Effect of the interaction of nutrient sources on the growth, yield and quality of tomato (*Solanum lycopersicum* L.)

ABSTRACT

The present field investigation was conducted in the years 2021 and 2022 at Horticultural Farm, Faculty of Agriculture Science & Technology, Mansarovar Global University, Sehore (Madhya Pradesh). The experiment was carried out to find out the interaction effect of various sources of nutrients on the growth, yield, and quality of tomatoes. The study comprised a total of 16 different treatment combinations of inorganic plant nutrients; biofertilizers included a control. It was found that the application of treatment T_8 (*Azotobacter* 1 kg/ha + 120kg N_2 + 60kg P_2O_5) recorded significantly higher growth attributes (number of branches per plant), days to first flowering, and days to first picking crop duration than the control. It has been determined that the maximum yield of 409.82 q ha-1 was recorded in 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 yields of 394.74 q ha-1 and 361.91 ha-1. The maximum TSS of 5.45 °brix was recorded in 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 N2 + 60 kg P2O5) over the control. The ascorbic acid content of 33.56 mg per 100 ml of juice was recorded in 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 treatment T_1 (Control). The results obtained during the investigation with different combinations of nutrient sources of inorganic fertilizers and biofertilizers on the growth, yield, and quality of tomato (*Solanum lycopersicum* L.) Hence, it is concluded that application of biofertilizers and inorganic fertilizers with the combination significantly effect on growth parameters, yield attributing characters and fruit quality characters also significantly affected were maximum in *Azotobacter* 1 kg/ha + 120 kg Nitrogen + 60 kg Phosphorus.

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 for culinary purposes. India ranks second in area and production of tomatoes in the world. The leading tomato-growing states in India are Uttar Pradesh, Karnataka, Maharashtra, Haryana, Punjab, and Bihar. The tomato is one of the most common, leading, widely consumed, popular, staple, day-neutral, self-pollinated, annual, and economically important solanaceous fruit vegetable crops. 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 the tomato crop, have all been reported to rise in response to the application of organic and 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 in physiological, 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 alone (Blackshaw, 2005).

2. Material and Methods

In order to study of effect of the interaction of nutrient sources on the growth, yield, and quality of tomato (*Solanum lycopersicum L.),* A field experiment was conducted at the Horticulture Complex, Faculty of Agriculture Science and Technology, Mansarovar Global University, Bilkisganj,Sehore (M.P.) during the *rabi* season of 2021 and 2022. The experiment was conducted in a randomized block design with a factorial concept, and the experiment comprised a total of sixteen treatment combinations of inorganic nutrients, biofertilizers, and controls. The observations regarding growth and yield parameters were recorded by the 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 is dissolving in water to prepare slurry. Seedling uproot from 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 is dissolving in water to prepare slurry. Seedling uproots from the nursery 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 is dissolving in water to prepare slurry. Seedling uproots from the nursery and after then dip in slurry for 30 min. then they transplant 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 the fruit with the help of veneer calipers to calculate the mean value of the fruit diameter. After taking the diameter of the fruits, they weighed them collectively with the help of an electronic balance to 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 calculating the average yield per plot, 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 calculating the average yield q/ha.

The data collect during the study and analyze statistically by the method of Analysis of Variance and compare the treatments with the help of critical difference, following the techniques and evaluated the results at 5% level of significance.

3. Results and discussion

3.1 Growth parameters

Data pertaining to the number of primary and secondary branches in the tomato crop under different combinations of nutrient sources of inorganic fertilizers and biofertilizers is presented in Table 1. A keen observation of the data reveals that there was a significant effect on the number of primary branches in the tomato crop during both years of the experiment. It was observed that the maximum number of primary and secondary branches was recorded in treatment T_{12} (16.08 and 43.96), followed by treatment T_8 (16.06 and 43.94), whereas the lowest number of primary branches was recorded under treatment T_1 (10.97 and 38.85) in both years of the trial.

The pooled estimates also reveal that a 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 recorded a significantly higher number of days for first flowering as compared to treatments involving the application of *Azotobacter* (1 kg/ha + 120 kg nitrogen + 60 kg phosphorus). The maximum number of days for first flowering was recorded for treatment T_1 (56.14) as compared to all other treatments.

The pooled estimates also revealed a similar trend with the treatment comprising *Azotobacter* along with a higher dose of inorganic fertilizers, recording the minimum number of days for first fruit picking, and also revealed a similar trend regarding crop duration. The minimum crop duration was recorded under 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 treatment T_1 (144.14 days).

Table 1: Effect of the Interaction 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

The number of fruits per plant varied among different combinations of nutrient sources of inorganic fertilizer and biofertilizer treatments, as presented in Table 2. A close inspection of the data presented in the table reveals that all the treatments had a significant effect on the number of fruits per plant in the tomato crop as affected by the application of inorganic fertilizers and biofertilizers. The pooled estimates also revealed a similar trend, with the maximum number of fruits recorded in treatment T8 (22.45) followed by treatment T12 (21.85), whereas the minimum number of fruits was observed in treatment T1 (11.38). Such results have also been observed by Meena et al. (2010) and Paulraj et al. (1982) in tomato, wherein the integration of biofertilizers and inorganic fertilizers led to an 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 the diameter of the tomato fruit is presented in Table 4. 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 the tomato crop.

The pooled data also revealed the superiority of the T8 treatment, recording 7.48 cm of fruit diameter, followed by treatments T12 (7.43 cm) and T16 (7.39 cm). However, the minimum fruit diameter was recorded in treatment T1 (6.47 cm). Pooled data also revealed a similar trend over the two years of the experiment, with the maximum average fruit weight of the tomato crop being recorded in treatment T8 (82.15 g), followed by treatment T12 (81.51 g), whereas the minimum average fruit weight was recorded in treatment T1 (73.94 g). Fruit yield per plant depends upon the number and size of the fruits per plant. Both characters are higher in the treatment of *Azotobacter:* 1 kg/ha + 120 kg nitrogen + 60 kg phosphorus. Such a result has also been found by Meena et al. (2010) and Yadav and Pandey (2015) in tomatoes.

Data pertaining to average yield per plot (kg) is presented in Table 5. The 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 a similar trend in average yield per plot, with the maximum yield being recorded in treatment T8 (33.20 kg), followed by T12 (32.06 kg), and T16 (29.31 kg). The minimum average yield per plot was recorded in T1 (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 Mirza khan et al. (2009) and Poonia and Dhaka (2012), respectively. Baba et al. (2018) also confirmed Data pertaining to the total yield of the tomato crop in response to the application of different combinations of nutrient sources is presented in Tables 6a and 6b. Total yield was significantly affected by the average fruit weight of the tomato crop. The pooled data also revealed similar trends in the cumulative yield of tomatoes. The maximum cumulative yield of 409.82 q per ha was recorded in treatment T8, followed by a yield of 395.74 q per ha recorded in treatment T12 and 361.91 q per ha in treatment T16. A minimum yield of 186.89 q per ha was recorded in treatment T1 (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 plants, which 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 solubilize 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 2: Effect of the Interaction 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.. The analysis of the data reveals that the yield factor was greatly influenced by the different combinations of inorganic fertilizers and biofertilizers. The pooled data also revealed that a maximum TSS of 5.45 °brix was recorded in 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 a TSS of 5.4°brix was recorded. A minimum TSS of 4.05 °C was recorded in treatment T_1. Such results are in conformity with Sendur et al. (1998) and Yadav and Pandey (2015) in tomato.

The ascorbic acid content of tomato fruits under the effects of inorganic fertilizers and biofertilizers has been presented in Table 3. Perusal of the table reveals that treatments with medium application of inorganic fertilizers recorded maximum ascorbic acid content in tomato crops. The pooled estimates also revealed that a maximum ascorbic acid content of 33.56 mg per 100 ml of juice was recorded in treatment T7 (*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 an ascorbic acid content of 33.15 mg per 100 ml of juice was recorded. The minimum ascorbic acid content of 27.93 mg per 100 ml of juice was recorded in treatment T_1 (control). Similar results have also been reported by Sendur et al. (1998) and Meena et al. (2013).

Table 3: Effect of the interaction 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 (*Solanum lycopersicum* 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. Raghuwanshi carried 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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