Original Research Article

EFECT OF BIO-FERTILIZERS ON YIELD AND ITS ATTRIBUTING TRAITS ON FENNEL (*Foeniculum vulgare* L.)

ABSTRACT

The present investigation entitled **Effect of bio-fertilizers on yield and its attributing traits on fennel (*Foeniculumvulgare* L.)** was carried out during October, 2022 to April 2023 at Horticultural Research Field, Department of Horticulture, Naini Agricultural Institute, SHUATS, it was concluded that the application of bio fertilizer treatments rendered their significant effect on almost all the growth and yield characters as well as quality of fennel (At least two season crop data should be compared, good results not possible in six months study). The treatment T7, i.e. 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha) application was found superior in terms of plant height (203.47cm), number of branches (15.55), days taken for 50% flowering (105.33 days),days taken for maturity (159.68 days), number of umbel per plant (14.61), number of umbellates per umbel (23.16), number of seeds per umbellates (33.90), seed yield per plant (30.80 g), seed yield per hectare (2.41 t/ha) and test weight (7.17 g). Among the different treatments the highest Gross return (Rs/ha) (3,61,500), Net return (Rs/ha) (2,42,04.7), benefit cost ratio (3.02) was also obtained from treatment (T7), that is, 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha).

Key words:*Fennel, Bio fertilizers, growth, yieldAzotobacter, Azospirillium*

1. INTRODUCTION

Fennel (*Foeniculum vulgare Mill*.) is one of the most important seed spice crops grown in India belongs to the family Apiaceae (Umbelliferae),grown for its seeds. It is widely cultivated throughout the temperate and tropical regions of the world and is thought to be the native of

southern Europe and Mediterranean region. It is perennial, but it is grown as annual or biennial. It is cultivated throughout the temperate and subtropical regions of the world for its aromatic seeds which are used for culinary purpose. Plants have dark green or bronze wispy leaves with yellow flowers on compound umbels and are cross pollinated.

The seeds of fennel have been used for their flavour and spice in food industry. Fennel seeds are useful in various ailments as it contains phytonutrients and antioxidants.Theanethole, makes fennel highly nutritious and powerful. It has been used to stimulate lactation in animals. It is a remedy against colic, cough and asthma and is a safeguard against blindness (**Slmon*et al.*, 1984**). It has number of pharmaceutical uses and it is the most important medicinal crop that finds use in the indigenous 'Unani' and allopathic system of medicines. Phytochemicals found in fennel fruit have been shown in bio pharmacological investigations to be effective as an antioxidant, anticancer, antibacterial, antifungal, antithrombotic, anti-inflammatory, chemopreventive, hepatoprotective, memory-enhancing, anti-aging, antidiabetic, and insecticide (Hossam et al .2023)

India accounts about 45% of the global spice export. Major production centres of fennel in India are Rajasthan, Andhra Pradesh, Telangana, Punjab, Madhya Pradesh, Uttar Pradesh and Karnataka. In India, fennel is cultivated over an area of 1,00,000 ha with production of 1,43,000 m ton and productivity of 1430 kg/ha. (**Sharma*et al*, 2017**).

Indian farmers pay reasonable attention to cultivation, especially in respect of seed bed preparation, manuring and irrigation, however sufficient attention has not been paid to fertilizer management aspect which remains one of the constraints in boosting up the production. Among the several agro techniques, the proper supply of major nutrients like nitrogen, phosphorus and potassium are of greater importance. Nitrogen is an essential constituent of protein, chlorophyll and nitrogen is present in many compounds of physiological importance in crop metabolism such as nucleotides, phospholipids, alkaloids, enzymes, hormones and vitamins etc. Nitrogen promotes growth of leaves and stem. Phosphorus, being the constituent of nucleic acid and phospholipids is also very essential for proper development of crops. It imparts hardness to shoot, improves grain quality, regulates photosynthesis, governs physiochemical processes and helps in the enlargement of cell, develop resistant to diseases and fixation of phosphorus.

Bio fertilizer (Definition: Bio-fertilizers are biological preparations of efficient microorganisms that promote plant growth by improving nutrient acquisition) plays an important role in crop production as it acts on soil physical properties, facilitates the proper movement of air, water as well as absorption of rain water. It adds plant nutrient to the soil and organic acid during dry matter decomposition, which acts on the insoluble nutrient reserve in the soil and make them available. Bio fertilizer or microbial preparations of live or latent cells of efficient strain of nitrogen fixing microorganism in soil or rhizosphere and consequently improve the extent of microbiologically fixed nitrogen for plant growth. Phosphate solubilizing bacteria (PSB) solubilizes the unavailable bound phosphate of the soil and make them available to plants which increase overall plant growth thus helps to improve quality and quantity of yield. Azosprillium is an associate symbiotic nitrogen fixer, aerobic free living does the job of making the atmospheric nitrogen available to various crop. Azotobacter spp. are non-symbiotic heterotrophic bacteria capable of fixing an average 20 kg N/ha per year **(Kizilkaya R, 2009)**. It can fix nitrogen directly from the atmosphere that help plants for better grain production. Azotobacter plays an important role to fix nitrogen in the nitrogen cycle. Considering the need for proper fertilizer management in fennel, the goal of the study was to identify the significance of different biofertilizers along with N and P on growth, yield and quality of fennel.

2. MATERIALS AND METHODS

A field experiment entitled "Effect of bio fertilizers on yield and its attributing traits on fennel (*Foeniculum vulgare*L)" was carried out in the Department of Horticulture, Naini, Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences during 2022-2023. (Give details of Latitude & Longitude with elevations, No details primary physiochemical properties of soils).The experiment was laid out in randomized block design with nine treatments in three replications as follows- T_0- RDF(50:10:10 kg /ha),T_1-90 % N + Azospirillum (5kg/ha), T_2- 90 % N + Azotobacter (5kg/ha), T_3- 90 % P + PSB(5kg/ha), T_4 -90 % N + 90 % P + Azospirillum (5kg/ha) + PSB(5kg/ha),T_5- 90 % N + 90 % P + Azotobacter (5kg/ha) + PSB(5kg/ha), T_6 -90 % N + Azospirillum (5kg/ha) + Azotobacter (5kg/ha), T_7 - 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha),T_8 - 90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha).Fennel variety

Ajmer fennel-1 was grown in open field and biofertilizers were applied in the soil.The experiment included application of biofertilizerssuch as Azotobacter, Azospirillium and PSB were applied at required quantity as per the treatment combination before transplanting to all the plots in the field. The fertilizer urea containing 46% N and single super phosphate (SSP) containing 16% P_20_5 as basal dose was drilled as nitrogen and phosphorous source before transplanting as per treatments.All the package of practices were followed as per recommendation to raise a quality crop. Five plants were selected randomly from each treatment per replication and the observations were recorded on growth, yield and quality parameters on these plants. Data on various parameters were recorded and stastically analysed by applying the technique of analysis of variance using Randomized Block Design(Explain plot size..). The level of significance was kept at 5% ($p < 0.05$).

RESULTS AND DISCUSSION

The data pertaining to effect of bio-fertilizers on vegetative growth parameters like plant height, number of branchesat different stages of growth and developmental parameters like days to 50% flowering and days to maturity in fennel are depicted in table 1.

Plant height statistically varies among different biofertilizers. Maximum plant height was recorded in treatment T7- 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha) (203.47 cm), followed by treatment T8- 90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha) (200.88 cm) and the shortest is found in the treatment T0-Control (182.44 cm).The increased plant height might be because of biofertilizers which can directly increase plant growth by enhancing atmospheric nitrogen fixation, better proliferation of roots and higher uptake of nutrients. Among the bio-fertilizers azospirillum secrete bioactive substances(such as…….) which have performed similar as that of growth hormones besides biological nitrogen fixation noted by **Kalidasu*et al*. (2008)** in coriander.

Number of branches statistically varies among different concentrations of bio fertilizers. Maximum number of branches per plant recorded in treatment T_7-90 % N + 90 % P +

Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha) (15.55), followed by treatment T_8-90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha) (15.11) and the lowest is found in the treatment T0-Control (11.33). The increased number of branches by the treatment with biofertilizers performed better than control in the present investigation. The possible reason might be due to the increased rate of photosynthesis and leading to accumulation of photosynthate. This character is also found to be related with endogenous hormol level (quantify with examples)and apical dominance in the plant. The findings are in close harmony with the results of **Singh and Prasad (2006).**

Minimum days to 50% flowering was recorded in treatment T7-90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha) (105.33 days) and followed by the treatment T8 – 90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha) (108.50 days) whereas the maximum was in the treatment T0 – Control (115.33 days). The reason for earliness in flowering in this treatment might be due to the fact that plants treated with biofertilizer become physiologically more active and enable to synthesize required amount of hormone or to build up adequate food reserves. Similar results were found by **Hnamte*et al.*, (2013)** in coriander.

Minimum days to maturity was recorded in treatment T7- 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha) (159.68 days) and followed by the treatment T8– 90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha) (160.22 days) whereas the maximum was in the treatment T0 – Control (170.33 days). The possible reason of early maturity of crop may be due to increase availability of nutrients lead into high accumulation of net photo-synthetics with optimum dose of nitrogen and phosphorus along with biofertilizers and availability of energy source for prolonged time. Thus, good proliferation of roots and enhance the uptake of nutrients and increase growth attributing characters **(Meena*et al,*.2014).** Similar findings were also reported by **Mandal and Sinha (2002)**

The data's regarding yield parameters like number of umbels per plant, number of umbellates per umbel, number of seeds per umbellates, seed yield(g/plant), seed yield per hectare (t/ha), test weight and economicsare showed in the Table 2.

Number of umbels per plant was recorded with significant variations among different treatments. Maximum number of umbels per plant was recorded in treatment T7- 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha) (14.61) and followed by the treatment T8 – 90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha) (13.88) whereas the minimum number of umbels per plant was recorded in the treatment T0 – Control (8.61). The increase in number of umbels per plant with the application of this treatment containing optimum dose of nitrogen and phosphorous along with biofertilizers might be due to the increase in supply of major plant nutrients that are required in larger quantities forfruits productivity, growth and development of plants. The accessibility of phosphorous is improved by PSB (examples), nitrogen fixed from atmosphere by Azotobacter that leads to balance supply of major nutrients and ultimately contributed into the increase in number of umbels per plant **(Aishwath*et al.*, 2012).**

Number of umbellates per umbel was recorded with significant variations among different treatments. Maximum number ofumbellatesper umbel was recorded in treatment T7- 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha) (23.16) and followed by the treatment T8 – 90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha) (22.50) whereas the minimum number of umbellatesper umbel was recorded in the treatment T0 – Control (17.70). The increase in number of umbellates per umbel with the application biofertilizers along with optimum dose of nitrogen and phosphorous caused significant improvement in overall growth of crop by virtue of increased photosynthetic efficiency. Thus, greater availability of photosynthates, metabolites and nutrients to develop reproductive structures seems to have resulted in increased number of umbellates per umbel. The present findings are in line with those reported by **Giridharkalidasu (2008), Darzi*et al.*, (2009), Patel *et al*., (2010).**

Number of seeds per umbellet was recorded with significant variations among different treatments. Data recorded in table 3 and illustrated through fig.1. Maximum number of seeds per umbellet was recorded in treatment T7- 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha) (33.90) and followed by the treatment T8 – 90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha) (32.31) whereas

the minimum number of seeds per umbelletwas recorded in the treatment T0 – Control (22.20).

The increase in number of seeds per umbellet with the application of optimum dose of nitrogen and phosphorus along with biofertilizers might enhanced its availability to plants which resulted in increased photosynthetic activity and translocation of photosynthates from source to sink and this may be the cause of higher growth and yield attributes. Adequate supply of nitrogen and phosphorus play vital role in varies metabolic processes which resulted in increased flowering and improving number of seeds per umbellet. The present findings are within the close vicinity of those reported by **GiridharKalidasu (2008), Patel *et al.*, (2010), Aishwath*et al.*, (2012).**

Maximum seed yield per plant was recorded in treatment T7- 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha) (30.80 g) and followed by the treatment T8– 90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha) (29.41g) whereas the lowest seed yield per plant was recorded in the treatment T0 – Control (22.46 g). Increase in seed yield per plant with the application of optimum dose of nitrogen and phosphorus along with biofertilizers is an output of sequential metamorphosis from source to sink. Hence higher growth parameters in turn resulted in increasing the seed yield. Partitioning of photosynthates in vegetative and reproductive parts those simultaneously in the later growth phases which resulted in higher seed yield. These results are in accordance with the findings of **Naimuddin*et al.*, (2014) and Raiyani*et al.*, (2018)** in fenugreek.

Seed yield per hectare was recorded with significant variations among different treatments. Maximum seed yield per hectare was recorded in treatment T7- 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha) (2.41t/ha) and followed by the treatment T8– 90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha) (2.32 t/ha) whereas the lowest seed yield per hectare was recorded in the treatment T0 – Control (1.90 t/ha).

Test weight was recorded with significant variations among different treatments. Maximum test weight was recorded in treatment T7- 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha) (7.17) and followed by the treatment T8– 90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha) (7.07) whereas the

lowest test weight was recorded in the treatment T0 – Control (5.76). The significant improvement in test weight with the application of optimum dose of nitrogen and phosphorus along with biofertilizers might be due to the increased supply of easily unavailable nutrients into available form. Moreover, biofertilizers also perform better when soil is well supplied with nutrients, resulting in vigorous growth and quality seed production. The positive effects of biofertilizers on quality parameters are also reported by **Patel *et al.*, (2003)** in fennel.

In case of economic parameter, T7- 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha) gained maximum gross returns (Rs/ha) (3,61,500), net returns (Rs/ha) (2,42,041.7) and Benefit: Cost ratio (3.02).

Table 1: Effect of biofertilizers on vegetative growth and flowering parameters of fennel.

	Growth parameters		**Flowering parameters**	
Treatments	**Plant height (cm)**	**No. of branches**	**Days to 50% flowering (days)**	**Days to maturity (days)**
T0- 50:10:10 kg /ha	182.44	11.33	115.33	170.33
T1-90 % N + Azospirillum (5kg/ha)	192.70	12.50	113.38	163.33
T2-90 % N + Azotobacter (5kg/ha)	191.79	12.11	113.66	164.72
T3-90 % P + PSB(5kg/ha)	191.08	12.05	114.66	165.16
T4-90 % N + 90 % P + Azospirillum (5kg/ha) + PSB(5kg/ha)	197.55	15	110.38	160.77
T5-90 % N + 90 % P + Azotobacter (5kg/ha) + PSB(5kg/ha)	194.99	13.83	112.05	163.22
T6-90 % N + Azospirillum (5kg/ha) + Azotobacter (5kg/ha)	196.93	14.22	111.02	162.50
T7-90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha)	203.47	15.55	105.33	159.68
T8-90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha)	200.88	15.11	108.50	160.22

F-Test	S	S	S	S
S.ED	1.70	0.49	1.16	1.54
CD @ 5%	3.60	1.05	2.45	3.27

Table 2. Effect of biofertilizers on yield parameters and economics of fennel

	Yield parameters						Economics		
Treatments	**No. of umbels per plant**	**No. of umbellets per umbel**	**No. of seeds per umbellet**	**Seed yield per plant(g/plant)**	**Seed Yield per hectare (t/ha)**	**Test weight(g)**	**Gross returns (Rs/ha)**	**Net returns (Rs/ha)**	**Benefit Cost ratio**
T0- 50:10:10 kg /ha	8.61	17.70	22.20	22.46	1.90	5.76	2,85,000	1,68,072.3	2.43
T1- 90 % N + Azospirillum (5kg/ha)	11.66	19.91	28.98	26.61	2.09	6.33	3,13,500	1,97,729.2	2.70
T2- 90 % N + Azotobacter (5kg/ha)	11.42	19.42	27.94	25.70	2.05	6.26	3,07,500	1,92,229.2	2.66
T3- 90 % P + PSB(5kg/ha)	10	19.22	27.13	25.59	2	6.06	3,00,000	1,84,012.5	2.58
T4- 90 % N + 90 % P + Azospirillum (5kg/ha) + PSB(5kg/ha)	13.72	22.38	31.98	28.76	2.25	6.95	3,37,500	2,19,041.7	2.84
T5- 90 % N + 90 % P + Azotobacter (5kg/ha) + PSB(5kg/ha)	12	21.53	29.58	26.74	2.12	6.39	3,18,000	2,00,041.7	2.69
T6- 90 % N + Azospirillum (5kg/ha) + Azotobacter (5kg/ha)	13.05	21.76	30.11	28.26	2.18	6.51	3,27,000	2,10,229.2	2.80
T7- 90 % N + 90 % P + Azotobacter (5kg/ha) + Azospirillum (5kg/ha) + PSB (5kg/ha)	14.61	23.16	33.90	30.80	2.41	7.17	3,61,500	2,42,041.7	3.02

T8- 90 % N + 90 % P + Azotobacter (2.5kg/ha) + Azospirillum (2.5kg/ha) + PSB (2.5kg/ha)	13.88	22.50	32.31	29.41	2.32	7.07	3,48,000	2,30,291.7	2.95
F-Test	S	S	S	S	S	S			
S.ED	0.56	0.65	1.13	1.28	0.06	0.28			
CD @5%	1.19	1.38	2.40	2.71	0.13	0.58			

CONCLUSION

From the present investigation study, it may be concluded that the treatment T7 i.e. application of 90% N +90% P +Azotobacter(5kg/ha) +Azospirillum(5kg/ha) +PSB(5kg/ha), proved to be superior to other treatments in regarding all vegetative, flowering and yield parameters like plant height, number of branches, number of seeds per umbel, number of umbels per plant, number of umbellates per umbel, seed yield per plant, seed yield per hectare, test weightand economics. Earliness in flowering and seed maturity was also observed in treatment T7.Thus the application of bio-fertilizers to increase sustainable crop productivity of sweet fennel and the avoidance of synthetic fertilizers, as well as increased health advantages, return on revenue and fewer environmental damage.

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