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Effect of Integrated nutrient management on growth and yield of fennel (*Foeniculum vulgare*)

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ABSTRACT

A field experiment was conducted during the *rabi* 2016–17 and 2017–18 at Research Farm of CCS Haryana Agricultural University, Hisar. It comprised 16 treatment levels of fertilizer in randomized block-design with three replications. Growth parameters of fennel (*Foeniculum vulgare* Mill.) crop were significantly affected by the fertilizer treatments. Maximum plants height (16.49, 41.53, 106.13 and 177.00), number of primary branches (1.65, 5.27, 11.50 and 15.34) and number of secondary branches (2.98, 13.18 and 28.97) at 30, 60, 90 days after sowing and at harvest were observed in treatment T_{11}: RDF (100%) + *Azotobacter* + PSB. Days to 50% flowering ranged from 126.1 (T_{11}) RDF (100%) + *Azotobacter* + PSB to 119.8 (T_{16}) control. A maximum number of days to maturity were recorded in $T_{11:}$ Recommended dose of fertilizer along with *Azotobacter*+ PBS (171.6 days) and minimum were under control conditions (T_{16}) i.e. 147.8. Yield attributes like the number of umbels per plant (57.57), umbelets per umbel (33.33), seeds per umbel (613.67), seeds per umbelets (30.52), seed yield per plant (74.93), seed yield (2039.9 kg/ha), biological yield (6965 kg/ha), harvest index (32.08) etc. were highest in treatment T_{11}: RDF (100%) + *Azotobacter* + PSB per hectare.

Keyword: Biological yield, Harvest index, Maturity, Plant height, Seed yield,

Fennel (*Foeniculum vulgare* Mill.) is commonly known as '*saunf*.' It is an open-pollinated spice of temperate and subtropical regions belonging to the family Apiaceae. Seed spices account for about 37% and 18% of the total area and production of spices in the country, respectively (Sharma and Sharma 2017). It occupies an area of 91000 ha with a production of 153000 MT. In Haryana, fennel is mainly grown in the district of Rewari, Mahendragarh, Palwal, and Hisar, which occupy an area of about 0.27000 ha with the production of 0.17,000 MT (Anonymous 2018). Nowadays people are suffering due to agrochemical residues present in the soil. Use of organic manures and biofertilizers such as vermicompost provides high-quality products free from harmful agrochemicals for human safety (Mahfouz and Sharaf 2007).

Azotobacter is an aerobic free-living soil microbe, which plays an important role in the nitrogen cycle by binding atmospheric nitrogen through nitrogen fixation. Vermicompost is enriched with several beneficial soil microbes and also contains many essential plant nutrients like N, P and K (Sinha *et al.* 2010). There is a strong relation between soil organic matter content and soil fertility, which is widely and universally accepted by growers (Melero *et al.* 2007). At present, using organic manures and biofertilizers, such as vermicompost has led to a decrease in the application of chemical fertilizers and provides high quality products free of harmful agrochemicals for human safety (Mahfouz and Eldin 2007, Malik *et al*. 2009). Seeing all the beneficial effects of biofertilizers, FYM and vermicompost, an experiment was conducted to see the effect of integrated nutrient management on fennel including the recommended dose of chemical fertilizers.

MATERIALS AND METHODS

The present experiment was conducted at Research Farm, CCS Haryana Agricultural University, Hisar, during the *rabi* 2016–17 and 2017–18. The seeds of the variety Hisar Sawrup (HF-33) were procured from the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar. The field experiment consisted of sixteen treatments based on the recommended dose of fertilizers (N 50: P 25 kg/ha) for fennel. The experiment was conducted in Randomized Block Design with three replications and 45 cm × 20 cm spacing. Sowing was done in the month

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of November in both years (2016–17 and 2017–18). The seeds were treated with *Azotobacter* @100 ml/10 kg seed and PSB @100 ml/10 kg seed uniformly before sowing. To get optimum plant population, thinning operation was carried out when the plants attained a height of 10 cm and were bearing 3-4 leaves in order to keep a distance of 20 cm by removing weak and unhealthy seedlings. Only one plant was maintained per hill. In the present study, the status of available potassium falls under the soil rating status as medium (219.00 and 206.00 kg/ha) during 2016–17 and 2017–18. Rating of the N, P, K status was done based on the soil manual of the Department of Soil Science, CCS HAU Hisar.

RESULTS AND DISCUSSION

Maximum plant height was achieved with treatment T_{11} at 30, 60, 90 days after sowing and at harvest as compared to T_{16} i.e. control (Table 1). The per cent increase of pooled values for plant height of T_{11} RDF (100%) + *Azotobacter* + PSB over control T_{16} was 41.18, 40.30, 23.55 and 20.49% at 30, 60, 90 and at harvest, respectively. The recommended dose of fertilizers in fennel is Nitrogen 50 kg/ha and Phosphorus 25 kg/ha which as per soil testing were low and medium in the experimental soil and with the application of RDF, the crop requirement might have been fulfilled resulting in higher plant height. Fresh plant material about 94.0–99.5% is made of carbon, hydrogen and oxygen and the remaining 0.5–6.0% is made up of other nutrients. Waskela *et al*. (2017) also reported that increase in plant height in fennel with the recommended dose of fertilizer increased due to endogenous level of N P K in the plant under its increased availability in the soil medium and resulted in efficient absorption and translocation by way of active cell division and elongation resulting in

Table 1 Effect of integrated nutrient management on plant height and number of primary and Secondary branches per plant of fennel

Treatment	Plant height (cm)				Primary branches/plant				Secondary branches/ plant		
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest
T_1 : 100% RDN through FYM + *Azotobacter*	13.18	33.82	91.62	155.10	1.01	3.88	8.87	12.22	1.87	9.00	19.45
T_2 : 75% RDN through FYM + *Azotobacter*	11.93	31.23	86.83	147.90	0.79	3.43	8.00	11.20	1.50	7.68	16.43
T_3 : 100% RDN through Vermicompost + *Azotobacter*	13.73	36.33	96.43	162.10	1.24	4.33	9.77	13.30	2.23	10.33	22.35
T_4 : 75% RDN through Vermicompost + *Azotobacter*	13.33	33.57	91.50	155.10	1.04	3.90	8.87	12.27	1.85	9.02	19.43
T_5 : RDF (100%) + *Azotobacter*	15.10	38.86	101.20	169.40	1.46	4.74	10.69	14.38	2.63	11.77	25.65
T_6 : RDF (75%) + *Azotobacter*	13.90	36.19	96.32	162.30	1.27	4.30	9.80	13.35	2.27	10.42	22.63
T_7 : 100% RDN through FYM + *Azotobacter* + PSB	14.43	36.30	96.55	162.10	1.23	4.33	9.72	13.22	2.23	10.33	22.38
T_8 : 75% RDN through FYM + *Azotobacter*+ PSB	13.69	33.65	91.82	155.10	1.04	3.93	8.88	12.22	1.90	8.97	19.30
T_9 : 100% RDN through Vermicompost + *Azotobacter* + PSB	15.24	38.81	101.20	169.10	1.43	4.77	10.62	14.25	2.60	11.74	25.53
T_{10} : 75% RDN through Vermicompost + *Azotobacter* + PSB	14.79	36.14	96.33	162.20	1.35	4.35	9.77	13.23	2.25	10.38	22.48
T_{11} : RDF (100%) + *Azotobacter* + PSB	16.49	41.53	106.13	177.00	1.65	5.27	11.50	15.34	2.98	13.18	28.97
T_{12} : RDF (75%) + *Azotobacter* + PSB	15.50	39.03	101.45	170.10	1.46	4.82	10.62	14.27	2.60	11.83	25.88
T_{13} : 100% RDN through FYM	13.21	31.32	86.97	148.10	0.82	3.47	8.07	11.25	1.47	7.67	16.48
T_{14} : 100% RDN through Vermicompost	13.75	33.81	91.80	155.20	1.06	3.90	8.93	12.33	1.90	9.05	19.47
T_{15} : Recommended dose of fertilizer (N 50: P 25 kg/ha)	12.70	36.32	96.55	162.30	1.30	4.29	9.88	13.40	2.30	10.45	22.62
T_{15} : Control	11.68	29.60	85.90	146.90	0.73	3.38	7.85	11.08	1.35	7.50	16.22
SEm±	1.58	0.62	1.15	1.60	0.04	0.09	0.19	0.26	0.09	0.30	0.83
CD at 5%	NS	1.79	3.34	4.80	0.12	0.27	0.58	0.74	0.26	0.88	2.40

greater plant height. The results are in confirmation with Mehta *et al.* (2010).

Both primary and secondary branches per plant were highest with treatment T_{11} at 30, 60, 90 days after sowing and at harvest as compared to control (Table 1). The per cent increase of pooled values for primary branches of T_{11}RDF (100%) + *Azotobacter* + PSB over control T_{16} (control) was 126.02, 55.91, 46.49 and 38.44 % at 30, 60, 90 and at harvest, respectively. The per cent increase of pooled values for secondary branches of T_{11}RDF (100%) + *Azotobacter* + PSB over control T_{16} (control) was 120.74, 56.53 and 78.60% at 60, 90 days and at harvest, respectively. Subsequently, the most promising results for increasing the primary and secondary branches were observed under the treatment T_9: 100% RDN through Vermicompost + *Azotobacter* + PSB (for primary branches, 92.59, 41.12, 35.28, and 28.68% increase over control and for secondary branches, 92.59, 56.53 and 57.39% increase over control, respectively) and T_7: 100% RDN through FYM + Azotobacter + PSB (for primary branches, 40.65, 28.35, 23.82 and 19.31 and secondary branches, 65.18, 37.73 37.97% over control, respectively), as compared to T_{16} (Control). Application of RDF resulting in higher primary branches was attributed to the availability of adequate nutrients during the growth period. The results are in confirmation with Pariari *et al*. (2015). None of the integrated management treatment affected the days to 50% flowering significantly in fennel. However, the normal days to 50% flowering in T_{11} was recorded as 126.1 days and 119.8 days in control (T_{16}), respectively. The results are in confirmation with Bhardwaj and Kumar (2016) and

Table 2 Effect of integrated nutrient management on days to flowering, days to maturity, seed yield attributes and seed yield of fennel

Treatment	Days to 50% flowering	Days to maturity	Number of umbels per plant	Number of umbelets per umbel	Number of seeds per umbel	Number of seeds per umbelets	Seed yield per plant (g)	Seed yield (kg/ha)	Biological yield (kg/ ha)
T_1 : 100% RDN through FYM + *Azotobacter*	122.0	154.0	44.33	24.84	393.17	22.93	58.00	1736.6	5776
T_2 : 75% RDN through FYM + *Azotobacter*	121.8	148.1	40.18	22.00	323.50	20.42	52.40	1639.1	5367
T_3 : 100% RDN through Vermicompost + *Azotobacter*	122.9	159.9	48.60	27.34	462.83	25.42	63.57	1831.5	6180
T_4 : 75% RDN through Vermicompost + *Azotobacter*	122.6	153.9	44.40	24.67	393.33	22.93	57.95	1733.8	5773
T_5 : RDF (100%) + *Azotobacter*	124.0	165.9	52.77	30.33	536.33	28.00	69.22	1935.3	6583
T_6 : RDF (75%) + *Azotobacter*	123.2	160.0	48.57	27.67	466.50	25.43	63.63	1832.9	6181
T_7 : 100% RDN through FYM + *Azotobacter* + PSB	123.3	159.8	48.53	27.50	465.67	25.35	63.65	1836.3	6168
T_8 : 75% RDN through FYM + *Azotobacter*+ PSB	121.8	154.0	44.43	24.83	394.50	22.93	58.07	1740.3	5783
T_9 : 100% RDN through Vermicompost + *Azotobacter* + PSB	121.7	165.6	52.75	30.17	539.33	27.90	69.13	1932.1	6577
T_{10} : 75% RDN through Vermicompost + *Azotobacter* + PSB	122.8	159.9	48.52	27.67	465.00	25.45	63.53	1832.4	6183
T_{11} : RDF (100%) + *Azotobacter* + PSB	126.1	171.6	57.57	33.33	613.67	30.52	74.93	2039.9	6965
T_{12} : RDF (75%) + *Azotobacter* + PSB	122.5	165.8	53.43	30.84	543.67	27.72	69.18	1929.2	6568
T_{13} : 100% RDN through FYM	122.8	148.2	40.23	22.33	326.33	20.52	52.45	1641.6	5379
T_{14} : 100% RDN through Vermicompost	122.3	154.1	44.47	25.34	396.33	23.00	57.93	1736.7	5786
T_{15} : Recommended dose of fertilizer (N 50: P 25 kg/ha)	123.2	160.1	48.62	27.83	468.33	25.50	63.62	1833.0	6194
T_{15} : Control	119.8	147.8	39.47	21.33	313.83	20.25	52.10	1318.9	5325
SEm±	1.47	1.83	0.82	0.66	17.89	0.45	1.52	24.87	17.89
CD at 5%	NS	5.30	2.38	1.95	51.91	1.31	4.41	72.53	51.91

Godara *et al*. (2013).

Days to maturity was significantly delayed under treatment T_{11} (RDF 100%) + *Azotobacter* + PSB by 23.8, T_9 (100% RDN through Vermicompost + *Azotobacter* + PSB) by 17.8, T_7 (100% RDN through FYM + Azotobacter + PSB) by 12.0 days as compared to control (T_{16}). The most effective treatment was $T_{11}$where the sufficient nutrients provide the plants with an opportunity to remain in the reproductive period for a longer duration as compared to control conditions, where no fertilizer, biofertilizer, FYM and vermicompost were applied (Table 2). The results are in confirmation with Meena *et al*. (2013) and Tripathi *et al*. (2013). Yield attributes like number of umbles per plant, number of umblets per umble, number of seeds per umble, number of seeds per umblet, seed yield per plant and seed yield per hectare were significantly higher under T_{11}: RDF 100% + Azotobacter+ PSB) i.e. 57.57, 33.33, 613.67, 30.52, 74.93 g, 2039.9 kg/ha as compared to 39.47, 21.33, 313.83, 20.25, 52.10 g and 1318.9 kg/ha in T_{16} control (Table 2). The per cent increase in the above yield attributes and yield was 48.86, 52.26, 95.54, 50.72, 43.82 and 54.67%, respectively, over control. The yield attributes and yield was higher due to higher nutrient availability, under the recommended dose of fertilizer along with the *Azotobacter* + PSB. Both the biofertilizers contributed to the availability of nitrogen and phosphorus to plants by their action on mineral soils. Also, the vermicompost and FYM treatments especially, T_9 (100% RDN through Vermicompost + *Azotobacter* + PSB) and T_7 (100% RDN through FYM + *Azotobacter* + PSB) were successfully integrated nutrient management practices which significantly increased the yield i.e. 1932.1 and 1836.3 kg/ha, respectively, in fennel over control (T_{16}) and the per cent increase was estimated at 46.49 and 39.22%, respectively (Table 2).The results are in confirmation with Kumawat *et al.* (2015). The highest biological yield was 6965 kg/ha under treatment T_{11} (RDF 100%) + *Azotobacter* + PSB) and lowest 5325 kg/T_{16} (control). The results are in confirmation with Singh (2013), Valiki *et al.* (2015), Patel *et al.* (2010), Singh (2015), Godara *et al.* (2014).

Higher growth, yield attributes and yield under treatment T_{11}: RDF (100%) + *Azotobacter* + PSB made it most suitable *integrated nutrient management* by including biofertilizers along with 100% recommended dose of chemical fertilizers for fennel production. The experimental results also provided the scope of treatment T_9:100% RDN through vermicompost + *Azotobacter* + PSB in the long run under organic farming of fennel.

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