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IMPACT OF *AZOTOBACTER* WITH CHEMICAL FERTILIZERS ON GROWTH AND YIELD OF BRINJAL (*SOLANUM MELONGENA* L.) UNDER MID-HILLS OF HIMACHAL PRADESH, INDIA

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ABSTRACT

The study was conducted at the Research Farm of Abhilashi University, Mandi (H.P) during the summer season of 2024. Seven treatments have been studied using a randomized block design with three replications. The main objective of the research was to assess the impact of *Azotobacter* with chemical fertilizers on the growth and yield of brinjal crop. The results revealed that treatment T_2 (100% RDF + *Azotobacter*) recorded the maximum values of all parameters *viz*., plant height (88.54 cm), number of leaves per plant (98.12), leaf length (18.51 cm), leaf width (4.68 cm), number of fruits per plant (11.39), fruit length (20.65 cm), fruit diameter (5.12 cm), fruit weight (68.43 g), fruit yield per plant (779.41 g), fruit yield per plot (7.01 kg) and fruit yield per hectare (292.08 q) due to the combined use of inorganic fertilizers with *Azotobacter* which provide enough nutrients for their growth and development. The soil pH ranges from 5.8 to 5.9. The higher organic carbon (4.2%) was recorded in treatment T_6 (*Azotobacter*) and higher electrical conductivity (0.53 dS/m) was observed in treatment T_1 [100% RDF (220:375:85 kg/ha of NPK)]. The higher available N (306.52 kg/ha) in treatment T_2 (100% RDF + *Azotobacter*), P (24.57 kg/ha) and K (248.76 kg/ha) were recorded under treatment T_1 [100% RDF (220:375:85 kg/ha of NPK)]. In terms of economics, the maximum cost of cultivation (Rs. 92,662), gross returns (Rs. 4, 64,370), net returns (Rs. 3, 71,708) and B: C ratio (4.01) was recorded highest under treatment T_2 (100% RDF + *Azotobacter*). Hence, application of 100% RDF + *Azotobacter* can be recommended for its commercial use after verification of results by way of conducting on field trials across the brinjal growing areas of Himachal Pradesh.

Keywords: Brinjal, Fertilizers, Yield, Economics, *Azotobacter*.

Introduction

Brinjal (*Solanum melongena* L.) belongs to family Solanaceae having chromosome number is 2n = 2x = 24 and is an economically important vegetable crop grown in tropical and subtropical areas. Brinjal is a perennial but cultivated on commercial level as an annual crop. Because of its high productivity, it is typically considered as the poor man's crop. Plants are annual, herbaceous, and naturally erect or semi-spreading. After tomato, important vegetable crop is the brinjal. It originated in India and is sometimes referred to as eggplant (Kiran et al. 2010). Globally, India ranks second in brinjal after China. Other major brinjal producing countries include Indonesia, Egypt, Turkey, Iraq and the Philippines. In India it is grown in an area of 680.65 thousand hectares with the production of 12972.39 thousand MT (Anonymous 2022a). West Bengal, Odisha, Gujarat, Madhya Pradesh, Chhattisgarh, Maharashtra, Andhra Pradesh, Haryana, Assam, Uttar Pradesh, Jharkhand and Tamil Nadu are the leading states in India known for extensive brinjal cultivation. Being an important vegetable crop of mid hills of Himachal Pradesh it is grown in an area of about 1.16 thousand hectares with a production of 21.35 thousand MT (Anonymous 2022b).

In terms of nutritional value, raw brinjal containing low fat (0.18 - 0.20 g), 2.35 - 3.53 g of sugar, 9% dietary fibre, 6% carbohydrates, 2% protein and 92% water. It offers very modest percentages of the daily value (11%) for manganese and minimal levels of the other key nutrients (Ca, Fe, Mg, P, K and Zn). Brinjal is good for lowering blood cholesterol levels and controlling hypertension when eaten as part of a healthy diet (Gandhi and Sundari 2012). Fertilizer costs are rising daily, making it unsustainable for small and marginal farmers; also, the growing concern about environmental risks and the growing danger to sustainable agriculture are contributing to the depletion of soil fertility. In addition to the previously mentioned benefits, long-term usage of biofertilizers are more affordable, environment friendly, efficient, productive and accessible to small and marginal farmers than chemical fertilizers (Singh 2022).

Material and Methods

Experimental site

The present investigation was carried out at Research Farm, School of Agriculture, Abhilashi University, Mandi (H.P.) during the summer season of 2023. The Experimental site is located at 31°33’32’’N latitude and 77°00’40” E longitude with the elevation of 1,432 m amsl.

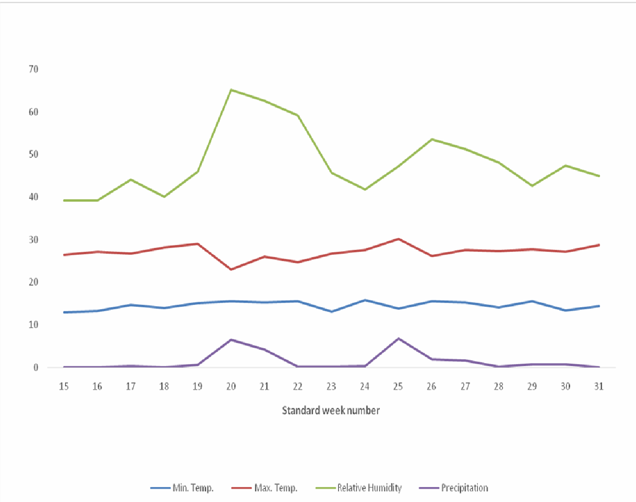

Fig. 1: Meteorological data of experimental farm was recorded from April to August, 2024.

Table 1 : Treatment details

Treatment code	Treatments
T_1	100% RDF
T_2	100% RDF + *Azotobacter*
T_3	75% RDF + *Azotobacter*
T_4	50% RDF + *Azotobacter*
T_5	25% RDF + *Azotobacter*
T_6	*Azotobacter*
T_7	Absolute Control

Design of experiment

The experiment was laid out in Randomized Block Design with three replications comprising seven treatment combinations of *Azotobacter* with chemical fertilizers. The layout plan is provided below:

Variety	Pusa Purple Long
Design	Randomized Block Design (RBD)
Replications (s)	3
Treatments	7
Plot size	1.60 m × 1.35 m
Spacing	45 cm × 45 cm
Date of sowing	1st March, 2024
Date of transplanting	9th April, 2024

Observations recorded

Crop studies

Five plants were randomly selected and tagged from each plot and observations were reported on the following characters.

1. Growth and yield parameters

Plant height (cm)

Five randomly selected plants were measured at harvest from base to the highest tip of the plant and the average mean height was calculated in centimetres.

Number of leaves per plant

Five random plants were selected from the plots and the number of leaves was counted. Further average was calculated as mean.

Leaf length (cm)

Five leaves were selected from lower, middle and top part of the selected plants per plot and then length of the leaves was measured from the tip of the entire leaf down to the base of the lowest leaflets where they meet the leaf stem the application ruler and average was worked out as mean length of leaves.

Leaf width (cm)

Leaf width was measured at the widest point perpendicular to the longitudinal axis of the leaf. The measurements were calculated and recorded by the application a measuring scale.

Number of fruits per plant

The total numbers of fruits harvested from five randomly selected plants in different pickings was summed up and average value per plant was worked out.

Fruit length (cm)

Mature fruits were selected and used for measuring the length of individual fruit. Fruit length was measured the application scale. The mean was calculated and expressed in centimetres.

Fruit diameter (cm)

After recording the length, same fruits were used for measuring the diameter. Fruit diameter was measured the application Vernier Calliper. The mean was calculated and expressed in centimetres.

Fruit weight (g)

After harvesting of fruits from selected 5 plants, the individual weight of fruit the application the digital balance was recorded and the average weight was calculated and expressed as fruit weight in grams.

Fruit yield per plant (kg)

Fruit produced from each plant was picked separately and the yield from various treatments was reported. The average yield of fruits per plant was calculated.

Fruit yield per plot (kg)

The total weight of harvested fruits of all the pickings was considered and the average yield per plant was calculated. From this value the total fruit yield per plot was worked out and values were expressed in kilogram.

Fruit yield per hectare (q)

On the basis of yield obtained from each plot in kilogram, yield per hectare (q) was calculated. The yield per plot (kg) was transformed into yield per hectare (q) by multiplying the respective figures with the common factor of 10.

2. Soil studies

After the experiment, random soil samples from the experimental site were collected at a depth of 0 to 15 cm was collected from all the plots separately. The soil samples were labelled, oven dried and grind with a wooden pestle and mortar to pass through a 2 mm sieve and stored in bags for chemical analysis.

Soil pH

Soil pH was determined in 1: 2.5 soil to water suspension after stirring the contents intermittently for half an hour. The pH value was recorded the application Glass electrode method (Jackson 1967).

Electrical conductivity (dS/m)

The electrical conductivity of soil was determined in 1:2 soil water suspension the application glass electrode digital EC meter (Jackson 1973).

Organic carbon (%)

Organic carbon or easily oxidizable organic carbon of soil samples were determined by Walkley and Blacks wet oxidation method. The soil (0.5 mm sieved) was treated with chromic acid to oxidize organic carbon to CO_2 and untreated $K_2Cr_2O_7$ was back titrated against standard ferrous ammonium sulphate the application diphenylamine indicator (Jackson, 1967).

Available N (kg/ha)

Available nitrogen in the soil (kg/ha) was determined through alkaline potassium permanganate method (Subbaiah and Asija 1956) by digestion, distillation and collection of NH_3 in 2 per cent boric acid and titrating it against standard sulphuric acid.

Available P (kg/ha)

Available phosphorus content was determined by stannous chloride reduced ammonium molybdate method the application Olsen's extractant (Olsen et al. 1954) and determined the application NUKES UV-VIS spectrophotometer at 660 nm wavelengths.

Available K (kg/ha)

Available potassium in soil (kg/ha) was extracted by neutral 1 N ammonium acetate and determined by flame photometer method as described by (Merwin and Peech 1951).

3. Economics

The cost of cultivation of each treatment was calculated per hectare on the basis of prevailing rates of labour, organic manures, irrigation and other expenditure. The total income per hectare was calculated as per the average wholesale price of broccoli in the market. The net profit per hectare was obtained by deducting the cost from treatment.

Cost of cultivation (Rs./ha)

By presuming the item-wise input cost based on the local market rate, the cost of cultivation per hectare of land was worked out and were computed treatment-wise also.

Gross returns (Rs/ha)

From the total yield of each treatment plot, the gross monetary return was worked out based on the average selling price of the product and it was recorded accordingly in Rs/ha.

Gross returns (Rs/ha) = Market price × yield/ha

Net returns (Rs/ha)

The most crucial factor to consider before recommending any remedies to farmers for widespread use is their economic viability. The cost of cultivation for each treatment was deducted from the gross return from the economic yield to determine the net return. Net returns (Rs/ha) are calculated as follows:

Net returns (Rs/ha) = Gross returns (Rs/ha) - Cost of cultivation (Rs/ha)

Benefit cost ratio (B: C ratio)

Benefit cost ratio was worked out for each nutrient treatment by adopting the following formula:

$$\text{Benefit : Cost ratio} = \frac{\text{Net returns (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

Results and Discussion

Growth studies

The maximum plant height (29.58 cm), maximum number of leaves per plant (98.12), maximum leaf length (18.51 cm) and maximum leaf width (4.68 cm) were recorded in treatment T_2 (100% RDF + *Azotobacter*). However, the minimum plant height (68.75 cm), number of leaves per plant (68.90), leaf length (10.13 cm) and leaf width (2.91 cm) were observed in T_7 (Absolute control). The increase in plant height with higher dose of nitrogen might be due to the fact that, nitrogen enhances the transport of metabolites and photosynthates in plant, which enables the plant to have quick and better upward vegetative growth. Phosphorus at highest level resulted in increase in plant height. It might be due to the role of phosphorus in structural components as in phospholipids and in absorbing and translocation of food material. The beneficial effect of potassium in promoting the growth of plants may be explained from the fact that potassium involved in synthesis of peptide bond as well as protein and carbohydrate metabolism. Increase in plant height with the application of NPK was in close proximity with the findings of Aminifard et al. (2010), Nafiu et al. (2011) and Sollapur and Hiremath (2017) in brinjal. However, Kiran (2006) found that the application of fertilizers combined with *Azotobacter* and PSB resulted in an increase in the number of leaves. In contrast, the application of chemical fertilizers alone led to a decrease in the number of leaves per plant. The application of 75% N of RDF + 2 kg *Azotobacter* showed the maximum number of leaves, maximum leaf length and maximum leaf width indicating that this treatment had the most significant positive effect on plant growth and development (Mishra et al. 2024).

Yield studies

The yield parameters were influenced by both inorganic fertilizers and biofertilizers. The maximum number of fruits per plant (12.14), maximum fruit length (20.65 cm), maximum fruit diameter (5.12 cm), maximum fruit weight (68.01 g), maximum fruit yield per plant (825.64 g), maximum yield per plot (7.43 kg) and maximum yield per hectare (309.58 q) were observed in treatment T_2 (100% RDF + *Azotobacter*). On the other hand, the minimum number of fruits per plant(7.26), maximum fruit length (10.05 cm), maximum fruit diameter (2.25 cm), maximum fruit weight (56.63 g), minimum fruit yield per plant (411.13 g), minimum yield per plot (3.70 kg) and minimum yield per hectare (154.16 q) were recorded in T_7 (Absolute control). When 100% NPK was applied along with *Azotobacter* can significantly enhance both growth and productivity of brinjal. This approach provides a balanced and sustainable method for improving crop performance while promoting soil health and reducing dependency on synthetic fertilizers. The results are in accordance with Anburani and Manivannan (2002). The application of *Azotobacter* with chemical fertilizers increased average fruit weight. These findings indicate that the combination of reduced fertilizer dosage with the addition of biofertilizers like *Azotobacter* can lead to significant improvements in brinjal growth**,** fruit production and yield. This approach not only enhances productivity but also promotes more sustainable agricultural practices by reducing dependency on synthetic fertilizers. The integration of biofertilizers offers an environmentally friendly way to optimize nutrient management, making it a promising strategy for maintaining or even enhancing crop yield while minimizing environmental impacts (Tank et al. 2010). The highest fruit yield per plant can be achieved by the application of 100% RDF + *Azotobacter*. Similar results were in accordance with Patel et al. (2011) in which the brinjal yield was increased with the application of 100% RDF combined with *Azospirillum*, *Azotobacter* and PSB. The minimum fruit yield per plant was obtained in treatment T_0 (Control) in which there was no use of chemicals and fertilizers. So the fruit yield per plant cannot be highest due to deficiency of nutrients (Sherpa et al. 2019). The increased number, size and weight of fruits resulted in higher fruit yield. The increase in fruit yield might be due to improvement in growth of plant which in turn led to higher production. Phosphorus fertilization also enhanced translocation and partitioning of assimilates to floral parts, resulting in improved yield attributes, which obviously resulted in higher fruit yield. The beneficial effect of potassium can be explained from the fact that potassium involved in synthesis of peptide bond and protein and carbohydrate metabolism, thus increases fruit yield. Similar results were obtained by Aminifard et al. (2010) in brinjal.

Soil studies

Available N, P and K (kg/ha)

The maximum amount of available nitrogen (306.52 kg/ha) was recorded in treatment T_2: 100% RDF + *Azotobacter*. Maximum available phosphorous (24.57 kg/ha) and potassium (248.76 kg/ha) were recorded in treatment T_1: 100% RDF. However, the minimum amount of available nitrogen (208.19 kg/ha), available phosphorus (14.08 kg/ha) and available potassium (194.52 kg/ha) was measured in T_7 (Absolute control). The increase in NPK content in soil with the application of 100% RDF might be due to the synergistic effect of NPK fertilizers. This combination likely reduces the fixation of water-soluble phosphorus while enhancing mineralization, which in turn increases phosphorus availability (Chumei et al. 2013). Significant differences were observed between the various treatments in terms of available nitrogen in the soil. As the NPK levels increased, the available nitrogen in the soil also showed a corresponding rise. This increase can likely be attributed to the higher availability of ammonium ions (NH_4^+) for soil bacteria, which convert these ions into nitrate (NO_3^-) through nitrification, thereby enhancing nitrogen availability. The higher nitrogen content in the soil may also be a result of increased application rates. Conversely, the control treatment showed a decline in available nitrogen, likely due to the depletion of soil nutrients by plant uptake. These findings align with the studies by Sollapur and Hiremath (2017).

Soil pH, EC and OC

The soil pH varied from 5.8 to 5.9. The highest electrical conductivity (0.53 dS/m) in soil was observed in treatment T_1 (100% RDF) while the highest organic carbon (0.42%) in soil was observed in treatment T_6 (*Azotobacter*) which was statistically at par with treatment T_5. However, the lowest organic carbon (0.29 %) was recorded in T_7 (Absolute control) and the lowest water-holding capacity (0.40 dS/m) was observed in T_7 (Absolute control). The lower organic carbon content in the control could be attributed to the absence of fertilizer, manure or biofertilizer. The higher organic carbon content in plots treated with vermicompost, chemical fertilizers or *Azotobacter* is likely due to better crop growth, which leads to increased root biomass. *Azotobacter* play a significant role in enhancing soil organic carbon by promoting microbial activity that helps sequester carbon from mineralized organic materials into the soil carbon pool (Singh and Bhatt 2016). This effect is further amplified by fertilizer application, which improves root and shoot growth, leading to increased root biomass and consequently higher organic carbon content. These findings are consistent with studies by Chumei et al. (2013) and Thingujam et al. (2016).

Economics

The combination of *Azotobacter* with chemical fertilizers has a significant effect on economics. The highest cost of cultivation (Rs. 92,662), gross returns (Rs. 4, 64,370), net returns (Rs. 3, 71,708) and B: C ratio (4.01) was recorded highest under treatment T_2 (100% RDF + *Azotobacter*) whereas the lowest cost of cultivation was found in T_7 (Absolute control) i.e. (Rs. 78,424). The highest gross returns (Rs. 4,64,370), net returns (Rs. 3, 71,708) and B: C ratio (4.01) were incurred in T_2 (100% RDF + *Azotobacter*) and the minimum gross returns (Rs. 2, 31,240), net returns (Rs. 1,52,816) and B: C ratio (1.94) was incurred in T_7 (Absolute control) respectively.

Conclusion

The present investigation pertaining to influence of *Azotobacter* with chemical fertilizers showed significant effect for all growth, yield and soil parameters. Results showed that the application of 100% RDF combined with *Azotobacter* proved best for growth, yield and soil parameters. Based on studies, it can be concluded that the treatment T_2 (100% RDF + *Azotobacter*) performed best in terms of growth, yield, available N, P and K, as well as gross returns, net returns and B: C ratio. Therefore, on the basis of present investigation it may be recommended for its commercialization after verification of results by way of conducting on farm trials across the brinjal growing areas of Himachal Pradesh.

Table 2 : Initial soil chemical properties of the experimental site

Sr. No.	Soil properties	Values obtained	Method employed
1.	Soil pH (1:2.5 soil: water)	5.7	Glass electrode pH meter (Jackson 1967)
2.	Electrical conductivity (dS/m)	0.39	Electrical conductivity meter 1:2.5 soil water suspension (Jackson 1973)
3.	Organic carbon (%)	0.28	Rapid titration method (Walkley and Black 1934)
4.	Available N (kg/ha)	225.43	Alkaline potassium permanganate method (Subbiah and Asija 1956)
5.	Available P (kg/ha)	13.54	Olsen's extraction method 0.5 $NaHCO_3$ at pH 8.5 (Olsen *et al.* 1954)
6.	Available K (kg/ha)	192.78	Neutral Ammonium acetate extraction method (Merwin and Peech 1950)

Table 3 : Influence of *Azotobacter* with chemical fertilizers on plant height (cm), number of leaves per plant, leaf length (cm) and leaf width (cm).

Treatment details	Plant height (cm)	Number of leaves per plant	Leaf length (cm)	Leaf width (cm)
100% RDF	81.46	91.03	16.87	3.87
100% RDF + *Azotobacter*	88.54	98.12	18.51	4.68
75% RDF + *Azotobacter*	84.27	94.62	17.46	4.32
50% RDF + *Azotobacter*	76.91	89.58	16.04	3.44
25% RDF + *Azotobacter*	72.09	85.75	13.82	3.25
Azotobacter	70.13	76.32	12.91	3.06
Absolute control	68.75	68.90	10.13	2.91
SE(m) (±)	**1.15**	**1.38**	**0.24**	**0.06**
CD (P=0.05)	**3.56**	**4.26**	**0.76**	**0.19**

Table 4 : Influence of *Azotobacter* with chemical fertilizers on number of fruits per plant, fruit length (cm), fruit diameter (cm) and fruit weight (g).

Treatment details	Number of fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)
100% RDF	11.78	16.38	4.36	66.25
100% RDF + *Azotobacter*	12.14	20.65	5.12	68.01
75% RDF + *Azotobacter*	11.97	18.13	4.78	66.54
50% RDF + *Azotobacter*	10.43	14.57	3.64	64.72
25% RDF + *Azotobacter*	9.61	13.29	3.43	62.36
Azotobacter	9.32	12.82	2.54	60.48
Absolute control	7.26	10.05	2.25	56.63
SE(m) (±)	**0.11**	**0.16**	**0.06**	**0.91**
CD (P=0.05)	**0.36**	**0.52**	**0.19**	**2.83**

Table 5 : Influence of *Azotobacter* with chemical fertilizers on fruit yield per plant (g), fruit yield per plot (kg) and fruit yield per hectare (q).

Treatment details	Fruit yield per plant (g)	Fruit yield per plot (kg)	Fruit yield per hectare (q)
100% RDF	780.42	7.02	292.50
100% RDF + *Azotobacter*	825.64	7.43	309.58
75% RDF + *Azotobacter*	796.48	7.16	298.33
50% RDF + *Azotobacter*	675.02	6.07	252.91
25% RDF + *Azotobacter*	599.27	5.39	224.58
Azotobacter	563.67	5.07	211.25
Absolute control	411.13	3.70	154.16
SE(m) (±)	**12.25**	**0.08**	**2.38**
CD (P=0.05)	**37.77**	**0.26**	**7.34**

Table 6 : Influence of *Azotobacter* with chemical fertilizers on available N, P and K, soil pH, electrical conductivity (dS/m) and organic carbon (%).

Treatment details	Soil pH	Electrical conductivity (dS/m)	Organic carbon (%)	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available potassium (kg/ha)
100% RDF	5.8	0.53	0.31	294.25	24.57	248.76
100% RDF + *Azotobacter*	5.9	0.48	0.34	306.52	24.16	246.08
75% RDF + *Azotobacter*	5.9	0.45	0.36	289.70	22.63	240.81
50% RDF + *Azotobacter*	5.9	0.44	0.39	273.97	20.85	235.43
25% RDF + *Azotobacter*	5.8	0.40	0.40	259.84	18.31	224.29
Azotobacter	5.9	0.40	0.42	246.38	14.10	218.63
Absolute control	5.8	0.40	0.29	230.19	14.08	194.52
SE(m) (±)	**0.0**	**0.03**	**0.01**	**4.81**	**0.20**	**3.64**
CD (P=0.05)	**NS**	**NS**	**0.02**	**14.85**	**0.63**	**11.24**

Table 7 : Economics

Treatment code	Treatment details	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B: C ratio
T1	100% RDF	89,812	4,38,120	3,48,308	3.87:1
T2	100% RDF + *Azotobacter*	92,662	4,64,370	3,71,708	4.01:1
T3	75% RDF + *Azotobacter*	89,815	4,48,125	3,58,310	3.98:1
T4	50% RDF + *Azotobacter*	86,968	3,86,865	2,99,897	3.44:1
T5	25% RDF + *Azotobacter*	84,121	3,36,870	2,52,749	3.00:1
T6	*Azotobacter*	81,274	3,16,875	2,35,601	2.89:1
T7	Absolute control	78,424	2,27,490	1,49,066	1.94:1

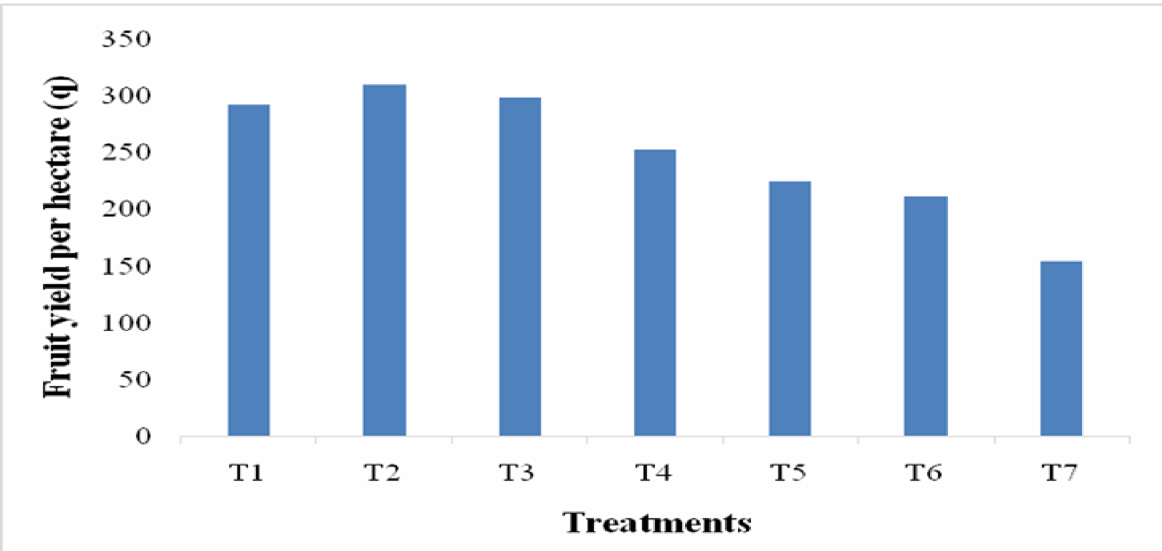

Fig. 2: Influence of *Azotobacter* with chemical fertilizers on fruit yield per hectare

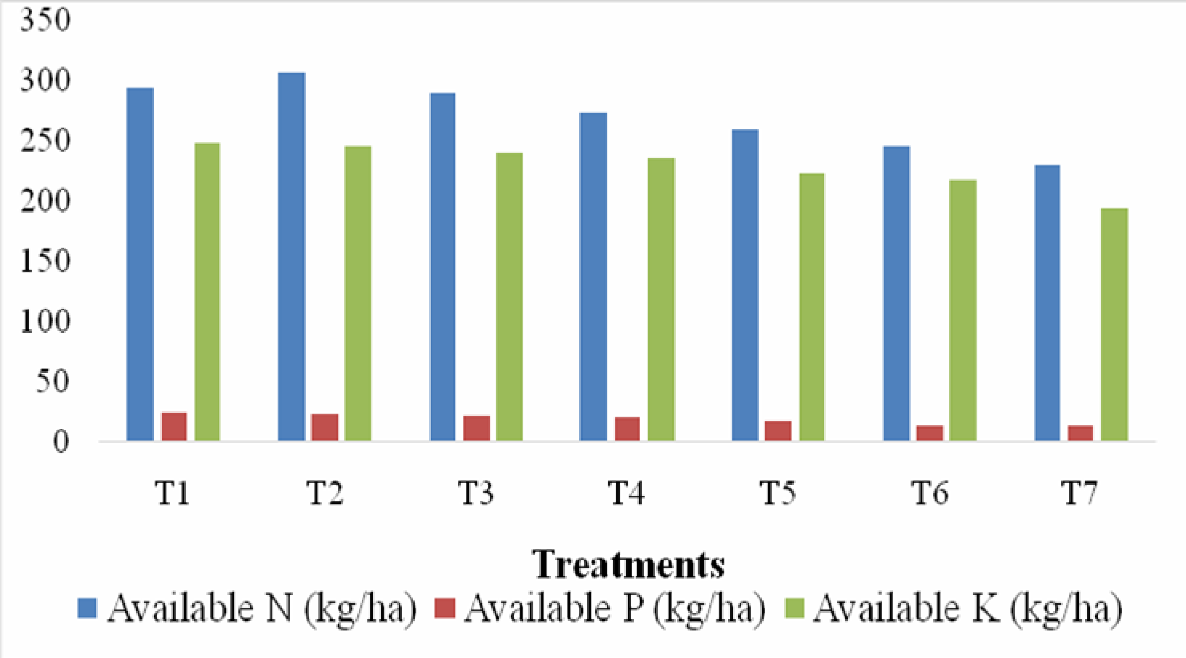

Fig. 3 : Influence of *Azotobacter* with chemical fertilizers on N, P and K (kg/ha)

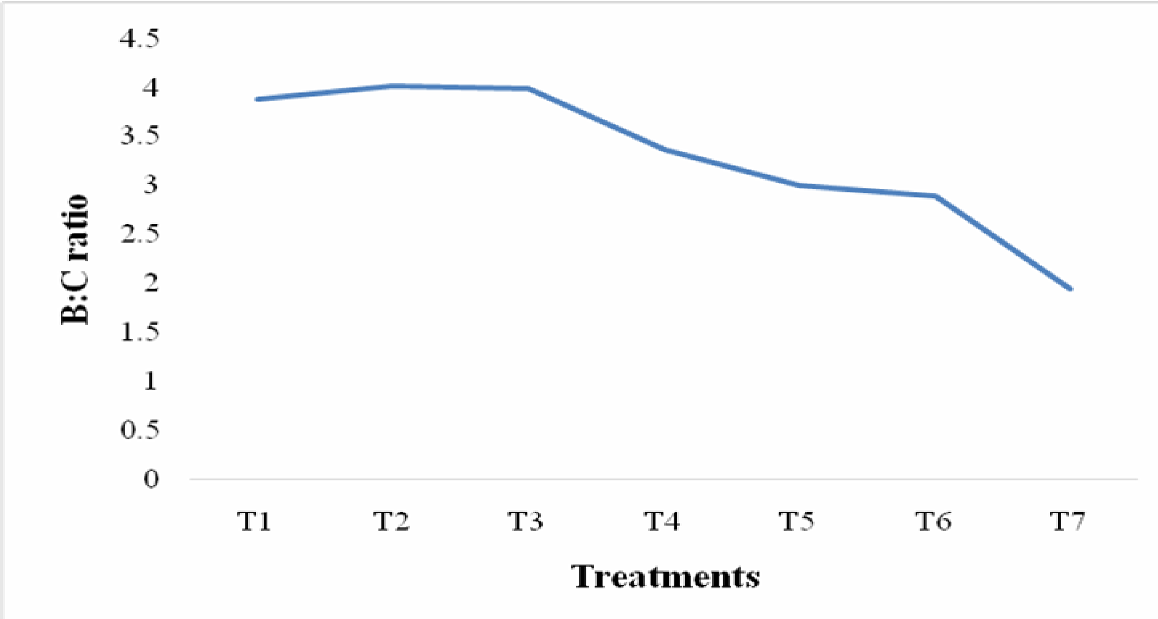

Fig. 4 : Influence of *Azotobacter* with chemical fertilizers on B: C ratio

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