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Research article

Evaluation of different fertilizer sources for sustainable carrot production in Tehuledere district, northern Ethiopia

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A R T I C L E I N F O

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A B S T R A C T

The demand for organic agriculture has been growing due to concerns about the environmental and health impacts of chemical-intensive farming. The study aimed to investigate the effects organic fertilizers on carrot (Nantes) growth and yield in Tehuledere district. The experiment was conducted at two sites (Gobeya and Libannos) using four fertilizer types (vermicompost, conventional compost, mixture of the two, and inorganic fertilizer) and a control. The experiment was laid out in randomized complete block design with three replications, and data were analyzed using R-software. The study analyzed various growth (emergence percentage, plant height, leaf number, fresh weight, and dry weight of leaves), and yield (root length, root diameter, fresh weight of roots, marketable root yield, unmarketable root yield, and total root yield) parameters. Generally, fertilizer application improved ($p < 0.001$) growth and yield compared to the control. Vermicompost and inorganic fertilizer (NPSB) showed similar results ($p > 0.001$) but the highest values ($p < 0.001$) for most of the parameters (marketable yield was 41.7 t/ha±0.76 for vermicompost and 42.5 t/ha±1.14 for NPSB). However, NPSB could pose negative environmental impact that could not result in sustainability if used in excess and inappropriate (method and time) in particular. Therefore, carrot production using vermicompost is recommended for farmers of Tehuledere district and similar agroecological areas to enhance productivity while contributing to sustainable agriculture. The results have implications for policy makers, researchers, and farmers interested in promoting environmentally friendly and sustainable carrot production.

1. Introduction

Carrot (*Daucus carota* L.) is one of the most widely consumed root vegetables worldwide, renowned for its nutritional value and versatility. This vegetable contains phytochemicals, vitamins and pro-vitamins that prevent chronic diseases, such as cancer, cardiovascular disease, and diabetes [1,2]. In recent years, there has been a growing interest in organic agricultural practices, driven by concerns about the environmental and health impacts of conventional chemical-intensive farming. As a result, research into ecological organic carrot production has gained significant attention, aiming to develop sustainable and environmentally friendly approaches to enhance crop productivity. This proposed study seeks to investigate the effects of various organic fertilizer types on carrot growth, yield, and quality in the specific agro-climatic conditions of Tehuledere District. By examining the performance of carrot crops under different organic fertilizer treatments, this research aims to contribute valuable insights to sustainable agricultural practices, specifically in organic carrot production.

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Ethiopia, with its diverse agro-climatic conditions, provides a favorable environment for carrot cultivation. However, traditional agricultural practices in the country have heavily relied on synthetic fertilizers, pesticides, and herbicides, leading to soil degradation, water pollution, and negative impacts on human health. Consequently, there is a pressing need to transition towards more sustainable and eco-friendly farming methods. In recent years, several studies have explored the potential of organic farming as an alternative approach to improve agricultural sustainability. Organic fertilizers, such as compost, manure, and green manure, are considered essential components of organic agriculture, as they enhance soil fertility, increase nutrient availability, and promote beneficial soil microorganisms. Studies by Refs. [3,4] have demonstrated the positive effects of organic fertilizers on crop growth and yield in different regions of Ethiopia.

However, specific research on organic carrot production in Tehuledere District remains limited, and there is a knowledge gap regarding the comparative performance of different organic fertilizers on carrot crops in this region. Understanding the effectiveness of various organic fertilizer types on carrot growth in the specific agro-climatic conditions of Tehuledere District is crucial for farmers to adopt sustainable agricultural practices and improve their livelihoods.

The rationale behind this study is to address the challenges posed by conventional agricultural practices in Tehuledere District and explore sustainable alternatives for carrot production. By evaluating the performance of carrot crops under different organic fertilizer types, this research aims to assess the growth and yield response of carrot crops to various fertilizers commonly available in the area, and to investigate the economic feasibility and practicality of adopting organic carrot production methods for local farmers in Tehuledere District.

The primary research problem addressed in this study is the lack of comprehensive data on the performance of carrot cultivation using organic fertilizers in Tehuledere District. Consequently, farmers may be hesitant to shift from using inorganic fertilizer to organic practices due to uncertainty about its efficacy and economic viability. This study focuses on data of carrot yield under organic fertilizers; however, further study that include information on the soil before and after application of treatments, composts nutrient statuses before using, and weather condition during the experiment are important and lack of such information is considered as a limitation of the study.

The main objective of this research is to evaluate the performance of Nantes carrot under different types of fertilizers in Tehuledere District, Ethiopia. By addressing this objective, the study endeavors to contribute to the body of knowledge on ecological organic carrot production and offer valuable insights to farmers, policymakers, and researchers interested in sustainable agriculture in Ethiopia. The study aims to evaluate the growth and yield of Nantes carrot under various fertilizer types, and to identify the best fertilizer type for optimum yield and sustainable organic carrot production in Tehuledere district and for areas with similar agro-ecological condition.

2. Material and methods

2.1. Study area

The experiment was conducted in Tehuledere district at two different sites (Libannos and Gobeya) during 2022/2023 cropping season. Libannos is located at 11.3737° N latitude and 39.6906° E longitude, whereas Gobeya at 11.31° N latitude and 39.72° E longitude. The temperature of the two experimental sites was similar with maximum and minimum temperatures of 33 °C and 6.1 °C, respectively. Likewise, the two sites recorded similar precipitation amount with a total of 444 mm during the crop growing season. In general, Tehuledere district is characterized by uni-modal rainfall pattern [5].

2.2. Seed material

The kind of carrot seed used in the experiment was Nantes and was bought from a seed importer company located in Addis Ababa. Before planting, the seeds were first checked for their germination rate. According to Ref. [6], Nantes has orange color and cylindrical roots with a blunt end and strong leaves. Farmers are highly needed for its good adaptation in highlands (1600–2400 m and annual precipitation 760–1010 mm), for its high market demand, and for its good color, thick and long roots and sweet taste.

2.3. Fertilizer type and experimental design

This experiment evaluated different organic fertilizers for carrot production at Gobeya and Libannos (Haike Estifanos) in Tehuledere district and one inorganic fertilizer for comparison. Five treatments were used ($T_{1:}$ Vermicompost, $T_{2:}$ Conventional compost, $T_{3:}$ Combination of vermicompost 50 % and 50 % conventional compost, $T_{4:}$ inorganic fertilizer/NPSB/, and $T_{5:}$ control) and were replicated three times using Randomized Complete Block Design. Vermicompost and conventional compost rates were 3 t/ha and 12 t/ha, respectively. NPSB Fertilizer was used based on recommended rate. Vermicompost (vermi-compost) is the product of the decomposition process of organic matter like crop-residues using worms placed under a shade in a constructed bed. Conventional compost on the other hand is the most common compost used by smallholder farmers, which are produced for instance from weeds, herbaceous and bushy plants buried for six or more weeks in airtight condition. A plot size of 3 m by 3 m (9 m^2) with a spacing of 1 m between blocks and 0.5 m between plots was used.

2.4. Experimental field management

The types of soils of experimental plots were clay loam for Gobeya and sandy loam for Libanos. The land was ploughed three times using oxen. All treatments were applied on well prepared experimental plots. The carrot seeds were drilled on experimental plots with recommended row spacing. After sowing, all the necessary agronomic management practices were done whenever required to keep the plants in healthy growth.

2.5. Data type and data collection technique

2.5.1. Phonological and vegetative growth parameters

Emergence percentage (%): After emergence of first seedling of every treatment, the numbers of emerged seedlings were counted daily up to 14 days after sowing. Emergence percentage was calculated as: Emergence (%) $= \frac{\text{total number of emerged seedling}}{\text{tatal seeds sown}} * 100$.

Mean emergence time (MET): Was calculated as MET = (Σn x D)/Σn; where n: Number of seeds emerged at day D, and D: The number of days since the start of emergence test (sowing).

Plant height (cm): From the ground level to the tip of upper most part of 10 randomly taken plants in net plot area was measured at maturity using meter tape and the mean values was calculated and used for further analysis.

Leaf number: From ten randomly sampled plants in the net plot area was counted at the time when plants fully covered the ground surface and mean values was calculated and used for further analysis.

Fresh weight of leaves per plant (mg): Was recorded by weighing the fresh weight of ten randomly selected plants from net plot area using sensitive balance, and then the average value was computed and used for further analysis.

Dry weight of leaves per plant (mg): Leaves from ten randomly taken carrot leaves was cut in to small pieces and oven dried. After oven drying, the samples were weighed by an electrical balance and the dry matter content was calculated and used for further analysis.

2.5.2. Yield and yield related parameters

Root length (cm): The average length of ten randomly taken roots was recorded by a meter scale from the point of attachment of the leaves (proximal end) to the last point of the root (distal end) in each treatment combination.

Diameter of root (cm): Was recorded by measuring the root diameter about 2 cm below the root collar of ten randomly selected carrot roots harvested from the net plot area using caliper and the mean value was computed and used for further analysis.

Fresh weight of root per plant (g root/plant): Was recorded by weighing ten randomly selected carrot roots harvested from the net plot using sensitive balance and the mean value was computed and used for further analysis.

Root dry weight (g): Immediately after harvest, roots were cleaned thoroughly by washing with water and air dried. Then ten randomly taken carrot roots was cut into small pieces and sun dried for 3 days and then oven dried for 72 h at 70–80 °C temperature. After oven drying, the samples were weighted by an electrical balance and dry matter content was calculated.

Marketable root yield (t ha^{-1}): Carrot roots, which are free from mechanical damages, disease and insect pest attack, small sizes (<50 g) and cracks, was considered as marketable. The weight of such carrots harvested from the net plot area was weighed using scale and expressed as ton *per* hectare.

Unmarketable root yield (t ha^{-1}): Carrot roots which are diseased, insect pest damaged, cracked and under sized (<50g) was considered as unmarketable. The weight of such carrots harvested from the net plot area was weighed using scale and expressed as t/ha.

Total root yield (t ha^{-1}): Was calculated by converting the yield obtained from plots to hectare and expressed as t/ha.

2.6. Statistical analysis

Data were subjected to analysis of variance using R-software. We went for homogeneity test using scattered plots before we run the

Table 1
Emergence percentage and plant height of carrot under different fertilizers in Tehuledere district.

Treatment	Plant Height (cm)			Emergence Percentage (%)		
	Gobeya	Libanos	Mean ± SE	Gobeya	Libanos	Mean ± SE
V compost	28.2^{bc}	33^{c}	$30.6^{b} \pm 0.8$	92.6^{c}	94.1^{c}	$93.4^{b} \pm 1.3$
C compost	27.5^{bc}	31.6^{c}	$29.5^{b} \pm 0.8$	94.2^{c}	93.3^{c}	$93.8^{b} \pm 1.3$
V and C mix	27.6^{bc}	32.8^{c}	$30.2^{b} \pm 0.8$	92.9^{c}	95.1^{c}	$94^{b} \pm 1.3$
NPSB	31^{bc}	32.7^{c}	$31.9^{b} \pm 1.2$	92.6^{bc}	91^{c}	$91.8^{b} \pm 1.7$
Control	23.1^{ab}	18.9^{a}	$21^{a} \pm 0.8$	83.1^{ab}	80.3^{a}	$81.7^{a} \pm 1.3$
Mean ± SE	$27.5^{a} \pm 0.6$	$29.8^{b} \pm 0.5$	28.5	$91.1^{a} \pm 1$	$90.8^{a} \pm 1$	90.8
Range	16.5–35.4			76.8–98.6		
Interaction effect	**			NS		
SEM	1.15			1.6		
CV (%)	4 %			1.8 %		
Treatment effect	***			***		

*C=Conventional; V=Vermi; SE = *standard error; SEM = standard error of means*; CV = coefficient of variation; *** = significantly different at $p < 0.001$; ** = significantly different at $p < 0.01$; NS = not significant; Means with the same letter superscripts within same columns are not significantly different.

ANOVA and the data distribution were found homogeneous, where there were no residual variations. The treatment means were compared using Tukey test at 5 % level of significance. Locations effects and interaction between treatments and locations were also considered.

3. Results

3.1. Growth parameters of carrot under different fertilizers and locations

3.1.1. Height and emergence rate of carrot

Table 1 presents the results of the experiment, evaluating the plant height and emergence percentage of carrot under different fertilizer treatments. The fertilizer types significantly influenced ($p < 0.001$) the plant height and emergence percentage compared to the control group but no difference among the treatment groups ($p > 0.05$). The study also indicated that there was no significant interaction ($p > 0.05$) between treatments and the localities for the emergence percentage, leaf number, and fresh weight of carrot leaves. However, there was a significant interaction for the plant height ($p < 0.01$) and dry weight ($p < 0.05$) of carrot leaves (Tables 1 and 2).

3.1.2. Leaf number and weight of carrot

Table 2 presents the results on leaf number, leaf fresh weight, and leaf dry weight in the two locations using the five treatment groups. The data is presented in terms of mean values and standard errors, as well as the range of values. The fertilizers had varying effects on the aforementioned parameters. For instance, in leaf number, the highest was observed in the inorganic fertilizer (13 ± 0.8), while the control group (6.67 ± 0.5) had the lowest leaf number ($p < 0.001$).

3.2. Yield and yield related parameters of under different fertilizers and locations

3.2.1. Length, diameter and fresh weight of carrot root

The root length values across all treatments ranged from 11.3 cm to 19.4 cm (Table 3). It is evident that the highest mean root length ($p < 0.001$) is observed in the "inorganic fertilizer" with a value of 21.3 cm whereas the lowest mean root length is recorded in the "control group" with a mean value of 12 cm. The other treatments, namely "sole vermi-compost", "conventional compost" and " mixture of conventional and vermi composts", fall in between with mean values of 19.6 cm, 17.1 cm, and 18.3 cm, respectively. The root diameter values across all treatments ranged from 1.35 cm to 6.95 cm (Table 3). The highest mean root diameter ($p < 0.001$) is observed in the treatment groups of "sole vermi-compost" and "inorganic fertilizer" with a mean value of 5.6 cm. The range of fresh root weight values across all treatments ranged from 15.7 g/plant to 101.5 g/plant (Table 3). The highest mean fresh root weight (79.9 g/plant) was observed in the "sole vermi-compost" and "inorganic fertilizer" treatments.

3.2.2. Marketable, unmarketable, and total yields of carrot production

The result for the effects of fertilizer types on marketable yield, unmarketable yield, and total yield is presented in Table 4. Marketable yield refers to the quantity of crops that meet the quality standards required for sale or consumption. On the contrary, unmarketable yield refers to the quantity of crops that do not meet the required quality standards for sale or consumption. In this study, the highest marketable yield of carrot ($p < 0.001$) was found in the sole vermi-compost application (41.t/ha ±0.76). Total yield is the sum of marketable and unmarketable yields, representing the overall productivity of the carrot. The vermi-compost (45.5 t/ha ±0.9) and the inorganic fertilizer (45.6 t/ha ±0.9) treatments again resulted in the highest total yields ($p < 0.001$).

Table 2
Leaf number, leaf fresh weight and leaf dry weight of carrot under different fertilizers and two locations in Tehuledere district.

Treatment	Leaf Number			Fresh leave weight (g)			Dry leave weight (g)		
	G	L	Mean ± SE	G	L	Mean ± SE	G	L	Mean ± SE
V compost	12^{c}	12^{c}	12^{c}±0.5	31.8^{b}	64^{e}	47.9^{c}±1.8	8.4^{bcd}	6.77^{bcd}	7.58^{b} ± 0.5
C compost	10.7^{bc}	9.33^{abc}	10^{b} ± 0.5	20.5^{ab}	45.7^{cd}	33.1^{b} ± 1.8	6.4^{bc}	7.8^{bcd}	7.12^{b} ± 0.5
V–C mix	12^{c}	12^{c}	12^{c}±0.5	25.6^{b}	49.9^{d}	37.8^{b} ± 1.8	7.23^{bc}	9.43^{cd}	8.33^{b} ± 0.5
NPSB	13^{bc}	13^{c}	13^{c}±0.8	26^{abc}	58^{cde}	42.2^{bc}±3	7.62^{bc}	10.4^{d}	9.0^{b} ± 0.8
Control	7.3^{ab}	6^{a}	6.67^{a}±0.5	11.9^{a}	27.7^{b}	19.8^{a}±1.8	2.37^{a}	5.53^{ab}	3.95^{a}±0.5
Mean ± SE	11^{a}±0.4	11^{a}±0.3	10.6	23^{a}±2	49^{b} ± 1	36.9	6.4^{a}	7.99^{b}	7.2
Range	4.43–15.93			6.28–69.6			0.74–12.02		
Interaction effect	NS			NS			*		
SEM	0.75			1.88			0.77		
CV (%)	7 % 5 %						10.7 %		
Treatment effect	***			***			***		

*G = Gobeya; L = Libanos; C=Conventional; V=Vermi; SE = *standard error; SEM = standard error of means*; CV = coefficient of variation; *** = significantly different at $p < 0.001$; * = significantly different at $p < 0.05$; NS = not significant; Means with the same letter superscripts within same columns are not significantly different.

Table 3
Root length, root diameter and fresh root weight of carrot under different types of fertilizer in Tehuledere district.

Treatment	Root length (cm)			Root diameter (cm)			Fresh root weight (g)		
	G	L	Mean ± SE	G	L	Mean ± SE	G	L	Mean ± SE
V compost	19.4^{cde}	19.8^{cde}	19.6^{c}±0.3	6.23^{d}	4.97^{cd}	5.6^{c}±0.2	89.9^{f}	69.9^{de}	79.9^{d} ± 2.25
C compost	17.1^{b}	17.1^{b}	17.1^{b} ± 0.3	4.87^{cd}	4.17^{bc}	4.52^{b} ± 0.2	68de	47.3^{bc}	57.6^{b} ± 2.25
V and C mix	18.1^{bc}	18.5^{bcd}	18.3^{b} ± 0.3	5.37^{cd}	4.57^{cd}	4.97^{bc}±0.2	78.7^{ef}	61.7^{cd}	70.2^{c}±0.3
NPSB	20.2^{de}	20.5^{de}	21.3^{d} ± 0.4	5.5^{cd}	5.7^{cd}	5.6^{c}± 3.6	89.9^{ef}	70de	79.9^{d} ± 3.2
Control	12.2^{a}	11.9^{a}	12^{a}±0.3	2.47^{ab}	2.07^{a}	2.3^{a}±0.2	35.5^{ab}	22.2^{a}	28.8^{a}±2.25
Mean ± SE	17.8^{a}±0.3	17.6^{a}±0.2	17.4	4.89^{b} ± 0.2	4.29^{a}±0.2	4.5	72.4^{b} ± 1.8	54.2 ± 1.6	61.4
Range	11.3–19.4			1.35–6.95			15.7–101.5		
Interaction effect	NS			NS			NS		
SEM	0.41			0.34			3.08		
CV (%)	2.4 %			7.6 %			5 %		
Treatment effect	***			***			***		

*G = Gobeya; L = Libanos; C=Conventional; V=Vermi; SE = *standard error; SEM = standard error of means*; CV=Coefficient of variation; *** = significantly different at $p < 0.001$; NS = not significant; Means with the same letter superscripts within same columns are not significantly different.

Table 4
Marketable, unmarketable and total yields of carrot produced under different type of fertilizers in Tehuledere district.

Treatment	Marketable yield (t/ha)			Unmarketable (t/ha)			Total yield (t/ha)		
	G	L	Mean ± SE	G	L	Mean ± SE	G	L	Mean ± SE
V compost	44.3^{c}	39^{c}	41.7^{d} ± 0.8	5^{abc}	2.77^{a}	3.88^{a}±0.5	49^{c}	41.8^{b}	45.5^{d} ± 0.9
C compost	33.1^{b}	30^{b}	31.5^{b} ± 0.8	6.6^{bc}	4.03^{ab}	5.32^{a}±0.5	40^{b}	34^{c}	36.9^{b} ± 0.9
V–C mix	39.7^{c}	33.2^{b}	36.4^{c}±0.8	6.4^{bc}	3.47^{ab}	4.95^{a}±0.5	46^{b}	36.6^{c}	41.4^{c}±0.9
NPSB	42^{c}	43^{c}	42.5^{d} ± 1.1	4.2^{abc}	2.07^{a}	3.13^{a}±0.7	46^{b}	45.1^{b}	45.6^{d} ± 0.9
Control	20.5^{a}	19^{a}	19^{a}±0.76	10.3^{d}	7.87^{cd}	9.1^{b} ± 0.5	31^{a}	26.9^{a}	28.9^{a}±0.9
Mean ± SE	35.9^{b} ± 0.6	32.8^{a}±0.5	33.8	6.5^{b} ± 0.4	4.04^{a} ±0.3	5.4	42^{a} ±0.6	36.9^{a}±0.6	39.2
Range	16.7–46.6			0.751–11.65			24.1–52.1		
Interaction effect	NS			NS			NS		
SEM	1.07			0.66			1.33		
CV (%)	3.2 %			12.3 %			3.4 %		
Treatment effect	***			***			***		

*G = Gobeya; L = Libanos; C=Conventional; V=Vermi; SE = *standard error; SEM = standard error of means*; CV=Coefficient of variation; *** = significantly different at $p < 0.00$; NS = not significant; Means with the same letter superscripts within same columns are not significantly different.

4. Discussion

4.1. Growth parameters of carrot under different fertilizers and locations

The use of organic fertilizers (vermi-compost, conventional compost, and the mixture) had a significant effect ($p < 0.001$) on the plant height, emergence percentage, leaf number, fresh weight of carrot leaves, and dry weight of carrot leaves compared to the control. On the other hand, the mean value for the organic fertilizers were found similar ($p > 0.05$) results of the inorganic fertilizer (NPSB). However, the use of NPSB, while providing comparable result, may result in negative impacts on soil health and environmental sustainability [7]. So, organic fertilizers could be viable alternatives to inorganic fertilizers for improving carrot growth and yield. This finding was in line with other studies that have reported the positive effects of organic fertilizers on plant growth and health [8,9]. The result is also in line with [10] who reported organic fertilizers particularly vermicompost increased the overall yield.

4.1.1. Height and emergence rate of carrot

The different fertilizer types significantly influenced ($p < 0.001$) plant height and emergence percentage compared to the control group but no difference among the treatment groups ($p > 0.05$). For instance, using sole vermi compost, a maximum height of 30.6 cm was recorded while the control group had the shortest plants, with a mean height of 21 cm. The results suggest that all fertilizer treatments positively influenced plant height and emergence percentage of carrot crop compared to control group. The organic fertilizers showed comparable effects to the inorganic fertilizer on plant height and seed germination, indicating their potential as sustainable alternatives in carrot production. These findings align with previous research that demonstrated the positive impact of organic fertilizers on plant growth and health [8,9]. Additionally, studies on the use of organic fertilizers in agriculture have highlighted their ability to improve soil fertility, nutrient availability, and overall crop productivity [7,11]. The result of this study for carrot height (30.6 cm for vermicompost and 29.5 cm for conventional compost) was higher compared to the finding of [12] who reported 29.16 cm by applying compost around Wolkite. However, the range of plant height in this study (16.5 cm–35.4 cm) was lower than the findings of [13] who reported height ranging from 10 cm to 70 cm using different organic fertilizers. Similarly, the result of this study (30.6 cm for vermicompost) as lower in height compared to the finding of [14] who reported 43 cm by applying vermicompost that was measured according to Ref. [15]. Overall, the use of organic fertilizers enhances the height and germination of carrot significantly which is similar with [10] who reported vermicompost increased the height.

4.1.2. Leaf number and weight of carrot

The fertilizers had varying effects on leaf number and weight. For instance, in leaf number, the highest was observed in the inorganic fertilizer (13 ± 0.8), while the control group (6.67 ± 0.5) had the lowest leaf number ($p < 0.001$). The range values of leaf number (4.43–15.93) was far higher than the findings of [13] who reported a result ranging from 2 to 11 using different organic fertilizers. Similarly, the leaf number result of this study (12 for vermicompost) was higher compared to the finding of [14] who reported a leaf number of 9 via the application of vermicompost. However, the result of this study (12 for vermicompost and 10 for conventional compost) was lower in carrot leaf number compared to the finding of [12] that reported 15 via application of 75 t/ha compost in Wolkite area. NPSB showed statically similar results with the organic fertilizers like the vermi-compost in the study area; however, NPSB has negative environmental impact especially through improper application method and timing problem in developing countries like Ethiopia unlike in developed countries which is due to excessive use.

4.2. Yield and yield related parameters under different fertilizers and locations

All of the fertilizer types significantly improved ($p < 0.001$) the yield of carrot compared to the control group. Vermi-compost resulted in the highest mean values ($p < 0.001$) for root length, root diameter, root fresh weight, marketable yield, and total yield followed by the mixture of fertilizers, whereas the control had the lowest values for all parameters (Tables 3 and 4). The potentials of organic fertilizers particularly vermi-compost demonstrated improving the root yield of carrot. On the other hand, the use of the inorganic fertilizer, NPSB, provided comparable result with the vermi-compost ($p > 0.05$), while it may result in negative impacts on soil health and environmental sustainability [7]. These findings were consistent with the reports of [7,11] that have shown the beneficial effects of organic fertilizers on crop productivity, and have important implications for sustainable agriculture and the development of environmentally friendly farming practices. The study provides valuable information for farmers and researchers interested in sustainable and organic methods for improving carrot productivity. The result of this experiment indicated when vermicompost is solely applied on a farmland; it played a significant role on the yield and yield contributing traits in carrot. It is also similar with the report of [16] who indicated that vermicompost acts as an organic fertilizer, enriching the soil with essential nutrients, improving plant nutrition, and overall crop quality.

4.2.1. Length, diameter and fresh weight of carrot root

The root length values across all treatments ranged from 11.3 cm to 19.4 cm. It is evident that the highest mean root length ($p < 0.001$) is observed in the "inorganic fertilizer" with a value of 21.3 whereas the lowest mean root length is recorded in the "control group" with a mean value of 12 cm. The other treatments, namely "sole vermi-compost", "conventional compost" and " mixture of conventional and vermi composts", fall in between with mean values of 19.6 cm, 17.1 cm, and 18.3 cm, respectively. The results of this study (19.8 cm and 17.1 cm) for sole vermicompost and for conventional compost, respectively for root length were in line with the findings of [12] that reported 19.66 cm by applying conventional compost at a rate of 75 t/ha in Wolkite area. However, the root length of this study (19.8 cm) for sole vermicompost was higher compared to the finding of [14] who reported a carrot root length of about 17 cm using vermicompost. Root length is a critical parameter as it indicates the extent of root development and exploration of the soil. Longer roots generally imply better nutrient and water absorption capabilities, which can lead to overall plant health and growth. The significantly higher root length observed in the "inorganic fertilizer" treatment suggests that this fertilizer might have provided better nutrient availability, promoting root growth despite its impact on pollution of the environmental.

The root diameter values across all treatments ranged from 1.35 cm to 6.95 cm. The highest mean root diameter ($p < 0.001$) is observed in the treatment groups of "sole vermi-compost" and "inorganic fertilizer" with a mean value of 5.6 cm, while the lowest mean root diameter is recorded in the "control group" with a mean value of 2.27 cm. The result of this study (5.6 cm and 4.5 cm) for sole vermicompost and conventional compost, respectively for the root diameter was much higher than the findings of [12] that reported 1.7 cm in Wolkite area. Similarly, the root length of this study (5.6 cm) for vermicompost was higher than the finding of [14] who reported a root length of about 3.5 cm via vermicompost application. Root diameter plays a crucial role in providing mechanical support to the plant and affects nutrient uptake efficiency. Generally, thicker roots indicate a stronger and healthier root system. The significantly higher observed root diameters suggest that the treatment fertilizers may have contributed to root thickening and potentially improved structural support for the plants.

The range of fresh root weight values across all treatments ranged from 15.7 g/plant to 101.5 g/plant. The highest mean fresh root weight (79.9 g/plant) were observed in the "sole vermi-compost" and "inorganic fertilizer" treatments recording the same values. The result is in line with [10] who reported vermicompost increased the fresh root weight. The lowest mean fresh root weight was recorded in the "control" with a value of 28.8 g/plant. The result of this study (79.9 g/plant for vermicompost and 57.6 g/plant for conventional compost) of fresh root weight was much higher than the findings of [12] that reported 23.48 g/plant. However, the fresh root weight of this study (79.9 g/plant for vermicompost) was lower compared to the finding of [14] who reported a fresh root weight of about 91 g/plant using vermicompost. Fresh root weight is a critical indicator of plant growth and biomass production. A higher fresh root weight signifies increased root mass and, in turn, more nutrient and water absorption. The significantly higher fresh root weights in the treatments suggest that the fertilizers might have provided essential nutrients, leading to better root development and higher biomass production.

4.2.2. Marketable, unmarketable, and total yields of carrot production

Marketable yield refers to the quantity of crops that meet the quality standards required for sale or consumption. On the contrary, unmarketable yield refers to the quantity of crops that do not meet the required quality standards for sale or consumption. In this study, the highest marketable yield of carrot ($p < 0.001$) was found in the sole vermi-compost application (41.t/ha ±0.76). Statically similar result ($p > 0.05$) was obtained in the inorganic fertilizer (42.5 t/ha ±1.14) treatment group. On the other hand, the lowest mean marketable yield was recorded in the control group (19 t/ha ±0.76). The marketable yield of this study (41.7 t/ha) for the sole vermicompost was found higher than the finding of [14] who reported a marketable yield of about 38 t/ha by applying vermicompost. Lower unmarketable yield is desirable, as it indicates less wastage and better overall crop quality [16]. In this study, the control (9.1 t/ha ±0.45) treatment had the highest unmarketable yield ($p < 0.001$) compared to the treatment groups.

Total yield is the sum of marketable and unmarketable yields, representing the overall productivity of the carrot. The vermicompost (45.5 t/ha ±0.9) and the inorganic fertilizer (45.6 t/ha ±0.9) treatments again resulted in the highest total yields ($p < 0.001$). The lowest mean total yield was recorded in the control group (28.9 t/ha ±0.9). The other treatments (conventional compost, and combination of vermi-conventional composts) were in between with a mean values of 36.9 t/ha ±0.9 and 41.4 t/ha ±0.9, respectively. The marketable carrot yield of this study (41.7 t/ha) for the sole vermicompost treatment was in line with the finding of [14] who reported a marketable yield of about 42 t/ha by applying sole vermicompost fertilizer. However, this study resulted in 24.1 t/ha to 52.1 t/ha which was higher than the findings of [13] who reported a total carrot yield ranging from 22.2 to 47.6 t/ha using different organic fertilizers.

Overall, the results suggest that the fertilizers (sole vermi-compost treatment and inorganic fertilizer) were the most effective in terms of yield. These treatments demonstrated better crop productivity compared to the conventional compost and the combination of fertilizers. This could be due to the diverse input of organic materials which yields a broader spectrum of nutrients and trace elements in the vermicompost [17]. The study is in line with [18,19] who reported that vermicompost rised as a promising organic fertilizer for maintaining good crop growth and yield. Similarly [10], indicated vermicompost increased root dry weight. The control group had the lowest marketable yield, indicating the necessity for appropriate agricultural practices to improve the carrot yield [20]. The use of organic fertilizers not only enhance yield but also contributes to environmentally friendly farming practices and soil health improvement [9,21]. By adopting such practices, farmers in the study area can move towards more sustainable and eco-friendly agricultural methods.

5. Conclusion

The result of the experiment indicated that applications of the fertilizers in general played an important role and the potential of the organic fertilizers in particular are demonstrated in improving the growth and yield of carrot. Applications of the sole vermi-compost and inorganic fertilizer (NPSB) were found the most effective having better and comparable results. However, the application of inorganic fertilizer (NPSB) has negative environmental impact leading to unsustainable agricultural production. As a result, sole application of vermi-compost is recommended for farmers of Tehuledere district and similar agroecology for improving carrot productivity in organic methods while contributing for sustainable agriculture. As this study focuses on carrot related data, further study that include information on the soil before and after application of treatments, composts nutrient statuses before using, and weather condition during the experiment are important.

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Data availability statement

Data included in article.

Consent for publication

The authors have provided their consent for publication.

CRediT authorship contribution statement

Faris Hailu: Writing – review & editing, Resources, Project administration, Methodology. **Seid Hassen:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis. **Seid Hussen:** Writing – review & editing, Writing – original draft, Methodology. **Eshetu Belete:** Writing – review & editing, Writing – original draft, Methodology. **Tewodros Alemu:** Writing – original draft, Formal analysis.

Declaration of competing interest

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