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INTEGRATED NUTRIENT MANAGEMENT PRACTICES IMPROVE GROWTH AND YIELD OF CARROT

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Abstract

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Soil nutritional status and their availability to plant is an important abiotic factor influencing the vegetables productivity. Integration of farmyard manure (FYM), leaf manures (LF), poultry manure (PM) and chemical fertilizers have pronounced effect on carrot growth and yield. In this study, 14 treatment combinations of FYM, LF, PM and urea based on the total nitrogen requirement was tested for two carrot cultivars (T-29 and Oranza). The experiment was laid out in Randomized Complete Block Design (RCBD) with factorial arrangements and replicated thrice. Results indicated that T-29 was significantly better for all the growth and yield attributes as well as nutrient uptake in leaves except root firmness and root to shoot ratio where Oranza showed its superiority. Among different fertilizer treatment combinations of FYM, LM, PM and urea, both carrot cultivars performed better when half PM + half FYM was applied. Overall results revealed that combination of organic sources to meet nutritional requirements of carrot would be beneficial not only to improve carrot productivity but also reducing the rising input costs of inorganic fertilizers.

Key words: farmyard manure, leaf manure, poultry manure, carrot, yield

Introduction

Carrot is one of the major vegetable crops grown throughout the world (Vilela, 2004) and considered to be an important economical vegetable as it has large yield per unit area (Hassan et al., 2005). The inclusion of carrots in human diet is highly appreciated due to high nutritional and positive impact on human health and immunity systems (Bressani, 2000). This is cheaply available and is equally consumed by poor and rich people in Pakistan (Amjad et al., 2013). Soil is the basic pool of plant nutrients however; it does not contain adequate reserve to supply sufficient amounts of nutrient elements to meet the increasing requirements for higher production. Proper use of mineral fertilizers and organic manures is of significant importance for obtaining high yield and quality produce. These also play role to prevent adverse effects on soil health and environment (Rani and Mallareddy, 2007).

Excessive usage of inorganic fertilizers adversely affects soil health and environment. But indiscriminate application of inorganic fertilizer changes physical, chemical and biological properties of soil as well as reduces the fertility status of soil (Zakir et al., 2012). Manure is key factor in restoring the productivity of degraded soils as it supplies multiple nutrients, decreasing soil pH and improves soil organic matter, which in turn improves the physical and microbial properties of the soil (Zingore et al., 2007). Well-decomposed manure enhances the vegetative growth, fresh root yield and quality of carrots (Jeptoo et al., 2013). The main sources of organic matter in Pakistan are; cattle dung, urine, litter, crop residues/waste like sugarcane trash, straw, poultry, sheep and goat dropping, waste from fruit and vegetables, press mud from sugar industries, rice husk and bran/dust from textile industries. These all can be used for up lifting and maintaining organic matter

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to conserve soil fertility and physical condition to increase the fertilizer use efficiency (Khan et al., 2010).

Carrots have not been traditionally supplied with animal manures, such as poultry manure, applied before planting or as a side dressing. Nutrient content of poultry manures is the highest among all manures and provides appreciable quantities of all important plant nutrients (Sims and Wolf, 1994). It is relatively resistant to microbial degradation but essential for establishing and maintaining optimum soil physical condition and plant growth. It is also very cheap and effective as a good source of N for sustainable crop production while inorganic fertilizer is no longer within the reach of poor-resource farmers due to its high cost (Rahman, 2004). Poultry manure contains higher nitrogen and phosphorus compared to other bulky organic manures and average nutrients contents in poultry manure were N-3.03%, P-2.63% and K-1.4% (Guled et al., 2003). Research trials have indicated increased yield and advanced maturity using poultry manure as a pre-planting treatment without increasing the percentage of root forming (Phillips et al., 2002). Use of poultry manure or other animal manure not only increases the soil inorganic N pool (Abbasi et al., 2007) but also increases the seasonal soil N mineralization available to the crops (Ma et al., 1999). Keeping in view the importance of different nutrients for crop productivity, present study was designed to generate precise information for local farming community by assessing the efficacy of inorganic and organic fertilizers sources on carrot yield and quality.

Materials and Methods

Seeds of two commercially grown carrot cultivars Oranza (Nantes-type, F_1 Hybrid, Orange) and T-29 (Open Pollinated, Red) were obtained from Agricopak (Pvt.) Limited, Gujranwala, Pakistan and Ayub Agriculture Research Institute, Faisalabad, Pakistan respectively. Direct seeding was done on ridges to establish crop. Experiment was laid out in Randomized Complete Block Design (RCBD) with factorial arrangements and replicated three times. There were 14 treatment combinations based on the total nitrogen requirement of carrot viz., T_o (control), T_1 (FYM) , T_2 (PM), T_3 (LM) , T_4 (½ PM + ½ FYM), T_5 (½ PM + ½ LM); T_6 (½ LM & PM + ½ FYM), T_7 (Only chemical fertilizer please explain the rate), T_8 (¼ FYM+ ¾ chemical fertilizer), T_9 (¼ PM + ¾ chemical fertilizer), T_{10} (¼ LM + ¾ chemical fertilizer), T_{11} (¾ + ¼ chemical fertilizer), T_{12} (¾ PM + ¼ chemical fertilizer) and T_{13} (¾ LM + ¼ chemical fertilizer). The physic-chemical analysis of soil was before sowing the crop was given in Table 1. Nutrient sources used in the current study were farm yard manure (NPK: 0.29%:0.17%:0.35%), poultry manure (NPK: 1.63%:1.54%:0.85%), leaf manure (NPK: 0.20%:0.12%:0.18%) and urea (NPK: 46%:0:%:0%).

Data collection

Data on plant height, number of leaves plant^{-1}, leaf area (cm^2), root length, root diameter, harvest index, root firmness root: shoot ratio, flesh: pith ratio and juice recovery (%) were recorded from ten randomly selected plants at harvest. Leaf area was measured with the help of portable leaf area meter (CI-202 CID Inc.). The root firmness was measured according to the method outlined by Rashid et al. (2010) using a Hounsfield texture analyzer (Hounsfield Corp., UK). Root color was noted using visual scale for both the cultivars i.e. Pale red (1), Red (2) and Deep red (3) for T-29 and Pale Orange (1), Orange (2) and Deep Orange (3) for Oranza. Harvest index was calculated by the following formula:

Harvest index = Root yield/Root yield + vegetative yield ×100

The initial weight of ten carrot roots was noted and juice was extracted from Juicer/Blender (Model: MJ-W176P; Panasonic, Japan). The weight of carrot pomace was noted and juice recovery percentage was calculated by the following formula:

Percent juice recovery (%) = Total weight of carrot root/ Total weight of carrot pomace × 100

Determination of leaf nutrient elements

The cleaned young leaves were collected from each of the ten selected plants in a replication and dried in an oven for 48 hours at 65°C, cooled with a drying agent (Silica Gel) for 1 hour. Dried samples were ground to fine powder in an electric stainless steel grinder and stored in properly labelled airtight plastic bottles. Nitrogen (N) was determined as described by Chapman and Parker (1961). The digestion for estimation of P and K was done according to the method described by Yoshida et al. (1976). Potassium was determined by flame photometric while phosphorus by spectrophotometric method (Chapman and Parker 1961).

Table 1
Soil characteristics of the experimental site

Soil type	Sandy loam
N, %	0.04%
P, ppm	10.96
K, ppm	220
OM, %	0.49
pH	8.3
EC, dSm^{-1}	0.92

Statistical analysis

Analysis of variance of the data from each attribute was computed using the statistical software Statistica®. The Least Significant Difference test (LSD) at 5% level of probability was used to test the differences among mean values (Steel et al., 1997).

Results

Morphological traits

Data regarding plant height depicted significant differences between two carrot cultivars and it was highest (42.81 cm) in T-29 than Oranza (20.64 cm). Among different nutrient treatments, maximum (39.98 cm) plant height was recorded in T_4, which was statistically at par with T_{10}, T_{11} and T_3. However, minimum plant height (22.42 cm) was recorded in T_0 (Table 2). The interactive effect between cultivar × treatments was also significant for this trait (Figure 1A). The data pertaining to number of leaves illustrated significant superiority of 'T-29' (7.87) than 'Oranza'. Similarly all fertilizer treatments differ significantly with highest (8.67) number of leaves was recorded in T_4 while minimum (4.67) number of leaves were observed in T_0 (control) plants. Table 2 revealed that T_4 was statistically at par with T_{10} and T_{11} respectively (Table 2). However, interaction between cultivar × treatments was observed non-significant (Table 2). Both carrot cultivars differed significantly for leaf area and it was greater (245.38 cm^2) in 'T-29' than 'Oranza. As for as the effect of different fertilizer treatments leaf area is concerned, it was highest (257.06 cm^2) in T_4 which was statistically at par with T_5, T_6, T_7 and T_8 respectively. However, minimum leaf area was recorded in T_0 while interactive effect between cultivar × treatments was non-significant. Oranza depicted higher (71.23%) values of harvest index as compared to T-29 (47.25%). Among different fertilizer treatments, T_4 gave significantly higher (67.99%) harvest index followed by T_7, T_6, T_{11} and T_{12} respectively while it was minimum (49.99%) in T_0. The interaction between cultivar × treatments was non-significant (Table 2).

Yield and yield components

Both carrot cultivars showed significant differences for firmness and it was higher (2888.1 N) in Oranza than T-29 (2726.2 N). Among different fertilizer treatments, it was greater (3179.30 N) in T_4 followed by T_{10}, which was statistically at par with T_1, T_5, and T_6 respectively. However, minimum (2263.30 N) value for firmness was observed in T_0 (Table 2). Interaction between cultivar × treatments was observed significant (Figure 1 A). Both cultivars showed statistically similar response for root color but fertilizer treatments differ significantly for this trait as compared to control treatment (Table 2).

The cultivar T-29 exhibited significant superiority for root length and width over Oranza (20.49 cm & 29.63 mm). Similarly, both root length and width were highest (21 cm & 30.38 cm) in T_4 followed by T_{10} and T_{11} respectively while it was lowest in T_0 (Table 2). The interaction between cultivar × treatments was found significant (Fig. 1B). Significant differences in root fresh weight were observed for both carrot cultivars and it was highest (94.61 g plant^{-1}) in T-29 than Oranza (62.68 g). All the fertilizer treatments also differ significantly for this reproductive trait and it was higher (128.18 g plant^{-1}) in T_4 followed by T_9, T_6, T_{11}, T_{10} and T_3 while it was minimum (38.91 g plant^{-1}) in T_0. The interaction between cultivar × treatments was significant (Figure 1C).

Flesh to pith ratio was significantly higher (1.63) in T-29 than Oranza (1.53). All fertilizer treatments differ significantly for flesh: pith ratio and it was highest (1.76) in T_{13} followed by T_7, T_6, T_4 and T_2 respectively while it was minimum in T_0 (Table 2). Interaction between cultivar × treatments for flesh: pith ratio was non-significant. Data pertaining to root: shoot ratio exhibited significant superiority of Oranza (2.62) over T-29. Similarly, among different combinations of fertilizer treatments root: shoot ratio was significantly higher in T_4 (2.31) while it was statistically at par with T_9, T_{11}, T_7, T_{10}, T_{12}, T_3, T_6, T_1 and T_8 respectively. However lowest values (1.41) for flesh to pith ratio were recorded in T_0 (Table 2). Interaction between cultivar × treatments was non-significant (Table 2).

Maximum juice recovery (37.99%) was observed in T-29 than Oranza while T_4 indicated the highest (46.53%) juice recovery among different treatments and it was statistically at par with T_2, T_3 and T_9 respectively. However, minimum juice recovery (16.92%) was recorded in carrots grown in T_0 plants (Table 2). Interaction between cultivar × treatments was significant and both cultivars gave highest juice recovery in T_4 (Figure 1D).

Leaf nutrient contents

Data regarding leaf nitrogen, phosphorus and potash contents indicated that their concentration was higher (2.39%, 0.23% and 3.07%, respectively) in 'T-29' than Oranza'. All fertilizer treatments differed significantly than control and T_4 showed its superiority for N, P and K uptake in carrot leaves. The highest leaf nitrogen was observed in T_4 followed by T_2, T_{10}, T_{11}, T_1 and T_{13} respectively. Similarly, T_4 gave higher (0.40%) values for phosphorus contents and it was statistically at par with T_1, T_9, T_{11}, T_8, T_{13} but differ significantly with followed by T_{13}, T_7, T_{10} , T_6 and control. The highest (3.14%) values were observed in T_4, which was sta-

Table 2
Effect of cultivars and different fertilizer treatments on carrot productivity

Cultivars, C	Plant height, cm	Number of leaves	Leaf area, cm^2	Harvest Index, %	Firmness, N	Root color	Root fresh weight, g $plant^{-1}$	Root length, cm	Root diameter, cm	Flesh:Pith ratio	Root: shoot ratio	Juice recover, %
T-29	42.81 a	7.87 a	245.38 a	1.04 b	2726.2 b	2.85 a	94.61 a	20.49 a	29.63 a	1.63 a	1.04 b	37.99 a
Oranza	20.64 b	7.48 b	204.09 b	2.62 a	2888.1 a	2.85 a	62.68 b	15.05 b	23.81 b	1.53 b	2.62 a	30.08 b
LSD value	2.001	0.3132	9.919	0.235	33.542	.056	4.884	0.834	1.378	0.060	0.235	2.699
Treatment (T)												
T_o = Control	22.42 e	4.67 g	93.47 f	49.95 g	2263.30 i	2.47 d	38.91 h	11.25 e	16.63 d	1.41de	0.96 d	16.92f
T_1 = FYM	36.35 ab	8.48 ab	219.00 d	53.79 defg	2982.2 bc	2.63 c	78.17 def	16.15 d	24.77 c	1.56 bcd	1.77 abc	36.26 cd
T_2 = PM	29.18 cd	8.15 abc	248.28 ab	53.25 efg	2756.00 efg	2.98 a	59.43 g	17.34 cd	28.15 abc	1.64 abc	1.66 bc	45.19 ab
T_3 = LM	37.77 a	7.83 bcd	241.89 abc	57.30 cdef	2528.30 h	2.75 bc	82.67 cde	18.56 bc	26.89 abc	1.53 cd	1.86 abc	38.79 bc
T_4 = ½ PM + ½ FYM	39.98 a	8.67 a	257.06 a	67.99 a	3179.30 a	2.88 ab	128.18 a	21.00 a	30.38 a	1.76 a	2.31 a	46.53 a
T_5 = ½ PM + ½ LM	29.80 cd	7.20 def	245.00 abc	52.43 fg	2844.00 de	2.91 a	74.58 def	17.97 bcd	28.67 ab	1.54 cd	1.80 abc	34.19 cde
T_6 = ½ LM & PM + ½ FYM	32.00 bc	8.40 ab	256.16 a	64.89 ab	2963.70 bc	2.93 a	91.50 bc	18.95 abc	27.56 abc	1.70 ab	1.81 abc	33.19 cde
T_7= chemical fertilizer	27.13 cde	7.43 cdef	256.50 a	65.26 ab	2748.3 fg	2.88 ab	75.67 def	19.10 abc	29.32 ab	1.71 ab	2.07 abc	30.94 de
T_8 = ¼ FYM+ ¾ chemical fertilizer	27.96 cd	7.00 ef	253.36 a	60.05 bcde	2903.70 cd	2.95 a	72.00 defg	16.13 d	27.87 abc	1.50 cde	1.77 abc	34.09 cde
T_9 = ¼ PM + ¾ chemical fertilizer	30.67 cd	7.80 bcde	233.85bcd	60.88 abcd	2695.30 g	2.93 a	99.17 b	18.03 bcd	26.68 bc	1.58 bc	2.26 ab	36.00 cd
T_{10} = (¼ LM + ¾ chemical fertilizer	38.10 a	8.87 a	215.33 d	59.12 bcdef	3031.7 b	2.93 a	79.97 cde	19.73 ab	27.40 abc	1.64 abc	1.96 abc	30.03 de
T_{11} = ¾ + ¼ chemical fertilizer	37.78 a	8.85 a	219.60 cd	61.88 abc	2775.70 efg	2.95 a	84.57 cd	19.50 abc	26.78 abc	1.57 bc	2.07 abc	27.17 e
T_{12} = (¾ PM + ¼ chemical fertilizer	28.90 cd	6.80 f	181.35 e	62.03 abc	2835.70 def	2.90 a	70.33 efg	17.32 cd	25.85 bc	1.36 e	1.86 abc	30.06 de
T_{13} = ¾ LM + ¼ chemical fertilizer	26.07 de	7.10 def	225.42bcd	60.56 bcd	2793.30 ef	2.85 ab	65.83 fg	17.70 bcd	27.13 abc	1.64 abc	1.49 cd	37.16 cd
LSD value	5.2958	0.8287	26.242	7.1432	88.744	0.1479	12.922	2.2083	3.645	0.1593	0.621	7.1433
Interactive effect = C x T	*	NS	NS	NS	NS	NS	*	*	NS	NS	NS	*

Mean having different letters differ significantly at 5% probability. *= significant NS= Non Significant

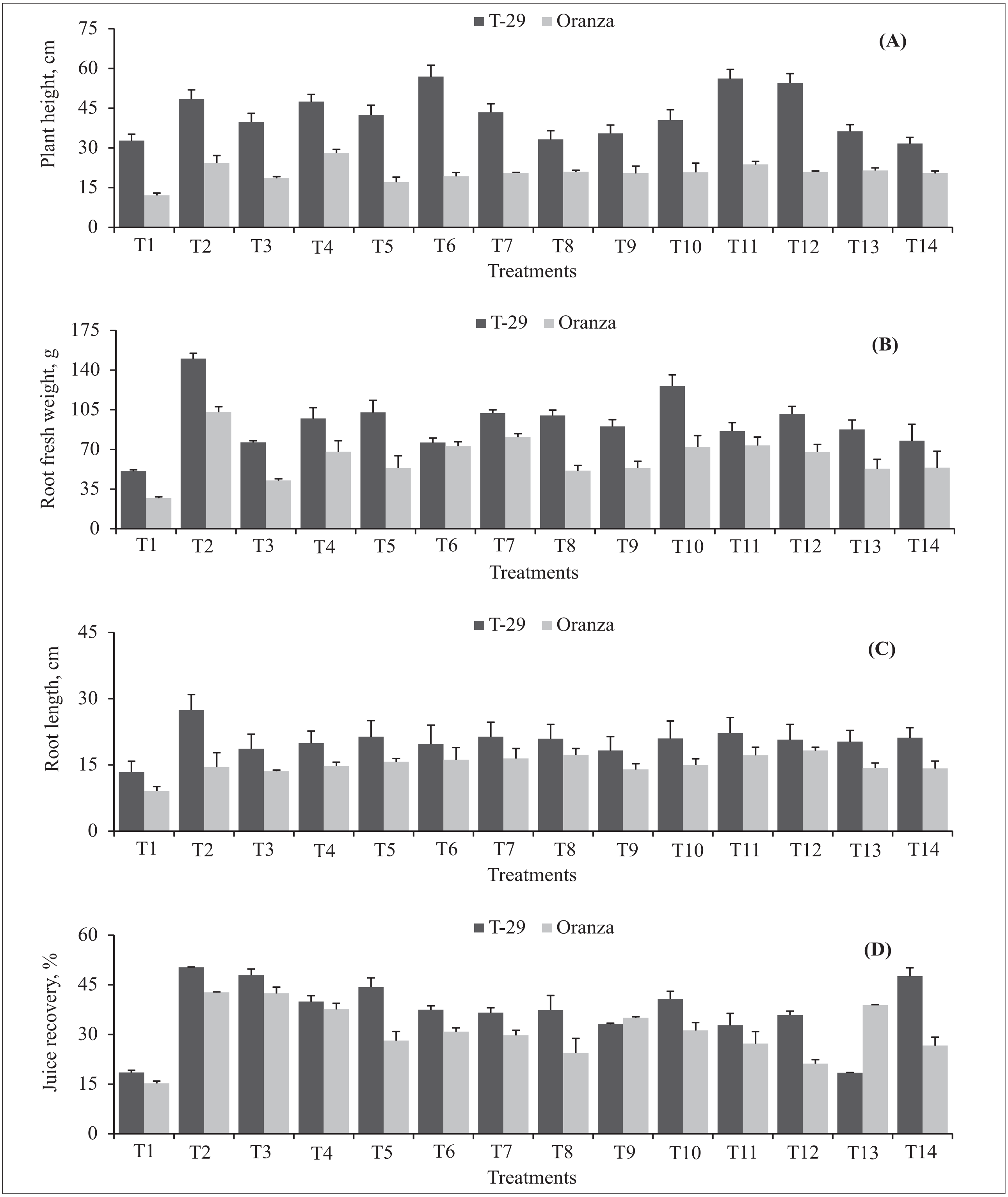

Fig. 1. Interactive effect between cultivars × treatment on (A) plant height, (B) root fresh weight per plant, (C) root length and (D) juice recovery; Vertical bars indicate standard error. n= 3 replicates

tistically at par with T_3, T_{11}, T_2, T_1, T_7, T_5, T_{13}, T_8 and T_{10} followed by T_9, T_{12} whereas minimum potash contents were observed in T_0. Interaction between cultivar × treatments was observed significant for leaf N, P and K contents (Figures 1 and 2).

Discussion

Morphological parameters

Present results indicated that both cultivars and fertilizer treatments differed significantly for plant height, num-

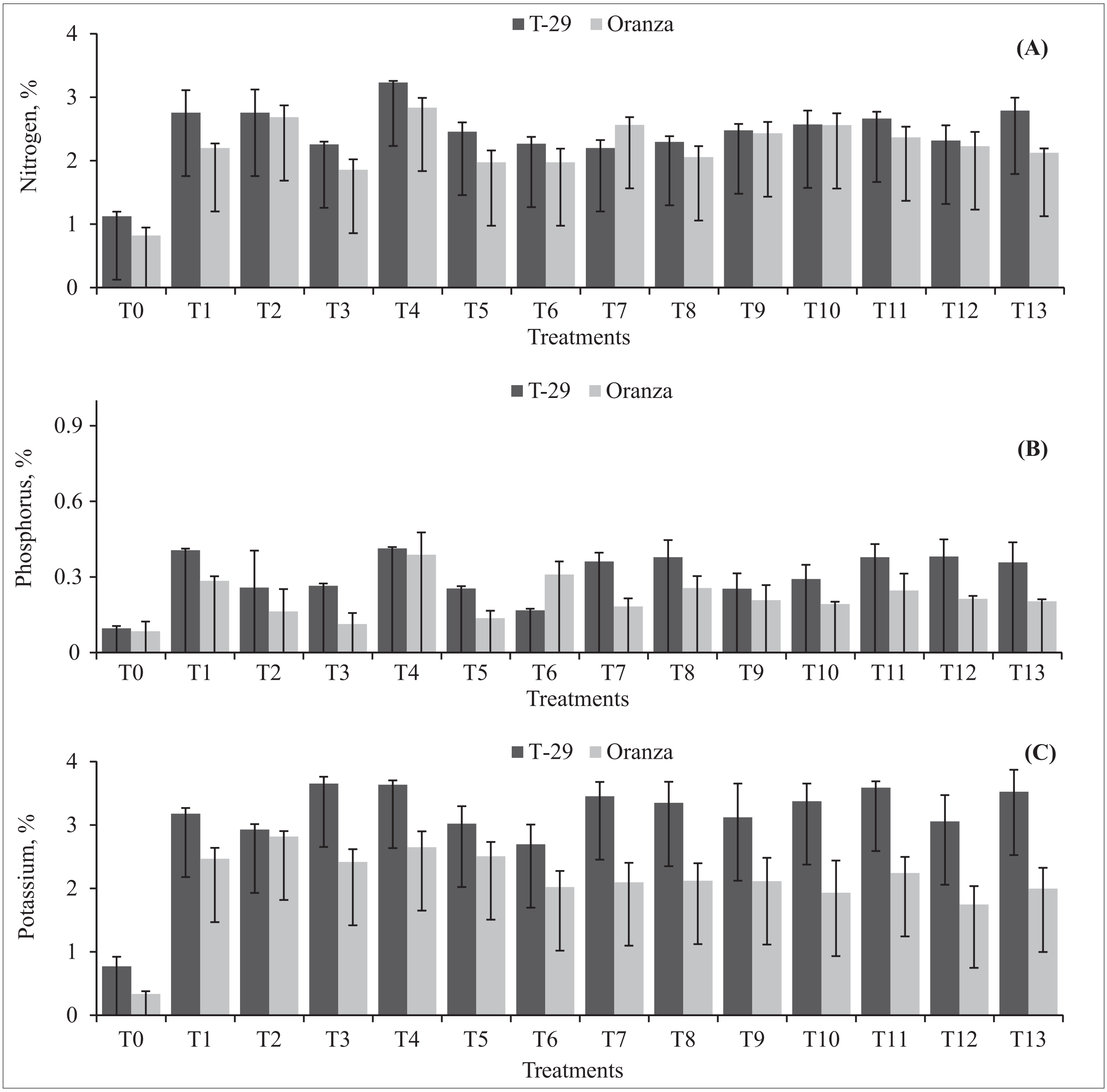

Fig. 2. Interactive effect between cultivars × treatment on (A) leaf nitrogen, (B) leaf phosphorus and (C) leaf potassium content; Vertical bars indicate standard error

ber of leaves and leaf area with 'T-29' showed superiority over 'Oranza'. All treatment combinations from different nutrient sources significantly increase plant height, number of leaves and leaf area than control in both carrot cultivars. This could be attributed to the improvement in soil structure and enhanced nutrient and moisture availability and uptake that may have favoured plant growth due to application of organic fertilizer. Leaf area fairly gives a good idea of photosynthetic capacity of the plant. Significant differences were noticed with regard to leaf area among the treatments and cultivars. The treatment T_4 showed significantly higher leaf area which could be due to increased cell division and elongation resulting in increased leaf expansion, more number of leaves due to beneficial influence of bio-fertilizers which release growth promoting substances and enhances the availability of nitrogen (Mog, 2007). Both T-29 and Oranza depicted higher root biomass under different fertilizers treatments, which might be due to, increased translocation of assimilates from leaf to the economic part as reported elsewhere (Ali et al., 2003).

Yield related parameters

Firmness in carrots is very important for the maintenance of proper texture and it depends on the moisture contents of the carrot roots. Greater the moisture contents in carrot roots, lesser will be the firmness. In present study, less firmness in T-29 could be due higher moisture contents as compared to Oranza. Root color of both carrot cultivars was better for all treatments than control, which indicated that the carrots grown with different combination of manures accumulated more carotenoids than control, and showed more intense color. Amount of total carotenoids and the accumulation of specific pigments is the main determinant of the visual color of carrot roots (Umiel and Gabelman, 1971). The amount of carotene and color of the root are determined genetically as well as growing conditions in the field. Generally, the carotene concentration correlates with an orange/red color and increases with light, fertilizer and age (Northolt et al., 2004).

Root length of carrot depends on the physical characteristics of the soil. The highest root length in T_4 might be due to the positive effects of FYM and PM on the physical characteristics of soil. Primarily, root diameter is a cultivar characteristic as different cultivars have different shape and size of the root. Secondly, different types and amount of fertilizers have significant effect on plant growth and development. In present study, difference in root size might be due to variation in genotype and fertilizer combinations. These findings are also in accordance as reported by Mog (2007) that different combinations of organic significantly affected root length and diameter and biofertilizers. The minimum size of carrot roots was witnessed in control than all other fertilizer treatments. In general, root fresh weight of both cultivars was greater for all fertilizer treatments as compared to control, which indicated that the carrots grown with different combination of fertilizers/manures accumulated more nutrients than control, and showed better growth and yield. These results are supported by the findings of Mog (2007) and Dawuda et al., 2011) that fresh weight of root was influenced by organics and bio-fertilizers as compared to control but in contradiction with Wudiri and Henderson (1985) that under high nitrogen application the plant grew well but had low yield because the vegetative growth was favored over root growth. They observed decrease in root weight due to excess N- fertilizer application above the recommended rate, which could be associated with the enhanced vegetative growth of carrot rather than root development due to high rate of N-fertilizer.

Both carrot cultivars differ significantly for root to shoot ratio under different treatment combinations and it was higher in Oranz. Root: shoot ratio is used as an indicator of efficiency of root production in relation to shoot growth. Growers sometimes relate greater shoot growth with greater root yields. Higher shoot growth with greater root: shoot ratios would point out more proficient root production, which is desirable for carrots (Hochmuth et al., 2006). Carrot juice is gaining attractiveness due to its reasonably lower cost than other fruit juices and high nutritive value. Mainly, juice recovery depends on the moisture contents in carrot root and the type of machine being used for extraction of juice. As the dry matter contents are less in 'T-29' when compared with 'Oranza', this might be the possible reason for higher juice recovery in 'T-29'. Similarly, fertilizers provide essential nutrients to crop plants for better growth, yield and yield components of carrot that ultimately leading towards the difference in juice recovery percentage. The highest juice content was obtained from the carrot plants treated with half PM and half FYM which might be due to better soil structure and easy movement of water and nutrients in response to organic fertilizer application. These results are in consistent with the findings of Hailu et al. (2008) that different fertilizer treatments had significant effect on the juice recovery of carrot.

Leaf nutrient contents

Overall results revealed that 'T-29' had higher concentrations of N, P and K as compared to 'Oranza', which could be attributed to their genetic background as well as different combinations of fertilizer, applied. Present results showed that nitrogen accumulation of carrot roots was significantly higher from organic fertilizer as compared to mineral fertilizers. Nitrogen (N) management in carrot production systems is critical for increasing efficiency of crop production, decreasing costs, and decreasing nitrate-leaching losses to groundwater. Nutritionally, N content of the plant is of great importance since it reflects directly the protein content (Jansson et al., 1985). Our results are in contradiction with the findings of Warman and Havard (1997); Phillips et al. (2002); Herencia et al. (2007) who reported higher N contents in carrot, bean, beet root, chard, pepper and tomato when fertilized with mineral fertilizer. The concentrations of P and K in carrot roots were in the range of 0.23% and 3.07%, respectively as reported by Jansson (1985) and Reuter and Robinson (1997). Both P and K contents were maximum in organically cultivated carrots as compared to those grown under mineral fertilizers as reported by Evers (1989). Organic manures improve soil physical structure and water holding capacity, resulting in a more extensive root development and enhanced soil microbial activity affecting availability of micronutrient levels in soil to plants (Stevenson 1994 add new reference too). On the other hand, it might be assumed that lower yield after organic fertilizer application favours high accumulations of minerals in carrots.

From these results it can be concluded that cultivar T-29 performed better than Oranza for different productive and qualitative traits while among different treatment combination of FYM, LM, PM and urea, combination of half poultry manure + half FYM was the best one for better yield and quality of carrots.

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