A COMPARISON OF ORGANIC AND CHEMICAL FERTILIZERS FOR TOMATO PRODUCTION

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Abstract

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and versatile vegetables in the world, and organic production with a high yield and desirable quality is a target of many producers. The effect of four different fertilizers (chemical, municipal solid waste compost, cattle manure, and spent mushroom compost) on four commercial tomato cultivars (Redstone, Flat, Peto Pride and Chief) was assessed in this research. The highest yield was obtained with the Chief cultivar when fertilized with chemical fertilizer and the lowest value was obtained with Peto Pride fertilized with 20 tonnes per hectare (t/ha) of cow manure. The difference between the two classes of fertilizers (organic and chemical) was not very high so that organic fertilizers are competitive and may be a suitable replacement for chemical fertilizer. According to our results, to achieve maximum yields with organic fertilizers, 20 t/ha of spent mushroom compost can be recommended for the Redstone cultivar, 30 t/ha of cow manure for Flat, 300 t/ha of municipal solid waste compost for Peto Pride, and 300 t/ha of municipal solid waste compost or 20 t/ha of spent mushroom compost can be recommended for the Chief cultivar. These recommended organic fertilizing regimes achieved cultivar yields comparable to the chemical fertilizer treatments, achieving a yield of 98.4% for Redstone, 99.5% for Flat, 97.6% for Peto Pride, and 95.7% for Chief.

Keywords: Tomato, municipal solid waste compost, cattle manure, cow manure, spent mushroom compost, organic agriculture.

Introduction

Iran has a total annual production of 4,826,396 tonnes of tomatoes and ranks seventh in the world for tomato production. Conventional production uses chemical fertilizers mainly urea, superphosphate and potash. However, the continuous use of chemical fertilization leads to deterioration of soil characteristics and fertility, and may lead to the accumulation of heavy metals in plant tissues which compromises fruit nutrition value and edible quality (Shimbo et al., 2001). Chemical fertilizer also reduces the protein content of crops, and the carbohydrate quality of such crops also gets degraded (Marzouk & Kassem, 2011). Excess potassium content on chemically overfertilized soil decreases Vitamin C, carotene content and antioxidant compounds in vegetables (Toor et al., 2006). Vegetables and fruits grown on chemically overfertilized soils are also more prone to attacks by insects and disease (Karungi et al., 2006).

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Although chemical fertilizers have been claimed as the most important contributor to the increase in world agricultural productivity over the past decades (Smil, 2001), the negative effects of chemical fertilizer on soil and environment limit its usage in sustainable agricultural systems (Peyvast et al., 2008). Weakening soil quality requires increasing inputs to maintain high yields. This, in turn, threatens future food security and raises production costs for often already poor farmers.

Research comparing soils of organically and chemically managed farming systems have recognized the higher soil organic matter and total nitrogen (N) with the use of organic agriculture (Alvarez et al., 1988; Drinkwater et al., 1995; Reganold, 1988). Soil pH becomes higher, plant-available nutrient concentrations may be higher, and the total microbial population increases under organic management (Clark et al., 1998; Dinesh et al., 2000; Reganold, 1988; Lee, 2010).

Organic fertilizers, which mainly come from agricultural waste residues such as cow manure and spent mushroom compost or municipal solid waste compost (MSWC), are often identified as suitable local organic fertilizers. These contain high levels of nutrients, e.g. N and P and high amounts of organic matter (Peyvast et al., 2007, Peyvast et al., 2008; Olfati et al., 2008; Shabani et al., 2011). According to these studies, the usage of MSWC can be an effective alternative to chemical fertilizers. However, the apparent deficiency of an adequate supply of plant-available N from organic fertilizer, resulting from a slow rate of mineralization, makes crop yields in fields treated with organic fertilizer lower than in those treated with chemical fertilizers (Blatt, 1991; Lee, 2010). Organic fertilizers should be used in appropriate amounts to achieve suitable yield and quality.

The aim of this study was to determine appropriate amounts of different organic fertilizers in tomato fields to achieve maximum yield and quality.

Materials and methods

The tomato plants (*Lycopersicon esculentum* Mill. Cvs. Chief, Redstone, Peto Pride and Flat) were grown in a research field at the University of Guilan (altitude 7 meters below mean sea level, 37°16′N, 51°3′E). The experiment was arranged in a randomized block design and comprised three different fertilizers, namely cow manure (20, 30 and 40 t/ha), spent mushroom compost (10, 20 and 30 t/ha), and municipal solid waste compost (100, 200 and 300 t/ha), as well as chemical fertilizer (150N-100P-300K kg/ha) and unfertilized plots as control. Each treatment had three replications with 10 plants in each replicate. After sowing, seedlings were transferred to a potting medium containing peat and cattle manure (1:1 v/v) and irrigated when it was necessary by tap water. Seedlings were transplanted with a distance of 0.5 m × 0.5 m between rows and plants, respectively.

The soil was a clay loam, pH 7.2, containing total N (1.2%), total C (0.6%), a C/N ratio of 0.5, with 12, 68, 167 mg/kg of Ca, P, and K, respectively, and with an EC of 0.09 dS/cm. Compost was purchased from Bazyafte Zobaleh Company in Rasht, Iran, and analyzed before using in the field (Table 1). The soil was prepared by ploughing and disking. Fruits were harvested manually when they had reached maturity stage 5 (Californian Tomato Commission, 2002) and total yield was calculated on a hectare basis. Chopped fruit tissues were placed in a forced air drying oven at 75°C for 48 h for dry matter determination.

Table 1. Chemical and physical characteristics of cow manure, municipal solid waste compost and spent mushroom compost.

Type of organic fertilizer	Cow manure	Municipal solid waste compost	Spent mushroom compost
Total-N (g/kg)	28.6	25.6	21
Organic-C (g/kg)	411.7	500	645
C:N ratio	14.4	19.5	30.7
Total-P (g/kg)	9.5	15.8	18
EC (dS/m)	8.8	4.9	10
pH	8.8	7.1	6.8
Ca (g/kg)	29.6	5.32	28
Mg (g/kg)	4	3.3	18
K (g/kg)	5	6.8	20

Phosphorus, calcium and magnesium (P, Ca & Mg) in fruits and leaves were measured by spectrometry (JENWAY 6105 U.V/V) (Elliot & Dempsey, 1991). Potassium (K) was determined by flame photometer (Latiff et al., 1996). One gram of dry matter was ashed at 550°C for 6 h (Gbolagade et al., 2006).

Data were subjected to analysis of variance in SAS (SAS Inc., Cary, N.C.). If interactions were significant they were used to explain the data. If interactions were not significant, means were separated with Tukey test.

Results

ANOVA determined that cultivar, type of fertilizer and their two way interactions had a significant effect on all measured characteristics of tomato (Tables 2-4). Due to the significant interactions between type of fertilizer and cultivar we were unable to propose an overall preferred type of fertilizer for all cultivars, but instead we have nominated one or several preferred fertilizer types for each cultivar.

Table 2. ANOVA table of cultivars and fertilizers on tomato total yield and yield characteristics.

		Mean square				
S.O.V.	d.f.	Number of fruit per plant	Fruit length (mm)	Fruit width (mm)	Mean of fruit weight (g)	Total yield (t/ha)
Block	2	23.92**	1.1 ns	5.55 ns	1.62 ns	0.7 ns
Cultivar (C)	3	271.74**	245.4**	1,504.35**	15,054.43**	358.8**
Fertilizers (F)	10	48.15**	155.6**	87.74**	1,374.84**	25.4**
C*F	30	11.54**	26.67**	27.22**	429.19**	7.2**
Error	86	1.91	0.98	2.06	1.18	1.49
C.V. (%)		14	1.77	2.89	1.33	0.24

(S.O.V. = Sources of variation; d.f. = degrees of freedom; C.V. = coefficient of variation; ns, **, *: non significant, and significant at $P \leq 0.01$ and $P \leq 0.05$ respectively)

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Table 3. ANOVA table of cultivars and fertilizers on tomato fruit and leaves dry matter and ash.

		Mean square			
S.O.V.	d.f.	Fruit dry matter (%)	Leaf dry matter (%)	Fruit ash (%)	Leaf ash (%)
Block	2	1.64 ns	0.03 ns	0.76 ns	0.03**
Cultivar (C)	3	5.01**	9.07**	6.83**	248.41**
Fertilizers (F)	10	1.77**	4.23**	2.43**	47.6**
C*F	30	1.36**	5.43**	1.29**	24.53**
Error	86	0.61	0.12	0.17	0.003
C.V. (%)		11.08	2.02	9.27	0.46

(S.O.V. = Sources of variation; d.f. = degrees of freedom; C.V. = coefficient of variation; ns, **, *: non significant and significant at P≤0.01 and P≤0.05 respectively)

Table 4. ANOVA table of cultivars and fertilizers on tomato fruits and leaves P, K, Ca and Mg.

		Mean square							
S.O.V.	d.f.	P (mg·100 g FW)		K (mg·100 g FW)		Ca (mg·100 g FW)		Mg (mg·100 g FW)	
		Fruit	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf
Block	2	177.02**	25.12 ns	37.42**	1009.8**	348.2**	11.72 ns	0.14 ns	1.01 ns
Cultivar (C)	3	352.92**	11,503.36**	62,985.86**	19,599**	184.4**	734.33**	50.83**	272.4**
Fertilizers (F)	10	257.75**	10,358.88**	15,075.3**	19,122**	385.7**	2,477.17**	233.64**	434.78**
C*F	30	112.95**	3,600.61**	17,387**	6,797**	134.8**	763.77**	72.87**	139.4**
Error	86	12.68	15.54	7.49	50.06	18	4.11	3.62	0.69
C.V. (%)		10.69	2.75	0.73	3.47	10.2	3.24	5.4	4.48

(S.O.V. = Sources of variation; d.f. = degrees of freedom; C.V. = coefficient of variation; ns, **, *: non significant and significant at P≤0.01 and P≤0.05 respectively)

The interaction between cultivar and type of fertilizer on number of fruit per plant showed that the highest number of fruit per plant was obtained in Flat cultivar fertilized with chemical fertilizer and the lowest value was obtained with Peto Pride fertilized with 30 t/ha of spent mushroom compost. ‘Red stone’ showed the highest number of fruit per plant when fertilized with 100 t/ha of municipal solid waste compost, while Flat brought on the highest number of fruit per plant when it was fertilized with chemical fertilizer. The highest number of fruit per plant by other cultivars was obtained when they were fertilized with 200 t/ha of municipal solid waste compost (Table 5).

Table 5. Influence of different cultivars and fertilizers interaction on tomato total yield and yield characteristics.

Cultivars	Fertilizers	Number of fruit per plant	Fruit length (mm)	Fruit width (mm)	Mean of fruit weight (g)	Total yield (t/ha)
Redstone	Control	15±0.7	54±0.01	42±0.1	59±0.5	41±0.6
Redstone	Chemical fertilizer	11.87±0.5	56±0.3	43±0.6	65.5±0.2	44±0.01
Redstone	10 t/ha SMC	15.66±0.4	59±0.3	42±0.2	66.5±0.5	42.5±0.2
Redstone	20 t/ha SMC	18.27±0.6	55±0.3	43±0.6	63.5±0.4	43.3±0.2
Redstone	30 t/ha SMC	13.25±0.5	60±0.6	43±0.4	69.7±0.5	41.3±0.04
Redstone	20 t/ha CM	13±0.7	56±0.5	43±0.9	62.5±0.6	41.3±0.03
Redstone	30 t/ha CM	11.41±0.5	56±0.6	45±0.5	63.5±0.6	41.4±0.2
Redstone	40 t/ha CM	14.19±0.4	59±0.4	46±0.2	75.3±0.5	41.5±0.1
Redstone	100 t/ha MSWC	19.58±0.3	57±1.2	40±0.5	58.2±0.5	42.4±0.3
Redstone	200 t/ha MSWC	14.5±0.3	50±0.5	41±0.2	55±0.2	42.5±0.2
Redstone	300 t/ha MSWC	19.52±0.3	44±0.2	39±0.6	38±0.5	41.3±0.2
Flat	Control	11.58±0.5	55±0.4	51±0.3	81.4±0.3	39.6±0.5
Flat	Chemical fertilizer	23.25±0.3	56±0.7	51±0.4	86±0.5	43.7±0.4
Flat	10 t/ha SMC	12.83±0.1	51±0.5	49±1	74.3±0.5	41.7±0.01
Flat	20 t/ha SMC	15±1.7	56±0.7	52±0.9	85.6±0.5	42.2±0.3
Flat	30 t/ha SMC	11.35±1.1	60±0.5	51±0.6	90.7±0.2	42.5±0.1
Flat	20 t/ha CM	11.5±0.3	53±0.6	53±0.4	86.7±0.3	41.4±0.4
Flat	30 t/ha CM	11.91±0.7	54±0.1	51±0.6	79.6±0.2	43.5±0.2
Flat	40 t/ha CM	13.52±0.3	52±0.3	52±0.9	78.5±0.6	42.8±0.4
Flat	100 t/ha MSWC	17.38±1.2	56±0.4	48±0.7	82.9±0.9	43±0.01
Flat	200 t/ha MSWC	19.5±1.1	51±0.5	47±0.5	89.5±0.5	43±0.01
Flat	300 t/ha MSWC	17.4±1.1	46±0.7	44±0.5	65.7±0.7	43±0.2
Peto Pride	Control	8±0.1	66±0.5	68±0.6	154.3±0.4	39.4±0.1
Peto Pride	Chemical fertilizer	9±0.6	62±0.3	63±1.2	127.9±0.3	46.6±0.2
Peto Pride	10 t/ha SMC	8.5±0.6	60±0.6	58±0.2	95.8±0.6	43.3±0.4
Peto Pride	20 t/ha SMC	10.5±0.6	60±0.5	57±2.8	108.5±0.7	39.6±0.1
Peto Pride	30 t/ha SMC	7.75±0.1	65±0.6	54±1.1	112.3±0.6	39±0.005
Peto Pride	20 t/ha CM	8.5±0.3	66±0.4	62±1	127.2±0.6	37.5±0.2
Peto Pride	30 t/ha CM	10±0.5	60±0.2	57±0.9	106.9±0.8	42±0.04
Peto Pride	40 t/ha CM	8.41±0.4	63±0.4	58±1.4	117.6±0.4	42.4±0.2
Peto Pride	100 t/ha MSWC	10.16±0.6	58±0.5	62±0.4	137±0.2	39±0.3
Peto Pride	200 t/ha MSWC	12.16±0.6	48±0.5	46±0.2	85±0.4	40.5±0.2
Peto Pride	300 t/ha MSWC	8.41±0.8	52±0.3	58±0.2	76.5±0.7	45.5±0.3
Chief	Control	14.83±1	56±0.5	52±0.5	77.3±0.3	48.3±0.1
Chief	Chemical fertilizer	15.83±0.6	56±0.5	47±0.4	81±0.2	53±0.5
Chief	10 t/ha SMC	16.27±0.4	54±0.6	46±0.3	67.7±0.6	48±0.5
Chief	20 t/ha SMC	14.75±0.8	56±0.2	50±0.3	78.3±0.3	50.5±0.1
Chief	30 t/ha SMC	15.66±0.8	55±0.6	48±0.6	76.3±0.6	47.9±0.2
Chief	20 t/ha CM	13.66±0.2	61±0.2	50±0.6	84±0.6	46.8±0.2
Chief	30 t/ha CM	13.41±1.7	53±0.4	49±0.2	72.5±1.1	48.8±0.04
Chief	40 t/ha CM	13.16±0.2	60±0.6	50±0.6	86.4±0.6	45±0.4
Chief	100 t/ha MSWC	15.5±1.1	51±0.2	45±0.2	62.3±0.9	46.4±0.2
Chief	200 t/ha MSWC	16.66±1.5	51±0.4	45±0.8	62.6±0.2	47.5±0.3
Chief	300 t/ha MSWC	16.58±2	51±0.6	45±0.4	67.8±0.3	50.7±0.4

(SMC = Spent mushroom compost, CM = cow manure, MSWC = municipal solid waste compost)

The interaction between cultivar and type of fertilizer on fruit length showed that the longer fruit was obtained in Peto Pride fertilized with 20 t/ha of cow manure and control, and the lowest value was obtained in Redstone fertilized with 300 t/ha municipal solid waste compost. ‘Red stone’ and Flat cultivars showed the highest fruit length when fertilized with 30 t/ha spent mushroom compost. Chemical fertilizer didn’t have any positive effect on Chief cultivar (compared to the control), and decreased Peto Pride fruit length (compared to the control). Chief cultivar showed the highest fruit length when fertilized with 20 t/ha cow manure (Table 5).

The highest fruit width was obtained in Peto Pride cultivar without any type of fertilizer (control), and the lowest value was obtained in Redstone fertilized with 300 t/ha of municipal solid waste compost. Redstone and Flat have showed the highest fruit length when fertilized with 40 and 20 t/ha of cow manure respectively. For the cultivar Chief all of the fertilizers decreased the fruit width, compared to the control (Table 5).

The highest mean of individual fruit weight was obtained in Chief without any type of fertilizer (control), and the lowest value was obtained with Redstone fertilized with 300 t/ha of municipal solid waste compost. ‘Red stone’ and Chief showed the highest fruit length when fertilized with 40 t/ha of cow manure. For Peto Pride fertilizers reduced fruit weights, compared to the control (Table 5).

The highest yield was obtained in Chief when fertilized with chemical fertilizer and the lowest value was obtained in Peto Pride fertilized with 20 t/ha of cow manure. Between different organic fertilizers the higher yield was obtained in Redstone and Chief when fertilized with 20 t/ha spent mushroom compost. The yield of Flat cultivar peaked when fertilized with 30 t/ha cow manure or chemical fertilizer. Similarly, the yield of Peto Pride peaked when fertilized with 300 t/ha municipal solid waste compost or chemical fertilizer (Table 5).

Interaction between cultivar and type of fertilizer on dry matter percent in tomato fruit showed that the highest dry matter was obtained in Peto Pride fertilized with 200 t/ha of municipal solid waste compost, and the lowest value was obtained in Chief fertilized with 40 t/ha of cow manure. ‘Red stone’ showed the highest dry matter of fruit when fertilized with 10 t/ha of spent mushroom compost, while chemical fertilizer decreased the dry matter in fruit. Flat showed the highest dry matter percent in fruit when fertilized with municipal solid waste compost. The highest dry matter percent in fruit was obtained by Peto Pride and Chief when fertilized with 200 and 100 t/ha of municipal solid waste compost respectively (Table 6).

The interaction between cultivar and type of fertilizer on dry matter percent in tomato leaves showed that the highest dry matter was obtained in Peto Pride fertilized with chemical fertilizer, and the lowest value was obtained in Chief when fertilized with 40 t/ha of cow manure. All types of fertilization decreased Redstone leaves dry matter. Flat cultivar showed the highest dry matter percent in leaves when fertilized with 20 t/ha of cow manure. Chemical fertilizer increased Peto Pride leaves dry matter while organic fertilizers didn’t show any significant effect. In contrast to the Peto Pride response to different types of fertilizer, Chief leaves dry matter decreased with chemical fertilizer and 200 t/ha of municipal solid waste compost achieved the highest dry matter percent in tomato leaves (Table 6).

Table 6. Influence of different cultivars and fertilizers on tomato fruit and leaves dry matter and ash.

Cultivars	Fertilizers	Fruit dry matter (%)	Leaf dry matter (%)	Fruit ash (%)	Leaf ash (%)
Redstone	Control	6.9±0.2	18.2±0.03	3.7±0.1	11.9±0.05
Redstone	Chemical fertilizer	6.2±0.1	17.4±0.04	4.3±0.1	9.8±0.1
Redstone	10 t/ha SMC	8.6±0.6	17±0.05	3±0.5	9.7±0.005
Redstone	20 t/ha SMC	6.8±0.5	17.4±0.005	2.6±0.2	7.8±0.005
Redstone	30 t/ha SMC	7.5±0.3	16.9±0.05	4.5±0.03	4±0.002
Redstone	20 t/ha CM	7.6±0.5	17±0.005	3.8±0.1	15.8±0.05
Redstone	30 t/ha CM	7.2±0.3	17.9±0.05	4.5±0.2	8.1±0.005
Redstone	40 t/ha CM	6.6±0.2	17.3±0.05	4.3±0.1	11.9±0.005
Redstone	100 t/ha MSWC	7.4±0.5	16.7±0.04	4.5±0.1	5.9±0.005
Redstone	200 t/ha MSWC	6.6±0.2	17.7±0.05	4.4±0.1	17.5±0.05
Redstone	300 t/ha MSWC	7.6±0.6	16.6±1	4.5±0.1	11.3±0.005
Flat	Control	6.54±0.2	18.56±0.03	4.7±0.05	17.2±0.005
Flat	Chemical fertilizer	6.7±0.5	17.29±0.05	3.2±0.03	13.7±0.005
Flat	10 t/ha SMC	6.8±0.3	16.69±0.04	5.2±0.05	17.9±0.01
Flat	20 t/ha SMC	6.26±0.5	17.45±0.03	4.2±0.1	15.6±0.005
Flat	30 t/ha SMC	6.62±0.4	17±0.05	4.3±0.02	11.6±0.005
Flat	20 t/ha CM	6.19±0.4	21.87±0.05	3.8±0.1	19.6±0.01
Flat	30 t/ha CM	6.2±0.05	17.96±0.03	4.3±0.2	20.7±0.02
Flat	40 t/ha CM	6.64±0.6	17.26±0.1	2.8±0.3	17.9±0.01
Flat	100 t/ha MSWC	7.29±0.1	17.14±0.1	5.5±0.05	17.5±0.05
Flat	200 t/ha MSWC	7.15±0.5	17.85±0.005	4.6±0.05	17.9±0.01
Flat	300 t/ha MSWC	7±0.3	16.4±0.005	4.3±0.1	13.7±0.005
Peto Pride	Control	6.92±0.04	17.42±0.02	5.6±0.2	10.5±0.005
Peto Pride	Chemical fertilizer	7.69±0.4	23.9±0.01	4.5±0.1	8.6±0.005
Peto Pride	10 t/ha SMC	7±0.4	17.1±0.01	3.8±0.1	15±0.005
Peto Pride	20 t/ha SMC	6.43±0.5	18.61±0.02	4.6±0.04	7.9±0.005
Peto Pride	30 t/ha SMC	6.98±0.1	17.36±0.4	5.5±0.2	10±0.005
Peto Pride	20 t/ha CM	7.61±0.05	17.99±0.1	3.5±0.2	10±0.01
Peto Pride	30 t/ha CM	6.83±0.6	18.31±0.004	4.9±0.4	11.7±0.01
Peto Pride	40 t/ha CM	8.52±0.7	17.92±0.1	4.3±0.2	10±0.005
Peto Pride	100 t/ha MSWC	7.89±0.5	18.04±0.01	6±0.2	8±0.005
Peto Pride	200 t/ha MSWC	9.31±0.2	17.28±0.005	5.1±0.05	15.3±0.005
Peto Pride	300 t/ha MSWC	7.67±0.05	17.37±0.004	4.2±0.05	10±0.005
Chief	Control	6.37±0.3	17.34±0.02	5.5±0.2	16.3±0.005
Chief	Chemical fertilizer	7.68±0.4	16.54±0.03	5.3±0.05	12±0.005
Chief	10 t/ha SMC	6.65±0.2	17.63±0.005	5.4±0.1	17±0.005
Chief	20 t/ha SMC	5.84±0.4	17.13±0.05	4.4±0.1	16±0.005
Chief	30 t/ha SMC	6.85±0.2	16.17±0.03	5.2±0.3	13±0.005
Chief	20 t/ha CM	7.78±0.5	16.96±0.005	4.7±0.5	14±0.01
Chief	30 t/ha CM	6.79±0.2	16.79±0.01	3.8±0.03	11±0.005
Chief	40 t/ha CM	5.62±0.2	15.6±0.02	4.7±0.1	14±0.005
Chief	100 t/ha MSWC	8.29±0.6	17.58±0.03	4.8±0.5	15.7±0.01
Chief	200 t/ha MSWC	6.57±0.4	18.11±0.004	5.6±0.05	13.7±0.005
Chief	300 t/ha MSWC	6.42±0.5	17.4±0.03	5.5±0.4	13±0.02

(SMC = Spent mushroom compost, CM = cow manure, MSWC = municipal solid waste compost)

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The interaction between cultivar and type of fertilizer on percent of ash in tomato fruits showed that the highest ash was obtained in Peto Pride and Redstone cultivars when fertilized with 100 t/ha of municipal solid waste compost (while Peto Pride also responded equally well on this measure with 20 t/ha of SMC, 30 t/ha of CM, and 300 t/ha of MSWC). The lowest value was obtained in Redstone fertilized with 20 t/ha of spent mushroom compost. For the Flat fruits, 100 t/ha of MSWC or 10 t/ha spent mushroom compost achieved the greatest increases in the ash percent, compared to the control and chemical fertilizer. For \`Peto Pride\` and Chief fruits, the highest ash percent was obtained with 100 and 200 t/ha of municipal solid wastes compost respectively (Table 6).

The highest ash percent of leaves was obtained in Flat fertilized with 30 t/ha of cow manure, and the lowest value was obtained in Redstone fertilized with 30 t/ha of spent mushroom compost. The highest ash percent in the Redstone cultivar leaves was obtained when fertilized with 20 t/ha of cow manure or 200 t/ha of MSWC. The highest ash percent in Flat and Chief cultivar leaves were obtained when fertilized with 30 t/ha of cow manure and 10 t/ha of spent mushroom compost, respectively. The highest ash percent in Peto Pride cultivar leaves was obtained when fertilized with 10 t/ha of spent mushroom compost and 200 t/ha of MSWC. Chemical fertilizer decreased the leaf ash percent in all varieties, compared to the controls (Table 6).

Interaction between cultivar and type of fertilizer on P content in tomato fruits and leaves showed that the highest P content were obtained in the Peto Pride cultivar fertilized with 200 t/ha of MSWC, and the Chief cultivar when fertilized with chemical fertilizer. The lowest values were obtained in Flat cultivar fertilized with 20 t/ha of spent mushroom compost, and Chief cultivar fertilized with 20 t/ha of cow manure. In the Redstone cultivar, the highest P content in fruits and leaves were obtained when fertilized with 20 and 40 t/ha of cow manure respectively, while in the Flat cultivar the highest P content in fruits and leaves were obtained when fertilized with 20 and 30 t/ha of cow manure respectively. In the Peto Pride and Chief cultivars, the highest P content in leaves were obtained when fertilized with chemical fertilizer, while the highest amount in fruit were obtained when fertilized with 200 and 100 t/ha of MSWC respectively (Table 7).

The interaction between cultivar and type of fertilizer on K content in tomato fruits and leaves showed that the highest K content were obtained in the Redstone cultivar fertilized with 200 t/ha of municipal solid waste compost, and Chief cultivar when fertilized with chemical fertilizer, and the lowest values were obtained in the Flat cultivar fertilized with chemical fertilizer, and the control. The reaction of cultivar to different type of fertilizer was quite varied (Table 7).

The highest Ca and Mg in tomato fruit was obtained from Chief cultivar with no fertilizer, and Peto Pride cultivar fertilized with 200 t/ha of MSWC. There was not any significant correlation between element content in tomato leaves and tomato fruits (Table 8).

Table 7. Influence of different cultivars and fertilizers on tomato fruits and leaves P and K.

Cultivars	Fertilizers	P (mg·100 g FW)		K (mg·100 g FW)	
		Fruit	Leaf	Fruit	Leaf
Redstone	Control	27.2±1.7	113±0.2	317±0.4	159±1.7
Redstone	Chemical fertilizer	28.2±1	151±0.2	371±0.1	201±0.9
Redstone	10 t/ha SMC	38±2.3	160±3	422±0.2	221±0.5
Redstone	20 t/ha SMC	37±1.8	156±0.01	393±0.3	224±2
Redstone	30 t/ha SMC	35±3	154±0.5	449±0.2	206±3
Redstone	20 t/ha CM	46±0.5	170±0.01	452±0.3	194±1.7
Redstone	30 t/ha CM	36.7±2.7	122±0.3	406±0.01	193±3
Redstone	40 t/ha CM	37.5±0.6	211±0.9	359±0.3	248±3
Redstone	100 t/ha MSWC	30±1.5	146±0.6	309±0.9	182±2.8
Redstone	200 t/ha MSWC	34±0.3	140±0.4	598±0.3	185±3
Redstone	300 t/ha MSWC	27±1.7	148±3	328±0.4	200±3
Flat	Control	27.5±1.8	108±0.2	329±0.2	97±1.5
Flat	Chemical fertilizer	26±2.1	185±0.7	225±0.1	275±1.2
Flat	10 t/ha SMC	32.5±0.8	94±0.2	369±0.7	174±1.5
Flat	20 t/ha SMC	18±3	101±0.2	355±0.4	184±2
Flat	30 t/ha SMC	26±1.3	169±0.6	303±0.7	224±3
Flat	20 t/ha CM	44.5±2.8	119±0.3	383±0.2	249±2
Flat	30 t/ha CM	30.5±0.2	129±0.1	313±0.9	277±2
Flat	40 t/ha CM	41±3	116±0.01	474±0.3	347±3
Flat	100 t/ha MSWC	23.8±1.7	147±3	320±0.7	225±3
Flat	200 t/ha MSWC	32.4±3	124±0.03	292±0.2	258±2
Flat	300 t/ha MSWC	26.9±2.8	106±0.03	294±0.4	258±2.3
Peto Pride	Control	25.4±1.1	103±0.1	440±3	121±1.7
Peto Pride	Chemical fertilizer	32.3±0.2	169±0.1	400±0.3	196±2.8
Peto Pride	10 t/ha SMC	36±2.3	97±0.01	353±2	123±1
Peto Pride	20 t/ha SMC	31±2.3	144±0.1	381±0.4	222±1.7
Peto Pride	30 t/ha SMC	43±0.9	139±0.5	458±2	217±3
Peto Pride	20 t/ha CM	29±0.2	94±3	246±0.2	178±3
Peto Pride	30 t/ha CM	31.3±2.3	126±0.02	386±0.8	162±1.3
Peto Pride	40 t/ha CM	52.6±1.7	152±1.5	563±0.2	192±0.3
Peto Pride	100 t/ha MSWC	37.7±2.8	140±0.1	382±3	121±2.3
Peto Pride	200 t/ha MSWC	53.3±0.5	126±0.01	504±0.1	177±1.7
Peto Pride	300 t/ha MSWC	39.3±1	106±0.02	475±0.7	205±1.5
Chief	Control	22.9±1.7	102±0.1	293±0.3	143±1
Chief	Chemical fertilizer	34.7±3	238±0.5	323±1	405±1.7
Chief	10 t/ha SMC	29.6±1.7	134±0.01	233±0.3	128±2.3
Chief	20 t/ha SMC	29.5±3	147±1.7	282±3	160±1.7
Chief	30 t/ha SMC	30.5±2.3	209±0.4	276±0.5	309±1
Chief	20 t/ha CM	39.6±0.6	76±0.03	464±0.4	156±1
Chief	30 t/ha CM	27±2.8	183±0.1	348±0.3	187±1.7
Chief	40 t/ha CM	32.3±1.7	229±0.4	318±0.3	189±2.8
Chief	100 t/ha MSWC	39.7±0.5	96±0.5	413±0.3	156±3
Chief	200 t/ha MSWC	31.2±2.8	96±0.01	379±0.3	176±1
Chief	300 t/ha MSWC	30.2±1	95±0.1	359±0.3	227±1

(SMC = Spent mushroom compost, CM = cow manure, MSWC = municipal solid waste compost)

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Table 8. Influence of cultivars and fertilizers on tomato fruits and leaves Ca and Mg.

Cultivars	Fertilizers	Ca (mg·100 g FW)		Mg (mg·100 g FW)	
		Fruit	Leaf	Fruit	Leaf
Redstone	Control	33.3±1.7	44±0.3	27±0.4	12±0.1
Redstone	Chemical fertilizer	36±1.3	55±0.1	32±0.6	11±0.1
Redstone	10 t/ha SMC	47±2.7	62±0.6	43±0.6	14±0.4
Redstone	20 t/ha SMC	46±0.3	41±0.3	38±0.2	14±0.2
Redstone	30 t/ha SMC	43±1.5	35±0.5	41±0.5	17±0.2
Redstone	20 t/ha CM	48±3	52±0.2	42±1	24±0.3
Redstone	30 t/ha CM	43±2.4	57±0.2	35±0.9	22±0.2
Redstone	40 t/ha CM	46±3	60±0.8	37±0.5	34±0.4
Redstone	100 t/ha MSWC	42±1.2	45±0.4	36±0.4	19±0.3
Redstone	200 t/ha MSWC	39±0.3	62±0.7	36±0.4	16±0.1
Redstone	300 t/ha MSWC	30±0.6	35±1.5	27±0.4	15±0.6
Flat	Control	33±1.9	45±0.1	30±0.3	17±0.2
Flat	Chemical fertilizer	31±1.7	66±0.4	28±0.7	20±0.1
Flat	10 t/ha SMC	41±3	44±0.1	37±0.1	11±0.4
Flat	20 t/ha SMC	31±1	46±0.3	28±0.8	11±0.3
Flat	30 t/ha SMC	33±1.7	53±0.2	34±3	17±0.4
Flat	20 t/ha CM	51±2.8	76±0.2	42±1.8	19±0.2
Flat	30 t/ha CM	33±0.3	46±0.1	32±0.1	20±0.2
Flat	40 t/ha CM	51±2.8	77±0.6	42±1.2	21±0.8
Flat	100 t/ha MSWC	33±3	72±0.8	25±0.6	11±1.5
Flat	200 t/ha MSWC	45±2.4	64±0.3	39±0.3	12±0.3
Flat	300 t/ha MSWC	38±3	42±0.2	29±0.01	12±0.1
Peto Pride	Control	30±1.7	57±0.1	25±0.2	12±0.1
Peto Pride	Chemical fertilizer	38±0.5	75±0.4	31±0.1	15±0.1
Peto Pride	10 t/ha SMC	42±3	56±0.2	36±0.9	12±0.4
Peto Pride	20 t/ha SMC	41±3	63±0.2	31±0.1	15±0.1
Peto Pride	30 t/ha SMC	52±0.9	63±3	45±0.6	13±0.6
Peto Pride	20 t/ha CM	32±3	62±2	29±1.9	17±1.4
Peto Pride	30 t/ha CM	38±0.4	70±0.1	31±0.02	11±0.4
Peto Pride	40 t/ha CM	61±3	74±1	44±1.8	15±0.1
Peto Pride	100 t/ha MSWC	48±2.8	46±0.4	38±1.2	21±0.1
Peto Pride	200 t/ha MSWC	57±0.1	65±0.4	49±0.7	13±0.1
Peto Pride	300 t/ha MSWC	43±3	60±0.4	38±0.1	17±0.1
Chief	Control	27±0.7	56±0.1	24±0.01	12±0.1
Chief	Chemical fertilizer	44±3	69±0.4	35±0.3	21±0.2
Chief	10 t/ha SMC	44±1.4	56±0.3	35±0.6	14±0.3
Chief	20 t/ha SMC	39±1.7	42±0.8	32±0.9	11±0.2
Chief	30 t/ha SMC	43±3	60±0.4	34±0.2	17±0.4
Chief	20 t/ha CM	60±3	53±0.2	42±0.1	11±0.1
Chief	30 t/ha CM	35±0.1	57±0.4	30±0.5	31±0.3
Chief	40 t/ha CM	44±1	58±0.9	35±0.2	30±0.4
Chief	100 t/ha MSWC	51±1.5	59±0.2	43±0.5	18±0.3
Chief	200 t/ha MSWC	43±1.9	58±0.2	38±0.3	18±0.2
Chief	300 t/ha MSWC	38±0.4	79±0.3	35±0.3	20±0.3

(SMC = Spent mushroom compost, CM = cow manure, MSWC = municipal solid waste compost)

Discussion and Conclusions

The present study found that different tomato cultivars respond differently to different fertilizers. For each of the four cultivars tested, the highest yields were achieved with chemical fertilizer, however, for each cultivar the difference between the yield under a chemical fertilizer regime and the best performing organic fertilizer for each cultivar was small. The yields achieved under the optimized organic fertilization were 99.5% of the chemical fertilized crop for Flat, 98.4% for Redstone, 97.6% for Peto Pride, and 95.7% for Chief.

The use of organic fertilizers can avoid or reduce the deleterious effects attributed to the use of chemical fertilizer. Applying chemical fertilizer leads to the deterioration of soil characteristics and fertility, and as well it leads to a reduction in fruit nutrition values and edible qualities (Shimbo et al., 2001). It also reduces the dry matter content of tomatoes (Marzouk and Kassem, 2011; Alvarez et al., 1988; Drinkwater et al., 1995; Reganold, 1988). The continuous use of chemical fertilizers may also lead to the accumulation of heavy metals in plant tissues which compromises the nutrition value and fruit quality (Shimbo et al., 2001). Although it is reported that the supply of plant-available N from organic fertilizer, resulting from a slow rate of mineralization, makes crop yields in fields treated with organic fertilizer lower than in those treated with chemical fertilizer (Blatt, 1991; Lee, 2010), the present study shows that the selection of a cultivar-appropriate organic fertilizer can narrow that yield decrement to between 0.5% to 4.7% in the case of the four cultivars that were the subject of the study.

Given the different response of cultivars to different types of fertilizer, we can recommend a particular amount of a specific type of fertilizer for each cultivar to replace chemical fertilizer. According to the results, where the criterion for fertiliser selection and its application rate is based on the total yield, then the following organic fertilizer regimes can be recommended: 20 t/ha of spent mushroom compost for Redstone, 30 t/ha of cow manure for Flat, 300 t/ha of municipal solid waste compost for Peto Pride and Chief.

For commercial cropping, aspects other than environmental outcome and crop yield come into play, and in the present study various other fruit attributes, besides gross yield, were reported (Tables 1 to 8). Other considerations such as the availability of various organic fertilizers, the security of supply, and the different supply costs of fertilizers, as well as the different costs of the management and application of the various fertilizers, will be further important considerations for commercial cropping and are worthy of further research.

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