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# Response of Red Beetroot (*Beta vulgaris L.)* to intra-row spacing and blended NPS fertilizer rates at Wolaita Sodo Zuria district, Southern Ethiopia

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## Abstract

Beetroot [(*Beta vulgaris* L.), Detroit Dark Red] is one of the root crops that is widely cultivated in the Wolaita Zone, southern Ethiopia. The crop is utilized as a vegetable to contribute the food and nutritional security of the farmers. Despite its economic importance, the crop yield productivity is very less in the study area due to inappropriate row spacing and lack of ideal fertilizer application rate. Therefore, this research was conducted to determine the effect of blended NPS fertilizer and intra-row spacing on red beetroot growth, yield components, and root yield in the study area. A total of 15 treatments were used as factorial combinations of three intra-row spacing's (10, 15 and 20 cm) and five blended NPS fertilizer rates (0, 60.5, 121, 181.5 and 242 kg NPS ha$^{-1}$) in three replications. Selected growth, yield components, and root yield parameters were collected and analyzed procedurally. The result revealed that blended NPS fertilizer rate application and intra-row spacing had shown a significant effect on growth, yield component, root yield, and marketable and unmarketable root yield of the Detroit dark red beetroot variety. The interaction had shown a significant effect on fresh and dry shoot weight. The highest total fresh and dry root weights were obtained from plants at 15 and 20 cm intra-row spacing and a 181.5 kg blended NPS ha$^{-1}$ fertilizer application rate. The highest marketable root yield (32.74 t ha$^{-1}$) was obtained at 15 cm intra-row spacing and by 181.5 kg ha$^{-1}$ NPS fertilizer application rate. The highest marginal rate of return (4219.5) coupled with the highest net benefit of 93717.08 Birr per hectare was obtained from plants received 181.5 kg ha$^{-1}$ NPS at 15 cm intra-row spacing. Thus, it was possible to conclude that the growing of the Detroit dark red beetroot variety with an application of 181.5 kg ha$^{-1}$ blended NPS fertilizer and using 15 cm intra-row spacing at the study area had a significant effect on the production of Detroit dark red beetroot.

**Keywords:** Blended, Fertilizer rate, Spacing pattern, Root yield and yield components.

## Introduction

Beetroot (*Beta vulgaris* L.) is a dicotyledonous tuberous vegetable crop that belongs to the family Chenopodiaceae, which is indigenous to Asia Minor, Europe, and North Africa. It is grown in more than 120 countries around the world, among which Germany and France are the largest producers (Jasmitha et al., 2018). The crop grows best under cool climatic conditions and can be grown successfully almost all year round. In the 2014/15 main season, a total of 18.2 thousand tons of beetroot were produced by around 333 thousand household growers from an area of 1.9 thousand ha with an average productivity of 9.3 t/ha. The total cultivated area under beetroot is 2,890.07 ha, with a total production of 25,638.513 tons. The southern regional state contributed the production of 4,305.223 tons from 524.32 ha of land. The country is endowed with different agro-ecologies that are appropriate for the production of tropical, subtropical, and temperate vegetables (Sinta and Garo, 2021).

Many beneficial things are important in the human diet, which are relatively cheap, locally produced, stored for a long period to ensure the availability of fresh product throughout the year, and widely used in the food industry (Szopinska and Gaweda, 2013). It could be processed into juice, which has high antioxidant and anti-inflammatory properties. The extracts also serve as: traditional medicine, additive to cosmetics used as decorative bedding or coloring food stuff, dairy and meat products (Georgiev et al., 2010). Beetroot is consumed as boiled or raw salad and could be used as an important aid in the treatment of many diseases and as a food security crop (Liliana and Oana-Viorela, 2020).

Despite these benefits, the production and productivity of beetroot vegetable is very low; due to various constraints. Inappropriate agronomic packages, soil fertility problem and poor extension services are the major challenges (Fikru et al., 2017). The crop productions in Ethiopia generally and in Wolaita particularly depends on either of the fertilizer application or row spacing. Agronomic practices such as plant density and fertilizer management are known to affect the crop environment, which influences the growth and ultimately the yield (Fageria, 2014; Babaji et al., 2012). However, inorganic fertilizer application is not common for beetroot production in the study area, except for limited research conducted nationally, i.e., urea fertilizer at the time of sowing (Fikru et al., 2017) with a spacing of 30 x 16 cm as a black recommendation. Therefore, this research was initiated to generate information on the response of red beetroot to NPS fertilizer rates and row spacing to increase the productivity and quality of the crop, as well as to estimate the cost-benefit of NPS fertilizer rates and intra-row spacing for red beetroot production.

## Materials and methods

Description of the experimental site

A field experiment was conducted in the 2019/2020 cropping season at Wolaita Sodo University in the Wolaita zone of southern Ethiopia. It is located 320 km from Addis Ababa and, astronomically, at 60° 49` N latitude and 370° 45` East longitude, with an altitude of 1886 meters above sea level. The mean maximum and minimum temperature were 26.80 °C and 11.40 °C, respectively. The mean maximum and minimum relative humidity were 91.4% and 31.2%, respectively. The annual mean rainfall is 1800 mm, and the soil of the experimental site is characterized as well-drained sandy loam (WSU student handbook, 2009).

Experimental material, treatments and experimental design

The beetroot seed (Detroit dark red) variety was used for this experiment. The treatments included three levels of intra-row spacing (10, 15, and 20 cm) and five rates of blended NPS fertilizer (0, 60.5, 121, 181.5, and 242 kg $ha^{-1}$) in a Randomized Complete Block Design (RCBD) with three replications and factorial arrangement, for a total of 15 treatment combinations.

Experimental procedures

The experimental plot was selected and cleared to remove unwanted materials. Then, the land was plowed to fine tillage by using a tractor three times prior to sowing. Representative soil samples were collected from 15 different spots of the experimental field using auger at 0-40 cm depth in a zigzag pattern before planting. The samples were composed to determine some selected soil physicochemical properties. The experimental plot measuring 37 m by 4.6 m (170.2 $m^2$) ploughed to a depth of 30 cm. The 45 experimental plots were prepared for sowing using human labor. Sowing was done on October 9, 2019. At the time of sowing, two seeds were sown on the aligned spacing, and NPS fertilizer was applied in bands. Furthermore, different inter-cultural operations like weeding, harrowing, and pest and disease control were performed as per normal recommendations. The seed of the Detroit dark red beetroot variety was used, which was produced on January 1, 2019, and had a three-year shelf life.

Soil laboratory analysis

Under standard laboratory procedures, the composited soil sample was analyzed at the Sodo Regional Soil Laboratory, Wolaita Sodo, Ethiopia. The soil sample was air-dried and ground to pass through a 2 mm mesh size for all except for organic matter; it passed through 0.2 mm. The organic matter content was determined by the volumetric method. Total nitrogen was determined using the Micro-Kjeldahl method with sulfuric acid (Cottenie, 1980). The cation exchange capacity (CEC) was diagnosed after soil saturation with 1N ammonium acetate (NH4OAc) and replacing it with 1N NaOAc Cottenie (1980). Available phosphorus was determined by Olsen's method using a spectrophotometer (Olsen et al., 1954). The Soil pH was measured in water at the soil-to-water ratio of 1:2.5 (Van Reeuwijk, 1992). Soil textural analysis was performed by the Bouyoucous hydrometer method.

Data collection

Phenological and growth parameters

Days to 50% Emergence (No.): It was recorded as the number of days from emergence to the time when 50 percent of the plant-stand in each experimental plot. Plant height (cm): Plant height was recorded by measuring the sample plant from the lower end of the stem that was above the ground up to the top of the plant. Leaf number per plant (No.): Leaf number was recorded by counting the number of leaves from randomly assigned sample plants, and the mean leaf number per plant was recorded.

Yield components and root yield

Shoot fresh weight (g/plant): The above ground biomass of the plant was harvested by cutting at the top of the root part and its shoot fresh weight determined and expressed in grams at physiological maturity. Shoot dry weight (g/plant): The fresh shoot was oven-dried at 80 $^{o}$C for 48 hrs. After drying, the weight was measured using a sensitive balance and divided by the number of sampled plants to get the mean shoot dry weight per plant. Root fresh weight (g/plant): the average weight of matured roots in grams was computed by weighing randomly selected plants at harvest.

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Root dry weight (g/plant): dry weight of randomly selected plant roots at harvest was measured using sensitive balance after drying them in oven dry for 48 hours at 80 °C and the mean value per plant was computed. Fresh biomass yield (g/plant) was recorded as the sum of the fresh weight of the above-ground parts and roots of the sample taken as soon as the crop was harvested at maturity. Then the average fresh biomass yield per plant was calculated. Dry biomass yield (g/ plant): was recorded as the sum of the dry weight of above ground parts and roots of sampled plants taken after oven drying. The average dry biological yield of sampled plants was calculated and recorded as dry biological yield per plant. Unmarketable root yield (URY) (t /$ha^{-1}$): was determined through subjective evaluation and recorded as the weight of roots which are diseased, insect attacked, deformed roots under or over weighted. Marketable root yield (MRY) (t /$ha^{-1}$): was recorded as the weight of healthy and saleable yield of all harvested roots by converting plot yield in to hectare.

Economic analysis

Partial budget analysis was employed for economic analysis of NPS fertilizer and beetroot seed. The price of fertilizer and seed plus potential of the crop response towards the added fertilizers was used to determine the economic feasibility of fertilizers. To estimate the total cost, mean market price of beetroot and NPS fertilizers were taken from market assessment at the time of planting. The economic analysis was based on the formula developed by (CIMMYT, 1988). Gross average root yield (t $ha^{-1}$) (AvY): is an average yield of each treatment converted in hectare base. 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 (t/ha) = AvY*(1-0.1). Gross field benefit (GFB) (ETB/ha): was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield. GFB = AjY*field/farm gate price for the crop. Total variable cost: is the cost of NPS fertilizer and cultivation for varied intra-row spacing. The costs of other inputs and production prices such as: labor cost for land preparation, planting, weeding, crop protection and harvesting was considered to remain the same or shall be insignificant among treatments. Net benefit (NB) (ETB/ha): were calculated by subtracting the total costs from gross field benefits for each treatment. NB = GFB – total cost

Marginal rate of return (MRR %): was calculated by dividing change in net benefit by change in cost. $MRR = \frac{\Delta NB}{\Delta TVC}$ Or MRR (%) = $\frac{\text{Marginal benefit}}{\text{Marginal Cost}} \times 100$

Data analysis

The analysis of variance (ANOVA) was performed using Stat 8 following the standard procedure. When ANOVA showed significant differences, mean separation was done using least significance difference (LSD) test at probability level of 5%.

**Results and discussion**

Physicochemical properties of the study area

The experimental site soil physicochemical properties of the study area determined before sowing the beetroot crop are shown in Table 1. The soil analysis result before planting indicated that the textural class of the experimental soil was sandy loam having a proportion of 56.5% sand, 24% silt, and 19.5% clay with a pH value of 6.

Table 1. The result of experimental site soil

| Soil property | Experimental field | Rating | Reference |
|---|---|---|---|
| Soil pH | 6 | Moderately acidic | Landon (1991) |
| Organic Carbon (%) | 2.8 | Low | Landon (1991) |
| Organic matter (%) | 3.5 | Medium | Landon (1991) |
| Total N (%) | 0.31 | Medium | Tekaligne (1991) |
| Available S (ppm) | 5 | Medium | Olsen (1982) |
| Available P (mg $Kg^{-1}$) | 3.24 | low | Tekalign (1991) |
| CEC (cmol$Kg^{-1}$) | 25.13 | High | Landon (1991) |

Growth characteristics of Beetroot variety

Plant height

The main effect of plant height on the Detroit dark-red beetroot variety was significantly influenced at $p < 0.05$ by the application of NPS fertilizer and intra-row spacing (Table 2). The tallest beetroot plant (24.83 cm) was observed for 242 kg $ha^{-1}$ NPS fertilizer, which was statistically similar to those plants supplied with 181.5 and 121 kg ha$^{-1}$ NPS fertilizer, while plants with no NPS fertilizer were recorded as having the shortest height (Table 2).

Similarly, the tallest plant heights (24.65 cm) and (23.14 cm) were obtained from 10 and 15 cm intra-row spacing, respectively, whereas the shortest plant height (21.17 cm) was observed at an intra-row spacing of 20 cm. This might be due to the narrow spacing when the competition of plants for sunlight and air was increased to get an adequate amount of sunlight and air, which as a result showed fast growth and produced tall plants (Masri and Safina, 2015). The increase in plant height under NPS application is associated with the combined effect of the N, P, and S nutrients in the blended NPS fertilizer, although either mineral or organic fertilizers increase plant height (Sapkota et al., 2021; Shafeek et al., 2019). The synergistic effect of NPS fertilizer in general, and nitrogen in particular, was also important.

Table 2. Plant height and number of leaves of *Detroit dark red* beetroot variety as influenced by NPS fertilizer and intra-row spacing at Wolaita zone in 2019

| Treatment | Growth characters | | | | | |
|---|---|---|---|---|---|---|
| | PH (cm) | Leaf number | | | | |
| NPS (kg ha$^{-1}$) | | 15 DAS | 30 DAS | 45 DAS | 60 DAS | At harvest |
| 0 | 21.38$^{b}$ | 2.5 | 5.26 | 8.35$^{b}$ | 11.46 $^{b}$ | 13.37$^{b}$ |
| 60.5 | 21.43$^{b}$ | 2.48 | 5.14 | 8.78$^{b}$ | 11.78$^{b}$ | 13.6$^{b}$ |
| 121 | 23.03$^{ab}$ | 2.59 | 5.2 | 8.94$^{b}$ | 12.15$^{\mathbf{b}}$ | 13.66$^{b}$ |
| 181.5 | 24.26$^{a}$ | 2.81 | 5.07 | 10.36$^{a}$ | 13.43$^{a}$ | 15.29$^{a}$ |
| 242 | 24.83$^{a}$ | 2.87 | 5.28 | 10.05$^{a}$ | 13.39$^{a}$ | 15.34$^{a}$ |
| LSD (5%) | 2.6745 | 0.45$^{ns}$ | 0.37$^{ns}$ | 0.9857 | 0.9852 | 1.429 |
| Intra-row spacing (cm) | | | | | | |
| 10 | 24.65$^{a}$ | 2.66 | 5.14 | 8.85$^{b}$ | 11.95$^{b}$ | 13.66$^{b}$ |
| 15 | 23.14$^{ab}$ | 2.63 | 5.23 | 9.2$^{ab}$ | 12.28$^{b}$ | 14.05$^{ab}$ |
| 20 | 21.17$^{b}$ | 2.65 | 5.21 | 9.84$^{a}$ | 13.1$^{a}$ | 15.05$^{a}$ |
| LSD (5%) | 2.0717 | 0.35$^{ns}$ | 0.29$^{ns}$ | 0.7636 | 0.7631 | 1.107 |
| CV | 12.05 | 17.61 | 7.41 | 10.98 | 8.3 | 10.39 |

Mean values with the same letters within the columns in each treatment do not significantly differ at $p < 0.05$. LSD (5%) = least significant difference at $p < 0.05$, ns = non-significant difference, PH (cm) = plant height and DAS = leaf number days after sowing.

Number of leaves at different stages of crop after sowing

The main effect of NPS fertilizer and intra-row spacing on the number of leaves per plant was significantly affected at $p < 0.05$. The beetroot plants showed a higher number of leaves, which ranged from 10.05 to 15.34 at 45 and 60 days after sowing with the application of 181.5 and 242 kg $ha^{-1}$ NPS fertilizer, with no significant variation for the two rates (Table 2). This might be due to: at the early stage of growth, the cultivator has not extensively utilized the applied NPS fertilizer. Similarly, the variation in number of leaves between the higher and lower rates of fertilizer application could be attributed to more availability of nutrients to the crop that enhanced photo-assimilation, cell division, and vegetative growth (Shinde, 2018; Jambukar and Wange, 2006). And also, the non-significant difference in number of leaves for all plants at all intra-row spacing at 15 DAS and 30 DAS might be attributed to low or the absence of severe competition at the early growth stages of plants, in agreement with Shinde (2018).

Shoot and root biomass of Beetroot

Fresh and dry shoot biomass

The results of the analysis of variance showed those fresh and dry shoot biomasses were significantly influenced by the interaction of blended NPS fertilizer and intra-row spacing ($p < 0.05$, Table 3). The highest fresh and dry shoot weight, 84.59 and 25.37 g, respectively, were obtained from the interaction of 242 kg $ha^{-1}$ NPS fertilizer rate and from 10 cm intra-row spacing. Whereas; the lowest fresh and dry shoot weight of 63.09 and 18.93 g respectively, were obtained from no NPS and for 10 cm intra-row spacing (Table 3).

The shoot increase could be explained by the fact that nitrogen increases the foliage growth of beetroot to enhance the increase in shoot dry biomass. Nitrogen fertilization increases leaf dry mass; the amount of metabolites synthesized by plants due to the effect of nitrogen in enhancing photosynthesis (Khogali et al., 2011). The fresh and dry shoot biomass accumulation were at peak (maximum) at 242 kg $ha^{-1}$ NPS fertilizer application and 10 cm intra-row spacing treatment combination (Table 3). The application of mineral nutrients at different rates might result in differences in fresh and dry shoot biomass. The plants spaced at varied intra-row spacing also could result in a varied degree of competition among plants for resources, which could be reflected on the shoot, root, and total biomass accumulation of plants, which is in agreement with Fikru et al. (2017).

Table 3. Interaction effect of blended NPS fertilizer application and intra-row spacing on shoot fresh and dry weight of *Detroit dark red* beetroot variety at Wolaita zone in 2019

| Treatment | | Parameter | |
|---|---|---|---|
| NPS rate (kg ha$^{-1}$) | Intra-row spacing (cm) | Shoot Fresh Weight (g/plant) | Shoot Dry Weight (g/plant) |
| 0 | 10 | 63.09$^{e}$ | 18.93$^{f}$ |
| 60.5 | 10 | 64.38$^{de}$ | 19.31$^{ef}$ |
| 121 | 10 | 66.39$^{cde}$ | 19.92$^{d-f}$ |
| 181.5 | 10 | 71.83$^{bcd}$ | 21.55$^{c-e}$ |
| 242 | 10 | 84.59$^{a}$ | 25.37$^{a}$ |
| 0 | 15 | 69$^{b-e}$ | 20.7$^{c-f}$ |
| 60.5 | 15 | 69.93$^{b-e}$ | 20.98$^{c-f}$ |
| 121 | 15 | 70.3$^{b-e}$ | 21.09$^{c-f}$ |
| 181.5 | 15 | 72.8$^{bc}$ | 21.84$^{b-d}$ |
| 242 | 15 | 73.33$^{bc}$ | 22$^{b-d}$ |
| 0 | 20 | 74.9$^{b}$ | 22.47$^{bc}$ |
| 60.5 | 20 | 73.92$^{bc}$ | 22.18$^{b-d}$ |
| 121 | 20 | 73.11$^{bc}$ | 21.93$^{b-d}$ |
| 181.5 | 20 | 75.67$^{b}$ | 24$^{ab}$ |
| 242 | 20 | 74.5$^{b}$ | 22.35$^{bc}$ |
| LSD (5%) | | 7.79 | 2.38 |

Mean values with the same letters within the column do not significantly differ at $p < 0.05$ and LSD (5%) = least significant difference at $p < 0.05$.

Fresh and dry root biomass of the crop

The main effect of fresh and dry root biomass on the Detroit dark-red beetroot variety was significantly influenced by blended NPS fertilizer and intra-row spacing (Figure 1). The highest mean fresh root weight of 184.4 g was obtained from the application of 181.5 kg ha$^{-1}$

NPS fertilizer (Figure 1). Similarly, the higher fresh root weight (155.75 g) was obtained at 15 and 20 cm intra-row spacing. The lowest fresh root weight of 81.39 g was obtained from no NPS fertilizer application. The dry root weight was also resulted significant at ($p < 0.05$) record from NPS fertilizer application and row spacing. The increase in NPS fertilizer application resulted in higher fresh and dry root biomass. The higher dry root weight (50.92 g) was the result of the 15 and 20 cm intra-row spacing. This could be due to NPS fertilizer application which promotes vegetative growth as a result higher amount of leaf number produced which would increase photosynthetic surface and the current photosynthetic would enhance the physiological activity leading the production of more assimilates which resulted in higher fresh and dry root weight (Idris et al., 2021; Sapkota et al., 2021; Fikru et al., 2017; Petek et al., 2012; Albayrak and Yüksel, 2010).

Regardless of fresh and dry root weight, the wider intra-row spacing resulted in maximum accumulation of biomass. Under wider spacing, more mineral nutrients, high moisture, and space become available for the vegetative growth to the efficiency of photosynthesis than in dense plantation. This in turn resulted in bigger sized and weighted roots; but due to low plant density, the average yield of ha-1 was low. However; in closer spacing as accumulated more number of plants per unit area due to high density, obtained higher yield of roots (Fikru et al., 2017).

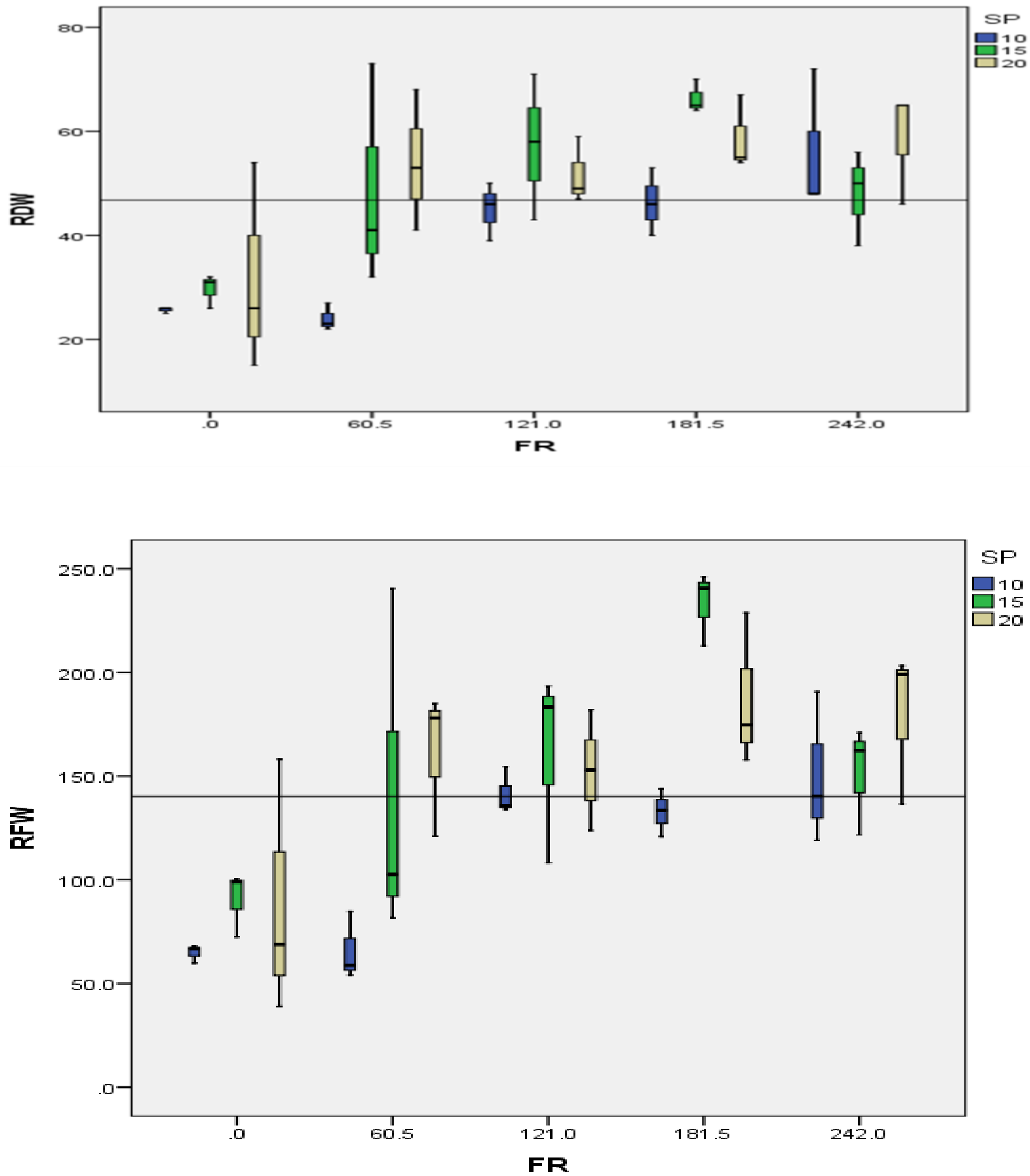


Figure 1. The grand mean of root fresh and dry weight (g/plant), indicated difference in using blended NPS fertilizer application rates and showed significant at 242 level of fertilizer rate for all the three intra row spacing at Wolaita zone in 2019

Unmarketable and marketable root yield

The analysis of variance revealed that unmarketable root yield was significantly affected by different rates of NPS fertilizer application and intra-row spacing patterns ($p < 0.05$). The maximum unmarketable root weight (11.644 g) was obtained from unfertilized plants, while the lowest (9.259 g) of unmarketable root weight was obtained from 242 kg NPS fertilizer ha-1 (Table 4). On the other hand, the maximum unmarketable root yield (4.53t $ha^{-1}$) was obtained from the intra-row spacing of 10cm which is the closer spacing. Whereas, the minimum unmarketable root yield (1.34t $ha^{-1}$) was obtained from the 20 cm intra row spacing which is the wider (Table 4). This increase in unmarketable root yield with the closer spacing and low level of fertilizer application might be due to the association with low levels of nutrients. The growth and development of the plant in closer spacing is hindered because of the high competition for moisture, sunlight, and nutrients; this in turn results in the development of very tiny roots that are less preferred by consumers.

The analysis of variance revealed that the application of blended NPS fertilizer and intra-row spacing had a highly significant ($p < 0.01$) effect on marketable root yield (Table 4). The highest marketable root yield (32.74 t $ha^{-1}$) was recorded at an intra-row spacing of 15 cm, and it was followed by an intra-row spacing of 10 cm, resulting in a marketable root yield of 32.47 t $ha^{-1}$) (Table 4). The lowest marketable root yield (24.32 t $ha^{-1}$) was recorded from intra-row spacing of 20 cm.

The highest marketable yield was obtained in closer spacing than in wider spacing this might be due to closer spacing that accumulated more number of plants per unit area. However; in wider spacing bigger sized and weighted roots could be obtained; but due to low plant density the average yield $ha^{-1}$ was low. This finding is in agreement with (Gaharwar, 2017), who reported that the application of NPS fertilizer had highly significant ($P < 0.05$) effect on the mean marketable root yield of beetroot. The maximum mean marketable root weight result (176.66 g) obtained from blended NPS fertilizer rate of 181.5 kg $ha^{-1}$ which is followed by NPS fertilizer rate of 242 kg $ha^{-1}$ and 121 kg $ha^{-1}$ resulted in (151.2 g and 142.1 g) of mean marketable root weight respectively. The lowest mean marketable root weight (69.74 g) was obtained from unfertilized treatment. The maximum mean marketable root weight per ha observed with the application of increased NPS blended fertilizer could be due to different nutrients in the NPS fertilizer playing a significant role in the increment in marketable yield of beet root.

However, the lowest mean marketable root weight was obtained from the treatment received, which was nil kg ha-1 NPS fertilizer application. This might be due to the absence of adequate nutrient levels needed for the proper growth, development, and yield of beetroot. Generally, the wider spacing decreases root yield due to low plant population, and in very close spacing, plants produce very small roots, which are not fit for the market; higher plant density increases the proportion of plants with small roots, usually at the expense of total yield (Patel et al., 2015).

Table 4. Marketable and unmarketable root yield of beetroot as affected by intra row spacing and NPS fertilizer at Wolaita zone in 2019

| Treatments | Marketable root yield(gram) | Unmarketable root yield(gram) |
|---|---|---|
| NPS kg ha$^{-1}$ | | |
| 0 | 69.74$^{c}$ | 11.644$^{a}$ |
| 60.5 | 111.41$^{b}$ | 11.523$^{a}$ |
| 121 | 142.10$^{ab}$ | 9.903$^{ab}$ |
| 181.5 | 176.66$^{a}$ | 7.699$^{b}$ |
| 242 | 151.20$^{a}$ | 9.259$^{ab}$ |
| LSD 0.05 | 36.514 | 2.53 |
| CV | 29.04 | 26.19 |
| Intra-row Spacing(cm) | | |
| 10 | 97.40$^{b}$ | 13.598$^{a}$ |
| 15 | 147.34$^{a}$ | 8.405$^{b}$ |
| 20 | 145.94$^{a}$ | 8.014$^{b}$ |
| LSD 0.05 | 28.284 | 1.9597 |

Partial budget analysis

A partial budget analysis is a way of calculating the total costs and the net benefits of each treatment in an on-farm experiment, which includes the average yields, the adjustable yields, the gross field benefit, and the varying costs for each treatment (CIMMYT, 1988). With this regard, the analysis revealed that the net revenue of these treatment combinations did not increase proportionally with the increased total cost, and net revenues were lower than the lowest total cost (Table 5). On the other hand, the treatment combinations (60.5, 121, 181.5 NPS kg ha$^{-1}$ with 15 cm intra-row spacing and 0, 60.5 NPS kg ha$^{-1}$ with 20 cm intra-row spacing) were found to be non-dominated and selected for the analysis of marginal rate of return.

Table 5. Partial budget analysis on the effect of NPS fertilizer and intra-row spacing on *Detroit dark red* beetroot variety at Wolaita zone in 2019

| Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|
| NPS | intra-row | Avj (kg/ha) | Ajy (kg/ha) | TVC ETB | GR ETB | NB ETB | Dominance |
| 0 | 20 | 14780 | 13302 | 19200 | 33255 | 14055 | ND |
| 60.5 | 20 | 26890 | 24201 | 20027.64 | 60502.5 | 40474.86 | ND |
| 0 | 15 | 20140 | 18130 | 20400 | 45325 | 24925 | D |
| 121 | 20 | 25480 | 22932 | 20855.28 | 57330 | 36474.72 | D |
| 60.5 | 15 | 31450 | 28305 | 21227.64 | 70762.5 | 49534.9 | ND |
| 0 | 10 | 21610 | 19450 | 21600 | 48625 | 27025 | D |
| 181.5 | 20 | 31190 | 28071 | 21682.92 | 70177.5 | 48494.58 | D |
| 121 | 15 | 35930 | 32340 | 22055.28 | 80850 | 58794.72 | ND |
| 60.5 | 10 | 21960 | 19760 | 22427.64 | 49400 | 26972.4 | D |
| 242 | 20 | 29950 | 26960 | 22510.56 | 67400 | 44889.44 | D |
| 181.5 | 15 | 51820 | 46640 | 22882.92 | 116600 | 93717.08 | ND |
| 121 | 10 | 47150 | 42440 | 23255.28 | 106100 | 82844.72 | D |
| 242 | 15 | 33700 | 30330 | 23710.56 | 75825 | 52114.44 | D |
| 181.5 | 10 | 44250 | 39830 | 24082.92 | 99575 | 75492.08 | D |
| 242 | 10 | 50010 | 45009 | 24910.56 | 112522.5 | 87611.94 | D |

Price of NPS = 13.68 Birr kg$^{-1}$, Unit price of 1kg beetroot seed=1200 ETB, Field price of beetroot during harvesting = 250birr/Quintal, Avj = Average yield, Ajy = Adjusted yield, TVC= Total Variable Cost, GR = Gross return, NB = Net benefit, D = Dominated and ND = none dominated. (Source: 2019/20 Wolaita Damota farmer's cooperative union Meher season agricultural input tentative price report and Wolaita Zone Finance and Economy development Office).

The highest net benefit (93,717.08 ETB) was recorded in response to the application of 181.5 kg NPS ha$^{-1}$ with 15 cm intra row spacing and the highest (4219.51%) marginal rate of return (Table 5). This indicates that, for every 1 birr ha$^{-1}$ invested on the respective treatments, there was a rate of return of 42.19 birr ha$^{-1}$. Nevertheless, all the non-dominated treatment combinations resulted in a rate of return above the minimum acceptable value of (50-100%)

as outlined by CIMMYT (1988). Therefore, application of 181.5 kg NPS $ha^{-1}$ with 15 cm intra-row spacing resulted in the highest net benefit compared to the other treatment combinations, and its marginal rate of return is also the highest among other treatments. Hence, according to a partial budget analysis, the combination of 181.5kg NPS $ha^{-1}$ with 15cm intra-row spacing was considered the relatively best treatment in terms of its economic return.

**Conclusion**

This research assessed the effect of NPS fertilizer rates (0, 60.5, 121, 181.5 and 242 kg $ha^{-1}$) and intra-row spacing (10, 15 and 20 cm) on red beetroot root yield, and yield related traits and to estimate the cost-benefit of NPS fertilizer rates and intra-row spacing for red beet root production in Wolaita zone of South Ethiopia. The application of the highest rate of 242 kg $ha^{-1}$ NPS fertilizer produced the tallest beetroot plant and a higher number of leaves at 45 and 60 days after sowing and at harvest. The higher fresh and dry root weight per plant was obtained by the application of 181.5 kg $ha^{-1}$ NPS fertilizer, but there was no significant difference with the application of 242 kg $ha^{-1}$ NPS fertilizer. The interaction of 242 kg $ha^{-1}$ NPS and 10 cm intra-row spacing produced the highest fresh and dry shoot weight. The plants at intra-row spacing of 10 cm were tallest, whereas the plants at 20 cm produced higher mean number of leaves, but had non-significant differences with plants spaced at 15 cm registered. The higher fresh and dry root weight was obtained from plants at 15 and 20 cm intra-row spacing. Moreover, the highest marketable root yield was obtained from plants at an intra-row spacing of 15 cm (32.74t $ha^{-1}$).

The research results indicated: (i) the overall performance of the Detroit dark red beetroot variety was higher due to the application of higher rates of NPS fertilizer (181.5 and 242 kg $ha^{-1}$) at 10 and 15 intra-row spacing, (ii) the application of 181.5 kg $ha^{-1}$ NPS and 15 cm intra-row spacing resulted in higher marketable root yield, and (iii) the tentative recommendation was made in favor of the application of 181.5 kg $ha^{-1}$ NPS at 15 cm intra-row spacing; since it could offer an acceptable economic rate of return, highest root yield and net benefit for beetroot producers in the study area. The highest marginal rate of return (4219.5) coupled with the highest net benefit of 93717.08 birr per hectare was obtained from plants that received 181.5 kg $ha^{-1}$ NPS at 15 cm intra-row spacing. Thus, it was possible to conclude that growing the Detroit dark red beetroot variety with an application of 181.5kg $ha^{-1}$ NPS fertilizer at 15 cm intra-row spacing in the study area is feasible. However, this research could not make remarkable recommendations because of its focus on one season and one location.

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**Conflict of interest**

Authors declare that they do not have any conflict of interest.

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