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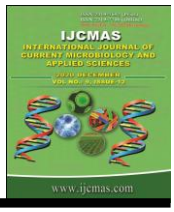

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Effect of VA Mycorrhizal Fungus and Bioformulations on Quality, Root Parameters, Microbial Analysis and Economics of Fennel under Northern Dry Zone (ZONE-3) of Karnataka

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A B S T R A C T

Field trial on the Effect of VA Mycorrhizal fungus and bioformulations on quality, root parameters, beneficial microbial count and economics of fennel under northern dry zone (zone-3) of karnataka was carried out at KRCCH, Arabhavi, Karnataka during *Rabi* season of 2017 and 2018. There was significant variation was observed for quality, root parameters, beneficial microbial count and economics of fennel due to application of VAM and bioformulations. The maximum anethole content (59.22, 58.92 and 59.07%) was recorded in the treatment T_5 (VAM 25 kg ha^{-1} + Amrutpani 3% (Drench). The highest essential oil content (1.04, 1.05 and 1.05%), Per cent root colonization (96.00, 95.00 and 95.50%), number of chlamydospores per 50 g of soil (1430.00, 1316.00 and 1373.00), length of longest root (26.50, 26.25 and 26.38 cm), number of roots (8.00, 8.00 and 8.00), root volume (70.00, 69.00 and 69.50 cm^3), bacterial count (144.00, 134.00 and 139.00 × 10^6 CFU/g of soil), fungal count (242.00, 225.00 and 233.50 × 10^3 CFU/g of soil) and actinomycetes count (84.00,78.00 and 81.00 × 10^4 CFU/g of soil) were recorded in the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) in 2017, 2018 and pooled data respectively.

Introduction

India is known as the land of spices from the times immemorial and has been the global leader in the production, consumption and export of spices. Fennel (*Foeniculum vulgare* Mill.) is one of the popular seed spice in India mainly grown in *rabi* season. It is locally known as *saunf* and belongs to the family Apiaceae (Umbelliferae). Fennel is native to Southern Europe and Mediterranean region. It is a hardy perennial, but is grown as annual or biennial. It is cultivated throughout the temperate and subtropical regions of the world for its aromatic seeds which are used for culinary purpose. Fennel seed is small, oblong or cylindrical, 6-8 mm. long straight or slightly curved yellowish brown. It

possesses an agreeable, aromatic and sweet aroma due to higher content of volatile oil (0.7 to 1.2%).

The volatile oil contents mainly anethole (50.03%) and fenchone (2.67%). It is widely used as flavouring agent in culinary preparations, confectioneries, cordials and liquors. Fennel oil is also used as important ingredient in several allopathic as well as ayurvedic medicines which are used in diseases *viz*., diabetes, bronchitis and chronic coughs, treatment of kidney stones and is considered to have diuretic and galactogogue properties. The use of bio-fertilizers and bio-formulations play an important role as they help in availability and supply of plant nutrients thereby, providing a scope for reduction in use of costly chemical fertilizers which pollute soil in long term (Kale *et al.*, 1991)[2]. It is reported that 10 to 20 per cent of crop yield can be increased with biofertilizer application alone (Brown, 1972)[1]. The increasing concern about the environment and socio-economic impact of chemical agriculture has led to seek alternative practices for agricultural sustainability and marketability by progressive farmers. To minimize the adverse effects of conventional agriculture (e.g. polluted water and soil by chemical fertilizers, entering pesticides to the food chain, compaction of the soil by heavy machinery *etc*.), different alternative concepts of production have been developed. Currently, low input cropping systems and innovation of resource management are of the most important objectives of sustainable agriculture.

Chemical free traditional farming technologies *viz*., bio-fertilizers, biodynamics, agnihotra (homa farming), panchagavya, Amrit Pani, rishi krishi, jeevamrutha *etc*., are gaining a new momentum not only in India, but also world over (Singh *et al.*, 2007)[9]. These systems offer a means to address self-reliance, rural upliftment and conservation of natural resources. The connections between fungi and the roots of higher plants are referred to as mycorrhiza. Such interactions are mutualistic relationships undertaken by more than 80 per cent of plant species and approximately 6000 species of fungi. Arbuscular mycorrhizal (AM) fungi enable the host plant to establish and grow more efficiently under biotic and abiotic stress conditions, including drought through a series of complex communications between the host and fungus (Salam *et al.*, 2017)[7]. Keeping this in view the present investigation was undertaken to study the Effect of VA Mycorrhizal fungus and bioformulations on quality, root parameters, beneficial microbial count and economics of fennel under northern dry zone (Zone-3) of Karnataka.

Materials and Methods

The experiment was laid out in sandy loam soil with pH 6.5-8. Arabhavi is considered to have the benefit of both South-West and North-East monsoon. The mean annual rainfall for the past 20 years of this area is 449.25 mm, distributed over a period of six to seven months from April to November. The monthly mean maximum temperature goes up to 38.45°C (March) and monthly mean minimum temperature drops down to 11.55°C in January.

The meteorological data for the period of experimentation (*Rabi* 2017 and 2018) was recorded at the meteorological observatory of the Agricultural Research Station, Arabhavi (UAS, Dharwad) which is situated at 2 km from the college campus. The experiment was laid out in RCB Design replicated three times using Ajmeer Fennel-1 variety with nine treatments *viz*., T_1– 90: 40: 30 N: P: K kg ha^{-1} (Check), T_2– VAM 25 kg ha^{-1}, T_3– 90: 40: 30 N: P: K kg ha^{-1} + VAM 25 kg ha^{-1}, T_4– VAM 25 kg ha^{-1} + Panchagavya 3% (Drench), T_5–

VAM 25 kg ha^{-1} + Amrutpani 3% (Drench), T_6– VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% (Drench), T_7–90: 40: 30 N: P: K kg ha^{-1} + Vermiwash 10% (Drench), T_8– VAM 25 kg ha^{-1} + Vermiwash 10% (Drench), T_9– VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash). A spacing of 50 cm between rows and 25 cm between the plants was followed. *Glomus fasciculatum*, a VA Mycorrhizal fungus was applied in the rows of nursery beds prior to sowing of seeds at one kg/plot. Five representative samples were selected at random from each plot for recording the observations. The average from these five samples were worked out for the statistical computation.

The data recorded for various observations on three experiments were subjected to statistical analysis using the Fischer's method of analysis of variance with 5 per cent level of significance for 'F' and 't' tests. Pooled analysis of 2017 and 2018 was also carried out to draw conclusion. Wherever the 'F' test was significant, the critical difference (C.D.) values were worked out at 5 per cent level of significance (Panse and Sukhatme, 1985)[5] (Table 1–5).

Results and Discussion

Qualitative parameters

Significant difference was observed for qualitative parameters by the application of VAM and bioformulations. The highest essential oil content (1.04, 1.05 and 1.05%) was recorded in the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash). And the lowest (1.00, 1.00 and 1.00%) was recorded in treatment T_2 (VAM 25 kg ha^{-1}) in 2017, 2018 and pooled data respectively.The maximum anethole content (59.22, 58.92 and 59.07%) was recorded in the treatment T_5 (VAM 25 kg ha^{-1} + Amrutpani 3% (Drench)) in 2017, 2018 and pooled data respectively. And the minimum (39.83, 39.56 and 39.70%) was recorded in treatment T_7 (90: 40: 30 N: P: K kg ha^{-1} + Vermiwash 10% (Drench). Findings are in confirmation with Hannah *et al.*, (2005) who reported that banana sprayed with panchagavya solution at 3 per cent resulted in improvement in quality of fruits *viz.*, total soluble sugars, total sugars and reduced the negative quality characters like acidity and ascorbic acid content.

The improvement in quality of fennel with application of VAM and bioformulations may be attributed to the enhanced metabolic activities. Krishnamurthy and Sharanappa (2005)[3] also reported improved quality parameters of rose onion bulbs through different source of organic nutrient application.

Root parameters

Significant difference was observed for root attributes by the application of VAM and bioformulations. The highest length of longest root (26.50, 26.25 and 26.38 cm), was recorded in the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) in 2017, 2018 and pooled data respectively. And the lowest (21.00, 21.00 and 21.00 cm) was recorded in treatment T_7 (90: 40: 30 N: P: K kg ha^{-1} + Vermiwash 10% (Drench) which was at par with T_1 (22.00, 21.50 and 21.75 cm). The highest number of roots (8.00, 8.00 and 8.00) was recorded in the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) in 2017, 2018 and pooled data respectively. And the lowest (5.00, 4.50 and 4.75) was recorded in treatment T_1 (90: 40: 30 N: P: K kg ha^{-1} (Check).

Table.1 Essential oil in seeds and anethole in oil content as influenced by the application of VAM and bioformulations during *rabi* 2017 and 2018

Treatments	Essential oil (%)			Anethole content (%)		
	2017	2018	Pooled	2017	2018	Pooled
T_1- 90: 40: 30 N: P: K kg ha^{-1} (Check)	1.01	1.01	1.01	41.06	41.03	41.05
T_2- VAM 25 kg ha^{-1}	1.00	1.00	1.00	44.67	44.50	44.59
T_3- 90: 40: 30 N: P: K kg ha^{-1} + VAM 25 kg ha^{-1}	1.03	1.04	1.04	56.89	56.80	56.85
T_4- VAM 25 kg ha^{-1} + Panchagavya 3% (Drench)	1.01	1.01	1.01	44.09	44.01	44.05
T_5- VAM 25 kg ha^{-1} + Amrutpani 3% (Drench)	1.02	1.02	1.02	59.22	58.92	59.07
T_6- VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% (Drench)	1.03	1.05	1.04	49.75	49.15	49.45
T_7- 90: 40: 30 N: P: K kg ha^{-1} + Vermiwash 10% (Drench)	1.02	1.02	1.02	39.83	39.56	39.70
T_8- VAM 25 kg ha^{-1} + Vermiwash 10% (Drench)	1.01	1.01	1.01	45.37	45.24	45.31
T_9- VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch	1.04	1.05	1.05	49.66	49.60	49.63
S.Em.±	0.00	0.00	0.00	0.85	0.77	0.80
CD at 5%	0.00	0.00	0.00	2.54	2.29	2.41
CV (%)	12.54	12.61	12.57	14.56	13.70	14.03

Note: 1. Bioformulations *viz.*, Panchagavya, amrutpani and vermiwash were drenched at monthly interval from the day of sowing up to 2nd harvest
2. Common dose of FYM (12.5 t ha^{-1}) was applied at the time of sowing

Table.2 Per cent root colonization, number of chlamydospores and length of longest root in fennel as influenced by the application of VAM and bioformulations during *rabi* 2017 and 2018

Treatments	Per cent root colonization			Number of chlamydospores/ 50 g of soil			Length of longest root (cm)		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1- 90: 40: 30 N: P: K kg ha^{-1} (Check)	40.00	41.00	40.50	325.00	299.00	312.00	22.00	21.50	21.75
T_2- VAM 25 kg ha^{-1}	81.00	79.00	80.00	1265.00	1164.00	1214.50	23.00	22.80	22.90
T_3- 90: 40: 30 N: P: K kg ha^{-1} + VAM 25 kg ha^{-1}	94.00	92.00	93.00	1140.00	1049.00	1094.50	24.00	23.00	23.50
T_4- VAM 25 kg ha^{-1} + Panchagavya 3% (Drench)	86.00	86.00	86.00	1290.00	1187.00	1238.50	24.00	24.00	24.00
T_5- VAM 25 kg ha^{-1} + Amrutpani 3% (Drench)	91.00	91.00	91.00	1325.00	1219.00	1272.00	23.70	23.25	23.48
T_6- VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% (Drench)	94.00	93.00	93.50	1370.00	1260.00	1315.00	25.40	25.00	25.20
T_7- 90: 40: 30 N: P: K kg ha^{-1} + Vermiwash 10% (Drench)	89.00	89.00	89.00	550.00	506.00	528.00	21.00	21.00	21.00
T_8- VAM 25 kg ha^{-1} + Vermiwash 10% (Drench)	85.00	85.00	85.00	1210.00	1113.00	1161.50	25.10	25.00	25.05
T_9- VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch	96.00	95.00	95.50	1430.00	1316.00	1373.00	26.50	26.25	26.38
S.Em.±	2.15	1.55	1.40	44.75	35.62	40.00	0.44	0.44	0.44
CD at 5%	6.44	4.64	4.18	134.17	106.78	119.93	1.32	1.32	1.32
CV (%)	19.99	19.97	19.68	14.62	14.79	14.68	15.24	15.30	15.26

Note: 1. Bioformulations *viz.*, Panchagavya, amrutpani and vermiwash were drenched at monthly interval from the day of sowing up to 2nd harvest
2. Common dose of FYM (12.5 t ha^{-1}) was applied at the time of sowing

Table.3 Total number of roots, root volume and bacterial count in fennel at harvest as influenced by the application of VAM and bioformulations during *rabi* 2017 and 2018

Treatments	Total number of roots			Root volume (cm^3)			Bacteria No. × 10^6 CFU/g of soil		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1- 90: 40: 30 N: P: K kg ha^{-1} (Check)	5.00	4.50	4.75	40.00	38.00	39.00	23.00	21.00	22.00
T_2- VAM 25 kg ha^{-1}	6.50	6.00	6.25	55.00	52.00	53.50	106.00	99.00	102.50
T_3- 90: 40: 30 N: P: K kg ha^{-1} + VAM 25 kg ha^{-1}	7.00	7.00	7.00	65.00	66.00	65.50	97.00	90.00	93.50
T_4- VAM 25 kg ha^{-1} + Panchagavya 3% (Drench)	6.00	5.67	5.83	45.00	42.00	43.50	118.00	110.00	114.00
T_5- VAM 25 kg ha^{-1} + Amrutpani 3% (Drench)	7.66	7.50	7.58	63.00	65.00	64.00	123.00	114.00	118.50
T_6- VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% (Drench)	7.00	7.00	7.00	68.00	69.00	68.50	135.00	126.00	130.50
T_7- 90: 40: 30 N: P: K kg ha^{-1} + Vermiwash 10% (Drench)	5.00	4.50	4.75	60.00	60.00	60.00	93.00	87.00	90.00
T_8- VAM 25 kg ha^{-1} + Vermiwash 10% (Drench)	7.00	7.00	7.00	43.00	40.00	41.50	110.00	103.00	106.50
T_9- VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch	8.00	8.00	8.00	70.00	69.00	69.50	144.00	134.00	139.00
S.Em.±	0.15	0.07	0.08	1.09	0.88	0.60	2.03	2.93	2.04
CD at 5%	0.45	0.20	0.25	3.27	2.65	1.80	6.08	8.78	6.11
CV (%)	16.84	19.80	18.19	19.93	18.18	18.90	13.26	12.71	12.92

Note: 1. Bioformulations *viz.*, Panchagavya, amrutpani and vermiwash were drenched at monthly interval from the day of sowing up to 2nd harvest
2. Common dose of FYM (12.5 t ha^{-1}) was applied at the time of sowing

Table.4 Fungi and actinomycetes count in fennel roots as influenced by the application of VAM and bioformulations during *rabi* 2017 and 2018

Treatments	Number of fungi × 10^3 CFU/g of soil			Number of actinomycetes × 10^4 CFU/g of soil		
	2017	2018	Pooled	2017	2018	Pooled
T_1- 90: 40: 30 N: P: K kg ha^{-1} (Check)	52.00	48.00	50.00	23.00	21.00	22.00
T_2- VAM 25 kg ha^{-1}	169.00	157.00	163.00	59.00	55.00	57.00
T_3- 90: 40: 30 N: P: K kg ha^{-1} + VAM 25 kg ha^{-1}	154.00	143.00	148.50	54.00	50.00	52.00
T_4- VAM 25 kg ha^{-1} + Panchagavya 3% (Drench)	207.00	193.00	200.00	71.00	66.00	68.50
T_5- VAM 25 kg ha^{-1} + Amrutpani 3% (Drench)	221.00	206.00	213.50	76.00	71.00	73.50
T_6- VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% (Drench)	234.00	218.00	226.00	81.00	75.00	78.00
T_7- 90: 40: 30 N: P: K kg ha^{-1} + Vermiwash 10% (Drench)	151.00	140.00	145.50	47.00	44.00	45.50
T_8- VAM 25 kg ha^{-1} + Vermiwash 10% (Drench)	186.00	173.00	179.50	63.00	59.00	61.00
T_9- VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch	242.00	225.00	233.50	84.00	78.00	81.00
S.Em.±	3.37	4.55	3.19	2.15	1.59	1.37
CD at 5%	10.10	13.65	9.56	6.44	4.77	4.11
CV (%)	11.37	13.36	12.75	11.21	11.39	11.21

Note: 1. Bioformulations *viz.*, Panchagavya, amrutpani and vermiwash were drenched at monthly interval from the day of sowing up to 2nd harvest
2. Common dose of FYM (12.5 t ha^{-1}) was applied at the time of sowing

Table.5 Effect of VAM and bioformulations on economics of Fennel

Treatments	Economics (`)											
	2017				2018				Pooled			
	Total Cost	Gross returns	Net returns	B:C ratio	Total Cost	Gross returns	Net returns	B:C ratio	Total Cost	Gross returns	Net returns	B:C ratio
T_1	39312	139620	100308	3.55	39312	134030	94718	3.41	39312	136825	97513	3.48
T_2	40600	130260	89660	3.21	40600	124930	84330	3.08	40600	127595	86995	3.14
T_3	41812	151840	110028	3.63	41812	145730	103918	3.49	41812	148785	106973	3.56
T_4	41350	133250	91900	3.22	41350	127920	86570	3.09	41350	130585	89235	3.15
T_5	41200	145860	104660	3.54	41200	140010	98810	3.40	41200	142935	101735	3.47
T_6	41950	157690	115740	3.76	41950	151320	109370	3.61	41950	154505	112555	3.68
T_7	40562	142610	102048	3.52	40562	136890	96328	3.37	40562	139750	99188	3.44
T_8	41850	132340	90490	3.16	41850	127010	85160	3.03	41850	129675	87825	3.09
T_9	43200	162500	119300	3.76	43200	156000	112800	3.61	43200	159250	116050	3.68

T_1- 90: 40: 30 N: P: K kg ha^{-1} (Check).
T_2- VAM 25 kg ha^{-1}.
T_3- 90: 40: 30 N: P: K kg ha^{-1} + VAM 25 kg ha^{-1}
T_4- VAM 25 kg ha^{-1} + Panchagavya 3% (Drench)
T_5- VAM 25 kg ha^{-1} + Amrutpani 3% (Drench)
T_6- VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% (Drench)
T_7- 90: 40: 30 N: P: K kg ha^{-1} + Vermiwash 10% (Drench)
T_8- VAM 25 kg ha^{-1} + Vermiwash 10% (Drench)
T_9- VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch

Significant difference was observed for root volume by the application of VAM and bioformulations. The highest root volume (70.00, 69.00 and 69.50 cm^{-3}) was recorded in the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) which was at par with T_6 (68.00, 69.00 and 69.50 cm^3) in 2017, 2018 and pooled data respectively. And the lowest (40.00, 38.00 and 39.00 cm^3) was recorded in treatment T_1 (90: 40: 30 N: P: K kg ha^{-1} (Check).

Microbial analysis

The highest per cent root colonization (96.00, 95.00 and 95.50%) was recorded in the treatments T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) which was at par with T_6 (94.00, 93.00 and 93.50%), T_3 (94.00, 92.00 and 93.00%) and T_5 (91.00, 91.00 and 91.00%) in 2017, 2018 and pooled data respectively. And the lowest (40.00, 41.00 and 40.50%) was recorded in treatment T_1 (90: 40: 30 N: P: K kg ha^{-1} (Check). The highest number of chlamydospores per 50 g of soil (1430.00, 1316.00 and 1373.00) was recorded in the treatments T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) which was at par with T_6 (1370.00, 1260.00 and 1315.00) and T_5 (1325.00, 1219.00 and 1272.00) in 2017, 2018 and pooled data respectively. And the lowest (325.00, 299.00 and 312.00) was recorded in treatment T_1 (90: 40: 30 N: P: K kg ha^{-1} (Check).

Beneficial microbial count

Significant difference was observed for bacterial count per gram of soil by the application of VAM and bioformulations. The highest bacterial count (144.00, 134.00 and 139.00 × 10^6 CFU/g of soil) was recorded in the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) in 2017, 2018 and pooled data respectively. And the lowest (23.00, 21.00 and 22.00 × 10^6 CFU/g of soil) was recorded in treatment T_1 (90: 40: 30 N: P: K kg ha^{-1} (Check). The highest fungal count (242.00, 225.00 and 233.50 × 10^3 CFU/g of soil) was recorded in the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) which was at par with T_6 (234.00, 218.00 and 226.00 × 10^3 CFU/g of soil) in 2017, 2018 and pooled data respectively. And the lowest (52.00, 48.00 and 50.00 × 10^6 CFU/g of soil) was recorded in treatment T_1 (90: 40: 30 N: P: K kg ha^{-1} (Check).The highest actinomycetes count (84.00,78.00 and 81.00 × 10^4 CFU/g of soil) was recorded in the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) which was at par with T_6 (81.00,75.00 and 78.00 × 10^6 CFU/g of soil) in 2017, 2018 and pooled data respectively. And the lowest (23.00, 21.00 and 22.00 × 10^4 CFU/g of soil) was recorded in treatment T_1 (90: 40: 30 N: P: K kg ha^{-1} (Check).

Economics analysis

Higher cost of production (43200, 43200 and 43200 Rs/ha) was accounted in the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) in 2017, 2018 and pooled data respectively. While the lower (39312, 39312 and 39312 Rs/ha) was accounted in treatment T_1 (90:40:30 N:P:K kg ha^{-1}). Highest gross returns (162500, 156000 and 159250 Rs/ha), net returns (119300, 112800 and 116050 Rs/ha) and Benefit:cost ratio (3.76, 3.61 and 3.69) were accounted in

the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) in 2017, 2018 and pooled data respectively. While the lowest (130260, 124930 and 127595 Rs/ha), (89660, 84330 and 86995 Rs/ha) and (3.16, 3.03 and 3.10) were accounted in treatment T_1 (90:40:30 N:P:K kg ha^{-1}) and T_8 (VAM 25 kg ha^{-1} + Vermiwash 10% (Drench) respectively. Similar findigs were also reported by Meena *et al.,* (2013)[4], Rana *et al.,* (2015)[6] and Singh and Amin (2015)[8] (Table 5).

Significantly higher essential oil content (1.04, 1.05 and 1.05%) was recorded in the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) in 2017, 2018 and pooled data respectively.

Significantly higher anethole content (59.22, 58.92 and 59.07%) was recorded in the treatment T_5 (VAM 25 kg ha^{-1} + Amrutpani 3% (Drench)) in 2017, 2018 and in the pooled data respectively.

Significantly higher per cent root colonization (96.00, 95.00 and 95.50), number of chlamydospores per 50 g of soil (1430.00, 1316.00 and 1373.00), length of longest root (26.50, 26.25 and 26.38 cm), number of roots (8.00, 8.00 and 8.00), root volume (70.00, 69.00 and 69.50 cm^3), bacterial count (144.00, 134.00 and 139.00 × 10^6 CFU/g of soil), fungal count (242.00, 225.00 and 233.50 × 10^3 CFU/g of soil) and actinomycetes count (84.00,78.00 and 81.00 × 10^4 CFU/g of soil) were recorded in the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) in 2017, 2018 and in the pooled data respectively.

Maximum net returns (119300, 112800 and 116050 Rs/ha) and Benefit:cost ratio (3.76, 3.61 and 3.69) were accounted in the treatment T_9 (VAM 25 kg ha^{-1} + Panchagavya 3% + Amrutpani 3% + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) in 2017, 2018 and in the pooled data respectively.

In conclusion the application of VAM and bio-formulations along with optimum dose of fertilizer influenced the quality attributes, root parameters, beneficial microbial count and economics of fennel. Application of VAM (25 kg ha^{-1}) along with foliar spray of Panchagavya (3%), Amrutpani (3%) + Vermiwash 10% (Drench) + Mulch (Sugar cane trash) resulted in higher values for quality attributes, root parameters, beneficial microbial count and economics of fennel under northern dry zone of Karnataka.

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