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Influence of Bio-Fertilizers on Growth and Yield Attributing Attributes in Tomato

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The investigation was conducted to study the effect of integrated nutrient management studies in tomato (*Solanum lycopersicum* L.). The cultivar Punjab Ratta and Punjab Varkha Bahar-4 comprised the plant material in autumn and rainy season, respectively. The experiment comprised fourteen treatments of biofertilizers and organic manures with or without chemical fertilizers. The experiment was conducted in randomized complete block design with three replications. The cultures of biofertilizers i.e. *Azotobacter*, *Azospirillum* and *Phosphorus Solublizing Bacteria* (PSB) were applied to the seedlings while *Vesicular-Arbuscular Mycorrhizae* (VAM) was applied directly in the treatment plots @ 500 g/ha. The treatment with *Azotobacter* was found beneficial for improving plant height, number of branches per plant and leaf area when it was applied along with recommended dose of fertilizers (RDF). *Azotobacter* along with VAM and RDF improves the number of branches per plant, leaf area, fruit diameter and number of fruits per plant. Likewise *Azospirillum* along with RDF and *Azotobacter* along with VAM and RDF helped to increase the fruit yield in rainy and autumn season to the tune of 549 and 543.1 q ha^{-1} which was 25 % and 19.3 % higher than the RDF respectively. The application of *Azotobacter* and *Azospirillum* along with 75 % recommended dose of nitrogen during autumn season and *Azotobacter*, *Azospirillum*, PSB and VAM treatments along with 75 % N and 75 % P of the recommended dose of nitrogen and phosphorus during rainy season recorded yield at par with RDF. It is concluded that *Azotobacter* along with VAM and 75 % dose of N and P saves the nitrogenous and phosphorus fertilizers without any significant reduction in yield. The application of *Azotobacter* along with VAM and recommended dose of N, P and K during *autumn* season and the application of *Azospirillum* along with recommended dose of fertilizers during rainy season proves beneficial for production of tomato under Punjab conditions.

Introduction

Tomato (*Solanum lycopersicum* L.) is an important nutritious vegetable crop of the world. Its fruits are consumed both as raw and in processed form. Tomato yield potential largely depends on various agronomic factors. Among these factors plant nutrition is

important that affects growth and yield of tomato (Dumas *et al.,* 2003). Tomato is a heavy feeder of nutrients and requires large quantities of chemical fertilizers (Samaila *et al.,* 2011). Since last decade, tomato production has increased due to increased use of fertilizers and cultivation of high yielding varieties. Tomato crop consumed 280 kg N, 55 kg P_2O_5 and 540 kg K_2O ha^{-1} for producing 30t ha^{-1} (Akhtar *et al.,* 2003). However excessive use of chemical fertilizers pollutes not only environment and underground water but also makes the soil acidic and reduces the soil fertility gradient. On the other hand high cost of chemical fertilizers makes crop production uneconomical for small and middle class farmers. Organic manures alone also cannot produce yield similar to chemical fertilizers (Heeb *et al.,* 2006). Integration of biofertilizers with inorganic fertilizers at rates below those recommended for optimum tomato production may result in saving of inorganic fertilizers and sustain production (Taiwo *et al.,* 2007). Therefore, the present investigation was planned and conducted to study the effect of biofertilizers on growth and yield attributes of tomato.

Materials and Methods

The study was conducted at vegetable research farm, Punjab Agricultural University, Ludhiana during the *autumn* and *rainy* season of 2015-16 to access the impact of different combinations of bio-fertilizer (*Azotobacter*, *Azospirillium*, VAM, PSB) along with inorganic fertilizers and organic manures (FYM) on growth and yield characters of tomato cultivars Punjab Ratta and Punjab Varkha Bahar-4 comprised the plant material in autumn and rainy season. The soil of the experimental field with loamy sand texture, good water holding capacity, pH of 7.6 and 7.4 (during autumn and rainy season respectively) and moderate soil fertility status. The fourteen treatments were replicated three times in randomized block design in 3.0m × 3.0m plots. Full dose of inorganic phosphorus and potash was applied at the time of transplanting. Half of nitrogen was applied as basal and the remaining dose of N was applied 30 days after planting. Bio-fertilizer was applied on day of transplanting by seedling treatment except VAM which was mixed in soil. The crop was irrigated to avoid moisture stress. Plant height, number of branches per plant, leaf area, fruit diameter, fruit weight and fruit yield was measured. The fruits were harvested on maturity. The statistical analysis was done as per the standard procedure for analysis of variance for RCBD. Least significant difference was employed for mean comparison.

Results and Discussion

Plant height (cm)

During a*utumn* season, after 30 days of transplanting (DAT), plant height attained with application of *Azotobacter* along with VAM and recommended dose of fertilizers (T_9) was significantly higher from the treatments where 75% dose of fertilizers was applied (Table 1). Plant height with recommended dose of fertilizers (T_{13}) was statistically at par with all the recommended dose of fertilizers treatments along with biofertilizers and significantly higher with 75% dose of fertilizer treatments. At 60 DAT, maximum plant height was achieved in treatment with VAM along with recommended dose of fertilizers (T_7) that was 48.4 cm which was significantly higher from rest of treatments except treatments where PSB along with 75% dose of P and recommended dose of N and K was applied (T_6 = 46 cm) and *Azotobacter* along with VAM and 75% dose of N and P (T_9 = 47.2 cm) (Table 1). Minimum plant height was attained in the treatment where no fertilizer was applied (T_{14}). At 90 DAT, application of

Azotobacter along with recommended fertilizer dose (T_1) resulted in maximum plant height (67.2 cm) which was significantly higher from attained with *Azotobacter*, *Azospirillum* along with 75 % P and recommended dose of N and K (T_2 andT_4) FYM alone or along with *Azotobacter* and VAM (T_{11} and T_{12}) and control (T_{14}) treatments (Table 1). Plant height in case of without application of fertilizers (T_{15}) was significantly lower than all treatments of biofertilizers along with recommended dose of N, P and K.

During *Rainy* season, plant height was recorded after 30, 60 and 90 days of transplanting (DAT), maximum plant height was recorded in T_1 treatment where *Azotobacter* along with recommended dose of inorganic fertilizers was applied and it was significantly higher from recommended dose of fertilizers (T_{13}) and control (T_{14}) treatments (Table 1). At 60 days of transplanting, plant height was significantly higher in treatment T_1 as compare to treatments where PSB and VAM biofertilizers along with 75 % dose of P was applied (T_6 and T_8) (Table 1).

While at 90 days of transplanting, T_1 treatment was significantly higher than that attained with PSB along with 75 % P and recommended dose of N and K (T_6) and FYM along with *Azotobacter* and VAM (T_{11}).

Biofertilizers along with recommended dose of inorganic fertilizers recorded maximum plant height at 30, 60 and 90 DAT of transplanting as compared to treatments where 75% dose of inorganic fertilizers along with biofertlizers and where alone inorganic fertilizers treatment were applied due to the reason that bio-inoculums increase the nutrient fixation and make available to plant and increase production of growth promoting hormones which improves the vegetative growth of plant.

Optimum N application and fixation through *Azotobacter* and *Azospirillum* treatments resulted in production of carbohydrates and phytohormones which improve the plant growth. Similar results were notified by Talwar *et al.,* (2016), Jayathilake *et al.,* (2002) in bulbaceous crops. Similarly highest plant height (65.1 cm and 63.9 cm) were observed with treatment of *Azotobacter* and *Azospirillum* along with recommended dose of fertilizers in cauliflower (Singh and Singh 2005).

Number of branches per plant

In Autumn season, Maximum number of branches per plant (15.4) was observed with application of *Azospirillum* along with recommended dose of fertilizers (T_3) and *Azotobacter* along with VAM and recommended dose of fertilizers (T_9) and it was statically at par with treatments where PSB, VAM and *Azotobacter* along with VAM and 75% dose of inorganic fertilizers was applied (T_5, T_6, T_8, and T_{10}) and was significantly at par with all other treatments (Table 1). While, in *Rainy* season, highest number of branches per plant (12.6) was recorded in T_1 treatment where *Azotobacter* along with recommended dose of inorganic fertilizers was applied and it was significantly higher from all other treatments (Table 1).

More number of branches per plant was observed in treatment where biofertilizers applied along with recommended dose of fertilizers (T_3 and T_9) as compared to control may be attributed to the production of growth promoting substances by biofertilizers.

The results are in line with Ramakrishnan and Selvakumar (2012) that highest number of branches per plant was recorded with application of *Azospirillum* or *Azotobacter* along recommended dose of inorganic fertilizers as compared to control.

Table.1 Effect of different treatments on growth parameters in *autumn* and *rainy* seasons in tomato

Treatment Details		Plant Height						Number of Branches per plant		Leaf Area (cm^2)	
		Autumn season			*Rainy* season			*Autumn* season	*Rainy* season	*Autumn* season	*Rainy* season
		30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT				
T_1	*Azotobacter* + N + P + K	30.3	43.8	67.2	24.7	41.9	54.8	12.6	12.6	7.9	6.8
T_2	*Azotobacter* + 75% N + P + K	23.8	37.4	63.7	22.9	37.8	51.5	13.4	11.1	7.5	6.4
T_3	*Azospirillum*+ N + P + K	30.5	43.9	65.1	24.6	41.3	53.8	15.4	11.6	7.9	6.8
T_4	*Azospirillum*+ 75% N + P + K	24.3	40.6	63.7	23.2	38.3	52.8	13.1	10.7	7.5	6.4
T_5	PSB+ N + P + K	29.3	44.2	65.3	24.0	39.8	53.4	14.2	11.0	7.5	6.5
T_6	PSB + 75% P + N + K	26.0	46.0	66.2	22.3	35.4	46.2	14.4	10.5	7.3	6.4
T_7	VAM + N + P + K	29.0	48.4	65.7	23.7	39.0	53.2	13.5	11.0	7.6	6.5
T_8	VAM + 75% P + N + K	27.9	44.4	66.6	21.8	34.9	51.1	14.6	10.3	7.4	6.2
T_9	*Azotobacter* +VAM + N + P + K	32.4	47.2	65.2	24.1	41.1	53.7	15.4	11.2	7.9	6.8
T_{10}	*Azotobacter* + VAM + 75% N + 75% P + K	28.2	38.9	64.5	22.1	35.0	51.6	14.1	10.5	7.2	6.0
T_{11}	FYM @ 20 t/ha +*Azotobacter* + VAM	31.1	34.3	54.2	22.7	36.7	47.2	13.5	10.1	7.7	6.6
T_{12}	FYM @ 20 t/ha	24.7	37.3	53.6	22.9	37.5	52.6	13.1	10.0	7.5	6.5
T_{13}	N + P + K (Recommended)	31.4	43.2	65.3	21.3	34.0	49.5	12.6	9.6	7.1	5.9
T_{14}	Control (Unfertilized)	21.4	33.7	53.3	18.5	27.1	38.8	10.8	8.9	6.5	5.2
CD (p=0.05)		3.5	3.9	3.4	2.7	5.9	5.3	1.6	0.6	0.3	0.6

*RD: Recommended dose of fertilizers (150 kg/ ha N, 62.5 kg/ha P, 62.5 kg/ha K)
** DAT: Days after transplanting

Table.2 Effect of different treatments on fruit diameter (cm), fruit weight (g), number of fruits per plant and fruit Yield (q/ha) in tomato

Treatments		Fruit diameter (cm)		Fruit weight (g)		Number of fruits per plant		Fruit yield (q/ha)	
		***Autumn* season**	***Rainy* season**	***Autumn* season**	***Rainy* season**	***Autumn* season**	***Rainy* season**	***Autumn* season**	***Rainy* season**
T_1	*Azotobacter* + N + P + K	4.7	5.4	73.2	94.7	37.0	35.2	529.0	528.9
T_2	*Azotobacter* + 75% N + P + K	4.5	5.2	70.8	84.0	33.5	30.7	506.5	487.6
T_3	*Azospirillum*+ N + P + K	4.8	5.5	77.9	98.0	36.7	35.1	540.0	549.0
T_4	*Azospirillum*+ 75% N + P + K	4.4	5.2	68.3	85.3	32.9	31.3	507.4	491.4
T_5	PSB+ N + P + K	4.5	5.3	77.9	90.7	35.1	31.8	524.7	514.7
T_6	PSB + 75% P + N + K	4.4	5.2	73.4	79.7	33.4	26.6	507.8	486.3
T_7	VAM + N + P + K	4.5	5.3	73.8	89.0	36.2	31.7	530.6	493.9
T_8	VAM + 75% P + N + K	4.3	5.1	64.9	77.7	35.1	29.0	504.8	484.8
T_9	*Azotobacter* +VAM + N + P + K	4.9	5.3	73.5	94.0	38.1	34.5	543.1	506.9
T_{10}	*Azotobacter* + VAM + 75% N + 75% P + K	4.5	5.2	71.9	82.7	33.5	29.5	514.7	484.4
T_{11}	FYM @ 20 t/ha +*Azotobacter* + VAM	4.5	5.2	76.0	80.7	30.2	33.3	526.2	514.6
T_{12}	FYM @ 20 t/ha	4.6	5.3	72.5	84.7	30.1	27.5	482.0	472.5
T_{13}	N + P + K (Recommended)	4.2	4.9	66.6	86.5	33.8	27.0	469.2	461.1
T_{14}	Control (Unfertilized)	3.6	4.5	56.3	61.7	23.7	21.1	383.4	389.4
CD (p=0.05)		0.4	0.3	4.8	12.1	4.3	5.7	24.3	35.1

*RD: Recommended dose of fertilizers (150 kg/ ha N, 62.5 kg/ha P, 62.5 kg/ha K)

Maximum number of branches per plant was recorded with application of combined treatment of biofertilizers along with recommended dose of inorganic fertilizers as compare to alone *Azotobacter* or *Azospirillium* treatment due to tomato plants inoculated with combination of Biofertilizer-VAM and *Azospirillum*/*Azotobacter* fixed more nitrogen (Tilak, 1995).

Leaf area (cm^2)

Leaf area is used to predict photosynthetic primary (compound) production, evapo-transpiration and as a reference tool for crop growth. Leaf area plays an essential role in theoretical production ecology (Wilhelm *et al.*, 2000).

In Autumn season, leaf area in treatments with *Azotobacter, Azospirillum* along with recommended dose of N, P and K (T_1 and T_3) and *Azotobacter* along with VAM and recommended dose of fertilizers (T_9) was significantly higher from all treatments except T_7 and T_{11} (Table 1). While, in *Rainy* season, maximum Leaf area (6.8 cm^2) was recorded with T_1, T_3 and T_9 which was significantly higher than that attained with *Azotobacter* along with VAM and 75 % dose of N, P and recommended dose of K (T_{10}), recommended dose of fertilizers (T_{13}) and control treatment (T_{14}) where no fertilizer was applied (Table 1).

Highest leaf area was recorded with application of *Azotobacter* and *Azospirillum* due to higher plant height and greater number of photosynthetically active compounds in leaves per palnt, which were enhanced by the production of bioactive substances having similar effects as that of growth regulators besides nitrogen fixation through bacterial fertilizers. The results are in line with Shashi and Manoj (2012) that maximum leaf area index (3.41 cm^2) was recorded with the application of *Azotobacter* along with recommended dose of fertilizers which was significantly higher from the control and inorganic fertilizer alone treatments.

Fruit diameter (cm)

Tomato fruit diameter is an important parameter in promoting the yield potential of the crop. Fruit diameter has strong and positive correlation with the fruit weight suggesting that the increased individual fruit size is fundamental to maximize tomato yield productivity per unit area.

In *Autumn* season, application of *Azotobacter* along with VAM and recommended dose of N, P and K (T_9) resulted in maximum fruit diameter (4.9 cm) that was significantly higher than that attained with T_4 (4.4 cm), T_6 (4.4 cm), T_8 (4.3 cm) and T_{13} (4.2 cm) and was statistically at par with rest of the treatments (Table 2). In *Rainy* season (cm) maximum fruit diameter (5.5 cm) was recorded in T_3 treatment which was statistically at par with all other treatments except T_8 (5.1), T_{13} (4.9) and control (4.5) treatments (Table 1). Regardless of the rate, N fertilization along with *Azospirillum* during *rainy* season increased fruit diameter by about 13% in reference to the control. This was in agreement with Nasreen *et al.*, (2007). The results are in conformity with the findings Meena *et al.*, (2014) significant higher fruit diameter of tomato was recorded with application of *Azospirillum* (6.58 cm).

Average fruit weight (g)

In *Autumn* season, maximum fruit weight (Table 2) of tomato was recorded in the treatment T_3 where *Azospirillium* along with recommended dose of fertilizers and T_5 treatment where PSB along with recommended dose of fertilizers was applied (77.9 g). Similarly in *Rainy* season, maximum

fruit weight (98.0 g) was recorded with application of *Azospirillium* along with recommended dose of fertilizers (T_3). In both the seasons, maximum fruit weight attained treatments was significantly higher from all treatments where 75 % dose of recommended dose of fertilizers was applied (T_2, T_4, T_8 and T_{10}) and from T_{13} (recommended dose of fertilizer treatment) and T_{14} (Control) treatments (Table 2).

This might be due to essential effects of biofertilizers that enhances the root development, improves the nutrient uptake potential of roots and to some extent ability of nitrogen fixation (Okon and Itzigsohn 1995). The results are in line with Ramakrishnan and Selvakumar (2012) that with the combined application of *Azotobacter* and *Azospirillum* average fruit weight of tomato (25.36 g) was significantly improved as compare to dose of fertilizers (18.34 g). Similar results were recorded by Meena *et al.,* (2014) that highest fruit weight was recorded with application of *Azospirillum* (70.24 g) as compare to PSB (64.16g) or recommended dose of fertilizer (33.76 g) treatment alone.

Number of fruits per plant

In *Autumn* season, fruits per plant were directly related with fruit yield. More the number of fruits per plant there will be more yield of tomato. The data reveals that maximum number of fruits per plant (38.1) was obtained with application of *Azotobacter along with* VAM and recommended dose of fertilizers (T_9) was applied and it was significantly higher than that recorded with all treatments where 75 % dose of recommended dose of fertilizers was applied (T_2, T_4, T_6 and T_{10}) and from all organic manure treatments (T_{11} and T_{12}) and from control treatment (T_{14}) and was statistically at par with all other treatments (Table 2). In *Rainy* season, maximum number of fruits per plant (35.2) was obtained with application of T_1 treatment which was significantly higher than treatment T_6, T_8, T_{12}, T_{13} and T_{14} (control) and was statistically at par with all other treatments (Table 2).

The results are in conformity with Hossain and Mohanty (1999) and Gupta and Sengar (2000) that increase in yield of tomato with application of biofertilizers due to increase in number of fruits per plant and average fruit weight. The results are in line with Meena *et al.,* (2014) where treatment of *Azospirillum* produces maximum number of fruits per plant as compare to control in tomato. This might be due to reason that with application of biofertilizers, considerable amounts of biologically active substances like B vitamins, nicotinic acid, pantothenic acid, biotin, heteroxins, gibberellins etc. are produced which improves the growth of plants and significantly improves number of fruits per plant.

Fruit yield (q/ha)

Tomato yield is an important growth contributing parameter. Yield represents the benefit or losses from the crop.In *Autumn* season, the perusal of data showed that maximum fruit yield was recorded with *Azotobacter* along with VAM and recommended dose of fertilizers (T_9) was statically at par with application of T_1 (529 q ha^{-1}) and T_3 (540 q ha^{-1}), T_5 (524.7 q ha^{-1}), T_7 (530.6 q ha^{-1}), T_{11} (526.2 q ha^{-1}) and significantly higher from rest of treatments (Table 2). While, in *Rainy* season, highest fruit yield (549.0 q/ha) was recorded in T_3 treatment where *Azospirillum* along with recommended dose of fertilizers was applied and it was significantly more from rest of treatments except T_1 (*Azotobacter* along with RDF), T_5 (PSB along with RDF) and T_{11} (FYM along with *Azotobacter* and VAM) treatments.

Results are in conformity with Ramakrishnan and Selvakumar (2012) that maximum tomato yield was observed in biofertilizers (518.4 q/ha) followed by *Azotobacter* (502.2 q/ha) as compared to *Azospirillum* (492.1 q/ha) and control treatment. The results are in line with the results of Nanthakumar and Veeraraghavathatham (2000) in brinjal, Govindarajan and Thangaraju (2001) in chilli and Talwar *et al.,* (2016) in onion. Meena *et al.,* (2014) observed that highest tomato fruit yield was recorded with *Azospirillum* (363.6 q/ha) treatment as compare to PSB (317.5 q/ha) and control treatment (241.5 q/ha). This might be due to with application of biofertilizer, secretion of ammonia also enhanced in the rhizosphere, which enhance the nutrient uptake potential of plant and improve the fruit yield. *Azospirillum* also produce plant growth regulatory substances which stimulate plant growth and yield.

It is concluded from the present investigation that *Azospirillum* along with RDF and *Azotobacter* along with VAM and RDF improves the growth and yield attributing parameters of tomato. *Azotobacter, Azospirillum* treatments along with 75 % dose of N and PSB or VAM treatments along with 75 % dose of P recorded the tomato yield statistically at par with the yield obtained with RDF which saves 25 % nitrogen and phosphorus fertilizers during *rainy* season. The present investigation encourage the use of biofertilizers along with organic and inorganic fertilizers for sustainable tomato production.

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