Effect of different organic sources on seed yield of *rabi* fennel *(Foeniculam vulgare* P. Mill.) under organic farming

ABSTRACT

The present study titled "Effect of different organic sources on seed yield of *rabi* fennel *(Foeniculam vulgare* P. Mill.) under organic farming" was carried out at Agronomy Instructional Farm of the Chimanbhai Patel College of Agriculture, Sardar krushinagar Dantiwada Agricultural University, Sardar krushinagar, Gujarat during *Rabi* season of the year 2015-16, 2016-17 and 2019-20. *Foeniculum vulgare*, commonly known as fennel, is a widely recognized and essential medicinal and aromatic plant from the Apiaceae family. This study also examines the impact of organic sources in fennel cultivation, highlighting their potential to improve soil structure and microbial biomass. Organic sources, derived from both animal and plant sources, are considered eco-friendly alternatives with long term benefits. Results from the study indicate that for growing *rabi* fennel under organic farming application of 75% RDN (67.5 kg N/ha) either through castor cake or FYM at the time of sowing along with seed inoculation with *Azotobacter* and PSB @ 5 ml/kg seed for obtaining higher seed yield and net returns. These findings suggest the potential of organic manures to improve the growth and yield of funnel. In conclusion, this provides an extensive overview of funnel, addressing its botanical characteristics, chemical composition, pharmacological attributes, traditional uses, and agricultural practices. The experimental data highlights the positive impact of organic manures on fennel growth parameters, offering valuable insights for sustainable cultivation practices.

.

Keywords: Organic sources, Castor cake, FYM, Vermicompost, *Azotobacter*, PSB and Fennel

I. INTRODUCTION

Comment [N1]: clarify review of literature

Foeniculum vulgare (Apiaceae) frequently accepted as fennel is an able-bodied accepted and important alleviative and ambrosial bulb broadly acclimated as carminative, digestive, lactogogue and diuretic and in alleviative respiratory and gastrointestinal disorders. Hanif *et al.*(2020). Phenolic compounds isolated from *F. vulgare* are advised to be amenable for its antioxidant action while the airy aroma compounds accomplish it an accomplished flavouring agent. The present assay is an abreast and absolute assay of the chemistry, pharmacology, acceptable uses and assurance of *F. vulgare* (Rather *et al*., 2016). Fennel is a cross-pollinated crop from the Apiaceae family. It is a diploid species with 2n=22 chromosomes that originated in Europe (Solanki *et al*., 2001). Fennel is an herb with a slender, extendable, smooth stem that grows to be 100-180 cm tall. The inflorescence is terminal, with a complex umbel surrounded by bract involucres. Small, bisexual, complete, typical, and pentamerous flowers. A schizocarp of two mericarps attached to a partitioning carpophore is the typical product known as the seed. A fully formed normal seed measures 4 to 8 mm in length. Fennel capital oil or its accustomed apparatus such as a net hole characterize altered activities like antifungal, insecticidal, and antibacterial activity. Fennel possesses antioxidant property, antibacterial activity, anti-inflammatory effect, antiallergic and hepatoprotective action and antispasmodic activity (Javed *et al*., 2020). The seeds have a protein content of 9.5 percent, a fat content of 10.0 percent, a starch content of 42.3 percent, a rough fiber content of 18.5 percent, and a mineral content of 13.4 percent. The seeds contain a variable amount of oil, ranging from 2.5 to 6.5 percent, depending on the

genotypes or organic kinds. Seed oil is used for scenting purifiers and flavoring cakes because it is unstable Bernath *et al*. (1996). The total area under cultivation is around 0.90 lakh hectares, with a yield of 1.57 lakh tonnes and a productivity of 1744.44 kg ha^{-1} (FAOSTAT, 2020). Organic manures in allegory of the actinic fertilizers accept lower comestible agreeable and are apathetic absolution but they are as able as actinic fertilizers over best periods of use Continuous acceptance of asleep fertilizer affects clay structure. Hence, amoebic manures can serve as another to mineral fertilizers for convalescent clay anatomy and microbial biomass. Organic fertilizers are acquired from beastly sources such as beastly admixture or bulb sources like blooming manure (Lal *et al*., 2019). Mention purpose of the study

Materials and Methods

Comment [N2]: mention statistical procedure used for analysis and other technique/tools nutrient uptake data taken

The current field experiment was conducted during *Rabi* season of the year 2015-16, 2016-17 and 2019-20 atthe Agronomy Instructional Farm of the Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat. The experiment was laid out in RBD comprising 8 treatments and replicated four consists of

T_1: 50 % RDN through FYM + *Azotobacter* + PSB (PSB 10),

T_2: 75 % RDN through FYM + *Azotobacter* + PSB (PSB 10),

T_3: 50 % RDN through Vermicompost + *Azotobacter* +PSB (PSB 10),

T_4: 75 % RDN through Vermicompost + *Azotobacter*PSB (PSB 10),

T_5: 50 % RDN through Castor cake + *Azotobacter* + PSB (PSB 10),

T_6: 75 % RDN through Castor cake + *Azotobacter* + PSB (PSB 10);

T_7: Seed treatment with *Azotobacter* and PSB (PSB 10) and

T_8: Control (RDF: 90-30-00 NPK kg/ha).

Azotobacter and PSB each was applied @ 5.0 ml/k seed as seed inoculation. Experiment was conducted on fixed site in organically converted plot for treatments T_1 to T_7.Treatment T_8: Control (RDF: 90-30-00 kg NPK /ha was conducted in conventional plot and site was changed every year. Manures were applied 15- 20 days before sowing. GF-12 variety of fennel was used for sowing. Spacing for crop is 45 cm and seed rate was 5 kg/ha. Crop management practices were followed as per the recommendation of the area.

Results and interpretation

Comment [N3]: discuss more

Pooled (2015-16, 2016-17 and 2019-20)

The data summarized in Table 5 revealed that use of different sources of nitrogen along with biofertilizers had significant effect on seed and stalk yield of *rabi* fennel in pooled results of three years. Application of 75% RDN through castor cake along with seed inoculation of *Azotobacter and* PSB(T_6) registered significantly higher seed (1500 kg/ha) and stalk (4231 kg/ha) yields over rest of the treatments, which was found at par with treatments T_2 (75 % RDN through FYM + *Azotobacter* + PSB) and T_8(Control: RDF: 90- 30-00 kgNPK/ha)in case of seed yield and treatment T_2 with respect to stalk yield. When comparision made among different treatments received organic sources, treatment T_6 (application of 75% RDN through castor cake along with seed inoculation of *Azotobacter and* PSB) gave significantly higher seed as well as stalk yields as compared to rest of the

treatments except treatment T_2 (75 % RDN through FYM + *Azotobacter* + PSB). Significantly the lowest seed (1014 kg/ha) and stalk (3141 kg/ha) yields were registered under treatment T_7 (seed inoculation with *Azotobacter* and PSB).

2017-18 and 2018-19

Comment [N4]: what does it mean

Severe infestation of aphid was observed at grain setting stage in *rabi* fennel so no seed yield was obtained during both the years. Therefore, experiment was vitiated.

Economics (pooled data)

The data on economics highlighted in Table 7 showed that maximum gross (Rs 99594/ha) and net return (Rs 58185/ha) with BCR of 2.41 was realized with application of 75% RDN through castor cake along with seed inoculation of *Azotobacter and* PSB (T_6) followed by treatments T_8(Control: RDF: 90-30-00 kgNPK/ha) and T_2 (75 % RDN through FYM + *Azotobacter* + PSB)in pooled results. However, treatment T_7 (RDF *i.e.* control) recorded the lowest gross return (Rs 67481/ha) and net returns (Rs 34692/ha) and BCR (2.06) with treatment T_4 (75% RDN through vermicompost + seed inoculation with *Azotobacter and* PSB).

Microbial study

The initial and final population of beneficial soil bacteria like *Rhizobium, Azotobacter* and PSB were evaluated in the field soil of *rabi* fennel using serial dilution and standard plating. The data on population of soil bacteria highlighted in Table 7 showed significant variation among the treatments under investigation during individual year as well as in pooled results of three years. The treatment T_6 [75% RDN through castor cake + *Azotobacter* + PSB (PSB10)] showed highest number of *Rhizobium, Azotobacter*, and PSB in the soil which was followed successively for the treatments T_2 (75% RDN through FYM+ *Azotobacter* + PSB (PSB10)] and T_5 (50% RDN through castor cake + *Azotobacter* + PSB (PSB10)]. However, the least bacterial populations of *Rhizobium, Azotobacter*, and PSB were reported in the treatment T_8(Control *i.e.* RDF: 90-30-00 kgNPK/ha)in which neither biofertilizers nor organic supplements were applied.

Effect on uptake of nutrients

1. Uptake of N, P and K by seed and stalk

Uptake of N, P and K by seed and stalk was influenced significantly due to different treatments during all the years of experimentations as well as in pooled analysis (Table 13). During first year, application of 75 % RDN through castor cake + *Azotobacter* + PSB (T_6) recorded significantly higher N uptake by seed as compared to other treatments but found at par with treatments T_5, T_2, T_8 and T_4. Same treatment *i. e.* T_6 registered significantly higher N uptake as compared to other treatments but found on par with treatments T_5 and T_2 in second year and with T_2, T_8 and T_4 in third year and in pooled data.

In case of N uptake by stalk, treatment T_6 recorded the highest uptake, but it remained at par with T_2, T_5 and T_4 treatments in first year and second year and with T_2, T_4 and T_8 in third year. Significantly the highest removal of N by stalk was registered with treatment T_6 over rest of the treatments in pooled data.

The significant effect of different treatments on P uptake by seed and stalk was found during both the years and in pooled analysis (Table 14).Among different treatments, treatment T_6 registered significantly higher P uptake by seed as compared to treatment T_7 in first year. Same treatment *i. e.* T_6 also recorded significantly higher P uptake by seed as compared to other treatments except T_4, T_2 and T_5 treatment in second year and T_2, T_4 and T_8 treatments in pooled data. However during third year, treatment T_2 being at par with T_6,T_8 and T_4 treatments recorded significantly higher P uptake by seed over rest of the treatments.

During first year of study, treatment T_4 recorded significantly higher P uptake by stalk as compared to T_8 and T_7 treatments. However, treatment T_6 registered significantly higher removal of P by stalk over treatments T_1 and T_7 in second year and T_1, T_5 and T_7 in third year of experimentation. In pooled data, treatment T_6 registered significantly higher P uptake by stalk over rest of the treatments except T_4 and T_2 treatments.

The variation in K uptake by seed and stalk was significantly influenced due to different treatments (Table 15) during individual year as well as in pooled data. Among different treatments, an application of 75 % RDN through castor cake + *Azotobacter* + PSB (T_6) recorded significantly higher K uptake by seed as compared to T_8 and T_7 in first year and T_3, T_8 and T_7 in second year. However in third year, treatments T_2 being at par with T_6, T_8 and T_4 treatment recorded significantly higher K uptake by seed over rest of the treatments. In pooled data T_6 recorded significantly the highest K uptake by seed over rest of the treatments except T_2 and T_4 treatments. In case of K uptake by stalk, treatment T_2 recorded significantly higher uptake as compared to T_8 and T_7 treatments in first and second year. However, treatment T_6 registered significantly higher K uptake by stalk over T_8 and T_7 treatments in third year. In pooled data, significantly the highest K uptake by stalk was noted under T_6 treatment over rest of the treatments except treatments T_2 and T_4.

2. Uptake of Fe, Mn, Zn and Cu by seed and stalk

The significant effect of different treatments was observed on Fe uptake by seed and stalk during all the years of study as well as in pooled analysis except Fe uptake by stalk in 2019-20 (Table 16). Significantly the highest uptake of Fe by seed was obtained under the application of 75 % RDN through castor cake + *Azotobacter* + PSB (T_6) over rest of the treatments except T_5 and T_2 treatments during first year of experimentation. Though the highest uptake of Fe by seed was recorded due to 75 % RDN through FYM + *Azotobacter* + PSB (T_2), it remained at par with T_1, T_6 and T_4 treatments in second year, T_6 in third year and T_6, T_4 and T_1 in pooled data. During first year of experimentation, treatment T_2 registered significantly higher removal of Fe by stalk over rest of the treatments except T_1, T_4 and T_6 treatments. However, the maximum removal of Fe by stalk was obtained with T_6, it remained at par with T_2, T_4 and T_5 in second year and with T_2 and T_4 in pooled data.

The uptake of Mn by seed and stalk was influenced significantly due to different treatments during all the years as well as in pooled data except Mn uptake by stalk in 2019- 20 (Table 17).

An application of 75 % RDN through castor cake + *Azotobacter* + PSB (T_6) recorded significantly higher Mn uptake by seed as compared to T_7 in first year and T_8, T_3 and T_7 in second year. However, treatment T_2 registered significantly highest Mn uptake by seed over other treatments except treatments T_6, T_8 and T_4. Significantly the highest Mn uptake by seed was recorded due to T_6treatment but, it remained at par with T_2treatment in pooled data.

An application of 75 % RDN through FYM + *Azotobacter* + PSB (T_2) recordedsignificantly higher Mn uptake by stalk as compared to T_7 in first year and in pooled data and T_8 and T_7 in second year.

The data given in Table 18 indicated that the different treatments had significant effect on Zn uptake by both seed and stalk during all the years as well as in pooled analysis except Zn uptake by stalk in 2019-20. Among different treatments, an application of 75 % RDN through FYM + *Azotobacter* + PSB (T_2) registered significantly higher Zn uptake by seed and stalk as compared to T_8 and T_7 in first year and second year and T_7 in third year and pooled data except Zn uptake by stalk in third year.

The data presented in Table 19 indicated that different treatments exerted their significant influence on Cu uptake by seed and stalk during all the years as well as in pooled analysis.

Significantly the highest Cu uptake by seed was obtained due to 75 % RDN through FYM + *Azotobacter* + PSB (T_2) over rest of treatments but it remained at par with T_1 and T_6 in first year and in third year, T_1, T_6 and T_4 in second year and T_6 in pooled data.

Same treatment *i. e.* T_2 also recorded significantly higher removal of Cu by stalk as compared to T_3, T_8 and T_7 in first year and T_5, T_3, T_8 and T_7 in pooled data.

An application of 75 % RDN through castor cake + *Azotobacter* + PSB (T_6) registered significantly higher uptake of Cu by stalk as compared to T_8 and T_7 treatments in second and third year.

3. Effect on organic carbon and available nutrients (N, P_2O_5 and K_2O) in soil

A perusal of data presented in Table 20 revealed that organic carbon content in soil significantly changed due to different treatments in all the year of study.

Among different organic treatments, an application of either 75 % or 50 % RDN through FYM or vermicompost or castor cake (T_2, T_4, T_6, T_1, T_3 and T_5) did not differed significantly with each other but registered significantly higher organic carbon content in soil after harvest of crop as compared to seed treatment with *Azotobacter* and PSB (T_7) in all years of study. The maximum value of organic carbon content in soil was found under T_2 treatment in first year whereas in second and third year, maximum value of organic carbon was noted under T_4 treatment.

Significant effect of different treatments on available N content in soil after harvest of crop was found in all the years of experimentation. Among different organic treatments, all the treatments of organic sources *i.e.* T_1, T_2, T_3, T_4, T_5 and T_6 did not differ significantly with each other but recorded significantly higher available N content in soil as compared to seed treated with *Azotobacter* and PSB (T_7) in first and second years of study. However in third year, treatment T_4, T_2, T_6, T_3 and T_1 being at par with each other but recorded significantly higher available N content in soil as compared to T_5 and T_7 treatments (Table 20).

The data given in Table 21showed that different treatments had significant effect on available P_2O_5 content in soil after harvest of crop during all the years of study. During first and third year of study, an application of 75 % RDN through vermicompost + *Azotobacter*+ PSB (T_4) being at par with T_3, T_6, T_2, T_1 and T_5 and registered significantly higher available P_2O_5 content in soil as compared to seed treated with *Azotobacter* and PSB (T_7). During second year, same treatment *i. e.* T_4 also being at par with T_3, T_6 and T_2 treatmentsbut recorded significantly higher available P_2O_5 content in as compared to T_1, T_5 and T_7 treatments.

Available K_2O content in soil varied significantly due to different treatments during all the three years of study (Table 21). Among different organic treatments, an application of 75 % RDN through FYM + *Azotobacter* + PSB (T_2) being at par with T_4, T_1, T_3 and T_6 recorded significantly higher available K_2O content in soil as compared to T_5 and T_7 treatments in first and third year. However in second year, treatment T_4 recorded significantly higher available K_2O content in soil as compared to T_6, T_5 and T_7 treatments but at par with T_2, T_1 and T_3 treatments.

This indicated that bio-fertilizers play significant role in increasing growth attributes of fennel at harvest. *Azotobacter* bacteria have the capacity to fix atmospheric nitrogen to soil and make it available to plant. (Guleria *et al*.,2004). Phosphorus solubilizing microorganisms reserved in available form of readily hydrolyzes organic phosphate and degrade them in the soil through production of organic acids. (Malhotra *et al*.,2008). Seed inoculation with *Azotobacter*+ PSB increased growth attributes.(Meena *et al*., 2020)

The crop accumulates more amount of constituent and nutrients from organic manures (FYM + castor cake). Some beneficial microorganisms (*Azotobacter*) fixed atmospheric nitrogen which readily available to plant and from this plant can easily uptake of nitrogen which results to stimulate the cell division in meristem tissue and an increase in the yield and yield attributes. This was confirmed with the findings of the findings are in agreement with those reported by Godara (2014), Lal*et al*. (2019)Increase in yield per plant at higher rate of CC and FYM or its combination with *Azotobacter* and PSB is might be due to balanced nutrition and favorable soil environment, better plant growth and ultimately photosynthesis increase which leads to maximum seed yield per plant. The increase in seed yield/plant of crop due to application of organic manure is not only because of improved nutrient availability, but also its beneficial effect on physical and biological environment. This has special reference in fennel crop as umbel setting and development take place in sub-surface soil and the crop is mainly grown in arid and semi-arid climate were water storage capacity plays vital role. These results are in agreements with earlier worker Mohamed *et al*. (2004) and Singh *et al*., (2023).

Conclusion

This study comprehensively analyzed the growth and yield parameters of *Foeniculum vulgare* (fennel) under various organic fertilizer treatments. The results revealed significant differences in growth, yield, yield attributes, microbial activity and soil parameters from application of 75% RDN (67.5 kg N/ha) either through castor cake or FYM at the time of sowing along with seed inoculation with *Azotobacter* and PSB @ 5 ml/kg seed. It means application of organic manures also maximization yield and net return. Such research contributes valuable insights into optimizing agricultural practices and enhancing crop productivity under organic farming for fennel.

References

Comment [N5]: refer according to journal rules of referencing.
Give journal link

1. Bernath J, Nemeth E, Kattaa A, Hethelyi E. Morphological and chemical evaluation of fennel (Foeniculum vulgare Mill.) populations of different origin. *Journal of Essential Oil Research*. 1996;8(3):247-253.
2. FAOSTAT. Statistical Database. Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/faostat/en. Published 2020.

3. Godara AS, Gupta US, Lal G, Singh R. Influence of organic and inorganic sources of fertilizers on growth, yield and economics of fennel (*Foeniculum vulgare* Mill.) cultivation under semi-arid conditions. *Journal of Spices and Aromatic Crops*. 2014;23(2):200-204.
4. Guleria V, NayitalRK, Bhardwaj SD. Nutrition of Albizia chinensis Merr. As Affected by Farm Yard Manure and Phosphorus Interaction under Nursery. *International Journal of Agricultural Sciences.* 2006;2(2):599-600.
5. Hanif MA, Nawaz H, Khan MM, Byrne HJ. Medicinal Plants of South Asia. Amsterdam: Susan Dennis; c2020.
6. Javed R, Hanif MA, Ayub MA, Rehman R. Fennel. In: Medicinal Plants of South Asia. Elsevier c 2020. p. 241-256.
7. Lal G, Meena N, Chaudhary NK, Choudhary MK. Performance of fennel varieties under organic production system. *International Journal of Seed Spices.* 2019;9(1):21-26.
8. Malhotra SK, Vashishtha BB. Organic production of seed spices. National Research Centre for Seed Spices, Ajmer, India; c2008.
9. Meena NK, Lal G, Meena RD, Choudhary MK. Pest status on fennel (Foeniculum vulgare Mill) under organic production system in semi-arid region of Rajasthan, India. *Journal of Entomology and Zoology Studies.* 2020;8(6):181-184.
10. Mohamed MA, Abdu M. Growth and oil production of fennel (Foeniculum vulgare Mill): Effect of irrigation and organic fertilization. *Biological Agriculture & Horticulture*. 2004;22(1):31-39.
11. Rather MA, Dar BA, Sofi SN, Bhat BA, Qurishi MA.International Journal of Research in Agronomy https://www.agronomyjournals.comFoeniculum vulgare: A comprehensive review of its traditional use, phytochemistry, pharmacology, and safety. *Arabian Journal of Chemistry*. 2016;9:S1574-S1583.
12. Sharma N, Kumar A. Effect of integrated nutrient management on growth and yield of fennel (Foeniculum vulgare). *Indian Journal of Agricultural Sciences*. 2022;92(1):00-00.
13. Singh A, Singh D, Wesley CJ. Effect of Bio-fertilizers on Yield and Its Attributing Traits on Fennel (Foeniculum vulgare L.). *International Journal of Environment and Climate Change*. 2023;13(9):2645-2652.
14. Solanki HU, Dwivedi RM, Nayak SR. Synergistic analysis of Sea WiFS chlorophyll concentration and NOAA-AVHRR SST features for exploring marine living resources. *International Journal of Remote Sensing.* 2001 Jan 1;22(18):3877-3882.

Table 1: Plant population of *rabi* fennel as influenced by different treatments

Treatments	Plant population at harvest (Grossplot)			
	2015-16	2016-17	2019-20	Pooled
T_1	233.5	243.0	243.3	239.9
T_2	231.0	244.8	242.3	239.4
T_3	227.5	241.3	239.3	236.0
T_4	236.0	243.0	244.0	241.0
T_5	225.5	238.5	232.0	232.0
T_6	225.0	237.0	230.0	230.7
T_7	227.5	246.0	244.3	239.3

T_8	224.0	241.8	235.8	233.9
S.Em.±	9.79	9.22	9.51	5.01
CD(P=0.05)	NS	NS	NS	NS
CV(%)	8.56	7.62	7.97	8.04
YxT	-	-	-	**NS**

Table 2: Plant height and number of umbels per plant of *rabi* fennel as influenced by different treatments

Treatments	Plant height (cm)				Number of umbels per plant			
	2015-16	2016-17	2019-20	Pooled	2015-16	2016-17	2019-20	Pooled
T_1	109.1	119.3	125.2	117.9	7.75	7.85	8.25	7.95
T_2	112.8	124.0	133.7	123.5	8.60	8.65	10.90	9.38
T_3	104.8	118.3	124.5	115.9	7.20	7.75	7.80	7.58
T_4	109.1	119.1	130.5	119.6	7.98	8.25	8.25	8.16
T_5	115.6	126.4	136.7	126.2	8.50	9.93	9.55	9.33
T_6	120.3	130.0	143.3	131.2	10.18	10.58	11.50	10.75
T_7	96.0	100.5	113.9	103.4	6.85	7.03	7.10	6.99
T_8	111.6	119.5	128.8	120.0	8.18	8.10	8.75	8.34
S.Em.±	5.09	5.38	5.71	2.86	0.41	0.44	0.51	0.27
CD(P=0.05)	15.0	15.8	16.80	8.05	1.22	1.29	1.50	0.75
CV(%)	9.27	9.00	8.82	9.03	10.17	10.30	11.30	10.65
YxT	-	-	-	**NS**	-	-	-	**NS**

Table3: Number of umbelets per umbel and number of seeds per umbelet of *rabi* fennel as influenced by different treatments

Treatments	Number of umbelets per umbel				Number of seeds per umbelet			
	2015-16	2016-17	2019-20	Pooled	2015-16	2016-17	2019-20	Pooled
T_1	14.85	15.43	17.40	15.89	11.03	12.68	16.00	13.24
T_2	15.98	16.50	19.25	17.24	12.05	13.20	17.75	14.33
T_3	13.88	14.70	17.40	15.33	10.45	12.05	14.50	12.33
T_4	15.08	16.03	18.20	16.44	11.88	13.18	16.20	13.75
T_5	14.78	16.23	18.90	16.64	11.30	13.75	17.60	14.22
T_6	16.45	18.30	19.75	18.17	12.10	14.98	19.25	15.44
T_7	13.15	12.90	15.75	13.93	9.33	11.53	12.95	11.27
T_8	13.83	14.93	17.20	15.32	11.20	12.65	16.20	13.35
S.Em.±	0.69	0.92	0.89	0.45	0.66	0.64	0.96	0.44
CD(P=0.05)	2.02	2.70	NS	1.26	NS	1.87	2.84	1.23
CV(%)	9.29	11.76	9.89	10.39	11.83	9.79	11.84	11.39

YxT	-	-	-	**NS**	-	-	-	**NS**

Table4: Test weight and seed yield per plant of *rabi* fennel as influenced by different treatments

Treatments	Test weight(g)				Seed yield per plant(g)			
	2015-16	**2016-17**	**2019-20**	**Pooled**	**2015-16**	**2016-17**	**2019-20**	**Pooled**
T_1	5.95	6.13	5.93	6.00	7.35	9.36	11.99	9.57
T_2	6.26	6.37	6.14	6.26	7.85	9.87	14.03	10.58
T_3	5.97	6.17	5.25	5.80	7.30	9.15	11.59	9.35
T_4	6.34	6.30	5.61	6.08	7.80	9.72	13.93	10.48
T_5	6.48	6.36	5.95	6.26	8.00	9.59	13.98	10.52
T_6	6.59	6.60	6.21	6.47	8.60	10.87	16.12	11.86
T_7	5.95	5.38	5.05	5.46	6.40	7.87	9.74	8.00
T_8	6.30	6.11	5.32	5.91	7.50	9.41	13.37	10.09
S.Em.±	0.26	0.30	0.27	0.16	0.44	0.55	0.57	0.42
CD(P=0.05)	NS	NS	0.80	0.44	NS	NS	1.69	1.27
CV(%)	8.48	9.82	9.55	9.29	11.45	11.61	8.78	10.41
YxT	-	-	-	**NS**	-	-	-	**Sig(1.48)**

Table5: Volatile oil content and harvest index of *rabi* fennel as influenced by different treatments

Treatments	Volatile oil content (%)				Harvest index (%)			
	2015-16	**2016-17**	**2019-20**	**Pooled**	**2015-16**	**2016-17**	**2019-20**	**Pooled**
T_1	1.84	1.87	1.41	1.71	23.51	25.78	26.44	25.24
T_2	1.87	1.87	1.36	1.70	23.37	25.67	28.60	25.88
T_3	1.97	1.93	1.36	1.75	25.38	24.59	25.15	25.04
T_4	1.88	1.99	1.30	1.72	24.35	25.95	26.69	25.66
T_5	1.85	2.21	1.43	1.83	25.40	26.37	24.06	25.28
T_6	1.85	2.02	1.43	1.77	25.49	25.75	27.23	26.15
T_7	1.68	1.90	1.32	1.63	24.57	25.65	23.93	24.72
T_8	1.58	1.95	1.36	1.63	26.08	25.14	27.48	26.23
S.Em.±	0.05	0.08	0.05	0.05	1.56	1.44	1.33	0.82
CD(P=0.05)	0.15	NS	NS	NS	NS	NS	NS	NS
CV(%)	5.81	7.68	8.00	7.21	12.59	11.24	10.16	11.33
YxT	-	-	-	**Sig (0.17)**	-	-	-	NS

Table6: Seed and stalk yield of *rabi* fennel as influenced by different treatments

Treatments	Seed yield (kg/ha)				Stalk yield(kg/ha)			
	2015-16	**2016-17**	**2019-20**	**Pooled**	**2015-16**	**2016-17**	**2019-20**	**Pooled**

T_1	951	1216	1532	1233	3086	3494	4226	3602
T_2	1006	1308	1839	1384	3292	3795	4635	3907
T_3	967	1151	1411	1176	2906	3529	4196	3544
T_4	972	1298	1648	1306	3061	3713	4539	3771
T_5	1069	1365	1405	1280	3164	3838	4478	3827
T_6	1134	1463	1902	1500	3318	4234	5141	4231
T_7	794	1027	1221	1014	2443	3059	3921	3141
T_8	977	1185	1784	1315	2778	3532	4682	3664
S.Em.±	53.2	62.8	89.6	63.5	150.6	205.8	274.3	118.2
CD(P=0.05)	156.5	184.8	263.5	192.5	442.9	605.4	NS	332.7
CV(%)	10.82	10.04	11.25	11.01	10.02	11.28	12.25	11.65
YxT	-	-	-	NS	-	-	-	NS

Table7: Gross realization and cost of cultivation of *rabi* fennel as influenced by different treatments

Treatments	Gross realization (Rs/ha)				Total cost of cultivation (Rs/ha)			
	2015-16	2016-17	2019-20	Pooled	2015-16	2016-17	2019-20	Pooled
T_1	63358	80787	101693	81946	47532	47532	47704	47589
T_2	67036	86918	121853	91936	54802	54802	54974	54859
T_3	64308	76580	93813	78234	51512	51512	51684	51569
T_4	64711	86227	109390	86776	60902	60902	61074	60959
T_5	71067	90644	93564	85092	38522	38522	38694	38579
T_6	75369	97212	126201	99594	41352	41352	41524	41409
T_7	52832	68285	81326	67481	32732	32732	32904	32789
T_8	64894	78791	118301	87329	35637	35637	35809	35694

Table8: Net realization and BCR of *rabi* fennel as influenced by different treatments

Treatments	Net realization (Rs/ha)				BCR			
	2015-16	2016-17	2019-20	Pooled	2015-16	2016-17	2019-20	Pooled
T_1	15827	33256	53990	34357	1.33	1.70	2.13	1.72
T_2	12235	32116	66879	37077	1.22	1.59	2.22	1.68
T_3	12797	25068	42130	26665	1.25	1.49	1.82	1.52
T_4	3809	25325	48316	25817	1.06	1.42	1.79	1.42
T_5	32546	52123	54871	46513	1.84	2.35	2.42	2.21
T_6	34018	55861	84677	58185	1.82	2.35	3.04	2.41
T_7	20100	35553	48422	34692	1.61	2.09	2.47	2.06
T_8	29257	43154	82492	51635	1.82	2.21	3.30	2.45

Table9: Economics of *rabi* fennel as influenced by different treatments (Pooled data of 2015-16, 2016-17 and 2019-20)

Treatments	Yield(kg/ha)		Gross return (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	BCR
	Seed	Stalk				
T_1	1233	3602	81946	47589	34357	1.72
T_2	1384	3907	91936	54859	37076	1.68
T_3	1176	3544	78234	51569	26664	1.52
T_4	1306	3771	86776	60959	25817	1.42
T_5	1280	3827	85092	38579	46513	2.21
T_6	1500	4231	99594	41409	58185	2.41
T_7	1014	3141	67481	32789	34692	2.06
T_8	1315	3664	87329	35694	51634	2.45

Rate of produce and inputs used in fennel

(i) Seed :Rs65.00/kgseed
(ii) Stalk :Rs.0.50/kgstalk
(iii) Neem oil : Rs475/lit
(iv) *Azotobacter*:Rs150/lit
(v) PSB :Rs150/lit
(vi)FYM:Rs1.50/kg
(vii) Castorcake :Rs6.0/kg(Rs300/50kgbagofcastorcake)
(viii) Vermicompost:Rs4.0/kg
(ix)Urea:Rs6.00/kg(Rs270/45kgbagofurea)
(x) DAP :Rs24.0/kg(Rs1200/50kgbagofDAP)

Table12:Microbialpopulationinsoilbeforesowingandafterharvestof*rabi*fennelasinfluencedbydifferenttreatments

Treatments	Population of microorganisms in soil (CFU/gofsoilx10^4)											
	Rhizobium				*Azotobactr*				PSB			
	2015-16	2016-17	2019-20	Pooled	2015-16	2016-17	2019-20	Pooled	2015-16	2016-17	2019-20	Pooled
T_1	84.4	92.3	102.4	93.0	103.5	115.5	117.3	112.1	97.4	106.6	109.2	104.4
T_2	118.9	126.1	136.3	127.1	139.4	148.2	154.1	147.2	135.3	142.3	153.3	143.6
T_3	78.6	86.2	97.4	87.4	97.5	108.6	111.8	105.9	91.6	99.5	104.3	98.4
T_4	92.6	98.4	108.5	99.8	110.4	121.6	125.7	119.2	104.2	112.8	116.5	111.1
T_5	99.3	105.7	114.5	106.5	117.4	127.1	132.3	125.6	112.3	118.7	121.5	117.5
T_6	152.1	165.4	173.2	163.5	142.2	165.3	184.3	163.9	129.5	161.5	174.4	155.1
T_7	71.4	83.1	92.6	82.3	93.3	101.4	105.3	100.0	84.2	82.5	89.7	85.5
T_8	63.6	75.8	84.5	74.6	82.4	93.5	98.4	91.4	85.6	84.3	81.6	83.8
S.Em±	2.7	2.8	3.3	0.9	2.5	2.9	3.2	2.9	2.1	2.6	2.5	4.7
CD(P=0.05)	8.0	8.3	9.8	2.8	7.6	8.5	9.5	8.7	6.0	7.9	7.2	14.3
CV(%)	5.71	5.40	5.96	1.53	5.13	6.22	5.53	4.12	4.11	5.37	4.04	7.30
Initial												
i.Conventional plot	38.4	45.6	52.8		52.6	62.6	71.4		44.7	54.5	61.8	
ii.Organic plot	51.6	-	-		61.7	-	-		53.8	-	-	

Table13: N uptake by seed and stalk of *rabi* fennel as influenced by different treatments

Treatments	N uptake (kg/ha) by seed				N uptake (kg/ha) by stalk			
	2015-16	2016-17	2019-20	Pooled	2015-16	2016-17	2019-20	Pooled
T_1	23.44	30.05	38.02	30.50	17.82	20.60	26.01	21.49
T_2	26.52	35.07	49.86	37.15	21.01	24.47	31.89	25.79
T_3	24.05	28.76	36.16	29.66	17.76	21.91	25.27	21.64
T_4	25.90	34.36	44.75	35.00	19.56	24.33	31.61	25.17
T_5	27.42	36.74	36.84	33.67	19.97	24.37	27.98	24.10
T_6	30.14	39.87	52.01	40.67	21.46	28.24	35.78	28.49
T_7	19.45	25.19	30.22	24.96	13.81	17.66	23.36	18.28
T_8	26.49	29.86	48.20	34.85	18.27	23.98	30.20	24.15
S.Em.±	1.60	1.64	2.54	1.95	0.97	1.47	1.92	0.85
CD(0.05%)	4.72	4.82	7.48	5.92	2.84	4.32	5.66	2.39
CV(%)	12.62	10.09	12.10	11.87	10.33	12.64	13.27	12.74

Table14: P uptake by seed and stalk of *rabi* fennel as influenced by different treatments

Treatments	P uptake (kg/ha) by seed				P uptake (kg/ha) by stalk			
	2015-16	2016-17	2019-20	Pooled	2015-16	2016-17	2019-20	Pooled
T_1	4.07	5.43	7.20	5.57	2.14	2.87	3.67	2.89
T_2	4.61	6.13	8.96	6.57	2.50	3.27	4.48	3.42
T_3	4.50	5.46	6.92	5.62	2.25	3.19	4.11	3.19
T_4	4.61	6.28	8.33	6.40	2.55	3.41	4.59	3.51
T_5	4.39	5.98	6.01	5.46	2.16	3.06	3.66	2.96
T_6	4.93	6.62	8.95	6.83	2.40	3.50	4.75	3.55
T_7	3.22	4.46	5.17	4.28	1.59	2.25	3.19	2.34
T_8	4.27	5.52	8.58	6.12	2.03	3.01	4.31	3.12
S.Em.±	0.29	0.30	0.46	0.36	0.17	0.21	0.27	0.12
CD(0.05%)	0.86	0.87	1.36	1.08	0.48	0.62	0.80	0.35
CV(%)	13.48	10.37	12.35	12.29	15.15	13.67	13.27	14.11

Table15: K uptake by seed and stalk of *rabi* fennel as influenced by different treatments

Treatments	K uptake (kg/ha) by seed				K uptake (kg/ha) by stalk			
	2015-16	2016-17	2019-20	Pooled	2015-16	2016-17	2019-20	Pooled
T_1	15.46	20.72	28.37	21.37	23.63	27.61	35.23	28.82
T_2	16.72	22.02	35.17	24.63	24.82	31.58	38.96	31.79
T_3	15.83	18.96	26.19	20.33	21.87	26.88	34.81	27.85
T_4	15.98	21.78	30.98	22.91	23.42	30.44	38.00	30.62
T_5	16.40	21.19	25.25	20.94	22.47	27.37	34.83	28.22
T_6	18.09	23.24	34.72	25.35	24.59	30.51	41.76	32.29
T_7	11.82	15.56	20.40	15.92	16.36	20.52	27.03	21.46
T_8	14.93	18.13	31.06	21.37	19.71	25.15	32.99	25.95
S.Em.±	0.97	1.29	1.83	1.23	1.30	1.69	2.67	1.07
CD(0.05%)	2.85	3.80	5.37	3.73	3.83	4.98	7.86	3.01

CV(%)	12.40	12.83	12.59	13.03	11.75	12.31	15.08	15.61

Table16: Fe uptake by seed and stalk of *rabi* fennel as influenced by different treatments

Treatments	Fe uptake (g/ha) by seed				Fe uptake (g/ha) by stalk			
	2015-16	**2016-17**	**2019-20**	**Pooled**	**2015-16**	**2016-17**	**2019-20**	**Pooled**
T_1	66.40	119.81	169.03	118.41	320.73	395.12	506.34	407.39
T_2	80.53	136.32	208.76	141.87	345.68	430.90	562.19	446.26
T_3	63.19	101.19	142.05	102.14	278.14	393.20	496.37	389.24
T_4	73.48	114.20	173.39	120.35	310.75	414.96	539.50	421.40
T_5	83.13	106.81	134.63	108.19	291.00	407.96	505.89	401.44
T_6	96.46	115.99	191.80	134.75	308.64	457.86	584.76	450.42
T_7	49.93	74.27	112.41	78.87	221.45	316.52	438.93	325.63
T_8	70.45	80.74	157.97	103.05	245.06	361.53	522.49	376.36
S.Em.±	5.85	9.50	11.21	8.20	17.50	19.36	35.45	13.98
CD(0.05%)	17.20	27.93	32.97	24.88	51.47	56.95	NS	39.37
CV(%)	16.03	17.89	13.90	16.09	12.06	9.75	13.65	12.64

Table17: Mn uptake by seed and stalk of *rabi* fennel as influenced by different treatments

Treatments	Mn uptake (g/ha) by seed				Mn uptake (g/ha) by stalk			
	2015-16	**2016-17**	**2019-20**	**Pooled**	**2015-16**	**2016-17**	**2019-20**	**Pooled**
T_1	64.67	90.60	114.71	89.99	69.47	85.06	102.88	85.80
T_2	74.22	103.31	144.55	107.36	77.29	95.72	118.61	97.21
T_3	66.30	84.98	104.70	85.33	63.12	80.25	99.17	80.84
T_4	66.15	96.30	124.17	95.54	67.13	85.61	109.22	87.32
T_5	70.50	98.58	103.16	90.75	66.18	84.25	100.21	83.55
T_6	76.46	107.95	139.58	108.00	71.32	94.18	117.60	94.37
T_7	50.67	71.57	86.55	69.59	48.20	63.93	86.71	66.28
T_8	63.86	84.99	129.17	92.67	56.53	75.86	100.66	77.68
S.Em.±	4.38	6.68	7.16	3.82	3.97	5.19	7.68	3.10
CD(0.05%)	12.90	14.48	21.05	10.76	11.68	15.27	NS	8.73
CV(%)	13.17	19.65	12.10	13.40	12.24	12.49	14.71	13.84

Table18: Zn uptake by seed and stalk of *rabi* fennel as influenced by different treatments

Treatments	Zn uptake (g/ha) by seed				Zn uptake (g/ha) by stalk			
	2015-16	**2016-17**	**2019-20**	**Pooled**	**2015-16**	**2016-17**	**2019-20**	**Pooled**
T_1	28.43	36.82	50.03	38.43	40.92	47.07	67.44	51.81
T_2	30.41	41.64	61.63	44.56	44.42	54.76	76.25	58.47
T_3	27.06	33.02	41.39	33.82	35.93	45.94	64.35	48.74
T_4	27.80	38.65	52.32	39.59	38.81	49.32	70.75	52.96
T_5	28.22	36.88	39.72	34.94	37.35	48.10	65.20	50.22
T_6	30.34	40.11	56.61	42.35	38.74	54.10	76.55	56.46
T_7	19.30	26.12	31.07	25.50	26.77	35.74	52.11	38.21
T_8	24.44	31.08	47.07	34.20	32.05	44.14	68.10	48.10
S.Em.±	1.88	2.46	2.88	2.26	3.06	3.43	5.17	2.17
CD(0.05%)	5.54	7.22	8.47	6.86	9.01	10.09	NS	6.10
CV(%)	13.94	13.82	12.13	13.31	16.62	14.48	15.29	15.78

Table19: Cu uptake by seed and stalk of *rabi* fennel as influenced by different treatments

Treatments	Cu uptake(g/ha) by seed				Cu uptake (g/ha) bys talk			
	2015-16	**2016-17**	**2019-20**	**Pooled**	**2015-16**	**2016-17**	**2019-20**	**Pooled**
T_1	10.01	15.94	21.20	15.71	20.91	26.29	42.35	29.85
T_2	10.88	16.82	25.72	17.80	23.79	29.47	47.49	33.59
T_3	8.51	12.43	16.32	12.42	19.03	24.65	40.48	28.05
T_4	8.71	14.04	19.57	14.11	20.55	26.91	44.93	30.79
T_5	8.62	13.64	15.44	12.57	19.88	25.71	39.80	28.46
T_6	9.78	15.48	21.95	15.74	21.45	29.50	49.46	33.47
T_7	5.68	9.95	12.18	9.27	15.33	18.99	27.60	20.64
T_8	7.17	11.60	18.39	12.38	17.31	22.87	36.47	25.55
S.Em.±	0.61	0.98	1.70	0.73	1.53	1.68	3.85	1.47
CD(0.05%)	1.80	2.87	5.01	2.06	4.51	4.94	11.31	4.15
CV(%)	14.13	14.21	18.09	17.27	15.51	13.15	18.72	17.91

Table20: Organic carbon and available N content in soil after harvest of *rabi* fennel as influenced by different treatments

Treatments	Organic carbon(%)			Available N (kg/ha)		
	2015-16	**2016-17**	**2019-20**	**2015-16**	**2016-17**	**2019-20**
T_1	0.401	0.418	0.420	223.4	228.9	235.2
T_2	0.411	0.427	0.442	228.9	238.3	246.2
T_3	0.397	0.420	0.432	225.8	233.6	237.2
T_4	0.406	0.430	0.446	232.9	242.3	248.9
T_5	0.390	0.401	0.414	224.6	231.7	233.6
T_6	0.392	0.406	0.415	227.4	240.7	245.3
T_7	0.356	0.365	0.379	208.9	213.9	216.8
T_8	0.268	0.289	0.291	210.5	218.0	224.6
S.Em.±	0.011	0.011	0.011	4.5	4.7	4.2
CD(0.05%)	0.033	0.033	0.032	13.4	13.9	12.5
CV(%)	5.90	5.72	5.45	4.08	4.09	3.59
Initial						
i.Conventional plot	0.264	0.280	0.288	200.7	211.7	219.5
ii.Organicplot	0.353	-	-	207.0	-	-

Table21: Available $P_2O_5$and K_2O content in soil after harvest of *rabi* fennel as influenced by different treatments

Treatments	AvailableP_2O_5(kg/ha)			AvailableK_2O(kg/ha)		
	2015-16	**2016-17**	**2019-20**	**2015-16**	**2016-17**	**2019-20**
T_1	63.7	66.4	73.3	181.6	183.9	191.5
T_2	65.2	68.3	74.4	185.3	187.5	192.5
T_3	67.9	71.4	75.6	179.4	183.5	187.1
T_4	69.4	74.4	77.1	183.7	190.5	190.0
T_5	63.7	66.0	73.2	173.2	177.4	178.5
T_6	66.4	69.1	76.3	178.3	180.1	182.4
T_7	57.6	60.7	65.3	161.5	165.2	166.8

T_8	47.3	49.2	51.1	134.2	140.8	146.2
S.Em.±	1.9	1.7	2.1	3.6	3.5	3.7
CD(0.05%)	5.4	4.9	6.1	10.7	10.4	10.8
CV(%)	5.89	5.07	5.86	4.22	4.00	4.10
Initial						
i.Conventional plot	44.4	48.4	50.4	131.0	136.4	142.5
ii.Organic plot	54.2	-	-	157.3	-	-