Original Research Article

Growth and Yield Response of Carrot (*Daucus carota* L.) to Different Soil Amendments

Abstract

Carrot (*Daucus carota L.*) is an important vegetable that is ranked third among the succulent vegetables in world production. They are simple to grow and require only a moderate amount of nutrients when compared to other vegetables. However, carrot production in Liberia is almost zero, as farmers are not aware of its requirements and its cultivation, and due to unsuitable environmental conditions. The objective of this study was therefore to assess the growth and yield performance of carrots under different soil amendments at the Cuttington University research and demonstration site. The experiment was done in a randomized complete block design (RCBD) with three replications. The treatments were: 10 t ha^{-1}, 15 t ha^{-1}, and 20 tha^{-1} compost; 300 t ha^{-1} NPK (15:15:15); and control(0 t ha^{-1}). The distance between plots and between blocks was 0.5 cm and 1 m, respectively. Results indicated that the longest plant root length (11.10 cm) was recorded in the 20 t ha^{-1} compost application, while the lowest plant root length (6.84 cm) was measured in the control treatment. The highest root diameter (22.89 mm) was recorded in the treatment with 20 t ha^{-1} while the lowest mean value of root diameter (17.59 mm) was recorded in the control (0 t ha^{-1}) treatment. The result revealed that the maximum root weight (31.73 g) was recorded in the 20 tha^{-1} compost rate, while the minimum (12.33 g) was recorded in the control. These differences are probably due to the nutrient levels, which are responsible for facilitating the growth and development of root length, diameter, and yield in the plant. That means the lowest values in all the parameters might be due to the low rate of compost applied to the soil. It is concluded that the overall growth and yield performance of carrot plants were recorded at 20 t ha^{-1}, followed by 15 t ha^{-1}, NPK, 10 t ha^{-1}, and control treatments. It is therefore recommended that farmers apply 20 t ha^{-1} of compost for maximum growth and yield performance in carrot production.

Keywords: Carrot, compost, soil amendment, yield response

1. Introduction

Carrot (*Daucus carota* L.) is an important vegetable that is ranked third among the succulent vegetables in world production. It belongs to the *Umbeliferae* family and is one of the major root vegetables used as salad and cooked vegetables. It is a rich source of beta-carotene. Because of their high beta-carotene content, which is a precursor to vitamin A and can prevent infection, certain types of cancer, and improve vision, carrots are becoming more and more popular. They also include riboflavin B2, vitamin C, and thiamin B1. Apart from its high potential for agricultural product import and export in continental trade, it is one of the exotic vegetables with high nutritive and economic value and of great demand (Mbatha et al.,2014).

Carrots react well to fertilizers that are both organic and inorganic. However, excessive amounts of inorganic fertilizer result in soil acidification, increased greenhouse gas (GHG) emissions, and increased eutrophication of water bodies. These are detrimental to the production and loss of nutritional qualities of most crops. Excessive amounts of soil organic matter also promote forking and reduce market acceptability and profitability (Adelaide, 2011).

As a way to mitigate the environmental pressure resulting from inorganic fertilizers and simultaneously improve carrot quality and yield, soil amendment using compost has been recommended. Poor soil and crop management practices have been observed, among other things, as the leading causes of poor production and the attendant low nutritional qualities of most crops in sub-Saharan Africa. Most farmers in these areas have limited access to good production information, which often results in limited knowledge coupled with their inability to afford production inputs such as fertilizers and good seeds (Yasoda et al.,2018).

Carrots are one of the most widely grown vegetables by small-scale farmers around the world. They are simple to grow and require only a moderate amount of nutrients when compared to other vegetables. These farmers' carrot yields, on the other hand, are low and of poor quality. Organic fertilizers, such as chicken or kraal manure, as well as compost, are used by farmers to feed nutrients to vegetables since they are less expensive than artificial fertilizers (Fikadu and Refisa, 2019).

Carrots, despite their reputation as medium feeders, nonetheless require fertile soil to allow for normal plant growth. Carrot roots that are rough, gritty, and forked due to overuse of organic fertilizers will grow excessively.These root changes could be caused by a number of other variables, including temperature, high nitrogen fertilizer rates, poor soil structure (compacted soil), high clay content, and varying soil moisture levels (Achakzai and Panizai, 2007).

Osman and Osman (2018) claim that soils in wet locations are naturally acidic, leach rapidly, and may require a lot of fertilizer. To avoid the occurrence of hairy and coarse roots, they recommend applying compost or organic manures to the prior crop. Organic fertilizers applied to clay-rich soil may reduce soil density, allowing carrot roots to penetrate to a depth of 35–110 cm. The use of organic fertilizer increases the soil structure in sandy soil, allowing carrot shoulders to expand more easily (Snr et al.,2020).

Because microorganisms are more active during the warmer months of the year than during the cooler months, the timing of organic fertilizer application is critical. Microorganisms become inactive at low soil temperatures (below 15 °C). Organic material is mineralized, and plant nutrients become available at soil temperatures of 20 °C and above. Soil pH, in addition to low soil temperature, has an impact on organic nutrient uptake (Rahman et al.,2018).

Carrot is an important vegetable that can be grown and marketed by farmers. The crop provides substantial income, which can help improve their livelihoods. Most of the produce is transported to large urban centers, where it is sold and used for food preparation. However, carrot production in Liberia is zero due to several factors, including poor soil management. The objective of this study was there for to examine the yield response of carrot to different soil amendments and to evaluate different rates of soil amendments on the growth response of carrot.

2. Material and Methods

2.1 Study site

The study was conducted at the Cuttington University research and demonstration site in Suakoko, Bong County, Liberia. The experimental site lies at an altitude of 270 m above sea level and is located at 7.0451° latitude and -9.5508° longitude. Climatic variables such as temperature and rainfall pattern are largely tropical, with an annual average temperature of 25 °C and an annual average rainfall of 2013 mm distributed from May to October. The main soil types in the district include *latosols*, *lithosols*, *regosols,* and *alluvial* or swamp soils.

2.2 Experimental design and treatments application

The experimental area was slashed, ploughed, and harrowed to a fine tilth. The debris was raked off the field, and the area was demarcated into three blocks. A block had 5 plots, each measuring 1 m long, 1 m wide, and 0.25 m high. The experiment was done in a randomized complete block design (RCBD) with three replications. The treatments (soil amendments) considered in the study were: 10 t ha^{-1}, 15 t ha^{-1}, and 20 t ha^{-1} compost; 0.33 t ha^{-1} NPK (15:15:15); and control. The distance between plots and between blocks was 0.5 cm and 1 m, respectively. The various rates of compost were incorporated into the soil during the preparation of the beds, while the NPK fertilizer granules were applied thirty days after the germination of the carrot seeds by side dressing.

The seeds were drilled to a depth of 1-2 cm. Before watering, gardens were mulched by covering them with palm fronds. After seeding, the palm fronds were cut off fourteen days later, and the seedlings were spaced out to a maximum of five centimeters between each plant. To maintain the soil's moisture content during the growth season, daily irrigation was conducted. Twice a week, the areas between the rows of carrot plants were turned over with a hand fork to get rid of weeds and soften the soil for better aeration and infiltration. In order to keep the root shoulders from turning green, they were covered with soil.

2.3 Sample size determination

From a total population of 2,565 plants, the required sample size was determined as follows:

$$N/1+N(e^2)$$

Where: N is the total population; e is the margin sampling error.

However, during the germination period of the seeds, torrential rainfall came and caused damage to the newly emerged seedlings. Therefore, data was collected from the available plants: 9 samples from 10 t ha^{-1}, NPK, and control; 27 samples from 20 t ha^{-1}; and 18 samples from 15 t ha^{-1}, totaling 72 sampling plants, were collected.

2.4 Data collection procedures

Data was collected on root length, root weight, and root diameter from 72 plants, which were randomly selected. Root length was measured from one end to the tip of the other end. Veneer calipers were used to measure the root diameter at a distance of around 1 cm from the root shoulder. We used a digital balance to find the root weight.

2.5 Statistical analysis

Data on plant growth performance and yield of carrots was summarized using descriptive statistics such as mean and standard errors. An analysis of variance (ANOVA) was performed to see if there were any significant differences among the selected treatments. Pearson correlation analysis was also done to see if there was any relationship between the parameters. Mean comparisons were made using the Tukey Honest Significant Difference (TSD) at 0.05 significant levels. The IBM SPSS 25 package was used to perform all the statistical analyses.

3. Results and Discussion

3.1 Root length

The length of the root is an important parameter contributing to the yield of root vegetables. The measured root length of the carrot plants was significantly affected by the application of different rates of compost and NPK fertilizer. A general increase in plant root length was observed parallel to an increase in the amount of compost (Table 1). The longest plant root length (11.10 cm) was recorded in the 20 t ha^{-1} compost application, while the lowest plant root length (6.84 cm) was measured in the control treatment. Probably, this is due to low nutrient levels that facilitate the growth and development of the root length of the plant.

This finding is in correspondence with the findings of Yasodaet al.(2018), who stated that carrot root length performs best with a high compost level in the soil. Dry soils crack the roots of carrots and increase the percentage of rotten roots, which in turn reduces the yield of the plant. In contrast, in favorable soil conditions with a high compost level, it produces long roots and favors yield performance.

Similarly, this result also coincided with the investigation of Rahman et al. (2018), who stated that the application of compost led to a significant increase in the growth and yield of carrots over the control. Application of compost at a rate of 15 to 20 t ha^{-1} significantly improved the performance of the carrot plant.

3.2 Root diameter

The measured root diameter of the carrot plant was significantly affected due to the different levels of compost and the NPK applications. The mean values of the measured root diameter showed a constant increment as the rate of compost application increased. The highest root diameter (22.89 mm) was recorded in the treatment with 20 t ha^{-1} while the lowest mean value of root diameter (17.59 mm) was recorded in the control (0 t ha^{-1}) treatment (Table 1). This is in correspondence with the report of Fikadu and Refisa (2019), who stated that the application of compost had a significant effect on carrot root diameter.

This study clearly showed that with an increase in the rate of compost, the root diameter increased. A similar study was conducted by Achakzai and Panizai (2007) to see the effect of compost on the yield of carrots. They found that the maximum root fresh weight (160.70 g) was recorded from a 15 t ha^{-1} compost application. Similarly, Snr et al.(2020) also reported that the maximum root fresh weight of 146.50 g was recorded from the 25 t ha^{-1} compost application and the lowest (123.96 g) from the control treatment. Dawuda*et al.,* (2011) added that application of bio-slurry manure at 7.8 t ha^{-1} increased the yield of carrots by 23.5% over control.

The increased response of root fresh weight might be due to the increasing level of fertility status of the soil. This is in line with the finding of Kiran et al.(2016), who reported that compost is very effective in improving soil fertility, particularly for growing vegetable crops. Similarly, Adelaide (2011) found that compost is a good fertilizing material that can be used to maintain soil fertility status and improve crop production. These results correspond to the findings reported by Asante et al. (2019), who observed significant variations in carrot root diameter with the application of chemical fertilizers and organic manures.

3.3 Root weight

Root weight is an important parameter contributing to the yield of root vegetables. The results differed significantly (p< 0.001) among the five different treatments. Because the recorded average root weight of the carrot plants showed a continuous increment with increasing the level of compost, a great deal of root weight was also recorded in the NPK treatment as compared to the 10 t ha^{-1} and the control treatments. The result revealed that the maximum root weight (31.73 g) was recorded at the 20 t ha^{-1} compost rate, while the minimum (12.33 g) was recorded at the control. The lowest root weight mean value might be due to the low rate of compost applied to the soil. Mbatha et al.(2014) also reported that an increase or decrease in the yield of carrots is directly related to the amount of compost applied to the soil.

These results collaborated with the findings of Yasoda et al.(2018), who found that compost has considerable amounts of plant nutrients. They reported that continual applications of compost not only supply plant nutrients but also enrich agricultural soils. Likewise, Rahman et al.(2018) revealed that compost increased the N uptake and yield of carrots. However, the availability of the nutrients in the soil can vary significantly in terms of the source of the nutrients.

Kiran et al.(2016) found a significant increase in plant growth and yield of carrots with the application of a higher dose of compost than its lower dose. Achakzai and Panizai (2007) also noted increased carrot yield with the addition of 40 t ha^{-1} of compost.

Table 1. Root length, root diameter, and root weight comparisons among the selected treatments

Treatment	Root length (cm)	Root diameter (mm)	Root weight (g)
10 t ha^{-1} compost	$(7.67 \pm 1.08)^{bc}$	$(18.45 \pm 1.63)^{ab}$	$(16.90 \pm 2.37)^{b}$
15 t ha^{-1} compost	$(10.52 \pm 0.55)^{ab}$	$(19.96 \pm 1.00)^{ab}$	$(22.93 \pm 2.92)^{ab}$
20 t ha^{-1} compost	$(11.10 \pm 0.52)^{a}$	$(22.89 \pm 0.72)^{a}$	$(31.73 \pm 2.46)^{a}$
control	$(6.84 \pm 0.73)^{c}$	$(17.59 \pm 1.30)^{b}$	$(12.33 \pm 1.38)^{b}$
0.33 t ha^{-1} NPK (15:15:15)	$(8.22 \pm 1.20)^{abc}$	$(22.82 \pm 1.63)^{ab}$	$(20.19 \pm 4.47)^{ab}$

*Means followed by the same letter are not significantly different at P ≤ 0.05 as determined by Tukey Honest Significant Difference (HSD) test. Values are expressed as mean ± standard error.

Root length, root diameter, and root weight were found to be strongly positively correlated, according to the correlation analysis. The person-correlation coefficient indicated that there was a strong correlation between root length and root weight (r = 0.6982). Similarly, a strong correlation was observed between root diameter and root weight (r = 0.7356). Less correlation (r = 0.4921) was recorded between root length and root diameter, but it was enough to explain the relationship that exists between the two variables.

Table 2. The correlation matrix of the root length, root weight, and root diameter

	Root Length (cm)	Root Weight (g)	Root Diameter (mm)
Root Length (cm)	1	0.6982	0.4921
Root Weight (g)	0.6982	1	0.7356
Root Diameter (mm)	0.4921	0.7356	1

4. Conclusion

In summary, the present study has yielded vital insights on the notable effects of NPK fertilizer and compost on root weight, root diameter, and root length in carrot plants. According to the study, the amount of compost that is added to the soil has a significant impact on the length of carrot roots. The application of 20 t ha^{-1} of compost resulted in the longest roots among carrot plants, suggesting a favorable correlation between compost levels and root length.

The study also demonstrated the positive link that exists between root length, root diameter, and root weight, highlighting the interdependent nature of these factors in affecting the growth and yield of carrot plants. The relevance of these parameters in influencing overall root vegetable output is highlighted by the substantial correlations found between root diameter and weight and between root length and weight. This study highlights how crucial it is to maintain soil properly, using compost, in order to optimize root characteristics and eventually increase the yield of root crops like carrots.

In conclusion, this study's findings advance our knowledge of the significant effects that NPK fertilizer treatments and compost can have on the length, width, and weight of carrot plants' roots. Farmers and other agricultural professionals who want to increase the yield of root vegetables by using efficient soil nutrient management techniques may find these ideas to be helpful. This research highlights the possibility for greater agricultural production and food security in areas where root vegetables are important for dietary diversity and nutrition by highlighting the significance of soil fertility and nutrient levels.

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