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Effects of Nutrient Enriched Vermicompost on Growth Indices of Tomato and Elemental Stoichiometric Ratio of Major Nutrients in Inceptisol of Middle Gangetic-Plain

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ABSTRACT

Organic farming aims at providing quality food along with sustainable soil ecosystem. A pot experiment was carried out in Inceptisol during *rabi* season, 2019-2020 with tomato cv. Kashi Vishesh using farm yard manure (FYM) and enriched vermicompost (VC). The experiment comprised of eleven treatments viz. T_1 (control), T_2 (FYM @ 4.5 g kg^{-1} soil), T_3 (FYM @ 9.0 g kg^{-1} soil), T_4 (FYM @ 13.5 g kg^{-1} soil), T_5 (VC @ 4.5 g kg^{-1} soil), T_6 (VC @ 9.0 g kg^{-1} soil), T_7 (VC @ 13.5 g kg^{-1} soil), T_8 (50 per cent N and recommended dose of P & K through fertilizers + 50 per cent N through FYM), T_9 (50 per cent N and recommended dose of P & K through fertilizers + 50 per cent N through VC), T_{10} (50 per cent N and recommended dose of P & K through fertilizers + 25 per cent N through FYM + 25 per cent N through VC) and T_{11} (N, P & K from commercial fertilizers). Urea, diammonium phosphate (DAP) and muriate of potash (MOP) were used as commercial fertilizers. The results showed that the significant increment in plant height and dry matter production per plant and per unit area in unit time with treatments receiving FYM and VC at 90 days after transplanting. The study indicated that the application of enriched vermicompost @ 4.5 g kg^{-1} soil resulted in enhanced fruit yield (196.4 t acre^{-1}). The soil organic matter and elemental stiochiometric ratio (N: P, N: S and P: S) were found to be affected positively with application of VC and use of enriched VC was more pronounced than traditional FYM in organic tomato production system.

Key words: FYM, Vermicompost, Tomato, Inceptisol, Organic cultivation

With the advent of new agricultural technologies and the massive use of chemical fertilizers and agro-chemicals has increased crop production at lower price, but, resulted in ecosystem imbalances and ill-effects on human health. Continuous and increased use of chemical fertilizers lead to several detrimental effects not only on soil and water quality but reduction in soil productivity as well [1]. Excessive use of synthetic chemicals has been found to have negative impact on phyto-nutritional quality of crops especially, fruits and vegetables [2]. Intensive cultivation practices and non-effective soil conservation practices have led to excessive soil erosion, nutrient run-off and depleting soil organic matter leaving soil prone to damage [3]. Increase in awareness about the negative environmental and health impacts of fertilizers, pesticides, synthetic plant growth hormone etc. in agriculture have led to rise of organic food empire [4]. Organic farming has ample benefits over industrial farming system in enhancing soil health [5] protecting environment and providing nutritionally safe food along with premium returns in terms of economics [6]. Thus, organic farming has become buzzword with one of the fastest growing sector of agriculture for providing with goal of attaining sustainability without comprising yield. Tomato is a universally accepted table crop which is consumed in fresh as well as processed product forms for minerals and vitamins that has found to have protective roles in reducing risk of chronic diseases, such as cancer and cardiovascular disease [7]. Being, consumed largely in fresh form, the organically grown tomato is prepping for huge market in India with 10.4% share in world production and second only to China [8].

The additional benefits of healthy soil ecosystem associated with organics had attracted scientific community. The organic sources of plant nutrients are the pillars for organic farming system to survive and flourish as well, but the fact of less nutrient availability in manures and compost can't be ignored. There is need to explore the best organic nutrient sources along with proper dose and schedule of application. The present investigation aimed to study the comparative effect of NPK enriched vermicompost and traditional farm yard manure alone or in combination with chemical fertilizers on growth

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indices of tomato crop and stiochiometric ratio of major nutrients in residual soil.

MATERIALS AND METHODS

A pot experiment was conducted in the Net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi in clay loam soil of order Inceptisol during *rabi* 2019-20 with tomato cv. Kashi Vishesh (H-86) using farm yard manure (FYM) and rock-phosphate enriched vermicompost (VC) with eleven treatments viz. T_1 (control), T_2 (FYM @ 4.5 g kg^{-1} soil), T_3 (FYM @ 9.0 g kg^{-1} soil), T_4 (FYM @ 13.5 g kg^{-1} soil), T_5 (VC @ 4.5 g kg^{-1} soil), T_6 (VC @ 9.0 g kg^{-1} soil), T_7 (VC @ 13.5 g kg^{-1} soil), T_8 (50 per cent N and full dose of P & K through chemical fertilizers + 50 per cent N through FYM), T_9 (50 per cent N and full dose of P & K through chemical fertilizers + 50 per cent N through VC), T_{10} (50 per cent N and full dose of P & K chemical through fertilizers + 25 per cent N through FYM + 25 per cent N through VC) and T_{11} (recommended dose of N, P & K from chemical fertilizers). All treatments were replicated thrice in completely randomized block design. Urea, diammonium phosphate (DAP) and muriate of potash (MOP) were used as source of chemical fertilizer, while FYM and VC were used as organic sources of nutrients. Rock phosphate enriched VC was prepared and collected from the vermicompost unit of Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Sabour, Bhagalpur, Bihar and FYM was collected from Dairy Farm of Institute of Agricultural Sciences, Banaras Hindu University. Seeds of tomato (variety: Kashi Vishesh) was obtained from ICAR-Indian Institute of Vegetable Research, Varanasi. The experiment was carried out in earthen pots of 10 kg soil capacity with coverage area- 0.28 m^2 and transplanting of 25 days seedlings was done. The soil was treated with organic manures 7 days prior transplanting, while chemical fertilizers were added according to recommended dose of fertilizers (RDF); N: P_2O_5: K_2O (120: 80: 80 kg ha^{-1}), a day before transplanting. The moisture in soil was maintained with 60 per cent of the water holding capacity and one plant per pot was kept for recording of growth parameters and yield. The suitable crop production practices were followed and no synthetic pesticides and growth hormones were sprayed during the entire crop season. The growth parameters were recorded (days after transplanting, DAT) at vegetative (30 DAT), flowering (45 DAT) and fruiting stage (90 DAT). The crop was harvested at 170 DAT and residual soil samples were analyzed for soil fertility. The FYM and enriched VC were characterized for nutrient composition following wet digestion method [9]. The N, P and K content in FYM was 0.5, 0.32 and 0.52 per cent, respectively, while 1.3, 2.4 and 1.2 per cent in enriched VC, respectively. The initial and post-harvest soil analysis were performed following standard procedures for pH and EC with soil-water ratio 1: 2.5 [9]; oxidizable organic carbon and organic matter [10]; $KMnO_4$-hydrolyzable nitrogen [11]; available phosphorus [12] and $CaCl_2$-extractable sulphur [13]. The initial soil samples were found neutral in reaction (pH-7.58) and non-saline (EC-0.31 dSm^{-1}) with organic matter content of 1.31 per cent. The available nitrogen, phosphorus (P_2O_5) and sulphur of experimental soil samples were 301.1, 67.6 and 15.9 kg ha^{-1}, respectively with N: P, N: S and P: S ratio; 4.45, 18.93 and 4.25, respectively. The plant height was measured at 30, 45 and 90 DAT and expressed in centimeters. The dry matter weight of plant at 30, 45 and 170 DAT was calculated by drying fresh plant samples in oven at 60ºC and results were expressed in grams per plant. The tomato fruit yield per pot was noted and projected yield was calculated in tons $acre^{-1}$. From plant height and dry matter weight, plant growth rate, absolute growth rate, crop growth rate and relative growth rate were computed using following formula:

Increment in plant height

It denotes the increment in plant height per unit time (cm day^{-1}) and was determined at different growth stages (30, 45 and 90 DAT) using following formula:

$$\text{Increment in plant height} = \frac{\text{H2} - \text{H1}}{\text{T2} - \text{T1}}$$

Where;
H_1- Plant height at time T_1, H_2 – Plant height at time T_2, T_1 - First sampling time and T_2 - Second sampling time (Days)

Absolute growth rate (AGR)

It denotes the dry matter weight per plant per unit time (g $plant^{-1}$ day^{-1}) and was determined at different growth stages (30, 45 and 170 DAT) using following formula:

$$\text{AGR} = \frac{\text{W2} - \text{W1}}{\text{T2} - \text{T1}}$$

Where;
W_1- Dry matter weight per plant at time T_1, W_2 - Dry matter weight per plant at time T_2, T_1 - First sampling time and T_2 - second sampling time (Days).

Crop growth rate (CGR)

The daily increment in crop biomass is referred to as crop growth rate (CGR) and was determined at different growth stages (30, 45 and 170 DAT) by using the formula [14] and expressed in g m^{-2} day^{-1}.

$$\text{CGR} = \frac{\text{W2} - \text{W1}}{\text{A(T2} - \text{T1)}}$$

Where;
W_1 - Dry matter weight (g) of plant at T_1, W_2 - Dry matter weight (g) of plant at T_2, A-ground area in m^2, T_1 - First sampling time and T_2 - second sampling time (Days).

Relative growth rate (RGR)

The RGR refers to dry matter weight increase in the given time interval to its initial weight. It was determined at different growth stages (30, 60 and 170 DAT) by using the formulae [15] and expressed in g g^{-1} day^{-1}.

$$\text{RGR} = \frac{\text{loge(W2)} - \text{loge(W1)}}{\text{T2} - \text{T1}}$$

Where;

loge - natural log, W_1 - Dry matter weight (g) of plant at T_1, W_2 - Dry matter weight of plant (g) at T_2, T_1 - First sampling time and T_2 - Second sampling time (Days).

The collected experimental data were statistically analyzed [16] and Duncan's multiple range test (DMRT) was done to compare significant differences between the treatments at $p \leq 0.05$ of least significant difference (LSD).

RESULTS AND DISCUSSION

Effect on growth indices and yield of tomato plant

Increment in plant height

The plant height growth rate (cm day^{-1}) was found to be significantly influenced by organic and inorganic sources of nutrition at 90 DAT (fruiting stage of tomato crop). Significantly highest increment in plant height (0.46 cm day^{-1}) was observed in integrated nitrogen management system with FYM and VC (T_{10}) followed by T_8 (integrated nitrogen management with FYM). T_8 was found to be at statistically at par with T_5 (VC @ 4.5 g kg^{-1} soil) and T_{11} (RDF) (Table 1, Fig 1). The organic manures (FYM/VC) application had resulted in increased plant height rate at 30 and 45 DAT, though results were statistically insignificant. It was also noted that the plant height rate was decreased from 30 to 90 DAT, with maximum rate at 30 DAT.

Table 1 Effects of organic/industrial plant nutrients treatments on increment in plant height (cm day^{-1}) of tomato crop

Treatments	30 DAT	45 DAT	90 DAT
T_1 ($N_0P_0K_0$)	1.82	1.29	0.27fg
T_2 ($FYM_{4.5}$)	2.00	1.80	0.24g
T_3 ($FYM_{9.0}$)	1.92	1.73	0.32de
T_4 ($FYM_{13.5}$)	1.93	1.64	0.32de
T_5 ($VC_{4.5}$)	2.02	1.36	0.38bc
T_6 ($VC_{9.0}$)	1.93	1.71	0.30ef
T_7 ($VC_{13.5}$)	2.04	1.24	0.31df
T_8 ($N_{1/2\text{-}FYM} + N_{1/2\text{-}F} + PK_F$)	1.98	1.44	0.41b
T_9 ($N_{1/2\text{-}VC} + N_{1/2\text{-}F} + PK_F$)	1.93	1.40	0.35cd
T_{10} ($N_{1/4\text{-}FYM} + N_{1/4\text{-}VC} + N_{1/2\text{-}F} + PK_F$)	1.90	1.44	0.46a
T_{11} (NPK_F)	2.06	1.44	0.39bc
Sem (±)	0.05	0.15	0.07
CD (P=0.05)	NS	NS	0.04

DAT= days after transplanting of tomato seedlings

Table 2 Effects of organic/industrial plant nutrients treatments on absolute growth rate (g $plant^{-1}$ day^{-1}) of tomato crop

Treatments	30 DAT	45 DAT	170 DAT
T_1 ($N_0P_0K_0$)	0.263h	0.367f	0.246g
T_2 ($FYM_{4.5}$)	0.384g	0.507e	0.436f
T_3 ($FYM_{9.0}$)	0.406g	0.664cd	0.450f
T_4 ($FYM_{13.5}$)	0.443f	0.660cd	0.458ef
T_5 ($VC_{4.5}$)	0.502e	0.827b	0.602a
T_6 ($VC_{9.0}$)	0.521de	0.904b	0.582ab
T_7 ($VC_{13.5}$)	0.532cd	1.011a	0.561b
T_8 ($N_{1/2\text{-}FYM} + N_{1/2\text{-}F} + PK_F$)	0.507de	0.498e	0.457ef
T_9 ($N_{1/2\text{-}VC} + N_{1/2\text{-}F} + PK_F$)	0.572ab	0.680c	0.523c
T_{10} ($N_{1/4\text{-}FYM} + N_{1/4\text{-}VC} + N_{1/2\text{-}F} + PK_F$)	0.557bc	0.556e	0.494d
T_{11} (NPK_F)	0.586a	0.578de	0.472de
Sem (±)	0.009	0.031	0.009
CD (P=0.05)	0.027	0.090	0.026

DAT= days after transplanting of tomato seedlings

Absolute growth rate

(Table 2, Fig 2) showed the impact of organic and inorganic nutrition on absolute growth rate (g $plant^{-1}$ day^{-1}) of tomato plant. The results clearly depicted the significant effect of organic manures application on AGR. At vegetative stages (30 DAT), the dry matter production per plant per day was observed significantly high (0.586 g $plant^{-1}$ day^{-1}) with T_{11} which was at par with integrated nitrogen management with VC (T_9). At flowering stage, VC application @ 13.5 g kg^{-1} soil (T_7) recorded highest AGR value (1.011 g $plant^{-1}$ day^{-1}) which was significantly superior to rest of the treatments. The tomato plants at harvesting stage (170 DAT) observed significantly highest AGR value (0.602 g $plant^{-1}$ day^{-1}) with sole application of VC @ 4.5 g kg^{-1} soil (T_5). The result showed that though application of chemical fertilizers resulted in increased AGR value during initial crop stage, but enhanced AGR values was observed with application of VC alone or in combination with chemical fertilizers during later crop growth stages. The organic manures application, especially enriched VC was prominent in producing increased dry matter during crucial flowering and fruiting stages. However, minimum growth rate was noted in control (T_1).

Table 3 Effect of Effects of organic/industrial plant nutrients treatments on crop growth rate (g m^{-2} day^{-1}) of tomato

Treatments	30 DAT	45 DAT	170 DAT
T_1 ($N_0P_0K_0$)	0.940g	1.310f	0.878g
T_2 ($FYM_{4.5}$)	1.373f	1.810e	1.557f
T_3 ($FYM_{9.0}$)	1.448f	2.373cd	1.609ef
T_4 ($FYM_{13.5}$)	1.583e	2.357cd	1.636ef
T_5 ($VC_{4.5}$)	1.794d	2.952b	2.149a
T_6 ($VC_{9.0}$)	1.861cd	3.230b	2.078ab
T_7 ($VC_{13.5}$)	1.901bc	3.611a	2.004b
T_8 ($N_{1/2\text{-}FYM} + N_{1/2\text{-}F} + PK_F$)	1.810cd	1.778e	1.632ef
T_9 ($N_{1/2\text{-}VC} + N_{1/2\text{-}F} + PK_F$)	2.044a	2.429c	1.868c
T_{10} ($N_{1/4\text{-}FYM} + N_{1/4\text{-}VC} + N_{1/2\text{-}F} + PK_F$)	1.988ab	1.984e	1.766d
T_{11} (NPK_F)	2.091a	2.063de	1.687de
Sem (±)	0.033	0.110	0.032
CD (P=0.05)	0.098	0.323	0.094

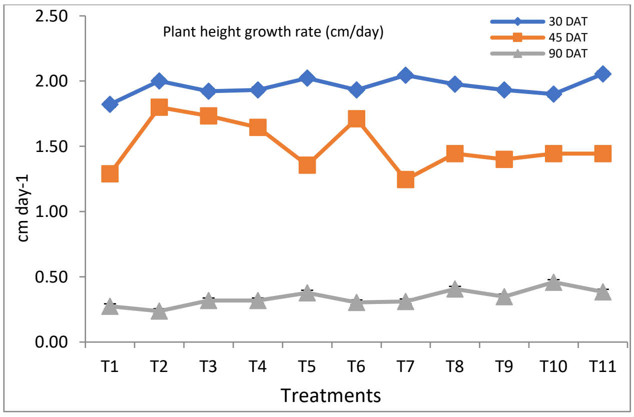

Fig 1 Effect of different treatments on plant height growth rate (cm day^{-1}) of tomato crop

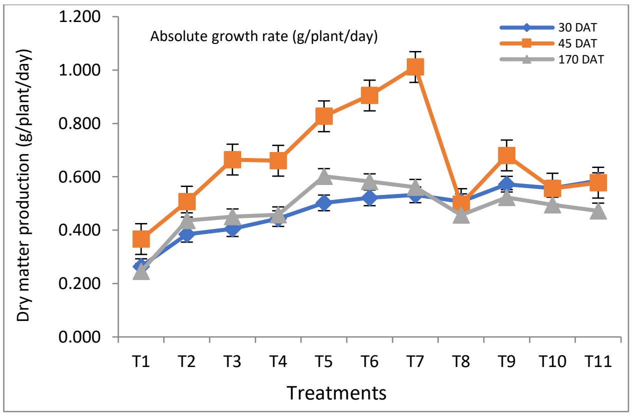

Fig 2 Effect of different treatments on absolute growth rate (g plant^{-1} day^{-1}) of tomato crop

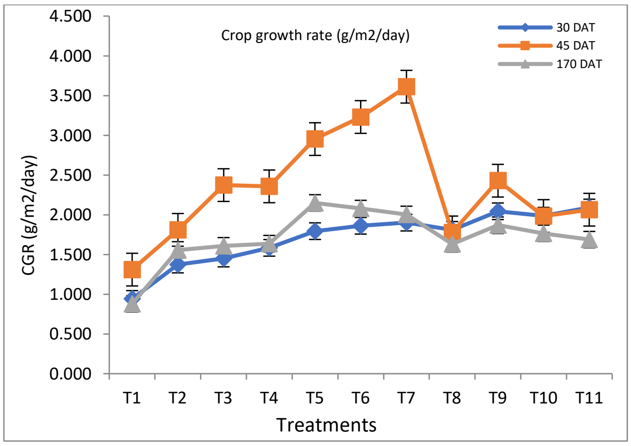

Fig 3 Effect of different treatments on Crop growth rate (g m^{-2} day^{-1}) of tomato

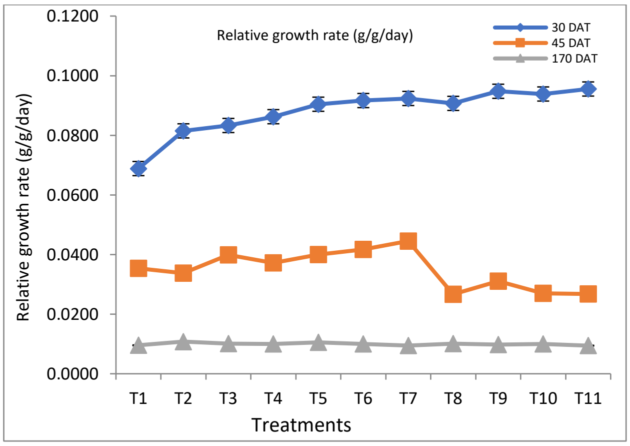

Fig 4 Effect of different treatments on Relative growth rate (g g^{-1} day^{-1}) of tomato plant

Crop growth rate

The organic manures (FYM/VC) have significant impacts on dry matter production per ground area covered by one plant per unit time ((g m^{-2} day^{-1}) (Table 3, Fig 3). At 30 DAT, integration of VC with chemical fertilizers (T_9) resulted in increased crop growth rate (2.044 g m^{-2} day^{-1}) which was statistically at par with T_{10} and application of recommended dose of chemical fertilizers (T_{11}). At flowering growth stage, significantly highest crop growth rate (3.611 g m^{-2} day^{-1}) was observed with sole application of VC @ 13.5 g kg^{-1} soil (T_7) followed by T_6, T_5 and T_9. At harvesting stage of crop, the dry matter production per unit area was increased significantly with application of VC @ 4.5 g kg^{-1} soil (T_5) which was at par value with T_6. It was worth to note from the result that crop growth rate was highest at flower initiation stage in tomato crop (45 DAT). The application of organic manures had significant impact on dry matter production per unit area and surpassed the effect of chemical fertilizers during later growth stages of tomato crop. Minimum value for crop growth rate was noticed in control (T_1).

Table 4 Effects of organic/industrial plant nutrients treatments on relative growth rate (g g^{-1} day^{-1}) of tomato plant

Treatments	30 DAT	45 DAT	170 DAT
T_1 ($N_0P_0K_0$)	0.0688f	0.0353cde	0.0095de
T_2 ($FYM_{4.5}$)	0.0815e	0.0337de	0.0108a
T_3 ($FYM_{9.0}$)	0.0833e	0.0399abc	0.0101bc
T_4 ($FYM_{13.5}$)	0.0862d	0.0371bcd	0.0100cd
T_5 ($VC_{4.5}$)	0.0904c	0.0400ab	0.0106ab
T_6 ($VC_{9.0}$)	0.0917bc	0.0417ab	0.0100cd
T_7 ($VC_{13.5}$)	0.0924bc	0.0445a	0.0094e
T_8 ($N_{1/2\text{-}FYM}$ + $N_{1/2\text{-}F}$ +PK_F)	0.0907c	0.0267f	0.0101bc
T_9 ($N_{1/2\text{-}VC}$ + $N_{1/2\text{-}F}$ + PK_F)	0.0948a	0.0311ef	0.0098cde
T_{10} ($N_{1/4\text{-}FYM}$ + $N_{1/4\text{-}VC}$ + $N_{1/2\text{-}F}$ + PK_F)	0.0939ab	0.0270f	0.0100cd
T_{11} (NPK_F)	0.0955a	0.0267f	0.0094e
Sem (±)	0.0008	0.0017	0.0002
CD (P=0.05)	0.0022	0.0051	0.0005

DAT= days after transplanting of tomato seedlings

Relative growth rate

The application of VC with integration with chemical fertilizers (T_9) showed at par value with chemical fertilizer treatment (T_{11}) for relative growth rate (g g^{-1} day^{-1}) at vegetative stage of crop (30 DAT). At reproductive stage (45 DAT), the significant effect of VC in graded doses (4.5, 9.0 and 13.5 g kg^{-}

[1] soil) was evident (Table 4, Fig 4). At harvesting stage of tomato, application of FYM (T_2) had significant effect on relative growth rate with highest value (0.0108 g g^{-1} day^{-1}).

Yield of tomato

Sole application of VC (T_5) as nutrients showed maximum tomato yield (196.4 t $acre^{-1}$) which was statistically at par with T_6 (185.5 t $acre^{-1}$), T_7 (174.2 t $acre^{-1}$), T_9 (187.0 t $acre^{-1}$) and T_{11} (186.2 t $acre^{-1}$). The application of enriched VC was highly effective in producing at par yield as from recommended dose of chemical fertilizers (Table 5). However, lowest yield (53.1 t $acre^{-1}$) was recorded with no application of manures or fertilizers (T_1).

Effect on post-harvest soil
Physico-chemical properties

Soil pH is an important indicator which controls the nutrient availability and microbial activities in soil. The data of soil pH ranged 7.52- 7.56, showed that, though there was small change in pH among different treatments, but the change was statistically non-significant (Table 6). The organic matter in soil after harvest of crop was found to have significantly enhanced by organic manures treatment. FYM (T_4 and T_5) and VC (T_6 and T_7) application showed higher soil organic matter value (T_4-1.33%, T_5- 1.32%, T_6-1.33% and T_7-1.34%) after harvest of tomato crop (Table 6). Lower values of soil organic matter were observed in soil treated completely with industrial fertilizers (T_{11}) and control (T_1).

Table 5 Effects of organic/industrial plant nutrients treatments on estimated fruit yield (tons/acre) of tomato

Treatments	Yield (t/acre)
T_1 ($N_0P_0K_0$)	53.1d
T_2 ($FYM_{4.5}$)	98.5c
T_3 ($FYM_{9.0}$)	112.0bc
T_4 ($FYM_{13.5}$)	111.1bc
T_5 ($VC_{4.5}$)	196.4a
T_6 ($VC_{9.0}$)	185.5a
T_7 ($VC_{13.5}$)	174.2a
T_8 ($N_{1/2\text{-}FYM}$ + $N_{1/2\text{-}F}$ +PK_F)	126.6bc
T_9 ($N_{1/2\text{-}VC}$ + $N_{1/2\text{-}F}$ + PK_F)	187.0a
T_{10} ($N_{1/4\text{-}FYM}$ + $N_{1/4\text{-}VC}$ + $N_{1/2\text{-}F}$ + PK_F)	138.7b
T_{11} (NPK_F)	186.2a
Sem (±)	10.8
CD (P=0.05)	31.7

Table 6 Effect of different treatments on physico-chemical and elemental stoichiometric ratios in post-harvest soil

Treatments	pH	EC (dSm^{-1})	Organic matter (%)	N: P ratio	N: S ratio	P: S ratio
T_1 ($N_0P_0K_0$)	7.55	0.29	1.28d	3.67g	16.21g	4.42f
T_2 ($FYM_{4.5}$)	7.54	0.28	1.31bc	4.41ef	19.51e	5.18e
T_3 ($FYM_{9.0}$)	7.52	0.27	1.32ab	5.09ab	22.49ab	5.51d
T_4 ($FYM_{13.5}$)	7.53	0.28	1.33ab	5.24a	23.14a	5.97c
T_5 ($VC_{4.5}$)	7.56	0.28	1.31b	4.64cd	20.50cde	6.08bc
T_6 ($VC_{9.0}$)	7.52	0.29	1.33ab	4.71cd	20.82cd	6.23abc
T_7 ($VC_{13.5}$)	7.54	0.26	1.34a	4.86bc	21.49bc	6.38ab
T_8 ($N_{1/2\text{-}FYM}$ + $N_{1/2\text{-}F}$ +PK_F)	7.55	0.26	1.31bc	4.64cde	20.48cde	6.17abc
T_9 ($N_{1/2\text{-}VC}$ + $N_{1/2\text{-}F}$ + PK_F)	7.52	0.27	1.31b	4.49def	19.84def	6.45a
T_{10} ($N_{1/4\text{-}FYM}$ + $N_{1/4\text{-}VC}$ + $N_{1/2\text{-}F}$ + PK_F)	7.53	0.28	1.31b	4.49def	19.83de	6.30ab
T_{11} (NPK_F)	7.53	0.31	1.29cd	4.27f	18.85f	5.18e
Sem (±)	0.05	0.01	0.01	0.09	0.35	0.11
CD (P=0.05)	NS	NS	0.02	0.26	1.01	0.32

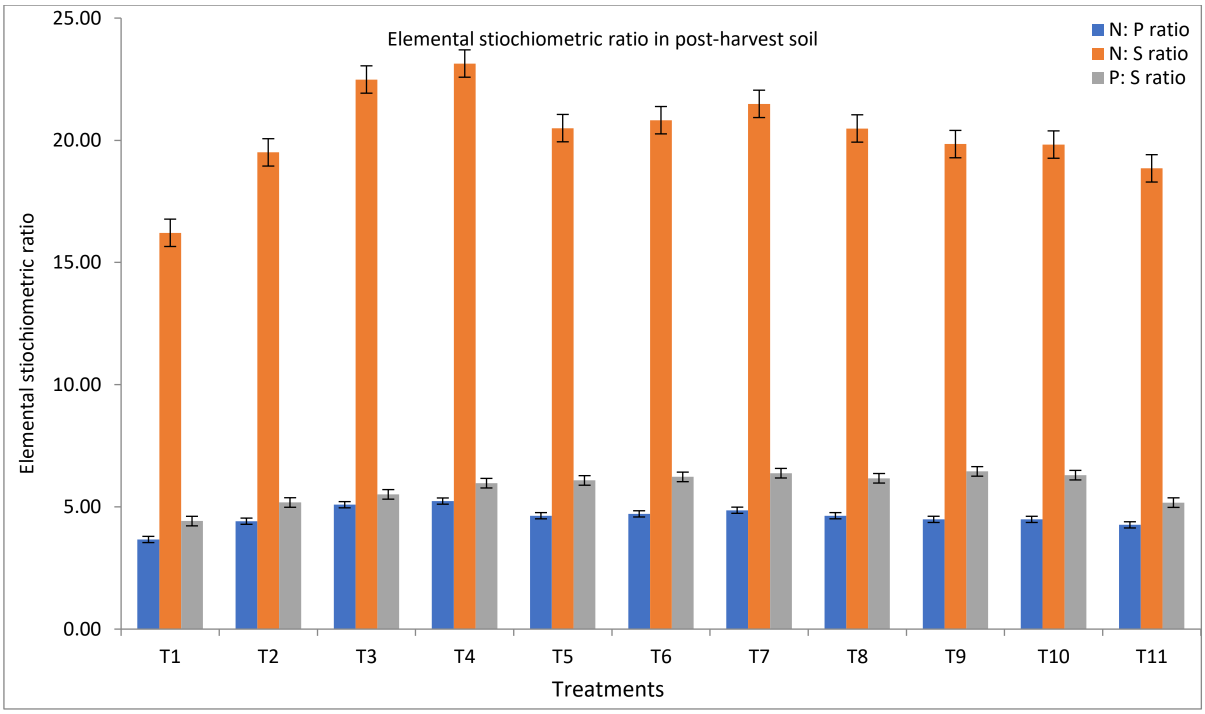

Fig 5 Effect of different treatments on elemental stiochiometric ratio (N: P, N: S and P: S) in post-harvest soil

Elemental stiochiometric ratio of N, P and S in post-harvest soil

Organic manures are known to have significant store house of nitrogen, phosphorus and sulphur. The elemental stiochiometric ratios of available nitrogen, phosphorus and sulphur were calculated in post-harvest soil to predict the buildup of organic matter and nutrient cycling efficiency. The obtained results from application of organic manures (FYM/VC) revealed that significantly highest N: P (5.24) and N: S (23.14) ratio were found with application of FYM @ 13.5 g kg^{-1} soil (T_4) showing appreciable amount of mineralizable N in soil. The P: S ratio was found to be affected greatly by application of rock-phosphate enriched VC alone or in combination with chemical fertilizers (Table 6 and Figure 5). It was noted that VC application in combination with chemical fertilizers (T_9) had significantly improved P: S ratio (6.45) in soil. The lowest value for all the ratios were observed in control (T_1).

The increased effect of FYM/VC on growth indices of tomato plant might be due to release of macro and micronutrients from organic manures decomposition in synchronisation with the crop nutrients demand, while application of chemical fertilizers provides macro nutrients (N, P and K) maximum during initial crop growth stages. Organic manures help to supply balanced nutrition at all the stages of crop growth, particularly both the vegetative and reproductive stages. The overall performance of enhanced vegetative growth as determined by plant height and dry matter production rate (absolute growth rate), crop growth rate and relative growth rate leads to enhanced fruit yield. The growth and yield potential depends mainly on plant physiological process efficiency, which is controlled by genetic make-up as well as environmental factors. The crop nutrient elements are considered one of the important environmental factors that control metabolic functions of plants and plant can't complete life cycle without it [17]. The application of organic manures not only provides balanced nutrition, but helped to improves soil physical, chemical and biological condition that facilitate better absorption of nutrients by plant roots and thus enhanced dry matter production per plant per unit time. The improvements in fruit yields with organic amendments in soil might be partially due to enhanced enzymatic activities after organic matter application causing production of humate compounds in the composts that acts as plant growth regulators [5]. Isah *et al.* [18] also reported increment in plant height, enhanced crop growth rate, relative growth rate, absolute growth rate and yield in tomato plant with application of organics over NPK fertilization.

The application of organic manures is known to impact soil properties in all possible ways. The continuous cropping system and long-term application of chemical fertilizers not only destroy soil organic matter, but affect soil pH as well [19]. The organic manures contain sufficient basic cations and carbonate ions to neutralize the acidification caused by synthetic fertilizers. However, long-term application of organic manure is recommended to bring change in soil pH [20]. Soil organic matter is indicative of nutrient storing capacity and cycling of nutrients. The decrease in N: P ratio is indication of increased P concentration in soil as compared to nitrogen. FYM treatments showed high N: P ratio indicating high mineralizable N in post-harvest soil, while decline in ratio in VC applied soil indicated high P content of organic manure. N: S and P: S ratios were observed higher value with FYM/VC treatments over other treatments, indicating lower availability of S in soil. The total P and S might show increased values in soil due to higher P and S content in manure, but is less available in soil solution owing to lesser mobility than nitrogen that can be mineralized easily. Zhang *et al.* [21] similarly verified that soil C, N, P and S increased significantly with application of manure and showed high N: P, N: S and P: S ratio in post-harvest soil and the change in nutrient availability was attributed to soil organic carbon balance facilitated by organic manure application.

CONCLUSION

The application of organics mainly nutrient enriched vermicompost was found highly beneficial in not only plant growth and development, but helped to provide yield at par with recommended dose of fertilizers with additional benefit on soil organic matter and nutrient availability. The elemental stiochiometric ratio helped to predict the comparative availability of nutrients in soil and nutrient cycling process involving organic matter. The low N: P and high N: S and P: S ratio with enriched VC application in graded doses @ 10, 20 and 30 tons/ha, had verified the increased P content in VC and plant availability of P besides the N which is more mobile than P. It also reflects better availability of nutrients from decomposition of organic manures that was reflected in better growth indices of organically grown tomato plants.

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