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Full Length Research Paper

Effect of combined application of organic P and inorganic N fertilizers on post harvest quality of carrot

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A study was undertaken to assess the effect of combined application of organic-P and inorganic-N fertilizers on post harvest quality of carrot (*Daucus carota* l.) stored at 1°C and ambient conditions (8.6 - 24.8°C). For the fertilizer treatments, 309 kg orga ha^{-1} (for P) in combination with each of six rates of urea (0, 68.5, 267.2, 274, 342.5 and 411 kg urea ha^{-1}) was used. Carrot shelf life assessment was carried out in a factorial experiment with pre-harvest fertilizer treatments as one-factor and storage conditions as another factor. Pre-harvest fertilizer and post harvest storage treatments significantly affected the post harvest quality of carrot. The weight loss, contents of ascorbic acid, reducing sugar, total sugar, as well as titrable acidity and percentage marketability of carrot were significantly ($p < 0.05$) affected by the different pre-harvest combinations of fertilizer treatments both at harvest and during the storage period of 28 days at 1°C and ambient storage conditions. The storage temperature also showed significant ($P < 0.01$) influence on the weight loss, ascorbic acid, total soluble solids, total sugar, pH, titratable acidity and percentage marketability of carrots. After 28 days carrots subjected to 1°C storage had 51.4% less weight loss, 17.1% more ascorbic acid, 15.0% lower total soluble solids, 20.7% more total sugar and 30.1% more marketable compared to carrots stored under ambient conditions. This indicated that shelf life of carrots stored at 1°C exceeded that of samples stored under ambient conditions. Significant interaction was also observed between pre-harvest fertilizer treatments and post-harvest storage conditions in most of the quality parameters of carrot. The pre-harvest combined application of orga with urea at 309 kg ha^{-1} and 274 kg ha^{-1}, respectively, and post harvest storage at 1°C is recommended for better postharvest quality maintenance of carrot.

Key words: Organic, inorganic, orga, pre-harvest, carrot, post harvest, storage, quality.

INTRODUCTION

The nutritive value and quality of vegetables depend upon genetic, climatic, biotic, edaphic, chemical and other factors as well as combinations of these factors. Some ecological, cultural and physical factors including fertilizer management have significant influence on the chemical and nutritional composition of plants as well as their anatomical and morphological structure (Salunkhe et al., 1991). Organic fertilizers are critical in enhancing soil fertility besides improving the crops (Kaack et al., 2002; Ashraf et al., 2004). In addition to nutritive organic fertilizers improve soil structure, stimulate soil biological activity and enhance the solubility of phosphorus applied as fertilizer (Stevenson and Ardakani, 1972). The term Orga is the trade name of an organic fertilizer manufactured by the National Fertilizer Manufacturing pvt. Ltd. Co. (NAFMAC) containing 1% N + 23% P_2O_5. Orga fertilizer comprises ground animal bones, stomach paunch, horns and hooves by phosphate-solubilizing and nitrogen fixing bacteria (Active+) (NAFMAC, 2002). Little work on Orga has been reported in literature in relation to quality of horticultural crops.

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Organic fertilizers and inorganic ones can be combined to enhance efficacy (AVRDC, 2000). Organically-fertilized soils generally produce plants with lower amounts of nitrogen than chemically fertilized ones. As a result, it would be expected that organic crops would have more vitamin C, less nitrates and less protein, and a higher chemical quality than comparable conventional crops (Bear et al., 1949; AVRDC, 2000). Typically, organic fertilizers do not have phosphorus content of more than 10%. According to Jema et al. (1997), the highest P concentration in manures is 4.9 g kg^{-1} (0.49%). However, orga contains a minimum of 23% phosphorus (P_2O_5) and 21% calcium oxide (CaO). In addition, most organic fertilizers are bulky and their application needs much more labor and time compared to inorganic fertilizers. Nevertheless, the application rate of orga is much reduced since it has relatively high nutrient content compared to other organic fertilizers. Bone meal has a phosphorus content amounting to 26 kg ha^{-1} P_2O_5, which is equivalent to that contained in triple super phosphate (TSP) (Taye and Hoefner, 1993). Furthermore, the price of orga is lower and affordable to resource-poor farmers than the prices of inorganic fertilizers. In spite of having high content of phosphorus, orga has very low nitrogen content. This was the major reason for combining pre-harvest application of orga and inorganic N-fertilizer in this study.

During development and storage, carrots undergo a complex series of physiological and biochemical events involving changes in post harvest quality (Rosenfeld et al., 1998b; Suojala, 2000). Temperature and relative humidity are important factors that affect the quality and shelf life of vegetable crops. Seyoum (2002) indicated that low storage temperature and high relative humidity can enhance the shelf-life of carrot. But still there is a need to study postharvest response of carrot to pre-harvest organic and inorganic fertilizer treatments. A second focus of this study is to investigate the effect of pre-harvest conditions on post harvest quality. Therefore, the objectives of the study are to evaluate the effects of combined application of organic-P and inorganic-N fertilizers on post harvest quality of carrot.

MATERIALS AND METHODS

Experimental site

A field experiment was conducted on black vertisol of Kombolcha ATVET College, South Wollo. Kombolcha is located in North Eastern Ethiopia at the latitude of 11°04′N and longitude of 39°44′ E, 380 km away from Addis Ababa. The area has the elevation of 1800 m above sea level. Mean annual rainfall is 1046 mm while mean annual maximum and minimum temperatures are 26.5 and 12.3°C, respectively. The average yield of carrot in the research area is 11- 15 ton ha^{-1}.

Experimental materials and design

The field experiment was conducted by combining organic-P fertilizer (309 kg orga ha^{-1}) with six rates of inorganic-N fertilizer (0, 68.5, 267.2, 274, 342.5 and 411 kg urea ha^{-1}). The nitrogen and phosphorus contents of urea and orga are 46 and 23%, respectively. Applied rates of urea used for the treatment were 0, 25%, (100% - N content in orga), 100, 125 and 150% of recommended rates of urea for carrots respectively based on the recommendation by IFA (2005). The recommended rates of orga (309 kg orga ha^{-1}) and urea (274 kg urea ha^{-1}) for carrot production were based on National Fertilizer Manufacturing pvt. Ltd. Co. (NAFMAC) (2002) and IFA (2005), respectively. A total of 7 pre-harvest fertilizer treatments, 0 + 0, 309 + 0, 309 + 68.5, 309 + 367.2, 309 + 274, 309 + 342.5 and 309 + 411 kg ha^{-1} orga and urea, respectively, were employed under field condition. 126 kg N ha^{-1} and 71 kg P_2O_5 ha^{-1} are the recommended amounts of nutrients for optimum carrot production (IFA, 2005).

A randomized complete block design (RCBD) with five replications. The plot size was 9 m^2, with a distance of 50 cm between plots and 1 m between blocks and 15 rows of carrots per raised plot bed. Border rows were not included. For post harvest trial, seven fertilizer treatments with two storage temperatures were replicated three times. The treatments were arranged in a RCBD.

Orga application was made one week before sowing. Urea was applied in three split doses; emergence, 2 months after planting and 1 month before harvest. Fertilizers were banded a few inches away from the plant. Carrot seeds of the Nantes cultivar were directly sown on prepared land on 6 January, 2006. Seeds were mixed with sand at 1:1 ratio. After emergence the plants were thinned to approximately 5-10 cm apart. All other agricultural inputs remained the same between the treatments.

When the crop reached maturity (four months), carrots were harvested and topped in the field, and were immediately taken to the Plant Science Laboratory at Kombolca ATVET College. Harvesting, topping, and washing of carrots were done early in early morning before the temperatures were too high to prevent moisture loss. Carrots were packed in plastic bags and kept in during transport. Samples were kept in a refrigerator at -30°C for 0 day analysis.

For post harvest quality analysis, 30 kg carrot samples were taken randomly from each treatment and packed in 1 kg unit and put under two storage conditions (stored at 1°C in a refrigerator and at ambient temperature). The average maximum and minimum ambient temperatures during the storage period were 24.8 and 8.6°C, respectively. A total 105 kg carrot samples were stored under refrigerated condition and 105 kg carrot samples were stored under room storage condition for post harvest quality analysis. Data were recorded 0, 7, 14, 21 and 28 days after storage. Three replications of 1 kg unit samples were stored under each storage condition for a single interval analysis, so that a total of 42 kg samples were analyzed for post harvest quality in a single interval.

Physiological weight loss

Physiological weight loss (PWL) was determined by using Tefera et al. (2007) method, by periodical weighing of carrots 0, 7, 14, 21 and 28 days after storage. The differential weight losses were calculated for each interval and converted into percentage by dividing the change with the initial weight recorded on each sampling interval. The cumulative PWL was expressed in percent with respect to different treatments. The difference between the initial weight and successive weights gave the rate of weight loss (as percentages).

Total soluble solids

An aliquot of juice was extracted using a juice extractor (6001 x model No. 31JE35 6x.00777) and 50 ml of the slurry was filtered using cheesecloth (Tefera et al., 2007). Total soluble solids (TSS) was determined by a hand refractometer {Atago N1) with a range of 0 to 32 °Brix, and a resolution of 0.2 °Brix by placing 1 to 2 drops of clear juice on the prism. Between the intervals of sampling, the prism of the refractrometer was washed with distilled water and dried before use. The refractometer was standardized against distilled water (0% TSS).

Ascorbic acid

Ascorbic acid (AA) content of carrot was determined by the 2,6-dichlorophenolindophenol method (AOAC, 1970; Tefera et al., 2007). An aliquot of 10 ml carrot juice extract was diluted to 50 ml with 3% metaphosphoric acid in a 50 ml volumetric flask. The aliquot was filtered and titrated with the standard dye to a pink end-point (persisting for 15 s).

Sugar

Reducing and total sugars were estimated by using the calorimetric methods (Somogyi, 1945). Clear juice (10 ml) was added to 15 ml of 80% ethanol, mixed and heated in a boiling water bath for 30 min. After extraction, 1 ml of saturated lead acetate ($Pb(CH_3COO)_2.3H_2$) and 1.5 ml of saturated sodium hypophosphate ($NaHPO_4$) were added and the contents were mixed by gentle shaking. After filtration, the extract was made up to 50 ml with distilled water. An aliquot of 1 ml extract was diluted to 25 ml with distilled water in 1 ml copper reagent in a test tube and heated for 20 min in a boiling water bath. After heating, the contents were cooled under running tap water without shaking. Arsenomolybdate color reagent was added, mixed, made up to 10 ml, and left for about 10 min to allow color development, after which the absorbance was determined by a spectrophotometer at 540 nm. For total sugar determination, sugar was first hydrolyzed with 1 N HCl by heating at 70°C for 30 min. After hydrolysis, the determination of total sugar was made by following the same procedure employed for the reducing sugar. Blanks were prepared using distilled water instead of extract.

pH

An extract of an aliquot of juice was prepared according to Nunes and Emond (1999), the aliquot of juice was first filtered with cheesecloth and the pH value of carrot juice was measured with a Metrohn 691 pH meter.

Titratable acidity

The titratable acidity (TA) of carrot was measured by the methods as described by Maul et al. (2002) and Tefera et al. (2007). An aliquot of carrot juice was extracted from the sampled carrots with the juice extractor (6001 x model No. 31JE35 6 x.00777). The aliquot of carrot juice was filtered through cheesecloth and the decanted clear juice was used for the analysis. The titratable acidity expressed as percent citric acid was obtained by titrating 10 ml of carrot juice to the pH 8.2 with 0.1 N NaOH.

Percentage marketability

The percent marketability of carrot was subjectively assessed at all sampling intervals. A package of carrots containing 5 representative carrots were randomly selected from each treatment at each day intervals for quality analysis according to the methods used by Tefera et al. (2007). These descriptive quality attributes were determined subjectively by observing the level of visible mould growth, decay, shriveling or dehydration and firmness of carrots. A rating with poor (unmarketable), fair (some marketable), good (marketable), very good and excellent was used (Tefera et al., 2007).

Statistical analysis

Analysis of variance (ANOVA) as per Gomez and Gomez (1984) was used to determine differences between treatment means. An MSTAT-C software package (MSTAT, Michigan Univ. East Lansing) was used for the analysis. Multiple comparisons of the treatment means were done by Duncan's multiple test range (Duncan, 1955).

RESULTS AND DISCUSSION

Ascorbic acid

Ascorbic acid (AA) content of carrot over 28 days storage period at 1°C and ambient temperatures are shown in Table 1. Significant ($P < 0.01$) difference was observed in ascorbic acid content of carrot in response to pre-harvest fertilizer treatments both at harvest and during the storage period of 28 days. Application of orga treatment resulted in significantly ($P < 0.01$) higher ascorbic acid content of carrot compared to the control treatment at the time of harvest. Carrot subjected to pre-harvest orga treatment had shown 14.4% more AA compared to the control treatment. Similar finding was reported by Raupp (1996) who emphasized the positive effect of organic fertilizer on dry matter content, sugar and AA in vegetables. The earlier studies by Cacek and Lagner (1986) also confirmed the enhanced effect of organic fertilizer on the nutritional value of vegetables.

Incorporating N-fertilizer with orga has shown no significant benefit in AA accumulation in carrot. Only 3% more AA accumulation was observed due to combined application of orga and urea at the rates of 309 and 274 kg ha^{-1}, respectively, compared to the application of 309 kg orga ha^{-1} alone at the time of harvest. However, it was not significantly different from the pre-harvest application of orga alone. In general, a slight increase in AA content of carrot was observed due to increased application of N-fertilizer. Lower AA content was detected in carrot roots treated with excess nitrogen fertilizer; 309 kg orga ha^{-1} combined with 342.5 kg urea ha^{-1} and 309 kg orga ha^{-1} combined with 411 kg urea ha^{-1}. The least ascorbic acid content of carrot was recorded both at the time of 0 and after 28 days of storage from the carrot subjected to pre-harvest application of 309 kg orga ha^{-1} combined with 411 kg urea ha^{-1}. Augustin (1975) and Lisiewska and Kmiecik (1996) also reported a decrease in ascorbic acid content of fruit and vegetables with increasing amounts of nitrogen fertilizer application. Therefore, the current result confirms better nutritional values in terms of AA content and maintaining better AA content during storage. This is evident from the data of carrots subjected to pre-harvest orga application at the rate of 309 kg ha^{-1} and no nitrogen application.

Table 1. Changes in physiological weight loss (%), ascorbic acid content (mg 100 g^{-1}) and total soluble solid content (ºBrix) of carrot subjected to pre-harvest organic-P and inorganic-N fertilizer and storage treatments during storage period of 28 day at 1°C and ambient condition.

Treatment	Physiological weight loss (%)				Ascorbic acid (mg 100 g^{-1})					Total soluble solid (ºBrix)				
	Storage period, day				Storage period, day					Storage period, day				
	7	14	21	28	0	7	14	21	28	0	7	14	21	28
Fertilizers (kg ha^{-1})														
0 + 0P	4.17^{b}	9.50^{d}	14.50^{bc}	17.50^{bc}	9.61^{ab}	8.80^{bc}	8.29^{bc}	7.81^{ab}	7.00^{bc}	9.820	11.43	12.55	13.20	13.33
309 + 0	5.50^{ab}	10.33^{cd}	14.33^{bc}	17.83^{bc}	10.99^{a}	9.98^{ab}	9.50^{ab}	8.95^{a}	8.42^{ab}	10.07^{b}	11.47	12.50	12.83	13.13
309 + 68.5	4.33^{b}	9.17^{d}	14.17^{c}	17.00^{c}	10.89^{a}	10.00^{ab}	9.44^{ab}	8.73^{ab}	8.15^{abc}	10.73	11.50	12.16	12.83	13.83
309 + 267.2	4.17^{b}	9.50^{d}	15.17^{b}	18.50^{b}	11.18^{a}	10.37^{a}	9.83^{a}	9.26^{a}	8.73^{a}	9.73	11.43	12.50	13.00	13.47
309 + 274	5.50^{ab}	10.83^{bc}	14.67^{bc}	18.17^{bc}	11.32^{a}	10.50^{a}	9.87^{a}	9.22^{a}	8.50^{ab}	10.13	11.98	12.76	13.07	13.53
309 + 342.5	5.50^{ab}	11.67^{ab}	-	-	9.98^{ab}	9.13^{abc}	8.75^{abc}	7.97^{ab}	7.58^{abc}	9.53	11.03	12.61	13.42	13.94
309 + 411	6.33^{a}	12.50^{a}	17.33^{a}	21.17^{a}	8.95^{b}	8.38^{c}	7.81^{c}	7.37^{b}	6.72^{c}	10.10	11.57	13.27	13.86	13.97
SE	0.35	0.32	0.23	0.30	0.41	0.35	0.34	0.36	0.33	–	–	–	–	–
Storage														
1°C	2.62^{b}	5.67^{b}	8.71^{b}	10.86^{b}	10.44	10.10^{a}	9.61^{a}	9.14^{a}	8.61^{a}	10.04	10.85^{b}	11.85^{b}	12.26^{b}	12.50^{b}
RT	7.52^{a}	15.33^{a}	18.43^{a}	22.33^{a}	10.39	9.09^{b}	8.53^{b}	7.80^{b}	7.14^{b}	10.00	12.13^{a}	13.39^{a}	14.08^{a}	14.71^{a}
Significance														
A	**	**	**	**	**	**	**	**	**	NS	NS	NS	NS	NS
B	**	**	**	**	NS	**	**	**	*	NS	**	**	**	**
AXB	**	**	**	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS, *, ** Non-significant or significant at P < 0.05 or 0.01, respectively.
Means within a column followed by the same letter(s) are not significantly different according to Duncan's multiple range tests.

Ambient temperature significantly (P <0.01) decreased the ascorbic acid content of carrot during 28 days of storage. After 28 days of storage, carrot roots stored at 1°C had 1.47 mg 100 g^{-1} more ascorbic acid than those stored at ambient temperature. A general drop in ascor-bic acid content both at 1°C and ambient storage conditions was observed during the course of storage. But the rate of reduction was lower at 1°C storage which is an indication of better quality maintenance. This result is consistent with that of Seyoum (2002) who observed high contents of ascorbic acid for carrots stored at 1°C compared to those stored at room temperature. This could be attributed to the high and low temperature effects. Basically, low temperature delays aging through reduced respiration rate and other undesirable metabolic changes. In contrast, high temperature is known to promote enzymatic catalysis and lead to biochemical breakdown of compounds in fruit and vegetables (Yoshida et. al., 1984). Ascorbic acid (AA) content of carrot was not significantly influenced by the interaction effect of pre and postharvest treatment at time of harvest and during the course of storage for 28 days.

Physiological weight loss

Significant (P < 0.01) loss in weight of carrot roots was observed in response to pre-harvest treat-ments, storage temperature and their interaction during the storage of 28 days (Table 1). The pre-harvest treatments significantly (P < 0.01) affected changes in PWL throughout the storage period. After 28 days of storage, higher PWL (21.17%) was observed in carrots treated with the highest rate of nitrogen fertilizer (411 kg urea ha^{-1}). Exces-sive N fertilization resulted in increased PWL in sweet potato during storage (Mark et al., 2003), which is in agreement with the present study.

Dehydration and shriveling of carrot roots were some of the physical observations observed in carrots stored at ambient temperature. Although, there was an increasing trend of PWL with the advancement of storage period, the rate of PWL was much lower in carrots stored at 1°C compared to carrots stored under ambient storage conditions. After 28 days of storage, there was 11.47% more PWL in carrots stored at ambient storage conditions than at in those 1°C storage. This result is in agreement with the previous findings of Seyoum (2002), in which reduced storage temperature led to significantly ($P < 0.001$) lower PWL during the storage period.

The two-way interaction of pre-harvest fertilizer treatment and post harvest storage conditions resulted in significant difference ($P < 0.01$) in PWL of carrots throughout the storage period. In all pre-harvest treated carrots, the storage PWL was by far lower at 1°C than at ambient conditions. Prolonged storage period resulted in great variation in the storage length regarding PWL. Increased inorganic-N fertilizer application resulted in higher weight loss, and even total loss of the crop under ambient condition after two weeks of storage. This is in line with the results of Mark et al. (2003) who reported significant weight loss in sweet potato under storage due to excess pre-harvest fertilizer application.

Total soluble solids

The total soluble solids (TSS) of carrot significantly increased ($P < 0.05$) with increased storage temperature in all treatments (Table 1). After 28 days of storage, 17.68% more TSS was observed in carrot roots stored under ambient condition than those stored at 1°C. Higher rates of increase in TSS of carrots stored at ambient condition may be associated with accelerated PWL. Excess loss of moisture is responsible for rapid weight loss and hence increased total soluble solid content. The positive correlation between weight loss and increased TSS content of stored vegetables had previously been reported by Seyoum (2002). Waskar et al. (1999) also reported excessive moisture loss as well as hydrolysis of carbohydrates to soluble sugars as possible causes for higher rates of increased TSS content of vegetables stored under ambient conditions.

The TSS of carrot were not significantly ($P < 0.05$) affected by the pre-harvest fertilizer treatments. Similarly, McCollum et al. (2004) found little difference in TSS between conventionally grown and organically grown fruits. Although the difference was non-significant, application of both orga and inorganic fertilizers resulted in slightly more TSS content of carrot than the control treatment at the time of harvest. Increased TSS content of fruit and vegetables at the time of harvest due to fertilizer application was reported by Jenifer (2003). In the current study, the pre-harvest combined orga and urea treatment at the rates of 309 kg ha^{-1} and 68.5 kg ha^{-1}, respectively, resulted in better accumulation of total soluble solids at time of harvest. Increasing the application of urea had no effect on TSS content of carrot, which is in agreement with Raupp (1996), where organically grown vegetables accumulated more TSS by harvest.

Reducing sugar content

At harvest 22.71% more reducing sugar was obtained from carrots pre-treated with organic fertilizer (orga) application than those from the control treatment (Table 2). Combining urea with orga resulted in slightly better accumulation of reducing sugar in carrot than application of orga alone, although it was not consistent. Such an increase in sugar content due to the application of organic fertilizers was also reported by Raupp (1996) and Cacek and Lagner (1986). Application of urea at the rate greater than 274 kg ha^{-1} had reducing effect on accumulation of sugar. Therefore, it could be assumed that that pre-harvest application of 309 kg orga ha^{-1} combined with 267.2 kg urea ha^{-1} is more advantageous for enhanced quality regarding reducing sugar content of carrot.

However, as storage time advanced, reducing sugar content declined. A general increase and then decrease was observed in reducing sugar content of carrot during the storage period of 28 days. Similar changes were also observed by Seyoum (2002). This could be due to accelerated breakdown of polysaccharides and the accumulation of hexose sugars immediately after harvest that may be driven by the removal of above ground plant parts. The drop in reducing sugar content on 28 days may be due to the recombination of hexose sugars into sucrose. Rutherford (1981) found that some recombination of reducing sugars to sucrose occurred after prolonged periods of storage in vegetables, which was also observed in the current study.

The storage conditions have shown significant difference ($P<0.01$) in reducing sugar content of carrot after 14 days in storage. This may be attributed to greater increase in reducing sugar content under ambient temperature than at 1°C. This could be due to the increased activation of enzymatic catalysis of the breakdown of polysaccharides at relatively higher temperature that ensures the advantage of storage at 1°C over ambient temperature storage. Normally, reducing sugar decreases faster if there is high respiration rate, since respiration in plants involves the oxidation metabolism of sugar and organic acids to end products, CO_2 and H_2O with the simultaneous production of energy (Varoquaux and Wiley, 1994). In general, a consistent reduction in total and non-reducing sugar content of carrot was observed while the reducing sugar content of the crop showed an increasing trend during the course of storage, which is in agreement with Phan et al. (1973), Nilsson

Table 2. Reducing and total sugar content of carrot subjected to pre-harvest organic-P and inorganic-N fertilizer and storage treatments during storage period of 28 days at 1°C and ambient environmental conditions.

Treatment	Reducing sugar (g 100 g^{-1})					Total sugar (g 100 g^{-1})				
	Storage period, day					Storage period, day				
	0	7	14	21	28	0	7	14	21	28
Fertilizers (kg ha^{-1})										
0 + 0	2.29^{b}	2.58^{cd}	2.79^{c}	2.63^{d}	2.38^{b}	6.67^{cd}	6.24^{bc}	5.95^{ab}	4.72^{bc}	3.86^{ab}
309 + 0	2.81^{a}	3.28^{a}	3.34^{a}	3.15^{a}	2.58^{a}	6.95^{b}	6.80^{a}	6.42^{a}	5.06^{ab}	4.34^{a}
309 + 68.5	2.65^{a}	2.90^{b}	3.09^{b}	2.10^{ab}	2.69^{a}	6.88^{bc}	5.84^{c}	5.46^{bc}	4.66^{bc}	4.06^{a}
309 + 267.2	2.88^{a}	2.91^{b}	3.08^{b}	2.90^{bc}	2.59^{a}	7.11^{ab}	6.67^{ab}	5.80^{b}	5.54^{a}	4.06^{a}
309 + 274	2.61^{a}	2.74^{bc}	2.85^{c}	2.77^{cd}	2.35b	6.46^{d}	6.09^{c}	5.56^{b}	4.81^{bc}	4.28^{a}
309 + 342.5	2.79^{a}	3.26^{a}	3.05^{b}	2.70^{cd}	2.35^{b}	7.33^{a}	6.70^{ab}	5.71^{b}	4.42^{c}	3.74^{ab}
309 + 411	2.22^{b}	2.53^{d}	2.82^{c}	3.05^{ab}	2.41^{b}	5.87^{e}	5.09^{d}	4.95^{c}	4.50^{bc}	3.27^{b}
SE	0.06	0.05	0.04	0.05	0.04	0.06	0.12	0.13	0.14	0.18
Storage										
1°C	2.64	2.88	2.93^{b}	2.91	2.43^{b}	6.73	6.45^{a}	5.90^{a}	5.05^{a}	4.40^{a}
RT	2.58	2.89	3.07^{a}	2.86	2.53^{a}	6.78	5.96^{b}	5.48^{b}	4.58^{b}	3.49^{b}
Significance										
A	**	**	**	**	**	**	**	**	**	**
B	NS	NS	**	NS	**	NS	**	**	**	**
AXB	**	**	**	**	**	NS	**	*	**	NS

NS, ** Non-significant or significant at $P < 0.01$, respectively.
Means within a column followed by the same letter(s) are not significantly different according to Duncan's multiple range tests.

(1987b), and Seyoum (2002).

After 14 days of storage, all pre-harvest treatments showed an increase in reducing sugar contents. Increases were observed in crops treated with pre-harvest combined application of orga and urea at 309 kg ha^{-1} and 411 kg ha^{-1}, respectively, and stored under ambient temperature. After 28 days of storage, low reducing sugar content was maintained in carrot roots treated with high rates of urea (274, 342.5 and 411 kg urea ha^{-1}) and the control treatment under both storage conditions. In general, the pre-harvest organic fertilizer (orga) application resulted in sustained maintenance of reducing sugar under both 1°C and ambient storage conditions during the storage period of 28 days.

Total sugar

Changes in total sugar content of carrot in response to different rates of nitrogen fertilizer were observed (Table 2). These are agreement with Hogstad et al. (1997) in which large variations in total sugar content and composition as a result of differences in fertilization, susceptibility of the soil to drought and other cultivation practices. The highest total sugar accumulation at time of harvest was obtained from carrots that received 309 kg orga ha^{-1} combined with 342.5 kg urea ha^{-1}. Lower sugar content was found in the 309 kg orga ha^{-1} /411 kg urea ha^{-1} treatment. The control treatment also showed sugar accumulation at time of harvest, similar to the combined application of the recommended rates of fertilizers (309 kg orga ha^{-1}/274 kg urea ha^{-1}). This could be due to excessive fertilizer application. Consistent with this result, Evers (1989) observed that unfertilized treatments had a tendency to yield higher glucose and fructose and thus also had higher sugar contents than the nitrogen fertilized treatments. In general, a decrease in total sugar contents of carrots in all treatments during storage. After 28 days, no difference in total sugar retention among the carrot roots received pre-harvest fertilizer treatments. The lowest total sugar content, was, however, obtained from carrots treated with the highest amounts of urea, i.e., 411 kg urea ha^{-1}. Therefore, the result evidently demonstrated that supplying carrot plants with orga in combination with lower amounts of N may lead to enhanced accumulation and maintenance of total sugar in the roots during the storage period.

Earlier, research related the temperature of the growing region to the sugar content of carrot differently. High sugar content was previously associated with lower temperatures (Evers, 1989). Other studies, however, reported high sugar concentrations at higher temperatures (Nilsson, 1987b; Hogstad et al., 1997; Rosenfeld et al., 1998b), and temperature was found to have a stronger influence on chemical composition than light. During storage, a general trend of lower total sugars was observed under ambient temperature compared to 1°C.

During 7 days of storage at 1°C, highest total sugar content was maintained in carrot roots treated with the recommended rate of orga (309 kg orga ha^{-1}) with no combination of urea. Conversely, the lowest total sugar content was recorded in carrots treated with the highest rate of N- fertilizer (411 kg urea ha^{-1}) and stored at ambient temperature. In general, higher total sugar content was maintained in carrots stored at lower temperature compared to those stored under ambient conditions. After 21 days pre-harvest applications of orga treatment alone showed the best retention of high total sugar content compared to any other pre-harvest treatments at both storage conditions.

Further, increase in the application of N-fertilizers slow advantage in maintaining total sugar content during storage. Therefore, the result clearly demonstrated the appropriateness of fertilizing carrot plants with orga at the recommended rate both for the highest accumulation of total sugar at the time of harvest and for better maintenance of sugar contents during the storage period of 28 days at 1°C.

pH

The pH of carrots is one factor used to determine the quality of the crop at harvest and during storage period. pH accounts much for changes in flavor. Immediately after harvest, significant variation ($P < 0.01$) was observed in pH values of carrot due to pre-harvest fertilizer treatments (Table 3). An elevated pH value of 6.42 was recorded for carrots treated with pre-harvest 309 kg orga ha^{-1} with no urea combined. Pre-harvest combined application of orga and urea at 0 + 0, 309 + 0, 309 + 68.5 and 309 + 267.2 kg ha^{-1} gave significant ($P > 0.05$) effect on pH values of carrot. On the other hand, the lowest pH value of 6.27 was observed in carrots treated with the recommended rate of orga combined with 150% recommended rate of urea i.e. 309 kg orga ha^{-1} combined with 411 kg urea ha^{-1}.

In general, a decrease in pH values of carrots with increasing application of inorganic-N fertilizer at the time of harvest. The change in pH values of carrots remained significant ($P < 0.01$) during the storage period of 28 days at 1°C and ambient condition. Even after 28 days, a higher pH values were recorded for carrot roots that received pre-harvest sole orga fertilization and the control treatment.

A drop in pH values were observed during storage under ambient conditions, which is prompted by formation of acids due to catabolism of carbohydrates (Hao et al., 1999; Seyoum, 2002). In contrast, Hao et al. (1999) found that storage temperatures did not significantly affect carrots pH. Conversely, low temperature storage resulted in relatively higher pH. The current result is in agreement with the findings of Seyoum (2002) who reported higher pH values of carrots stored at 1°C. The tendency of increasing pH value of stored vegetables with extended storage period was also reported by Medlicoot et al. (1986). According to Mizrach et al. (1997), carbohydrate and acid metabolism are closely connected with post harvest storage.

On day 14 and 21, all pre-harvest treatments had non significant effect on the pH of carrot under both storage temperatures (Table 3). On day 28, pre-harvest recommended orga + 150% recommended rate of urea at both storage conditions resulted in significantly ($p < 0.01$) lower pH than the control treatment. These findings counter the effect of increased pre-harvest application of N-fertilizer in retaining pH of stored carrot.

Titratable acidity

At harvest, significantly ($p < 0.01$) higher titratable acid content of carrot was found in carrots treated with N-fertilizer rate compared to 25 and 50% more than the recommended rates of urea (Table 3). These results agree with that of Hegde and Srinivas (1990), but disagree with results by Jenifer (2003) in which application of fertilizer had showed no effect on titratable acid content of apple.

A general decrease in TA content of carrot was observed under storage from 1°C to ambient conditions. Mohammed et al. (1999) reported similar trends on changes in TA of tomato during ripening and storage. However, in carrots treated with combined 309 kg orga ha^{-1} and 342.5 kg urea ha^{-1} as well as 309 kg orga ha^{-1} and 411 kg urea ha^{-1}, higher acidity content of carrot was maintained throughout the storage period of 28 days compared to the other treatments. During 28 days of storage, a decrease in titratable acidity was found in carrots treated with the pre-harvest 309 kg ha^{-1} sole orga and the control treatment.

After 7 days, no significant difference was recorded in TA content of carrot in response to different storage conditions. With increasing storage time, a slight increase was observed in TA of carrot subjected to ambient storage conditions and a general trend of decrease was evident in TA of stored carrot under refrigerated storage at 1°C. The increase in pH value of carrot at 1°C but a decrease in the value at ambient conditions during the course of storage is most probably related to its TA content.

The interaction between pre-harvest fertilizer and post harvest storage conditions had no significant effect on the TA content of stored carrot except up to 7 days of storage and after 28 days of storage where significant interaction effect was detected. On the 7^{th} days of storage, TA content of carrot stored at 1°C was significantly ($P < 0.01$) different from those carrots stored under ambient condition. On this day, the pre-harvest control and 309 + 68.5 kg ha^{-1}, orga + urea treatments, displayed the lowest TA content at both storage temperatures.

Table 3. pH values, titratable acidity (% citric acid) and percentage marketability of carrot subjected to preharvest organic-P and inorganic-N fertilizer and storage treatments during storage period of 28 days at 1°C and ambient conditions.

Treatment	pH					Titratable acidity (%)					Percentage marketability			
	Storage period, day					Storage period, day					Storage period, day			
	0	7	14	21	28	0	7	14	21	28	7	14	21	28
Fertilizers (kg ha^{-1})														
0 + 0	6.41^{a}	6.42	6.43	6.46^{a}	6.45^{a}	0.120^{b}	0.102^{c}	0.105^{bc}	0.092^{c}	0.092c	96.67^{a}	90.00^{a}	76.67^{a}	66.67^{a}
309 + 0	6.42^{a}	6.42	6.42	6.47^{a}	6.46^{a}	0.112^{bc}	0.115^{bc}	0.117^{bc}	0.117^{b}	0.100bc	96.67^{a}	96.67^{a}	83.33^{a}	73.33^{a}
309 + 68.5	6.41^{a}	6.46	6.43	6.43^{ab}	6.44^{a}	0.095^{c}	0.102^{c}	0.102^{c}	0.100^{c}	0.102bc	93.33^{a}	93.33^{a}	80.00^{a}	73.33^{a}
309 + 267.2	6.38^{a}	6.42	6.36	6.40^{ab}	6.41^{ab}	0.107^{bc}	0.108^{bc}	0.100^{c}	0.100^{c}	0.100bc	90.00^{a}	90.00^{a}	80.00^{a}	66.67^{a}
309 + 274	6.32^{b}	6.38	6.33	6.37^{b}	6.35^{bc}	0.120^{b}	0.120^{b}	0.122^{b}	0.118^{b}	0.115b	93.33^{a}	86.67^{a}	70.00^{a}	73.32^{a}
309 + 342.5	6.30^{bc}	6.41	6.37	6.36^{bc}	6.33^{c}	0.145^{a}	0.147^{a}	0.147^{a}	0.140^{a}	0.135a	86.67^{ab}	80.00^{a}	60.00^{a}	46.67^{ab}
309 + 411	6.27^{c}	6.41	6.35	6.29^{c}	6.30^{c}	0.153^{a}	0.153^{a}	0.153^{a}	0.148^{a}	0.137a	73.33^{b}	46.67^{b}	30.00^{b}	26.67^{b}
SE	0.01	–	–	0.03	0.02	0.047	0.004	0.041	0.004	0.004	5.00	4.90	5.67	6.60
Storage														
1°C	6.33	6.48	6.47	6.44	6.47	0.126	0.122	0.112^{b}	0.100^{b}	0.091^{b}	97.14^{a}	88.57^{a}	80.00^{a}	69.52^{a}
RT	6.38	6.35	6.30	6.35	6.31	0.117	0.120	0.130^{a}	0.133^{a}	0.132^{a}	83.81^{b}	67.62^{b}	57.14^{b}	48.57^{b}
Significance														
A	**	NS	NS	**	**	**	**	**	**	**	*	**	**	**
B	**	**	**	**	**	NS	NS	**	**	**	**	**	**	**
AXB	**	**	NS	NS	**	*	**	NS	NS	*	NS	**	NS	NS

NS, ** Non-significant or significant at P < 0.01, respectively.
Means within a column followed by the same letter(s) are not significantly different according to Duncan's multiple range tests.

Highest TA content was observed in carrot roots treated with pre-harvest orga + urea at 309 + 411 kg ha^{-1} and stored at 1°C. With progressing storage time, TA content of carrot stored at ambient conditions exceeded those stored at 1°C. After 28 days, TA content of carrot was significantly ($P < 0.05$) affected by the interaction of pre and post harvest storage treatments. During this period, relatively lower TA content was maintained in carrot crops treated with 309 + 0, 309 + 68.5 kg ha^{-1} orga + urea and the control treatment stored at 1°C. The result apparently demonstrated the importance of integrating low pre-harvest N-fertilizer application with low postharvest storage temperature for better maintenance of TA content and reduced rate of respiration and hence extended postharvest shelf life.

Percentage marketability

Pre-harvest treatments significantly ($p < 0.01$) affected percent marketability of carrot after 7 days (Table 3). A general decrease in percentage marketability of stored carrot was observed with increased pre-harvest N-fertilizer application. On day 7, the pre-harvest application of orga + urea at the rates of 309 + 0, 309 + 68.5, 309 + 267.2, 309 + 274 kg ha^{-1} and the control treatments indicated significantly ($p < 0.05$) higher percentage marketability of carrot when compared to the other treatments. On the same day, pre-harvest application of orga + urea at the rate of 309 + 411 kg ha^{-1} resulted in lower percentage marketability. The present finding is in agreement with Bose and Som (1990), who showed reduced marketability due to high rate of N-fertilizer application. The report also showed more cracking with increased levels of nitrogen.

On day 14, the pre-harvest application of orga + urea at a rate of 309 + 411 kg ha^{-1} resulted in significantly ($p < 0.01$) lower percentage marketability of carrots over other treatments. Post harvest storage losses like rotting, visible mould growth, dehydration and shriveling were among the physical appearances observed in unmarketable carrots during the storage period of 28 days. Increased rate of pre-harvest urea application resulted in uniform decreases in percent marketability, although differences were non significant. After 28 days of storage, pre-harvest treatment of carrot with orga alone and orga + 25 % recommended rate of urea (i.e. 309 kg orga ha^{-1} combined with 68.5 kg urea ha^{-1}) resulted in the best marketable carrots compared to the other the treatments.

Lower marketability was found for carrots treated with pre-harvest excess N (orga combined with urea at the rate of 309 kg orga ha^{-1} and 411 kg urea ha^{-1}). This resulted in 46.66% loss in marketability compared to the best-rated marketable carrots (IFA, 2005). Storage temperature affected ($P < 0.01$) marketability of carrot throughout the storage period. High marketability was maintained in carrot roots stored at 1°C compared to carrot roots stored at ambient conditions regardless of pre-harvest fertilizer treatments. During 28 days storage, carrot roots stored under ambient condition showed wilting, shriveling and rubberness due to desiccation. Sprouting was also observed late in the storage period under ambient conditions. No sprouting, shriveling or sign of mould growth was observed in carrot roots stored at 1°C.

Seven days after storage, 13.33% more marketable carrots were found when compared to carrots stored with ambient storage conditions. On day 14, carrots stored at 1°C had 20.95% more marketable carrots than those stored those under ambient environment. After 21 days of storage, 22.85% more marketable carrots were found in refrigerated storage. During the last day of storage, 20.95% more marketability was recorded in refrigerated storage than in storage under ambient condition. The results of the study support post harvest storage of carrots at 1°C over storing under ambient temperature storage. By 21 days of storage, there was no significant difference in marketability of carrot due to interaction between pre-harvest fertilizer and post harvest storage treatments.

Conclusion

Combined application of organic and inorganic fertilizers influenced the quality of carrot both at harvest and during storage at 1°C and under ambient conditions. The weight loss, ascorbic acid, reducing sugar, total sugar, titratable acidity and percentage marketability of carrot were significantly affected by the different pre-harvest fertilizer treatments both at harvest and during the storage period of 28 days at 1°C and ambient conditions. In all the cases, the best post harvest quality of carrot was obtained from pre-harvest combined application of orga with reduced amounts of (N) fertilizers or no (N) fertilizer at all. Therefore, orga application resulted in the production of better quality carrot roots at the time of harvest and during storage. Carrot quality was maintained better under storage at 1°C than under ambient storage condition. The weight loss, ascorbic acid, total soluble solids, total sugar, pH, titratable acidity and percentage marketability of carrots were significantly affected by the post harvest storage temperatures. Reducing sugar was also affected by storage temperatures in some of the storage intervals. The post harvest quality of carrot is largely dependent on pre-harvest use of fertilizer treatments. Increased application of the chemical or inorganic N fertilizer reduced the post harvest quality of carrot both at harvest and during the storage period. Therefore, it is recommended that fertilizing carrot plants with 309 kg ha^{-1} orga combined with 64.5 kg ha^{-1} urea as well as 309 kg ha^{-1} orga without urea, and storing the harvested roots at 1°C could be the most appropriate practice for better post harvest quality and shelf life of the crop plant.

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