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Vermicompost, Mulching and Irrigation Level on Growth, Yield and TSS of Tomato (*Solanum lycopersicum* L.)

B.K. Siingh[1 *], K.A. Pathak[1], Y. Ramakrishna[1], V.K. Verma[2], B.C. Deka[3]

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ABSTRACT

A field experiment was conducted for two years to investigate the effect of vermicompost, organic mulching and irrigation level on growth, yield and quality attributes of tomato (*Solanum lycopersicum* L.) with an ultimate aim of optimizing water and nutrient requirement of tomato in mild-tropical climate during dry season. The vermicompost together with organic mulching increased plant height (106.5 cm), leaf area (40.6 cm^2), leaf weight (1301 mg/ leaf), fruit weight (92.9 g), fruit yield (4.013 kg/ plant), fruit density (0.972 g/ cc), post-harvest shelf-life (15.0 days) and TSS (5.2° Brix) of tomato significantly. Application of vermicompost alone too increased the shelf-life of fruits by 25-106 % and TSS beyond 4.5 %, both of which are traits highly desirable for production of summer tomato and the related processing industry. The application of vermicompost @ 5 tonnes/ ha, 5 cm thick mulching with dried crop residues, two-thirds dose of NPK fertilizer (80:40:40 kg/ ha) and 30 % irrigation is optimum for obtaining better quality and productivity of field grown tomatoes during dry period of mild-tropical climate.

Key words: *Solanum lycopersicum*; vermicompost; mulching; irrigation; quality; yield.

INTRODUCTION

Sustainable commercial vegetable production must include increased productivity, maximization of water use efficiency, reduced costs of production, integration of organic inputs, higher input use efficiency, and no harm to the soil, ground water, environment and product quality. Soil-plant-environment systems should be integrated sustainably, locally and economically, and free from overuse and misuse of the inputs especially chemicals. World agriculture is increasingly dependent on irrigation, synthetic pesticides and chemical fertilizers which present serious challenges and threaten sustainability due to indiscriminate use of chemical fertilizers and irrigation water.

Water availability for agricultural use is decreasing due to increasing population and industrialization particularly in developing countries. Mizoram, an Indian state, has an annual rainfall of 2000-3250 mm, but the main tomato growing season, November to March, is almost dry (5-25 mm). Tomato (*Solanum lycopersicum* L.) production is limited by soil moisture stress despite appropriate temperature and length of day for crop growth and fruiting. Additional irrigation could be used to alleviate soil moisture deficit and increase yield. Shortage of precipitation during the winter necessitates that water be used efficiently. One possible way of husbanding water is with organic mulching. Human, livestock and crops produce approximately 38 trillion metric tons of organic wastes worldwide, and around 600 to 700 million metric tons of agricultural wastes (including 272 million metric tons of crop residues) in India are available every year, but most remains unutilized (Suthar 2009). In most parts of Mizoram and the

[1]ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib-796081, Mizoram
[2]ICAR-RC-NEH Region, Umroi Road, Barapani-7793103, Meghalaya
[3]ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani-797106, Nagaland
*Corresponding author present address: IIVR, Shahanshahpur-221305, Varanasi, Uttar Pradesh;
e-mail: bksinghkushinagar@yahoo.co.in

North East Hill Regions of India, forest and crop-plant residues are abundant, available and could be utilized for vermicomposting *i.e.* bio-oxidation and stabilization of organic materials involving the activity of earthworms and micro-organisms (Singh et al. 2013). The quantity of crop-plant residues could be converted into nutrient rich vermicompost and used as mulch for sustainable production with integrated farming systems. After the vegetable growing season, the organic mulch can be ploughed in to decompose. Increased amounts of humus support favourable changes in physical, chemical and biological properties of soil, and increases water-holding capacity.

Mulch improves the soil environment; stimulates microbial activity; enhances oxygen availability to roots; moderates soil temperature; increases soil porosity and water infiltration; increases nutrient availability; reduces evaporation, fertilizer leaching and soil compaction; controls weeds, runoff and soil erosion; and increases plant growth, yield and quality (Liasu et al. 2008; Ekinci and Dursun 2009). Species of earthworm can consume, and degrade, a wide range of organic residues including plant residues, animal wastes, forest residues, sewage, sludge and industrial refuse. Vermicompost is an eco-friendly, cost effective and ecologically sound bio-fertilizer. Use of vermicompost is effective for improving soil aggregation, structure, aeration and fertility; contains most of the nutrients in plant-available form such as nitrates, phosphates, exchangeable calcium and soluble potassium; increases beneficial microbial population diversity and activity; improves soil moisture-holding capacity; contains vitamins, enzymes and hormones; and accelerates the population and activity of earthworms (Albiach et al. 2000; Arancon et al. 2006; Azarmi et al. 2008; Marinari et al. 2000).

Poor soil respiration and complete destruction of natural decomposer communities from agro-ecosystems threatens sustainability and food security. The escalation in cost and access to chemical fertilizers (particularly N, P and K) in remote area by poor farmers, acute water deficit during growing season, being an organic production state and ecological concerns have increased interest of use of integrated approaches (vermicompost and mulch) to facilitate sustainable commercial tomato production in mild-tropical conditions during dry season. The objective of the present study, therefore, was to ascertain effects of vermicompost, mulching and irrigation level on plant growth, fruiting, fruit density, TSS and post-harvest life of tomato under field condition.

MATERIALS AND METHODS

The experiment was carried out at the Research Farm of ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram in the 2007-2008 and 2008-2009 cropping seasons. The tomato cv. 'Avinash-2' (Syngenta India Ltd.) has high yield potential, uniformity in shape and size, attractive and excellent color, persistent calyx and excellent marketing potential. The soil type is an Alfisol and acidic (pH 5.8). The experimental Farm lies at 24.12º N latitude and 92.40º E longitude with an altitude of 650 m above mean sea level and has a mild-tropical climate. Following was the range of variation for monthly mean temperature and monthly mean relative humidity (RH) during the crop growth period (November-March), Tmin-max (ºC) 14.6-27.3 and RH (%) 40-83. Cumulative rainfall during the growth period ranged from 24-215 mm. The terraced field was tilled and divided into plots. A 60 cm wide space was left between plots. Plot size for each treatment was 3×3 m and inter- and intra-row spacing was 60×50 cm having 30 plants in each. The experiment was laid out in randomized complete block design with three replications. Eight treatment combinations (T-1: mulch only, T-2: vermicompost @ 5 t/ ha and mulch; T-3: mulch and irrigation at 10 days interval; T-4: vermicompost @ 5 t/ ha, mulch and irrigation at 10 days interval; T-5: mulch and irrigation at 6 days interval; T-6: vermicompost @ 5 t/ ha, mulch and irrigation at 6 days interval; T-7: irrigation at 3 days interval; and T-8: vermicompost @ 5 t/ ha and irrigation at 3 days interval) were used to undertake the present study. Each plot (9 m^2) received approximately 250 lit of water (2.8 cm) during each irrigation. Locally available dried grasses and crop residues were used as mulch. Vermicompost was prepared from crop residues and 15 day-old cow dung in 1:4 ratios using red crawler earthworm (*Eisenia foetida*) in shaded beds. The uniform dose of FYM @ 7.5 t/ ha and lime @ 2 t/ ha was applied to plots at last tilling. Synthetic fertilizers *i.e.* $N:P_2O_5:K_2O$ @ 80:40:40 kg/ ha was supplied by urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. The full dose of N, P_2O_5 and K_2O was applied at transplanting. The FYM, lime, vermicompost and fertilizers were incorporated into the top 15 cm of soil. One-month-old uniform seedlings rose under a polyhouse and having 4-5 leaves were transplanted during the 2nd week of November in each year. Transplants were watered uniformly, three times in a week for 3.5 weeks. A 5 cm thick mulching was applied at 25 days after transplanting. Four irrigation intervals, 0 (no additional irrigation) and 3, 6, and 10 days were used.

Observations were recorded on 15 randomly chosen plants in each treatment and replication. Plant height, and stem diameter at the root collar were measured at the last harvest. To estimate the leaf area, leaf fresh weight and specific leaf weight of the 4th, 5th and 6th leaves from top were sampled at full-bloom stage in each replication. Marketable fruit were harvested at hard ripe stage, counted, measured and weighed to determine total yield. Forty-five fruits, three from 15 marked plants (in each treatment and replication) were harvested at hard ripe stage to estimate fruit size, weight and density. Fruit size was calculated by multiplying the equatorial and polar diameters. Fruit density was estimated by ratio of fruit weight and volume (by water displacement). Rotten and unmarketable fruits were counted as damaged fruits. Thirty fruits, two from 15 marked plants, were harvested at red ripe stage to estimate the total soluble solids (TSS) and post-harvest life. TSS was determined by convex refractometer, while fruits were kept at room temperature to determine the post-harvest life. Data were subjected to analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) using IRRISTAT software (Version 3/93) to identify homogeneity of data between treatment combinations.

RESULTS AND DISCUSSION

The partitioning of mean squares into replications, combinations, treatments, years and treatment × year interactions revealed that mean squares due to replication, year and treatment × year interaction were non-significant for all the traits which are indicating the homogeneity of measurements for various traits in both years. All the traits; other than stem diameter, specific leaf weight and fruit number; were significantly affected by various combinations of vermicompost, organic mulching and irrigation level revealing the importance of organic inputs in sustainable and integrated production system.

Effect of vermicompost, mulching and irrigation level on plant growth of tomato

Plant height, leaf area and leaf fresh weight showed significant differences among the various treatments; while differences for stem diameter and specific leaf weight were insignificant (Table 1). The average plant height ranged from 90.1-106.6 cm (T-1 and T-6). The plant height was measured maximum in T-6 treatment which was at par with

Table 1: Response of tomato to vermicompost, mulching and irrigation

Treatment	Plant height (cm)			Stem diameter (mm)			Leaf area (cm^2/ leaf)			Leaf fresh weight (mg/ leaf)			Specific leaf weight (mg/ cm^2)		
	07-08	08-09	Pooled	07-08	08-09	Pooled	07-08	08-09	Pooled	07-08	08-09	Pooled	07-08	08-09	Pooled
T-1	88.9c	91.4b	90.1b	15.5a	17.1a	16.3a	30.5c	34.1bc	32.3d	1039bc	1081b	1060bc	34.2a	32.2a	33.2a
T-2	90.4bc	92.2b	91.3b	15.2a	15.1a	15.1a	34.3bc	35.1bc	34.7cd	1074bc	1103b	1089bc	31.5a	31.4a	31.4a
T-3	103.8a	104.1a	103.9a	16.9a	17.4a	17.1a	34.2bc	36.7abc	35.4cd	1133bc	1082b	1107bc	33.4a	29.5a	31.5a
T-4	105.2a	106.9a	106.0a	17.5a	17.1a	17.3a	38.5ab	40.7a	39.6ab	1199ab	1321a	1260a	31.2a	32.8a	32.0a
T-5	102.1a	108.3a	105.2a	16.1a	15.6a	15.9a	35.5abc	37.9ab	36.7bc	1175ab	1127b	1151b	33.2a	30.4a	31.8a
T-6	106.0a	107.3a	106.6s	17.6a	17.0a	17.3a	40.1a	41.1a	40.6a	1294a	1308a	1301a	32.3a	31.9a	32.1a
T-7	100.0ab	98.8ab	99.4a	16.5a	15.4a	16.0a	31.5c	32.1c	31.8d	1004c	997b	1001c	31.9a	31.4a	31.7a
T-8	98.7ab	102.2a	100.5a	16.7a	15.9a	16.3a	36.1abc	33.4bc	34.8cd	1070bc	1104b	1087bc	29.7a	33.1a	31.4a
T × Y CD at 5 %		9.3			4.4			5.1			143			6.3	

T: treatment, Y: year, Means followed by common letter are not significantly different by DMRT.

T-1: no vermicompost + mulch + no irrigation, T-2: vermicompost @ 5 t/ ha + mulch + no irrigation, T-3: no vermicompost + mulch + irrigation at 10 days interval, T-4: vermicompost @ 5 t/ ha + mulch + irrigation at 10 days interval, T-5: no vermicompost + mulch + irrigation at 6 days interval, T-6: vermicompost @ 5 t/ ha + mulch + irrigation at 6 days interval, T-7: no vermicompost + no mulch + irrigation at 3 days interval and T-8: vermicompost @ 5 t/ ha + no mulch + irrigation at 3 days interval

T-4, T-5, T-3, T-8 and T-7. This finding indicates that irrigation plays more important role than vermicompost and mulching for plant height which might also be due to low nitrogen content in organic inputs (Sharma et al. 1999). Similarly, leaf area was also measured highest in T-6 having at par value with T-4, T-5 and T-3 treatments. The treatments without irrigation and non-mulching showed minimum leaf size. The result infers that mulching together with reduced quantity of water for irrigation (6-10 days interval *i.e.* 30-60 % less) may provide maximum area for assimilation of CO_2. Significant gain in leaf fresh weight was observed in T-6 and T-4 indicating that application of vermicompost, organic mulching and only 30 % water is sufficient to grow the tomato crop having higher source assimilation efficiency. These results showed that increase in plant growth (plant height, leaf area and leaf weight) could probably be due to improvement in the physio-chemical properties of soil; increase in enzymatic activity; increase in microbial population, diversity and activity; easy availability of macro- and micro-nutrients; and also increase in plant growth hormones by application of vermicompost and organic mulching (Albiach et al. 2000; Arancon et al. 2006; Azarmi et al. 2008; Ekinci and Dursun 2009; Singh et al. 2010; Singh et al. 2011). Zinc is part of several enzymes such as carboxypeptidase, alcohol dehydrogenase, carbonic anhydrase, etc. and mediates leaf formation and auxin synthesis (Cheng 1947) which might have also played an important role in plant height, leaf area and leaf weight. Hernandez et al. (2010) also estimated higher content of Mg, Fe, Zn, and Cu, and lower Na in lettuce leaf through vermicomposting. Further, non-significant of specific leaf weight among the treatments revealed that the increase in leaf weight was only due to increase in leaf area and not due to leaf diameter and accumulation of photo-assimilates. The finding clearly showed vermicompost and organic mulching play indirect role in partitioning of photo-assimilates from source to sink.

Effect of vermicompost, mulching and irrigation level on fruit and yield of tomato

The significant differences were also estimated for fruit size, number of fruits, fruit weight, fruit yield and damaged fruit percentage among various treatment combinations (Table 2). No-irrigation treatments (T-1 and T-2) showed significantly reduced measurements for fruit size, fruit weight and fruit yield. The lower measurement of fruit size for no-irrigated treatments was an indicative that fruit growth is mainly accelerated by cell expansion rather than cell division. The application of vermicompost and mulching has no effect either on cell expansion and or cell division of fruits. In our own experiment carried out by applying various doses of vermicompost and NPK fertilizer in tomato also revealed the non-significant value for fruit size. Cell division in pericarp (flesh) of tomato is limited to a short period of fruit development; once cell division ends, cell expansion becomes the dominant way to increase tomato fruit size (Bertin 2005). Number of fruits/ plant was harvested more in T-4, T-5 and T-6 treatments which showed at par result with T-3, T-7 and T-8 indicated that irrigation at 6-10 days interval instead of 3 days interval along with application of vermicompost and mulching is suitable to produce maximum numbers of fruits/ plant. This might be due to enhanced activity of

Table 2: Effect of vermicompost, mulching and irrigation on fruit and yield of tomato

Treatment	Fruit size (cm^2)			No. of fruit/ plant			Fruit weight (g)			Fruit yield (kg/ plant)			Damaged fruit (%)		
	07-08	08-09	Pooled	07-08	08-09	Pooled	07-08	08-09	Pooled	07-08	08-09	Pooled	07-08	08-09	Pooled
T-1	24.8b	26.0b	25.4b	31.5b	36.7a	34.1ab	55.2b	57.5b	56.4 c	1.731c	2.055b	1.893d	9.8b	8.2b	9.0b
T-2	26.0b	27.6ab	26.8b	33.8ab	33.7a	33.8b	58.3b	61.1b	59.7c	1.988c	2.048b	2.018d	8.3b	9.5b	8.9b
T-3	33.0ab	33.3ab	33.2a	39.7ab	40.3a	40.0ab	83.6a	84.8a	84.2ab	3.311ab	3.383a	3.347abc	10.5b	11.1b	10.8b
T-4	32.6b	34.2ab	33.4a	43.0ab	40.1a	41.5ab	93.3a	91.1a	92.2ab	4.017ab	3.680a	3.848ab	11.3b	10.7b	11.0b
T-5	32.9ab	34.7a	33.8a	44.8ab	41.9a	43.4a	92.7a	91.5a	92.1ab	4.157a	3.845a	4.001a	11.6b	13.2b	12.4b
T-6	35.0a	33.5ab	34.2a	45.1a	41.7a	43.4a	92.0a	93.7a	92.9a	4.162 a	3.864a	4.013 a	12.2b	12.8b	12.5b
T-7	31.2ab	30.0ab	30.6ab	36.9ab	37.4a	37.1ab	83.7a	82.6a	83.1b	3.074b	3.012ab	3.043c	21.5a	23.4a	22.4a
T-8	32.5ab	31.9ab	32.2a	36.1ab	38.6a	37.4ab	84.9a	83.9a	84.4ab	3.063b	3.265a	3.164bc	22.8a	21.4a	22.1a
T × Y CD at 5 %		7.2			11.9			11.7			0.936			5.8	

T: treatment, Y: year, Means followed by common letter are not significantly different by DMRT.

flowering and fruit setting hormones in mulching and vermicompost applied plots. Naphthalene acetic acid (NAA), an auxin, plays a very crucial role in flowering and fruit setting of tomato. As like number of fruits/ plant; single fruit weight and fruit yield/ plant were found to be higher in T-3, T-7 and T-8, and lower in T-1 and T-2. The percentage of damaged fruits was counted almost double in non-mulched treatments (T-7 and T-8). Significant increase in fruit weight and fruit yield/ plant was observed for treatments such as T-4, T-5 and T-6. The increase in fruit weight is mainly because of more accumulation solid matters and not due to higher size of fruit. The result inferred that vermicompost and or mulching improve the partition of photo-assimilates from source to sink and thereby increases the fruit weight. However, the yield difference among T-4, and T-5 and T-6 treatments (irrigation at 10, 6 and 6 days interval, respectively) is at par which revealed that vermicompost and mulching play a crucial role in moisture conservation. The finding has also been supported by Marinari et al. (2000). Ultimately, application of vermicompost and organic mulching not only saves irrigation water (40-70 %) but also increases the productivity (26-31 %). The increased yield potential of vegetables through application of vermicompost and mulching has also been confirmed by Liasu et al. (2008); Singh et al. (2010); Singh et al. (2011); Suthar (2009); and Yadav and Choudhary (2012). Significantly higher percentage of damaged fruits in non-mulched plots is very obvious because of higher fruit rotting resulted by contact of fruits with moistened soil.

Effect of vermicompost, mulching and irrigation level on fruit quality of tomato

The quality parameters such as fruit density, TSS and post-harvest life articulated significant differences among the treatments. The mentioned traits of economic importance were found to be higher in T-4 and T-6 treatments, while lower estimate was observed in T-7 (Table 3). All the studied quality parameters were found to be higher in vermicompost treated plots as comparison to non-vermicompost plots. As like fruit weight, higher fruit density and more TSS is only due to more accumulation of reserve substances in fruits. The quality parameters were more affected by vermicompost than mulching. The vermicompost applied plots revealed that the higher values for quality parameters than non-vermicompost plots. Higher the TSS (> 4.5 %) is advantageous to processing industries for harnessing the more processed product. Tomato being a climacteric fruit, ethylene release is an obvious to start fruit ripening. The moisture content and ethylene concentration play an important role in post-harvest life of tomato fruits. The present study revealed that more solid content in fruits might have contributed for longer shelf-life. Reddy et al. (2013) have reported a positive correlation between TSS and shelf-life among 59 genotypes of tomato. Furthermore, post-harvest life of fruit has increased by 25-106 % with the application of vermicompost. Also, vermicompost promotes the development of the outer covering (pericarp), strengthen fruit firmness of tomato which could lead to a longer shelf-life (Mena-Violante et al. 2009; Chaterjee et al. 2013).

Table 3: Response of vermicompost, mulching and irrigation on quality of tomato

Treatment	Fruit density (g/ cc)			TSS (° Brix)			Post-harvest life (day)		
	07-08	08-09	Pooled	07-08	08-09	Pooled	07-08	08-09	Pooled
T-1	0.840b	0.846bc	0.843bc	4.4c	4.2a	4.3c	10.8ab	9.8bc	10.3c
T-2	0.857b	0.862bc	0.860b	4.6abc	4.5a	4.6bc	12.0ab	13.7ab	12.9abc
T-3	0.861b	0.883b	0.872b	4.6abc	4.7a	4.7abc	10.3bc	10.7abc	10.5bc
T-4	0.965a	0.979a	0.972a	5.2ab	5.0a	5.1ab	14.4ab	15.2a	14.8a
T-5	0.870b	0.879b	0.875b	4.5bc	4.8a	4.6abc	10.5bc	9.6bc	10.1c
T-6	0.965a	0.975a	0.970a	5.3a	5.1a	5.2a	15.4a	14.6a	15.0a
T-7	0.808b	0.796c	0.802c	4.3c	4.3a	4.3c	6.3c	7.0c	6.6d
T-8	0.870b	0.834bc	0.852b	4.7abc	4.9a	4.8abc	13.73ab	13.4ab	13.6ab
T × Y CD at 5 %		0.064	0.7	4.2					

T: treatment, Y: year, TSS: total soluble solid.
Means followed by common letter are not significantly different by DMRT

Therefore, it is advisable to apply vermicompost especially in summer tomato and processing tomato to enhance the shelf-life of fruits as well as recovery of processed products, respectively. In our own experiment carried out on various doses of vermicompost and NPK fertilizer in tomato revealed that fruit density, post-harvest life and TSS are increasing with increase in rate of vermicompost application (Singh et al. 2010). Additionally, the increased amount of humus in soil through application of vermicompost and decomposition of organic mulches by earthworms would certainly help favourable change in physical, chemical and biological properties of soil, and in enhancing the water-holding capacity.

In conclusion, the present study shows that application of vermicompost @ 5 t/ ha, 5 cm thick mulching with dried crop residues, 2/3rd dose of NPK fertilizer (80:40:40 kg/ ha) and 30 % irrigation is the most suitable and sustainable strategy for improving growth, yield and quality of tomato and soil health of mild-tropical climate during dry season.

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