Interaction effect of different sources of nutrients on growth, yield and quality of Tomato (*Solanum lycopersicum* L.)

ABSTRACT

The present field investigation was conductedin the years of 2021& 2022 at HorticulturalFarm, Faculty of Agriculture Science & Technology, Mansarovar Global University, Sehore(Madhya Pradesh). The experiment was carried out to find out the interaction effect of various source of nutrient on growth, yield &quality of tomato, the studycomprised of total 16diverse treatments combinations of inorganic plant nutrients, biofertilizers included control.It is resulted that application of treatment T_8 (*Azotobacter* 1 kg/ha + 120kg N_2 + 60kg P_2O_5) recorded significantly with growth attributes as number of branches plants^{-1}, days to first flowering, days to first picking crop duration, over the control. It has beenresulted that the maximum yield of 409.82q ha^{-1} was recorded in the treatment T_8 followed by treatment T_{12} (*Azospirillum* 1 kg/ha + 120 kg N_2 + 60 kg P_2O_5) and T_{16} total yield of 394.74 q ha^{-1}and 361.91 ha^{-1}. The maximum TSS of 5.45 °brix was recorded in the treatment T_{12} (*Azospirillum* 1 kg/ha + 120 kg N_2 + 60 kg P_2O_5) followed by treatment T_8 (*Azotobacter* 1 kg/ha + 120 kg N_2 + 60 kg P_2O_5) over the control. The ascorbic acid content of 33.56 mg per 100 ml of juice was recorded in the treatment T_7(*Azotobacter* 1 kg/ha + 80 kg N_2+ 40 kg P_2O_5) followed by treatment T_{11} (*Azospirillum* 1 kg/ha + 80 kg N_2+ 40 kg P_2O_5) over the treatment T_1 (Control).

Keywords:*Inorganic fertilizers, biofertilizers, growth, yield, quality, tomato.*

1. Introduction

Tomato (*Solanum lycopersicum*L.) is one of the most popular vegetable crops grown all over the world due to its wider adaptability to various agro-climatic conditions as well as in culinary purposes. India ranks second in area and production of tomato in the world. The leading tomato growing states in India are Uttar Pradesh, Karnataka, Maharashtra, Haryana, Punjab and Bihar. Tomato is one of the most common, leading, widely consumed, popular, staple, day neutral, self-pollinated, annual and economically important solanaceous fruit vegetable crop. It is also a very good source of income for small and marginal farmers and also contributes to the nutrition of the consumer (Singh *et al*., 2010).

The growth, yield, and quality of the tomato fruit in addition to the total yields in tomato crop have all been reported to rise in response to the application of organic, inorganic inputs in addition to biofertilizers.Under these conditions, it is crucial to integrate biofertilizers and inorganic fertilizers, which help maintain soil fertility and increase productivity. According to Kumar and Sharma (2004), to get the most out of your tomato crop and provide it with all the macronutrients it needs, combine mineral nitrogen, phosphorous, and potassium fertilizers with organic fertilizer sources. A combination of organic and inorganic fertilizers is important for higher crop output because mineral fertilizers, compost, animal manures, and bio-fertilizers, among others, do not provide all of the nutrients that crops need. Increases inphysiological, growth, and yield characteristics may be attributable to the biofertilizers' gradual but consistent action, which fixes some nutrients and makes them available to plants (Sengupta et al. 2002). Combining inorganic and biofertilizers has frequently resulted in higher yields than each method by alone (Blackshaw, 2005).

2. Material and Methods

In order to study to assessment, the interaction effect of nutrient sources on growth, yield and quality of tomato (*Solanum lycopersicum*L.). a field experiment was conducted at Horticulture complex, Faculty of Agriculture Science and Technology, Mansarovar Global University, Bilkisganj,Sehore (M.P) during *rabi* season of 2021 and 2022. The experiment was conducted in Randomized Block Design with factorial concept andthe experiment comprised of total sixteen treatments combinations of inorganic nutrients, biofertilizers and control.Theobservations regarding growth and yield parameters were recorded by average of five randomly selected plants and analyzed. The experiment will be conducted as per the plan given below:

Factor A:
Biofertilizers
***Azotobacter*:**A carrier-based inoculum of *Azotobacter* @ 1 kg/ ha isdissolving in water to prepare slurry. Seedling uprootfrom the nursery and after then dip in slurry for 30 min. then they transplant to the main field.
***Azospirillum*:**A carrier-based inoculum of *Azospirillum*@ 1 kg/ ha isdissolving in water to prepare slurry. Seedling uproots from thenursery and after then dip in slurry for 30 min. then they transplant to the main field.
***Phosphobacteria*:**A carrier-based inoculum of Phosphobacteria @ 1kg/ ha isdissolving in water to prepare slurry. Seedling uproots fromthe nursery and after then dip in slurry for 30 min. then theytransplant to the main field.

Factor B:
Inorganic fertilizers
1. Nitrogen + Phosphorus (Source: Urea and SSP)
Treatment detail
B0 – No bio-fertilizer
B1 – *Azotobacter* 1 kg/ha
B2 – *Azospirillum*1 kg/ha
B3 – *Phosphobacteria*1 kg/ha
F0 – No inorganic fertilizer
F1 – 40 kg Nitrogen + 20 kg Phosphorus
F2 – 80 kg Nitrogen + 40 kg Phosphorus
F3 – 120 kg Nitrogen + 60 kg Phosphorus

Treatment combinations:

Treatment	Symbol Treatment details
T_1	B_0F_0 (No bio-fertilizer + No inorganic fertilizer) (Control)
T_2	B_0F_1 (No bio-fertilizer + 40 kg Nitrogen + 20 kg Phosphorus)
T_3	B_0F_2 (No bio-fertilizer + 80 kg Nitrogen + 40 kg Phosphorus)
T_4	B_0F_3 (No bio-fertilizer + 120 kg Nitrogen + 60 kg Phosphorus)
T_5	B_1F_0 (*Azotobacter* 1 kg/ha + No inorganic fertilizer)
T_6	B_1F_1 (*Azotobacter* 1 kg/ha + 40 kg Nitrogen + 20 kg Phosphorus)
T_7	B_1F_2 (*Azotobacter* 1 kg/ha + 80 kg Nitrogen + 40 kg Phosphorus)
T_8	B_1F_3 (*Azotobacter* 1 kg/ha + 120 kg Nitrogen + 60 kg Phosphorus)
T_9	B_2F_0 (*Azospirillum*1 kg/ha + No inorganic fertilizer)
T_{10}	B_2F_1 (*Azospirillum*1 kg/ha + 40 kg Nitrogen + 20 kg Phosphorus)
T_{11}	B_2F_2 (*Azospirillum*1 kg/ha + 80 kg Nitrogen + 40 kg Phosphorus)
T_{12}	B_2F_3 (*Azospirillum*1 kg/ha + 120 kg Nitrogen + 60 kg Phosphorus)

T_{13}	B_3F_0 (*Phosphobacteria* 1 kg/ha + No inorganic fertilizer)
T_{14}	B_3F_1 (*Phosphobacteria* 1 kg/ha + 40 kg Nitrogen + 20 kg Phosphorus)
T_{15}	B_3F_2 (*Phosphobacteria* 1 kg/ha + 80 kg Nitrogen + 40 kg Phosphorus)
T_{16}	B_3F_3 (*Phosphobacteria* 1 kg/ha + 120 kg Nitrogen + 60 kg Phosphorus)

The five tomato fruits of different sizes from each group (small, medium and large) were selected from each plot and measured the diameter of fruit with the help of veneer calipers and calculate the mean value of fruit diameter and after taking the diameter of fruits, they weighed collectively with the help of electronic balance and calculate the average fruit weight.Select the edible fruits at different times and record the total yield of each plot picking wise and thus by adding the yield of all picking the total yield of fruits obtained plot wise and calculate the average yield per plot and select the edible fruits at different times and record the total yield of each plot picking wise and thus by adding the yield of all picking the total yield of fruits obtained plot wise and calculate the average yield q/ha.

3. Results and discussion

3.1 Growth parameters

Data pertaining to number of primary and secondary branches in tomato crop under the different combinations of nutrient sources of inorganic fertilizers and biofertilizers is presented in Table 3.1.A keen observation of the data reveals that there was a significant effect on number of primary branches in tomato crop during both the years of the experiment. It was observed that maximum number of primary and secondary branches were recorded in the treatment T_{12} (16.08 and 43.96) followed by treatment T_8 (16.06 and 43.94) whereas lowest number of primary branches were recorded under the treatment T_1 (10.97 and 38.85) in both year of trial.

The pooled estimates also reveal that minimum number of days for first flowering were observed in the treatment T_8(Azotobacter 1 kg/ha + 120 kg Nitrogen + 60 kg Phosphorus) having 29.09 days to first flowering followed by T_{12} recording 30.13 days to first flowering. All other treatments had recorded significantly higher number of days for first flowering as compared to treatment involving application of Azotobacter 1 kg/ha + 120 kg Nitrogen + 60 kg Phosphorus. Maximum number of days for first flowering were recorded for treatment T_1 (56.14) as compared to all other treatments.

The pooled estimates also revealed the similar trend with the treatment comprising Azotobacter along with higher dose of inorganic fertilizers recording minimum number of days for first fruit picking and also revealed the similar trend regarding the crop duration. Minimum crop duration was recorded under the treatment T_8 (117.09 days of crop duration) followed by treatment T_{12} (118.13 days of crop duration). Maximum crop duration was recorded in the treatment T_1 (144.14 days).

Table 3.1: Interaction effect of different sources of nutrients on growth parameters of tomato.

Treatment	Number of primary branches			Number of secondary branches			Days taken to first flowering			Days taken to first picking			Crop duration		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1	10.69	11.24	10.97	38.24	39.46	38.85	55.28	56.99	56.14	68.28	69.99	69.14	143.28	144.99	144.14
T_2	13.74	14.29	14.02	41.29	42.51	41.9	46.83	48.54	47.69	59.83	61.54	60.69	134.83	136.54	135.69
T_3	14.28	14.83	14.56	41.83	43.05	42.44	44.27	45.98	45.13	57.27	58.98	58.13	132.27	133.98	133.13
T_4	14.59	15.14	14.87	42.14	43.36	42.75	41.34	43.05	42.20	54.34	56.05	55.20	129.34	131.05	130.20
T_5	13.41	13.96	13.69	40.96	42.18	41.57	47.29	49	48.15	60.29	62	61.15	135.29	137	136.15
T_6	15.32	15.87	15.60	42.87	44.09	43.48	35.28	36.99	36.14	48.28	49.99	49.14	123.28	124.99	124.14
T_7	15.5	16.05	15.78	43.05	44.27	43.66	31.79	33.5	32.65	44.79	46.5	45.65	119.79	121.5	120.65
T_8	15.78	16.33	16.06	43.33	44.55	43.94	28.23	29.94	29.09	41.23	42.94	42.09	116.23	117.94	117.09
T_9	12.97	13.52	13.25	40.52	41.74	41.13	49.48	51.19	50.34	62.48	64.19	63.34	137.48	139.19	138.34
T_{10}	15.24	15.79	15.52	42.79	44.01	43.4	37.82	39.53	38.68	50.82	52.53	51.68	125.82	127.53	126.68
T_{11}	15.43	15.98	15.71	42.98	44.2	43.59	33.47	35.18	34.33	46.47	48.18	47.33	121.47	123.18	122.33
T_{12}	15.8	16.35	16.08	43.35	44.57	43.96	29.27	30.98	30.13	42.27	43.98	43.13	117.27	118.98	118.13
T_{13}	12.24	12.79	12.52	39.79	41.01	40.4	52.64	54.35	53.50	65.64	67.35	66.50	140.64	142.35	141.50
T_{14}	14.86	15.41	15.14	42.41	43.63	43.02	38.45	40.16	39.31	51.45	53.16	52.31	126.45	128.16	127.31
T_{15}	15.1	15.65	15.38	42.65	43.87	43.26	37.96	39.67	38.82	50.96	52.67	51.82	125.96	127.67	126.82
T_{16}	15.66	16.21	15.94	43.21	44.43	43.82	31.64	33.35	32.50	44.64	46.35	45.50	119.64	121.35	120.50
S.Em(±)	**0.55**	**0.62**		**0.61**	**0.59**		**0.67**	**0.98**		**1.05**	**0.96**		**1.32**	**1.36**	
CD (@5%)	**1.17**	**1.37**		**1.27**	**1.21**		**1.05**	**2.05**		**2.15**	**2.19**		**2.68**	**2.71**	

3.2 Yield parameters

Number of fruits per plant varied among different combinations of nutrient sources of inorganic fertilizer and bio fertilizer treatments as presented in Table 3.2. A close inspection of the data presented in the table reveals that all the treatments had a significant effect on number of fruits per plant in tomato crop as affected by application of inorganic fertilizers and biofertilizers.The pooled estimates also revealed similar trend and maximum number of fruits were recorded in the treatment T_8 (22.45) followed by treatment T_{12} (21.85) whereas minimum number of fruits were observed in the treatment T_1 (11.38). Such results have been also observed by Meena et al. (2010), Paulraj et al. (1982) in tomato wherein integration of biofertilizers and inorganic fertilizers led to increased number of fruits in tomato owing to better fruit set and fruit retention.Fruit diameter is an important parameter along with other yield attributing parameters contributing to tomato yield.

Data pertaining to diameter of the tomato fruit is presented in Table 3.2.1. Analysis of the data presented in the table reveals significant differences in the diameter of the tomato fruits as affected by the application of inorganic fertilizers and biofertilizers in tomato crop.

The pooled data also revealed the superiority of the T_8 treatment recording 7.48 cm of fruit diameter followed by treatment T_{12} (7.43 cm) and T_{16} (7.39 cm). However, minimum fruit diameter was recorded in the treatment T_1 (6.47 cm).Pooled data also revealed similar trend over the two years of the experiment with maximum average fruit weight of tomato crop being recorded in the treatment T_8 (82.15 g) followed by treatment T_{12} (81.51 g) whereas minimum average fruit weight was recorded in the treatment T_1 (73.94 g).Fruits yield per plant depends upon the number of fruits and size of the fruits per plant. There both the characters are higher in treatment of Azotobacter 1 kg/ha + 120 kg Nitrogen + 60 kg Phosphorus. Such result has also been found by Meena et al. (2010) and Yadav and Pandey (2015) in tomato.

Data pertaining to average yield per plot (kg) is presented in Table 3.2 a. Average yield per plot was affected by the average fruit weight per plant and was significant in all the treatments as compared to the control treatment.The pooled estimates also revealed similar trend in average yield per plot with maximum yield being recorded in the treatment T_8 (33.20 kg) followed by T_{12} (32.06 kg) and T_{16} (29.31 kg). Minimum average yield per plot was recorded in T_1 (15.14 kg).

These results are consistent with those of Wange et al. (1998) and Tripathi et al. (2010) who found that applying Azotobacter and PSB increased strawberry yield. While nitrogen fixers and phosphorus solubilizers boosted the availability of nitrogen and phosphorus to the plants as well as their transfer from root to flower through plant foliage, the rise in yield may be attributable to an increase in fruit set per plant (Singh and Singh, 2009). Similar findings in safflower and tomatoes were reported by Mirzakhani et al. (2009) and Poonia and Dhaka (2012), respectively. Baba et al. (2018) also confirmed Data pertaining to total yield of tomato crop in response to application of different combinations of nutrient sources is presented in Table 3.2.2 and 3.2.2a. Total yield was significantly affected by the average fruit weight in tomato crop.The pooled data also revealed similar trends in the cumulative yield of tomato. Maximum cumulative yield of 409.82 q per ha was recorded in the treatment T_8 followed by a yield of 395.74 q per ha recorded in treatment T_{12} and 361.91 q per ha in T_{16}. Minimum yield of 186.89 q per ha was recorded in the treatment T_1 (control).

Integration of biofertilizer and inorganic fertilizers led to increased growth parameters which led to the strengthening of the photosynthetic area of the plant. This might have led to increased assimilation of the carbohydrates and better assimilate partitioning in the tomato plantswhich led to increased yield as compared to the control treatment. These findings are in line with the findings of Wange et al., (1998) and Tripathi et al., (2010). The increase in yield might be due to increased fruit set per plant, due to the fact that nitrogen fixers and phosphorous solubilizes not only increased the availability of nitrogen and phosphorous to the plants but also increased their translocation from root to flower through plant foliage (Singh and Singh, 2009). Similar results were reported by Mirza khan et al., (2009) in safflower and Poonia and Dhaka (2012) in tomato.

Table 3.2: Interaction effect of different sources of nutrients on yield and yield attributing parameters of tomato.

Treatment	Number of fruits per plant			Diameter of fruit (cm)			Average fruit weight (g)			Average yield per plot (kg)			Total yield (q/ha)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T1	11.3	11.45	11.38	6.45	6.49	6.47	74.06	73.81	73.94	15.06	15.21	15.14	185.97	187.81	186.89
T2	15.6	15.4	15.50	6.72	6.77	6.75	77.81	77.08	77.45	21.85	21.37	21.61	269.74	263.78	266.76
T3	16.3	16.2	16.25	6.88	6.91	6.90	77.23	78.45	77.84	22.66	22.88	22.77	279.74	282.42	281.08
T4	16.6	16.4	16.50	6.95	6.89	6.92	80.41	79.42	79.92	24.03	23.44	23.74	296.62	289.44	293.03
T5	14.9	14.8	14.85	6.65	6.69	6.67	76.45	76.91	76.68	20.50	20.49	20.50	253.13	252.95	253.04
T6	18.3	18.6	18.45	7.38	7.32	7.35	79.65	78.21	78.93	26.24	26.18	26.21	323.91	323.27	323.59
T7	20.9	20.6	20.75	7.41	7.38	7.40	80.89	80.67	80.78	30.43	29.91	30.17	375.69	369.29	372.49
T8	22.3	22.6	22.45	7.5	7.46	7.48	82.56	81.74	82.15	33.14	33.25	33.20	409.13	410.52	409.82
T9	14.3	14.6	14.45	6.54	6.57	6.56	76.09	75.28	75.69	19.59	19.78	19.68	241.80	244.24	243.02
T10	18.3	17.9	18.10	7.34	7.31	7.33	78.63	79.28	78.96	25.90	25.54	25.72	319.76	315.36	317.56
T11	19.9	19.6	19.75	7.37	7.34	7.36	79.78	80.29	80.04	28.58	28.33	28.45	352.80	349.71	351.26
T12	21.6	22.1	21.85	7.42	7.44	7.43	82.13	80.89	81.51	31.93	32.18	32.06	394.22	397.26	395.74
T13	13.6	13.9	13.75	6.48	6.39	6.44	74.12	73.45	73.79	18.14	18.38	18.26	224.01	226.88	225.44
T14	17.9	17.3	17.60	7.12	7.16	7.14	78.24	79.71	78.98	25.21	24.82	25.02	311.22	306.44	308.83
T15	17.9	17.6	17.75	7.25	7.31	7.28	78.17	78.69	78.43	25.19	24.93	25.06	310.94	307.77	309.35
T16	20.3	19.9	20.10	7.4	7.38	7.39	81.46	80.58	81.02	29.77	28.86	29.31	367.48	356.34	361.91
S.Em(±)	**0.47**	**0.54**		**0.11**	**0.14**		**1.19**	**1.34**		**2.64**	**2.19**		**3.12**	**3.27**	
CD (@5%)	**1.06**	**1.11**		**0.19**	**0.21**		**2.06**	**2.14**		**5.21**	**4.86**		**5.68**	**6.04**	

3.3 Quality parameters

Data pertaining to total soluble solids in tomato fruit as affected by the application of inorganic fertilizers and biofertilizers is presented in Table 3.3. Perusal of the data reveals that yield factor was greatly influenced by the different combinations of inorganic fertilizers and biofertilizers.The pooled data also revealed that maximum TSS of 5.45 °brix was recorded in the treatment T_{12} (Azospirillum 1 kg/ha + 120 kg Nitrogen + 60 kg Phosphorus) followed by treatment T_8 (Azotobacter 1 kg/ha + 120 kg Nitrogen + 60 kg Phosphorus) where TSS of 5.4°brix was recorded. Minimum TSS of 4.05 °brix was recorded in treatment T_1. Such results are with the conformity with Sendur et al. (1998) and Yadav and Pandey (2015) in tomato.

Ascorbic acid content of tomato fruits under the effect of inorganic fertilizers and biofertilizers has been presented in Table 3.3. Perusal of the table reveals that treatments having medium application of inorganic fertilizers recorded maximum ascorbic acid content in tomato crop.The pooled estimates also revealed that maximum Ascorbic acid content of 33.56 mg per 100 ml of juice was recorded in the treatment T_7(Azotobacter 1 kg/ha + 80 kg Nitrogen + 40 kg Phosphorus) followed by treatment T_{11} (Azospirillum 1 kg/ha + 80 kg Nitrogen + 40 kg Phosphorus) where ascorbic acid content of 33.15 mg per 100 ml juice was recorded. Minimum ascorbic acid content of 27.93 mg per 100 ml juice was recorded in the treatment T_1 (Control). Similar results have also been reported by Sendur et al. (1998) and Meena et al. (2013).

Table 3.3: Interaction effect of different sources of nutrients on quality attributes in tomato.

Treatment	Total soluble solids (°Brix)			Ascorbic acid (mg/100 ml juice)		
	2021	2022	Pooled	2021	2022	Pooled
T_1	4.1	4.0	4.05	28.06	27.79	27.93
T_2	4.7	4.6	4.65	29.66	30.72	30.19
T_3	4.9	5.0	4.95	28.69	29.47	29.08
T_4	4.9	4.9	4.9	30.64	29.48	30.06
T_5	4.6	4.6	4.6	31.29	30.58	30.94
T_6	5.2	5.1	5.15	32.12	31.86	31.99
T_7	5.3	5.2	5.25	33.47	33.64	33.56
T_8	5.4	5.4	5.4	29.47	28.79	29.13
T_9	4.5	4.6	4.55	30.45	29.65	30.05
T_{10}	5.2	5.2	5.2	29.86	30.74	30.30
T_{11}	5.3	5.3	5.3	33.21	33.09	33.15
T_{12}	5.5	5.4	5.45	30.47	29.68	30.08
T_{13}	4.2	4.3	4.25	30.63	31.27	30.95
T_{14}	5.1	5.2	5.15	31.58	30.67	31.13
T_{15}	5.1	5.2	5.15	32.64	32.79	32.72
T_{16}	5.4	5.4	5.4	31.64	30.89	31.27
S.Em(±)	**0.05**	**0.04**		**0.49**	**0.47**	
CD (@5%)	**0.10**	**0.09**		**0.88**	**0.92**	

Conclusion

From the result obtained during the investigation with different combination of nutrient sources of inorganic fertilizers and biofertilizers on growth, yield and quality of tomato (*Solanumlycopersicum*L.). Hans, it is concluded that application of biofertilizers and inorganic fertilizers with the combination significantly effect on growth parameter of tomato ie., number of primary and secondary branches, first flowering and application of biofertilizers and inorganic fertilizers with the different combinations positively affected the yield attributing characters i.e; first fruit picking,crop duration, fruit size(diameter), Number of fruits per plant, average fruit weight and total yield per hectare and fruit quality characters also significantly affected were maximum in *Azotobacter* 1 kg/ha + 120 kg Nitrogen + 60 kg Phosphorus.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Author O.S. Raghuwanshicarried out research work. Author K. N. Nagaich fully guided about statistical analysis and supervise for completed the manuscript. Authors Devesh Pandey completely helped in drafting of manuscript. All authors read and approved the final manuscript.

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