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Influence of integrated nutrient management on yield and uptake of tomato (*solanum lycopersicum* l.) and availability of nutrients in soil under mid hill conditions of Himachal Pradesh

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Abstract
A field experiment was conducted during 2014-15 and 2015-16 at the experimental farm of Department of Soil Science and Water Management, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan. The experiment was laid out in Randomized Block Design with nine treatments and three replications. Among different INM treatments, 80% NPKM + 20% N through FYM and VC (50:50) + PGPR had significantly the highest uptake of N (97.81 kg/ha), P (25.08 kg/ha), K (55.94 kg/ha). Fruit yield (606.51 q/ha) of tomato were also highest in 80% NPKM + 20% N through FYM and VC (50:50) + PGPR whereas, interaction effect between treatment and year (T×Y) revealed a non significant effect, while treatment (T) recorded significant effect under tomato crop. The highest available N (404.50 kg/ha) P (91.07 kg/ha) K (285.38 kg/ha) was observed under 130% NPKM (50:50 of FYM and VC as per N content).

Keywords: Integrated nutrient management, Nutrient uptake, available nutrients, yield of tomato

Introduction
Tomato (*Solanum lycopersicum* L.) is one of the most important and widely consumed vegetable crop, belonging to family Solanaceae. It is also one of the most popular vegetable in India and is grown in tropical, subtropical and mild cold climatic regions on an area of 905 thousand hectare with annual production of 19104 thousand metric tones. In Himachal Pradesh, it occupies an area of 9.93 thousand hectare with annual production of 413.71 thousand metric tones. India is principal tomato growing country and comes second for its production after China (NHB, 2013) [8]. Integrated nutrient management (INM) is an approach to soil fertility management that combines organic and mineral methods of soil fertilization with physical and biological measures for soil and water conservation. Chemical fertilizers alone application, supply only one or two nutrient element to the crop. Moreover, the ever increasing prices of these fertilizers have discouraged the poor hill farmers to invest on these costly inputs. The integrated use of chemical fertilizers, FYM and vermicompost and other organics hold great promise in securing high level of crop productivity and also to protect soil health from deterioration and pollution hazards. The complementary use of chemical fertilizers, organic manures and vermicompost is important to maintain and sustain a higher level of soil fertility and crop productivity. The continuous use of high level of chemical fertilizers leads to decrease the nutrient uptake of plants, resulting in either stagnation or decrease in yield and also causing environmental pollution. The continuous use of chemical fertilizers increase the concentration of heavy metals in the soil, disturb soil health and quality which can't support plant growth in long term basis. Organic manures in proper blend with chemical fertilizers will predictably support crop growth (Kumar *et al.* 2009) [3]. Nutrient and soil health management should be sound to sustain as well as to increase the productivity of crops. Among all the strategies of sustainable crop production, integrated nutrient management plays an important role through minimizing the chemical fertilizers and integrated with organic manure without affecting the soil quality and fertility (Singh and Sinsinwar, 2006) [15].

Material and Methods
A field experiment was conducted during 2014-15 and 2015-16 at the experimental farm of Department of Soil Science and Water Management, Dr. Y.S. Parmar University of

Horticulture and Forestry, Nauni- Solan, H.P.). It is located at 30° 52' N latitude and 77° 11' E longitude and elevation of 1175 m above mean sea level having average slope of 7-8 percent. The experimental soil having pH (6.67), EC (0.38 dS m^{-1}), Organic Carbon (10.98 g kg^{-1}). With regard to soil fertility status Available N (351.78 kg ha^{-1}), Available P (56.89 kg ha^{-1}) and Available K 257.69 (kg ha^{-1}). The experiment was laid out in Randomized Block Design with nine treatments and three replications viz. T_1-Absolute control, T_2- 70% NPKM + 30% N through FYM and VC (50:50), T_3 -80% NPKM + 20% N through FYM and VC (50:50), T_4 -90% NPKM +10% N through FYM and VC (50:50), T_5- 100% NPK + 100% FYM, T_6 -100% NPK +100% VC (equivalent to FYM as per N content), T_7 -110% NPKM (50:50 of FYM and VC as per N content), T_8 -120% NPKM (50:50 of FYM and VC as per N content) and T_9 - 130% NPKM (50:50 of FYM and VC as per N content). The recommended dose (100% RDN) of inorganic fertilizer was 400 kg ha^{-1} N, 475 kg ha^{-1} P_2O_5 and 90 kg ha^{-1} K_2O to the tomato crop. In these treatments NPK was applied uniformly N applied according to the treatments. The two organic sources used for the study viz. FYM and vermicompost, respectively. Tomato variety used was Solan Lalima were sown in well prepared raised nursery beds two month before transplanting with the spacing of 90x30 cm. The full dose of FYM, Vermicompost, P, K fertilizers and 1/3 dose of N were applied at the time of field preparation as a basal dose. The rest of 1/3 dose of N was applied after one month of transplanting and the remaining N was applied after two month of transplanting. Vermiwash (1:8), and Biopesticides were used in experiment at 10 days interval during experiment for proper management of crop.

Result and Discussion

Effect of INM on Nitrogen uptake

The N uptake varied from treatment to treatment. At harvest stage, the lowest and highest N uptake values were recorded in T_1 (control) and T_3 80% NPKM + 20% N through FYM and VC (50:50) + PGPR, respectively. However T_9 was on par with T_8 and T_7, treatments indicating the importance of integrated use of organic and inorganic fertilizers in nutrient uptake.

Effect of INM on Phosphorous uptake

The phosphorous uptake by tomato plants also showed similar trends as that of N uptake at different harvest, the lowest and highest P uptake values were recorded in T_1 (control) and T_3 80% NPKM + 20% N through FYM and VC (50:50) + PGPR, respectively. However T_9 was on par with T_8 and T_7, treatments indicating the importance of integrated use of organic and inorganic fertilizers in nutrient uptake.

Effect of INM on Potassium uptake

With regard to K uptake by tomato, the values varied from treatment to treatment. At harvest stage, the lowest and highest K uptake values were recorded in T_1 (control) and T_3 80% NPKM + 20% N through FYM and VC (50:50) + PGPR, respectively. However T_9, T_8 and T_7, treatments was on par with each other and significantly different from all other treatments. The data on nutrient uptake was presented in Table 1.

The total NPK uptake by tomato crop at harvest stage was found highest in T_3 -80% NPKM + 20% N through FYM and VC (50:50) + PGPR, treatment 125.85, 13.15 and 84.26 kg/ha, respectively. These uptake values on at par with those records at T_9, T_8 and T_7.

The higher uptake of nutrients recorded under T_3 treatment might be due to presence of several enzymes and hormones present in vermicompost were responsible for stimulating the growth and development of plants, through their favorable effect in the root zone which might have resulted in increase availability and uptake of nutrients by the plants. The result further support the hypothesis that the organic manure in the root rhizosphere release a number of enzymes which enhances the transformations and release of nutrients and increase the nutrient uptake. The results are in agreement with the findings of Reddy 2008 [10], Chaitanya *et al.* (2013) [2] and Sepehya *et al.* (2012) [11] who also reported increased uptake of nutrients in tomato crop.

Effect of INM on Fruit Yield

The total fruit yield of tomato recorded at different pickings are presented in Table 2. The yield of tomato varied from (606.51) to (378.69). The lowest and highest yields were recorded in control (T_1) and T_3 80% NPKM + 20% N through FYM and VC (50:50) + PGPR, respectively. However, the fruit yield recorded at 80% NPKM + 20% N through FYM and VC (50:50) + PGPR, was at par with that recorded at 130% NPKM (50:50 of FYM and VC as per N content) (606.51 q ha-1) and 120% NPKM (50:50 of FYM and VC as per N content) (584.14 q ha^{-1}) and significantly superior over all other treatments. Conjunctive use of different levels of chemical fertilizers with any one of the organics produced higher yields. This was due to the application of NPK with FYM and vermicompost leading to increased uptake of NPK and direct availability of nutrients from inorganic fertilizers and higher available NPK contents in vermicompost. The enrichment of biological activity and release of organic acids might have degraed and mobilized the occluded soil nutrients to available form and the increased microbial activity in vermicompost stimulated the growth and yield in tomato Suthar (2009) [16], Chaitanya *et al.* (2013) [2], Shukla *et al.* (2009) [13] and Bhardwaj *et al.* (2010) [1].

Available nutrient status of the soil

The data pertaining to nitrogen, phoshphorus and potassium contents in soil at harvest of tomato are presented in Table 3.

Effect of INM on Available nitrogen

The perusal of data in Table 3 indicate a declining trend from its intial level of available nitrogen status, which indicates decline in available N after two years of cropping. The maximum decline was in control, and the magnitude of decline decreased with increasing level of NPK application. However, there was a significant build-up of available N in soil receiving 130% NPKM (50:50 of FYM and VC as per N content) as compare to rest of the treatments. The increase in available N occurs due to the enhanced multiplications of microbes by incorporation of crop residues which catalyze the conversion of organically bound N to inorganic form. Favorable soil conditions under crop residues might have helped in the mineralization of soil N leading to the build-up of higher available nitrogen. Studies of Kumar and Prasad (2008) [5], Prasad *et al.* (2010), Kumar and Singh (2010) [6] and Singh 2014 [14].

Effect of INM on Available phosphorus

With regard to phosphorus highest available phosphorus

(91.07 kg/ha) was recorded in T_3 80% NPKM + 20% N through FYM and VC (50:50) + PGPR treatment at harvest stage of the crop, respectively and the value were at par with T_8 and T_2 and it was significantly different from all other treatment and lowest were recorded in T_1 (42.00 kg/ha) (Absolute control). Higher soil P may be due to lower utilization of P by the crop from applied sources, which resulted in building up of higher soil P status Usha rani *et al.* 2002. The increase in available P might have resulted by the solubilization of insoluble P due to application of PGPR isolates having very high P solubilization efficiency. The release of various organic acids might have solubilized insoluble P fractions and thus resulting into a significant increased content of available P in the soil. These results are also in consonance with those of Sharma *et al.* 2000 [12]; Kumar and Singh 2010 [7]; Prasad *et al.* 2010.

Effect of INM on Available potassium

With regard to phosphorus highest available phosphorus (285.38 kg/ha) was recorded in T_3 80% NPKM + 20% N through FYM and VC (50:50) + PGPR treatment at harvest stage of the crop, respectively and the value were at par with T_8 and T_2 and it was significantly different from all other treatment and lowest were recorded in T_1 (222.58 kg/ha) (Absolute control). Significantly higher K under T_9 treatment could be attributed to the solubilization action of certain organic acids produced during decomposition and greater capacity to hold K in the available form. The potash build up in soil increased due to addition of inorganic, organic manures and biofertlizers. These results are also in consonance with those of Kumar 2007 [4]; Singh *et al.* 2006 [15] and Bhardwaj *et al.* 2010 [1]. It may be concluded from the present study that application of 80% NPKM + 20% N through FYM and VC (50:50) + PGPR and 130% NPKM (50:50 of FYM and VC as per N content) not increase the yield of tomato but also improved the soil fertility as compare to other treatments. Thus optimal conjunction with organic manures can play a vital role in exploiting high yield potentials of tomato through its favourable effect on nutrient supply and soil properties.

Table 1: Effect of INM on nitrogen, phosphorus and potassium uptake of tomato (pooled data of two years)

Treatments	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
T_1: Absolute control	51.83	14.91	35.31
T_2: 70% NPKM + 30% N through FYM and VC (50:50)	74.20	19.03	50.54
T_3: 80% NPKM + 20% N through FYM and VC (50:50)	97.81	25.08	55.94
T_4: 90% NPKM +10% N through FYM and VC (50:50)	81.85	19.56	50.85
T_5:100% NPK + 100% FYM	68.50	15.85	46.98
T_6:100% NPK +100% VC (equivalent to FYM as per N content)	69.81	17.16	48.67
T_7:110% NPKM (50:50 of FYM and VC as per N content)	91.19	21.01	51.60
T_8:120% NPKM (50:50 of FYM and VC as per N content)	93.12	20.67	51.83
T_9:130% NPKM (50:50 of FYM and VC as per N content)	95.65	23.57	53.20
CD (0.05)	5.24	2.44	1.08

Table 2: Effect of INM on fruit yield of Tomato (pooled of two years)

Treatments	Yield (q/ha)
T_1: Absolute control	378.69
T_2: 70% NPKM + 30% N through FYM and VC (50:50)	544.85
T_3: 80% NPKM + 20% N through FYM and VC (50:50)	606.51
T_4: 90% NPKM +10% N through FYM and VC (50:50)	512.90
T_5:100% NPK + 100% FYM	467.98
T_6:100% NPK +100% VC (equivalent to FYM as per N content)	486.33
T_7:110% NPKM (50:50 of FYM and VC as per N content)	499.99
T_8:120% NPKM (50:50 of FYM and VC as per N content)	584.14
T_9:130% NPKM (50:50 of FYM and VC as per N content)	596.78
CD (0.05)	19.11

Table 3: Effect of INM on available nitrogen (two years pooled data)

Treatments	N (kg/ha)
T_1: Absolute control	312.30
T_2: 70% NPKM + 30% N through FYM and VC (50:50)	377.31
T_3: 80% NPKM + 20% N through FYM and VC (50:50)	398.69
T_4: 90% NPKM +10% N through FYM and VC (50:50)	384.77
T_5:100% NPK + 100% FYM	360.15
T_6:100% NPK +100% VC (equivalent to FYM as per N content)	368.13
T_7:110% NPKM (50:50 of FYM and VC as per N content)	390.85
T_8:120% NPKM (50:50 of FYM and VC as per N content)	402.44
T_9:130% NPKM (50:50 of FYM and VC as per N content)	404.50
CD (0.05)	10.31

Table 4: Effect of INM on available P

Treatments	P (kg/ha)
T_1: Absolute control	42.00
T_2: 70% NPKM + 30% N through FYM and VC (50:50)	60.57
T_3: 80% NPKM + 20% N through FYM and VC (50:50)	84.09
T_4: 90% NPKM +10% N through FYM and VC (50:50)	66.65
T_5:100% NPK + 100% FYM	53.68
T_6:100% NPK +100% VC (equivalent to FYM as per N content)	59.09
T_7:110% NPKM (50:50 of FYM and VC as per N content)	83.30
T_8:120% NPKM (50:50 of FYM and VC as per N content)	88.15
T_9:130% NPKM (50:50 of FYM and VC as per N content)	91.07
CD (0.05)	4.13

Table 5: Effect of INM on available K

Treatments	K (kg/ha)
T_1: Absolute control	222.58
T_2: 70% NPKM + 30% N through FYM and VC (50:50)	275.32
T_3: 80% NPKM + 20% N through FYM and VC (50:50)	281.81
T_4: 90% NPKM +10% N through FYM and VC (50:50)	277.37
T_5:100% NPK + 100% FYM	269.89
T_6:100% NPK +100% VC (equivalent to FYM as per N content)	272.19
T_7:110% NPKM (50:50 of FYM and VC as per N content)	281.32
T_8:120% NPKM (50:50 of FYM and VC as per N content)	282.92
T_9:130% NPKM (50:50 of FYM and VC as per N content)	285.38
CD (0.05)	3.42

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