**VERMICOMPOST AND NPK FERTILIZER EFFECTS
ON MORPHO-PHYSIOLOGICAL TRAITS OF PLANTS,
YIELD AND QUALITY OF TOMATO FRUITS
(*SOLANUM LYCOPERSICUM* L.)**

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Summary

A field experiment was conducted with an objective to investigate the effects of vermicompost and NPK fertilizer application on morpho-physiological traits, yield and quality attributes of tomato (*Solanum lycopersicum* L.) with an ultimate aim of optimizing nutrient requirements of tomato in mild-tropical agro-climate. The application of vermicompost together with NPK fertilizer increased plant height, leaf area, leaf weight, fruit weight, fruit yield, fruit density, post-harvest life and TSS of tomato. Application of vermicompost alone too increased the shelf-life by 250% and TSS beyond 4.5%, both of which are traits highly desirable for summer production of tomato and the related processing industry. Present study reveals that application of vermicompost in the amount of 7.5 t·ha⁻¹ in combination with 50% dose of NPK fertilizer (60:30:30 kg·ha⁻¹) was optimum for obtaining better quality and productivity of field grown tomatoes in mild-tropical agro-climate, eventually integrated nutrient supply will sustain the soil fertility and plant productivity eco-friendlly.

key words: vermicompost, NPK, tomato, growth, yield, quality

INTRODUCTION

The development strategy of vegetable production in the present century must be through increased productivity of the land under cultivation, reduced costs of production and higher input use efficiency with no harm to the soil, ground water, environment and product quality. Soil-plant-environment system should be

free from economic exploitation, and overuse and misuse of the inputs. No doubt, the use of mineral fertilizers and pesticides which was a boon in the past, due to their non-judicious use is being considered a bane in the present scenario, causing a shift towards organic farming which has its own limitations. It is now time to reanalyse the production advantage to the cost of nature destruction, where

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impairment of soil physical, chemical and biological properties are the key problems associated with indiscriminate and over use of synthetic fertilizers and pesticides. The poor soil respiration rate and complete vanishing of natural decomposer communities from agro-ecosystems further threatens land sustainability and food security around the world (Suthar 2009a). Similarly, the escalation in the cost of chemical fertilizers; particularly N, P and K; coupled with related ecological concerns has moved the attention of scientific and farming community from chemical alone agriculture to integrated nutrient management strategy which utilizes both organic and inorganic nutrient forms.

It is interesting that humans, livestock and crops produce approximately 38000 million tons of organic wastes worldwide and around 600 to 700 million tons of agricultural wastes (including 272 million tons crop residues) in India every year, but most of it remain unutilized (Suthar 2009b). In most parts of Mizoram and North East Hill Regions of India, forest and crop-plant residues are readily available in plenty which could be utilized to generate nutrient rich bio-fertilizer, i.e. vermicompost for sustainable production and land fertility restoration. Further, species of earthworm that can consume and degrade a wide range of organic residues such as crop/plant residues, animal wastes, forest residues, sewage, sludge and industrial refuses are well known (Dominguez *et al.* 1997, Kaushik & Garg 2003).

Vermicompost is an eco-friendly, cost effective and ecologically sound bio-fertilizer that also played a significant role in soil biology,

chemistry and physics. The use of vermicompost has been recognized generally as an effective mean 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 the soil moisture-holding capacity; enriched with valuable vitamins, enzymes and hormones; accelerates the population and activities of earthworms (Bhasker *et al.* 1992, Tomati & Galli 1995, Orozco *et al.* 1996, Sainz *et al.* 1998, Aggelides & Londra 1999, Mascolo *et al.* 1999, Albiach *et al.* 2000, Marinari *et al.* 2000, Sailajakumari & Ushakumari 2002, Arancon *et al.* 2006, Prabha *et al.* 2007, Azarmi *et al.* 2008, Suthar 2009a).

There is accumulating scientific evidence that vermicompost has a significant positive influence on the growth, productivity and quality of crop plants. The research on vegetables confirms that vermicompost improves seed germination, seedling vigour, plant growth, flowering, fruiting, tuberization, root development, colour, shelf-life and quality of the economic produce (Tomati *et al.* 1990, Atiyeh *et al.* 2000, 2001, Suthar *et al.* 2005, Arguello *et al.* 2006, Alam *et al.* 2007, Ansari 2008, Gupta *et al.* 2008, Peyvast *et al.* 2008, Premsekhar & Rajashree 2009, Suthar 2009b). However, despite the beneficial effects on soil physio-biochemical properties, and growth, yield and quality of plants; presence of heavy metals in vermicompost prepared from urban and industrial wastes is a serious problem that limits

its utilization (Jordao *et al.* 2006) especially in vegetables. Therefore, the main objective of the present study was to ascertain the effect of different levels of vermicompost and NPK fertilizer application on plant growth, and fruit yield and quality of tomato (*Solanum lycopersicum* L., previously known as *Lycopersicon esculentum* Mill.) so as to determine the suitable combinations of nutrients under field conditions in mild-tropical agro-climate.

MATERIALS AND METHODS

The experiment was carried out at Research Farm of ICAR Research complex for NEH Region, Mizoram Centre, Kolasib, Mizoram, India for two subsequent cropping years, i.e. 2007-2008 and 2008-2009 in tomato hybrid 'Avinash-2'. It is one of the most popular hybrids because of high yield potential, uniformity in shape and size, attractive and excellent colour, and persistent calyx. The Experimental Farm is located at an altitude of 650 m above the mean sea level, 24.12°N latitude and 92.40°E longitude having mild-tropical agro-

climate. The soil of the Farm was of Alfisol having pH 5.8. The details of weather parameters for the cropping seasons are summarized in Table 1. The 20 year old terraced experimental field was ploughed three times with power tiller, pulverized, prepared and divided into five treatment plots of 10 m² sizes. A 60 cm wide space was left between two plots. Each treatment was replicated four times in randomized block design. Five organic and inorganic treatments, as described in Table 2, were used in the present study. The vermicompost was prepared from crop residues mixed with 15 days old cow dung in 1:4 ratios by using red earth worm (*Eisenia foetida*) in shade beds. It contains 0.85-1.21% N, 0.60-0.82% P₂O₅ and 0.55-0.89% K₂O in available form. The uniform dose of FYM and limes 7.5 t·ha⁻¹ and 2 t·ha⁻¹, respectively were applied in each plots. Forty plants were accommodated in each replication at the inter- and intra-row spacing of 50 cm. The crop was fertilized with N, P₂O₅ and K₂O supplied as urea, single superphosphate (SSP) and muriate of potash (MOP), respectively (Table 2).

Table 1. Weather parameters of ICAR, Mizoram Centre, Kolasib during cropping periods

Month	Monthly mean average temperature range (°C)		Monthly mean relative humidity range (%)		Rainfall (mm)		Number of rainy days	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
October	21.5-27.2	22.3-28.8	69.3-81.7	76.5-85.5	281.5	325.0	14	13
November	19.9-25.9	19.1-27.3	69.6-79.3	66.6-79.0	105.0	0.0	6	0
December	15.3-22.3	17.4-24.8	59.1-73.0	69.6-83.3	0	0.0	0	0
January	14.6-21.2	15.6-24.1	49.8-62.5	53.6-71.8	0	0.0	0	0
February	16.8-23.2	16.4-24.1	51.5-63.7	52.7-71.4	80.0	0.0	6	0
March	19.5-26.8	20.1-25.8	39.6-59.0	57.0-75.8	30.0	24.0	3	3
April	24.3-31.3	22.9-29.4	50.7-72.8	66.5-78.4	309.5	132.0	14	5

Table 2. Treatment design for tomato experiment

Treatment	Dosage of tested fertilizer
T-1	NPK 120:60:60 kg·ha ⁻¹
T-2	NPK* 90:45:45 kg·ha ⁻¹ + vermicompost 3.75 t·ha ⁻¹
T-3	NPK 60:30:30 kg·ha ⁻¹ + vermicompost 7.50 t·ha ⁻¹
T-4	NPK 30:15:15 kg·ha ⁻¹ + vermicompost 11.25 t·ha ⁻¹
T-5	Vermicompost 15 t·ha ⁻¹

RDF: recommended doses of fertilizer

*P and K expressed as P₂O₅ and K₂O, respectively

The N fertilizer was applied in three split doses; half at the time of transplanting as basal dressing, one fourth at 45-50 days after transplanting, i.e. active growth stage and rest one fourth at 110-120 days after transplanting, i.e. first fruit picking stage. The full dose of P₂O₅ and K₂O were applied at the time of transplanting. Hand weeding, watering, crop protection and other intercultural operations were done as and when necessary to raise the healthy crop. The FYM, lime, vermicompost and fertilizers were incorporated into the top 15 cm of soil in all the experimental plots at the time of last ploughing.

One month old and uniform seedlings of F₁ hybrid 'Avinash-2' having 4-5 leaves were transplanted on 14.11.2007 and 08.11.2008. During each year, well established 15 plants were marked randomly from each replication and tagged to record the data. At the time of last picking plant height and stem thickness at base were measured. To estimate the leaf area, leaf fresh weight, specific leaf weight and leaf chlorophyll; the 4th, 5th and 6th leaves from tagged plants were picked at full bloom stage in each replication. Dimethyl sulphoxide (DMSO) method was followed to determine the total chlorophyll content in leaf tissues (Hiscox & Israel-

stam 1979) and using the formula of Arnon (1949). Fruits were harvested at hard ripe stage, counted, measured and weighed to determine total yield. Equatorial and polar diameter was measured to calculate the fruit size. However, fruit density was estimated by fruit weight and water displacement technique. The total days between first and last picking were determined as fruiting days. Total thirty fruits, two each 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 (28-30°C) and counted post-harvest life.

The data were statistically analysed for analysis of variance (ANOVA) and Duncan's multiple ranged test (DMRT) by IRRISTAT software (Version 3/93, Biometrics Unit, International Rice Research Institute, Manila, Philippines) to identify the homogeneous type of data sets among different treatments for various growth, yield and quality parameters.

RESULTS AND DISCUSSION

The experiment was conducted for two consecutive cropping seasons, i.e. 2007-2008 and 2008-2009. All the

growth and yield parameters except specific leaf weight under present investigation showed significant higher measurements during 2008-2009 than 2007-2008. This might be attributed to a relatively warmer winter of December and January (vegetative stage), a little lower temperature during spring of March (peak flowering, fruit setting and development stage) and six days early transplanting of seedlings during 2007-08 cropping season which make the environment more favourable for growth and bearing in tomato.

Effect of different doses of vermicompost and NPK fertilizer on morpho-physiological traits

Significant differences were estimated among different treatments for plant height, leaf area, leaf fresh weight and leaf chlorophyll content; while it was absent for stem thickness and specific leaf weight during both cropping seasons (Table 3). An average plant height for different experimental plots was in the order of T-4 > T-3 > T-1 > T-2 > T-5 in both crop seasons. The value of leaf area was also highest in T-4 (34.2 and 39.9 cm² during first and second year) followed by T-2, T-3, T-1 and T-5 during both cropping seasons. Effect of NPK plus vermicompost (T-2, T-3 and T-4) and NPK alone (T-1) treatments on fresh leaf weight were found to be significant. These results revealed that increase in plant growth, i.e. 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, diver-

sity and activity; easy availability of macro- and micronutrients; and also increase in plant growth hormones by application of vermicompost (Bhasker *et al.* 1992, Mascolo *et al.* 1999, Albiach *et al.* 2000, Arancon *et al.* 2006, Prabha *et al.* 2007, Azarmi *et al.* 2008). Zinc is a part of several enzymes such as carboxypeptidase, alcohol dehydrogenase, carbonic anhydrase, etc. and mediates leaf formation and auxin synthesis (Cheng 1948), which might have played an important role in plant height, leaf area and leaf weight. Further, insignificant differences for specific leaf weight among nutrient treatments during both cropping seasons could imply that the increase in leaf weight is only due to increase in leaf area and not due to leaf thickness and or the accumulation of photo-assimilates. The finding clearly showed that vermicompost plays an indirect role in partitioning of photo-assimilates from source to sink. Leaf chlorophyll content was highest in T-1 (NPK alone) and was insignificantly different from T-2. The leaf chlorophyll content declined with an increase vermicompost share in the total nutrients applied to tomato crop in both season. The contrast result was reported by Mishra *et al.* (2005).

Effect of different doses of vermicompost and NPK fertilizer on fruit and yield

Among fruiting and yield parameters, the significant differences were estimated for number of fruits, fruit weight, number of fruiting days and fruit yield among various treatments for both crop seasons (Table 4).

Table 3. The influence of vermicompost and NPK fertilizer on morpho-physiological traits of tomato hybrid 'Avinash-2'

Treatment	Plant height (cm)		Stem thickness (mm)		Leaf area (cm ² ·leaf ⁻¹)		Leaf fresh weight (mg·leaf ⁻¹)		Specific leaf weight (mg·cm ⁻²)		Leaf chlorophyll (mg·g ⁻¹)	
	07-08	08-09	07-08	08-09	07-08	08-09	07-08	08-09	07-08	08-09	07-08	08-09
T-1	87.7b	99.4ab	14.1a	15.9a	30.6a	33.9ab	902.3a	1052.7a	30.0a	31.7a	1.598a	1.638a
T-2	85.6bc	96.7ab	14.3a	16.0a	34.1a	39.3a	935.7a	1095.0a	27.5a	28.0a	1.480ab	1.563a
T-3	90.3b	102.0a	14.7a	16.2a	32.9a	37.8a	905.0a	1070.4a	27.7a	28.7a	1.371bc	1.403b
T-4	96.4a	106.5a	13.6a	14.9a	34.2a	39.9a	915.7a	1083.5a	26.8a	27.2a	1.205cd	1.235c
T-5	80.5c	89.4b	13.8a	15.3a	24.8b	29.8b	664.3b	783.7b	26.7a	26.3a	1.017d	1.042d
CV (%)	3.5	5.5	5.5	6.6	8.5	10.0	7.0	6.8	8.0	9.9	8.0	3.7
CD at 5% (year)	2.5		0.4		1.8		38.6		NS		0.046	

Note: CV: coefficient of variation, CD: critical difference, NS: non-significant

Significant difference at $P < 0.05$ is indicated by different letters.

Means followed by the same letters are not significantly different by DMRT.

Table 4. The influence of vermicompost and NPK fertilizer on fruit parameters and yield of tomato hybrid 'Avinash-2'

Treatment	No. of fruits per plant		Fruit size (cm ³)		Fruit weight (g)		Fruiting days		Fruit yield (kg·plant ⁻¹)	
	07-08	08-09	07-08	08-09	07-08	08-09	07-08	08-09	07-08	08-09
T-1	33.7a	37.1a	26.4a	30.7b	79.2cd	83.1c	34.8a	37.1a	2.658ab	3.080ab
T-2	33.1a	36.7a	30.6a	36.0ab	85.4ab	90.2ab	32.1ab	37.0a	2.839ab	3.125ab
T-3	32.8a	35.8ab	31.0a	36.8a	88.9a	93.6a	30.0bc	34.1ab	2.939a	3.049a
T-4	27.3a	30.1b	28.6a	33.6ab	82.6bc	87.5bc	27.9cd	30.3bc	2.266b	2.187b
T-5	21.0b	23.4c	27.8a	32.8ab	77.3d	82.4c	25.8d	27.5c	1.628c	1.842c
CV (%)	11.1	9.9	8.4	8.7	3.1	3.6	5.8	6.4	13.0	12.5
CD at 5% (year)	0.9		1.2		0.9		2.7		0.271	

Note: see Table 3

The addition of vermicompost to soil had no significant effect on fruit size. Non-significance of fruit size reveals that vermicompost has no effect either on cell expansion or cell division of fruits. During both growing seasons, the number of fruits was highest in T-1 (33.7 and 37.1); followed closely by T-2 (33.1 and 36.7) and T-3 (32.8 and 35.8) treatments. The result infers that vermicompost does not affect the fruit setting in tomato. Naphthalene acetic acid (NAA), an auxin hormone, play very crucial role in flowering and fruit setting of tomato. Fruit weight was found to be significantly higher in T-3 (88.9 and 93.6 g) and T-2 (85.4 and 90.2 g) treatments. Increase in fruit weight without any change in fruit size may be due to greater accumulation of solid matters in the fruits. It appears from the findings that supply of nutrients from organic and inorganic sources, i.e. vermicompost and chemical fertilizers improves the partitioning of photo-assimilates from source to sink (leaf to fruit) and thereby increases the fruit weight. This finding agrees with Suthar (2009). The number of fruiting days was more and at par for T-1, T-2 and T-3 treatments during both the years; while minimum fruiting days were recorded for T-5 treatment. Moreover, higher the fruit weight for T-2 and T-3 treatment might be due to longer period of fruit retention on plants which might have facilitated a greater accumulation of photo-assimilates. Similar result has also been obtained by Arguello *et al.* (2006). The maximum fruit yield ($\text{kg} \cdot \text{plant}^{-1}$) was harvested from T-2, T-3 and T-1 in the same order. The increase in fruit yield was contributed chiefly by an improve-

ment in fruit weight and was not caused by an increase in fruit number. The increased yield of garlic through combined application of vermicompost and NPK has observed by Suthar (2009b).

Effect of different doses of vermicompost and NPK fertilizer on fruit quality

The quality parameters like fruit density, post-harvest life and TSS; in general; were found to be maximum in T-5 treatment which is showing increasing pattern with raising vermicompost rate and decreasing NPK dose (Table 5). As like fruit weight, higher fruit density is only due to more accumulation of reserve substances in fruit. Being a climacteric fruit, ethylene release is an obvious to start fruit ripening. The water content and ethylene concentration play an important role in post-harvest life of tomato fruits. The present study reveals that more solid content in fruits might have contributed for longer shelf-life. As like fruit density and fruit weight, TSS is also increasing with increase in vermicompost quantity which is only due to higher content of metabolites in fruit. Higher the TSS ($> 4.5\%$) is a boon for processing industry to harness the more processed product per unit of fruit weight. Post-harvest life of fruit has increased from 90-250% with the application of various doses of vermicompost as compare to fertilizer alone. Therefore, it is advisable to apply vermicompost especially in summer tomato to enhance the shelf-life of fruits and in tomato for processing purposes to get more recovery of processed products. The present results extend and confirm the hy-

pothesis that the application of vermicompost and NPK fertilizer simultaneously promotes the plant growth, and fruit yield and quality which might be due to increase in budget of

essential nutrients; improved soil texture and structure; and enhanced microbial population, activity and diversity by vermicompost.

Table 5. The influence of vermicompost and NPK fertilizer on quality of tomato hybrid 'Avinash-2'

Treatment	Fruit density (g·cc ⁻¹)		Post-harvest life (days)		TSS (% Brix)	
	07-08	08-09	07-08	08-09	07-08	08-09
T-1	0.792c	0.794c	6.3c	6.9d	4.3c	4.4b
T-2	0.894b	0.897b	12.0b	12.2c	4.3c	4.4b
T-3	0.907b	0.912b	13.7b	13.7bc	4.5bc	4.6ab
T-4	0.908b	0.906b	14.0b	14.6ab	5.2a	5.1a
T-5	0.971a	0.975a	16.0a	16.5a	5.1ab	5.1a
CV (%)	2.3	1.7	8.9	8.6	7.1	6.2
CD at 5% (year)	NS		NS		NS	

Note: see Table 3

CONCLUSIONS

The present study shows that application of vermicompost 7.5 t·ha⁻¹ along with 50% dose of NPK fertilizer (60:30:30 kg·ha⁻¹) was the most suitable dose and sustainable strategy for improving yield and quality of tomatoes grown under field conditions, and also supports the hypothesis that integrated nutrient supply will sustain the soil fertility and plant productivity eco-friendly.

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WPŁYW WERMIKOMPOSTU I NAWOZU NPK NA CECHY
MORFOLOGICZNO-FIZJOLOGICZNE ROŚLIN, ICH PŁONOWANIE
I JAKOŚĆ OWOCÓW POMIDORA (*SOLANUM LYCOPERSICUM* L.)

Streszczenie

Przeprowadzono doświadczenie polowe, celem którego było zbadanie wpływu zastosowania wermikompostu i nawozu NPK na cechy morfologiczno-fizjologiczne, plonowanie i cechy jakościowe pomidora (*Solanum lycopersicum* L.), a ostatecznym celem była optymalizacja wymagań odżywczych roślin pomidora w łagodnym agroklimacie tropikalnym. Zastosowanie wermikompostu wraz z nawozem NPK zwiększyło wysokość roślin, powierzchnię liści, masę liści, masę owoców, plon owoców, gęstość owocu, pozbiorną trwałość oraz zawartość ekstraktu w owocach pomidora. Zastosowanie samego wermikompostu również zwiększyło okres trwałości pozbiorną o 250% i zawartość ekstraktu o ponad 4,5%, a obie te cechy są niezmiennie pożądane w produkcji owoców pomidora w sezonie letnim i przez przemysł przetwórczy. Przeprowadzone badania wykazały, że stosowanie wermikompostu w ilości 7,5 t·ha⁻¹ łącznie z 50% dawką nawozu NPK (60:30:30 kg·ha⁻¹) było optymalne do uzyskania lepszej jakości i wydajności w polowej uprawie pomidorów w łagodnym agroklimacie tropikalnym, a zintegrowane zaopatrzenie w składniki pokarmowe przyczynia się do utrzymania żyzności gleby i plenności roślin w sposób ekologiczny.