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The Effects of Rate and Method of Aerated Compost Tea Application on Yield and Yield component of Tomato (*Lycopersicon esculentum* Mill.) at Burusa, South Western Ethiopia

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Abstract

Tomato (Lycopersicon esculentum Mill.) is one of the most popular and versatile vegetable in Ethiopia. The yield and quality of tomato at national level is, however, significantly low mainly due to improper fertilization. On the other hand, inorganic fertilizers remain the main yield-augmenting technology in Ethiopia. But unwise use of chemical fertilizer in tomato production could leads to deterioration of soil health and environments also encounter economic loss. Adopting low cost agricultural technology (compost tea) is economically, ecologically and socially feasible to ensure sustainable tomato production receiving prior attention. Therefore, a pot experiment was conducted at Burusa, IluAbabor Zone, south western Ethiopia to determine the rate and method of Aerated Compost Tea (ACT) for optimum yield and yield component of tomato during November, 2016 to June 2017. The treatments consisted of two levels application methods (foliar feeding & soil drench) and five levels of application rates (0, 300, 600, 900, 1200 ml pot^{-1}). The experiment was laid out using randomized complete design with three replications. Data on phenological, growth, quality, yield and yield components were recorded and subjected to analysis of variance using SAS version 9.3 software. The analysis of variance showed that there were significant ($P<0.05$) differences among application rates and methods of ACT for yield and other parameters considered. Using ACT as soil drench was superior in terms of yield as well as in other important yield components considered. Application rate greater than 300 ml per pot generally showed quit stimulation of growth and yield of tomato. Soil drench of ACT at the rate of 1200 ml per pot was gave the highest yield and all other parameters measured. Soil drench with maximum application rate (1200 ml pot^{-1}) resulted considerable yield increment by 187%. Therefore, soil drench at the rate of 1200 ml pot^{-1} is recommended for maximizing tomato production and also sustains organic tomato production, which is economically and environmentally feasible.

***Keywords**: Tomato, Aerated Compost Tea, Application Rate, Method, Yield*

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is commonly cultivated and the largest in volume of production after potato and sweet potato (Dorjee, 2000). The crop is cultivated in different regions of Ethiopia especially irrigation potential areas and used as home consumption as fresh and market commodity in many areas of the country (CSA, 2013). Currently, tomato mainly recognized as quality product for both local and export markets and providing a route out of poverty for small scale producers who live in developing countries in general and in Ethiopia in particular (Tewodros and Asfaw, 2013). Today, the importance of tomato is increasing in Ethiopia and it is widely accepted and commonly used in variety of dishes as row, cooked or processed products more than any other vegetables (Lemma, 2002).

Despite the importance of this crop, the production and productivity is constrained by different biophysical and socio-economic reasons (Mersha, 2008). According to FAOSTAT (2012) data, Ethiopia ranked among major tomato producing countries of the world in area harvested, production and yield as 58th, 84th and 146th respectively. The yield and quality of the crop at national level is significantly low. One of the contributing factors for low yield is improper fertilization; hence tomato is a heavy feeder that requires well balanced fertilizer (Clik *et al.,* 2004). On the other hand, inorganic fertilizers remain the main yield-augmenting technology being aggressively promoted by different institution in Ethiopia in general in the study area particular. But, continuous use of inorganic fertilizer and pesticides indiscriminately leads to deterioration of soil health and environments and decline in production and productivity of various crops including tomato. Diagnostic survey conducted by Edossa *et al.* (2013) at Central Rift Valley of Ethiopia indicated that,

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chemical fertilizers were not wisely used in tomato production systems and the applications are in excess rate, which could leads to pollution of the environment and water body with economic loss. Heavy application of inorganic fertilizers can also build up toxic concentrations of salts in the soil, and more so, the cost of purchasing inorganic fertilizers may be beyond the capacity of farmers (Agbede *et al.,* 2008).

Therefore, these aforementioned and other factors forces to look cheaper ways of increasing production through addition of locally produced organic fertilizers which are economically, ecologically and socially feasible. Among the alternative, compost tea is the most innovative organic fertilizer source derived from compost. As organic amendment compost tea was not yet introduced in to the growers and also research system in Ethiopia, though available feedstock are found nearby the farmers. Variable effects from a variety of compost tea application rate and methods have been reported by several authors (Jim, 2013), though no standards exist (Bryant *et al.,* 2011). Keeping these in view, the present study was conducted to determine the rate and method of aerated compost tea application for optimum growth, yield and yield component of tomato for tomato growers in Ethiopia.

Materials and Methods

Study Area Description

Container based experiment was conducted during November, 2016 to June 2017 at Burusa, Mettu University research site which is located at the south western part of Ethiopia in Oromia regional state at mid altitude sub humid zone and 617 km away from Addis Ababa and 17 km from Mettu town. The site located at 7^o 42` N latitude and 36$^o$ 50`E longitude with an altitude 1210 m above sea level. The area receives an average annual rain fall of 1200 mm. The area has average maximum temperature is 26.2^{o}C and minimum temperature of 11.3^{o}C; and average maximum and minimum relative humidity of 91.40 and 37.92%, respectively.

Experimental Material

Roma V-F Tomato variety was used for the experiment. It is processing type, compact and strong stem with semi-indeterminate growth habit, having oval shaped and fruit size of 50-60 gram, maturity time of 90-100 days and yield potential of 40 ton ha^{-1} (MARC, 2003).

Experimental treatment and design

The experiment consisted five levels of application rates (0 ml pot^{-1}, 300 ml pot^{-1}, 600 ml pot^{-1}, 900 ml pot^{-1} and 1200 ml pot^{-1}) and two levels of application methods (foliar application and soil drench). The experiment was laid out in Randomized Complete Design (RCD) in 5x2 factorial arrangements with three replications. There were ten treatment combinations, which were assigned to each pot randomly.

Experimental Procedure

Compost and Compost tea Preparation

The composting pile/above ground heap method (2 × 1.5 × 2 m^3) was prepared on a clean ground surface, located under shade. Poultry manure, dried cow dung, green leaves, ash, top soil, dried crop residue and compost starter were used as feedstock to made compost. The materials listed above were arranged by keeping proper thickness and the procedure was repeated for three layers and finally the heap was covered with banana leaves. The pile was turned manually on the 15th day of composting and then after every 10thday. The composting was terminated after three months. Finally, well-decomposed and matured compost was sieved by using wire mesh and ready for making compost tea. Among the ACT preparation methods, Bucket-Fermentation was used for compost tea preparation. The required amount of previously made compost was added and tied in lath house net with the ratio of compost to water of 1:5 (wt: vol.) then suspended and submerged to soak free in water for 72 hours. As additional microbial feeding, crude molasses was added to the fermenting tank with the ratio of molasses to water 1:40 by volume during brewing. Periodically, stirring and squeezing were done. At the end of time for brewing the extract was poured to another container; and again the extract or tea was passed through fine mesh sieve again to prevent plugging of emitters where tea is applied as a spray. Then the tea was transferred to sprayer and the activities were repeatedly applied every week until the frequency of application was completed.

Tomato Seedling Production, Transplanting and compost tea application

A seedling was raised on the nursery for one month before being transplanted onto experimental container/pot. All the necessary management/agronomic practices were given for the seedling at nursery level until transplanted. 30 pots, with the dimension of top diameter 32 cm bottom diameter 14 cm and height 46 cm having pores from the bottom were ready for the experiment. The pots were filled uniformly with top soil. Four seedlings per pot with vigorous and uniform appearance were transplanted on each experimental pot and thinned to a single seedling after survival. The readymade compost tea was sprayed late in the afternoon on foliage and soil in every week as per the treatment.

Data collection and Analysis

Data was recorded from each experimental unit for yield and yield related traits via: plant height (cm), number of primary branches, root length (cm), days to flower initiation, days to first harvest, number of truss per plant, number of fruits per truss, fruit yield per plant (kg), mean single fruit weight (g), fruit diameter/equatorial (cm), fruit length/polar (cm) and marketable yield per plant (kg). The data were subjected to the analysis of variance (ANOVA) using Statistical Analysis System (SAS) computer software Version 9.3 (SAS Institute, 2014). Significant means were separated using the least significant difference at 5% probability level.

Results and Discussion

The analysis of variance (ANOVA) showed that the application methods and rates of ACT significantly influenced the yield and all parameters considered for this study (Table 1 and 2).

Table 1: Mean squares of ANOVA for analysis of variance showing mean squares of plant height, number of primary branches, root length, days to flower initiation, days to first harvest and number of truss per plant of tomato

Source of variation	DF	PH	NPB	RL	DFI	DFH	NTPP
Application method	1	179.78**	1.20*	31.87**	6.53*	6.53*	15.62**
Application rate	4	1033.32**	9.05**	60.80**	35.47**	19.25**	38.79**
Method x Rate	4	30.10*	0.95*	0.83ns	2.20ns	1.12ns	0.56ns
Error	20	9.54	0.23	0.61	1.20	1.13	0.83

Where; DF = Degrees of freedom; PH= Plant height, NPB= Number of primary branches, RL= Root length, DFI= Days to flower initiation, DFH=, Days to first harvest, NTPP= Number of truss per plant; ns, * and ** implies non significant, significant and highly significance differences at 5% level of probability, respectively

Table 2: Mean squares of ANOVA for analysis of variance showing mean squares of number of fruit per truss, fruit yield per plant, single fruit weight, fruit diameter, fruit length, and marketable yield per plant of tomato

Source of variation	DF	NFPT	FYPP	SFW	FD	FL	MYPP
Application method	1	2.37**	0.52**	91.74**	0.65**	0.65**	0.60**
Application rate	4	5.25**	2.43**	770.38**	6.67**	2.82**	2.16**
Method x Rate	4	0.25ns	0.10*	18.45*	0.06ns	0.02ns	0.08ns
Error	20	0.20	0.59	5.66	0.04	0.03	0.04

Where; DF = Degrees of freedom; NFPT = Number of fruit per truss, FYPP = Fruit yield per plant, SFW = Single fruit weight, FD = Fruit diameter, FL = Fruit length, MYPP= Marketable yield per plant; ns, * and ** implies non significant, significant and highly significance differences at 5% level of probability, respectively

Plant Height (cm)

The main effects of aerated compost tea application method and rate and their interactions had significant (P<0.05) difference on plant height of tomato (Table 1). The highest height (157.64 cm) was recorded from soil drench at the application rate of 1200 ml pot^{-1}, which was statistically significant different form soil drench 900, 600, 300 ml pot^{-1} and foliar feed at rate of 1200, 900, 600 and 300 ml pot^{-1}. On the other hand, the lowest height (119.99 cm) was recorded from the control treatment (Table 3). ACT application at the rate of 1200 ml in soil drench increase plant height by 30.62 % over the control treatment. The probable reasons could be the presence of soluble essential nutrient specially, nitrogen and beneficiary microorganism found in ACT leads to increase nutrient availability and uptake which results stronger nutrient uptake by plant and there by develop the root and shoot system. Beside the hormone found in CT directs the shoot growth and development. This finding is in agreement with the finding of Badawi *et al*. (2014) who used higher doses of bio-enriched compost tea (300 L/fed.) relatively to the untreated plants or plants treated with 100 L/fed increases lentil plant height from 18.77 to 31.90% and from 14.75 to 28.88%. It was also reported by Azza *et al.* (2010) that, raising compost tea doses from 10 to 20 L/fed significantly increased plant height of Borage in two successive seasons.

Number of Primary Branches

The analysis of variance showed significant (P< 0.05) differences in number of primary branches due to the main effects of application methods, rate and the interaction effect (Table 1). Tomato planted in the highest rate of soil drench ACT (1200 ml pot^{-1}) was recorded highest number of primary branches (5.33), which was statistically in par with 900, 600 ml pot^{-1} soil drench and also 1200, 900 ml pot^{-1} foliar feed of ACT. On the other hand, the lowest number of primary branches (2.33) was recorded from the control treatment **(**Table 3). Increased number of branches per plant with an increased in application rate of ACT due to the fact that, the interaction of microbes and available mineral nutrients present in ACT makes greater nutrient availability thus insure better vegetative growth and development. High concentration of nitrogenous compounds, plant hormones, growth regulators could contribute for vigorous vegetative growth that made the tomato plant to have significantly higher number of primary branches per plant. This result was in agreement with the finding of Azza *et al*. (2010) who reported that, raising compost tea doses from 10 to 20 L/fed significantly increased number of branches of Borage plant.

Root Length (cm)

The analysis of variance showed highly significant (P< 0.01) differences in root length due to the main effects of application methods and rate but not for the interaction effect (Table 1). Tomato received 1200 ml of ACT in soil drench form had the highest root length (28.81 cm), which was statistically not significant different with tomato received 900 ml of soil drench. The lowest root length (19.47 cm) obtained from zero application of compost tea (Table 3). Soil drench with highest application rate increase root length, this might be the presence of microorganisms particularly fungi found in CT colonize the rhizosper and extend the root system of tomato plant.

This study agrees with the findings Siddiqui *et al.*(2008) reported that, CT application enhanced plant growth and increase tap root length of Okra plant. Similarly, Keeling *et al.,* (2003) also reported, application of CT on oil seed rape plants at an early stage of growth increased root development. Besides, Xu *et al.,* (2012) reported that, compost extract derived from animal manure and rice straw were shown to increase root biomass and promoted root growth of tomato as compared to control treatment.

Table 3: Interaction effects of application methods and rate of aerated compost tea on plant height, number of primary branches, root length, days to flower initiation, days to first harvest and number of truss per plant

Factors		Plant height (cm)	Primary branch	Root length (cm)	Days to flower initiation	Days to first harvest	Truss per plant
Application Methods	Application Rates (ml)						
Foliar Feed	0	119.99f	2.67bc	19.47f	48.67ab	82.67ab	5.07g
	300	129.09e	2.67bc	20.79ef	48.83a	82.67ab	6.87ef
	600	135.70d	3.00bc	21.96de	47.33bc	81.00bc	7.67de
	900	143.31c	5.00a	24.47c	45.00de	79.67cd	9.07cd
	1200	147.70bc	5.33a	27.05b	44.33de	79.67cd	11.32b
Soil Drench	0	120.69f	2.33c	21.02de	49.67a	83.00a	5.70fg
	300	128.73e	3.33b	22.16d	47.67bc	81.67ab	7.93de
	600	142.80c	4.67a	24.44c	46.00cd	79.67cd	9.90bc
	900	150.39b	5.00a	27.62ab	44.00e	79.00de	10.74b
	1200	157.64a	5.33a	28.81a	43.33e	77.67e	12.93a
CV (%)		2.25	12.28	3.29	2.35	1.32	10.47
LSD (5%)		5.26	0.82	1.33	1.87	1.81	1.55

Means in the column followed by the same letter(s) are not significantly different at 5% level of significance. LSD (5%) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Days to Flower Initiation

The result showed that, highly significant difference (p<0.01) was observed in number of days to tomato flower initiation (Table 1). The mean earliest days to flower initiation (43.33 days) was recorded at treatment received ACT of 1200 ml pot^{-1} which was not statistically different from treatments received 900 ml pot^{-1} (44.0 days). A prolonged day to flower initiation (49.67 days), that was delayed by about 6.34 days was observed in control treatment followed by treatment received 300 ml pot^{-1} with recorded date of 48.83 which still not statistically significant (Figure 1). The probable reason for the significant difference observed among tomato plants treated with different application rate in day to flower initiation is due to the direct and indirect effects of hormones present in an ACT thus, hormones found in ACT reasonably contributed to stimulation of flower initiation. Hence, flower initiation in tomato partly depends on hormones, especially GA and Auxin (Fos *et al*., 2000). This finding was well supported by previous experiments conducted by Naidu *et al.,* (2013) who reported that, microbial enriched compost tea increases in chlorophyll content caused stimulation of flowering.

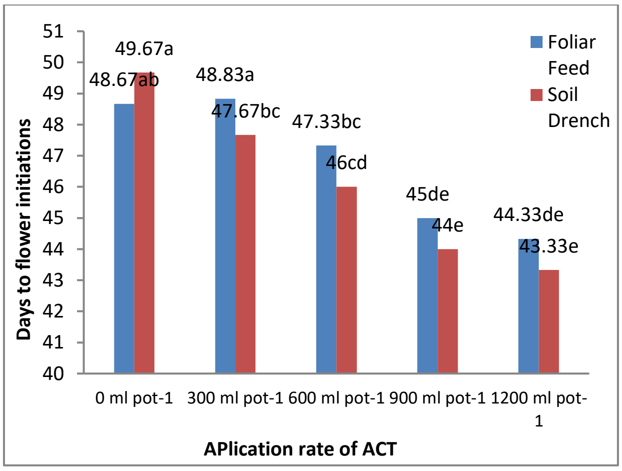

Figure 1 Effects application methods and rate of aerated compost tea on numbers of days to flower initiations of tomato.

Days to First Harvest

The number of days required to reach first harvest was significantly (P < 0.05) influenced by the main effects of application methods and rate of ACT (Table 1). Days to first harvest as affected by different application rates and application method of ACT followed a similar pattern to that of days to flowering. Results confirmed again the superiority of using ACT in achieving the earliest days to first harvest. With increase in ACT application rate, 1200 ml pot^{-1} reached maturity earlier (77.67) than the others. Tomato plant treated with ACT of 900ml pot^{-1} reached maturity on (79.00) days without showing statistical difference. Maximum days to first harvest that were delayed by about 5.33 days and 5 days were recorded in control treatment (83) and 300ml pot^{-1} (82.67) respectively (Figure 2).

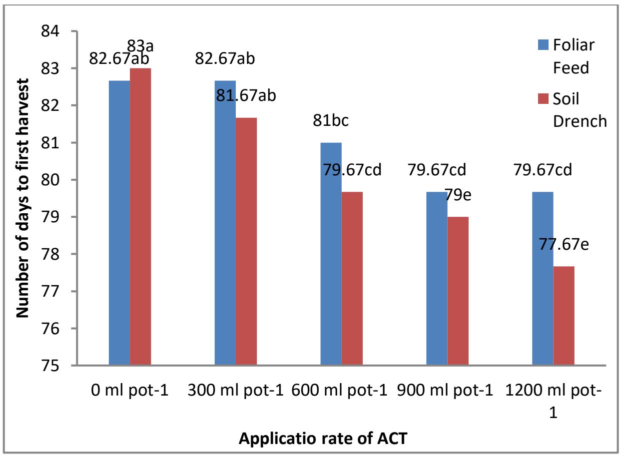

Figure 2 Effects of application methods and rates of aerated compost tea on number of days to first harvest of tomato fruits

Number of Truss per Plant

Mean number of trusses per plant were highly significant (p<0.01) different when ACT was applied at different rate and method of ACT application (Table 1). Maximum mean number of truss per plant (12.93) was observed in treatments received 1200ml pot^{-1}. This was followed by 900 and 600 ml pot^{-1}which resulted in 10.74 and 9.90 mean trusses per plant respectively without showing statistical difference. Lowest mean number of truss per plant (5.07) was recorded in control treatment (Table 3). Application method had also highly significant effect on average number of truss per plant. Maximum number of truss per plant was achieved when ACT applied as soil drench than foliar feeding. An increasing trend of number of truss per plant was linear with increasing rate of ACT. This was in agreement with the result of Badawi *et al.,* (2014) who reported that, using higher doses of bio-enriched compost tea (300 L/fed.) relatively to the untreated plants or plants treated with 100 L/fed increases lentil number of pods/plant were ranged from 9.24 to 25.50% and from 10.63 to 26.95%.

Number of Fruits per Truss

Analysis of the data regarding number of fruit per truss revealed highly significant (P<0.01) differences in number of fruit per truss among application methods and rate of ACT (Table 2). The mean greatest number of fruits per truss (6.32) was obtained when compost tea was applied at the rate of 1200 ml pot-1. A lowest mean number of fruit per truss (3.58) was recorded in control treatments (Table 4). Soil drench application method resulted in improved number of fruits per truss than foliar feeding. Similar results were reported by Badawi et al., (2014) that, using higher doses of bio-enriched compost tea 300 L/fed relatively to the untreated plants or plants treated with 100 L/fed increases lentil number of seeds/plant ranged from 10.40 to 25.37% and from 11.77 to 24.95%. Abira (2011) also reported high concentration of vermin compost tea resulted in significantly more tomato fruiting branches than commercial cytokines and control treatments.

Fruit Yield per Plant (kg)

Significant differences were recorded among the main effects of ACT application methods and rates and their interaction (Table 2). Maximum tomato fruit yield per plant (2.87kg) was obtained when ACT was applied at a rate of 1200 ml per pot as soil drench followed by 1200 ml per pot as foliar spray which yielded 2.57 kg of fruits per plant. The minimum yield of tomato fruits (1.00 kg) was recorded in the control treatments. Soil drench and foliar feeding application methods had significant difference in tomato fruit yield when ACT was applied at a rate of 1200 ml per pot and leaf respectively. Similarly, statistical difference was detected by applying ACT at a rate of 900 ml in the form of soil drench and foliar feed. In the current study, soil drench of ACT with maximum rate of 1200 ml per pot, resulted in a considerable yield increment by (187%). A substantial yield increment observed in this study is due to several interrelated positive factor of ACT including availability of soluble nutrients, beneficial microorganisms and microbial metabolites found in ACT that increased plant growth and yield. This finding is in line with the Hegazi and Algharib, (2014) who showed that compost tea as a soil drench better than as a foliar treatment for getting better seed yield characters of cow pea.

Mean Single Fruit Weight (g)

Similar to that of yield per plant, tomato single fruit weight was also significantly affected by the main effect, application methods and rate and their interaction effects (Table 1). The result showed that, significant (p<0.05) difference was observed in tomato single fruit weight. Greater single fruit weight (75.02 gm) was obtained when compost tea was applied at the rate of 1200 ml pot^{-1} as soil drench, followed by 1200 ml pot^{-1} as foliar feed (69.40 gm) and 900 ml pot^{-1} as soil drench which weighs (68.99 gm) which were statistically in par with each other. Minimum fruit weight (46.58 gm) was recorded from control treatments (Table 4). There was statistically significant difference detected when ACT applied as both foliar feeding and soil drench with the difference application rate in tomato single fruit weight. Marquez *et al.,* (2014) reported that, after cell division, photo-assimilates begin to accumulate and affect fruit weight and growth. It is therefore likely that, in the organic fertilizer, there was reduced demand for assimilates and other hormones in apical tissue, which favored the content of cytokines and the accumulation of photo-assimilates in fruits. This phenomenon is immensely contributed to increased tomato fruit weight.

Fruit Diameter and Length (cm)

The analyses of variance reveled highly significant (P<0.01) difference in fruit diameter and length due to the main effects of application methods and rate of ACT (Table 2). The highest fruit diameter and length was 5.63 and 6.74 cm, respectively which were obtained from soil application of ACT the rate of 1200 ml. On the other hand, the lowest fruit diameter (2.59 cm) and length (4.53 cm) was recorded form control treatment (Table 4).

Marketable Yield per Plant (kg)

Highly significant (p<0.01) differences in the total marketable yield per plant was recorded due to application methods and rate of ACT (Table 2). The average marketable yield per plant varies ranged from 0.64 to 2.44 kg per pot. The highest marketable fruit yield per plant (2.44 kg/plant) was recorded when 1200 ml pot^{-1}ACT was applied as a soil drench, while the lowest marketable fruit yield per plant (0.64 kg/plant) was observed in the control treatment (Table 4). Marketable yields obtained with soil drench application method at the rate of 900 ml pot^{-1} (1.91 kg/plant) and foliar application at the rate of 1200 ml pot^{-1} (2.44 kg/plant) were not statistically significant difference. Marketable yield increased as application rate of ACT increased.

This might have been achieved because, beneficiary microbes covering the rizhospeher and foliar part of the plant as a result pathogenic microorganism which cause distortion or damaging of the fruit may get rid of it. Besides, compost tea are known to contain soluble mineral nutrients both macro and micronutrients that improved fruit size thereby contributing to greater marketable fruit yield. To the best of our knowledge no reports so far published on the influence of macro and micro nutrients in compost tea on marketable fruit yield of tomato which perhaps greatly helped to substantiate the present finding.

Table 4: Interaction effects of application methods and rate of aerated compost tea on fruit per truss, fruit yield per plant, single fruit weight, fruit diameter/equatorial, fruit length/polar and marketable yield per plant

Factors							
Application Methods	Application Rate (ml)	Fruit per truss	Fruit yield per plant (kg)	Single fruit weight (g)	Fruit diameter(cm)	Fruit length(cm)	Marketable yield plant^{-1} (kg)
FF	0	3.58c	1.02f	47.84e	2.59f	4.53g	0.76fg
	300	3.60c	1.75de	43.40f	3.30e	5.04f	0.87efg
	600	3.80c	1.63e	56.78d	3.62de	5.65de	1.05ef
	900	4.82b	2.02cd	62.74c	4.45c	5.80cd	1.62cd
	1200	5.50b	2.57b	69.40b	5.04b	6.29b	2.00b
SD	0	3.83c	1.00f	46.58ef	2.74f	4.90f	0.64g
	300	3.82c	1.77de	49.54e	3.38e	5.35e	1.18e
	600	4.95b	2.13c	57.53d	3.89d	5.83cd	1.54d
	900	5.19b	2.54b	68.99b	4.82b	5.97c	1.91bc
	1200	6.32a	2.87a	75.02a	5.63a	6.74a	2.44a
CV (%)		9.80	8.87	4.12	5.13	3.21	14.93
LSD (5%)		0.76	0.29	4.05	0.34	0.31	0.36

Means in the column followed by the same letter(s) are not significantly different at 5% level of significance. LSD (5%) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Conclusion and Recommendations

Based on this study, application of aerated compost tea had significantly influence the yield and yield component of tomato. ACT as foliar feed and soil drench at different rates had the potential to improve tomato plant nutrient status and enhance plant growth and yield. However, using ACT as soil drench was superior in terms of yield as well as in other important yield components considered. Although application rate greater than 300 ml per pot generally showed quit stimulation of growth and yield of tomato, soil drench of ACT at the rate of 1200 ml per pot was superior to all other rate in terms yield and all other parameters measured. Soil drench with maximum application rate (1200 ml/pot) resulted considerable yield increment by 187%. Therefore, soil drench at the rate of 1200 ml per pot recommended not only for maximizing tomato production but also sustain organic farming system of tomato, which is economically and environmentally feasible. These application rates need to be confirmed on open field across different agro ecological condition.

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