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Studies on effect of integrated nutrient management on growth of fennel (*Foeniculum vulgare* Mill.)

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Abstract
An experiment was conducted during *Rabi* season of 2020-21 at College of Horticulture, Rajendranagar to study the effect of integrated nutrient management on growth of Fennel (*Foeniculam vulgare* Mill). The growth attributes were significantly affected due to the different INM treatments. Application of inorganic fertilizers in combination with organic manures and biofertilizers *i.e*., 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter @ 5kg ha^{-1} + Phosphorus solubilizing bacteria @ 3 kg ha^{-1} recorded significantly higher plant height (52.36 and 104.4 cm), number of primary branches (10.93 and 14.46), number of secondary branches (9.44 and 19.25) and plant spread (41.39 and 59.59 cm^2) at 60 and 90 days after sowing respectively. While the lowest was reported in Control (no use of fertilizers). Whereas non significance difference has been reported in growth attributes at 30 days after sowing among the treatments.

Keywords: Farmyard manure, Fennel, Vermicompost

Introduction
Fennel (*Foeniculum vulgare* Mill.) belongs to family Apiaceae. Fennel is diploid having 2n=22 chromosomes. It is a native of Southern Europe and Mediterranean region and one of the popular seed spices in India, mainly grown in Rabi season. Later, it spread to the far east and far north in Europe. Fennel was also a symbol of success to the Romans. During the thirteenth century in England, fennel was considered as a royal spice and was served to kings with fruits. The most common Indian name is Saunf and there are many popular regional names (Ashok kumar *et al*., 2017) [1]. India is the world's largest producer, consumer and exporter of the spices and among the spices, fennel is one of the most important seed spice. India occupies prime position in fennel and plays very important role in earning foreign exchange through export of the seed spice. In India, area under fennel is 90 thousand hectares with production of 128 metric tons. Gujarat stands with largest area under fennel cultivation with 97 metric tons of production (NHB, 2019-20). Area under Rabi direct seeded fennel is increasing day by day, because it is more profitable as a winter direct seeded crop. It grows to a height of 150-180 cm and stem is erect, stout, cylindrical, smooth and hollow at maturity with distinct veins. The plant is single stemmed in the beginning but 2 to 3 or even more (if plants are spaced wide apart), branches also emerge later from the base of the plant. Each main stem bears 4 to 8 alternate branches, which may bear secondary branches bearing compound leaves. Leaves stalked petiole very long, dilated for the greater part of its length into an open flattened sheath.

The inflorescence is a compound umbel appears terminally on the plant. Small yellow flowers with fine petals are borne on umbellate in umbels, bisexual, petals five, yellow, ovary inferior, bicarpellary, fruits oblong with persistent style.

Constant use of chemical fertilizers over a long period of time was found to impair the ecological balance. It, not only reduces the crop quality attributes, but also fetch poor market price to the farmers. In recent years, with the excess use of inorganic fertilizers and other chemicals, the natural fertility of soil has been lost, there by contaminating the soil, water and food. The chemical usage is hitting the sustainability in soil and decreasing its potency. Integrated nutrient management including compost, vermicompost and use of bio NPK consortium either alone or in combination of chemical fertilizers not only help to curtail chemical load in the soil, but also improves soil physical condition and augments microbial activities in the soil and thereby enhances sustainable yield potential (Gamar *et al*., 2018) [5].

Addition of organic manures like farm yard manure, vermicompost, neem cake, poultry manure etc., not only supplies most of the essential plant nutrients, but also improves the soil structure by providing binding substance to soil aggregates leading to increase in cation exchange capacity and water holding capacity of the soil. (Mahapatra *et al.*, 2009) [7]. Biofertilizers are one of the important and cheapest nutrient sources in the integrated nutrient management system. On application of biofertilizers to the seed, root or soil helps in fixing the nitrogen, mobilize the availability of nutrient and also helps in buildup of the micro flora. Combination effect of organic manures, nitrogen fixing biofertilizers and phosphate solubilizing bacteria helps to increase the availability of nutrients (Devi and Limi Ado, 2005) [4]. The extensive use of biofertilizers in crop production is the major breakthrough as pollution free low-cost input technology during recent years. Scientific evidence clearly showed that combined application of biofertilizers like nitrogen fixing, Phosphate solubilizing and mobilizing microbes had positive effect on crop growth and yield. The application of combined form of N fixing, P solubilizing and mobilizing, growth promoting microbes is difficult for farmers due to unavailability in one place which is a limiting factor. Hence, organic manures and biofertilizers are the important components of integrated nutrient management. There is a need to seek alternative nutrient sources which could be cheap and eco-friendly so that farmers may be able to reduce the investment on chemical fertilizers along with maintaining good soil environment conditions leading to ecological sustainable farming.

Materials and Methods

The experiment was conducted during *Rabi* season of 2020-21 at College of Horticulture, Rajendranagar to study the effect of integrated nutrient management on growth of Fennel (*Foeniculam vulgare* Mill) using cultivar Ajmer fennel-1. Treatment consisted of T_1- 100% RDF (recommended dose of fertilizers), T_2- 100% RDN (recommended dose of nitrogen) through vermicompost, T_3 - 100% RDN through FYM T4: 75% RDF + 25% RDN through FYM + Azotobacter + Phosphorous solubilizing bacteria (PSB), T_5 - 75% RDF +25% RDN through vermicompost + Azotobacter + Phosphorous solubilizing bacteria (PSB), T_6 - 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + Phosphorous solubilizing bacteria (PSB), T_7 - 50% RDF + 50% RDN through vermicompost, T_8 - 50%RDF +50% RDN through FYM, T_9 - 50% RDF + 25% RDN through FYM + 25% RDN through vermicompost + Azotobacter + phosphorous solubilizing bacteria (PSB), T_{10} - Control (no fertilizers). The experiment was conducted in randomized block design having three replications and recommended practices were undertaken. The soil of the experimental site was loamy texture with a pH of 6.7 and electrical conductivity of 0.12 dsm^{-1}. The organic carbon content was very low. The availability of nitrogen, phosphorous and potash per hectare was 225.30, 35 and 115.23 kg respectively.

Result and Discussion

The data on growth parameters *viz.*, plant height, number of primary branches per plant, number of secondary branches per plant and plant spread are presented in the table 1 and 2.

Plant height (cm): The data regarding plant height at 30, 60 and 90 days after sowing as influenced by the integrated nutrient management is presented in the table 1 and 2.

At 30 DAS: Plant height of fennel at 30 DAS was not influenced by any of the treatments as there was no significant difference in height among the plants due to treatments.

At 60 DAS: All integrated nutrient management treatments showed significant difference on plant height at 60 DAS. The highest plant height (52.36 cm) was recorded in T_6 -75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + PSB, followed by T_1- 100% RDF (47.72 cm) which was on par with T_5 -75% RDF + 25% RDN through VC + Azotobacter + PSB (45.16 cm) and T_4 - 75% RDF + 25% RDN through FYM + Azotobacter + PSB (43.67 cm). The lowest plant height (30.95 cm) was recorded in T_{10} - Control (no use of fertilizers and was at par with T_3 - 100% RDN through FYM (33.92 cm) and T_2 - 100% RDN through VC (35.07cm).

At 90 DAS: There was significant difference observed among the treatments with respect to plant height at 90 DAS. Among the treatments T_6 - 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + PSB recorded maximum plant height (104.04cm) and was at par with T_1 - 100% RDF (99.11cm), T_5- 75% RDF + 25% RDN through VC + Azotobacter + PSB (94.33 cm) and T_4 - 75% RDF + 25% RDN through FYM + Azotobacter + PSB (93.29 cm). Whereas T_{10} - Control (no use of fertilizers) recorded minimum plant height (71.63 cm) on par with T_3 - 100% RDN through FYM (76.97 cm) and T_2 - 100% RDN through VC (78.58 cm) treatment. The data enunciated on plant height at 60 and 90 DAS revealed that, among the treatments T_6 - 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + PSB recorded the highest value. Which might be due to the combined effect of organic, inorganic fertilizers, nitrogen fixing biofertilizers and phosphate solubilising bacteria which enhanced the availability of nitrogen and phosphates in the rhizosphere and uptake by the plants. The growth promoting effect of FYM as a source of plant nutrients and humus, improved physiological conditions of the soil in terms of good aeration and proliferation microbial activity. Similar results were also reported by Patel *et al*. (2010) [10] in fenugreek, Kalidasu *et al.* (2008) [6] in coriander, Naveen (2010) [9], Sunanda *et al.* (2014) [13] and Babaleshwar *et al*. (2017) [2] in kasurimethi.

Number of Primary branches per plant: The data pertaining to Number of primary branches per plant at 30, 60, 90 days after sowing as effected by the INM is presented in the table 1.

At 30 DAS: The data pertaining to number of primary branches at 30 DAS showed that there was no significance difference between treatments.

At 60 DAS: All treatments differed significantly on this parameter at 60 DAS. Significantly more number of branches per plant (10.93) was recorded in T_6 - 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + PSB and was on par with T_1 - 100% RDF (10.08) followed by T_5 - 75% RDF + 25% RDN through VC + Azotobacter + PSB (8.61) and T_4 - 75% RDF + 25% RDN through FYM + Azotobacter + PSB (8.18). The minimum number of primary branches (4.68) was recorded in T_{10} - Control (no use of fertilizers) and was on par with T_2 -100%

RDN through VC (5.67) and T_3 -100% RDN through FYM (5.77).

At 90 DAS: There was significant difference observed due to treatments with regard to number of primary branches at 90 DAS. Among the treatments, T_6 -75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + PSB recorded significantly maximum number of branches per plant (14.46) but was on par with T_1 - 100% RDF (13.45) and T_5 - 75% RDF + 25% RDN through VC + Azotobacter + PSB (12.15). The minimum number of primary branches (7.22) was recorded in T_{10} – Control (no use of fertilizers), which was at par with T_8 - 50% RDF + 50% RDN through FYM (8.25) and T_7 - 50% RDF + 50% RDN through VC (8.96).

Number of secondary branches per plant at 60 and 90 days after sowing was effected by the INM and the data is presented in the table 2.

At 60 DAS: All treatments differed significantly on this parameter at 60 DAS. Significantly more number of branches per plant was recorded in T_6 - 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + PSB (9.44) and was on par with T_1 - 100% RDF (9.20), T_5 - 75% RDF + 25% RDN through VC + Azotobacter + PSB (8.37) and T_4 - 75% RDF + 25% RDN through FYM + Azotobacter + PSB (8.04), whereas the minimum number of secondary branches was recorded in T_{10} - Control (no use of fertilizers) (5.88) and was on par with T_3 -100% RDN through FYM (6.31), T_8 - 100% RDN through VC (6.70) and T_2 - 100% RDN through VC (6.76).

At 90 DAS: There were significant differences observed due to treatments regarding secondary branches at 90 DAS. Among the treatments, T_6 - 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + PSB recorded significantly maximum number of secondary branches per plant (19.25) which was on par with T_1 -100% RDF (17.98) and T_5 -75% RDF + 25% RDN through VC + Azotobacter + PSB (17.67). The minimum was noticed in T_{10} - Control (no use of fertilizers) (11.29) which was on par with T_3 -100% RDN through FYM (12.76) followed by T_2 - 100% RDN through VC (13.44). In the present study, maximum number of primary and secondary branches per plant was recorded in T_6 -75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + PSB which might be due to application of RDF led to continuous and prolonged availability of nutrients during growth period and produced more number of branches per plant. Moreover, it might be due to combined application of Azotobacter and PSB, resulted in better utilization of nitrogen, phosphorus and more synthesis of plant growth hormones might lead to higher number of branches. Our results are comparable with that of Sunanda *et al*. (2014) [13] and Babaleshwar *et al.* (2017) [2] in kasurimethi, Kalidasu *et al*. (2008) [6] in coriander, Chattopadhyay *et al*. (2017) [3] and Singh *et al*. (2018) in dill.

Plant spread (cm^2): The results related to plant spread at 30, 60 and 90 days after sowing showed significance influence by the INM and the data is presented in the table 2.

At 30 DAS: No significant differences were observed due to treatments in plant spread at 30 DAS.

At 60 DAS: All treatments differed significantly regarding plant spread at 60 DAS. Among all the treatments, T_6 - 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + PSB recorded maximum plant spread (41.39 cm^2), which was comparable with T_1 - 100% RDF treatment (38.76 cm^2) at par with T_5 - 75% RDF + 25% RDN through VC + Azotobacter + PSB (34.91cm$_2$) and T_4 - 75% RDF + 25% RDN through FYM + Azotobacter + PSB (34.37cm^2). Whereas it was minimum in T_{10} - Control (no use of fertilizers) (19.49 cm^2) followed by T_3 - 100% RDN through FYM (24.50 cm^2) and T_2 - 100% RDN through VC (25.66 cm^2).

At 90 DAS: There was significant difference observed among the treatments on the plant spread at 90 DAS. Among all the treatments, maximum value was recorded in T_6 -75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + PSB (59.59 cm^2), which was comparable with T_1- 100% RDF (58.83 cm^2), T_5 - 75% RDF + 25% RDN through VC + Azotobacter + PSB (56.33 cm^2) and T_4 - 75% RDF + 25% RDN through FYM + Azotobacter + PSB (55.91cm^2). While T_{10} - Control (no use of fertilizers) recorded significantly minimum value (38.64 cm ^{2}) followed by T_3 - 100% RDN through VC (44.52 cm^2) T_2 -100% RDN through FYM (46.31 cm^2). The highest plant spread at 60 and 90 days after sowing was recorded in T_6 - 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermi compost + Azotobacter + PSB might be due to the same treatment registered maximum plant height and more number of branches per plant as compared to rest of the treatments. The above results are in agreement with the findings of Singh (2011) in coriander and Babaleshwar *et al*. (2017) [2] in kasurimethi.

Table 1: Effect of integrated nutrient management on plant height (cm) and number of Primary branches per plant of fennel at 30DAS, 60DAS and at 90DAS

Treatments	Plant height (cm)			Number of Primary branches		
	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days
T1	16.76	47.72^{b}	99.11^{ab}	2.86	10.08^{ab}	13.45 ^{a}
T2	13.90	35.07^{ef}	78.58^{e}	2.89	5.67^{f}	8.27^{c}
T3	13.70	33.92^{f}	76.97^{e}	2.81	5.77^{f}	7.55^{c}
T4	14.92	43.67^{bc}	93.29^{bc}	3.00	8.18^{c}	11.29^{b}
T5	16.16	45.16^{b}	94.33b	3.09	8.61^{bc}	12.15 ^{ab}
T6	17.04	52.36^{a}	104.04^{a}	3.08	10.93^{a}	14.46^{a}
T7	15.18	39.12^{de}	85.29^{cd}	2.73	6.81^{e}	8.96^{c}
T8	14.52	36.56^{e}	82.87^{de}	2.74	6.65^{ef}	8.25^{c}
T9	15.02	41.51^{cd}	89.03^{c}	2.71	7.52^{ce}	9.81^{bc}
T10	12.40	30.95^{f}	71.63^{f}	2.73	4.68^{g}	7.22^{d}
S.Em ±	0.94	1.42	2.93	0.11	0.56	0.86
CD at 5%	NS	4.22	8.71	NS	1.66	2.55

[T_1- 100% RDF (recommended dose of fertilizers), T_2- 100% RDN (recommended dose of nitrogen) through vermicompost, T_3 - 100% RDN through FYM, T_4: 75% RDF + 25% RDN through FYM + Azotobacter + Phosphorous solubilizing bacteria (PSB), T_5 - 75% RDF +25% RDN through vermicompost + Azotobacter + Phosphorous solubilizing bacteria (PSB), T_6 - 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + Phosphorous solubilizing bacteria (PSB), T_7 - 50% RDF + 50% RDN through vermicompost, T_8 - 50%RDF +50%RDN through FYM, T_9 - 50% RDF + 25% RDN through FYM + 25% RDN through vermicompost + Azotobacter + phosphorous solubilizing bacteria (PSB), T_{10} - Control (no fertilizers)]

Table 2: Effect of integrated nutrient management on number of secondary branches and Plant spread (cm^2) of Fennel at 30 DAS, 60DAS and at 90 DAS

Treatments	Number of Secondary branches			Plant spread (cm^2)		
	30 Days	60 Days	90 Days	30 Days	60 Days	90 Days
T1	0	9.20 ^{a}	17.98 ^{a}	16.76	38.76 ^{ab}	58.83 ^{a}
T2	0	6.76^{c}	13.44^{d}	12.88	25.66^{e}	46.31^{cd}
T3	0	6.31^{c}	12.76^{d}	11.58	24.50^{e}	44.52^{d}
T4	0	8.04^{b}	16.09^{bc}	15.91	34.37^{c}	55.91 ^{a}
T5	0	8.37 ^{ab}	17.67 ^{ab}	16.16	34.91^{bc}	56.33 ^{a}
T6	0	9.44 ^{a}	19.25 ^{a}	17.15	41.39 ^{a}	59.59 ^{a}
T7	0	7.19b^{c}	14.77^{c}	14.16	28.7^{8d}	52.14^{b}
T8	0	6.70^{c}	14.05^{cd}	13.64	27.59^{de}	50.50^{bc}
bT9	0	7.45^{b}	15.21^{c}	14.58	31.67^{cd}	54.90 ^{ab}
T10	0	5.88^{d}	11.29^{e}	10.74	19.49^{f}	38.64 ^{e}
S.Em ±	0	0.39	0.67	1.40	1.46	1.68
CD at 5%	0	1.18	1.99	NS	4.35	4.99

[T_1- 100% RDF (recommended dose of fertilizers), T_2- 100% RDN (recommended dose of nitrogen) through vermicompost, T_3 - 100% RDN through FYM, T_4: 75% RDF + 25% RDN through FYM + Azotobacter + Phosphorous solubilizing bacteria (PSB), T_5 - 75% RDF +25% RDN through vermicompost + Azotobacter + Phosphorous solubilizing bacteria (PSB), T_6 - 75% RDF + 12.5% RDN through FYM + 12.5% RDN through vermicompost + Azotobacter + Phosphorous solubilizing bacteria (PSB), T_7 - 50% RDF + 50% RDN through vermicompost, T_8 - 50%RDF +50%RDN through FYM, T_9 - 50% RDF + 25% RDN through FYM + 25% RDN through vermicompost + Azotobacter + phosphorous solubilizing bacteria (PSB), T_{10} - Control (no fertilizers)]

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