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IMPACT OF *AZOSPIRILLUM* WITH INORGANIC FERTILIZERS ON GROWTH AND YIELD OF CHILLI (*CAPSICUM ANNUUM* L.) UNDER NORTH WESTERN HIMALAYAN REGION

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ABSTRACT

The present investigation was carried out at the Research farm of Abhilashi University, Mandi (H.P) during the summer season of 2024. The experiment was laid out in a randomized block design with three replications comprising seven treatments consisting of different combinations of organic manures and inorganic fertilizers to assess the impact of integrated nutrient management on growth, yield, soil and economics of okra crop. The results revealed that treatment T_2 (100% RDF + *Azospirillum*) influenced all parameters like days of flower appearance (69.42), plant height (66.39 cm), number of primary (7.94 cm), ,fruit weight (3.55g), number of fruits per plant (28.45), yield per plot (1.52 kg), yield per hectare (60.52 q), available nitrogen (305.52 kg/ha), available phosphorus (14.20 kg/ha), available potassium (248.37 kg/ha). The maximum organic carbon (0.55%) was recorded in treatment T1 [100% RDF +150:475:90kg/ha] respectively. The economics in terms of gross returns (Rs. 332915), net returns (Rs. 241157) and B: C ratio (2.62) were also maximum in T_7.
Keywords: Chilli, *Azospirillum*, Yield, Economics.

Introduction

Chilli is a commercial important spice and vegetable crop cultivated across the world for its green and ripe fruits (*Capsicum annum* L.) belongs to the Solanaceae family. Chilli is grown for its pungent fruits, which are used both as green and ripe or dry form. It is becoming an important crop word wide due to it wide diversity and high-quality flavour, concentration of vitamins and other antioxidants (Bharurupe *et al.*, 2013).

In India chilli is grown in an area of 427 thousand hectare with the production of 4700 thousand metric tonnes (Anonmyous, 2022a). The major chilli producing states are Andhra Pradesh, Telangana, Madhya Pradesh, West Bengal, Karnataka and Tamil Nadu. In Himachal Pradesh, it is grown in area of 1.14 thousand hectare and production of 13.48 metric tonnes (Anonmyous, 2022b). Chilli contains a range of essential nutrients and bioactive compound which are known to exhibit antioxidant, antimicrobial, antiviral, anti- inflammatory and anticancer properties. It is an excellent source of vitamin A, B, C and E (Qureshi *et al.*, 2015). Pungency in chilli is due to an active principle capsaicin which can directly scavenge various free radicals and thus act as antcancerous compound. It is also a good source of oleoresin, which permits better distribution of colour and flavor in foods (Chattopadhyay *et al.*, 2011). Biofertilizers offer an economically viable and ecologically sound augmenting nutrient supplies and can play a key role in bridging gap between nutrient removal by crop and addition through fertilizer (Tewatia *et al.*, 2007; Chauhan *et al.*, 2023). Biofertilizer contains microorganism that helps in mobilizing nutritive elements from non-usable from to usable from through a different biological process. The microorganisms like *Azospirillum* are considered important not only for nitrogen fixing efficiency but also for their ability to produce antibacterial antifungal compound and growth regulators.

Material and Methods

Experimental site

The study was carried out at Research Farm, Department of Horticulture, School of Agriculture, Abhilashi University, Mandi (H.P.) during the summer season of 2023-24. Geographically the experimental farm is located at the latitude of 31º33'34''N and longitude of 77º00'44''E and a height of 1,416 meters above the average ocean level.

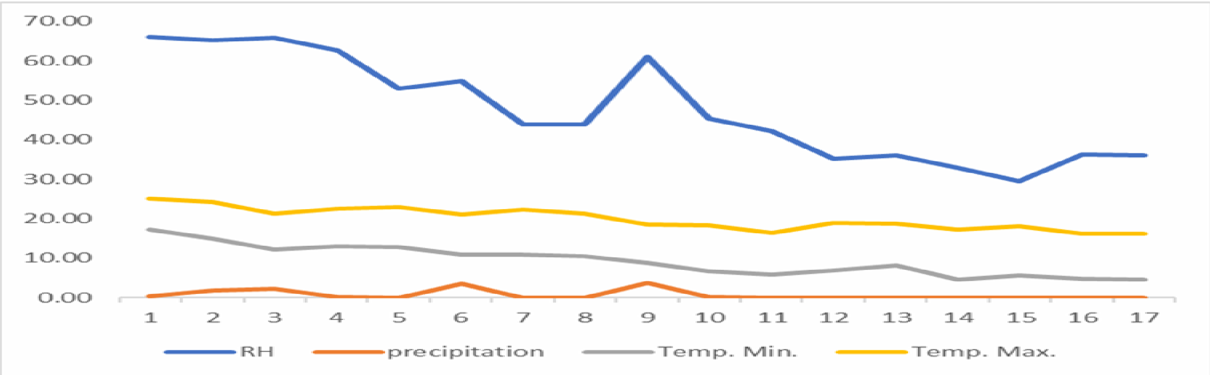

Fig. 1: Meteorological data of experimental farm was recorded from March, 2024 to July, 2024.

Table 1 : Treatment details

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

Note: Recommended dose of fertilizers 150: 475: 90 kg/ha N, P_2O_5 and K_2O

Design of experiment

The experiment was laid out in Randomized Block Design with three replications comprising seven treatment combinations of inorganic fertilizer with *Azospirillum*.

Variety	Pusa Jawala
Design	Randomized Complete Block Design (RCBD)
Replications (s)	3
Treatments	7
Plot size	1.60m × 1.60 m = 2.56m^2
Spacing	45 cm × 45 cm
Date of sowing	28th April, 2024

Crop Studies

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

Growth and yield parameters

Plant height (cm)

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

Number of primary branches

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

Days of flowering

It was recorded as number of days taken from the date of transplanting to the date when the flower emerged of the plants in a plot per treatment.

Number of fruits per plant

Among the five selected plants, the number of fruits on each plant were counted and an average was calculated.

Fruit weight (g)

Following the fruit harvesting process from five selected plants, each fruit's weight was measured with a digital balance. Among the five selected plants, the number of fruit on each plant was counted, and an average was calculated.

Fruit yield per plot (kg)

The weight of all the fruits collected over all harvests in a particular plot or treatment was combined to determine the yield per plot.

Fruit yield per hectare (q)

Yield per hectare was calculated in quintals using the yield produced from each plot in kilograms. The yield per plot (kg) was transformed into yield per hectare (q) by multiplying the respective figures with the common factor of 10.

Soil pH

The pH of the soil was measured in a 1:2.5 soil to water suspension after 30 minutes of sporadic stirring of the contents. The glass electrode method was used to record the pH value (Jackson 1967).

Electrical conductivity (dS/m)

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

Organic carbon (%)

The organic carbon in soil samples, or the easily oxidizable organic carbon, was measured using the Walkley and Blacks wet oxidation method. Using a diphenylamine indicator, untreated $K_2Cr_2O_7$ was back titrated against standard ferrous ammonium sulphate after the soil (0.5 mm sieved) was treated with chromic acid to oxidize organic carbon to CO_2 (Jackson1967).

Available N (kg/ha)

The alkaline potassium permanganate method (Subbaiah and Asija1956) was used to calculate the amount of available nitrogen in the soil (kg/ha). This involved digesting, distilling, and collecting NH_3 in 2% boric acid and titrating it against standard sulphuric acid.

Available P (kg/ha)

Olsen's extractant (Olsen *et al.*, 1954) was used to determine the available phosphorus level, which was then measured at 660 nm wavelength using a NUKES UV-VIS spectrophotometer.

Available K (kg/ha)

The amount of available potassium in the soil (kg/ha) was measured using a flame photometer after being extracted with neutral 1 N ammonium acetate (Merwin and Peech, 1951).

Economics

On the basis of current labour, organic manure, irrigation, and other expense rates, the cost of cultivation for each treatment was estimated per hectare. The average market price for capsicum at wholesale determined the total income per acre. After subtracting the treatment cost, the net profit per hectare was calculated.

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 return (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 were 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

Plant growth characters like plant height (66.39 cm) and number of branches (7.94) were recorded maximum in T_2 100% RDF + *Azospirillum* and minimum were in treatment T_7 (Absolute control). The minimum days of flowering (69.42) while the maximum days of flowering (94.88) was recorded in treatment T_7 (Absolute control) The possible reason for maximum plant height in T_2 might be due to use of nitrogen, phosphorus and potassium in higher amount which helped in enhancing better plant height the (Singh, 2009; Adhikari *et al.*, 2016). This might be due to availability of dry matter in organic manure namely poultry manure that contains more nutrients and higher light interception which resulted in increased leaf area and higher photosynthetic activity and improved plant growth. These results are in agreement with findings of Islam *et al*. (2018). Similar results were obtained by, Khan and Chattopadhyay (2009), Kumar *et al*. (2014), Chauhan *et al*. (2024) and Islam *et al*. (2018).

Yield studies

Yield parameters like number of fruits per plant (96.67), fruit weight (3.55 g), fruit yield per plot (1.52 kg) and fruit yield per hectare (60.53 q) were maximum in treatment $_{T2}$ 100% RDF + *Azospirillum* while minimum was recorded in treatment T_7 (Absolute control). Increase in yield plot by the application of T_2 was might be due to adequate supply of nutrients from *Azospirillum* and inorganic source of which probably favoured the production of maximum fruit with optimum size and led to higher yield per plot. Similar result was finding observed by Sheikh *et al*. (2017) and Aslam *et al*. (2022). This result indicates positive effects of integrating NPK with manures as well as biofertilizers. On the other hand, application of 100% NPK in chilli was found to produce inferior result than other treatments. The favourable response of biofertilizers in combination with organics or inorganics was also reported by Khan and Chattopadhyay (2009) and Chauhan *et al*. (2022).

Soil studies

Soil pH, EC and OC

Soil pH is most important parameter that influences the chemical, physical and biological properties of soil, thereby playing a crucial role in determining soil fertility and plant growth. It is a measure of the acidity or alkalinity of soil, indicating the concentration of hydrogen ions in the soil solution. The pH scale ranges from 0 to 14, with pH 7.0 being neutral, pH values below 7.0 indicating acidity and pH values above 7.0 indicating alkalinity. An introspection of data shown in Table 4 revealed that there was a substantial effect of different *Azospirillum* and inorganic fertilizer treatment combinations on soil pH. The pH of soil varied from 5.8 to 6.0, there is an increase in pH (5.84) with the application of treatment T2 (100% RDF +*Azospirillum*) maximum soil pH. Whereas minimum (5.79) soil pH was recorded in the treatment T7 (Absolute control).

Soil analysis revealed that the maximum (0.52ds/m) Electrical conductivity T_1 (100% RDF 150:475:90 kg/ha) while minimum was in treatment T_7 (Absolute control). Similarly, maximum pH (5.84) was observed under treatment T_1 (100% RDF 150:475:90 kg/ha) and minimum was recorded in treatment T_7 (Absolute control). Maximum organic carbon (0.55%) and minimum was recorded in treatment T_7 (Absolute control). Organic carbon of soil acts as a sink and source of nutrients for microbial population, which regulates the availability of different nutrients through microbial transformation. The net increase in organic carbon may be due to increased microbial activities in the root zone which decomposed organic manures and also fixed unavailable form of mineral nutrients into available forms in soil thereby substantiated crop requirements and improved organic carbon level and stabilized soil pH (Chumei *et al*. 2013). The net increase in organic carbon might be due to the combined application of organic manures, inorganic fertilizers and biofertilizers (Lal and Kanaujia, 2013). Similar results of this present investigation were also in concordance with the findings reported by (Lal and Kanaujia, 2013).

Available N, P and K (kg/ha)

Maximum NPK T_1 (100% RDF 150:475:90 kg/ha) and minimum was recorded in treatment T_7 (Absolute control). The higher content of potassium in soil were found in T1 (100% RDF + RDF 150:475:90 kg/ha) which is 248.37 (kg/ha) which was followed by T2 (100 % RDF+ *Azospirillum*). However lowest content of available potassium with T7 (Absolute control). The higher content (14.20) of available phosphorus was observed T1 (100 % RDF). Whereas lowest content of phosphorus (13.10 kg/ha) was followed in T3 (Absolute control) *Azosopirillum* inoculation saved 50% of the recommended nitrogen rate and improved N-use efficiency. Shalini *et al*. (2002) demonstrated that plots receiving organics and *Azospirillum* had higher available soil N content than those with inorganic fertilizers only. The similarly result were reported by Singh D *et al* (2009) and Raturi *et al*. (2019) The availability of available phosphorus content was increased by combining of organic manure and inorganic fertilizer. The similar result are in finding with Singh *et al.* (2009) and Raturi *et al*. 2019. The possible reason might be due to increasing soil moisture increase K movement to plant roots and enhances availability. The similar finding the result were recorded by Singh D *et al*. (2009) and Raturi *et al*. (2019).

Economics

A perusal of data revealed that maximum cost of cultivation Rs. 91758) was incurred in treatment T2 (100% RDF + *Azospirillum*) which was followed by T1 (100 % RDF 150: 475 :90 kg/ha) i.e. Rs. 90906 while the minimum cost of cultivation T7 (Absolute control) i.e. Rs. 77976 .The maximum gross returns income per hectare amounting to Rs. 332915 was obtained treatment T_2 (100% RDF + *Azospirillum*) which was followed by T3 (75% RDF + *Azospirillum*) Rs. 300025 . On the other hand the minimum gross return Rs. 223355 was recored in treatment T7 (Absolute control). Highest net return Rs. 241157 was estimated in T2 (100% RDF + *Azospirillum*). This treatment is followed by T3 (75% RDF + *Azospirillum*) which is Rs. 213661 and T4 (50% RDF + *Azospirillum*) Rs. 185335. Whereas lowest net return Rs. 144419 observed in T7 (Absolute control). The treatment T2 (100% RDF + *Azospirillum*) showed highest B :C ratio 2.62:8. It might be due to the low cost of cultivation 2.47:3 in the treatment which was followed by T 3 (75% RDF + *Azospirillum*) and minimum was recorded in treatment T_7 (Absolute control).

Conclusion

From the present studies, it can be concluded that among all the treatments, 100% RDF + *Azospirillum* performed best for most of the growth, yield and yield contributing traits. It also resulted in maximum gross returns and net return with highest benefit cost ratio. Under soil analysis treatment T_2 treatments shows increase in nutrient availability and improvement in chemical properties of soil. 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 chilli growing areas of Himachal Pradesh.

Table 2 : Physico-chemical parameters of the experimental plot

Sr. No.	Parameters	Values obtained	Methods used
1.	Water holding capacity (%)	18.1	Keen's box method (Keen and Raczkowaski, 1973)
2.	Soil pH (1: 2.5 soil: water)	5.9	Glass electrode method (Jackson, 1973)
3.	Available Nitrogen (kg/ha)	209.4	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
4.	Available Phosphorus (kg/ha)	13.8	Olsen's method of extraction with 0.5 1NaHCO_3 at pH 8.5 (Olsen *et al.,* 1954)
5.	Available Potassium (kg/ha)	196.7	Neutral ammonium acetate method (Merwin and Peech, 1950)
6.	Organic carbon (%)	0.7	Rapid titration method (Walkley and Black, 1934)

Table 3 : Effect of *Azospirillum* and inorganic sources of nutrient on plant height (cm), number of leaves per plant, days of flowering.

Treatment code	Treatments	Plant height (cm)	Number of primary branches	Days of flowering
T_1	100% RDF	56.78	7.52	74.45
T_2	100% RDF + *Azospirillum*	66.39	7.94	69.42
T_3	75% RDF + *Azospirillum*	61.44	6.50	71.49
T_4	50% RDF + *Azospirillum*	52.65	6.42	79.53
T_5	25% RDF + *Azospirillum*	48.92	5.50	84.55
T_6	*Azospirillum*	45.72	4.40	89.72
T_7	Absolute control	42.62	4.10	94.88
	SE(m) (±)	0.71	0.71	1.01
	CD (0.05)	2.20	2.20	3.13

Table 4: Effect of *Azospirillum* with inorganic sources nutrient on number of fruit, weight of whole plant (g), yield per plot (kg) and yield per hectare (q)

Treatment code	Treatments	Number of fruit per plant	Fruit weight (g)	Yield per plot (kg)	Yield per hectare (q)
T_1	100% RDF	89.82	2.77	1.29	51.37
T_2	100% RDF + *Azospirillum*	96.36	3.55	1.52	60.53
T_3	75%RDF + *Azospirillum*	91.55	2.98	1.37	54.55
T_4	50%RDF + *Azospirillum*	84.72	1.88	1.21	48.18
T_5	25%RDF + *Azospirillum*	79.45	1.73	1.11	44.22
T_6	*Azospirillum*	76.42	1.55	1.02	40.61
T_7	Absolute control	61.38	1.45	0.92	36.13
	SE(m) (±)	0.90	0.01	0.02	0.07
	CD (0.05)	2.80	0.05	0.06	2.09

Table 5 : Effect of *Azospirillum* and inorganic sources nutrient on available N, P and K, soil pH, Electrical conductivity and organic carbon (%).

Treatment code	Treatment details	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T1	100% RDF	293.25	14.20	248.37
T2	100% RDF + *Azospirillum*	305.52	13.15	241.76
T3	75% RDF + *Azospirillum*	288.70	14.10	239.80
T4	50% RDF + *Azospirillum*	272.97	13.90	234.42
T5	25% RDF + *Azospirillum*	258.84	13.10	223.28
T6	*Azospirillum*	245.38	13.60	217.62
T7	Absolute control	229.19	13.10	192.51
	SE(m) (±)	**3.79**	**0.46**	**3.59**
	CD (0.05)	**11.8**	**1.44**	**11.6**

Table 5 : Effect of different treatments on the economics of chilli

Treatment code	Treatment	Cost of cultivation (Rs.)	Gross return (Rs.)	Net return (Rs.)	Beneifit cost ratio
T1	100 % RDF	90906	282535	191626	2.10:1
T2	100% RDF + *Azospirillum*	91758	332915	241157	2.62:1
T3	75% RDF + *Azospirillum*	86364	300025	213661	2.47:1
T4	50% RDF + *Azospirillum*	79655	264990	185335	2.32:1
T5	25% RDF + *Azospirillum*	91168	243210	152042	1.66:1
T6	*Azospirillum*	78936	223355	144419	1.82:1
T7	Absolute control	77976	198660	120684	1.54:1

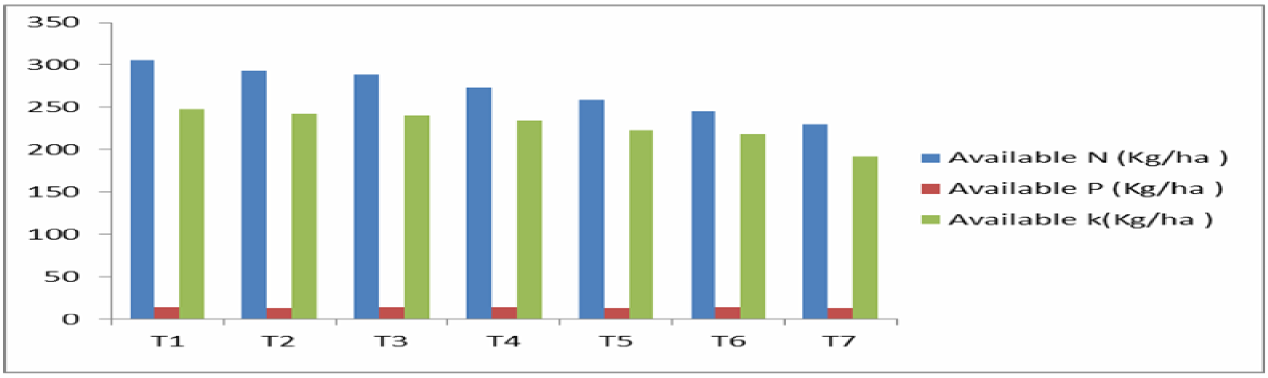

Fig. 2: Effect of *Azospirillum* and inorganic sources of nutrients on available N, P and K (kg/ha)

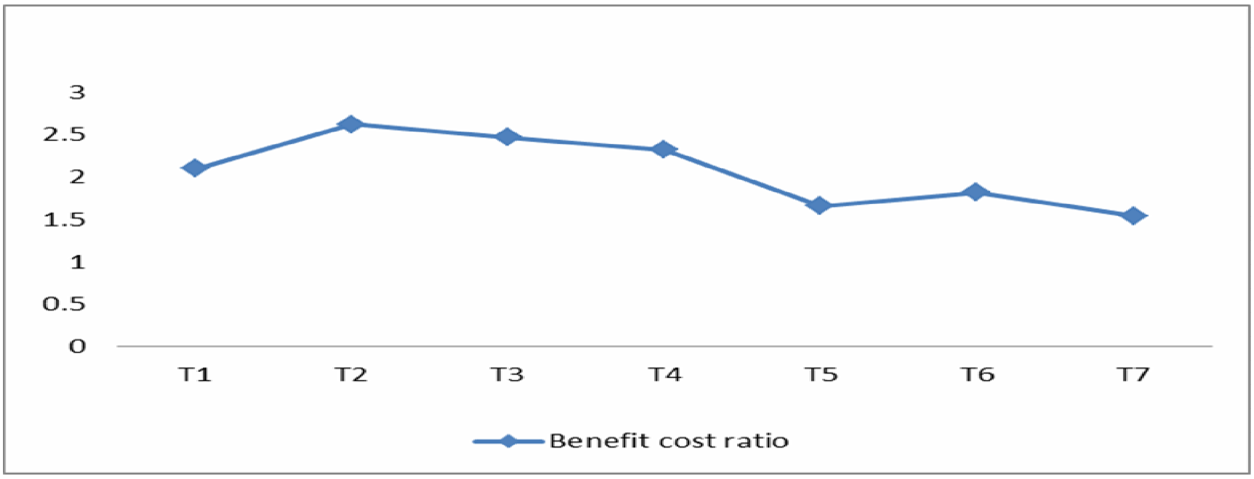

Fig. 3: Effect of *Azospirillum* and inorganic sources of nutrients on Benefit cost ratio

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