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Optimizing Nutrients Ratio for Enhancing the Tomato Productivity under Drip Fertigation

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ABSTRACT: The injudicious use of water and nutrients for crop production has emerged as a vital issue due to low fertilizer use efficiency and high cost besides having significant environmental contamination. Hence, the optimization of nutrients ratio for improving the productivity of Tomato Hybrid CO-3 through fertigation was investigated at TNAU, Coimbatore in a Completely Randomized Design with nine treatments each replicated thrice. Fertigation with 2:1:1 NPK @ 100% RDN resulted in minimum days to 50% flowering (66.4 days). Fertigation with 1:1:1 NPK @ 100% RDN with Ca and B significantly increased the total number of flowers per plant (108), total number of fruits per plant (51), yield per plant (2kg), fruit girth (15.57 cm), fruit length (7.37 cm), fruit weight (42.23 g) and fruit volume (45.4 cm^3). Fertigation with 1:1:1 NPK @ 100% RDN with Ca and B recorded maximum uptake of N, P and K and fruit yield. This study revealed that the application of recommended dose of nitrogen, phosphorus and potassium @ 1:1:1 ratio together with calcium and boron through drip fertigation has maximized the yield in tomato over the conventional method of fertilization.

Keywords*:* Fertigation, Nutrient Ratio, Tomato, Water Soluble Fertilizer.

INTRODUCTION

Fertilizers are the crucial and significant source of nutrition for increasing the production and productivity of crops in an intensive agriculture system. The balanced application of nutrients to crops helps to enhance its yield and quality. In the long run, balanced application of nutrients helps to ward off the nutrients leach from soil which may otherwise eventually cause contamination of water bodies. Balanced nutrition is hence inevitable requisite since otherwise excess and improper fertilization disturbs the ecological balance and agricultural sustainability. The continuous cultivation of crops on the same land, mismanagement of water and nutrients largely contributes to low productivity. The nutrients supplied through conventional fertilizers are not often fully accessible to plants and their inversion to sparingly soluble forms in the soil leads to very low utilization of most of the added macronutrients (Kumar *et al*., 2021). To overcome these issues drip fertigation is recommended which helps to supply the nutrients at the required rate to meet the crop demand during crop growth stages besides reducing the excess or imbalanced fertilization to the crops especially high-value perishable vegetables and fruits. According to Sivakumar and Vasuki, (2019), Anjos *et al*., (2015); Oliveira *et al*., (2013) drip fertigation is a relatively new concept and state of the art technology that has revolutionized crop production in the 21st century by applying fertilizer through irrigation which helps to achieve both fertilizer-use efficiency and water-use efficiency through improvement in crop yield per unit volume of water and nutrients used.

Among the vegetables, tomato (*Solanum lycopersicum* L.) synonymically known as *Lycopersicon esculentum* Mill) is the second most important crop next to potato for its fleshy fruit which is a rich source of vitamin A and C, minerals like iron, phosphorus and is known as a protective food since rich in anti-oxidants. India is the world's second-biggest giant in the production of tomatoes with a production of 2,11,95,000 tonnes from 8,13,000 hectares in 2020 (Pocket book of Agricultural Statistics 2020). Even though the area and production of tomatoes in India has witnessed a hike in the past decade due to increasing demand for tomatoes and tomato-based products, the increase in productivity of tomato from 18 tonnes ha^{-1} during 2007-08 to 24 tonnes ha^{-1} during 2016-17, is much lower than that of major tomato growing countries such as USA (88.85 tonnes ha^{-1}), China (52.63 tonnes ha^{-1}), and even the world average of 33.99 tonnes ha^{-1} (Madhumurthy and Sundaramoorthy, 2018).

Tomato responds well to additional fertilizer application and it is reported to be a heavy feeder of NPK (Hebbar *et al*., 2004). To reach the potential production, judicious and balanced application of fertilizer including macro, secondary and micronutrients is essential. Also, the phosphorus requirement in tomatoes is more when compared to other crops. Thus the enhanced yield of tomatoes demands supplementary addition of N, P, K, Ca and B to the soil. However, Gupta *et al*., (2015) reported that though the tomato crop is highly responsive to fertilizers, applications of excessive rates affects the quality and also reduce the fertilizer use efficiency. Therefore, the ratios at which the nutrients are supplied needs to be optimized since the over and underuse of fertilizers pose a problem to the soil health and crop productivity. This could be easily achieved through fertigation by which fertilizer is applied directly to the plant root through irrigation. Besides being superior to the traditional methods, fertigation gives the flexibility of nutrients supply precisely according to the plant's requirements, thereby ensuring the adequate application and uptake of nutrients at each growth stage. This also improves the fertilizer use efficiency, reduces the leaching losses and minimizes environmental contamination (Jha *et al*., 2015). Supply of nutrients through drip fertigation would also saves 30% of the fertilizer inputs (Sivanappan and Ranghaswami, 2005).

Generally, tomato plants need nutrients even up to fruit ripening, hence before split application of fertilizers, preferred at each critical stage of growth *viz*., vegetative, flowering, fruiting and harvest. The study conducted by Spehia, (2021) in capsicum revealed that growth stage-wise fertigation has a direct impact on the nutrient uptake as compared to soil fertilization or fertigation with single water soluble fertilizer and found that the stage-wise fertigation increased the fruit yield of capsicum significantly over the soil application. Hence the supply of nutrients at optimum ratio through fertigation using water soluble fertilizers (WSF) can promote nutrient use efficiency and crop productivity eventually resulting in enhanced growth and yield. With this background, the present experiment was conducted to study the influence of different ratio of nutrients supplied through fertigationon the growth, nutrients uptake and yield of TNAU Tomato Hybrid CO-3 and optimizing the ratio for higher productivity.

MATERIALS AND METHODS

Location and Experiment Details. A pot experiment was conducted during 2020-21 at the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agriculture University (TNAU), Coimbatore. The experimental location is geographically situated at 11°N latitude, 76°E longitude and an altitude of 426.7m above the mean sea level. The experiment was laid out in a Completely Randomized Design in 54 pots, each filled with 12 kg soil and kept open. The experimental soil collected from the Horticulture Orchard of TNAU, Coimbatore had a silty clay loam texture with a bulk density of 1.90 Mg m^{-3}, soil reaction (pH) 8.54 (strongly alkaline), electrical conductivity (EC) 0. 49 dSm^{-1}, (medium salinity according to USSL), organic Carbon 1.68% (high), Available alkaline potassium permanganate Nitrogen, Olsen Phosphorus, Ammonium acetate Potassium, exchangeable Calcium and available Boron (Hot water) of 327 (medium), 31.7 (high), 273 (medium) kg ha^{-1}, 6.4 ppm (medium) and 0.48 ppm (medium) respectively.

The semi-determinate TNAU Tomato Hybrid CO-3 was used in the study as the test crop owing to its wide acceptance in the region and moderate resistance to leaf curl virusand root-knot nematode. The seedlings for transplanting were raised in the shade house at the Horticulture Orchard, TNAU, Coimbatore. One-month-old tomato seedlings were transplanted to the pots after treating with Carbendazim.

The pot experiment comprised of nine treatments imposed in three replications. One treatment was kept as control with application of the recommended dose of fertilizers (RDF) (200:250:250 NPK kg ha^{-1}) (CPG, TNAU 2020), another treatment as absolute control without the addition of fertilizers and others with seven different combinations of WSF. WSF used as the source of nitrogen were Urea, Mono Ammonium Phosphate (MAP), Calcium Nitrate and 19:19:19. Phosphorus sources were Single Super Phosphate (SSP), MAP and 19:19:19. Potassium was supplied through Muriate of Potash (MOP) and 19:19:19. Calcium and boron sources were Calcium Nitrate and Borax respectively. The treatments imposed were T_1- NPK Solid Fertilizers @ 200:250:250 kg ha^{-1} (100% RDF) through urea, SSP and MOP respectively, T_2- 1:1:1 NPK Fertigation @ 100% RDN + Basal P (Solid) @ 75% RDF through 19:19:19 and SSP respectively, T_3- 1:1:1 NPK Fertigation @ 100% RDN through 19:19:19 alone, T4- 1:2:1 NPK Fertigation @ 100% RDN through urea, MAP and MOP, T_5- 2:1:1 NPK Fertigation @ 100% RDN through 19:19:19 and urea, T_6- 1:1:1 NPK Fertigation @ 100% RDN + Ca through 19:19:19, urea and calcium nitrate, T_7- 1:1:1 NPK Fertigation @ 100% RDN + B through 19:19:19 and borax, T_8- 1:1:1 NPK Fertigation @ 100% RDN + Ca + B through 19:19:19, calcium nitrate and borax, and T_9- Absolute Control. The amount of fertilizer to be applied to each pot at each stage of the plant growth was calculated according to the TNAU CPG for Horticulture (2020), with emphasis on the recommended dose of nitrogen (RDN). The P @ 75% RDF was supplied as basal dose in all the treatments except T_3 and T_9. T1 was supplied with solid fertilizers in the conventional method and T_2 to T_8 were fertigated four times with the WSF at 5, 15, 45, and 75 days after transplanting according to TNAU CPG (2020) so that the sampling coincides with the critical stages of tomato plant growth thus allowing the plant to utilize the supplied nutrient (Table 1).

Table 1: Total amount of nutrients supplied at critical growth stages based on TNAU CPG (2020).

Treatment	Total amount of nutrients supplied per pot at critical growth stages				
	N(g)	P_2O_5(g)	K_2O (g)	Ca(mg)	B(mg)
Solid Fertilizers @ 100% RDF	2.31	8.30	2.21	-	-
1:1:1 NPK Fertigation @ 100% RDN + Basal P (Solid) (75% RDF)	5.59	11.8	5.59	-	-
1:1:1 NPK Fertigation @ 100% RDN	5.59	5.59	5.59	-	-
1:2:1 NPK Fertigation @ 100% RDN	2.15	7.31	2.14	-	-
2:1:1 NPK Fertigation @ 100% RDN	5.64	7.97	1.75	-	-
1:1:1 NPK Fertigation @100% RDN+Ca	3.92	9.01	2.79	0.58	-
1:1:1 NPK Fertigation @ 100% RDN+B	5.59	11.8	5.59	-	0.38
1:1:1NPKFertigation@100%RDN+Ca+B	5.59	11.8	5.59	0.58	0.38
Absolute Control	-	-	-	-	-

Observations and Analysis. The observations for the study concerning the yield were taken from the plants in pots at the fruiting and harvesting stages. Observations made were on the number of days taken for 50% flowering, the total number of flowers per plant, number of days taken for first fruit set, fruit weight (g), fruit length (cm), fruit girth (cm), fruit volume (cm^3), number of fruits per plant and fruit yield per plant (kg).

Destructive sampling was done for plant tissue analysis. Tomato plants were uprooted at vegetative, flowering, fruiting and harvest stages for estimating the plant nutrient contents. The oven-dried and powdered plant and fruit samples were analyzed for total N (Humphries, 1956), total P and K (Jackson, 1973). The total N, P and K uptake for different treatments were worked out by taking into account the dry matter yield and N, P and K content in tomato plants and fruit.

Statistical Analysis. Statistical analyses of the data were carried out according to Completely Randomized Design. All the parameters were subjected to analysis of variance (ANOVA) as proposed by Gomez and Gomez (1984). Fisher's Least Significant Difference (LSD) was used to test the significant differences between the means, at probability level P=0.05 using the ANOVA and considered statistically significant at 95% confidence. The correlation and regression analyses were worked out in Microsoft Excel 2010.

RESULTS AND DISCUSSION

Yield Attributes. The tomato plants that received 1:2:1 NPK Fertigation @ 100% RDN (T_4) attained 50% flowering at the earliest (Table 3). This was followed by 1:1:1 NPK Fertigation @100% RDN+ Ca+ B (T_8), 1:1:1 NPK Fertigation @100% RDN+ Ca (T_6) and 1:1:1 NPK Fertigation @100% RDN+ B (T_7) which were comparable. Plants in the absolute control took the maximum days for attaining 50% flowering.

The availability and better uptake of nutrients, especially phosphorus which is extremely important at the beginning of the reproduction cycle when the buds are formed, through fertigation might have helped the transport of flowering hormones and metabolites towards the sink developed (flower buds). Phosphorus starvation resulted in a significant decrease in flower number in tomatoes (Menary and Staden, 1976).

Though 50% flowering was earliest in 1:2:1 NPK Fertigation @ 100% RDN ratio, the maximum number of flowers bloomed was significantly higher in the nutrient ratio of 1:1:1 NPK Fertigation @100% RDN+ Ca+ B (T_8) followed by 1:1:1 NPK Fertigation @100% RDN+ Ca (T_6) (Table 3). The higher number of flowers could be due to sufficient levels of carbohydrates available for flower formation and fruit set in tomatoes whose metabolism is regulated by Boron (Smit and Combrink 2005). Similarly, the total number of fruits per plant was significantly different among the various ratio of nutrients and highest under treatment which received 1:1:1 NPK @ 100 % RDN + Ca + B (T_8) through fertigation followed by treatments which received 1:1:1 NPK @ 100 % RDN + Ca (T_6) and 1:2:1 NPK @ 100% RDN (T_4) through fertigation (Table 3). The higher number of fruits might be due to the positive interaction between N, P, K, Ca and B that are essential for flowering and fruit set, applied through fertigation which enhances the availability, acquisition, mobilization and influx of nutrients into the plant tissues. Rab and Haq (2012) reported maximum number of tomato fruits per plant (96.37) due to foliar application of $CaCl_2$ (0.6%) and borax (0.2%). The addition of B improves pollen grain germination and pollen-tube elongation, consequently leading to higher fruit-set by delaying abscission of flowers, regulating water absorption and carbohydrate metabolism and, finally the yield (Smit and Combrink, 2005; Abd-Allah, 2006; Haque *et al.*, 2011). Application of neither Ca nor B alone with NPK could make a significant hike in the numbers as expected indicating that both Ca and B are required for decreasing the abscission of flowers and fruits and showed its importance in increasing tomato productivity.

Fruit Characteristics. Drip fertigated plants took a lesser number of days than the conventionally treated ones to set the fruit and ripe as well. Plants treated with 1:1:1 NPK @ 100% RDN + Ca (T_6) and 1:1:1 NPK @100 % RDN + Ca + B (T_8) through fertigation took the minimum number of days to set the fruits (Table 3). Yellow coloured fruits of plants imposed with 1:1:1 NPK Fertigation @ 100% RDN + Ca (T_6), as well as 1:1:1 NPK Fertigation @100 % RDN + Ca + B (T_8), took three days to ripe completely while all other treatments took longer time with the maximum number of days in the absolute control. All these can be attributed to the positive interactions between N, P, K, Ca and B supplied to the plant and its enhanced uptake due to fertigation. The addition of Ca and B has hastened the fruit set and ripening which confirms the role of Ca and B on regulating flowering and fruiting in tomatoes.

The fertigation treatment of 1:1:1 NPK @ 100 % RDN + Ca + B (T_8) very significantly influenced the fruit characters and resulted in the maximum weight**,** length, girth and volume of the harvested fruits when compared to those of the other treatments (Table 2). This treatment was followed by 1:1:1 NPK Fertigation @ 100% RDN + Ca (T_6) for all these fruit characters. An increase in these characters might be due to the increased allocation of photosynthates and its better utilization towards the development and production of economic parts. The balanced and optimum supply of all nutrients in the treatment 1:1:1 NPK @ 100 % RDN + Ca + B ensures the production and utilization of carbohydrates by supplying the required quantity of nitrogen, P and K which has a positive effect on fruit weight gaining. Further, the supply of Ca ensures the proper metabolism and uptake of nutrients (Kamal, 2000) and the absorption of water and carbohydrate metabolism (Haque *et al.,* 2011). Application of both Ca and B alone without NPK were less effective in increasing fruit characters when compared to their combined application indicating that a critical balance of Ca and B with major nutrients may determine the beneficial effects of these nutrients (Passam *et al.,* 2007; Tariq and Mote, 2007).

Table 2: Effect of different ratios of WSF on the fruit characteristics of TNAU Tomato Hybrid CO-3.

Treatment	Fruit girth (cm)	Fruit length (cm)	Fruit volume (cm^3)	Fruit weight (g)
Solid Fertilizers @ 100% RDF	11.4	5.33	28.8	33.5
1:1:1 NPK Fertigation @ 100% RDN + Basal P (Solid) (75% RDF)	11.9	5.55	33.7	35.6
1:1:1 NPK Fertigation @ 100% RDN	11.9	5.43	30.4	34.3
1:2:1 NPK Fertigation @ 100% RDN	12.6	6.06	28.2	30.7
2:1:1 NPK Fertigation @ 100% RDN	11.4	5.27	25.3	29.8
1:1:1 NPK Fertigation @ 100% RDN + Ca	14.1	6.47	34.5	37.5
1:1:1 NPK Fertigation @ 100% RDN + B	11.8	5.53	26.6	29.2
1:1:1 NPK Fertigation @ 100% RDN + Ca + B	15.6	7.37	45.4	42.2
Absolute Control	9.47	4.23	25.3	28.4
SEd	0.17	0.10	0.70	1.28
CD (P=0.05)	0.35	0.21	1.46	2.70

Tomato Yield. The method of fertilizer application as well as the ratio of nutrients supplied had a major impact on the tomato fruit yield. Application of 1:1:1 NPK @100 % RDN + Ca + B (T_8) through fertigation improved the yield significantly, followed by 1:1:1 NPK @100% RDN + Ca (T_6) through fertigation (Table 3). The yield obtained from the absolute control was found to be the lowest. The correlation analysis of the fruit characters and the number of days to the first fruit set indicated that all those parameters are significantly correlated to the yield (Table 4).

Table 3: Effect of different ratios of WSF on the flower and yield attributes of TNAU Tomato Hybrid CO-3.

Treatment	Number of days to 50% Flowering	Total number of flowers per plant	Number of days to first fruit set from transplanting	Number of days taken for fruit to turn yellow-red	Total number of fruits per plant	Yield per plant (Kg)
Solid Fertilizers @ 100% RDF	75.6	54.0	54.0	4.00	20.0	0.67
1:1:1 NPK Fertigation @ 100% RDN + Basal P (Solid) (75% RDF)	72.2	77.0	52.3	4.33	27.3	0.87
1:1:1 NPK Fertigation @ 100% RDN	74.3	74.7	54.3	4.00	19.0	0.64
1:2:1 NPK Fertigation @ 100% RDN	66.4	95.0	48.0	5.00	35.0	1.20
2:1:1 NPK Fertigation @ 100% RDN	72.9	88.0	56.0	6.33	23.0	0.67
1:1:1 NPK Fertigation @100% RDN+ Ca	69.7	93.0	43.3	3.00	35.0	1.34
1:1:1 NPK Fertigation @ 100% RDN+B	70.7	90.3	55.0	6.00	23.0	0.66
1:1:1NPKFertigation@100%RDN+Ca+B	69.5	108	44.3	3.00	51.0	2.00
Absolute Control	79.5	49.0	57.6	7.00	16.0	0.44
SEd	0.76	0.97	1.67	0.22	0.96	0.02
CD(P=0.05)	1.60	2.04	3.50	0.47	2.00	0.05

Table 4: Correlation of yield with the number of days to first fruit set and fruit characteristics.

	Yield	No. of days to first fruit	Total No. of fruits	Fruit Weight	Fruit Volume	Fruit Length	Fruit Girth
Yield	1						
No. of days to first fruit	-0.95**	1					
Total Number of fruits	0.99**	-0.95	1				
Fruit Weight	0.96**	-0.95	0.97	1			
Fruit Volume	0.99**	-0.92	0.99	0.97	1		
Fruit Length	0.95**	-0.94	0.95	0.94	0.95	1	
Fruit Girth	0.95**	-0.94	0.94	0.94	0.95	0.99	1

**Correlation is significant at the 0.01 level (2-tailed)

The number of fruits, fruit weight, fruit volume, fruit length and fruit girth were positively correlated to the yield, indicating that any increase in them increases the yield also. The number of days to the first fruit set was in negative correlation (r = -0.95**) with the yield which means that as the number of days to the first fruit set increased, yield reduced. The number of fruits, fruit length and fruit girth had respectively highest significant positive correlation with the yield, r = 0.99**, r = 0.95** and r =0.95**, indicating dependency of yield on these characters. The regression analysis of the fruit characters and number of days to first fruit set also strengthens the findings and shows that each of them had a significant impact on the yield (Figs. 1, 2 and 3). The highly significant and positive correlation between the number of fruits, fruit weight, fruit volume, fruit length and fruit girth and yield shows that the results of regression analysis are in harmony with correlation results, while, the number of days to first fruit set showed significant and negative 'b' values suggesting that yield would be decreased with the increase in the number of days to the first fruit set. Hence it is evident that the enhanced availability and uptake of nutrients resulting from the better distribution of nutrients in the root zone due to drip fertigation might have led to better production and assimilation of carbohydrates in the tomato fruit in fertigated treatments. Similar results were also reported by Rab and Haq (2012) obtained maximum fruit yield (21.33 t ha^{1}) of tomatoes due to the combined application of calcium and boron. Significant increase of tomato fruit yield due to fertigation @ 100% NPK water-soluble fertilizers over furrow irrigated control was also reported by Shedeed *et al.*, (2009); Hebbar *et al.*, (2004).

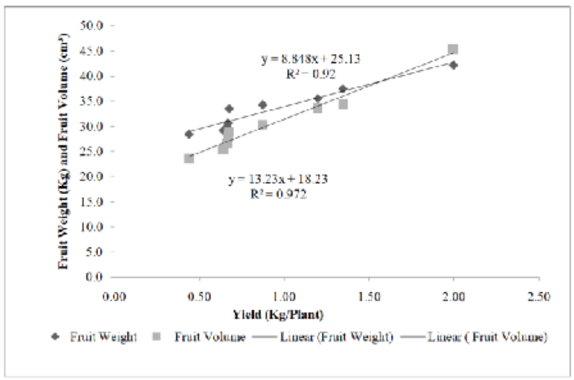

Fig. 1. Regression analysis of yield with fruit weight and fruit volume.

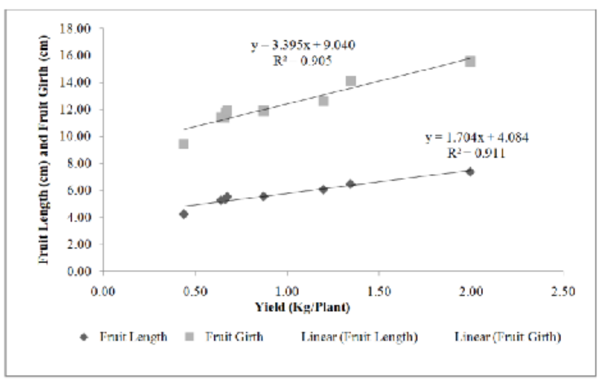

Fig. 2. Regression analysis of yield with fruit length and fruit girth.

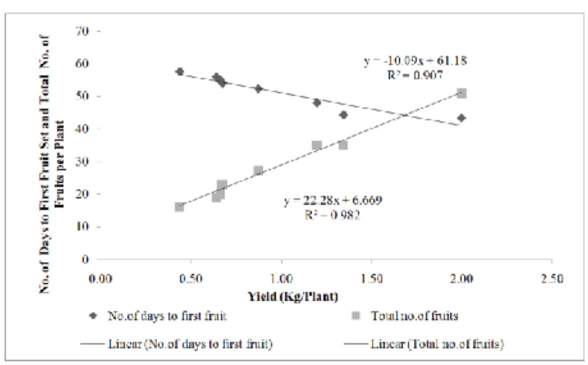

Fig. 3. Regression analysis of yield with number of days to first fruit set and total number of fruits stages.

Nutrient Uptake. The uptake of NPK by tomato was significantly affected by the fertilizer application method as well the nutrient ratios of fertigation (Figs. 4, 5 and 6). Drip fertigated treatments recorded greater NPK uptake over the control treatments. Uptake of NPK was highest under1:1:1 NPK Fertigation @100 % RDN + Ca + B (T_8) at all the stages. The frequent supply of nutrients judiciously through fertigation significantly increased the NPK uptake since nutrients were distributed in the rhizosphere region and the reduction of leaching losses. Regarding individual nutrients, maximum uptake of N occurred in the harvest followed by fruiting. The highest uptake of P was observed during the harvest stage followed by fruiting in all the treatments. The peak of K uptake was also observed during the harvest stage. This increase of NPK uptake during the harvest stage might be due to increased dry matter accumulation during this stage.

During all the critical stages of tomato growth, maximum nutrient taken up by the plant was potassium followed by nitrogen. Phosphorus uptake was the least among N, P and K uptake. This trend was in confirmation of the general uptake trend.

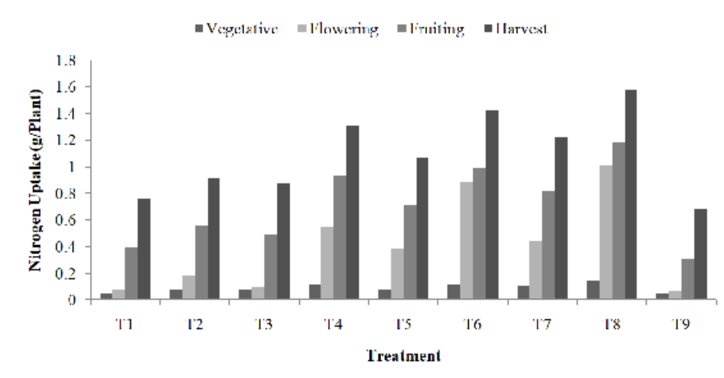

Fig. 4. Effect of different ratios of WSF on the Nitrogen uptake of TNAU Tomato Hybrid CO-3 at critical growth.

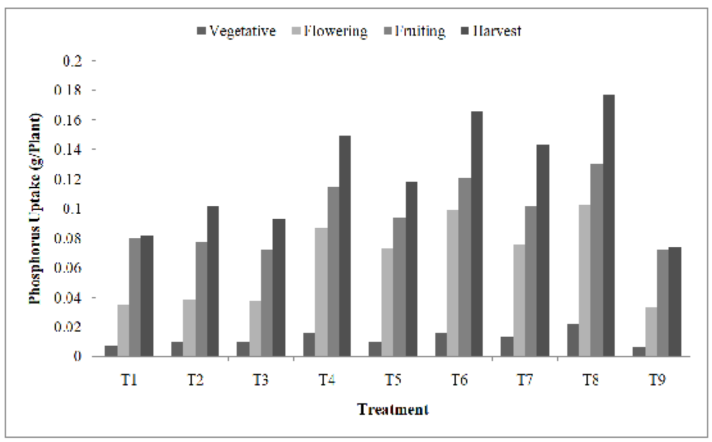

Fig. 5. Effect of different ratios of WSF on the Phosphorus uptake of TNAU Tomato Hybrid CO-3 at critical growth stages.

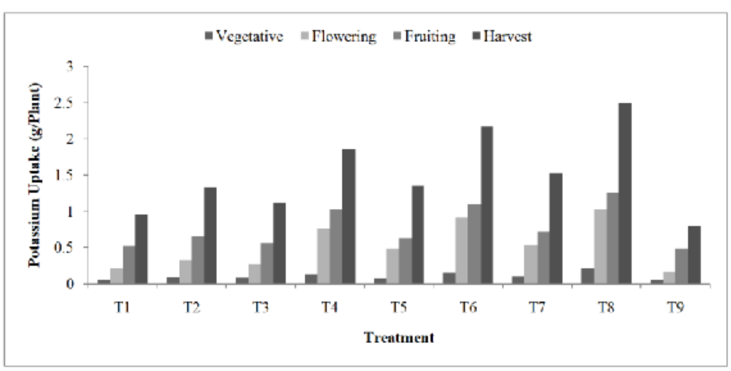

Fig. 6. Effect of different nutrient ratios on Potassium uptake of TNAU Tomato Hybrid CO-3 at critical growth stages.

The results of the present study are in confirmation with the findings of Ankush *et al*., (2017) who reported significantly higher NPK content in tomato plant (1.91 %, 0.43 %, and 1.95 %) and in tomato fruit (2.56 %, 0.63 % and 2.78 %) under 100 % RDF application through fertigation. Hebber *et al*., (2004) also found higher uptake of 165.7 kg N and 113.5 kg K ha^{-1} through drip fertigation with 100% water soluble fertilizers in tomatoes. Shyamaa *et al*., (2009) reported highest uptake of nitrogen (148 ka ha^{-1}) and potassium (97 kg ha^{-1}) as against drip irrigation (103 kg ha^{-1}) and furrow irrigation (76 kg of N ha^{-1} and 46 kg of K ha^{-1}) in tomato due to 100 % NPK fertigation through water soluble fertilizers.

CONCLUSION

The supply of right ratio of required nutrients at right time, in right amount using the right source is the key to produce high yield in crops and this was achieved in the present study through drip fertigation. The drip fertigated treatments headed the control treatments in the study, confirming its effect on the better performance of plant. The optimum ratio of NPK @ 1:1:1 with Ca and B nutrients supplied through drip fertigation resulted in enhanced fruit set, fruit size and uptake of major nutrients at different growth stages of the tomato Hybrid CO-3. The increased yield attributes and enhanced NPK uptake increased the tomato yield to the tune of 4.54 times. Therefore, the application of calcium and boron together with nitrogen, phosphorus and potassium @ 1:1:1 ratio at the right time through fertigation would be the best option for getting higher fruit yield with maximum net returns per unit area. The essentiality of calcium and boron substantiated should be further investigated to deduce the right amount of these nutrients required at each stage.

FUTURE SCOPE

The impact of suggested combination on fertilizer nutrients saving, soil fertility improvement and reduction in nutrient input loss and on soil health must be explored in future.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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