International Journal of Plant & Soil Science

32(10): 16-25, 2020; Article no.IJPSS.59869
ISSN: 2320-7035

Effect of Different Soil Amendments and Variety on the Growth and Yield of Carrot (*Daucus carota* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors JSA, VL and PAPS designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors CGK and PAPS performed the statistical analysis, managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2020/v32i1030335
Editor(s):
(1) Dr. Olanrewaju Folusho Olotuah, Adekunle Ajasin University (AAUA), Nigeria.
Reviewers:
(1) Okafor Maduabuchi Johnbosco, Nnamdi Azikiwe University, Nigeria.
(2) M. Mahadeva Swamy, University of Mysore, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/59869

Original Research Article

Received 28 May 2020
Accepted 05 August 2020
Published 13 August 2020

ABSTRACT

The objective for the study was to determine the effect of variety and different soil amendments on the growth and yield of carrot (*Daucus carota L.*). The study was conducted in Mampong-Ashanti which is located in the transitional zone of Ghana. The experiment was laid out in a 5 x 2 factorial and treatments arranged in Randomized Complete Block Design (RCBD). There were two varieties (Tokita and Kuroda) and five different types of soil amendment which were: control (T_1), 5 ton/ha poultry manure (T_2), 45-45-45 kg/ha NPK (T_3), 5 ton/ha compost (T_4) and 5 ton/ha biochar (T_5). Each treatment was replicated four times. Data was collected on vegetative growth and yield of carrot. Data obtained were subjected to analysis of variance (ANOVA) using GENSTAT Version 11.1. Results from the study showed that carrot plants amended with 5 ton/ha poultry manure significantly (P=.05) produced the tallest height and greater number of leaves. Application of 5 ton/ha compost recorded the widest (P=.05) canopy spread. Application of 5 ton/ha poultry manure recorded the highest ($p < 0.05$) fresh root weight, root length, root diameter and marketable root

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weight with the control treatment recording the least among all treatments. With respect to variety, Kuroda produced the tallest (P=.05) plants, greater (P=.05) number of leaves and wider (P=.05) canopy spread. In conclusion, the application of 5 t/ha poultry manure had improved growth performance with higher productivity in terms of marketable root weight and total yield. Among the two varieties Kuroda was the best with higher growth performance and yield.

Keywords: Carrot; vegetative growth; yield; harvest index; root cracking.

1. INTRODUCTION

Carrot (*Daucus carota L*.) is a very important root vegetable crop consumed by many Ghanaians and mostly used in the diet [1]. It is highly accepted and used as food mostly because it is a rich source of Vitamin A [2]. Carrot is a cool weather vegetable crop but some cultivars can tolerate quite high temperature [3]. Carrot belongs to the family Apiaceae which is also related to parsley, celery, parsnips and cilantro, it is usually orange in colour, though purple, black, red, white, and yellow cultivars exist [4]. The productivity of carrot in Ghana is very low and therefore, not able to meet consumers demand. This could be attributed to intensive cultivation on the same piece of land, farmers' inability to buy inorganic fertilizers due to high cost, inappropriate agronomic practices which include poor soil amendment, cultural practices and spacing [5].

Among all the farm lands in Ghana, soil fertility regeneration and maintenance appear to be the most serious agronomic challenge which significantly affect carrot production [3]. Furthermore, continuous cultivation of the land has resulted in accelerated soil nutrient depletion, decline in soil organic matter content, loss of physical structure and reduced crop productivity [6,7]. Poultry manure and compost can serve as alternative to mineral fertilizers as reported by Rasoli and Forghani [8] for improving soil fertility [9] and microbial biomass [10]. Compost can improve soil chemical and physical properties [11]. Research conducted by Hu and Barker [12] showed that compost has the potential to improve almost all relevant soil properties and can be particularly useful for high value vegetables, fruit and protected crops. Compost made with a combination of grass and straw can contain twice the potassium of chicken manure. Prevention of leaching and using covers will help preserve potassium [11]. A healthy soil, loaded with compost, will be naturally fertile.

Biochar as a kind of organic matter has been used as soil amendment to improve soil structure and fertility qualities [10,13]. Biochar is a fine-grained, highly porous charcoal substance that is distinguished from other charcoals in its intended use as a soil amendment [14]. Currently; there is not much information on the use of poultry manure, compost and biochar on growth, yield and quality characteristics of carrot in Ghana.

The objective for the study was to determine the effect of variety and different soil amendments on the growth and yield of carrot (*Daucus carota L*.) in the transitional zone of Ghana.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was carried out at the Multipurpose Crop Nursery of the College of Agriculture Education, University of Education, Winneba, Mampong- Ashanti campus located in the forest-savannah transitional zone of Ghana in 2019. Mampong-Ashanti lies in the transitional zone between the Guinea savanna zone of the north and the tropical rain forest of the south of Ghana.

The climatic, vegetation and demographic characteristics of Mampong-Ashanti have been described by [15]. FAO describe the soil at the experimental site as Chromic Luvisol [16]. The soil at the experimental site was sandy loam, well drained with thin layer of organic matter with characteristic deep yellowish red colour, friable and free from stones. The pH ranged from 6.5 - 7.0. It is permeable, and has moderate water holding capacity.

2.2 Experimental Design and Treatments

The experiment was a 5 x 2 factorial with treatments arranged in Randomized Complete Block Design (RCBD). There were five different soil amendment (biochar, compost, poultry manure, N.P.K fertilizer and the control treatments) and two varieties (Tokita and Kuroda). The total number of sub-plots on the experimental unit was 40, each sub-plot measured 1.5 m x 2 m and the total area of the

plot for the study was 125.0 m^2. There were five (5) soil amendments and two varieties in four (4) replicates. The different rates of soil amendments were; T1 = Control, T2 = 5 ton/ha poultry manure, T3 = 45-45-45 kg/ha NPK, T4 = 5 ton/ha Compost and T5 = 5 ton/ha biochar.

2.3 Land Preparation and Soil Analysis

2.3.1 Land preparation

The site was cleared of all vegetation using manual labour. The debris was gathered into heaps outside the demarcated areas for controlled burning and to allow for ease of ploughing, harrowing, lining and pegging. Plots measuring 2 m x 1.5 m (3 m²) were demarcated and prepared manually using hoes and rakes. Each block was separated from the next by a distance of one metre. The manure was incorporated into the soil and allowed to decompose before beds were raised on each plot to about 30 cm high.

2.3.2 Sowing and cultural practices

Carrot varieties (*New Improved Kuroda* and Tokita) were sown by drilling. The beds were covered with palm fronds to minimize excessive heat and to prevent falling off of the seeds during watering. The palm fronds were removed seven days after planting when the seedlings have emerged from the soil. Watering was done every day using watering can except on rainy days. Thinning out was done14 days after germination. NPK Fertilizer (NPK-45, 45, 45) was applied on the respective plots after thinning out at the rate of 135 kg/ha. Weeds were hand-picked as and when necessary. The paths between the blocks and plots were weeded using cutlass and hoe when the need arose. Earthening- up was carried out every two weeks to cover the root shoulders that have been exposed as a result of watering. Likewise the intra-rows were also stirred to improve aeration for proper growth and development of the crop.

2.4 Vegetative Parameters Measured

Ten plants were randomly selected from the middle rows of each plot and tagged for the measurement of growth. Plant height was measured from the base of the plant to the tip of the longest leaf using a metre rule. The measurement started from 4 weeks after transplanting and continued on 6, 8, 10 and 12 Weeks after Planting (WAP). The mean of every treatment was computed. With number of leaves, any emerged leaf was counted at the recording time. The mean number of plant leaves was calculated. Canopy spread was determined by measuring the spread of the canopy using tape measure. The average of the two lengths is considered as the canopy spread of the tagged plant at 6, 8, 10 and 12 Weeks after Planting (WAP). Shoots of ten plants were weighed, oven dried at 75°C to constant weight and the weight recorded as dry weight. The mean was then calculated. Roots with no deformities like cracks, nematode infection, forking, disease, malformation of size and those without spots and weighing above 40 grams were selected from each plot and weighed as the marketable yield.

2.5 Root Parameters

Total carrot roots obtained from each treatment plot within the harvestable area were taken and their fresh weight measured with the help of an electronic scale and the weight recorded as yield per plot. This was converted to tonnes per hectare. Root length was measured on ten random root samples from each treatment using a rule from the crown to the end of the root. The mean was then calculated. Root diameters of the 10 samples were measured using veneer caliper 2 cm from the crown. Mean root weight was measured from the 10 random roots from each treatment discussed above. Roots with weight above 40 g were selected from each plot and their weight recorded as marketable yield. Harvest index: This was expressed as the ratio of total carrot dry weight to the total biomass dry weight and expressed in percentage.

$$\text{Harvest Index} = \frac{\text{Total carrot dry weight}}{\text{Total biomass dry weight}} \times 100$$

2.6 Statistical Analysis

The data collected was analyzed using GenStat version 11.1 (2008), according to the procedure of Steel and Torrie [17]. The treatment means were separated by the Least Significant Difference (LSD) at 5 % probability level.

3. RESULTS AND DISCUSSION

3.1 Initial Soil Physio-chemical Properties at the Experimental Site

The result of the initial physico-chemical properties of soil at Mampong-Ashanti in 2019 is presented in Table 1. The average Al^{3+} level was

0.48, which falls within the normal range (0.40-0.60) for sandy loams and un-compacted mineral soils [18,19]. According to the rating of Hazelton and Murphy [19], the available Ca^{2+}, H^{+}, K^{+}, Mg^{2+} and Na^{+} contents were generally low. This shows that application of external source of Ca^{2+}, H^{+}, K^{+}, Mg^{2+} and Na^{+} is important for growing carrots. The soil was neutral with low mean organic carbon content of 1.04 %. The available P content was medium with values ranging from 10.87 - 12.22 mg/kg soil.

The mean pH value was 5.90, which is slightly acidic according to the rating of Murphy [20]. The optimum pH for carrot production ranges between 5 and 8 [18]. Accordingly, the pH of the soil was conducive for carrot production. The organic carbon as well as that of total nitrogen content of the soil was medium according to the rating of Tekalign [21]. This shows that the soil was moderate in supplying organic carbon for soil biota and as a source of mineralized nitrogen for uptake mineral nitrogen by crops [19, 22]. Hence, it requires application of nitrogen for carrot production. The percentage clay and silt was moderate, whiles that of sand was high which was very good for carrot production. The soil bulk density ranged between 1.17 – 1.42. The observed soil bulk density falls within the normal range for sandy loams and un-compacted mineral soils [21, 22]. In general, the soil at Mampong-Ashanti had a low fertility status, which requires soil amendment Table 1.

3.2 Soil Nutrient Levels after Fertilizer Application

Different soil amendment significantly (P=.05) increased the levels of K, soil pH and soil bulk density after harvest Table 2. Although, no significant (P=.05) difference was observed on all the other soil properties, the mean values recorded were higher as compared to the initial physico-chemical properties of the soil. Results from Table 2 shows that experimental plots amended with 5 ton/ha poultry manure recorded the highest ($p < 0.05$) level of K, soil pH and soil bulk density with means of 0.88 (cmol/kg soil), 6.85 and 1.51 (Mg/m^3). On the other hand, the control plots where no amendment was carried out recorded the least K, soil pH and soil bulk density with means of 0.41 (cmol/kg soil), 6.14 and 1.31 (Mg/m^3). In general, the soil at the experimental site had improved fertility status due to the various soil amendment applied to the soil except the control plots.

3.3 Growth Parameters

3.3.1 Plant height

Plant height was significantly (P=.05) influenced by the different soil amendments throughout the period of study (Fig. 1). Carrot plants treated with 5 ton/ha poultry manure produced the tallest (P=.05) height at 4, 6, 8, 10 and 12 WAP respectively. The control treatment was the lowest on all sampling days. There was no significant (P=.05) effect of variety on plant height. Similarly, interaction effects were not significant (P=.05).

3.3.2 Number of leaves

Number of leaves was significantly (P=.05) influenced by the different soil amendments throughout the period of study. Carrot plants treated with 5 ton/ha poultry manure produced the highest (P=.05) number of leaves on all sampling days. The control treatment produced the least number of leaves on all days of sampling (Table 3).There was significant (P=.05) effect of variety on number of leaves at 4, 6, 8 and 10 WAP (Table 4). The Kuroda variety produced the highest (P=.05) number of leaves throughout the sampling periods. The least (P=.05) number of leaves was observed in the Tokita variety (Table 3).

There was significant ($p < 0.05$) interaction on number of leaves throughout the period of study. Number of leaves across the period of study was significantly higher in the combined effect of 5 ton/ha poultry manure and Kuroda variety, and the least number of leaves were observed in the combined effect of the control treatment and Tokita variety (Table 3).

3.3.3 Canopy spread

Carrot plants treated with 5 ton/ha Compost recorded the widest (P=.05) spread on all sampling days while the control treatment recorded the least spread on all days of sampling. The Kuroda variety recorded the widest spread across the period of study, whereas the least canopy spread was observed in the Tokita variety (Table 4). Interaction effects were not significant (P=.05).

3.4 Root and Leaf Parameters

The application of 5 ton/ha poultry manure produced the highest fresh root weight, root length, root diameter, marketable root weight.

The control treatment gave the least fresh root weight, root length, root diameter, marketable root weight. The highest unmarketable root weight was observed among the control treatment and lowest in the 5 ton/ha poultry manure treatment (Table 5a and 5b).There was no significant (P=.05) effect of variety, root and leaf parameters. Similarly, interaction effects were not significant (P=.05).

4. DISCUSSION

4.1 Plant Height

The increase in plant height at 4 WAP, 8 WAP, 10 WAP 12 WAP as a result of the application of 5 ton/ha poultry manure could be as a result of the ability of the poultry manure to supply nutrients for the growth of carrots. This could also be explained that poultry manure has the ability to improve soil organic matter, soil structure, soil chemical properties and soil microbial activity [23]. According to Chan et al. [24], animal manure supplies most of the chemical compounds necessary for plant growth. Similar, findings were reported by Dawuda et al. [25] and Song and Guo [26] who observed that carrot plant increased with increasing levels of poultry manure up to 10ton/ha. This finding also attest to an assertion made by Xu et al. [27] that the application of 5 ton/ha poultry manure and 10 ton/ha poultry manure recorded similar plant height which was significantly taller as compared to the other soil amendment groups.

4.2 Number of Leaves

The higher number of leaves observed between the different rates of soil amendment could be attributed to the high nutrient status of the soil as a result of the application of the poultry manure. This could be explained that amendments contained essential nutrient elements associated with high photosynthetic activities and thus promoted root and vegetative growth [28]. Similar result with respect to increase in vegetative growth in treatment that receives poultry manure rates was reported by Khan et al. [29].

4.3 Canopy Spread

The increased in canopy spread due to the application of 5 ton/ha compost might be as a result of improved nutrient supply, as well as positive manipulation of soil physical properties such as moisture retention, soil structure and aeration. Other studies by Khan et al. [29] and Wong et al. [30] have shown that application of compost to carrot leads to increase in plant height and number of branches. The Kuroda variety had the widest spread throughout the period of study and this could be attributed to the genetic variations between the two varieties.

4.4 Root and Leaf Parameters

The higher marketable root weight and yield observed in this study among the treated plots as compared to the control could be attributed to the

Table. 1. Initial physico-chemical properties of soil at the experimental site

Soil property	Min	Max	Mean	SD
Chemical properties				
Al^{3+}	0.44	0.53	0.49	0.06
Ca^{2+} (cmol/kg soil)	2.25	2.28	2.26	0.02
H^{+} (cmol/kg soil)	0.17	0.18	0.17	0.01
K^{+} (cmol/kg soil)	0.31	0.34	0.32	0.02
Mg^{2+} (cmol/kg soil)	0.38	0.45	0.41	0.04
Na^{+} (cmol/kg soil)	0.002	0.002	0.002	0.00
Organic matter (%)	1.01	1.08	1.04	0.04
P (mg/kg soil)	10.8	12.2	11.5	0.95
Soil pH (1:1 H_2O)	5.82	5.99	5.90	0.12
Soil organic carbon (%)	0.59	0.61	0.60	0.01
Total N (%)	0.06	0.07	0.06	0.007
Physical properties				
Clay (%)	7.88	7.98	7.93	0.07
Sand (%)	80.2	82.4	81.3	1.51
Silt (%)	10.7	11.9	11.3	0.90
Texture	Sandy loam			
Bulk density (Mg/m^3)	1.17	1.42	1.30	0.12

Table 2. Soil chemical properties after fertilizer application

Soil property	T1	T2	T3	T4	T5	LSD (0.05)
Chemical properties						
Al^{3+} (cmol/kg soil)	0.16	0.13	0.13	0.10	0.16	NS
Ca^{2+} (cmol/kg soil)	4.66	4.90	5.33	4.63	3.83	NS
K^{+} (cmol/kg soil)	0.41	0.88	0.43	0.56	0.76	0.19
Mg^{2+} (cmol/kg soil)	1.14	1.51	0.98	1.33	1.25	NS
Na^{+} (cmol/kg soil)	0.38	0.63	0.37	0.40	0.31	NS
N (%)	0.10	0.11	0.11	0.10	0.10	NS
Soil pH	6.14	6.85	6.44	6.65	6.32	0.42
Physical properties						
Organic matter (%)	1.98	2.01	2.08	1.91	2.01	NS
SOC (%)	1.15	1.17	1.20	1.11	1.17	NS
Clay (%)	12.5	8.00	9.00	12.5	10.5	NS
Sand (%)	78.0	82.0	81.0	77.5	79.5	NS
Silt (%)	22.0	18.0	19.0	22.5	20.5	NS
Bulk density (Mg/m^3)	1.31	1.51	1.42	1.41	1.38	0.12

Table 3. Number of leaves of carrot following treatment application

Treatment	Number of leaves in weeks after planting				
	4	6	8	10	12
Soil amendment					
T1= Control (No soil amendment)	3.75	4.76	6.66	7.83	9.14
T2= 5 ton/ha Poultry manure	4.68	6.57	9.82	10.94	12.85
T3= 45-45-45 kg/ha NPK	4.50	5.72	8.60	9.62	11.00
T4= 5 ton/ha Compost	4.62	6.20	8.16	9.05	9.99
T5= 5 ton/ha Biochar	4.42	5.98	8.28	9.11	10.94
LSD (0.05)	0.37 (S)	0.42 (S)	0.88 (S)	1.09 (S)	0.95 (S)
CV (%)	8.3	7.2	10.5	11.5	8.7
Variety					
Tokita variety	4.12	5.54	7.71	8.74	10.58
Kuroda variety	4.67	6.16	8.89	9.88	10.98
LSD (0.05)	0.25 (S)	0.43 (S)	0.75 (S)	0.85 (S)	0.98 (NS)
CV (%)	9.2	11.6	14.3	14.3	14.3
Interaction					
T1 * Tokita variety	3.25	4.27	5.52	6.33	7.87
T2 * Tokita variety	4.50	6.42	9.37	10.6	12.68
T3 * Tokita variety	4.22	5.62	8.07	9.40	11.28
T4 * Tokita variety	4.45	5.88	8.02	9.10	9.88
T5 * Tokita variety	4.20	5.50	7.57	8.25	10.85
T1 * Kuroda variety	4.25	5.25	7.80	9.32	10.40
T2 * Kuroda variety	4.87	6.72	10.27	11.25	13.02
T3 * Kuroda variety	4.77	5.82	9.12	9.85	10.72
T4 * Kuroda variety	4.80	6.52	8.30	9.00	10.10
T5 * Kuroda variety	4.65	6.47	8.97	9.98	11.03
LSD (0.05)	0.27 (S)	0.30 (S)	0.75 (S)	1.02 (S)	1.09 (S)
CV (%)	4.40	3.70	6.30	7.60	7.00

S = Significant at 5%, NS = Not significant at 5%, T = treatment, LSD = Least significant difference, CV = Coefficient of variation

application of the amendments which improved soil organic matter content, nitrogen, available P and also some soil physical properties such as bulk density and infiltration rate which improved marketable root weight and total yield of carrot. This result is in accordance with the findings of Daniel and Corey [31] and Benjamin and Hypolite [4].

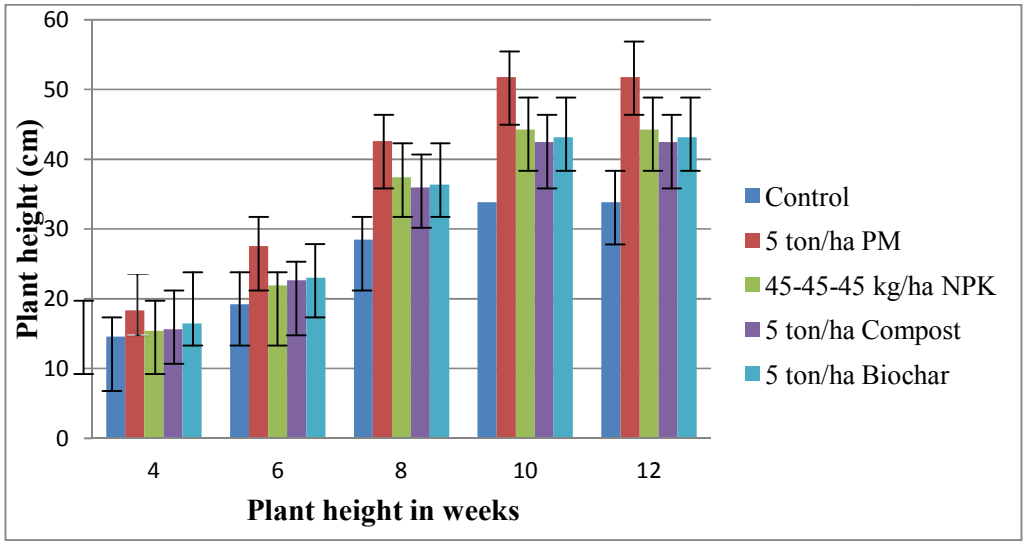

Fig. 1. Effect of different rates of soil amendment on plant height

Table 4. Canopy spread of carrot following treatment application

Treatment	Canopy spread (cm) in weeks after planting				
	4	6	8	10	12
Soil amendment					
T1= Control (No soil amendment)	14.32	18.34	30.77	40.88	43.25
T2= 5 ton/ha Poultry manure	17.24	21.56	37.69	44.75	48.62
T3= 45-45-45 kg/ha NPK	16.82	21.44	39.01	50.95	53.62
T4= 5 ton/ha Compost	18.25	24.69	41.40	55.16	57.75
T5= 5 ton/ha Biochar	17.04	21.90	39.65	46.10	50.38
LSD (0.05)	1.36 (S)	1.78 (S)	4.15 (S)	4.03 (S)	5.14 (S)
CV (%)	8.01	8.10	10.91	8.41	10.01
Variety					
Tokita variety	15.98	20.47	35.26	45.18	47.15
Kuroda variety	17.48	22.70	40.15	49.95	54.30
LSD (0.05)	1.07 (S)	1.54 (S)	3.09 (S)	3.76 (S)	3.79 (S)
CV (%)	10.1	11.2	12.8	12.4	11.7

S = Significant at 5%, NS = Not significant at 5%, T = treatment, LSD = Least significant difference, CV = Coefficient of variation

Table 5a. Root and leaf parameters of carrot following treatment application

Treatment	Total plant fresh weight (g)	Fresh leaves weight (g)	Fresh root weight (g)	Root length (cm)	Root diameter (cm)
Soil amendment					
T1= Control (No soil amendment)	104.02	42.01	62.01	14.34	31.94
T2= 5 ton/ha Poultry manure	133.52	43.90	81.42	18.90	47.86
T3= 45-45-45 kg/ha NPK	121.80	41.80	77.40	16.15	38.82
T4= 5 ton/ha Compost	125.51	44.91	79.21	16.01	38.44
T5= 5 ton/ha Biochar	124.41	43.22	76.40	15.71	36.20
LSD (0.05)	20.78 (NS)	7.76(NS)	13.51 (S)	1.19 (S)	4.05 (S)
CV (%)	16.6	17.7	17.7	7.2	10.3

S = Significant at 5%, NS = Not significant at 5%, T = treatment, LSD = Least significant difference, CV = Coefficient of variation

Table 5b. Root and leaf parameters of carrot following treatment application

Treatment	Marketable root weight (g)	Unmarketable root weight (g)	Harvest index	Yield (ton/ha)
Soil amendment				
T1= Control (No soil amendment)	0.98	1.23	0.55	0.64
T2= 5 ton/ha Poultry manure	1.74	0.44	0.61	0.84
T3= 45-45-45 kg/ha NPK	1.54	0.67	0.63	0.80
T4= 5 ton/ha Compost	1.24	0.51	0.61	0.79
T5= 5 ton/ha Biochar	1.40	0.67	0.63	0.82
LSD (0.05)	0.26 (S)	0.24 (S)	0.05 (S)	0.13(S)
CV (%)	0.19	0.34	8.4	17.4

S = Significant at 5%, NS = Not significant at 5%, T = treatment, LSD = Least significant difference, CV = Coefficient of variation

The highest fresh root weight, root length, root diameter, unmarketable root weight and harvest index observed from the application of 5 ton/ha poultry manure to carrot plants in this study could be attributed to the fact that poultry manure modifies the soil's performance by retaining moisture and making it available during periods of low precipitation. Unlike other fertilizers, poultry manure has an extremely long life in soils which improves soil fertility. Rashidi and Khabbaz [32] indicated that vegetables cultivated using poultry manure recorded bigger and more nutritious fruits. The authors also observed that if very low level of manure is applied, some problems may arise which include the production of light green leaves and curled or mottled leaves due to inadequate potassium. Furthermore, they reported that vegetables cultivated using poultry manure recorded bigger and more nutritious fruits. The combined effect of poultry manure and mineral fertilizer on crop yield was better than either of the two when applied on sole basis at all rates [25].

5. CONCLUSION

This study concludes that the vegetative growth of carrot recorded marked differences in the different amended plots as compared to the control plots. The application of 5 t/ha poultry manure had improved growth performance with higher productivity in terms of marketable root weight and total yield. This study recommends 5 ton/ha poultry manure to carrot farmers for higher productivity. Among the two varieties Kuroda was the best.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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