

Influence of Organic and Inorganic Fertilizers on Root Yield, Yield Components and Shelf-Life of Carrot (*Daucus carota*)

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How to cite this paper: Amartey, J.N.A., Sarkodie-Addo, J., Dapaah, H.K. and Essilfie, M.E. (2025) Influence of Organic and Inorganic Fertilizers on Root Yield, Yield Components and Shelf-Life of Carrot (*Daucus carota*). *American Journal of Plant Sciences*, 16, 668-681.

<https://doi.org/10.4236/ajps.2025.165048>

Received: January 22, 2025

Accepted: May 24, 2025

Published: May 27, 2025

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Abstract

High soil fertility is pre-requisite to enhancing crop production and obtaining high yields. Field studies were conducted in the 2018 major and minor seasons to assess the yield, yield components and shelf-life response of carrot to organic and inorganic fertilizers and their combinations at the Multipurpose nursery research site at the College of Agriculture Education, AAMUSTED, Mampong-Ashanti, Ghana. A randomized complete block design with four replications was used. The treatments were: (i) 10 t/ha cattle dung (full CD), (ii) 10 t/ha poultry manure (full PM), (iii) 300 kg/ha NPK (full NPK), (iv) 10 t/ha *Gliricidia sepium* prunnings (full GP), (v) 10 t/ha *Leucaena leucocephala* prunnings (full LP), (vi) 1/2 CD + 1/2 PM, (vii) 1/2 CD + 1/2 NPK, (viii) 1/2 CD + 1/2 GP, (ix) 1/2 CD + 1/2 LP, (x) 1/2 PM + 1/2 GP, (xi) 1/2 PM + 1/2 LP, (xii) 1/2 NPK + 1/2 GP, (xiii) 1/2 NPK + 1/2 LP, (xiv) 1/2 PM + 1/2 NPK, and (xv) control (no amendment). Generally, the combinations of the organic and inorganic fertilizers produced greater root yield and yield components than the sole fertilizers and control (no amendment). The 1/2 PM + 1/2 NPK, and 1/2 CD + 1/2 PM treatments produced wider root diameter of 4.0 cm in the major and minor seasons, respectively. Root length of 23.0 cm and 20.6 cm was highest on full LP and 1/2 PM + 1/2 GP amended plots in both seasons. Carrot root yields in both seasons for the organic and inorganic combinations ranged from 24.3 - 54.2 t/ha, which was 9 - 14% greater than the sole fertilizers (22.2 - 47.6 t/ha) and 25 - 95% greater than the no amendment control (19.4 - 27.8 t/ha). The 5 t/ha CD + 5 t/ha GP (1/2 CD + 1/2 GP) and 5 t/ha CD + 5

t/ha PM (1/2 CD + 1/2 PM) produced the highest root yields in the major and minor seasons, respectively. Harvest index differed significantly among treatments only in the minor season, with 1/2 LP + 1/2 PM producing the highest HI. Averaged over both seasons, the highest number of forked, cracked and deformed roots was produced on full PM, 1/2 CD + 1/2 PM, 1/2 PM + 1/2 GP, 1/2 CD + 1/2 GP amended plots, while the least deformed, forked and cracked roots were obtained on the full NPK, full GP, full LP, 1/2 CD + 1/2 LP, 1/2 CD + 1/2 NPK and 1/2 LP + 1/2 NPK.

Keywords

Cattle Dung, Poultry Manure, *Gliricidia sepium*, *Leucaena leucocephala*, Yield and Yield Components, Shelf-Life

1. Introduction

Carrot (*Daucus carota* L.) is one of the exotic vegetables with high value and great demand in urban centres and is also a huge export potential crop in Ghana [1]. It is one of the major vegetable crops cultivated in Ashanti-Mampong and its environs in the Ashanti Region of Ghana. Farmers resort to the use of different organic soil amendments due to their low levels of income and inability to afford recommended levels of inorganic fertilizers [2]. Organic manures can serve as substitutes to inorganic fertilizers. Manures supply the required nutrients, improve soil structure, increase microbial population and at the same time maintain the quality of crop produce [3] [4]. According to Sanwal *et al.* [5], even though there are large quantities of easily available plant nutrients contained in inorganic fertilizers compared to organic manures, the presence of growth promoting agents in organic fertilizers are them important for enhancement of soil fertility and productivity.

The average yield of carrot in the tropics has been estimated at 8 - 12 t/ha, which is far lower than the world average estimated at 21 t/ha [6]. Plant residues applied either as compost or directly to the soil decompose to supply sufficient nutrient for plant growth. Poku *et al.* [7] observed that *Mucuna pruriens* applied at rate of 30 t/ha, resulted in high vegetative growth, greater root length and produced 6.67 t/ha yield of carrot. Adekiya *et al.* [8] also noted that pawpaw, neem, mesquite and moringa leaves used as green manure performed significantly higher than NPK in okra, with mesquite leaves increasing pod yield by 53% over NPK. On the contrary, Habimana *et al.* [9] using NPK (17:17:17) at 300 kg/ha reported higher marketable root yield (8.55 t/ha) than poultry manure at 10 t/ha (5.7 t/ha). Similarly, Kiran *et al.* [10] reported that NPK at 100-100-125 kg/ha gave greater root diameter, root length, root weight per plant, biomass weight per plant and root yield of carrot compared to that of 10 t/ha poultry manure and 15 t/ha goat manure used. Olorunmaiye *et al.* [11] also reported highest yields, greater root tuber girth and length of carrot under inorganic fertilizer (NPK) against different levels of poultry manure. However, a combination of half poultry manure + half FYM produced the

highest carrot root yield and quality compared with only FYM, leaf manures (LF), poultry manure (PM) and chemical fertilizers on carrot growth and yield [12]. Similarly, a combined application of 120 kg N/ha, 92 kg P₂O₅/ha + 30 t/ha of cattle manure produced greater total potatoes tuber yield [13]. Fruits length, girth, weight and yield were the highest for okra plants treated with 50:50:50 kg NPK/ha + 10 t/ha FYM compared with only organic, inorganic and biofertilizers [14]. According to Zakir *et al.* [15], yield and yield components as well as major nutrients and biochemical properties of carrot were higher from a combination of full dose of inorganic fertilizer and half recommended dose of biomeal. Therefore, there is a huge potential for integrated nutrient management for increased carrot production and post-harvest storage. It is hypothesized that the combined use of organic and inorganic fertilizers would provide synergistic effects for greater soil improvement and crop nutrients for crop growth, development and yields. While organic fertilizers improve soil physical conditions by increasing soil porosity and decreasing bulk density allowing smooth root penetration, the inorganic fertilizers supply readily available plant nutrients for greater plant growth and increased crop yields and productivity. This study investigates the effects of various organic and inorganic fertilizers, and their combinations, on carrot yield, yield components (root length, diameter, and defects), and shelf-life.

2. Materials and Methods

Field experiments were conducted during two rainy seasons in Ghana. The average maximum and minimum temperatures recorded during the experimental periods were 31.3°C and 23°C, respectively for the major season, and 30.9°C and 22.2°C, respectively for the minor season. Total rainfall recorded in the major and minor growing seasons was 628.9 mm and 561.4 mm, respectively. The average maximum and minimum relative humidity recorded were 92.67% and 71.34%, respectively, for the major season and 93.7% and 60.29%, respectively for the minor season. Some of the initial soil physical and chemical characteristics of the soils at the experimental sites, which belong to the Bediesi series of the Savanna Ochrosol and have been classified as Chromic Luvisol according to the FAO/UNESCO classification (FAO/UNESCO, 1988) are shown in **Table 1**.

Table 1. Initial physical and chemical characteristics of soils at the sites during the two growing seasons.

Seasons	Physical properties				Chemical properties								
	Sand	Silt	Clay	pH	Org. C	Total N	Org. matter	P	K	Mg	Ca	Fe	Mn
	-----% -----			1:2.5	-----% -----		-----	ppm	--	Cmol/kg)	--	- mg/kg -	
Major season	84	8	8	5.06	0.23	0.2	0.40	21.21	0.09	0.85	2.98	52.6	12.0
Minor season	82	9	9	4.72	0.45	0.06	0.72	18.26	0.22	0.93	1.07	55.4	255

Source: Primary data from study sites.

The experimental design used was a Randomized Complete Block Design (RCBD) with four replications. A total of fifteen (15) treatments studied were: (i) 10 t/ha cattle dung (CD) (Full CD); (ii) 10 t/ha poultry manure (PM) (Full PM); (iii) 300 kg/ha NPK (Full NPK); (iv) 10 t/ha *Gliricidia sepium* (GP) (Full GP); (v) 10 t/ha *Leucaena leucocephala* (LP) (Full LP); (vi) 5 t/ha cattle dung + 5 t/ha poultry manure (1/2 CD + 1/2 PM), (vii) 5 t/ha cattle dung + 150 kg/ha NPK (1/2 CD + 1/2 NPK); (viii) 5 t/ha cattle dung + 5 t/ha *Gliricidia sepium*; (1/2 CD + 1/2 GP) (ix) 5 t/ha cattle dung + 5 t/ha *Leucaena leucocephala* (1/2 CD + 1/2 LP); (x) 5 t/ha poultry manure + 5 t/ha *Gliricidia sepium* (1/2 PM + 1/2 GP); (xi) 5 t/ha poultry manure + 5 t/ha *Leucaena leucocephala* (1/2 PM + 1/2 LP); (xii) 150 kg/ha NPK + 5 t/ha *Gliricidia sepium* (1/2 NPK + 1/2 GP); (xiii) 150 kg/ha NPK + 5 t/ha *Leucaena leucocephala* (1/2 NPK + 1/2 LP); (xiv) 5 t/ha poultry manure + 150 kg/ha NPK (1/2 PM + 1/2 NPK) and (xv) No fertilizer (control). **Table 2** indicates the nutrient composition of the organic manures used.

Table 2. Nutrient composition of organic manures used in the field study.

Site	Treatments	% N	% K	% P	% Ca	% Mg	Fe mg/kg	Mn me/kg
Mampong major	Cattle dung	2.13	0.67	0.33	2.40	0.29	2741.00	40.90
	Poultry manure	2.41	0.87	1.35	0.64	1.05	1929.30	70.30
	<i>G. sepium</i>	3.64	0.69	0.26	1.44	0.70	519.60	33.70
	<i>L. leucocephala</i>	5.24	0.93	0.32	0.96	0.48	275.60	21.80
Mampong minor	Cattle dung	1.23	1.18	0.49	1.28	0.58	4837.60	178.20
	Poultry manure	2.21	1.15	1.20	3.85	0.68	1794.00	105.60
	<i>G. sepium</i>	4.51	1.33	0.31	1.92	0.53	201.80	79.60
	<i>L. leucocephala</i>	4.03	0.91	0.22	2.08	0.73	220.80	63.00

Carrot seeds were planted at a depth of 2 - 3 cm. Each plot size measured 2 m long × 1 m wide, with adopted plant spacing of 25 cm between rows × 10 cm within rows, which is the recommended planting spacing for carrot cultivation and widely used by farmers. Carrot variety Kuroda (TOKITA) was used. The poultry manure and the cow dung obtained from the deep litter system and the cattle kraal at the livestock farm of AAMUSTED were heaped under shade for one month to dry and further decompose before application. Leaves prunings of *Gliricidia sepium* and *Leucaena leucocephala* were harvested from the same farm. The organic manures and leave prunings were applied to the soil three weeks before planting the carrots to allow further decomposition in the soil. The beds were watered twice a week to help in the decomposition. The inorganic fertilizer (N.P.K. 15-15-15) was applied 3 weeks after planting. Supplementary irrigation was done every three (3) days, especially during the root formation period, and earthen-up was also done to cover exposed roots. Manual weeding was done

when necessary.

At harvest, five (5) carrot roots were randomly selected from the harvestable central rows for each treatment and their root diameter and root length measured. Roots harvested from the harvestable central rows were divided into cracked, forked and deformed roots and their numbers were counted. Carrot roots with splits on them were classified as cracked root, roots with two (2) roots emanating from a single root were classified as forked, while roots without the normal shape of carrot was classified as deformed. The total root yield was obtained from the roots harvested from the harvestable central rows of each treatment, and harvest index was estimated as a ratio of root yield to total plant biomass yield. The percentage weight loss, firmness, and percentage root wrinkling were estimated to assess the shelf-life of the harvested roots in storage at room temperature for 9 days when the roots were adjudged unsaleable. Percentage weight loss was determined as: $(\text{initial weight} - \text{final weight}) / \text{initial weight} \times 100$ [16]. A Digital Shore C durometer was used to measure the firmness of the carrot. The carrot was held in one palm and the instrument in the other. The durometer was zeroed, and pressure was exerted to push the plunger head into the root for about 3 seconds at three different sides of the root. Values were read and recorded in Newtons (N). Percentage wrinkling was determined by recording the extent of surface wrinkling. Any root with more than 40% surface wrinkle was adjudged wrinkled [17].

The data collected was analyzed using Analysis of Variance with GenStat Version 17 Statistical package. The Least Significant Difference (LSD) at 5% was used to determine treatment differences.

3. Results and Discussion

3.1. Root Length and Root Diameter

There were statistical differences ($P < 0.05$) in root length between the amended treatments and the control during the major and minor seasons (**Figure 1**). The full LP, full CD, full PM, 1/2 CD + 1/2 NPK and 1/2 CD + 1/2 PM had higher but similar root lengths in the major season, while in the minor season full PM, 1/2 CD + 1/2 NPK and 1/2 CD + 1/2 PM had higher but similar root lengths, which were significantly higher than that of the full NPK and control treatments. All the other treatment differences were not significant. Generally, the root length of various treatments was greater in the major season than the minor season. This could be attributed to the greater amount of rainfall (156.5 mm) in the major season compared with 140.4 mm in the minor season. Vanlauwe *et al.* [18] and Biratu *et al.* [19] have reported climatic and soil factors, as important factors that affect growth and yield of carrot. Agbede *et al.* [20] in their study concluded that sole or mixed forms of organic fertilizers showed significant improvement in soil physical conditions for improving agronomic productivity of yam compared with NPK and the control.

In the major season, full CD, 1/2 PM + 1/2 NPK and full GP treatment effects

had the widest root diameter, while the greatest root diameter was obtained in the full PM, 1/2 CD + 1/2 PM and 1/2 PM + 1/2 GP treatments in the minor season (as shown in **Figure 2**). Poultry manure was present in the treatments with the widest diameter, and this could be due to the rapid decomposition rate of the poultry manure, providing readily available nutrients to root for growth. Agbede *et al.* [20] reported that the application of PM + NPK fertilizer produced carrot root with higher diameters. Dawuda *et al.* [21] also reported increased root diameter of carrot with the application of poultry manure. From the study a range of 3.0 - 4.1 cm root diameter was obtained, and this was similar or within the range obtained by Mbatha *et al.* [22], who noted that the normal shoulder diameter of “Kuroda” was 3 - 5 cm. Statistically, all treatments were not significantly different from the control treatment. Similar findings by Ahmad *et al.* [12], Osaeyei and Bayor [23] and Fikadu and Refisa [24] indicated that carrot does not need much nutrients to give a meaningful root diameter. Phosphorus in organic manure enhances nitrogen uptake in plants by improving soil structure, promoting microbial activity, and increasing the availability of nitrogen for plants. Phosphorus acts as a catalyst, accelerating the conversion of organic forms of nitrogen into plant-available forms like ammonium and nitrate. Additionally, it stimulates root growth, expanding the surface area for nutrient absorption, and it can also improve the efficiency of nitrogen-fixing bacteria in legumes [25].

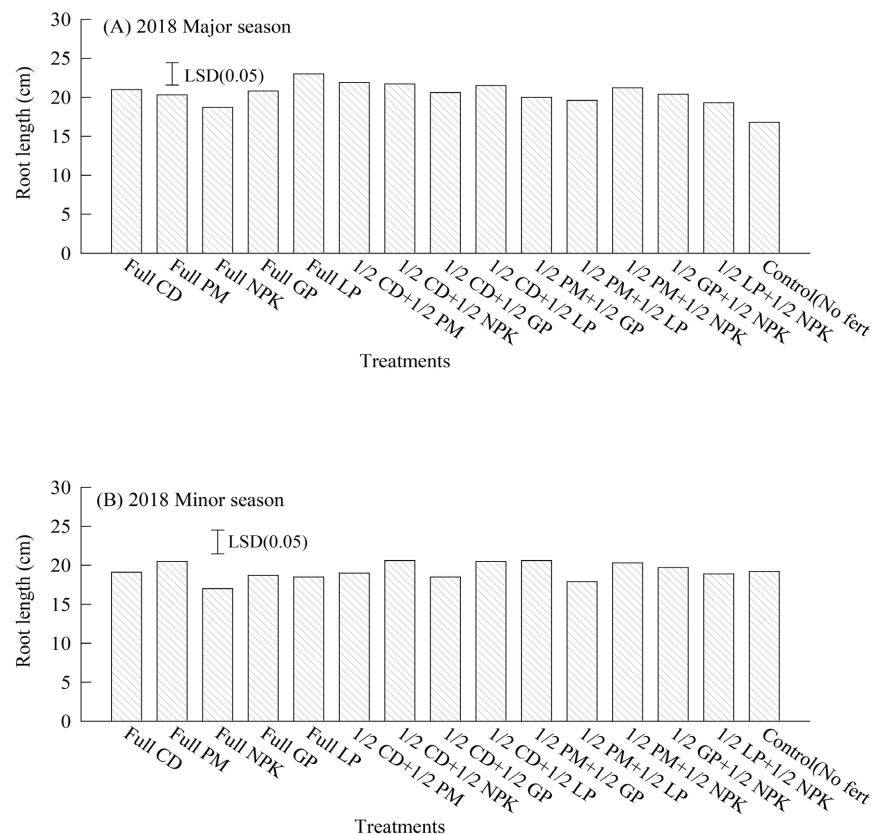


Figure 1. Root length of carrots as influenced by organic and inorganic fertilizers during 2018 major and minor seasons.

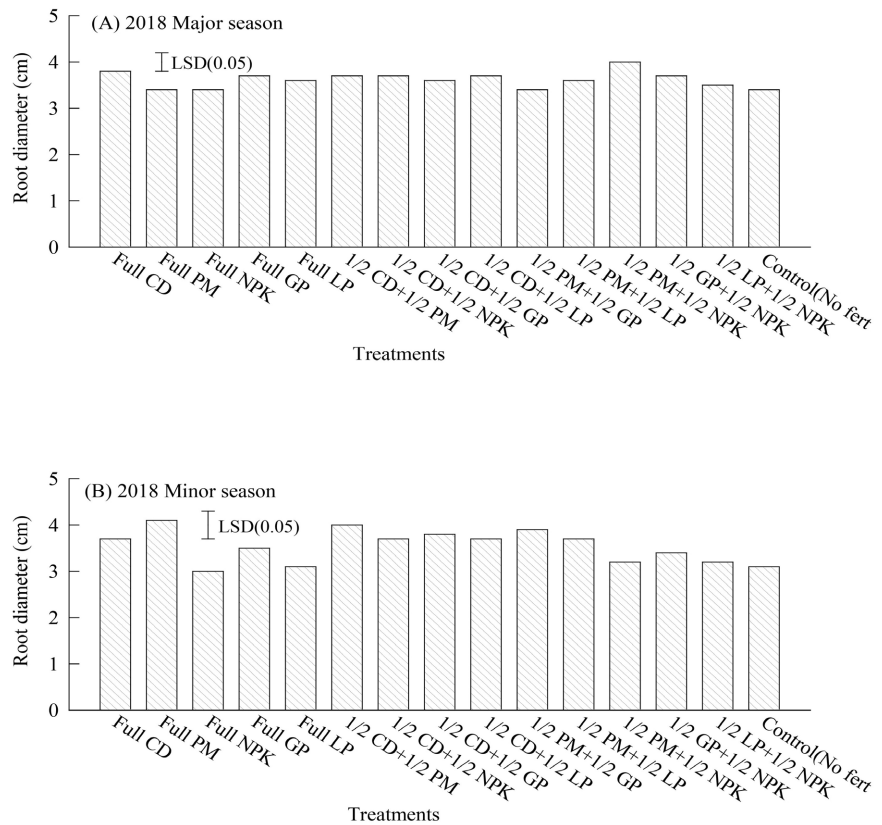


Figure 2. Root diameter of carrots as influenced by organic and inorganic fertilizers during 2018 major and minor seasons.

3.2. Number of Forked, Cracked and Deformed Roots

Averaged over both seasons, the highest number of forked, cracked and deformed roots was produced on full PM, 1/2 CD + 1/2 PM, 1/2 PM + 1/2 GP, 1/2 CD + 1/2 GP amended plots, while the least deformed, forked and cracked roots were obtained on the full NPK, full GP, full LP, 1/2 CD + 1/2 LP, 1/2 CD + 1/2 NPK and 1/2 LP + 1/2 NPK (Figure 3). These results agree with Zakir *et al.* [15], who reported that the application of organic manure reduced the marketable yield of carrot. Habimana *et al.* [26] in their study on the effect of poultry manure and NPK (17-17-17) on growth and yield of carrot also observed that 10 t/ha PM increased the number of forked roots. The influence of organic fertilizers on cabbage and carrots yield and quality showed that the development of forked roots was promoted by rate of organic fertilizer applied [27] and that large quantities of manure supplied to vegetables tend to result in their roots being cracked or forked [26]. Additionally, the results indicated that the number of deformed, forked and cracked roots was greater in the major season than in the minor season. This might probably be due to rapid growth and extension of the root because of higher rainfall in the major season. Bender *et al.* [28] made similar observations.

3.3. Root Yield and Harvest Index

The root yield was significantly influenced by amendments in both seasons (as seen

in **Figure 4**). The highest yields were produced on 1/2 CD + 1/2 GP and 1/2 CD + 1/2 LP applied plots in the major season (32.6 - 34.0 t/ha). These yields were 68 - 75% higher than the yield on the control (no fertilizer treatment). The rest of the treatments yielded 22.2 - 31.9 t/ha, which were 14.4 - 64.4% higher than the control (no fertilizer treatment).

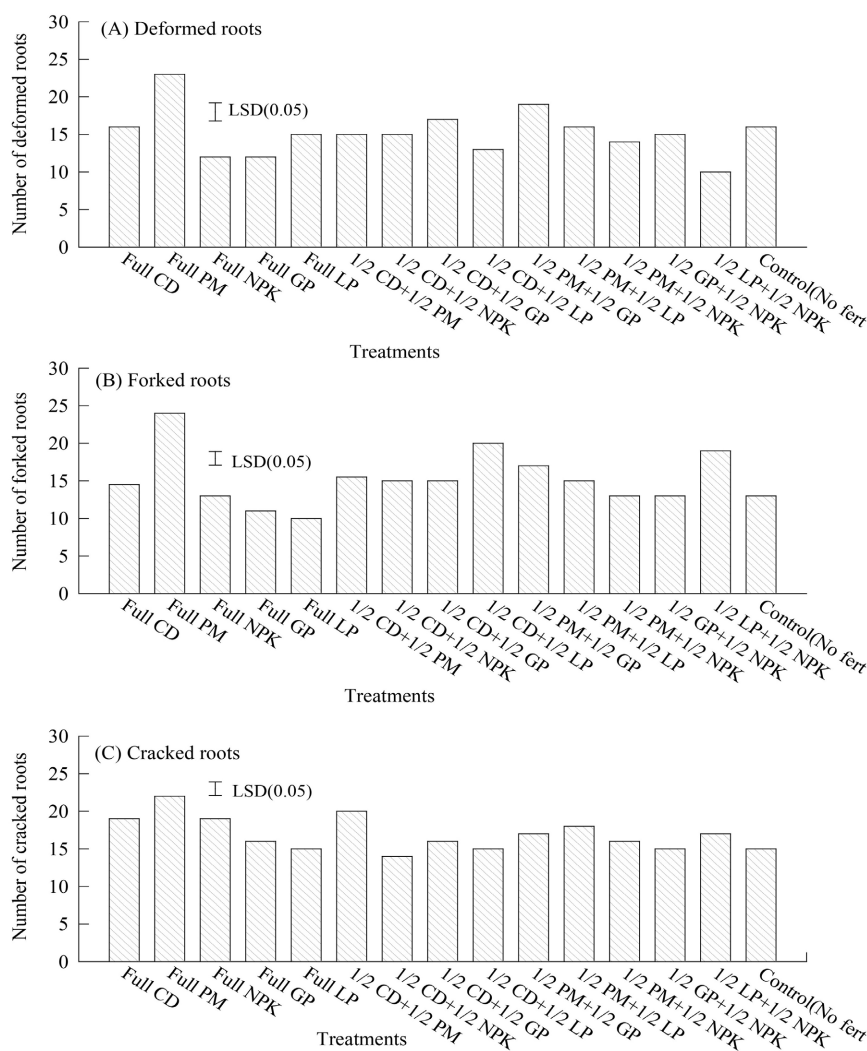


Figure 3. Number of deformed, forked and cracked roots of carrots averaged 2018 major and minor seasons as influenced by organic and inorganic fertilizers.

In the minor season, full PM, 1/2 CD + 1/2 PM and 1/2 PM + 1/2 GP produced the highest yields (47.6 - 54.2 t/ha), which were 71 - 95% more than the control treatment. The rest of the treatments on the average or overall yielded 33.02 t/ha in the minor season, which was 18.8% higher than the control (no fertilizer treatment). On the average, the organic + inorganic fertilizer combinations produced 34 - 40% higher root yields than their sole applications in the major season and 56 - 94% in the minor season. Animal or organic manures have been shown to supply required plant nutrients, improve soil structure and water holding capacity, in-

crease microbial population, and promote plant growth and carrot productivity [4] [29]. Mbatha [27] reported similar trends in yield increase with increase in manure application in carrots production.

The harvest index ranged from 0.55 - 0.58 and 0.61 - 0.74 in the major and minor seasons, respectively (Figure 5). There were no significant differences in harvest index among the treatments in the major season. However, in the minor season, full CD, full PM, 1/2 LP + 1/2 NPK and 1/2 CD + 1/2 PM had the highest harvest index, while full GP, 1/2 CD + 1/2 LP and 1/2 PM + 1/2 GP had the lowest harvest index (Figure 5). The control treatment had an intermediate harvest index, which was similar to a number of the amended plots. Appiah *et al.* [30] observed that the application of green manure and 300 kg/ha NPK (15:15:15) improved vegetative growth as well as increased yield of carrot which resulted in higher harvest index.

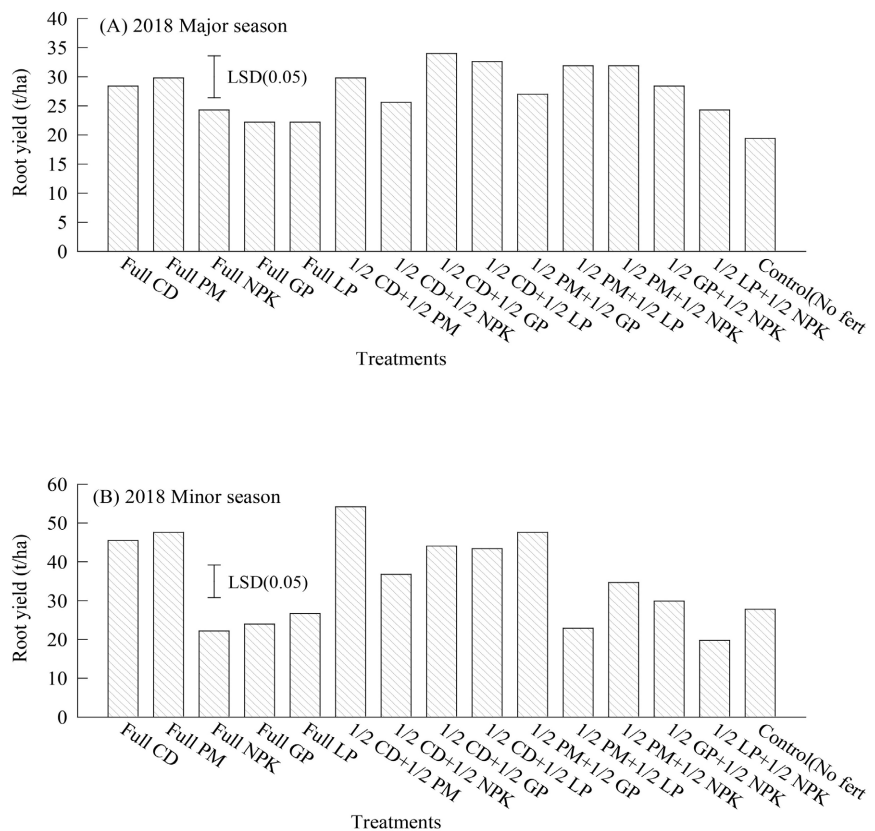


Figure 4. Root yield of carrots as influenced by organic and inorganic fertilizers during 2018 major and minor seasons.

3.4. Shelf-Life of Carrot Roots

Percentage weight loss, percentage loss in firmness and percentage wrinkling ranged from 34.8 - 42.3%, 30.1 - 37.7% and 38.8 - 58.8%, respectively in the major season (Table 3). In the minor season, the ranges were 32.8 - 48.3%, 13.9 - 30.7% and 13.3 - 33.0% for percentage weight loss, percentage loss in firmness and percentage wrinkling, respectively (Table 3). Generally, full LP and LP in combination with CD, PM

and NPK recorded the highest weight loss and loss in firmness, during both seasons. *Leucena leucocephala* is a leguminous plant and is known for its high nitrogen content. Hailu *et al.* [31] observed that carrots treated with the highest rate of nitrogen fertilizer lost greatest weight throughout the storage period. Similarly, Mark *et al.* [32] reported an increased weight loss in sweet potato under storage due to excess nitrogen fertilizer application. Weight loss and loss in firmness in carrot roots are principal causes of postharvest loss during storage and commercialization [33]. A weight loss of about 5% or higher causes wrinkling in most vegetables and affect consumer preference [34]. Generally, full PM and its combination with NPK, CD and LP had the least percentage weight loss, firmness and percentage wrinkling than the other treatments. The minor season also had lower percentage loss in firmness and wrinkling compared with the major season.

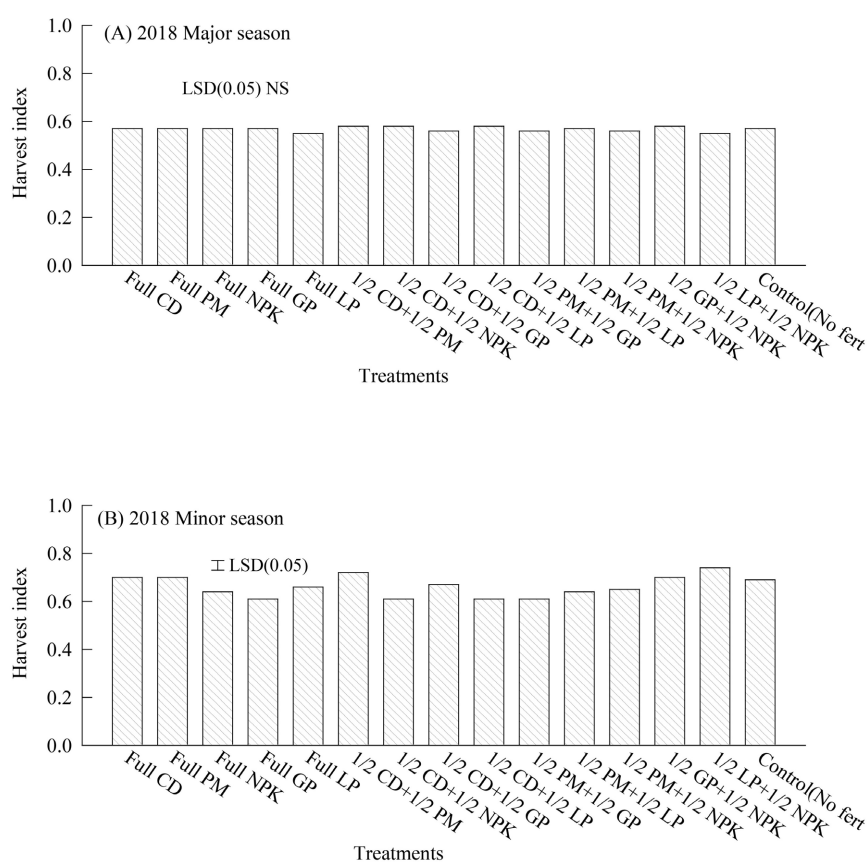


Figure 5. Harvest index of carrots as influenced by organic and inorganic fertilizers during 2018 major and minor seasons.

Table 3. Percentage weight loss, loss of firmness and wrinkling of carrot roots as influenced by organic and inorganic fertilizer.

Treatments	Percentage weight loss		Percentage loss of firmness		Percentage wrinkling of roots	
	Major	Minor	Major	Minor	Major	Minor
Full CD	37.3	38.0	36.6	25.3	54.5	21.0

Continued

Full PM	36.6	32.8	29.7	21.3	41.2	13.3
Full NPK	36.2	40.7	33.8	27.8	56.2	27.3
Full GP	36.1	36.6	33.9	21.3	53.2	23.0
Full LP	39.5	37.9	37.7	25.9	38.8	21.8
1/2 CD + 1/2 PM	40.8	32.2	31.7	23.7	53.8	16.3
1/2 CD + 1/2 NPK	38.7	36.9	31.4	23.4	48.0	21.0
1/2 CD + 1/2 GP	36.8	33.8	32.6	19.4	52.0	21.5
1/2 CD + 1/2 LP	42.3	37.3	30.6	19.5	57.5	31.8
1/2 PM + 1/2 GP	39.8	34.3	33.0	16.7	58.8	23.0
1/2 PM + 1/2 LP	38.0	48.3	30.1	28.6	45.8	17.8
1/2 GP + 1/2 NPK	39.6	43.7	32.1	19.3	49.5	25.0
1/2 LP + 1/2 NPK	41.4	47.2	34.1	30.7	56.2	33.0
1/2 PM + 1/2 NPK	34.8	34.7	30.0	13.9	51.2	25.0
Control	34.8	46.2	34.8	22.5	55.5	31.0
LSD ($P \leq 0.05$)	6.7	9.5	5.6	13.6	14.0	NS
C. V. (%)	16.0	20.4	18.6	19.4	19.8	6.2

4. Conclusion

The findings suggest that integrated nutrient management using a combination of organic and inorganic fertilizers enhances root yield and yield components compared to sole applications of either organic or inorganic fertilizers. Root length and root diameter were highest for 1/2 PM + 1/2 NPK, 1/2 CD + 1/2 NPK and 1/2 PM + 1/2 GP treatments in both seasons. The 5 t/ha CD + 5 t/ha GP (*i.e.* 1/2 CD + 1/2 GP) and 5 t/ha CD + 5 t/ha PM (*i.e.* 1/2 CD + 1/2 PM) produced the highest root yields during the major and minor seasons. Generally, across both seasons, the highest number of forked, cracked and deformed roots was produced on full PM, 1/2 CD + 1/2 PM, 1/2 PM + 1/2 GP, 1/2 CD + 1/2 GP amended plots, while the least deformed, forked and cracked roots were obtained on the full NPK, full GP, full LP, 1/2 CD + 1/2 LP, 1/2 CD + 1/2 NPK and 1/2 LP + 1/2 NPK.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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