Journal of Applied Horticulture, 10(2): 116-122, July-December, 2008

Effects of different preharvest treatments on yield and chemical quality of tomato

M. Melkamu[A], Tilahun Seyoum[B]* and Kebede Woldetsadik[A]

[A]Haramaya University, College of Agriculture, Department of Plant Science, P.O. Box 138, Dire Dawa, Ethiopia, [B]Haramaya University, College of Agriculture, Department of Food Science and Postharvest Technology, P.O. Box 131, Haramaya, Ethiopia.*E-mail: Tilahun_Seyoum@yahoo.com

Abstract

Field experiment was conducted to study effects of preharvest treatment of ComCat® spray, organic manure, NP fertilization and the combinations of ComCat® with the two forms of fertilizers on yield and chemical quality of tomato (*Lycopersicon esculentum* Mill.). Total and marketable yields were significantly influenced by the preharvest treatements. The result showed that the use of ComCat® and its combination with organic manure gave the highest total yield of 58.5 and 55.8 t ha^{-1}, respectively. At harvest, 94 and 93% of tomatoes subjected to preharvest ComCat® and ComCat® plus organic manure treatment were marketable, respectively. The chemical quality parameters tested such as total soluble solids, pH, titratable acidity, ascorbic acid, reducing sugar and total sugar were significantly (P<0.01) affected by the preharvest treatments. The study clearly demonstrated the importance of integerated agro-technology in order to simultaneously improve the yield and quality of tomatoes.

Key words: ComCat®, manure, NP fertilization, yield, quality

Introduction

Postharvest qualities of tomatoes partly depend up on preharvest factors such as cultural practices, genetic makeup and environmental conditions (Hobson, 1988). Cultural practices such as nutrient, water supply and harvesting methods are claimed to be factors influencing quality of tomato before and after harvest (Fischer and Richter, 1986; Watkins and Pritts, 2001). Recent research findings also indicated the possibility of screening natural plants as original untouched wild species, for their bio-stimulatory activity (Hüster, 2001; Schenabel *et. al.,* 2001). As a result, ComCat® was developed as a natural product with its plant strengthening properties and the ability to improve growth and yield in different agricultural crops. ComCat® is natural biocatalysts, which is extracted from seeds of plants and mainly consists of amino acids, gibberellins, cytokinins, auxin (indole-3-acitic acid), brassinosteroids, natural metabolites, pathogen-resistance-proteins with defense reactions, terpenoids, flavonoids, vitamins, inhibitors, other signal molecules, biocatalysts and cofactors (Schenabel *et al*., 2001). On the other hand, organic manure application is common practice in Ethiopia to improve tomato yield. However, the effect of preharvest treatments on chemical quality of tomatoes at harvest is not yet extensively investigated.

Quality management starts in the field and continues until produce reaches the end user. The response of fruit and vegetables during storage to postharvest factors also, in part, depends on preharvest practices like use of natural plant extract such as ComCat®, fertilizers, manure and environmental factors. Understanding and managing the various roles that preharvest factors play on quality is very important in order to achieve maximum harvest and postharvest quality of any crop. Mostly, preharvest conditions are of overriding importance in determining storage behavior. In some cases, their effects can be greater than the effects of adjustment of storage environment. To date, preharvest treatment recommendations for fruits and vegetables have been established primarily for higher productivity and not for improving quality, nutritive value and shelf life. Therefore, the present study was designed to investigate the effect of farmyard manure, NP fertilizers and ComCat® on the growth, yield and chemical quality of tomatoes at harvest.

Materials and methods

Site description: Field experiment was conducted at Haramaya University farm located in Dire Dawa, Ethiopia, during September to January, 2004/2005. The research site is located at an altitude of 1197 m above sea level and lies at 9° 6' N and 41° 8' E. The station lies in the semi-arid belt of the eastern rift valley escarpment with mean annual rainfall of 520 mm and mean maximum and minimum temperatures ranging from 28.1 to 34.6 and 14.5 to 21.6°C, respectively (Belay, 2002).

Experimental materials and design: Fresh market tomato variety, Marglobe, was raised in glass house for about two weeks pricked and grown on nursery bed for another three weeks. The seedlings were transplanted to plots consisting of six rows 0.75 m apart, with 90 plants per plot and spaced 0.5 m apart in the row. The spacing between plots in each replication and adjacent replications was 2 and 1.5 m, respectively.

Field treatments consisted of recommended rate of NP fertilization (92 kg of P_2O_5 and 95 kg N ha^{-1}), farmyard manure (20 tons ha^{-1}), ComCat® (100 g ha^{-1}), NP and manure each in combination with ComCat®. The source for NP fertilizer was diammonium phosphate (DAP) and urea. Manure, DAP and half of the nitrogen fertilizer were incorporated to the experimental plots before planting while the rest of the nitrogen was applied two weeks after the establishment of seedlings. ComCat® was applied at 100 g ha^{-1} in 350 L and sprayed twice during the growth period. First spray was just prior to transplanting of seedlings while the second was carried out before flowering as recommended by Hüster (2001). Other agronomic practices (weeding, irrigation, staking, etc.) were applied uniformly as needed to all plots. Plots were irrigated every other day for the first two weeks and then at weekly interval. Fungicides (Ridomil+ MZ 63% and Mancozeb 3.5 kg ha^{-1}) were used to control leaf diseases and cypermethrin (100 g ha^{-1}) was used to control insect pests; and were sprayed at seven days interval from transplanting to 20 days before first harvest. The experiment was laid out in randomized complete block design with three replications.

Data collection: The following data were recorded from the central four rows of ten randomly selected plants per plot. The total numbers of leaves was counted at weekly intervals starting from crop emergence till 50% of the plants got bloomed. The heights (cm) of plants were measured from the ground level to the highest point at blooming stage. The number of primary and secondary branches of each plant was recorded. Mean height (cm) of primary lateral shoots of each plant of each treatment at blooming stage was recorded. The average length of three leaves (cm) from the upper, middle and lower part of the plant was measured at blooming stage. The average size of three leaves (cm) at the widest point from the upper, middle and lower part of the plant was measured at blooming stage. Days to 50% flowering was recorded when approximately 50% of the flower clusters on the plant had some flowers that were in bloom. Days to maturity was recorded when approximately 70% of the plants had attained physiological maturity. Number of cluster per plant was counted at physiological maturity. Number of fruit per cluster was counted at physiological maturity.

Yield assessment: Tomato fruit, which were handpicked at the green mature, were selected from each treatment of the middle four rows. Harvesting was carried out once a week. The total fruit yield, marketable fruit yield, and fruit number per plant, were determined immediately after each harvest while fruit volume, fruit size and juice content was determined at the third harvest. Harvesting for yield comparison was done eight times roughly at weekly interval. Dropped fruits were not considered.

Total number/weight of fruits is the sum total number/weight of fruits of successive harvests.

Marketable and unmarketable fruit number and weight: At each harvest, fruits were categorized as marketable and unmarketable fruits of each treatment. Fruits, which were cracked, damaged by insect, diseases, birds and sunburn, etc. were considered as unmarketable while fruits, which were free of damage, were considered as marketable.

Fruit size: Diagonal section of the fruit measured by caliper.

Fruit volume: Ten randomly selected fruits from ten plants in a plot were taken and floated in a water jar and their displacement was recorded. Average fruit volume was taken by subtracting the initial water level in the jar from the final and by the number of fruit immersed.

Fruit juice content: The juice content of tomato was extracted using a juice extractor (60001 X, 31Je35 6X-00777, BauJhar-93, Hesteller). The intact tomato weight was recorded prior to juice extraction. After extraction, extracted juice was measured using a graduated glass cylinder and expressed in milliliter of juice per kilogram of fruit weight (mL kg^{-1}).

Chemical Analysis

Total soluble solids: The total soluble solids (TSS) was determined using an aliquot of juice extracted using a juice extractor. A bench top 60/70 ABBE (A90067, Bellingham & Stanley Ltd, England) refractometer with a range of 0 to 32 °Brix and resolutions of 0.2 °Brix was used to determine TSS by placing 1 to 2 drops of clear juice on the prism.

Ascorbic acid: The ascorbic acid content (AA) was determined by the 2, 6-dichlorophenol indophenol method (AOAC, 1970). An aliquot of 10 mL tomato juice extract was diluted to 50 mL with 3% metaphosphoric acid in a 50 mL volumetric flask. The aliquot was then centrifuged for 15 min and titrated with the standard dye to a pink end point (persisting for 15 sec). The ascorbic acid content was calculated from the titration value, dye factor, dilution and volume of the sample.

pH and titratable acidity: Tomato juice was extracted from the sample with a juice extractor (60001 X, 31Je35 6X-00777, BauJhar-93, Hesteller) and clear juice was used for the analysis of titratable acidity (TA). The titrable acidity expressed as percent citric acid, was obtained by titrating 10 ml of juice to pH 8.2 with 0.1N NaOH. The pH value of the juice was measured with a pH meter.

Sugar analysis: Reducing sugar (RS) and total sugar (TS) were estimated by using calorimetric method as described by Seyoum (2002). Liquidized fresh tomato tissue (10 g) was added to 15 mL of 80% ethanol, mixed and heated in a boiling water bath for sufficient time until the ethanol odor went off. After extraction, 1 mL of saturated lead acetate ($Pb(CH_3COO)_2.3H_2O$) and 1.5 mL of saturated sodium hypophosphate (Na_2HPO_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 mLextract was diluted to 25 mL with 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 (1 mL) was added, mixed, made up to 10 mL with distilled water and left for about 10 minutes to allow color development, after which the absorbance was determined by Jenway model 6100 spectrophotometer at 540 nm. For total sugar determination, sugar was first hydrolyzed with 1N HCl acid by heating at 70°C for 30 min. After hydrolysis, total sugar was determined following the same procedure employed for the reducing sugar. A blank was prepared using distilled water.

Data analysis: Difference between the treatments were determined by analysis of variance (ANOVA) for factorial experiment in randamized complete block design (RCBD) using MSTAT-C software (MSTAT, Michigan University, East Lansing) and comparison of the treatment mean by Duncan's Multiple range test.

Results and discussion

Growth of plant: One month after transplanting, there was a relatively poor stand of seedlings in manure, ComCat® + manure and control plots while the application of NP fertilizer enhanced early growth. The reason for poor stand of seedlings could be attributed to competition of decaying microorganisms for nutrients and slow availability of nutrient during early stage. The higher initial growth in NP treated plants could also be the addition of NP fertilizer that dissolves rapidly to meet the immediate nutrient demand of the plant. Initial growth in terms of leaf number was significantly ($P \leq 0.01$) higher for ComCat®, ComCat® + NP and NP treatments (Table 1). For the leaf counting, well established and strong seedlings were observed in the case of ComCat® treated tomato plants. This could be due to the ability of ComCat® to enhance better root development that could enable plants absorb water and nutrients (Hüster, 2001; Schnabel *et al.*, 2001) and resistance to disease and environmental stress (Pretorius *et al.,* 2003; Hüster, 2001; Schnabel *et al.*, 2001).

The preharvest treatments significantly ($P<0.01$) affected number of leaves (Table 1). During the second count, the number of leaves of tomato plants subjected to NP, ComCat® + NP and ComCat® + manure treatments were significantly ($P<0.01$) higher compared with the number of leaves of tomato plants subjected to farmyard manure and control treatments. This result clearly showed that nitrogen enhances the vegetative growth during the early developmental stage of tomato plants.

Manure application resulted in significantly ($P<0.05$) longer tomato plants compared to control (Table 2). This might be because of the ability of manure in creating suitable plant growing environment by improving moisture and nutrient status of the soil. Hader (1986) reported that organic fertilizers compensate both the deficit and the excess of elements in the soil, which can take place with mineral fertilization. ComCat® had no significant effect on the plant height when compared to the control plants. Similar finding was reported by Hüster (2001). There was no difference in plant height among the manure, ComCat® + manure, ComCat® + NP and ComCat® treatments. However, manure treated tomato plants were relatively taller followed by ComCat® + manure, ComCat® + NP and ComCat® treated plants.

Application of NP and ComCat® + NP fertilizer resulted in significantly ($P<0.01$) higher number of primary lateral branches per plant compared to ComCat®, ComCat® + manure, manure and control tomato plants. The application of ComCat®, manure and their combinations had no significant ($P>0.01$) difference on the number of primary lateral shoot. Although vegetative growth (plant height and number of lateral shoots) was enhanced by the application of inorganic fertilizer and ComCat® + NP treatments, ComCat® had no significant effect on the vegetative growth but the branches were observed to be stronger. This might indicate that nitrogen stimulates excessive vine growth while ComCat® does not have such an effect. Hüster (2001) reported the simulating effect of nitrogen on vegetative growth of beet root and cauliflower while such property is absent in ComCat® treated plants.

Leaves were significantly ($P<0.01$) longer in ComCat® treated tomato plants compared to manure, NP, ComCat® + NP, ComCat® + manure and control tomato plants (Table 2). Similarly, the

Table 1. Weekly count of tomato plant leaf number starting from establishment

Treatment	Week						
	1	2	3	4	5	6	7
CC	36.90a	88.80bc	102.07bcd	205.70b	288.90ab	313.03bc	355.67c
M	-	69.57cd	83.00cd	197.73b	246.60b	326.80bc	340.77c
NP	33.63a	96.40ab	110.77bc	235.27ab	338.03a	384.63ab	434.33b
CC + M	-	100.50ab	133.00b	241.63ab	293.03ab	326.80bc	356.97c
CC + NP	42.13a	115.57a	216.87a	282.67a	313.57ab	452.70a	571.50a
Control	-	50.80d	65.70d	107.37c	251.83b	275.23c	298.40c
CV (%)	32.4	12.32	18.83	14.73	13.92	14.03	9.62
LSD	11.07	19.48	40.62	56.73	73.09	86.32	68.75
SE ±	3.51	6.18	12.89	18.01	23.19	27.39	21.82
Significance	*	**	**	**	NS	*	**

- indicates that leaf count on week one was not done since plants of respective treatments did not establish well. Means within a column followed by the same letter (s) are not significantly different according to Duncan's multiple range test P=0.05) where NS, *, ** indicate nonsignificant or significant difference at $P<0.05$ or 0.01, respectively; CC, ComCat®; M, manure; NP, nitrogen and phosphorus; CC + M, ComCat® + manure; CC + NP, ComCat® + nitrogen and phosphorus; C, control.

Table 2. Effects of ComCat®, manure, nitrogen and phosphorous, and their combinations on growth components of fresh market marglobe tomato cultivar

Treatment	LL (cm)	LW (cm)	PLH (cm)	LSN (cm)	LSH (cm)	SLSN (cm)	SLSH (cm)	DYF (days)	DYM (days)
CC	5.42a	12.48a	52.47ab	5.86b	20.52a	2.57a	7.20a	40.67c	76.33c
M	4.78b	11.42ab	59.70a	6.00b	24.88a	2.27a	7.97a	41.67c	78.33bc
NP	4.53b	10.70bc	49.90ab	7.63a	25.50a	2.37a	11.86a	52.00b	89.67ab
CC + M	4.57b	11.24b	57.13ab	6.03b	23.12a	2.70a	10.75a	47.00bc	79.33abc
CC +NP	3.41c	9.14d	54.80ab	8.43a	21.85a	3.34a	9.18a	60.33a	91.00a
C	3.54c	9.87cd	45.17b	4.93b	21.75a	3.47a	10.44a	40.67c	75.67c
Significance	**	**	*	**	NS	NS	NS	**	*
SE ±	0.18	0.39	4.08	0.39	3.38	0.74	1.94	2.21	3.77

Means within a column followed by the same letter (s) are not significantly different according to Duncan's multiple range test $P<0.05$) where NS, *, ** indicate nonsignificant or significant difference at P=0.05 or 0.01, respectively, by LSD, respectively. LL, leaf length; LW, leaf width; PLH, plant height; LSN, lateral shoot number; LSH, lateral shoot height; SLSN, secondary lateral shoot number; SLSH, secondary lateral shoot height; DYF, days to flowering; DYM, days to maturity; CC, ComCat®; M, manure; NP, nitrogen and phosphorus; CC + M, ComCat® + manure; CC+NP, ComCat® + nitrogen and phosphorus; C, control.

application of manure, NP and ComCat® + manure resulted in significantly (P<0.01) longer leaves when compared to ComCat® + NP and the control tomato plants.

ComCat® significantly (P<0.01) increased both leaf length and width when compared with the other treatments. As a result, large and broad leaves were observed in ComCat® treated tomato plants. In addition, the leaves were deep green in colour which is in agreement with the previous findings by Pretorius *et al.* (2003). The vegetative growth of tomato in terms of the height of primary shoots, number and height of secondary shoots did not show significant variation among the treatments tested (Table 2).

Application of ComCat® + NP treatment took significantly (P<0.01) longer time (60 days) for 50% of flower clusters to bloom compared to the rest of the treatments (Table 2). NP fertilizer application took significantly (P<0.01) longer time (52 days) to bloom compared to ComCat®, manure and control tomatoes. This seems to indicate that excess nitrogen resulted in excessive lateral shoot growth that probably has impaired reproductive development by decreasing sink strength of inflorescences relative to vegetative tissues. This result is in agreement with the findings of Dieleman and Heuvelink (1992) who reported delayed flowering due to over fertilization. ComCat® (41 days), manure (42 days), ComCat® + manure (47 days) and control plants resulted in early flowering.

ComCat® + NP took significantly (P<0.05) longer time (91 days) for 70% of the fruits to get matured compared to ComCat®, manure and control tomato plants (Table 2). Similarly, NP treatment took significantly (P<0.05) longer time (90 days) compared to ComCat® and control tomato plants. As indicated earlier, ComCat®, manure and control treated tomato plants bloomed earlier.

Yield and fruit characterstics: The results of preharvest treatments on yield and yield related traits of tomato are presented in Table 3. ComCat® treated tomato plants had significantly (P<0.01) higher number of clusters per plant (17.3) compared with manure (14.7), ComCat® + NP (13.3) and control (9.6) tomatoes. NP and ComCat® + manure treated plants had statistically similar amount of cluster number per plant with that of ComCat® treated tomato plants. ComCat® + manure treatment had significantly (P<0.05) higher number of fruit per cluster compared to ComCat® + NP and control tomatoes. The maximum cluster number associated with ComCat® treated plants could be due to the activity of ComCat® in accelerating flower bud formation and increasing plant self defense mechanism and resistance (Hüster, 2001; Pretorius *et al.*, 2003). ComCat® improves better development that enables plants to adapt better and utilize the available soil water as well as nutrient.

Table 3. The effects of ComCat®, manure, nitrogen and phosphorous fertilizer on the yield components of fresh market Marglobe tomato cultivar

Treatment	CN (No)	F/CL (No)	FRS (cm^3)	FV (cm^3)	FJ (ml kg^{-1})
CC	17.30^{a}	2.89^{ab}	7.61^{a}	0.26^{a}	680.50^{bcd}
M	14.70^{bc}	2.26^{cd}	7.03^{ab}	0.23^{a}	963.90^{a}
NP	16.50^{ab}	3.32^{a}	6.39^{bc}	0.14^{a}	864.70^{ab}
CC + M	16.37^{ab}	2.70^{bc}	7.33^{ab}	0.23^{a}	624.30^{cd}
CC + NP	13.27^{c}	2.05^{d}	6.01^{c}	0.12^{a}	545.30^{d}
Control	9.57^{d}	2.23^{d}	6.78^{abc}	0.15^{a}	770.10^{abc}
Significance	**	*	*	**	*
SE ±	0.65	0.14	0.31	0.01	31.00

Means within a column followed by the same letter(s) are not significantly different according to Duncan's multiple range test P=0.05) where NS, *, ** indicate nonsignificant or significant difference at P<0.05 or 0.01, respectively. CN, cluster number; F/CL, fruit per cluster; FRS, fruit size; FV, fruit volume; FJ, fruit juice; CC, ComCat®; M, manure; NP, nitrogen and phosphorus; CC + M, ComCat® + manure; CC + NP, ComCat® + nitrogen and phosphorus; C, control.

ComCat® treatment significantly (P<0.05) increased fruit size compared to NP and ComCat® + NP treated tomato plants. Manure and ComCat® + manure treated tomato plants significantly (P<0.05) increased fruit size than ComCat® + NP treated tomato plants. Lower fruit size was obtained from tomatoes treated with NP, ComCat® + NP and control treatments. This result indicates that the addition of NP resulted in significant (P<0.05) reduction in fruit size. This may have been due to higher nitrogen levels promoting the development of more clusters per plant, which resulted in a greater fruit load per plant and smaller fruit size (Brecht *et al.,* 1976).

ComCat® stimulates higher sugar production which is the building blocks for cellulose and fruiting bodies (Seyoum, 2002). One of the physical expressions of theses response is better flowering and greater fruit biomass that can lead to increased yield in fruit and vegetables (Hüster, 2001; Schenabel *et al.,* 2001).

An overview of total, marketable and unmarketable fruit number and yield response of tomato plant to different preharvest treatments is presented in Table 4. ComCat® treated tomatoes had significantly (P<0.05) higher total fruit yield compared to NP, ComCat® + NP and control tomatoes. Similarly, ComCat® + manure treated tomatoes had significantly (P<0.05) higher total fruit yield than ComCat® + NP and control.

The total and marketable fruit number obtained from ComCat® + NP treated tomatoes was significantly (P<0.05) lower compared to other treatments (Table 4). The total and marketable fruit number obtained from that of the tomatoes grown using manure and NP fertilizers were not significantly (P<0.05) different from control tomatoes. Significantly (P<0.05) higher number and yield of unmarketable fruit was obtained from NP fertilized tomatoes, followed by ComCat® + NP treated tomatoes.

Table 4. The effects of ComCat®, manure, and nitrogen and phosphorus fertilization on the marketable, unmarketable, total fruit number and weight of fresh market tomato

Treatments	Number of fruit per plot			Fruit yield (ton ha^{-1})		
	M	UM	Total	M	UM	Total yield
CC	938.67^{a}	61.67^{c}	1000.34^{a}	55.00^{a}	3.52^{d}	58.53^{a}
M	689.33^{b}	58.33^{c}	747.66^{b}	41.65^{bc}	4.79^{bc}	46.44^{abc}
NP	615.67^{b}	122.00^{a}	737.67^{b}	36.69^{c}	6.13^{a}	42.82^{bc}
CC +M	987.33^{a}	65.67^{c}	1053.00^{a}	52.01^{ab}	3.76^{cd}	55.77^{ab}
CC+NP	445.00^{c}	95.33^{b}	540.33^{c}	13.74^{d}	4.99^{ab}	18.73^{d}
C	623.30^{b}	69.00^{c}	692.^{b}	33.48^{c}	4.19^{bcd}	37.67^{c}
Significance	*	*	*	*	*	*
SE±	31.268	6.9926	30.397	3.9781	0.3856	4.0848

Means within a column followed by the same letter(s) are not significantly different according to Duncan's multiple range test P=0.05) where * indicate significant difference at P<0.05. M, marketable yield or number; U, unmarketable yield or number; T, total yield or number; ComCat, M, manure NP, nitrogen&phosphorus CC + M, ComCat + manure, C + NP; ComCat + nitrogen and phosporus, C; control.

The higher marketable fruit yield of tomato treated with ComCat® compared to NP, manure, ComCat® + NP and control tomatoes, is in agreement with the findings of Schnabel *et al.* (2001) who reported the yield increase by 16-19% due to ComCat® treatment in different crops including tomato. In addition, Hüster (2001) reported that ComCat® reduced the occurrence of disease by more than 40% which could be, in part, the reason why ComCat® performed better than others.

For the increase in yield of ComCat® + manure treatment, it seems that the ComCat® enabled better nutrient uptake during the earlier growth stage and the slow release of nitrogen from manure might have contributed to the nutrient demand of the plant in the later stage of growth.

The highest unmarketable fruit yield was obtained from NP while the least was from ComCat® treated tomatoes. The unmarketable tomato fruit yield obtained from manure treated tomatoes was significantly (P<0.05) lower than NP treated tomato fruit. Most of the fruit grouped as unmarketable were bird attack, crack, soft rot and irregular shape. Blossom end rot appeared due to preharvest ComCat® + NP fertilizer treatment. This could be due to the excess N that might have fostered Ca^{++} deficiency, which is responsible for the cause of blossom end rot (Shaykewich *et al.*, 1971).

The difference in marketable fruit yields from manure and inorganic fertilizer was not significant (P>0.05); however, higher yield was obtained from manure than inorganic fertilizer treated tomato plants. In support of this study, Cacek and Lagner (1986) reported the less danger of over-fertilization by adding decomposed organic material. Application of manure and inorganic fertilizer did not show significant (P<0.05) variation in both total and marketable fruit yield compared to control. However, contrary to this result, Winsor (1970) reported yield increase in tomato due to nitrogen application. Some of the possible reasons for the comparable performance of control with fertilizer application under the present study could be attributed to the inherent fertility of the soil and uniform irrigation. The application of ComCat® + NP fertilizer depressed the performance of the crop, even when compared to the control treatment. It is reported that ComCat® is applied additional to normal fertilizers (Schenabel *et al.*, 2001). However, contrary to their findings, ComCat® + NP highly reduced yield in the present study. This could also be due to the cumulative effect of nitrogen in the soil and the additional N application, which leads to excessive vegetative growth. In this condition the plant may grow well, but be late yielding or low yielding because vegetative growth is favoured over reproductive growth (Wudiri and Henderson, 1985).

In general, both ComCat® and ComCat® + manure treatments had an enhancing effect on the yield of tomatoes where 39.1 and 35.62% more marketable yield increase was shown than in the control tomatoes, respectively. Hüster (2001) reported yield increase due to ComCat® in cabbage, cauliflower, beetroot and other cereal crops (wheat and maize).

Application of manure resulted in 19.6% increment in marketable yield while application of inorganic fertilizer resulted in only 8.74% increment when compared to the control. Even though there has been much controversy over manure versus inorganic fertilizer on yield increment, in the present study, manure outperformed by 10.86%.

Table 5. The effects of preharvest treatments on the chemical quality atributes of green mature tomato fruits

Treatment	Chemical composition at harvest					
	TSS	pH	TA	AA	RS	TS
CC	4.867[a]	3.839[c]	1.254[a]	11.72[bc]	0.6912[bc]	1.841[c]
M	4.533[ab]	3.981[b]	1.209[a]	14.92[a]	0.7094[b]	2.027[b]
NP	4.333[bc]	4.017[b]	1.376[a]	12.97[b]	0.7732[ab]	1.633[d]
CC + M	4.333[bc]	3.929[bc]	0.4463[bc]	12.36[b]	0.6212[cd]	1.125[e]
CC + NP	4.067[c]	4.038[b]	0.5887[b]	10.88[c]	0.5546[d]	1.156[e]
C	4.667[ab]	4.213[a]	0.37[c]	13.00[b]	0.7998[a]	2.623[a]
Significance	**	**	**	**	**	**
SE±	0.063	0.005	0.007	0.561	0.0211	0.005

Means within a column followed by the same letter (s) are not significantly different according to Duncan's multiple range test P=0.05) where NS, *, ** indicate nonsignificant or significant difference at P<0.05 or 0.01, respectively, by LSD. TSS, total soluble solid; TA, titratable acidity; AA, ascorbic acid; RS, reducing sugar; TS, total sugar; CC, ComCat; M, manure; NP, nitrogen and phosphorus; CC + M, ComCat + manure; CC + NP, ComCat + nitrogen and phosphorus; C, control.

The high performance of ComCat® over other treatments in both total and marketable yield could be due to the larger and broader leaves produced by ComCat® and might have increased the photosynthetic effeicency. Similarly, the increase in plant height and primay lateral shoot number in ComCat® + NP and NP fertilized tomato plants did not lead to increase in total and marketable yield. This indicates that stimulation of early growth could compete with fruit set and development and is not desirable for obtaining acceptable yields. ComCat® does not have an early vegetative growth stimulating effect, as is well known for early nitrogen fertilization (Hüster, 2001).

Chemical quality: At harvest, the green mature tomatoes subjected to preharvest ComCat® treated contained significantly (P<0.01) higher TSS compared with NP, ComCat® + NP and ComCat® + manure treated tomato fruits (Table 5). However, it did not show significant difference (P>0.01) when it is compared with the control and manure treated tomatoes. Seyoum (2002) reported that ComCat® increased the biosynthesis of polysaccharide carbohydrates while efficiently utilizing free sugars for physiological processes during growth and development. ComCat® is also known to increase the chlorophyll content and hence increase the production of total available carbohydrates (Seyoum, 2002).

At harvest, manure treatment showed an increase in TSS content of tomatoes than NP treatment, although it was not significant at P>0.01 (Table 5). This increase in the TSS content of manure treated tomatoes could be due to higher photosynthetic efficiency by the relatively larger and broader leaves and increase of fruit sink strength. This result contradicts with findings of DeEll (2003) who reported higher TSS concentration at harvest and after storage due to conventional fertilizer application in apple. However, the result is in agreement with the findings of Raupp (1996) who reported the positive effect of manure on TSS content of vegetables. Mccollum *et al.* (2004) found slight difference in soluble solids or acidity between conventional grown and organically grown fruit. Among the preharvest treatments, only ComCat® + NP treatment significantly (P<0.01) decreased the TSS content of tomato at harvest compared with the control. The rate of assimilate export from leaves and rate of import by fruit might be lower as vegetative growth was favored than reproductive growth in this treatment.

Preharvest treatment significantly (P<0.01) reduced the pH value of tomato fruits (Table 5). Moreover, preharvest treatments significantly affected the TA of tomato fruits at harvest (Table 5). Significantly (P<0.01) higher titratable acid content of tomato fruit was found in NP, manure and ComCat® treated tomato fruits compared to ComCat® combined with the fertilizers and control tomatoes. The increase in TA of tomato where manure and NP fertilizer applied is in accordance with the result reported by Hegde and Srinivas (1990) where acidity increased with increasing fertilizer. Contrary to this, DeEll (2003) reported no difference in TA content of apple due to fertilizer application. The high TA of ComCat® treated tomato than in control tomatoes is in agreement with report of Seyoum (2002). ComCat® + NP treated tomato also showed significantly (P<0.01) higher TA than in the controls, however, ComCat® + manure treated tomato had statistically similar TA content with that of ComCat® + NP and control. The least TA value was observed in the control tomatoes and ComCat® + manure treated tomatoes.

At harvest, the application of manure had a positive effect on the accumulation of AA content in tomatoes. Raupp (1996) indicated the positive effect of manure on the content of dry matter, sugar and AA in vegetables. Earlier studies by Cacek and Lagner (1986) also showed the positive effect of organic fertilizer on the nutritional value of vegetables. ComCat® + NP treatment significantly (P<0.01) lowered AA content of tomato fruits compared to the control. The lower AA content in the preharvest NP and ComCat® + NP treatments could be due to the effect of N fertilization. Likewise, Lisiewska and Kmiecik (1996) reported a decrease in AA content of fruits and vegetables with increasing amounts of nitrogen fertilizer.

Field study on the effect of preharvest treatment of ComCat®, ComCat® + manure, ComCat® + NP, NP and manure were conducted on Marglobe tomato. Vigorous growth was observed in ComCat® treated tomato plants. Seedling established earlier in ComCat®, ComCat® + NP and NP treated tomato plants whereas establishment was delayed in manure, ComCat® + manure and control tomato plants. The yield of fresh tomato was significantly (P<0.05) influenced by treatments. The highest yield was obtained from foliar application of ComCat® and ComCat® + manure treatments. Supplementing the recommended NP fertilizers with ComCat® reduced both marketable and total yield. Supplementing ComCat® with manure fertilizer slightly improved yield over ComCat® alone. In general, both ComCat® and ComCat® + manure treatments had an enhancing effect on the yield of tomatoes where 39.1 and 35.62% yield increase was shown than the control tomatoes, respectively. The difference in marketable fruit yields from manure and NP fertilizer was not significant (P>0.05); however, higher yield was obtained from manure than inorganic fertilizer treated tomato plants. Application of manure resulted in 19.6% increment in marketable yield while application of inorganic fertilizer resulted in only 9% increment compared to the control. Manure outperformed by about 10.6% compared to NP fertilizer.

In summary, the yield of tomatoes was improved under semi-arid conditions of the experimental area through the use of preharvest ComCat® and ComCat® + manure treatment. Generally, this study clearly demonstrated the importance of integerated agrotechnology in order to improve yield while improving or maintaining quality after harvest. The preharvest treatments had influenced the quality of tomatoes at harvest. ComCat® treated tomato fruits had lower pH, AA, reducing sugar and total sugar, and higher TA and TSS content. ComCat® treatment combined with manure and NP fertilizers had shown lower pH, TSS, TA, AA, RS and TS. Manure treated tomato fruits had higher TSS, TA, AA, TS and RS. NP fertilizer application resulted in higher TA.

Acknowledgements

The authors acknowledge Mr. Thomas Hüster of AgraFurum, Germany, for providing the experimental material (ComCat®) and assistance during this research.

References

AOAC, 1970. *Official Methods of Analysis.* 12th edn. Association of Agricultural Chemists, Washington, DC.

Belay, A. 2002. *Factors influencing loan repayment performance of rural women in eastern Ethiopia: The case of Dire Dawa Area.* An M.Sc. Thesis presented to the School of Graduate Studies of Alemaya University, 102p.

Brecht, J.K., L. Bisogini and H.M. Mungek, 1976. Effect of fruit position, stage of ripening and growth habit on chemical composition of fresh tomatoes. *Journal American Socity Horticultural Science,* 41: 945-948.

Cacek, T. and L.L. Lagner, 1986. The economic implications of organic farming. *American Journal Altern. Agriculture,* 1: 25-29.

DeEll, Jennifer, 2003. *Postharvest quality and sensory attributes of organically grown apples*. Minsitry of Agric and Food, Ontario, Canada.

Dieleman, J.A. and E. Heuvelink, 1992. Factors affecting the number of leaves preceeding the first inflorescence in the tomato. *Journal Horticultural Science,* 67: 1-10.

Fischer, A.D.A. and C.H. Richter, 1986. Influence of organic and mineral fertilizers on yield and quality of potatoes. *Proceedings of the Fifth IFOAM Conferences*, Germany. 75p.

Hader, Y. 1986. The role of organic matter in the introduction of biofertilizers and biocontrol agents to soil. In: Chen, Y., Y. Avnimelech, eds. *The Role of Organic Matter in Modern Agriculture*. Boston: Martinus Nijhoff Publishers, pp169-180.

Hegde, D.M. and K. Srinivas, 1990. Effect of irrigation and nitrogen on yield, nutrient uptake and water use of tomato. *Gartenbauwissenschaft*, 55(4): 173-177.

Hobson, G.E. 1988. Pre-and postharvest strategies in the production of high quality tomato fruit. *Applied Agricultural Research,* 3(5): 282-287.

Hüster, T. 2001. ComCat®. *Personal Communication*. Institute of Molecular Physiology and Biotechnology of Plants. University of Bonn. AgraFurum, Germany.

Lisiewska, Z. and W. Kmiecik, 1996. Effect of level of nitrogen fertilizer, processing conditions and period of storage for frozen broccoli and cauliflower on vitamin C retention. *Food Chemistry*, 57: 267-270.

Mccollum, T.G., D.O. Chellemi, E.N. Rosskopf, G.T. Church and A. Plotto, 2004. Postharvest quality of tomatoes produced in organic and conventional production systems. *American Society of Horticulture Science Meeting,* 40(4): 959-965.

Pretorius J.C., E. Van der Watt and R.A. Buitendag, 2003. *Natural products from plants*. Department of Soil-, Crop- and Climate Sciences, University of the Free State, PO Box 339, Bloemfontein**.**

Raupp, J., 1996. Quality of plant products grown with manure fertilization. In: *Comparision of food quality organically versus conventionally grown vegetables*. www.eap.mcgill.ca/publications/EAP 38.htm. pp 44-48.

Schenabel, H., U. Roth and A. Friebe, 2001. Brassinosteroids-induced stress tolerances of plants. *Recent Res. Devel. Phytochem,* 5: 169-183.

Shaykewich, C.F., M. Yamaguhi and J.D. Campbell, 1971. Nutrition and blossomend rot of tomatoes as influenced by soil water regime. *Can. Journal Plant Science*, 51: 505-511.

Seyoum, T. 2002. *The improvement of the shelf life of vegetables through pre and post harvest treatment.* Ph.D. Dissertation presented to the University of Free State. South Africa.

Watkins, C.B. and M.P. Pritts, 2001. The influence of cultivars on postharvest performance of fruits and vegetables. Proceedings of the Fourth International Conference on Postharvest Science. *Acta Hortic.* 1(553): 59-63.

Wudiri, B.B. and D.W. Henderson, 1985. Effect of water stress on flowering and fruit set in processing tomatoes. *Scientia Hortic.*, 27: 189-198.

Winsor, G.W., 1970. A long-term factorial study of the nutrition of greenhouse tomatoes, fertilization of protected crops. *Proceedings of the 6th Colloquium of the International Potash Institute*, Florence 1968, International Potash Institute, Berne, Switzerland. pp. 269-281.