sapkota *et al.* (2021) who reported the highest plant height of beetroot at harvesting from application of 6.55 ton ha<sup>-1</sup> of poultry manure plus 60 kg ha<sup>-1</sup> of N from urea. Also, Hussain and Kerketta (2023) found the maximum height of beetroot at 60 DAS from treatment of 25% RDF (recommended dose of fertilizer) plus 75% vermicompost.

According to Najm *et al.* (2013) the maximum plant height at the 60<sup>th</sup> DAE (days after emerged) was obtained by using 20 tons ha<sup>-1</sup> of cattle manure + 150 kg ha<sup>-1</sup> of N fertilizer.

Similarly, Kumar *et al.* (2021) indicated that the integrated application of FYM, Vermicompost, and PSB (Phosphorus solubilizing bacteria) attained maximum value of plant height (34.04 cm) of beetroot plant at harvesting. According to Sapkota *et al.* (2021) highlighted that the maximum plant height at 60 DAS were obtained due to combined application of 6.55 ton ha<sup>-1</sup> of PM with 60 kg ha<sup>-1</sup> of N from urea fertilizer. Similarly, potato plant height was increased with increased use of combined application of organic and inorganic fertilizer (Aseffa *et al.*, 2016).

#### 4.2.2. Leaf Number

The number of leaves were significantly ( $P < 0.05$ ) affected by main effect of farmyard manure and nitrogen fertilizer rates at 35 DAP, 50 DAP and harvesting, while their interaction had non-significant effect except on 65 DAP (Appendix Table 1). The individual application of farmyard manure and nitrogen fertilizer at highest rates (22.5 ton ha<sup>-1</sup> FYM and 150 kg ha<sup>-1</sup> N) was observed with maximum leaf numbers at 35 DAP, 50 DAP and harvesting. On the other hand, with no application of farmyard manure (0 ton ha<sup>-1</sup>) and nitrogen fertilizer at lowest rates (0 and 50 kg ha<sup>-1</sup>) minimum leaf numbers were recorded at 35 DAP, 50 DAP and harvesting stage (Table 2).

Increasing application rate of farmyard manure from 0 to 22.5 ton ha<sup>-1</sup> and nitrogen fertilizer from 0 to 150 kg ha<sup>-1</sup> significantly increased leaf number through all growth stages. The increase in number of leaves was due to increased solubilization effect and availability of nutrients by the addition of organic manures which relatively results in better development of more leaves (Tovihoudji *et al.*, 2015). Additionally, nitrogen has a direct effect on vegetative growth, playing role in cell division, cell enlargement, and protein synthesis, which led to induced leaf initiation (Khattab *et al.*, 2019).

Similar result by Dlamini *et al.* (2020) was reported that application of cattle manure in higher amount recorded maximum leaf number on beetroot. Likewise, Aisha *et al.* (2014) reported that adding organic manure at high rates (20 m<sup>3</sup>) had a significant effect on growth characters including plant length, number of leaves per plant, fresh and dry weight per plant. According

to Jagadeesh *et al.* (2018), application of poultry manure (PM) had significant effect on leaf number of beetroot, with highest leaf number recorded at 50 and 75 DAS.

Additionally, Rantao (2013) reported that application of nitrogen fertilizer at 100 kg ha<sup>-1</sup> of N resulted in more beetroot leaves than at any other level. Another study conducted on beetroot have reported that the total number of leaves per plant (at 80 days after transplanting) was significantly higher at 120 kg ha<sup>-1</sup> of N, which was similar with the applications of 150 kg ha<sup>-1</sup> of N fertilizer (Mampa *et al.*, 2017). Similarly, Hemmat *et al.* (2010) noticed that the number of leaves per plant increased by increasing urea fertilizer rate from zero to 200 kg N ha<sup>-1</sup>. Additionally, Majhi *et al.* (2024) have also described that the maximum leaf number of beetroot plant at 60 DAS (28.07 cm) was recorded from application of vermicompost.

Table 3. Plant height and leaf numbers as affected by interaction effect of FYM and N fertilizer rates at 65 DAP (days after planting) of beetroot plant in 2024 under irrigation.

Plant Height(cm) at 65 DAP					Leaf Number(No) at 65 DAP			
Rate of FYM (ton ha <sup>-1</sup> )	Rate of N (Kg ha <sup>-1</sup> )				Rate of N (Kg ha <sup>-1</sup> )			
0	50	100	150	0	50	100	150	
0	18.25 <sup>a</sup>	20.20 <sup>ab</sup>	23.66 <sup>de</sup>	25.27 <sup>ef</sup>	9.67 <sup>a</sup>	11.50 <sup>bc</sup>	12.22 <sup>bcde</sup>	13.50 <sup>ef</sup>
7.5	19.76 <sup>ab</sup>	20.81 <sup>bc</sup>	22.66 <sup>cd</sup>	24.89 <sup>def</sup>	11.16 <sup>b</sup>	11.94 <sup>bcd</sup>	11.78 <sup>bc</sup>	12.77 <sup>cdef</sup>
15	23.59 <sup>de</sup>	23.80 <sup>def</sup>	25.77 <sup>efg</sup>	25.64 <sup>efg</sup>	11.83 <sup>bc</sup>	12.22 <sup>bcde</sup>	13.27 <sup>ef</sup>	13.78 <sup>f</sup>
22.5	25.40 <sup>ef</sup>	24.67 <sup>def</sup>	26.55 <sup>g</sup>	26.06 <sup>fg</sup>	13.57 <sup>f</sup>	12.55 <sup>cdef</sup>	13.28 <sup>ef</sup>	13.22 <sup>def</sup>
LSD(0.05)	2.289				1.281			
CV%	5.8				7.8			

CV: Coefficient of variations; LSD: Least significant difference; FYM: farmyard manure :means sharing common letter(s) are not significantly different at 5% level of significance

Of the interaction effect of FYM and N fertilizer, the maximum leaf number (13.78) at 65 DAP was recorded from the combined application of 15 ton ha<sup>-1</sup> of farmyard manure with 150 kg ha<sup>-1</sup> of N fertilizer, which was non-significantly different from application of 150 kg of N with all levels of FYM, 22.5 ton ha<sup>-1</sup> of FYM with all levels of N and 15 ton ha<sup>-1</sup> of FYM with 100 kg N ha<sup>-1</sup>, whereas the minimum leaf number (9.67) was obtained at 0 ton ha<sup>-1</sup> of FYM with 0 kg ha<sup>-1</sup> of N fertilizer application (Table 3). The combined use of 15 ton ha<sup>-1</sup> of farmyard manure with 150 kg ha<sup>-1</sup> of nitrogen fertilizer increased leaf numbers by 42.5% at 65 DAP. This increased leaf numbers could be attributed to the synergistic effect of organic manure and inorganic fertilizer that produced sufficient plant nutrient which resulted in rapid

cell division and elongation in the meristematic region of plants, which promoted vegetative growth (Naik and Sreedhar, 2018).

The result of the study corroborate with that of Sapkota *et al.* (2021) who mentioned that the leaf number of beetroot plant was significantly influenced by different source of N fertilizer and that the highest number of leaf at 30 DAS was observed due to application of 12.90 ton ha<sup>-1</sup> of FYM combined with 130.43 kg of N. According to Jagadeesh *et al.* (2018), who conducted study on Crimson Globe variety beetroot in alkali soil, the maximum number of leaves was recorded with the application of poultry manure. Also, Rashid *et al.* (2013) reported that the application of the different level of farmyard manure and nitrogen fertilizer significantly affected the number of leaf per plant. Similarly, Kumar *et al.* (2022) indicated that integrated application of FYM, Vermicompost, and PSB(Phosphorus solubilizing bacteria) had significant effect on leaf number and the maximum leaf number 18.58 were recorded at harvesting of beetroot plant. The highest number of leaves per plant also resulted due to increasing the level of organic and inorganic nutrients (Odedina *et al.*, 2012).

#### **4.2.3. Leaf Area**

The leaf area of beetroot was significantly ( $P < 0.05$ ) influenced by main effect of FYM and N fertilizer at 35 and 50 DAP. The maximum leaf area (104.15 cm<sup>2</sup> and 135.4 cm<sup>2</sup>) were recorded from the treatment of 22.5 ton ha<sup>-1</sup> of farmyard manure, which did not differ statistically from the application of 15 ton ha<sup>-1</sup> of FYM. The minimum leaf area (72.62 cm<sup>2</sup> and 116.5 cm<sup>2</sup>) were observed from control treatment at 35 and 50 DAP, respectively. Similarly, the highest leaf area (102.53 cm<sup>2</sup> and 136.1 cm<sup>2</sup>) were observed from the treatment of 150 kg ha<sup>-1</sup> of N fertilizer rate; however, it had not significant differences from the treatment of 50 kg ha<sup>-1</sup> and 100 kg ha<sup>-1</sup> of N fertilizer while the lowest leaf area (72.47 cm<sup>2</sup> and 107.3 cm<sup>2</sup>) were obtained from 0 kg ha<sup>-1</sup> of nitrogen fertilizer at 35 and 50 DAP respectively (Table 4).

Table 4. Leaf area as affected by main effect of FYM and N fertilizer rates at 35 and 50 DAP (day after planting) of beetroot plant in 2024 under irrigation.

Treatments	Leaf Area(cm <sup>-2</sup> )	
	at	
Rate of FYM(ton ha <sup>-1</sup> )	35 DAP	50 DAP
0	72.62 <sup>a</sup>	116.5 <sup>a</sup>
7.5	80.72 <sup>ab</sup>	120.7 <sup>ab</sup>
15	95.14 <sup>bc</sup>	130.9 <sup>bc</sup>
22.5	104.15 <sup>c</sup>	135.4 <sup>c</sup>
LSD(0.05)	14.59	13.40
Rate of N (Kg ha <sup>-1</sup> )		
0	72.47 <sup>a</sup>	107.3 <sup>a</sup>
50	90.20 <sup>b</sup>	130.2 <sup>b</sup>
100	95.41 <sup>b</sup>	129.9 <sup>b</sup>
150	102.53 <sup>b</sup>	136.1 <sup>b</sup>
LSD(0.05)	14.59	13.40
CV%	19.9	12.8

CV: Coefficient of variations; LSD: Least significant difference; FYM: farmyard manure: means sharing common letter(s) are not significantly different at 5% level of significance

The increment in leaf area of beetroot plant could be due to increasing application level of both farmyard manure and nitrogen fertilizer that adequately supplied nutrient, mainly nitrogen which induced plant metabolic activity and increased endogenous plant hormone in plant tissue that enabled beetroot plant to have more leaf area. The adequate input of N increases the level of cytokinin in the plant, which may have stimulated shoot growth rate resulting in leaf length and leaf breadth of the plant (Güsewell, 2004).

The results are in conformity with Fikru *et al.* (2017) who have stated that the leaf area of beetroot plant was increased linearly with increased rate of nitrogen. In same manner, Idris *et al.* (2021) showed that application of 120 kg N ha<sup>-1</sup> increased leaf number, leaf area index, leaf dry weight, root diameter and root fresh weight of beet crop. Likewise, Aseffa (2016) stated that as the amount of farmyard manure increased, the leaf area of the plants increased, which may be due to the positive role of farmyard manure on soil fertility

Additionally, Majhi *et al.* (2024) described that application of compost significantly elongated and broadened leaf of beetroot compared to other fertilization sources. According to Olorukooba *et al.* (2023), application of poultry manure and cattle dung (10 ton) showed

significant effect on leaf area of beetroot throughout sampling stages as compared to other fertilizer sources and the control. Also the authors concluded that the increase of leaf area with nutrient application (10 tons per hectare) on beetroot plant may be because of adequate organic matter which is a storehouse for nutrients and provides active site for nutrient retention.

The interaction effect of FYM and N fertilizer had significant ( $P < 0.005$ ) effect on the leaf area of beetroot at 65 DAP and harvesting, but it had non-significant effect at 35 DAP and 50 DAP (Appendix Table 1). The maximum leaf area ( $189.2 \text{ cm}^{-2}$ ) at 65 DAP was recorded from the combined application of  $22.5 \text{ ton ha}^{-1}$  of FYM with  $100 \text{ kg ha}^{-1}$  of N fertilizer, which was non-significant difference from application of  $22.5 \text{ ton ha}^{-1}$  of FYM with  $150 \text{ kg ha}^{-1}$  of N fertilizer,  $15 \text{ ton ha}^{-1}$  of FYM with  $150 \text{ kg ha}^{-1}$  of N, whereas the minimum leaf area ( $131.3 \text{ cm}^{-2}$ ) was obtained at  $0 \text{ ton ha}^{-1}$  of FYM with  $0 \text{ kg ha}^{-1}$  of N fertilizer application (Table 5).

In a similar manner, the maximum leaf area ( $211.4 \text{ cm}^{-2}$  and  $210.6 \text{ cm}^{-2}$ ) at harvesting were obtained from the combined application of  $15 \text{ ton ha}^{-1}$  of FYM with  $150 \text{ kg ha}^{-1}$  N and  $22.5 \text{ ton ha}^{-1}$  of FYM with  $100 \text{ kg ha}^{-1}$  of N fertilizer. However it were statistically non-significant from application of  $22.5 \text{ ton ha}^{-1}$  of FYM with  $150 \text{ kg ha}^{-1}$  of N and  $15 \text{ ton ha}^{-1}$  of FYM with  $100 \text{ kg ha}^{-1}$  of N,  $22.5 \text{ ton ha}^{-1}$  of FYM with  $50 \text{ kg ha}^{-1}$  N fertilizer, whereas the minimum leaf area ( $151.3 \text{ cm}^{-2}$ ) was obtained at  $0 \text{ ton ha}^{-1}$  of FYM with  $0 \text{ kgha}^{-1}$  of N fertilizer application (Table 5).

Table 5. Leaf area as affected by interaction effect of FYM and N fertilizer rates at 65 DAP and harvesting of beetroot plant in 2024 under irrigation.

Rate of FYM ( $\text{ton ha}^{-1}$ )	Leaf Area( $\text{cm}^{-2}$ ) at 65 DAP				Leaf Area( $\text{cm}^{-2}$ ) at Harvest			
	0	Rate of N ( $\text{Kg ha}^{-1}$ )			Rate of N ( $\text{Kg ha}^{-1}$ )			
	0	50	100	150	0	50	100	150
0	131.3 <sup>a</sup>	143.9 <sup>ab</sup>	166.7 <sup>cd</sup>	77.4 <sup>def</sup>	151.3 <sup>a</sup>	159.8 <sup>ab</sup>	186.4 <sup>cd</sup>	197.1 <sup>def</sup>
7.5	146.2 <sup>b</sup>	171.3 <sup>cde</sup>	168.5 <sup>cd</sup>	170.4 <sup>cd</sup>	164.5 <sup>ab</sup>	172.9 <sup>bc</sup>	190.1 <sup>de</sup>	196.7 <sup>def</sup>
15	163.0 <sup>c</sup>	176.2 <sup>def</sup>	169.2 <sup>cd</sup>	184.7 <sup>efg</sup>	193.0 <sup>def</sup>	197.8 <sup>def</sup>	208.3 <sup>fg</sup>	211.4 <sup>g</sup>
22.5	174.4 <sup>cdef</sup>	178.6 <sup>defg</sup>	189.2 <sup>g</sup>	185.7 <sup>fg</sup>	205.4 <sup>efg</sup>	207.3 <sup>fg</sup>	210.6 <sup>g</sup>	208.0 <sup>fg</sup>
LSD(0.05)		14.01			15.73			
CV%		5.0			4.9			

CV: Coefficient of variations; LSD: Least significant difference; FYM: farmyard manure; means sharing common letter(s) are not significantly different at 5% level of significance

The combined use of 22.5 ton ha<sup>-1</sup> of farmyard manure with 100 kg ha<sup>-1</sup> N fertilizer increased leaf area by about 44% at 65 DAP. Similarly, plants that received integrated 15 ton ha<sup>-1</sup> of FYM and 150 kg ha<sup>-1</sup> of N fertilizer increased leaf area by 39.7% at harvesting. The average leaf area was significantly increased possibly by macro and micronutrients, especially nitrogen, which resulted in greater meristematic activities of cells and consequently the number of leaves, length and width of leaf of plant (Ingole *et al.*, 2018).

In agreement with the present result, the study conducted on beetroot by Sapkota *et al.* (2021) also showed that the longest leaf length and leaf breadth at 60 DAS were obtained due to combined application of 6.55 ton ha<sup>-1</sup> of PM with 60 kg ha<sup>-1</sup> of N from urea fertilizer. According to Dlamini *et al.* (2020), the leaf length and width of beetroot plants well responded to different level of cattle manure application, and the highest leaf area was obtained by application of cattle manure at the highest level.

Moreover, Olorukooba *et al.* (2023) mentioned that individual application of cow dung and poultry manure each at rate of 10 tons per hectare had the highest mean value of leaf area of beetroot plant at eight week after seedling. Also Jagadeesh *et al.* (2018) mentioned that application of poultry manure had significantly increased the leaf area of beetroot plant at various stage of plant growth. Similarly, Taye (2011) indicated that the integrated nutrient management practices significantly influenced total leaf area. The increase in leaf area due to increase of combined application of inorganic fertilizer and farmyard manure fertilizer might be because of both fertilizer being rich with nitrogen compound, which which plays a role in plant protein formation through the preparation of amino acids, nucleic acids, nucleotides, coenzymes, phytohormones, cytokinins, and chlorophyll that enabled the plant to have broad leaf (Naik and Sreedhar, 2018; Biratu, 2019; Pangestika *et al.*, 2024).

#### 4.2.4. Fresh weight and dry matter of leaf

The main effect of farmyard manure and nitrogen fertilizer had significant ( $P < 0.05$ ) effects on leaf fresh weight; similarly the interaction of both factors had significant effect for the variable (Appendix Table 1). The average leaf fresh weight of beetroot plant increased as the rate of integrated FYM and N fertilizer applications increased. The highest leaf fresh weight (144.6 g) was recorded by the treatment of 22.5 ton ha<sup>-1</sup> farmyard manure mixed with 150 kg ha<sup>-1</sup> of nitrogen fertilizer, followed by the plot that received 15 ton ha<sup>-1</sup> of farmyard manure with 150 kg ha<sup>-1</sup> of nitrogen fertilizer, while the minimum leaf fresh weight (62.3 g) was recorded by the control treatment (Table 6).

Table 6. Means of leaf fresh weight as influenced by interaction effect of FYM and N fertilizer rates after harvesting of beetroot plant in 2024 under irrigation.

LFW(g)				
Rate of FYM (ton ha <sup>-1</sup> )	Rate of N (Kg ha <sup>-1</sup> )			
	0	50	100	150
0	62.3 <sup>a</sup>	90.7 <sup>b</sup>	130.0 <sup>cdef</sup>	138.8 <sup>ef</sup>
7.5	86.5 <sup>b</sup>	116.8 <sup>c</sup>	125.4 <sup>cd</sup>	123.7 <sup>cd</sup>
15	128.5 <sup>cde</sup>	121.5 <sup>cd</sup>	139.4 <sup>ef</sup>	142.6 <sup>fg</sup>
22.5	141.4 <sup>efg</sup>	132.4 <sup>def</sup>	142.2 <sup>fg</sup>	144.6 <sup>g</sup>
LSD(0.05)	13.27			
CV%	6.5			

CV: Coefficient of variations; LSD: Least significant difference; FYM: farmyard Manure; LFW: leaf fresh weight; means sharing common letter(s) are not significantly different at 5% level of significance

The combined application of farmyard manure and nitrogen fertilizer at highest rates (22.5 ton ha<sup>-1</sup> FYM and 150 kg ha<sup>-1</sup> N) increased leaf fresh weight of beetroot by 132% (Table 6). This is due to the capacity of organic manures in increasing availability of numerous plant nutrients, mainly N, P and K which have led to enhanced vegetative and normal root growth, thus resulting in more foliage growth of plant. The N could have also been synthesized into amino acids, which could have built complex proteins and helped in promoting luxurious growth (Naik and Sreedhar, 2018). Besides, the synergistic effect of N with P and K in optimal doses increased the plant height and the total number of leaves (Razaq *et al.*, 2017; Debbarma *et al.*, 2017) eventually increasing the photosynthate assimilation and shoot weight (Baloch *et al.*, 2014).

The result of current finding align with that of Shafeek *et al.* (2019) who reported the highest values of the growth characters of beet root plant such as plant height, leaf number and fresh weight by adding high level of cattle manure. The application of poultry manure 10 ton ha<sup>-1</sup> was shown with maximum mean leaf fresh weight yield of beetroot plant (Olorukooba *et al.* (2023). Another study conducted on beetroot by Nadeeka and Seran (2020) reported that integrated application treatment received 10 ton of GM (goat manure) + 3 ton SM (sugarcane molasses) + 50% TSP were attained with maximum leaf fresh weight. According to Iqbal *et al.* (2017), the inorganic N and FYM when applied in combination at higher rates produced excellent performance for fresh weight; while in absence of FYM the crop performance for this trait was adversely affected.

Furthermore, Hasanen *et al.* (2013) reported that the highest shoot fresh weight of beet plant was achieved by application of 350 kg of N combined with 20 m<sup>3</sup> of FYM fertilizer. Mampa *et al.* (2017) conducted study on beetroot in South Africa and reported that an increase in N application resulted in increased total leaf fresh weight at 80 DAT, although the fresh leaf yield at 150 kg ha<sup>-1</sup> of N was not significantly different with 90 and 120 kg ha<sup>-1</sup> of N fertilizer application. Leilah *et al.* (2007) also have mentioned that foliage fresh mass of beetroot was increased with each increase in nitrogen level up to the highest rate (216 kg ha<sup>-1</sup>) application.

The statistical analysis showed significant ( $P < 0.05$ ) differences in leaf dry matter of beetroot due to main effect of farmyard manure and nitrogen fertilizer application, but the interaction effect of both factor had non-significant effect on this variable (Appendix Table 1). The maximum percentage of leaf dry matter (19.29% and 19.31%) were recorded by the application of 15 ton ha<sup>-1</sup> and 22.5 ton ha<sup>-1</sup> of FYM fertilizers, whereas the minimum percentage of leaf dry matter (17.81%) was obtained at the control plots. In the same way, the highest percentage of leaf dry matter (19.49%) was found by the application of 100 kg ha<sup>-1</sup> of N fertilizer, which was non-significant difference from the application of 150 kg ha<sup>-1</sup> of N fertilizer, while the minimum percentage of leaf dry matter (17.81%) was response to control treatment.

The results revealed that increasing application rate of farmyard manure and nitrogen fertilizers increased means percentage of leaf dry matter; however, the increasing nitrogen fertilizer above 100 kg ha<sup>-1</sup> reduced average leaf dry matter percentage of beetroot plant. The result aligned with that of Radish, where the application of nitrogen fertilizer at 150 kg ha<sup>-1</sup> resulted in decrease of leaf dry mass of the crop (Akoumianakis *et al.*, 2011). The increased leaf dry matter could be as a result of increments in leaf area that increased the rate of plant photosynthesis and thus increased dry matter production of the plants.

According to the study conducted on beetroot by Nadeeka and Seran (2020) the combined applications of 10 ton of GM (goat manure) + 3 ton SM (sugarcane molasses) + 50% TSP increased dry weight as compared to rest of treatments. This results are also in agreement with Saxena and Singh (2022) who reported the highest total dry weight and fresh weight of leaves recorded by treatment of FYM (10 ton) + VC (5 ton) + CU (50% of cow urine). Lairon (2009) also determined that organic fertilizer tend to increase dry matter content of plants.

Furthermore, Olorukooba *et al.* (2023) indicated that the application of the poultry manure (10 ton) recorded the highest dry weight and fresh weight of leaves, which were non-significantly different from cattle manure (10 ton) application. The finding of current experiment contradict with result of the study undertaken in Jima University that that showed urea application did not significantly affect above ground fresh weight and dry weight of beetroot (Fikru *et al.*, 2017). On other hand, Kebede *et al.* (2016) reported that leaf dry matter yield of beet plant was significantly affected by the interaction of inorganic and organic fertilizers application. Similarly, Heidarian *et al.* (2018) reported the integrated treatment of N with FYM produced the highest leaves dry weight of beetroot plant both under stress and well watered conditions.

### 4.3. Yield Components and Yield

#### 4.3.1. Root length and diameter

Root length was highly significant ( $P < 0.001$ ) and significantly ( $P < 0.05$ ) influenced by main effects of farmyard manure and nitrogen fertilizer, but not by their interaction effect, respectively (Appendix Table 2). The longest root (10.8 cm) was recorded from farmyard manure treatment at the highest rate of application (22.5 ton ha<sup>-1</sup>) and the shortest (9.4 cm) from no application of farmyard manure. Of the nitrogen fertilizer, the longest root (10.6 cm) was observed at 100 kg ha<sup>-1</sup> of N fertilizer application, whereas the shortest (9.6 cm) was recorded from the control treatment (Table 7).

Table 7. Means of root length and diameter, root dry matter as influenced by main effect of FYM and N fertilizer rates after harvesting of beetroot plant in 2024 under irrigation.

Treatments Rate of FYM (ton ha <sup>-1</sup> )	RL (cm)	RD (cm)	RDM (%)
0	9.4 <sup>a</sup>	5.3 <sup>a</sup>	19.92 <sup>a</sup>
7.5	9.8 <sup>ab</sup>	5.5 <sup>a</sup>	20.65 <sup>a</sup>
15	10.3 <sup>bc</sup>	6.0 <sup>ab</sup>	22.48 <sup>b</sup>
22.5	10.8 <sup>c</sup>	6.3 <sup>b</sup>	22.49 <sup>b</sup>
LSD(0.05)	5.636	6.68	1.598
<hr/>			
Rate of N (Kg ha <sup>-1</sup> )			
0	9.6 <sup>a</sup>	5.4	19.83 <sup>a</sup>
50	9.7 <sup>ab</sup>	5.6	21.04 <sup>ab</sup>
100	10.6 <sup>c</sup>	6.0	22.77 <sup>c</sup>
150	10.3 <sup>bc</sup>	6.1	22.58 <sup>bc</sup>
LSD(0.05)	5.636	NS	1.598
CV%	6.7	13.9	9.0

CV: Coefficient of variations; LSD: Least significant difference; FYM: farmyard Manure; RL: root length; RD; root diameter; RDM; root dry matter; NS: Non-significant: means sharing common letter(s) are not significantly different at 5% level of significance

Increasing doses of both farmyard manure and nitrogen fertilizer rate application from 0 to 22.5 ton ha<sup>-1</sup> and to 100 kg ha<sup>-1</sup> were observed to increase root length from 9.4 cm to 10.8 cm and 9.6 cm to 10.6 cm of FYM and N, respectively, however increasing the rate nitrogen fertilizer from 100 kg ha<sup>-1</sup> to 150 kg ha<sup>-1</sup> slightly reduced root length from 10.6 cm to 10.3 cm (Table 7).

The result of ANOVA demonstrated that the main effect of farmyard manure significantly ( $P < 0.05$ ) influenced the diameter of root, but differences were not significant for main effect of nitrogen fertilizer and their interaction effects (Appendix Table 2). The maximum root diameter (6.3 cm) was found from the application of farmyard manure at 22.5 ton ha<sup>-1</sup>, followed by 15 ton ha<sup>-1</sup> of manure with no significant difference among them and the minimum root diameter (5.3 cm) was observed at 0 ton ha<sup>-1</sup> manure application (Table 7).

This result appear to be due to manure that may have improved soil structure and led to efficient utilization of nutrient and moisture, which ultimately enhanced vegetative growth. More number of leaves accumulates more photosynthates that is utilized in root cell differentiation, elongation, and also stored in roots (Shrestha and Thapa, 2018); this has led to highest root length and diameter. Moreover, application of organic manure helps soil microorganisms to produce polysaccharides and thus leads to better soil structure useful for root growth (Sapkota *et al.*, 2021). Particularly for crops that are cultivated for their root and tubers, farmyard manure creates the reduction of soil bulk density so that the roots freely extend to scavenge available nutrient and moisture so that it increases its diameter (Aoyama *et al.*, 1999).

According to report by Birhanu and Dawit (2020), the longest root length of *Detroit* dark red variety was obtained by 50 kg ha<sup>-1</sup> of N fertilizer application. The result is also in line with Jagadeesh *et al.* (2018) who reported the highest root length recorded from treatment received FYM (50%) + PM (50%). It also in agreement with Majhi *et al.* (2024) who indicated that application of organic manure at 20 ton ha<sup>-1</sup> showed significantly larger beetroot diameter and greater beetroot length as compared to other treatments. Another study on beetroot by Curvelo *et al.* (2018) reported that the organic chicken manure surpassed mineral fertilizers in regard to roots diameters and root fresh weight per plant. Also, Pervez *et al.* (2004) indicated that the root length of beetroot was increased significantly due to application of nitrogen fertilizer.

In same manner, Eraqui *et al.* (2023) highlighted that the combined use 50% of vermicompost and 50% poultry manure were recorded with maximum root length (6.00 cm) and diameter (6.80 cm) of beetroot crop. However, Heidarian *et al.* (2018) stated the highest root diameter was obtained by application of combined nitrogen fertilizer and cow manure treatment, resulting in increased root diameter by 21 and 24% compared to individual application of nitrogen fertilizer and cow manure. Furthermore, Zerihun and Gezaheng (2021) indicated the root diameter increased with rate of N application; also the authors suggested the maximum root diameter was obtained from 92 and 138 kg ha<sup>-1</sup> of N fertilizer applications.

#### 4.3.2. Fresh weight and dry matter of root

The analysis of variances showed highly significant ( $P < 0.001$ ) differences in root fresh weight due to main effect of farmyard manure and nitrogen fertilizer, as well as their interaction effect (Appendix Table 2). The maximum root fresh weight (154.6 g) was attained from the integrated treatments of 22.5 ton ha<sup>-1</sup> of FYM with 100 kg ha<sup>-1</sup> of N; however, the value is statistically at par with treatments involving 22.5 ton ha<sup>-1</sup> of FYM with 150 kg ha<sup>-1</sup> and 15 ton ha<sup>-1</sup> of FYM with 100 and 150 kg ha<sup>-1</sup> of N fertilizer. The minimum root fresh weight (77.6 g) was recorded from the treatment assigned with 0 ton ha<sup>-1</sup> of FYM with 0 kg ha<sup>-1</sup> of N fertilizer (Table 8).

Table 8. Means of root fresh weight as influenced by interaction effect of FYM and N fertilizer rates after harvesting of beetroot plant in 2024 under irrigation.

Rate of FYM (ton ha <sup>-1</sup> )	RFW(g)			
	Rate of N (Kg ha <sup>-1</sup> )			
	0	50	100	150
0	77.6 <sup>a</sup>	97.9 <sup>b</sup>	127.1 <sup>cde</sup>	145.3 <sup>efg</sup>
7.5	101.2 <sup>b</sup>	111.4 <sup>bc</sup>	123.3 <sup>cd</sup>	133.8 <sup>defg</sup>
15	128.2 <sup>cde</sup>	130.6 <sup>def</sup>	147.5 <sup>fgh</sup>	152.4 <sup>gh</sup>
22.5	147.2 <sup>fgh</sup>	136.9 <sup>defg</sup>	154.6 <sup>h</sup>	151.8 <sup>gh</sup>
LSD(0.05)	18.45			
CV%	8.6			

CV: Coefficient of variations; LSD: Least significant difference; FYM: farmyard manure  
RFW: root fresh weight: means sharing common letter(s) are not significantly different at 5% level of significance

The combined application of 22.5 ton ha<sup>-1</sup> farmyard manure with 100 kg ha<sup>-1</sup> of nitrogen fertilizer increased root fresh weight of beetroot by 128.3% over that of control. This could be due to optimal nitrogen level in urea fertilizer and addition of farmyard manure at highest level that could have increased availability of macro and micronutrient to the plant that improved plant growth and consequently resulted in more photosynthate product translocated from the source to the sink and enhanced root development. Additionally, the role of N as an essential structural element in building plant organs and enhancing its growth increased root fresh weight per plant (Elwan and Samar, 2018).

The result was in line with Dlamini *et al.* (2020) who reported that the highest root fresh mass per plant was recorded from addition of cattle manure at highest level. Another study conducted in Wolaita Sodo by Afework *et al.* (2022) reported that the highest mean fresh root weight was obtained from the application of 181.5 kg ha<sup>-1</sup> NPS fertilizer. Additionally, Shafeek *et al.* (2019) revealed that increasing the rate of organic cattle manure up to higher level resulted in the highest root fresh weight per plant. Also, Sapkota *et al.* (2021) showed that the highest root fresh weight was obtained due to treatment of 12.90 ton ha<sup>-1</sup> of FYM with 130.43 kg ha<sup>-1</sup> of N. In similar ways,

Eraqui *et al.* (2023) reported that the combined use 50% of vermicompost and 50% poultry manure were recorded with maximum root weight (126.92 g) of beetroot plant. Sulfab *et al.* (2017) observed the highest plant growth character, root fresh weight and diameter responded to application of N at 60 and 80 kg ha<sup>-1</sup> and, the increased in root weight may be the effective role of nitrogen fertilizer on cell division and elongation which consequently increased assimilate produced that reflected on root fresh weight (Abdou *et al.*, 2014).

Similarly, the analysis of variance showed that the main effects of farmyard manure and nitrogen fertilizer had significant effect on root dry matter of beetroot; however, their interaction had non-significant effect on the parameter (Appendix Table 2). Higher percentage of root dry matter (22.48 and 22.49%) were recorded by the application of 15 ton ha<sup>-1</sup> and 22.5 ton ha<sup>-1</sup> of FYM fertilizers, which were 12.9 % and 8.9% more than the values obtained at 0 and 7.5 ton ha<sup>-1</sup> of FYM, respectively. Likewise, highest root dry matter with nitrogen application was recorded from the application of 100 kg ha<sup>-1</sup> of N (22.77%), which was

statistically at par with values recorded with application of 150 kg ha<sup>-1</sup> of N. On the other hand, lowest root dry matter (19.83%) was obtained from the control plot.

The finding was align with Mustafa (2007) who also mentioned that applications of nitrogen fertilizer tend to increase shoot and root dry weigh of beet crop. Also Birhanu and Dawit (2020) have stated that the maximum total dry root weight (5.37 ton) was obtained at 100 kg ha<sup>-1</sup> of N fertilizer application; however increasing N from 100 kg ha<sup>-1</sup> to 150 kg ha<sup>-1</sup> was reduced dry root yield by 62.73%. Also, Kebede *et al.* (2016) indicated the root dry matter yield of beet plant was significantly respond to interaction of different level of organic(FYM) and inorganic (NP) fertilizer.

#### 4.3.3. Marketable Root Yield

Marketable root yield was significantly ( $P < 0.05$ ) influenced by main effect of farmyard manure and nitrogen fertilizer, as well as their interactions effects (Appendix Table 2). The highest marketable root yields (29.14 ton ha<sup>-1</sup>) was produced by the combination of 22.5 ton ha<sup>-1</sup> of farmyard manure with 100 kg ha<sup>-1</sup> of nitrogen fertilizer which was statistically similar with treatment received 15 ton ha<sup>-1</sup> farmyard manure with 150 kg ha<sup>-1</sup> of nitrogen, whereas the lowest root yield (13.49 ton ha<sup>-1</sup>) was obtained from control plot (Table 9).

The combined application of 22.5 ton ha<sup>-1</sup> of FYM with 100 kg ha<sup>-1</sup> of N fertilizer increased marketable yield by 116% over that of control. This is because of manure increased supply of organic matter and beneficial microorganisms that improved soil physical property and enhanced availability of various nutrients associated with more phothosynthates and accumulation of sugar for root cell division and enlargement that resulted in increased marketable root yield. Furthermore, an increment in root yield as a result of the integration of organic and inorganic fertilizer might be due to the reduction in nutrient losses, improved fertilizer use efficiency, and increased soil water availability to plants, resulting in higher root yield (Kiran *et al.*, 2019). Besides, the presence of N in right proportions might have attributed in enhancement of optimum foliage for more phothosynthates that translocated to the sink, and lead to higher marketable root yield.

The finding had conformity with Sapkota *et al.* (2021) who reported that the highest economic yield was obtained due to applied treatment of 12.90 ton ha<sup>-1</sup> of FYM with 130.43 kg ha<sup>-1</sup> of

N from urea fertilizer. Similarly, Eraqui *et al.* (2023) reported that the combined use 50% of vermicompost and 50% of poultry manure were recorded with maximum root yield of beetroot plant over rest of treatments. Also, Jagadeesh *et al.* (2018) stated that the highest root of beetroot plant was obtained due to the application of poultry manure. Furthermore, it was reported that the combined application of 100 kg ha<sup>-1</sup> of nitrogen fertilizer and 15 ton ha<sup>-1</sup> farmyard manure resulted in increased beetroot yield by 28 and 32% compared with single application of nitrogen and farmyard manure fertilizers, respectively (Heidarian *et al.*,2018).

Moreover, Dlamini *et al.* (2020) reported the highest marketable root yield of beetroot with the application of cattle manure at highest level. Bewket (2019) also reported that the highest marketable yield (31.7 ton ha<sup>-1</sup>) observed from the combined application of blended 199 kg ha<sup>-1</sup> of NPSZnB with 30 ton ha<sup>-1</sup> of cattle manure. Conversely, Fikru *et al.* (2017) who had conducted study on beetroot in Jimma University stated the urea application had no significant effect on yield of the crop. According to Birhanu and Dawit (2020) described that increasing N level from 0 to 100 kg ha<sup>-1</sup> increased marketable root yields per hectare, but increasing of the N to 150 kg N ha<sup>-1</sup> in both Crimson globe and Farida decreased the yield, because of over application of N fertilizer, which resulted in negative response to marketable root yields.

#### **4.3.4. Unmarketable Root Yield**

The analysis of variance showed highly significant ( $P < 0.001$ ) differences in nonmarketable root yield due to main effect of farmyard manure and nitrogen fertilizer as well as their interaction effect (Appendix Table 2). The highest unmarketable root yield (6.87 ton ha<sup>-1</sup>) was obtained from the plots that did not receive both fertilizers, while the lowest unmarketable root yield (1.93 ton ha<sup>-1</sup>) was recorded from the plot received 22.5 ton ha<sup>-1</sup> farmyard manure with 100 kg ha<sup>-1</sup> of nitrogen application, followed by 15 ton ha<sup>-1</sup> with 150 kg ha<sup>-1</sup>, 22.5 ton ha<sup>-1</sup> with 50 kg ha<sup>-1</sup> of N and FYM fertilizers, respectively (Table 9).

Table 9. Means of marketable and non-marketable root yield as influenced by interaction effect of FYM and N fertilizer rates after harvesting of beetroot plant in 2024 under irrigation.

Rate of FYM (ton ha <sup>-1</sup> )	MRY(ton ha <sup>-1</sup> ) Rate of N (Kg ha <sup>-1</sup> )				NMRY(ton ha <sup>-1</sup> ) Rate of N (Kg ha <sup>-1</sup> )			
	0	50	100	150	0	50	100	150
0	13.49 <sup>a</sup>	18.48 <sup>bc</sup>	23.80 <sup>efg</sup>	25.74 <sup>fgh</sup>	6.876 <sup>g</sup>	5.138 <sup>f</sup>	4.148 <sup>def</sup>	2.321 <sup>ab</sup>
7.5	17.80 <sup>b</sup>	19.12 <sup>bcd</sup>	21.38 <sup>cde</sup>	24.69 <sup>efgh</sup>	5.074 <sup>ef</sup>	5.150 <sup>f</sup>	4.081 <sup>def</sup>	3.200 <sup>bcd</sup>
15	23.45 <sup>ef</sup>	22.20 <sup>de</sup>	27.19 <sup>ghi</sup>	28.41 <sup>hi</sup>	3.911 <sup>cde</sup>	3.000 <sup>abcd</sup>	2.756 <sup>abc</sup>	2.183 <sup>ab</sup>
22.5	26.06 <sup>fgh</sup>	26.26 <sup>fgh</sup>	29.14 <sup>i</sup>	27.54 <sup>hi</sup>	2.148 <sup>ab</sup>	2.444 <sup>ab</sup>	1.930 <sup>a</sup>	3.202 <sup>bcd</sup>
LSD(0.05)	3.487				1.194			
CV%	8.9				19.9			

CV: Coefficient of variations; LSD: Least significant difference; FYM: farmyard manure; MRY: marketable root yield; NMRY: nonmarketable root yield; means sharing common letter(s) are not significantly different at 5% level of significance

The higher unmarketable root yield in the control treatment might be due to unfavorable environment for root growth and inadequate amount of nutrient needed for foliage growth to exhibit good root yield. On the other hand, the FYM might have created favorable media and ensured nutrient quantity required for better plant growth that increased proportion of marketable root yield. The regular use of cattle manure as fertilizer, can adjust plant nutrient ratios to be more in line with crop requirements, which help to improve crop and yields, consequently reduce nonmarketable yield growth (FAO, 2008),.

The maximum unmarketable root yield in unfertilized plots is supported by Afework *et al.* (2022), who conducted study on response of red beetroot (*Beta vulgaris* L.) to intra-row spacing and blended NPS fertilizer rates at Wolaita Sodo Zuria district, southern Ethiopia. Furthermore, Addo (2021) reported the highest nonmarketable yield from the control plot, whereas lowest nonmarketable yield was observed by application of compost. On the other hand, Birhanu and Dawit (2020) observed application of nitrogen fertilizer had non-significant effect on unmarketable beetroot number per plot. Similarly, Mohammed *et al.* (2018) highlighted the individual application of N, P and FYM as well as their interaction effects had not significantly affected unmarketable tuber yield.

#### 4.3.5. Total Root Yield

The main effect of farmyard manure and nitrogen fertilizer had highly significant ( $P < 0.001$ ) effect on the total root yield; however, their interaction had non-significant effect (Appendix Table 2). The results indicated that increasing the level of applied farmyard manure fertilizer from 0 ton ha<sup>-1</sup> to 22.5 ton ha<sup>-1</sup> increased total root yield by 18.7%. In the same way, increasing the level of applied nitrogen fertilizer from 0 kg ha<sup>-1</sup> to 150 kg ha<sup>-1</sup> increased total root yield from 24.70 ton ha<sup>-1</sup> to 29.32 ton ha<sup>-1</sup>. Xiao *et al.* (2006), noted soil treated with cattle manure was loose, which probably provided adequate aeration and moisture into the soil and improved soil microbial activities which resulted in higher growth and maximum root yield.

The result was in agreement with findings of Shafeek *et al.* (2003; 2019) on radish and beetroot, respectively, who reported that increasing the rate of organic manure increased the total roots yield of both crops. In the same manner, Ahmed *et al.* (2015) noted the highest values of the total tubers yield from the application of farmyard manure (at highest level 20 m<sup>3</sup>). Moreover, Abd El-Lateef *et al.* (2019) reported that the maximum total yield of beetroot (43.22 ton) plant was recorded from the application of compost manure (20 ton). Additionally, Birhanu and Dawit (2020) have indicated that total root yield of beetroot plant were highly significantly affected by variety and different level of nitrogen fertilizer application.

#### 4.4. Partial Budget Analysis

The partial budget analyses were performed for the treatments that had statistical significance differences to the marketable root yield of the crop. With this regard, the adjusted yield was obtained by reducing 10% of the yield obtained from each treatment. The net yield was multiplied by the market price to obtain the gross field benefit. Costs and benefits were calculated for each treatment (Table 10).

The results of partial budget analyses revealed that highest net benefit of 698289.9 Birr ha<sup>-1</sup> was attained from the combined application of farmyard manure at 22.5 ton ha<sup>-1</sup> with mineral nitrogen at 100 kg ha<sup>-1</sup>. The lowest net benefit of 340044.4 Birr ha<sup>-1</sup> was recorded from the

control treatment. The net benefit was increased proportionally as the level of both fertilizer applications rates increased. Overall, the results showed that the combined application of highest rate of farmyard manure and 100 kg ha<sup>-1</sup> nitrogen fertilizer provided highest gross farm income and net benefit than other treatments.

The marginal rate of return (MRR) analysis was based on pooled result of non-dominated treatments. In order to make farmer recommendations from a marginal analysis, it is necessary to estimate the minimum rate of return which was acceptable to farmers in the recommendation domain. According to CIMMYT (1988) the minimum acceptable marginal rate of return should be ranged between 50 and 100%. In this research, all fertilizer application treatments (except dominated) had marginal rate of return greater than (787.29%) minimum acceptable level. Therefore, integrated application of 22.5 ton ha<sup>-1</sup> of FYM and 100 kg ha<sup>-1</sup> of N fertilizer that produced the highest net benefit with acceptable MRR could be recommended for beetroot production in study area and other area of similar agro-ecology.

Table 10. Partial budget analysis of FYM (ton ha<sup>-1</sup>) and N (kg ha<sup>-1</sup>) fertilizer applied at different levels of combinations.

Treatments FYM(ton) N(kg)	AVRY (ton ha <sup>-1</sup> )	AJRY (ton ha <sup>-1</sup> )	GFB (ETB)	TVC (ETB)	NB (ETB)	MRR (%)
0 0	13.4938	12.144	340044.4		340044.4	-
0 50	18.48395	16.635	465795.6	6559.79	459235.8	1816.9
7.5 0	17.79877	16.0188	448528.9	9000	439528.9	-
0 100	23.79753	21.4177	599697.8	11994.6	587703.2	4948.1
7.5 50	19.11667	17.205	481740	15559.8	466180.2	-
15 0	23.45432	21.10889	591048.9	16500	574548.9	11526.1
0 150	25.74074	23.16667	648666.7	17429.4	631237.3	6099.8
7.5 100	21.37531	19.23778	538657.8	20994.6	517663.2	-
15 50	22.19704	19.97733	559365.3	23059.79	536305.5	902.7
22.5 0	26.06296	23.45667	656786.7	24000	632786.7	10261.7
7.5 150	24.68889	22.22	622160	26429.36	595730.6	-
15 100	27.19012	24.47111	685191.1	28494.6	656696.5	2952.04
22.5 50	26.25926	23.63333	661733.3	30559.8	631173.5	-
15 150	28.41111	25.57	715960	33929.4	682030.6	1509.3
22.5 100	29.1383	26.2244	734284.4	35994.6	698289.9	787.29
22.5 150	27.54444	24.79	694120	41429.4	652690.6	-

AVRY=Average root yield, AJRY=Adjusted root yield, GFB=Gross field benefit, TVC=Total variable cost, NB=Net benefit, and MRR=marginal rate of return.

## 5. SUMMARY AND CONCLUSIONS

Beetroot is one of the major root vegetables cultivated and consumed throughout the world due to biologically active substances and nutritional elements present in its tuberous root. Beetroot production in Ethiopia, particularly in eastern part of the country, is increasing from time to time as a result of high demand from domestic and abroad market. However, yields are substantially lower than expected for the crop in similar environments. Among the major production constrains of the crop, poor agronomic practices and soil fertility, lack of adapted and high yielding variety are among the obstacles faced by the farmer in the study area. Thus, this study was conducted to assess the effect of different levels of nitrogen fertilizer and cattle manure on growth, yield components, and yield of beetroot, and to estimate the cost benefit of the rates of N and cattle manure for optimum yield of beetroot crop at Haramaya, Eastern Ethiopia.

The treatments included factorial combinations of farmyard manure at four rates (0, 7.5, 15 and 22.5 ton ha<sup>-1</sup>) and nitrogen fertilizer at four levels (0, 50, 100 and 150 kg ha<sup>-1</sup>), and were investigated under randomized complete block design with three replications. Accordingly, the data on growth parameters and yield components of the crop were collected and analyzed, using GenStat 18 edition.

The result of the study demonstrated that the main effect of FYM and N fertilizer as well as their interactions had positive effects on most of the growth characters at various growth stages of the plant. Increasing applied level of FYM from 0 to 22.5 ton and N fertilizer from 0 to 150 kg ha<sup>-1</sup> resulted in increased plants height, leaf numbers and leafs area at 35, 50, 65 DAP and at harvesting. The highest plants height, leaf numbers and leaf area at above mentioned growth stages were recorded by individual application of 22.5 ton ha<sup>-1</sup> of FYM and 150 kg ha<sup>-1</sup> of N, except plant height at 35 DAP for both factors and at harvest only for FYM. The maximum plant height and leaf numbers at 65 DAP, leaf area at 65 DAP and harvesting were recorded by integrated application of 22.5 ton with 100 kg, 15 ton with 150 kg, 22.5 ton with 100 kg and 15 ton with 150 kg ha<sup>-1</sup> of N and FYM, respectively, whereas the minimum were obtained from the control treatments.

The analysis of variances indicated that application of FYM and N fertilizer had significant differences on fresh weight and dry matter of leaf, fresh weight and dry matter of root, length and diameter of root. The highest leaf dry matter (19.31% and 19.49%) and root dry matter (22.49% and 22.77%) were obtained from main effects of FYM at 22.5 ton and N at 100 kg ha<sup>-1</sup>. The combined use of 22.5 ton ha<sup>-1</sup> of FYM and 150 kg ha<sup>-1</sup> of N increased leaf fresh weight by 132% over the control, likewise interaction effect of 22.5 ton ha<sup>-1</sup> of FYM and 100 kg ha<sup>-1</sup> of N was increased root fresh weight by 128.3% over the control treatment.

The results of the study indicated that marketable root yield and unmarketable root yield were significantly influenced by interaction effect of farmyard manure and nitrogen fertilizer, however the total root yield positively responded only to the main effect of the two factors. The combined application of farmyard manure at 22.5 ton ha<sup>-1</sup> and nitrogen fertilizer at 100 kg ha<sup>-1</sup> increased marketable root yield from 13.49 ton to 29.14 ton ha<sup>-1</sup> and also reduced unmarketable root yield from 6.87 ton to 1.93 ton ha<sup>-1</sup>. The partial budget analyses also indicated that the application of farmyard manure at 22.5 ton ha<sup>-1</sup> with nitrogen fertilizer at 100 kg ha<sup>-1</sup> resulted in the highest net benefit (698289.9 Birr ha<sup>-1</sup>) with acceptable marginal rate of return (787.29%).

In general, the application of farmyard manure(22.5 ton ha<sup>-1</sup>) and nitrogen fertilizer(100 kg ha<sup>-1</sup>) as individual and combined form had significant changes to most of the growth and yield characters of beetroot plant at the study area, particularly the economic analysis showed this combination could have remarkable benefits to the small holders farmers. Therefore, the combined use of 22.5 kg ha<sup>-1</sup> of FYM with 100 kg ha<sup>-1</sup> of N fertilizer could be a better option to enhance incomes for beetroot producers and to sustain the soil productivity in the study area. However, since the experiment was done for one season at one location with single variety, it is suggestible to conduct the experiment on more locations, seasons and variety and assess long term effect of farmyard manure on soil properties to arrive at a sound recommendation.

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## 7. APPENDICES

Appendix Table 1. Mean squares from analysis of variance for growth variables as affected by FYM, N fertilizer and their combinations at various growth stages of beetroot plant in 2024 under irrigation.

Variables	Rep(2)	FYM(ton ha <sup>-1</sup> )(3)	N(ton ha <sup>-1</sup> ) (3)	FYM* N(9)	Error(30)	CV(%)
PH at 35 DAP	10.786	6.061Ns	1.811Ns	2.089Ns	4.359	16.5
PH at 50 DAP	3.001	60.437**	51.669*	16.520Ns	7.926	15.6
PH at 65 DAP	5.228	32.049**	14.243*	8.212*	3.382	7.7
PH at Harvest	7.126	64.266**	49.307*	15.165Ns	8.659	10.9
LN at 35 DAP	3.8125	5.7431**	4.1319*	0.7431Ns	0.6792	13.1
LN at 50 DAP	2.2860	5.402*	4.529*	0.433Ns	0.9259	11.0
LN at 65 DAP	2.7959	5.6357**	6.8966**	1.7032*	0.4469	5.4
LN at Harvest	3.5313	11.1035**	3.0352*	0.5050Ns	0.7150	5.9
LA at 35 DAP	1575.1	2404.7**	1425.6*	410.6Ns	223.4	17.0
LA at 50 DAP	801.0	917.9*	1937.4**	561.3Ns	223.5	11.9
LA at 65 DAP	543.7	2185.8**	1631.9**	837.5*	214.7	8.3
LA at Harvest	377.5	2485.2**	954.3*	588.7*	221.8	7.7
LFW Harvest	124.3	3041.0**	2578.0**	890.5*	275.0	13.6
LDW Harvest	0.442	6.458*	7.828*	2.093Ns	1.685	6.9

Ns=non-significant, \*&\*\*=Significant and highly significant at (P<0.05), CV=coefficient of variation, Number in parenthesis in each source of variation represents degree of freedom, PH=plant height, LN=leaf number, LA=leaf area, DAS=day after seedling, LFW=leaf fresh weight, and LDW=leaf dry weight.

Appendix Table 2. Mean square from analysis of variance for yield variables as affected by FYM, N fertilizer and their combinations on beetroot plant after harvesting in 2024 under irrigation.

Variables	Rep(2)	FYM( $\text{ton ha}^{-1}$ )(3)	N( $\text{ton ha}^{-1}$ ) (3)	FYM* N(9)	Error(30)	CV(%)
RFW	82.2	3537.5**	2808.1**	378.6*	122.4	8.6
RDW	5.365	20.296*	18.222*	3.754Ns	3.676	9.0
RL	77.67	375.13**	240.93*	45.45Ns	43.81	6.6
RD	193.41	286.77*	136.74Ns	53.91Ns	56.03	13.0
MRY	13.427	100.937**	103.553**	10.054*	4.307	8.5
NMRY	0.2381	13.6719**	7.3049**	2.8650**	0.5127	19.9
TRY	17.218	40.348**	57.460**	3.486Ns	5.335	8.3

Ns=non-significant( $P>0.05$ ),\*&\*\*=Significant and highly significant( $P<0.05$ ), CV=coefficient variation, RFW=root fresh weight, RDW=root dry weight, RL=root length, RD=root diameter, MR Y=marketable root yield, NMRY=nonmarketable root yield, and TRY=total root yield.

Appendix Table 3. Mean value of some growth variables as influenced by main effect of FYM and N fertilizer rates at 65 DAP and after harvesting of beetroot plant in 2024 under irrigation.

Treatments	PH(cm)	LN(No)	LA(cm <sup>2</sup> )		LFW(g)	LDW(%)
Rate of FYM (ton ha <sup>-1</sup> )	at 65 DAP	at 65 DAP	at 65 DAP	at Harvesting	at Harvesting	at Harvesting
0	22.14 <sup>a</sup>	11.72 <sup>a</sup>	154.8 <sup>a</sup>	173.6 <sup>a</sup>	106.4 <sup>a</sup>	17.8 <sup>a</sup>
7.5	22.84 <sup>a</sup>	11.93 <sup>a</sup>	164.1 <sup>b</sup>	181.0 <sup>a</sup>	111.2 <sup>a</sup>	18.38 <sup>ab</sup>
15	25.31 <sup>b</sup>	12.77 <sup>b</sup>	172.0 <sup>c</sup>	202.6 <sup>b</sup>	131.0 <sup>b</sup>	19.29 <sup>b</sup>
22.5	25.27 <sup>b</sup>	13.15 <sup>b</sup>	182.0 <sup>d</sup>	207.8 <sup>b</sup>	139.9 <sup>b</sup>	19.31 <sup>b</sup>
Rate of N (Kg ha <sup>-1</sup> )						
0	23.06 <sup>a</sup>	11.56 <sup>a</sup>	153.7 <sup>a</sup>	178.6 <sup>a</sup>	105.3 <sup>a</sup>	17.81 <sup>a</sup>
50	22.88 <sup>a</sup>	12.05 <sup>a</sup>	166.2 <sup>b</sup>	184.5 <sup>a</sup>	115.2 <sup>a</sup>	18.23 <sup>ab</sup>
100	24.59 <sup>b</sup>	12.64 <sup>b</sup>	173.4 <sup>c</sup>	198.8 <sup>b</sup>	129.9 <sup>b</sup>	19.49 <sup>c</sup>
150	25.03 <sup>b</sup>	13.32 <sup>c</sup>	179.5 <sup>c</sup>	203.3 <sup>b</sup>	138.1 <sup>b</sup>	19.25 <sup>bc</sup>
LSD	1.533	0.557	6.50	8.01	6.63	1.082

Means sharing common letter (s) are not significantly different at the 5% level of significance. PH=plant height, LN=leaf number, LA= leaf area, DAS= day after seedling, LFW= leaf fresh weight, and LDW=leaf dry weight.

Appendix Table 4. Mean value of some yield variables as influenced by main effect of FYM and N fertilizer rates after harvesting of beetroot plant in 2024 under irrigation.

Treatments Rate of FYM (ton ha <sup>-1</sup> )	RFW (ton ha <sup>-1</sup> )	MRY (ton ha <sup>-1</sup> )	NMRY (ton ha <sup>-1</sup> )	TRY (ton ha <sup>-1</sup> )
0	112.0 <sup>a</sup>	20.38 <sup>a</sup>	4.621 <sup>b</sup>	25.0 <sup>a</sup>
7.5	117.4 <sup>b</sup>	20.74 <sup>a</sup>	4.376 <sup>b</sup>	25.67 <sup>a</sup>
15	139.7 <sup>b</sup>	25.31 <sup>b</sup>	2.962 <sup>a</sup>	28.28 <sup>b</sup>
22.5	147.6 <sup>b</sup>	27.25 <sup>c</sup>	2.431 <sup>a</sup>	29.68 <sup>b</sup>
Rate of N (Kg ha <sup>-1</sup> )				
0	113.5 <sup>a</sup>	20.20 <sup>a</sup>	4.502 <sup>b</sup>	24.70 <sup>a</sup>
50	119.2 <sup>a</sup>	21.51 <sup>a</sup>	3.933 <sup>b</sup>	25.45 <sup>a</sup>
100	138.1 <sup>b</sup>	25.38 <sup>b</sup>	3.229 <sup>a</sup>	28.60 <sup>b</sup>
150	145.9 <sup>b</sup>	26.60 <sup>b</sup>	2.726 <sup>a</sup>	29.32 <sup>b</sup>
LSD	9.22	1.743	0.597	1.912

Means sharing common letter(s) are not significantly different at the 5% level of significance. RFW=root fresh weight, MRV=marketable root yield, NMRV=nonmarketable root yield, TRY=total root yield.