

Original Research Article

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Effect of Integrated Nutrient Management on Growth and Yield of Fennel (*Foeniculum vulgare* Mill.)

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ABSTRACT

Keywords

Organic and inorganic sources, N equivalent application, Bio fertilizers, Fennel

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A field experiment was conducted at research block of the Department of Plantation, Spices, Medicinal and Aromatic Crops, Kittur Rani Channamma College of Horticulture, Arabhavi, Belagavi district during rabi-2015-16 and 2016-17 to study the effect of integrated nutrient management on growth and yield of fennel (*Foeniculum vulgare* Mill.). The experiment was laid out in randomized complete block design and treatments were replicated thrice. The experiment consisted of twelve treatments. Among the different treatments, significantly higher seed yield per plant and hectare was recorded with T₆-RDFYM+ 75% RDN + RDPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹ (30.47 g plant⁻¹ and 2.29 t ha⁻¹, respectively) this was on par with T₄- vermicompost at 2.5 t ha⁻¹+ RDNPK+ *Azospirillum* at 5 kg ha⁻¹+PSB at 3 kg ha⁻¹ (29.85 g plant⁻¹, 1.44 kg plot⁻¹ and 2.21 t ha⁻¹, respectively). Significantly higher growth and yield parameters viz., plant height (209.97cm), number of primary and secondary branches (16.43 and 7.50, respectively), maximum number of umbels per plant (29.24), number of umbellets per umbel (23.68), number of seeds per umbellate (35.07) and test weight (7.35 g) were recorded with treatment receiving T₆- RDFYM+ 75% RDN + RDPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹.

Introduction

Among the spices, seed spices are the group, which denotes all those annuals whose dried fruit or seeds are used as spices. The seed spices are aromatic vegetable products of tropical origin and are commonly used in pulverized form, primarily for seasoning or garnishing the foods and beverages. They are also used in preparation of various value

added products viz., spice oils, oleoresins and spice powders. Seed spices also have industrial importance and are used in various pharmaceutical preparations and medicines. Seed spices contribute about 50 per cent of total area and 20 per cent of production of spices in the country. Presently, 17.40 lakh hectares of area is under seed spices cultivation with a production of 14.54 lakh tonnes annually.

Fennel is one of the important major seed spice crops, botanically named as (*Foeniculum vulgare* Mill. or *Foeniculum officinale* All.), belongs to the family Umbelliferae (Apiaceae) and having chromosome number of $2n=22$. The generic name derives from the Latin “*foenum*”, which means ‘hay’, referring to the foliar structure. It is a well known aromatic medicinal plant used in traditional medicine and also as spice and substrate for different industrial purpose (Telci *et al.*, 2009). Vernacularly it is called *Saunf* or *Badi Saunf*. Fennel is a digestive adjuent, highly aromatic and flavorful herb with culinary uses. In India, it's seeds are used for mastication and chewing alone or with betel leaves. Fennel is believed to be native of Southern Europe and Mediterranean region. It is widely cultivated throughout the temperate and subtropical region of the world. In India fennel is mainly grown in Gujarat and Rajasthan and to some extent in Uttar Pradesh, Karnataka, Andhra Pradesh, Punjab, Madhya Pradesh, Bihar, Haryana and Jammu and Kashmir as a winter crop covering a total Among these seed spices, fennel is cultivated in an area of 0.75 lakh hectares with a production of 1.25 lakh tonnes with an average productivity of 1.66 tonnes per hectare (Anon., 2018).

Integrated nutrient management includes use of organic manure/ compost, bio- fertilizer, chemical fertilizer, green manuring, residue management, legume based cropping system, use of nutrient – responsive varieties, proper method and time of organic manure and fertilizer application, soil and water management to minimize the nutrient losses occurring through volatilization, denitrification, runoff and leaching. Application of plant nutrients in proper balance form is also a part of integrated plant nutrient management (IPNM) system. Supply of nutrients to seed spices in appropriate quantities and at the correct time is essential for economically and environmentally

sustainable agriculture. Soil organic matter, crop residues and manures play a vital role in the supply of macro and micronutrients and the transformation between the various organic and inorganic forms often control availability, both for plant uptake and loss to environment (Aishwath and Vashistha, 2008 and Lal *et al.*, 2009).

Materials and Methods

A field experiment was conducted at research block of the Department of Plantation, Spices, Medicinal and Aromatic Crops, Kittur Rani Channamma College of Horticulture, Arabhavi, Belagavi district which is situated in Northern Dry Zone of Karnataka at a latitude of 16°15' N latitude and 94°45' E longitude and at an altitude of 612 m above Mean Sea Level (MSL). The experiment was conducted to study the effect of growth regulators on growth and yield of fennel (*Foeniculum vulgare* Mill.) cv. Gujarat Fennel 1 during *rabi* – 2015-16 and 2016-17 with irrigated condition. The experiment was laid out in split plot design and treatments were replicated thrice. The net plot size was 1.8 m × 1.8 m (3.24 m²). Recommended dose of nutrients for fennel is 90:60:30 N:P₂O₅:K₂O kg ha⁻¹. The experiment consisted of twelve treatments and treatment details were as follows- T₁- RDFYM (15 t ha⁻¹) + RDNPK (90:60:30 kg ha⁻¹), T₂- RDFYM+ RDNPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹, T₃- RDFYM + RDNPK + *Azotobacter* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹, T₄- Vermicompost 2.5 t ha⁻¹+ RDNPK+ *Azospirillum* at 5 kg ha⁻¹ + PSB at 3 kg ha⁻¹, T₅- RDFYM+ 75% RDN (67.5 kg ha⁻¹) + RDPK (60: 30 kg ha⁻¹) + 25% N equivalent of FYM (4.5 t ha⁻¹), T₆- RDFYM+ 75% RDN + RDPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹, T₇- RDFYM + 75% RDN + RDPK + *Azotobacter* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹, T₈- RDFYM+ 50% RDNPK (45:30:15 kg ha⁻¹), T₉- RDFYM + 50% RDN + RDPK + 50% N equivalent of

FYM (9 t ha⁻¹), T₁₀- RDFYM + 50% RDN + RDPK + *Azospirillum* at 5 kg ha⁻¹ + PSB at 3 kg ha⁻¹, T₁₁- RDFYM + 50% RDNPK + *Azospirillum* at 5 kg ha⁻¹ + PSB at 3 kg ha⁻¹, T₁₂- RDFYM + 50% RDN + RDPK + *Azotobacter* at 5 kg ha⁻¹ + PSB at 3 kg ha⁻¹. Treatments were imposed as per the treatment combinations. Soil of the experimental site was red sandy loam with a pH of 7.56, EC (0.22 dSm⁻¹), low in organic carbon (0.52 %) and low in available nitrogen (160.54 kg ha⁻¹), medium in P₂O₅ (27.57 kg ha⁻¹) and low in K₂O (196 kg ha⁻¹). Experimental data collected was subjected to statistical analysis by adopting Fisher's method of analysis of variance (ANOVA) as outlined in Gomez and Gomez (1984). Critical difference (CD) values were calculated whenever the "F" test was significant at 5 per cent level.

Results and Discussion

Optimum growth, productivity and quality of any crop are influenced by several factors of which genetic constitution of the variety, environmental factors and agro- techniques adopted play a vital role. Although, every plant has its own specific inherent characters and genetic potential which are fully expressed only when they have favourable environment conditions. In modern production technology, great emphasis is being given for choosing appropriate variety and density of plant population in order to boost up the production per unit area besides adopting integrated nutrient management practices through organic and inorganic which enhances growth, yield and quality of the crop. Integrated nutrient management practices help in maintaining soil health and reduces the cost of inputs.

Effect of INM practices on growth parameters of fennel

The vegetative growth parameters *viz.*, plant height, number of primary and secondary

branches, plant spread and total dry matter production differed significantly among the treatments at all the stages of crop growth during two consecutive years (Table 1 and 2). Plants supplied with RDFYM+ 75% RDN + RDPK + *Azospirillum* 5 kg ha⁻¹ + PSB 3 kg ha⁻¹ (T₆) resulted in maximum plant height (209.97cm) at harvesting stage. The reason for better growth and development under this treatment could be attributed to increased availability of nitrogen to the plants initially through inorganic fertilizer and later by FYM/ organic sources, matching to the need of plants throughout the cropping season.

The superiority of combination, but nitrogen through inorganic source might be due to added advantage of FYM, which besides supplying all the essential nutrients, also improves physical conditions of soil in respect of granulation, friability, porosity and water holding capacity which enable the crop to utilize nutrients and water more efficiently especially under light textured loamy sand soils (Yadav, 2005). Nitrogen being the main constituent of protein and nucleic acid, which greatly influences the cell division, cell elongation and cell enlargement and thereby it could increase the shoot length. Moreover, *Azospirillum* enhanced the activity of growth hormones like IAA, GA and dehydrozeatin, which promotes the vegetative growth. This was also related to application of recommended dose of N, P and K through fertilizers enhanced the availability of nutrients, which resulted in increased photosynthetic activity and translocation of photosynthates from source to sink and resulted in increased plant growth. Godara *et al.*, (2014) also recorded higher growth and yield attributes when RDF was applied through chemical fertilizers in fennel followed by integrated nutrient management. These phytohormones might have caused proliferation of roots and thereby increased the uptake of nutrients resulted in better plant height. This is in conformity with the findings

of Dadkhah (2012). Increased growth could be correlated to suitable combination of organic and inorganic source of nutrients which ensured readily availability of nutrients for initial requirement through inorganic source and slow pace as long term availability through organic source and resulted in higher plant height, branches per plant, plant spread and dry matter production (Choudhary *et al.*, 2011).

Increased growth was also related to suitable combination of organic and inorganic nitrogenous fertilizer maintained the sustainable soil fertility in soil and enhances high level of productivity (Pillai *et al.*, 1985). Increase in growth parameters can be attributed to the positive effect of bio-fertilizers on nutrient uptake by plants (Gad, 2001).

Maximum number of primary and secondary branches (16.43 and 7.50, respectively) were recorded in plant supplied with RDFYM+ 75% RDN + RDPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹(T₆) followed by T₄ and T₂ (15.50 and 14.87, respectively) (Table 2). This could be attributed to the application of FYM with chemical fertilizers and bio-fertilizers. The growth promoting effect of FYM as a source of plant nutrients and humus, improved the soil physical conditions by increasing its capacity to absorb and store water, improving aeration and favouring beneficial microbial activity is well established. Besides, bio-fertilizers had the similar effects of hormones create favourable effect on active root rhizosphere and helps for better uptake of nutrients which helps growth of plants.

These phytohormones might have caused proliferation of roots and increased the uptake of nutrients which helped in fast multiplication of cells and cellular elongation resulting in better growth of roots and shoots which helped better vegetative growth including plant height, plant spread and number of

primary and secondary branches. These results are in conformity with the finding of Kaushik *et al.*, 2000 and De Salamone *et al.*, 2001, Meena, 2001, Joy *et al.*, 2005, Naveen, 2010 and Dadkhah, 2012.

Dry matter production was significantly differed by integrated nutrient management practices in fennel during both the years (Table 2). The maximum dry matter production was recorded with RDFYM+ RDNPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹(T₂) (170.33 g plant⁻¹ and 12.62 t ha⁻¹) which was on par with Vermicompost at 2.5 at t ha⁻¹+ RDNPK+ *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹ (T₄) and RDFYM+ 75% RDN + RDPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹ (T₆) (170.00 g plant⁻¹ and 12.59 t ha⁻¹, respectively).

The increased dry matter production could be attributed to better vegetative growth and production of more fresh weight. Better uptake of nutrients due to influence of biofertilizers supplied along with chemical fertilizers and organic manures. The better absorption and accumulation of nutrients promotes growth and metabolism. Effect of biofertilizer on the dry weight of plant was due to increased nitrogen uptake and the growth rate improvement. Effect of biostimulant on the dry weight of plant was due to increased nitrogen uptake. This in turn resulted in production of more dry matter (Mahfouz and Sharaf Eldin, 2007). The effectiveness of vermicompost in increasing the dry weight of plant could be attributed to increased the growth rate because of the better water and mineral uptake such as nitrogen and phosphorus (Arancon *et al.*, 2006; Zaller, 2007), which leads to the improvement in dry weight of plant. The result of present finding are in agreement with the reports of Meena *et al.*, (2009), Moradi *et al.*, (2011), Darzi (2012) in fennel crop and Bajya *et al.*, (2017) fennel crop.

Table.1 Plant height, number of primary and secondary branches of fennel as influence by integrated nutrient management practices

Treatments	Plant height (cm)			No. of primary branches per plant			No. of secondary branches per plant		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T ₁ : RDFYM (15 t ha ⁻¹) + RDNPK (90:60:30 kg ha ⁻¹)	190.57	197.75	194.16	12.80	13.75	13.28	7.33	7.33	7.33
T ₂ : RDFYM+ RDNPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	204.45	209.75	207.10	14.47	15.27	14.87	7.67	8.00	7.83
T ₃ : RDFYM + RDNPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	200.21	201.55	200.88	13.53	14.48	14.01	7.00	7.67	7.33
T ₄ : VC 2.5 t ha ⁻¹ + RDNPK+ <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	202.86	204.08	203.47	15.40	15.60	15.50	7.33	8.33	7.83
T ₅ : RDFYM+ 75% RDN + RDPK + 25% N equivalent of FYM	196.01	199.10	197.56	12.15	13.50	12.82	6.00	6.33	6.17
T ₆ : RDFYM+ 75% RDN + RDPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	207.90	212.03	209.97	16.20	16.66	16.43	8.00	8.33	8.17
T ₇ : RDFYM + 75% RDN + RDPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	196.02	199.08	197.55	14.27	14.33	14.30	6.67	6.67	6.67
T ₈ : RDFYM+ 50% RDNPK (45:30:15 kg ha ⁻¹)	170.35	178.12	174.23	11.70	12.63	12.17	5.33	6.00	5.67
T ₉ : RDFYM + 50% RDN + RDPK + 50% N equivalent of FYM	181.27	192.22	186.74	12.29	13.46	12.88	6.00	7.33	6.67
T ₁₀ : RDFYM + 50% RDN + RDPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	194.62	195.78	195.20	13.15	12.70	12.93	6.67	8.33	7.50
T ₁₁ : RDFYM + 50% RDNPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	194.38	195.23	194.81	13.15	12.67	12.91	6.33	6.67	6.50
T ₁₂ : RDFYM + 50% RDN + RDPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	193.97	190.59	192.28	13.16	12.00	12.58	6.67	7.33	7.00
S.Em.±	2.91	3.33	2.70	0.18	0.34	0.19	0.42	0.40	0.32
CD at 5%	8.55	9.77	7.92	0.53	0.99	0.57	1.25	1.17	0.96

Table.2 Plant spread and total dry matter production of fennel as influence by integrated nutrient management practices

Treatments	Plant spread (cm ²) (North- South)			Plant spread (cm ²) (East- West)			Total dry matter production (g plant ⁻¹)		
	2015- 16	2016- 17	Pooled	2015- 16	2016- 17	Pooled	2015- 16	2016- 17	Pooled
T ₁ : RDFYM (15 t ha ⁻¹) + RDNPk (90:60:30 kg ha ⁻¹)	56.01	58.10	57.06	64.27	66.57	65.42	158.33	163.00	160.67
T ₂ : RDFYM+ RDNPk + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	55.97	58.03	57.00	65.17	66.27	65.72	165.00	175.67	170.33
T ₃ : RDFYM + RDNPk + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	54.87	57.35	56.11	64.67	65.87	65.27	162.33	132.83	147.58
T ₄ : VC 2.5 t ha ⁻¹ + RDNPk+ <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	59.70	58.57	59.13	65.77	66.90	66.33	164.67	175.33	170.00
T ₅ : RDFYM+ 75% RDN + RDPK + 25% N equivalent of FYM	54.57	55.80	55.18	62.15	64.93	63.54	151.00	162.33	156.67
T ₆ : RDFYM+ 75% RDN + RDPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	60.57	60.07	60.32	69.83	71.00	70.42	165.00	175.00	170.00
T ₇ : RDFYM + 75% RDN + RDPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	58.37	59.17	58.77	66.83	67.47	67.15	160.00	170.67	165.33
T ₈ : RDFYM+ 50% RDNPk (45:30:15 kg ha ⁻¹)	54.00	55.40	54.70	60.80	65.17	62.98	148.00	155.67	151.83
T ₉ : RDFYM + 50% RDN + RDPK + 50% N equivalent of FYM	56.56	57.20	56.88	65.28	66.93	66.11	158.67	165.67	162.17
T ₁₀ : RDFYM + 50% RDN + RDPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	57.01	58.58	57.80	66.79	67.60	67.20	161.67	166.33	164.00
T ₁₁ : RDFYM + 50% RDNPk + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	56.13	56.73	56.43	66.13	67.37	66.75	158.67	164.00	161.33
T ₁₂ : RDFYM + 50% RDN + RDPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	55.00	58.97	56.98	66.67	68.10	67.38	159.00	160.67	159.83
S.Em.±	0.36	0.29	0.21	0.31	0.37	0.26	0.79	0.86	0.62
CD at 5%	1.05	0.86	0.62	0.91	1.09	0.77	2.32	2.53	1.84

Table.3 Number of umbels per plant, no. of umbellets per umbel and no. of seeds per umbellet in fennel as influenced by integrated nutrient management

Treatments	No. of umbels			No. of umbellets per umbel			No. of seeds per umbellet		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T ₁ : RDFYM (15 t ha ⁻¹) + RDNPK (90:60:30 kg ha ⁻¹)	26.39	28.06	27.23	17.57	17.83	17.70	29.88	32.10	30.99
T ₂ : RDFYM+ RDNPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	27.62	28.33	27.78	21.08	22.43	21.76	31.83	32.93	32.38
T ₃ : RDFYM + RDNPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	26.91	27.79	27.35	19.44	20.83	20.14	26.57	31.40	28.98
T ₄ : Vermicompost 2.5 t ha ⁻¹ + RDNPK+ <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	27.93	28.78	27.66	21.34	23.10	22.22	32.60	35.74	34.17
T ₅ : RDFYM+ 75% RDN + RDPK + 25% N equivalent of FYM	21.40	23.48	23.81	16.67	18.50	17.58	24.33	26.50	25.42
T ₆ : RDFYM+ 75% RDN + RDPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	28.14	31.05	29.24	22.80	24.57	23.68	33.70	36.43	35.07
T ₇ : RDFYM + 75% RDN + RDPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	26.85	28.11	26.25	18.73	22.77	20.75	30.33	29.53	29.93
T ₈ : RDFYM+ 50% RDNPK (45:30:15 kg ha ⁻¹)	20.62	23.07	22.60	8.98	10.63	9.81	20.00	22.47	21.23
T ₉ : RDFYM + 50% RDN + RDPK + 50% N equt. of FYM	25.58	27.50	26.96	14.05	15.55	14.80	29.43	27.83	28.63
T ₁₀ : RDFYM + 50% RDN + RDPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	27.71	29.47	28.17	17.38	17.70	17.54	28.23	29.37	28.80
T ₁₁ : RDFYM + 50% RDNPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	26.57	27.25	26.91	14.77	17.35	16.06	26.00	28.40	27.20
T ₁₂ : RDFYM + 50% RDN + RDPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	26.70	27.89	27.30	16.35	17.00	16.68	28.33	30.00	29.17
S.Em.±	0.49	0.48	0.66	0.44	0.64	0.29	1.48	1.18	0.91
CD at 5%	1.46	1.41	1.95	1.31	1.88	0.87	4.35	3.46	2.68

Table.4 Effect of integrated nutrient management on seed yield per plant (g), seed yield per plot (kg) and seed yield per hectare (t) in fennel

Treatments	Seed yield (g/ plant)			Seed yield (kg/ plot)			Seeds yield (t/ha)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T ₁ : RDFYM (15 t ha ⁻¹) + RDNPk (90:60:30 kg ha ⁻¹)	27.76	29.44	28.60	1.33	1.41	1.37	2.06	2.18	2.12
T ₂ : RDFYM+ RDNPk + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	29.29	30.18	29.65	1.41	1.45	1.43	2.17	2.23	2.20
T ₃ : RDFYM + RDNPk + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	25.79	29.94	27.87	1.24	1.44	1.34	1.91	2.22	2.07
T ₄ : Vermicompost 2.5 t ha ⁻¹ + RDNPk+ <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	29.42	30.27	29.85	1.41	1.46	1.44	2.18	2.24	2.21
T ₅ : RDFYM+ 75% RDN + RDPK + 25% N equivalent of FYM	27.34	30.57	29.30	1.31	1.47	1.39	2.02	2.27	2.15
T ₆ : RDFYM+ 75% RDN + RDPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	29.91	32.01	30.47	1.43	1.54	1.49	2.21	2.37	2.29
T ₇ : RDFYM + 75% RDN + RDPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	24.17	29.69	26.25	1.16	1.43	1.29	1.79	2.20	2.00
T ₈ : RDFYM+ 50% RDNPk (45:30:15 kg ha ⁻¹)	20.19	25.04	22.79	0.97	1.20	1.09	1.50	1.86	1.68
T ₉ : RDFYM + 50% RDN + RDPK + 50% N equat. of FYM	27.57	26.63	27.45	1.32	1.28	1.30	2.04	1.97	2.01
T ₁₀ : RDFYM + 50% RDN + RDPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	27.38	28.08	27.87	1.32	1.35	1.33	2.03	2.08	2.06
T ₁₁ : RDFYM + 50% RDNPk + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	26.56	28.67	27.61	1.28	1.38	1.33	1.97	2.12	2.05
T ₁₂ : RDFYM + 50% RDN + RDPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	27.17	28.12	27.64	1.30	1.35	1.33	2.01	2.08	2.05
S.Em.±	0.54	0.51	0.52	0.02	0.02	0.02	0.04	0.03	0.03
CD at 5%	1.59	1.50	1.53	0.07	0.07	0.06	0.11	0.11	0.09

Table.5 Test weight (g) and harvest index (%) as influenced by integrated nutrient management in fennel

Treatments	Test weight (g)			Harvest index (%)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T ₁ : RDFYM (15 t ha ⁻¹) + RDNPK (90:60:30 kg ha ⁻¹)	7.02	7.18	7.10	17.96	18.68	18.32
T ₂ : RDFYM+ RDNPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	7.07	6.90	6.98	17.15	17.56	17.36
T ₃ : RDFYM + RDNPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	6.34	7.02	6.68	15.28	22.55	18.91
T ₄ : Vermicompost 2.5 t ha ⁻¹ + RDNPK+ <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	6.56	7.05	6.81	18.76	19.17	18.97
T ₅ : RDFYM+ 75% RDN + RDPK + 25% N equivalent of FYM	6.86	6.64	6.75	20.08	18.20	19.14
T ₆ : RDFYM+ 75% RDN + RDPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	7.33	7.36	7.35	19.34	19.62	19.48
T ₇ : RDFYM + 75% RDN + RDPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	6.65	7.00	6.83	15.11	17.40	16.25
T ₈ : RDFYM+ 50% RDNPK (45:30:15 kg ha ⁻¹)	5.81	6.04	5.93	13.64	17.43	15.53
T ₉ : RDFYM + 50% RDN + RDPK + 50% N equt. of FYM	6.31	6.92	6.61	20.10	18.15	19.13
T ₁₀ : RDFYM + 50% RDN + RDPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	6.56	6.86	6.71	18.18	16.80	17.49
T ₁₁ : RDFYM + 50% RDNPK + <i>Azospirillum</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	6.34	6.76	6.55	16.38	17.89	17.13
T ₁₂ : RDFYM + 50% RDN + RDPK + <i>Azotobacter</i> 5 kg ha ⁻¹ +PSB 3 kg ha ⁻¹	7.02	6.86	6.94	17.72	17.50	17.61
S.Em.±	0.16	0.11	0.10	1.00	0.63	0.50
CD at 5%	0.47	0.32	0.29	2.95	1.85	1.47

Effect of INM practices on yield and yield parameters of fennel

The significantly higher seed yield per plant, plot and hectare was recorded with T₆-RDFYM+ 75% RDN + RDPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹ (30.47 g plant⁻¹, 1.49 kg plot⁻¹ and 2.29 t ha⁻¹, respectively) this was on par with T₄- vermicompost at 2.5 t ha⁻¹+ RDNPK+ *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹ (29.85 g plant⁻¹, 1.44 kg plot⁻¹ and 2.21 t ha⁻¹, respectively) (Table 4). Increased seed yield could be owing to the improvement of yield components such as umbel number per plant, test weight and dry weight of plant. The organic sources of fertilizer is not only supplies the major nutrients but also minor nutrients which might have played crucial role in enzymatic reactions in rhizosphere of the plant and thus helped the plant to produce better growth and yield attributes lead to produce more yield. The important reason responsible for better production of yield components and yield could be the supply of nutrients in balanced amount and available form. The increased growth in term of plant height, branches per plant, expansion of leaf lamina and chlorophyll content provided greater sites for photosynthesis and diversion of photosynthates towards sink (umbels and seed). The beneficial effect on yield attributes might be also due to increased supply of all the essential nutrients by FYM which might have resulted in higher synthesis of food and its subsequent partitioning to sink. The increased yield might also be owing to better nutritional status of the soil which might have stimulated the rate of various plant physiological processes which lead to increased yield attributing characteristics and their cumulative effect resulted in enhanced seed yields of fennel. These findings of present investigation are in conformity of the results of Rahman *et al.*, (1990), Vadiraj *et al.*, (1998), Bhat and Sulikeri (1992), Baboo

and Rana (1995), Tiwari and Banafar (1995), Gaur (1998), Tripathi *et al.*, (2001), Kumar *et al.*, (2002), Rai *et al.*, (2002), Khoja (2004), Meena (2005) and Singh (2013) in coriander.

Yield is the manifestation of growth and yield parameters. Plants supplied with RDFYM+ 75% RDN + RDPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹(T₆) was recorded maximum number of umbels per plant (29.24) which was on par with T₁₀, T₂, T₄ and T₁₂ (28.17, 27.78, 27.66 and 27.30, respectively), maximum number of umbellets per umbel (23.68) and maximum number of seeds per umbellate (35.07) this was on par with T₄-Vermicompost 2.5 t ha⁻¹+ RDNPK+ *Azospirillum* at 5 kg ha⁻¹ +PSB 3 kg ha⁻¹ and T₂- RDFYM+ RDNPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹ (34.17 and 32.38, respectively) (Table 3). The ultimate aim of any farmer is to get more yield and return. Among the several yield components production of umbels and umbellets, which are directly or indirectly influenced by the number of seeds. Vermicompost affected the umbel number through microbial stimulation and gradual mineralization of soil. Vermicompost application through the improvement of biological activities of soil and mineral element absorption, caused more biomass production and subsequently enhanced umbel number per plant. Biofertilizers has significantly influenced the flowering and umbel number per plant. On the other hand, nitrogen fixing bacteria application through the improvement of biological activation caused more biomass production and umbel number. These findings are in accordance with the observations made by (Mahfouz and Sharaf Eldin, 2007) on *Foeniculum vulgare*, Sahu *et al.*, 2013 on *Coriandrum sativum* and Darzi *et al.*, 2013 on coriander.

Plants provided with RDFYM+ 75% RDN + RDPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3

kg ha⁻¹(T₆) was recorded maximum test weight (7.35 g), which was on par with T₁-RDFYM (15 t ha⁻¹)+ RDNPK (90:60:30 kg ha⁻¹) (7.10 g) (Table 5). The overall improvement in plant growth by cell division, cell enlargement and production of sufficient photosynthates through increased chlorophyll content of leaves on one hand and efficient utilization/ mobilization of photosynthates towards development of flowers and fruits on the other hand, might have been responsible for increased yield attributes like test weight and harvest index. This might be due to the fact that with the microorganisms are capable of mobilizing the soil bound nutrients which facilitated the availability of balanced amount of essential nutrients throughout the plant growth season resulting in better nourishment of plants and the formation of bold grains, ultimately increased the test weight. Besides biofertilizer have increased weight of 1000 seeds by enhancing the rate of photosynthesis and the biomass production improvement (Valadabadi and Farahani, 2011) on *Nigella sativa*, Sahu *et al.*, 2013 on *Coriandrum sativum*). Maximum harvest index was recorded with T₆- RDFYM+ 75% RDN + RDPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹ (19.48 %), which was on par with RDFYM+ 75% RDN + RDPK + 25% N equivalent of FYM (T₅) (19.14 %) and RDFYM + 50% RDN + RDPK + *Azospirillum* at 5 kg ha⁻¹ +PSB at 3 kg ha⁻¹ (T₁₀) (19.13 %) (Table 5).

From this study it can be concluded that integrated application of both organic and inorganic nutrients are beneficial in achieving higher yield of fennel due to steady and constant availability of mineralized nutrients in rhizosphere region.

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