



Physiological attributes of tomato (*Lycopersicon esculentum* Mill.) influenced by different sources of nutrients at foothill of eastern Himalayan region

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Abstract: The present investigation was aimed to assess the influence of different organic manures (Farmyard manure and vermicompost), inorganic fertilizers and *Azophos* biofertilizer on different physiological attributes of tomato. The field experiment was conducted during 2005-06 and 2006-07 at Uttar Banga Krishi Viswavidyalaya (UBKV), Pundibari, Cooch Behar, West Bengal, India by combining 14 treatments in randomized block design with 3 replications. The results revealed that nutrient sources significantly influenced different physiological attributes as the chlorophyll content of leaves and LAI (Leaf area index) kept on increasing and peaked at 60 DAT (Days after transplanting) and 75 DAT respectively and declined thereafter. The dry matter production was highest at 75 DAT. Again application of vermicompost (4 t/ha) with 75% of inorganic fertilizers inoculated with biofertilizer resulted in significant improvement of physiological attributes as well as yield. Vermicompost emerged as better organic nutrient source over farmyard manure. Inoculation with biofertilizer exerted more positive results over uninoculated treatments and benefits of biofertilizer application were more in presence of vermicompost as compared to farmyard manure.

Keywords: Biofertilizer, Farmyard manure, Inorganic fertilizers, Physiological attributes, Tomato, Vermicompost

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is consumed fresh or utilized in preparation of wide range of processed products. The ripe fruits provide an excellent source of vitamins, minerals and antioxidants which protects human body from oxidative damages that may lead to heart disease, cancer and ageing. The fruit yield depends in the capacity of the plant to accumulate and translocate the photosynthates towards the sink (De *et al.*, 2008). The physiological attributes *viz.* chlorophyll content of leaves, leaf area index (LAI) and dry matter accumulation are closely related with the plant growth and have considerable bearing on yield attributes and fruit yield of tomato. The nutritional status of the soil plays significant role in modification and improvement of different physiological attributes (Roy and Chakraborty, 1993). The incorporation of organic nutrients in the form of vermicompost, farmyard manure and biofertilizer is known to influence favourably to the physico chemical and biological properties of the soil thus resulting in enhanced crop growth and yield (Gour, 1992). Vermicompost, organic manure obtained in the form of casting of ingested biomass by earthworm after undergoing physical, chemical and microbial transformations. Besides macro and micronutrients it also contains humic acids, plant growth promoting substances

like auxins, gibberellins, and cytokinins (Krishnamoorthy and Vajrabhiah, 1986), N-fixing and P-solubilizing bacteria, enzymes and vitamins (Ismail, 1997). The water soluble components of vermicompost such as humic acid, growth regulators, vitamins, micronutrients and beneficial microorganism increases the availability of plant nutrients, results in increased growth, higher yield and better quality produce (Atiyeh *et al.*, 2002). In addition to vermicompost, farmyard manure and biofertilizer also play vital role as organic nutrient sources for sustainable soil health and crop growth (Mali *et al.*, 2005). Incorporation of more organic nutrients were found effective in increasing the growth and yield parameters through enhanced biomass production and translocation of assimilates toward developing sink. Some studies suggested that higher amount of organic sources of nutrients and reduced level of inorganic fertilizers can enhance the physiological efficiency of pea (Reddy *et al.*, 1998) and okra (Paramasivan, 2005). In light of the fact, the present experiment was undertaken to study the influences of different sources of nutrients and their combination on important physiological attributes and subsequently on yield attributes and fruit yield of tomato.

MATERIALS AND METHODS

The field experiment was conducted at the experimental field of Uttar Banga Krishi Viswavidyalaya (UBKV),

Pundibari, CoochBehar, West Bengal (89°23' 53'' E longitude and 26°19' 86'' N latitude) during winter season (November to March) of 2005-2006 and 2006-2007. The soil was well drained sandy loam having pH of 5.74, organic carbon content 0.85% and available N, P₂O₅, K₂O, were 155.85 kg/ha, 20.23 kg /ha and 125.90 kg/ha respectively (Chatterjee, 2009). The treatment consisted of 14 combinations of different nutrient sources and was laid out in randomized block design with three replications. The treatments were selected for sole and combined application of varied levels of vermicompost and farmyard manure (FYM) along with 100% and 75% of recommended dose of inorganic fertilizers in presence and absence of biofertilizer. The combinations were T₁-100% Recommended fertilizer dose (R.F.D.) (100:60:60 kg N P K /ha) ; T₂-100% R.F.D. + 6 tonnes FYM/ha + biofertilizer ; T₃-100% R.F.D. + 2 tonnes vermicompost/ha + biofertilizer ; T₄-100% R.F.D. + 3 tonnes FYM/ha + 1 ton vermicompost/ha + biofertilizer ; T₅-75% R.F.D. + 6 tonnes FYM/ha ; T₆-75% R.F.D. + 6 tonnes FYM/ha + biofertilizer ; T₇-75% R.F.D. + 2 tonnes vermicompost/ha ; T₈-75% R.F.D. + 2 tonnes vermicompost/ha + biofertilizer ; T₉-75% R.F.D. + 3 tonnes FYM/ha + 1ton vermicompost/ha + biofertilizer ; T₁₀-75% R.F.D. + 12 tonnes FYM/ha ; T₁₁-75% R.F.D. +12 tonnes FYM/ha+ biofertilizer ; T₁₂-75% R.F.D. + 4 tonnes vermicompost/ha ; T₁₃-75% R.F.D. + 4 tonnes vermicompost/ha + biofertilizer and T₁₄-75% R.F.D. + 6 tonnes FYM/ha + 2 tonnes vermicompost/ha + biofertilizer. Tomato seedlings (cv. Pusa Ruby) were transplanted in 3.75 m × 3.75 m plots with a spacing of 75 cm within and between rows. Vermicompost and farmyard manure were applied to the respective plots at the time of transplanting. *Azophos*, the *Azotobacter* and phosphate solubilizing bacteria containing biofertilizer was applied as seedling dipping (250g/litre water) just before transplanting. Full dose of P₂O₅ and K₂O along with half N were applied as basal and rest N was top dressed at 30 days after transplanting. The crop was raised adopting standard cultural practices. The physiological attributes were recorded at periodic interval of 30, 60, 75, 90 and 105 DAT (Days after transplanting). The chlorophyll content of tomato leaves was measured by using portable leaf chlorophyll meter (Minolta, Japan) and express in terms of SPAD 502 value. The leaf area index (LAI) was determine with standard procedure after measuring the area of leaves by using leaf area meter (Model 22, Systronics). To estimate dry matter, fresh whole plant samples were dried individually till constant weight was recorded. The data was analyzed statistically with the help of INDOSTAT statistical package.

RESULTS AND DISCUSSION

Physiological parameters

Chlorophyll content of leaves: The results revealed that

chlorophyll content of tomato leaves showed increasing trend from vegetative to flowering phase and reached its peak at 60 DAT, thereafter it showed decline trend towards maturity of the crop for all the treatments, irrespective of treatment combinations (Table 1). At 30 DAT, the highest chlorophyll content of tomato leaves (42.40) was recorded for the plants received only sole chemical fertilizers (T₁). Increased nitrogen assimilation due to adequacy of instant nitrogen ion might have increased the chlorophyll content of tomato leaves at early stage. This was followed by the treatments T₃, T₄ and T₂. At 45 DAT unlike 30 DAT, the higher chlorophyll content of tomato leaves was recorded by integrated application of inorganic, organic and biological sources of nutrients and the highest value (49.30) was measured by the treatment (T₃). Although it was statistically at par with the treatments T₄ and T₁₃. Higher chlorophyll content by the treatment T₃ at this stage may be due to supply of continuous and gradual release of nutrients by the combined effect of 100% chemical fertilizers along with vermicompost and biofertilizer. At 60 DAT the maximum chlorophyll content of tomato leaves (59.40) was recorded by the treatment T₁₃ followed by the treatments T₁₂ and T₃. The treatment T₁₂ and T₃ were statistically at par to each other, whereas the treatment T₁₃ was statistically superior over both the treatment. From 75 DAT onward the chlorophyll content of tomato leaves showed a decline trend for all the treatments, irrespective of treatment combinations may be due to utilization or mobilization of nutrients for the development of fruits, instead of growth of leaves. However the highest chlorophyll content of tomato leaves at 75 DAT (53.60), 90 DAT (48.30) and 105 DAT (43.60) were observed for the treatments T₁₃ followed by the treatment T₁₂ and T₁₄. Highest chlorophyll content of tomato leaves by the treatment T₁₃ at these stages may be due to the favourable effect of higher amount of organic manure in the form of vermicompost along with inorganic fertilizers and biofertilizer resulted in enhanced absorption of nutrients and effective conversion of the nutrients into pigments resulted in accumulation of more chlorophyll in the leaves. The results are in conformity with El-Sabour *et al.*, 1997 who also found increased chlorophyll content of leaves in *Helianthus annuus* (sunflower) when soil was treated with organic compost. Vignesh *et al.* (2012) observed increased chlorophyll concentration and antioxidant activity of spinach leaves under organic fertilizer amendments.

Leaf area index (LAI): The observation recorded on leaf area index of tomato (Table 1) at successive growth stages of tomato (30, 45, 60, 75, 90 and 105 DAT) revealed that LAI was low at the early stages of crop growth and kept on increasing with the advancement of age of the tomato plant till 75 days when it reaches its peak and thereafter LAI showed declining trend towards maturity for all the

Table 1. Effect of different nutrient sources on leaf chlorophyll content and leaf area index of tomato (pooled mean of 2 years) .

Treatments	Chlorophyll content (SPAD 502 value)												Leaf area index											
	30		45		60		75		90		105		30		45		60		75		90		105	
	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT
T ₁ -100% R.F.D. (100 : 60 : 60 kg N P K /ha)	42.40	44.20	47.20	37.40	30.60	28.30	0.467	0.523	0.556	0.583	0.462	0.424												
T ₂ -100% R.F.D. + 6 t FYM/ha + biofertilizer	36.10	45.50	49.30	39.50	36.30	33.30	0.386	0.563	0.621	0.722	0.694	0.668												
T ₃ -100% R.F.D. + 2 t VC /ha + biofertilizer	38.40	49.30	53.50	43.40	39.40	35.60	0.431	0.616	0.664	0.791	0.761	0.728												
T ₄ -100% R.F.D. + 3 t/ha FYM + 1 t/ha VC + biofertilizer	41.60	47.30	51.20	41.50	38.20	35.10	0.406	0.589	0.643	0.764	0.739	0.712												
T ₅ -75% R.F.D. + 6 t FYM/ha	26.30	32.20	37.20	35.30	33.20	30.20	0.213	0.323	0.456	0.562	0.548	0.513												
T ₆ -75% R.F.D. + 6 t FYM/ha + biofertilizer	27.30	34.10	39.10	37.30	35.30	31.30	0.219	0.356	0.494	0.596	0.581	0.557												
T ₇ -75% R.F.D. + 2 t VC/ha	28.30	36.30	40.50	38.40	36.20	32.20	0.231	0.408	0.564	0.678	0.663	0.646												
T ₈ -75% R.F.D. + 2 t VC/ha + biofertilizer	29.20	36.20	42.20	39.40	37.00	34.00	0.241	0.436	0.651	0.776	0.748	0.753												
T ₉ -75% R.F.D. + 3 t FYM/ha + 1 t VC/ha + biofertilizer	29.20	39.30	43.50	41.40	39.20	35.10	0.238	0.432	0.593	0.717	0.690	0.676												
T ₁₀ - 75% R.F.D. + 12 t FYM/ha	30.20	40.20	46.00	43.40	41.20	36.20	0.246	0.451	0.682	0.841	0.834	0.791												
T ₁₁ -75% R.F.D. +12 t FYM/ha+ biofertilizer	31.40	41.30	49.40	44.10	41.40	37.40	0.254	0.463	0.714	0.883	0.862	0.824												
T ₁₂ -75% R.F.D. + 4 t VC/ha	32.40	43.30	54.30	49.20	45.20	41.20	0.266	0.479	0.741	0.928	0.912	0.863												
T ₁₃ -75% R.F.D. + 4 t VC/ha + biofertilizer	33.10	46.10	59.40	53.60	48.30	43.60	0.287	0.503	0.821	1.024	0.986	0.931												
T ₁₄ -75% R.F.D. +6 t FYM/ha + 2 t VC/ha + biofertilizer	31.50	42.20	51.00	47.30	43.30	39.00	0.271	0.487	0.763	0.964	0.948	0.897												
S.Em (±)	1.10	1.22	1.42	1.41	1.39	1.30	0.01	0.01	0.01	0.02	0.02	0.02												
CD (P=0.05)	3.10	3.45	4.00	3.97	3.93	3.68	0.03	0.03	0.03	0.06	0.06	0.06												

R.F.D.-Recommended fertilizer dose; FYM: Farmyard manure; VC-Vermicompost; S.Em-Standard error; of the mean; CD-Critical difference

treatments. At 30 DAT the LAI value of tomato was the lowest among all the growth stages however, the highest LAI (0.467) was obtained in the treatment T₁ and was significantly superior over rest of the treatments. This was followed by the treatments T₃ and T₄. The highest LAI of tomato with the treatment T₁ may be due to the direct effect of straight fertilizer particularly nitrogen. At 45 DAT the LAI of tomato kept on increasing for all the treatments and unlike 30 DAT the higher leaf area index was recorded by integrated application of inorganic fertilizer in combination with organic and biological sources of nutrients and the highest value (0.616) was measured by the treatment T₃ followed by the treatments T₄ and T₂. Highest LAI of tomato by the treatment T₃ could be attributed to increased nitrogen supply, which might have promoted synthesis of new leaves led to higher LAI at this stage. At 60 DAT increasing trend of LAI of tomato was observed among the different treatments and unlike 45 DAT, the highest LAI (0.821) was obtained for the treatment T₁₃ followed by the treatments T₁₄ and T₁₂. The treatment T₁₄ and T₁₂ were statistically at par to each other, whereas the treatment T₁₃ was statistically superior over all the treatments. At 75 DAT the highest value of LAI of tomato was measured among the different growth stages for all the treatments irrespective of treatment combination. The maximum LAI (1.024) was noticed for the treatment T₁₃ followed by the treatments T₁₄ and T₁₂. Unlike 75 DAT, the LAI at 90 DAT and 105 DAT starts declining for all the treatments irrespective of treatment combinations. However the highest LAI of tomato at 90 DAT (0.986) and 105 DAT (0.931) was recorded for the treatment T₁₃ followed by the treatments T₁₄ and T₁₂. Maximum LAI by the treatment T₁₃ could be attributed to the favourable effect of higher amount of organic manure in the form of vermicompost in combination with inorganic fertilizers and biofertilizer. Again *Azophos* in presence of vermicompost would have enhanced the synthesis of growth hormones and improved the nitrogen fixing ability as well as mobilizing the phosphorus of the soil. All these factors led to production of more number of leaves and higher leaf area, ultimately greater leaf area index in tomato plants. Rao and Sankar (2001) established that higher amount of organic sources of nutrients enhanced the leaf number and subsequently the leaf area index in brinjal.

Dry matter accumulation (g/plant): The dry matter accumulation (DMA) of tomato at 30, 45, 60, 75, 90 and 105 DAT were presented in Table 2. The experimental results showed that there was a progressive increase in DMA from vegetative to reproductive phase. The initial dry matter production was low at vegetative stage and was triggered as the crop approached towards reproductive phase. At 30 DAT, the accumulation of dry matters was the lowest among all other growth stages

and the highest DMA (21.46 g) was observed in the treatment T₁ followed by the treatments T₃, T₄ and T₂. The treatment T₁ was significantly superior over all the treatments whereas the treatment T₃, T₄ and T₂ were statistically at par to each at this stage. The faster rate of DMA of tomato with the treatment T₁ might be due to increased nitrogen uptake resulted in increased synthesis of photosynthetes and enhanced the plant vegetative growth at early stages of crop growth. At 45 DAT the dry matter accumulation kept on increasing for all the treatments and the highest DMA of tomato was recorded by the treatment T₃ (46.52 g) followed by the treatments T₄ and T₂. At 60 DAT increasing trend of DMA of tomato was noticed among all the treatments and unlike 45 DAT the treatment T₁₃ recorded the maximum DMA of tomato (69.71 g) followed by the treatments T₁₄ and T₁₂. The treatment T₁₃ was significantly superior over all other treatment and the treatments T₁₂ and T₁₄ were statistically at par to each other at this stage. At 75 DAT significant improvement of DMA of tomato was observed for all the treatments which were highest among all the growth stages, irrespective of treatment combinations. The treatment T₁₃ recorded maximum DMA of tomato (128.34 g) at this stage, which was 51% higher over the sole 100% inorganic fertilizers (T₁). This was followed by the treatments T₁₄ and T₁₂. At 90 DAT and 105 DAT, the increasing trend of the DMA of tomato was noticed for all the treatments irrespective of treatment combination. The maximum DMA of tomato at 90 DAT (189.26 g) and 105 DAT (226.58 g) were observed for the treatment T₁₃ which was followed by the treatments T₁₄ and T₁₂. The treatment T₁₃ was statistically superior over all other treatments at this stage, while the treatments T₁₄ and T₁₂ were statistically at par to each other. Dass *et al.* (2008) in their experiment with Navjyoti variety of tomato recorded 243.90 g DMA at first picking when 50% of recommended dose of fertilizer (100:50:50 kg NPK /ha) and 5 tonnes vermicompost /ha was applied compared to 109.80 g under control. The superiority of the integrated application of nutrients may be due to the positive response of organic, inorganic and biological sources of nutrients combination in increasing the translocation and accumulation of photosynthetes in the plants. Again the efficacy of vermicompost supposed to be enhanced due to certain hormonal activity associated with it. All these might have promoted the development of growth parameters like production of more number of roots, branches and leaves and exhibited better plant vigour that subsequently contributed to greater dry matter accumulation.

Yield attributes and yield: The yield attributing characters were significantly influenced by combined application of inorganic, organic and biological sources of nutrients. The results (Table 2) showed that the

Table 2. Effect of different nutrient sources on dry matter accumulation, yield attributes and yield of tomato (pooled mean of 2 years).

Treatments	Dry matter accumulation (g/plant)										No. of fruits/plant	Fruit weight (g)	Fruit yield/plant (kg)	Fruit yield/plot (kg)	Fruit yield (t/ha)		
	30		45		60		75		90							105	
	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT	DAT						DAT	DAT
T ₁ -100% R.F.D. (100 : 60 : 60 kg N P K /ha)	21.46	37.39	46.53	63.24	87.63	113.52	33.41	41.27	1.13	22.86	15.42						
T ₂ -100% R.F.D. + 6 t FYM/ha + biofertilizer	16.43	41.39	59.31	91.42	112.37	143.78	38.87	48.51	1.52	31.48	21.67						
T ₃ -100% R.F.D. + 2 t VC /ha + biofertilizer	18.12	46.52	62.19	103.08	129.24	151.71	40.37	51.17	1.58	34.97	22.20						
T ₄ -100% R.F.D.+3 t/ha FYM+ 1 t/ha VC+ biofertilizer	16.86	43.26	57.48	95.27	121.43	146.56	39.50	50.21	1.54	34.21	21.89						
T ₅ -75% R.F.D. + 6 t FYM/ha	6.74	19.61	48.31	71.20	93.47	129.43	36.24	45.34	1.34	28.30	19.68						
T ₆ -75% R.F.D. + 6 t FYM/ha + biofertilizer	6.91	20.12	51.27	78.26	104.29	138.24	36.96	46.83	1.36	29.14	20.23						
T ₇ -75% R.F.D. + 2 t VC/ha	8.43	22.37	53.48	83.17	119.82	151.83	37.42	47.36	1.40	30.30	20.89						
T ₈ -75% R.F.D. + 2 t VC/ha + biofertilizer	9.26	24.63	55.86	97.53	131.43	164.58	38.74	49.57	1.51	32.74	21.48						
T ₉ -75% R.F.D.+3 t FYM/ha+1t VC/ha + biofertilizer	8.74	25.42	54.63	93.34	123.35	156.31	37.79	47.91	1.46	31.77	21.13						
T ₁₀ -75% R.F.D. + 12 t FYM/ha	9.87	27.61	57.19	102.53	147.66	179.56	41.29	51.86	1.61	35.82	22.76						
T ₁₁ -75% R.F.D. + 12 t FYM/ha+ biofertilizer	11.14	28.41	59.17	109.21	158.41	187.37	41.84	53.41	1.64	36.01	23.82						
T ₁₂ -75% R.F.D. + 4 t VC/ha	11.83	29.86	62.38	116.47	168.53	198.18	43.92	56.12	1.68	36.98	24.26						
T ₁₃ -75% R.F.D. + 4 t VC/ha + biofertilizer	13.36	32.48	69.71	128.34	189.26	226.58	47.39	59.48	1.89	42.78	26.14						
T ₁₄ -75% R.F.D.+6 t FYM/ha+2 t VC/ha+ biofertilizer	12.41	31.27	66.21	121.47	176.53	212.28	45.54	57.64	1.74	39.36	24.83						
S.Em (±)	1.08	1.78	3.20	5.12	9.94	11.38	1.72	1.80	0.08	1.29	0.98						
CD (P=0.05)	3.06	5.02	9.03	14.46	28.08	13.16	4.86	5.09	0.21	3.76	2.77						

R.F.D.-Recommended fertilizer dose; FYM: Farmyard manure; VC- Vermicompost; S.Em-Standard error of the mean; CD-Critical difference

integration of 75% of recommended inorganic fertilizer along with higher amount of organic manures have surpassed the treatments having 100% inorganic fertilizers combination. Application of 4 tonnes vermicompost per hectare in conjunction with 75% of recommended inorganic fertilizer and biofertilizer (T_{13}) recorded the maximum number of fruits per plant (47.39), average fruit weight (59.48 g), highest fruit yield per plant (1.89 kg) and per plot (42.78 kg) as well as per hectare (26.14 ton). However the treatments T_{14} and T_{12} were statistically at par with the treatment T_{13} for all these yield characters. The treatment T_{13} recorded 41.84% more number of fruits, 44.12% higher fruit weight and 67.26% greater fruit yield per plant over the treatment T_1 . The results further revealed that among the 75% inorganic fertilizer treatment combination, yield attributes were significantly influenced by the form and level of the organic manures and higher levels of vermicompost performed better over higher levels of farmyard manure. Again the performance of biofertilizer was influenced by the forms and levels of organic manures. In case of higher level of farmyard manure, presence of biofertilizer (T_{11}) resulted 2% more fruit yield over the uninoculated treatment combination T_{10} , where as for higher level of vermicompost, addition of biofertilizer (T_{13}) resulted in 11% improvement in fruit yield over the uninoculated treatment combination T_{12} . These findings indicated that combined application of vermicompost, inorganic fertilizers and biofertilizer have pronounced influenced on yield attributes of tomato. The increased fruit yield under integrated use of higher amount of vermicompost and reduced level of inorganic fertilizer in presence of biofertilizer may be due to large uptake of nutrients and effective utilization of these nutrients for increased synthesis of carbohydrates, greater vegetative growth and subsequently better partitioning and remobilization of accumulated assimilates towards developing fruits (sink). Enhanced growth parameters and higher head yield in tomato under diverse nutrient sources was earlier reported by Patil *et al.*, 1998 and Das *et al.*, 2008.

Conclusion

The present study revealed that integrated use of different source of nutrients enhanced the desirable physiological traits such as higher chlorophyll content, larger leaf area index and greater dry matter content of tomato which subsequently imparted the desirable fruit weight and yield of tomato. Partial substitution of inorganic fertilizers through vermicompost is highly effective and higher levels of vermicompost emerged as better organic source over that of farmyard manure. Application of biofertilizer exerted more benefits over the uninoculated treatments.

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