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Growth and yield of fennel (*Foeniculum vulgare* L.) as influenced by integrated nitrogen management and spacing

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ABSTRACT

To study the effect of spacing and combination of nitrogen from organic and inorganic sources on growth and yield of fennel an experiment was conducted during consecutive two winter seasons in the Gangetic alluvial plains of West Bengal at Horticultural Research Station of Bidhan Chandra Krishi Viswavidyalaya, Mondouri, Nadia. The experiment was designed in Randomised Block Design with sixteen treatments and three replications. The seed of fennel was sown with five different spacing i.e., 60 × 45 cm, 60 × 35 cm, 45 × 45 cm, 45 × 35 cm and 35 × 25 cm. The plants were manured with six different combination of nitrogen from organic and inorganic sources along with bio-fertilizer and phosphorus and potassium. The results showed that the maximum seed yield (13.79q ha^{-1}) of fennel was obtained with 50% nitrogen as urea in combination with Azospirillum in addition to phosphorus and potassium, when the plants were spaced at 45×35 cm. The minimum yield (8.86q ha^{-1}) was recorded with 25% N from urea alog with Azospirillum at a spacing of 35×25 cm.

Keywords **:** *Azospirillum*, fennel, growth, spacing, yield

Fennel *(Foeniculum vulgare* Mill.) is an important seed spice belongs to family Apiaceae and widely grown in the states like Gujarat, Rajasthan and Uttar Pradesh in India. It contributes about 9.0 % and 4.7% of total seed spices production and area respectively in our country with a productivity of 1245 kg^{-1}. During 2012-13, an amount of 13,811 ton fennel was exported to foreign countries to earn Rs.10,466.12 lakh.

Plant nutrition is one of the key factors influencing the growth and yield of crop plants. Continuous and indiscriminate use of chemical fertilizer has caused serious damage to the soil and ecology. Large scale use of chemical fertilizers in soil has depleted its good microbial colonies and also caused pollution and deterioration of soil structure. Application of bio-fertilizers provides effective implementation of biological mechanism of plant nutrition and growth promotion Bio-fertilizers are preparations containing live or latent cells of efficient strains of nitrogen fixing or potash and phosphorus mobilizing micro-organisms to augment the availability of nutrients that can be easily assimilated by plants. Low cost and safety for the environment made bio-fertilizers advantageous as an alternative to mineral fertilizers. It improves the sustainability of the soil and make it more productive. Most important growth inducing bacteria that are presently considered in crop production include *Azospirillum* which fixes nitrogen. Free living nitrogen fixing bacteria like *Azospirillum lipoferum*, can not only fix atmospheric nitrogen, but can also release plant hormones such as gibberellins and IAA to stimulate plant growth. Eco-friendly and cost effective nutrient management for fennel is of great importance. Earlier studies in fennel with different bio-fertilizers incorporation with inorganic fertilizers and organic manures combined with different spacing yielded good results in different locations of India . But less study so far has been conducted on fennel in West Bengal condition. Hence, the present investigation was undertaken to determine the influence of *Azospirillum (Azospirillum lipoferum)* with graded level of inorganic fertilizer combined with different spacing on the growth and seed yield of fennel in the new alluvial zone of West Bengal.

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MATERIALS AND METHODS

The investigation was undertaken during two consecutive *Rabi* (winter) season of the year 2012-2014 at the Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India. The experimental site was located at 23.5^0 N latitude and 80^0 E longitude, with an altitude of 9.75 m above the mean sea level in Gangetic alluvial plains with sandy loam soil with a soil pH of 6.8. The experiment was designed in the Factorial Randomized Block Design with 16 treatments and 3 replications. Cow dung @ 10t ha^{-1} was applied at the time of land preparation. *Azospirillum* @ 10 g was applied in each plot before sowing except untreated control plot. The NPK fertilizers were applied @ 80:40:40 kg per hectare. Half dose of N and full dose of P and K were applied as basal and remaining half dose of N was top dressed after 45 days of sowing. The treatment details are presented in table- 1.

Table 1: Details of the treatments

Notations	Treatments	Notations	Treatments
T_1	75%N+PK + *Azos*. and 60×45 cm spacing	T_9	50%N+PK + *Azos*. and 45×35cm spacing
T_2	75%N+PK + *Azos*. and 45×45 cm spacing	T_{10}	50%N+PK + *Azos*. and 35×25cm spacing
T_3	75%N+PK + *Azos*. and 60×35 cm spacing	T_{11}	25%N+PK + *Azos*. and 60×45cm spacing
T_4	75%N+PK + *Azos*. and 45×35cm spacing	T_{12}	25%N+PK + *Azos*. and 45×45cm spacing
T_5	75%N+PK + *Azos*. and 35×25 cm spacing	T_{13}	25%N+PK + *Azos*. and 60×35cm spacing
T_6	50%N+PK + *Azos*. and 60×45cm spacing	T_{14}	25%N+PK + *Azos*. and 45×35cm spacing
T_7	50%N+PK + *Azos*. and 45×45 cm spacing	T_{15}	25%N+PK + *Azos*. and 35×25cm spacing
T_8	50%N+PK + *Azos*. and 60×35 cm spacing	T_{16}	Control (Full NPK) 60×45cm spacing

Note. Azos. - Azospirillum

Seeds were soaked overnight and dried under shade and were sown in previously prepared plots at a depth of 2-3cm and covered with a layer of fine soil. Fennel seeds were sown in 1st week of November in flat beds with a spacing of 60× 45 cm, 45×45 cm, 60×35 cm, 45×35cm and 35×25 cm row to row and plant to plant and thinning was done 3 weeks after germination to maintain the plant to plant distance. First irrigation was given immediately after planting. Then the subsequent irrigations were given at an interval of 15 days depending upon the soil moisture and weather condition. Plant is individually tied with stake by rope to protect from wind damage. Staggered harvesting was done when seeds became brownish in colour. Proper care was taken during drying and threshing of seeds. The observation on growth characters like plant height, number of primary branches, number of secondary branches per plant and yield attributes like number of umbels plant^{-1}, number of umbelletes umbel^{-1}, yield and test weight were recorded and were analyzed statistically. The significance of different treatment of variation was tested by Fisher & Snedecor's 'F' test at a probability of 0.05 per cent (Gomez and Gomez, 1984).

RESULTS AND DISCUSSIONS

Plant height

It is evident from the data presented in table- 2 that plant height varied significantly at different stages of growth at 40, 60 and 80 and 100 days after planting among different treatments. The maximum plant height was noticed under 50%N+PK +*Azospirillum* with 45×35cm spacing in all the four days of observation with a maximum value at 100 DAS (166.21cm), whereas the shortest plant (137.77cm) was observed under 25%N+PK +*Azospirillum* with 35×25cm spacing, which is even lower than control. Observations showed that the application of less amount of inorganic nitrogen (25%) with lower spacing lowers the growth of the plants, as inorganic nitrogen enhances the height of the plant very rapidly.

Number of primary branches per plant

Number of primary branches per plant varied significantly with application of different treatments. The maximum no of primary branches was recorded under the treatment of 50%N+PK +*Azospirillum* with 60×35 cm spacing at 3 days of observations *viz*, 40 DAS (2.68), 60 DAS (6.33) and 80 DAS (10.55); while the lowest value was obtained under treatment of 25%N+PK +*Azospirillum* with 35x25cm spacing.

Number of secondary branches per plant

A significant variation in secondary branches was also observed in different treatment. A similar trend of result was noted in this parameter like primary branches of plant. The combined application of 50%N+PK +*Azospirillum* with 60×35 cm spacing produced maximum number of secondary branches (8.89 and 18.44) at 60 DAS and 80 DAS. Whereas the least number of secondary branches (8.89 and 18.44) under the treatment of 25%N+PK +*Azospirillum* and 35×25cm spacing was observed at 60 DAS and 80 DAS respectively also.

Number of umbel per plant

It is clear from Table 2 that the umbel per plant varied significantly at three stages of growth (80,100 and120 DAS). Among different treatment combination, 50%N+PK +*Azospirillum* with 45×35cm spacing produced the highest number of umbel at 80 DAS (4.94) , 100 DAS (55.33) and 120 DAS (124.00). But under the treatment of 25%N+PK +*Azospirillum* with 35×25cm spacing the minimum number of umbel per plant was recorded at all the three stages of growth.

Number of umbelletes per umbel

Combination of different spacing in fennel plants treated with inorganic and bio-fertilizers were influenced significantly in respect of number of

umbelletes per umbel. The maximum number of umbellates per umbel at 80 DAS was (29.56) noticed under the combined inoculation of 50%N+PK +*Azospirillum* with 45×35cm spacing whereas the lowest (16.77) was noticed at the combination of 25%N+PK +*Azospirillum* with 35×25cm spacing and in case of 100 DAS the similar pattern was followed with a highest production of 37.44 umbellets per umble by 50%N+PK +*Azospirillum* with 45×35cm spacing and the lowest (24.57) was obtained under the treatment of 25%N+PK +*Azospirillum* and 35×25cm spacing.

Yield (kg ha^{-1})

The highest seed yield of 16.79 q ha^{-1} was noticed under the treatment of 50%N+PK +*Azospirillum* with 45×35cm spacing. However, the minimum yield of 7.86 q ha^{1} was noticed under 25%N+PK +*Azospirillum* with 35×25cm spacing.

Test weight

A significant difference in thousand seed weight was witnessed among different treatments. The highest test weight of 8.30g was noticed under the treatment of 50%N+PK +*Azospirillum* with 45×35cm spacing. However, the minimum weight of 8.30 g was noticed under 25%N+PK +*Azospirillum* with 35×25cm spacing.

Table 2: Effect of spacing and integrated nutrient management on growth and yield parameters of fennel

Treatment	Plant height (cm)			Primary branches		Secondary branches		Umbel plant^{-1}			Umblet umbel^{-1}	Harvesting yield	Test weight
	60 DAS	80 DAS	100 DAS	60 DAS	80 DAS	60 DAS	80 DAS	80 DAS	100 DAS	120 DAS	100 DAS	(q/ha^{-1})	(g)
T_1	61.0	79.4	151.9	5.4	8.7	6.1	13.0	2.2	27.3	87.1	29.9	13.1	6.6
T_2	61.3	83.4	153.0	5.3	8.8	6.3	15.6	2.6	35.7	91.7	30.0	13.4	5.4
T_3	63.2	90.8	158.6	5.6	8.8	7.3	15.8	3.7	44.6	95.2	33.3	14.1	6.2
T_4	64.4	101.2	161.2	6.0	9.0	8.0	18.2	4.7	53.2	120.9	36.1	15.9	6.6
T_5	58.7	86.2	154.6	5.6	9.0	6.8	15.7	3.6	41.2	93.7	32.1	13.5	6.4
T_6	50.4	85.8	153.4	5.8	8.7	6.0	17.1	3.0	35.2	91.0	31.2	13.5	6.4
T_7	67.7	93.7	160.4	5.9	9.4	8.9	17.4	3.8	52.7	113.4	36.0	15.6	6.1
T_8	59.0	91.9	159.1	5.7	9.0	7.7	15.9	3.7	45.0	101.8	35.3	15.4	7.4
T_9	71.7	95.9	166.2	6.3	10.6	8.1	18.4	4.1	55.3	124.0	37.4	16.8	8.3
T_{10}	60.7	74.6	141.2	4.4	8.1	5.2	10.0	1.4	18.7	77.2	32.3	10.1	6.5
T_{11}	49.0	82.9	149.2	5.3	8.4	6.6	10.8	2.0	25.8	83.9	32.1	12.4	6.4
T_{12}	59.6	80.3	146.3	4.7	8.2	5.2	9.1	1.8	23.8	74.0	29.7	12.7	6.2
T_{13}	58.9	83.9	148.6	4.9	7.3	5.3	10.6	1.9	21.2	81.9	29.9	11.7	6.6
T_{14}	51.4	78.6	139.7	4.3	7.3	5.0	8.9	2.0	25.3	85.0	29.6	9.5	6.7
T_{15}	47.0	75.8	137.8	4.1	6.8	6.1	7.9	1.4	16.2	62.1	24.6	8.9	4.7
T_{16}	59.5	85.6	156.6	4.4	8.2	7.1	12.5	2.7	27.3	89.9	31.4	12.7	6.8
SEm (±)	**1.41**	**1.75**	**1.28**	**0.38**	**0.44**	**0.30**	**0.45**	**0.40**	**0.68**	**1.87**	**1.01**	**0.14**	**0.40**
LSD (0.05)	**4.12**	**5.11**	**3.73**	**1.12**	**1.29**	**0.89**	**5.82**	**1.18**	**3.39**	**5.45**	**2.94**	**0.40**	**10.95**

The experiment was conducted with Nitrogen fixing bacteria *Azospirillum* bio-fertilizers in combination with inorganic nitrogen at different levels and with fixed phosphorus & potassium and sown at different spacing. Considering the yield and other parameters, the treatment combination 50%N+PK +*Azospirillum* with 45x35cm spacing produced the highest yield (16.79 q ha^{-1}). Investigation also revealed that the same treatment recorded maximum plant height, number of branches and number of umbels per plant. The reason behind the positive role of *Azospirillum* may be that bio-fertilizers are artificially multiplied cultures of latent cells of efficient strains of micro-organisms capable of fixing atmospheric nitrogen and decomposing cellulolytic waste materials and for effective recycling of solid wastes and even produce growth promoting substances. Rahimi *et al*. (2009) also observed highest plant height, number of branches, number of umbels, dry weight and fruit yield per plant of coriander with the treatment combination of *Azospirillum* + 50 % N. Bio-fertilizers add nutrients through the natural processes of nitrogen fixation and stimulating plant growth through synthesis of growth promoting substances and might have positively influenced the crop yield. The beneficial role of supplemented organic manures and bio-fertilizers in improving soil physical, chemical and biological role is well known, which in turn helps in better nutrient absorption by plants and resulting higher yield (Prabu *et al*., 2002).

The increase in number of branches might be due to more number of vegetative bud subtended by taller plants. Similar to the present findings, Malhotra *et al*. (2006) reported that *Azospirillum* inoculation along with nitrogen and FYM increased the number of branches per plant on coriander. Sokhangoy *et al.* (2012) suggested that application of bio-fertilizers significantly increased plant height, number of spikes per plant, number of seeds per spike, number of seeds per plant and the weight of 1000 seeds in dill. Bio-fertilizer has significantly influenced the flowering and umbel number per plant. Application of nitrogen fixing bacteria caused improvement of biological activities of soil and mineral element absorption caused more biomass production and umbel number. These findings are in accordance with the observations of Abdou *et al*. (2004), Subramanian *et al.* (2001) and Mahfouz and Sharaf Eldin (2007) on fennel.

Regarding spacing of the rows, the results corroborate the earlier findings of different scientists. Ahmad *et al.* (2004) reported that 40 cm gave the greatest plant height (114.7 cm), seed weight per umbel (2.2 g) and seed yield ha^{1} (369.7 kg), while the lowest plant height (78.1 cm), seed weight per umbel (1.8 g) and seed yield/ha (192.5 kg) were recorded with 70-cm spacing. The interaction of autumn sowing and 40-cm row spacing produced the highest seed yield (560.5 kg ha^{1}). According to Amin *et al*. (2005) crops sown on 45 cm row spacing recorded significantly higher fennel seed and stover yield and yield attributes. Whereas, growth attributes increased with increase in row spacing from 30 to 60 cm.

The study revealed that the most promising treatment under the alluvial tracts of West Bengal for fennel production is 50%N+PK +*Azospirillum* with 45×35cm spacing. Hence, there is a chance of saving 50% of nitrogen with inoculation of *Azospirillum* which may also leads to reduction of environmental pollution to some extent and *Azospirillum* was proved to be better supplement of nitrogen.

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