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Original Research Article

Influence of Organic Manures, Plant Growth Promoting Rhizobacteria and Micronutrients on Growth and Grain Yield of Ajwain (*Trachyspermum ammi* L.)

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A B S T R A C T

An experiment was conducted to study the individual and combined effect of organic manures, plant growth promoting rhizobacteria and micronutrients on growth and grain yield of Ajwain (*Trachyspermumammi L.)*" at College of Horticulture, Anantharajupeta, Y.S.R. Kadapa District, Andhra Pradesh. Farm yard manure and Vermicompost were used as organic sources at 50% and 75% recommended dose of nitrogen (RDN).PGPRs namely *Azospirillumlipoferium*, *Bacillus megathurium* and *Frateuriaaurantia*were used for seed priming. Micronutrients like $ZnSO_4$ and Fe_2SO_4 were applied as foliar application at 0.5% at before flowering,50% flowering and during grain formation. The result revealed that sole application of vermicompost and FYM was significantly on par on growth grain yield of Ajwain .Among the PGPR,seed priming with*Azospirillumlipoferium*and foliar application of zinc was found significantly superior in augmenting higher plant growth. Significantly highest grain yield and yield attributing characters like number umbels per plant, number of umbellets per umbel,number of fruits per umbel,number of fruits per umbellet,number of fruits per plant and total number of seeds per plant were recorded with sole application of 50% RDN through VC and FYM,seed priming with*Azospirillum* and foliar application of zinc. Among the combined effect,application of 50% of RDN through vermicompost and seed priming with *Azospirillum*along with foliar application of zincwas found significantly superiorin promoting growth characters like highest plant height,fresh weight of aerial parts ,dry matter content per plant and maximum crop growth rate.Significantly highest number of umbels per plant, umbellets per umbel, fruits per umbel , seed yield per plant, test weight of seeds,straw yield, biological yield and seed yield per hectare were observed by combined application of 50% of RDN through vermicompost along with seed priming with Azospirillum and foliar application of zinc which was statistically on par with application of 50% of RDN through FYM along with seed priming with Azospirillum and foliar application of zinc.

Keywords

Vermicompost, FYM, Azospirillum, Bacillus, Frateuria, $ZnSO_4$, Fe_2SO_4

Introduction

The capacity of spices to impart biological activity is now slowly reemerging as an area of interest for human health. Ajwain or Bishop's weed (*Trachyspermum ammi* L. Sprague) is an important seed spice that belongs to family apiaceae. Its characteristic aromatic smell and pungent taste is widely used as a spice in curries. It employed either alone or in mixture with other spices and condiments. More important use of ajwain is medicinal and it is a household remedy for indigestion. It is much valued for its antispasmodic, stimulant, tonic and aromatic carminative properties. Ajwain is erect, glabrous or minutely pubescent branched annual herb which grows up to 75-80cm in height.

In India, it is cultivated on commercial scale in the states of Madhya Pradesh, Andhra

Pradesh, Gujarat, Maharashtra, Uttar Pradesh, Rajasthan, Bihar and West Bengal. India is the largest producer and exporter of the Ajwain seeds in the world. During the year 2017-18, the area under the Ajwain crop was 35,000 ha and the production was 24,000 MT with a productivity of 703.70 kg ha^{-1} (Anon., 2018). The seed yield depends not only on genetic factors and the developmental stage of plants, but also on environmental factors. It is desirable to develop techniques of agronomical management to improve the growth and yield. Looking to the importance of this crop there is an urgent need for enhancing the productivity and quality of this crop by adopting integrated nutrient management practices . The promising research on effect of nutrient levels on Ajwain is a major limitation in one hand however, on the other hand this will open new vistas of wide scope to check the performance of organically grown Ajwain with plant growth promoting rhizobacteria and micronutrient sprays and restructuring of nutrient doses for getting economic yields with sustainable soil health. Keeping these points in view, the present study was conducted to study the interaction effect of organic manures, PGPR and micronutrients on vegetative growth, yield and quality of Ajwain.

Materials and Methods

The study was carried out at College of Horticulture, Anantharajupeta, Y.S.R. Kadapa District, Andhra Pradesh during 2017-18 and 2018-19. LTa-26, variety of Ajwain, released by Dr. Y.S.R.H.U was used for the study. The experiment consisted of 25 treatments, laid out in Factorial RBD with single control design and replicated thrice. Farm yard manure and vermicompost were used as organic source at 50% and 75% recommended dose of nitrogen (RDN). PGPRs namely *Azospirillum lipoferium*, *Bacillus megathurium* and *Frateuria aurantia* were used for seed priming. Micronutrients namely, $ZnSO_4$ and Fe_2SO_4 were applied as foliar spray @0.5% before flowering, 50% flowering and during grain formation stages. All the morphological, growth, yield and quality parameters were recorded.

Results and Discussion

Growth parameters

The morphological study (Table 1) of the plant revealed that the traits plant height (98.07 cm), crop growth rate (4.48g $m^{-2}d^{-1}$) and dry matter content per plant (50.03 g $plant^{-1}$) were high with sole application of 50% RDN through VC and this treatment was on par with 50% RDN through FYM. Among the PGPR, seed priming with *Azospirillum lipoferium* was found significantly superior in augmenting plant height (96.93cm), crop growth rate (4.43g $m^{-2}d^{-1}$) and dry matter content per plant(49.26g $plant^{-1}$). Foliar application of zinc was found significantly superior with maximum plant height (95.84cm), crop growth rate(4.33g $m^{-2}d^{-1}$) and high dry matter content per plant (48.52 g $plant^{-1}$) .

It was also evident from the Table (1) that combined effect of organic manures, PGPR and micronutrient produced significant influence on phenotypical growth of Ajwain. Maximum plant height (104.96cm), crop growth rate (5.00g $m^{-2}d^{-1}$) and maximum dry matter production (51.70 g $plant^{-1}$) was recorded with application of 50% of RDN through vermicompost +seed priming with *Azospirillum*+ foliar spray of Zn at 0.5% which was on par with 50% of RDN through FYM + seed priming with *Azospirillum*+ foliar spray of Zn at 0.5% .

Adequate supply of vermicompost early in the crop season resulted in greater availability of nutrients particularly in crop root zone. Increased availability of nutrients in the root zone coupled with higher metabolic activity at the cellular level might have enhanced the nutrient uptake and accumulation in the vegetative parts, which in turn resulted in higher plant height, number of leaves, fresh weight and dry mater content (Atiyeh *et al*., 2002).

From the table it was evident that supplementation of organic manures (VC/FYM), PGPR *(Azospirillum)* and micronutrient (Zn) either sole or in combinations could promote plant height and increased production of leaves in Ajwain. The reason for the changes might be due to cell multiplication and cell enlargement and cell differentiation, which could have resulted in increasing the height and number of leaves in the plant. The favourable effect of combination between organic manures, PGPR, and micronutrients may be attributed to the effect of the beneficial bacteria on availability of the nutrients, vital enzymes and hormonal stimulating effects on plant growth or increase of photosynthetic activity. Moreover, biofertilizers have several possible modes of action on plant growth on nitrogen fixation which contributed to the plant, hormonal effects, which alter the plant metabolism and thereby increasing the height and number of leaves. The above results are in accordance with findings of Abdel *et al.,* (2016) in Fennel and Mehta *et al.,* (2007) in Ajwain

Yield characters

The results (Table 2 & 3) clearly indicated that application of organic manure, plant growth promoting rhizobacteria and foliar application of micronutrients significantly increased the yield attributing characters in Ajwain. Significantly highest number of umbels per plant (213.98), number of umbellets per umbel (13.29), number of fruits per umbel (286.90), seed yield per plant (11.29 g) and test weight of seeds (1.10 g) was recorded with sole application of 50% RDN through VC which was on par with 50% RDN through FYM. Seed priming with *Azospirillum* recorded significantly higher number of umbels per plant (207.13), number of umbellets per umbel (13.10), number of fruits per umbel (279.79), seed yield per plant (10.99 g), and high test weight of seed (1.05g). In case of micronutrients application, foliar spray of Zn at 0.5% produced significantly higher number of umbels per plant (202.21), number of umbellets per umbel (12.90) number of fruits per umbel (271.9),higher seed yield per plant (10.74 g) and higher test weight of seed (1.02 g)

The integrated application of organic manures, PGPR and micronutrients could also exert significant influence on yield and its attributing characters. Significantly highest number of umbels per plant(226.71), number of umbellets per umbel (14.13), number of fruits per umbel (315.94), maximum seed yield per plant (12.28 g), and test weight of seed (1.18 g) was observed by combined application of 50% of RDN through vermicompost along with seed priming with *Azospirillum* and foliar application of zinc which was statistically on par with application of 50% of RDN through FYM along with seed priming with *Azospirillum* and foliar application of zinc.

The above results are in agreement with the findings of Meena *et al.,* (2009), Fachekardoni and Neda (2013) in Ajwain, Kusuma *et al.,* (2019) in Fennel, Mounika *et al.,* (2018) and Suman *et al.,* (2019) in Coriander.

The reason attributed for increased number of umbels, umbellets and fruits per umbel was due to supply of nutrients in balanced amounts and in available forms through FYM and vermicompost. Positive effect of Zn with respect to number of fruits and yield is due to the fact that Zn favours the enzyme system, auxin, and protein synthesis and seed production directly or indirectly (Sharma *et al*., 1999). In the present experiment, the increased number of fruits per umbellet and number of umbellets per umbel might have lead to the maximum number of fruits per umbel.

There was a significant difference in seed yield of Ajwain due to different treatments of sole application of organic manures PGPRs and micronutrients during both the years. The pooled data (Table 4) showed highest straw yield (310.73 gm^{-2}) seed yield per hectare (1239.00 Kg ha^{-1}) and biological yield (4346.31 Kg ha^{-1}) with sole application of 50% RDN through VC which was on par with 50% RDN through FYM. Among the plant growth promoting rhizobacteria, seed priming with *Azospirillum* recorded significantly high straw yield (294.72 gm^{-2}), seed yield per hectare (1211.0 Kg ha^{-1}) and high biological yield (4158.21 $Kgha^{-1}$),In case of micronutrients application, foliar spray of Zn at 0.5% produced significantly higher straw yield (283.73 gm^{-2}), seed yield (1181.32 Kg ha^{-1}) and maximum biological yield(4018.58 Kg ha^{-1}).

It was also evident from the Table (4) that combined effect of organic manures, PGPR and micronutrient produced significant influence on the straw yield of Ajwain. Maximum straw yield (349.72 gm^{-2}), seed yield per hectare (1336.43 Kg ha^{-1}) and biological yield (4833.63 Kg ha^{-1}) were recorded with application of 50% of RDN through vermicompost, seed priming with *Azospirillum* and foliar spray of Zn at 0.5% which was on par with 50% of RDN through FYM, seed priming with *Azospirillum* and foliar spray of Zn at 0.5%. The balanced application of nutrients resulted in faster growth of the plants as evidenced from increased biomass at successive stages of crop growth subscribed to the ways that there was better availability of nutrients which synchronised to the demand for growth and development of each reproductive structure of Ajwain plant. This inturn ascribed to its direct influence on dry matter accumulation at successive growth stages. While, indirect influence seems to be improvement in various morphological and yield attributing characters like seed yield, straw yield and biological yield of the crop.

The application of organic manures along with biofertilizers and micronutrients has profound effect on vegetative growth due to higher photosynthetic rate and chlorophyll content of the plant. The increased availability of nitrogen might have also improved the growth attributes which resulted in production of higher quantity of straw yield. Similar results were obtained by Meena *et al.,* (2009) in Ajwain and Mehta *et al.,* (2014) in Cumin and Gour *et al.,* (2017) in Dill.

In the present study, the interaction between organic manures, PGPR and micronutrients on seed yield of Ajwain was significant. This implies greater availability of nutrients and metabolites for the growth and development of reproductive structure, which ultimately led to realization of higher productivity. Further, in most of the seed spices, greater assimilating surface at reproductive development results in better grain formation because of adequate production of metabolites and their translocation towards grain as evident from improvement in nutrient concentration and their uptake.

Table.1 Plant height, crop growth rate and drymatter of Ajwain as influenced by organic manures, plant growth promoting rhizobacteria and micronutrients

	Plant height(cm)				Crop growth rate (g $m^{-2}d^{-1}$) at 120 DAS				Drymatter (g $plant^{-1}$)		
	2017-18	2018-19	Pooled		2017-18	2018-19	Pooled		2017-18	2018-19	Pooled
Organic manures (A)											
A_1	97.37	97.10	97.24		4.46	4.40	4.43		50.39	48.70	49.54
A_2	89.99	89.34	89.66		3.95	3.90	3.92		48.58	42.62	45.60
A_3	98.20	97.94	98.07		4.51	4.45	4.48		50.76	49.30	50.03
A_4	90.88	90.28	90.58		4.06	4.00	4.03		48.90	43.06	45.98
SEm±	2.27	2.01	2.14		0.1	0.12	0.11		0.48	0.62	0.75
CD (P=0.05)	6.76	6.12	6.44		0.28	0.32	0.30		1.35	1.77	2.15
Plant Growth Promoting Rhizobacteria (B)											
B_1	97.20	96.66	96.93		4.46	4.40	4.43		50.35	48.17	49.26
B_2	91.13	90.71	90.92		4.06	4.00	4.03		48.90	43.65	46.27
B_3	94.01	93.62	93.81		4.22	4.16	4.19		49.73	45.93	47.83
SEm±	0.88	0.67	0.78		0.06	0.07	0.09		0.21	0.52	0.48
CD (P=0.05)	2.59	2.08	2.34		0.2	0.22	0.24		0.57	1.45	1.38
Micronutrients (C)											
C_1	96.09	95.59	95.84		4.36	4.29	4.33		50.10	46.94	48.52
C_2	92.13	91.74	91.93		4.13	4.08	4.11		49.22	44.89	47.06
SEm±	1.08	0.95	1.02		0.07	0.04	0.06		0.23	0.63	0.47
CD (P=0.05)	3.19	2.86	3.03		0.18	0.11	0.15		0.76	1.82	1.34

Treatment details		
A-Organic manures	**B- Plant Growth Promoting Rhizobacteria**	**C-Micronutrients**
A_1: 50% of RDN through FYM	B_1: Azospirillum	C_1: Zn @ 0.5%
A_2: 75% of RDN through FYM	B_2: Phosphorus Solubilising Bacteria (PSB)	C_2: Fe @ 0.5%
A_3: 50% of RDN through VC	B_3: Potash Mobilizing Bacteria (KMB)	
A_4: 75%of RDN through VC		

Table 1 contd...

	Plant height(cm)				Crop growth rate (g $m^{-2}d^{-1}$) at 120 DAS				Dry matter (g $plant^{-1}$)		
	2017-18	2018-19	Pooled		2017-18	2018-19	Pooled		2017-18	2018-19	Pooled
A x B x C (Organic manures x PGPR x Micronutrients)											
$A_1B_1C_1$	104.40	103.86	104.13		4.89	4.77	4.83		51.35	50.45	50.90
$A_1B_1C_2$	97.06	96.98	97.02		4.47	4.36	4.41		50.75	49.13	49.94
$A_1B_2C_1$	96.99	96.84	96.92		4.41	4.36	4.39		50.48	48.79	49.64
$A_1B_2C_2$	92.47	92.14	92.31		4.19	4.15	4.17		49.12	46.22	47.67
$A_1B_3C_1$	98.28	97.98	98.13		4.50	4.46	4.48		51.09	49.96	50.53
$A_1B_3C_2$	95.03	94.82	94.93		4.32	4.29	4.31		49.55	47.62	48.59
$A_2B_1C_1$	95.02	94.79	94.91		4.27	4.25	4.26		49.41	47.11	48.26
$A_2B_1C_2$	90.70	89.67	90.19		4.03	3.97	4.00		48.95	43.60	46.28
$A_2B_2C_1$	87.87	87.68	87.78		3.79	3.72	3.76		48.40	40.19	44.30
$A_2B_2C_2$	86.26	85.14	85.70		3.76	3.68	3.72		47.14	38.16	42.65
$A_2B_3C_1$	90.95	89.96	90.46		4.04	4.00	4.02		49.04	45.67	47.36
$A_2B_3C_2$	89.11	88.78	88.95		3.80	3.76	3.78		48.55	40.97	44.76
$A_3B_1C_1$	105.83	104.08	104.96		5.02	4.98	5.00		52.16	51.24	51.70
$A_3B_1C_2$	97.64	96.84	97.24		4.50	4.43	4.46		51.09	49.85	50.47
$A_3B_2C_1$	95.71	94.92	95.32		4.37	4.29	4.33		50.43	48.79	49.61
$A_3B_2C_2$	92.78	92.64	92.71		4.21	4.19	4.20		49.29	46.72	48.01
$A_3B_3C_1$	101.43	103.01	102.22		4.60	4.47	4.54		51.17	50.24	50.71
$A_3B_3C_2$	95.81	96.14	95.98		4.39	4.35	4.37		50.44	48.96	49.70
$A_4B_1C_1$	95.31	95.82	95.57		4.33	4.28	4.31		50.01	48.05	49.03
$A_4B_1C_2$	91.63	91.25	91.44		4.15	4.12	4.14		49.09	45.94	47.52
$A_4B_2C_1$	90.35	89.06	89.71		4.02	3.92	3.97		48.59	41.46	45.03
$A_4B_2C_2$	86.58	87.24	86.91		3.77	3.70	3.73		47.74	38.86	43.30
$A_4B_3C_1$	90.97	89.04	90.01		4.05	4.02	4.04		49.06	41.34	45.20
$A_4B_3C_2$	90.46	89.24	89.85		4.03	3.96	3.99		48.90	42.70	45.80
SEm±	1.27	0.36	0.85		0.08	0.11	0.13		0.28	0.31	0.33
CD (P=0.05)	3.76	1.01	2.47		0.25	0.29	0.32		0.89	0.91	0.95
Controlvz Rest	82.85	83.56	83.21		3.67	3.63	3.65		43.39	37.12	40.26
SEm± (Control)	7.61	7.75	7.88		0.61	0.53	0.56		1.18	1.07	1.13
CD (P=0.5) (Control)	22.76	23.18	22.97		1.79	1.54	1.67		3.52	3.19	3.37
CV%	13.96	13.24	13.60		3.32	3.82	3.57		4.35	4.13	4.94

Table.2 Number of umbels per plant, number of umbellets per umbel and number of fruits per umbels of Ajwain as influenced by organic manures, plant growth promoting rhizobacteria and micronutrients

	Number of umbels per plant				**Number of umbellets per umbel**				**Number of fruits per umbel**		
	2017-18	**2018-19**	**Pooled**		**2017-18**	**2018-19**	**Pooled**		**2017-18**	**2018-19**	**Pooled**
Organic manures (A)											
A_1	214.43	209.62	212.02		13.24	13.12	13.18		287.05	279.32	283.18
A_2	178.48	170.83	174.65		11.98	11.86	11.92		239.76	226.36	233.06
A_3	216.61	211.36	213.98		13.35	13.23	13.29		291.00	282.81	286.90
A_4	185.44	178.44	181.94		12.25	12.14	12.19		248.57	237.12	242.85
SEm±	5.60	3.75	4.52		0.14	0.13	0.15		5.16	5.45	4.88
CD (P=0.05)	15.93	11.12	13.47		0.41	0.32	0.38		15.50	16.28	14.57
Plant Growth Promoting Rhizobacteria (B)											
B_1	209.79	204.47	207.13		13.19	13.02	13.10		284.80	274.79	279.79
B_2	186.17	179.66	182.92		12.23	12.13	12.18		247.75	236.00	241.88
B_3	200.25	193.55	196.90		12.69	12.60	12.65		267.24	258.41	262.83
SEm±	2.95	2.06	2.42		0.13	0.08	0.12		4.49	4.81	5.21
CD (P=0.05)	8.80	6.08	7.12		0.32	0.28	0.30		13.44	14.38	15.62
Micronutrients (C)											
C_1	205.24	199.19	202.21		12.97	12.83	12.90		276.11	266.47	271.29
C_2	192.24	185.93	189.09		12.43	12.34	12.39		257.08	246.33	251.71
SEm±	3.76	3.32	3.51		0.19	0.16	0.18		3.68	3.84	4.61
CD (P=0.05)	11.26	9.86	10.47		0.51	0.45	0.50		10.98	11.43	13.75

Treatment details		
A-Organic manures	**B- Plant Growth Promoting Rhizobacteria**	**C-Micronutrients**
A_1: 50% of RDN through FYM	B_1: Azospirillum	C_1: Zn @ 0.5%
A_2: 75% of RDN through FYM	B_2: Phosphorus Solubilising Bacteria (PSB)	C_2: Fe @ 0.5%
A_3: 50% of RDN through VC	B_3: Potash Mobilizing Bacteria (KMB)	
A_4: 75%of RDN through VC		

Table.2 Contd...

	Number of umbels per plant				Number of umbellets per umbel				Number of fruits per umbel		
	2017-18	2018-19	Pooled		2017-18	2018-19	Pooled		2017-18	2018-19	Pooled
A x B x C (Organic manures x PGPR x Micronutrients)											
$A_1B_1C_1$	224.22	220.66	222.44		14.11	13.76	13.94		316.93	298.45	307.69
$A_1B_1C_2$	215.88	211.65	213.77		13.22	13.17	13.20		285.86	283.05	284.46
$A_1B_2C_1$	215.70	210.47	213.09		13.22	13.15	13.19		282.90	280.13	281.52
$A_1B_2C_2$	202.22	197.53	199.88		12.66	12.59	12.63		266.14	257.38	261.76
$A_1B_3C_1$	222.66	217.86	220.26		13.33	13.29	13.31		295.99	288.56	292.28
$A_1B_3C_2$	205.88	199.56	202.72		12.88	12.75	12.82		274.48	268.32	271.40
$A_2B_1C_1$	203.33	195.37	199.35		12.77	12.63	12.70		269.11	265.28	267.20
$A_2B_1C_2$	185.77	178.23	182.00		12.22	12.15	12.19		250.47	236.77	243.62
$A_2B_2C_1$	169.27	159.24	164.26		11.50	11.38	11.44		218.59	205.11	211.85
$A_2B_2C_2$	152.90	147.78	150.34		11.08	10.97	11.03		209.77	187.13	198.45
$A_2B_3C_1$	187.22	180.22	183.72		12.33	12.25	12.29		251.30	245.88	248.59
$A_2B_3C_2$	172.40	164.11	168.26		11.99	11.78	11.89		239.33	217.98	228.66
$A_3B_1C_1$	228.76	224.65	226.71		14.33	13.92	14.13		326.62	305.26	315.94
$A_3B_1C_2$	219.44	215.34	217.39		13.31	13.25	13.28		290.63	285.17	287.90
$A_3B_2C_1$	210.11	205.46	207.79		13.11	13.05	13.08		280.57	275.27	277.92
$A_3B_2C_2$	203.33	195.22	199.28		12.77	12.70	12.74		269.07	263.06	266.07
$A_3B_3C_1$	224.11	219.38	221.75		13.44	13.35	13.40		298.25	290.33	294.29
$A_3B_3C_2$	213.88	208.11	211.00		13.11	13.08	13.10		280.86	277.75	279.31
$A_4B_1C_1$	209.11	202.67	205.89		13.10	12.92	13.01		279.18	270.55	274.87
$A_4B_1C_2$	191.84	187.22	189.53		12.44	12.37	12.41		259.56	253.81	256.69
$A_4B_2C_1$	178.08	168.90	173.49		12.11	11.95	12.03		242.52	224.54	233.53
$A_4B_2C_2$	157.77	152.67	155.22		11.36	11.26	11.31		212.43	195.39	203.91
$A_4B_3C_1$	190.31	185.38	187.85		12.33	12.28	12.31		251.34	248.24	249.79
$A_4B_3C_2$	185.55	173.78	179.67		12.13	12.05	12.09		246.40	230.19	238.30
SEm±	1.54	1.38	1.56		0.14	0.10	0.11		8.37	4.48	6.66
CD (P=0.05)	4.61	4.12	4.57		0.36	0.26	0.31		25.03	13.36	20.16
Controlvz Rest	152.91	145.24	149.08		11.88	11.43	11.66		178.22	165.25	171.74
SEm± (Control)	14.56	10.87	12.72		0.37	0.31	0.34		13.46	9.52	11.49
CD (P=0.5) (Control)	41.39	32.56	36.98		1.06	0.89	0.98		40.33	28.48	34.41
CV%	12.07	10.13	11.10		4.80	5.30	5.05		8.81	9.20	9.01

Table.3 Seed yield per plant and Test weight of seed (g) of Ajwain as influenced by organic manures, plant growth promoting rhizobacteria and micronutrients

	Seed yield per plant (g)				Test weight of seed (g)		
	2017-18	**2018-19**	**Pooled**		**2017-18**	**2018-19**	**Pooled**
Organic manures (A)							
A_1	11.29	11.01	11.15		1.11	1.05	1.08
A_2	9.68	9.17	9.43		0.90	0.82	0.86
A_3	11.38	11.20	11.29		1.13	1.07	1.10
A_4	9.89	9.53	9.71		0.94	0.86	0.90
SEm±	0.25	0.23	0.27		0.05	0.03	0.05
CD (P=0.05)	0.72	0.61	0.74		0.12	0.11	0.13
Plant Growth Promoting Rhizobacteria (B)							
B_1	11.14	10.85	10.99		1.08	1.02	1.05
B_2	9.91	9.55	9.73		0.95	0.87	0.91
B_3	10.63	10.28	10.46		1.02	0.95	0.98
SEm±	0.22	0.15	0.17		0.01	0.01	0.02
CD (P=0.05)	0.62	0.48	0.50		0.03	0.05	0.06
Micronutrients (C)							
C_1	10.91	10.58	10.74		1.05	0.99	1.02
C_2	10.21	9.87	10.04		0.98	0.90	0.94
SEm±	0.18	0.22	0.24		0.01	0.01	0.02
CD (P=0.05)	0.51	0.62	0.68		0.03	0.03	0.06

Treatment details		
A-Organic manures	**B- Plant Growth Promoting Rhizobacteria**	**C-Micronutrients**
A_1: 50% of RDN through FYM	B_1: Azospirillum	C_1: Zn @ 0.5%
A_2: 75% of RDN through FYM	B_2: Phosphorus Solubilising Bacteria (PSB)	C_2: Fe @ 0.5%
A_3: 50% of RDN through VC	B_3: Potash Mobilizing Bacteria (KMB)	
A_4: 75%of RDN through VC		

Table.3 Contd...

	Seed yield per plant (g)				Test weight of seed (g)		
	2017-18	**2018-19**	**Pooled**		**2017-18**	**2018-19**	**Pooled**
A x B x C (Organic manures x PGPR x Micronutrients)							
$A_1B_1C_1$	12.21	11.71	11.96		1.17	1.14	1.16
$A_1B_1C_2$	11.38	11.10	11.24		1.13	1.08	1.11
$A_1B_2C_1$	11.03	10.98	11.01		1.13	1.07	1.10
$A_1B_2C_2$	10.56	10.25	10.41		1.03	0.91	0.97
$A_1B_3C_1$	11.77	11.46	11.62		1.15	1.11	1.13
$A_1B_3C_2$	10.77	10.54	10.66		1.07	0.96	1.02
$A_2B_1C_1$	10.61	10.43	10.52		1.06	0.97	1.02
$A_2B_1C_2$	9.93	9.36	9.65		0.90	0.85	0.88
$A_2B_2C_1$	9.47	8.67	9.07		0.84	0.74	0.79
$A_2B_2C_2$	8.33	8.01	8.17		0.79	0.70	0.75
$A_2B_3C_1$	10.14	9.58	9.86		0.93	0.86	0.90
$A_2B_3C_2$	9.60	8.97	9.29		0.85	0.77	0.81
$A_3B_1C_1$	12.43	12.13	12.28		1.19	1.16	1.18
$A_3B_1C_2$	11.54	11.36	11.45		1.14	1.10	1.12
$A_3B_2C_1$	10.93	10.82	10.88		1.10	1.02	1.06
$A_3B_2C_2$	10.59	10.37	10.48		1.05	0.95	1.00
$A_3B_3C_1$	11.79	11.58	11.69		1.16	1.13	1.15
$A_3B_3C_2$	11.02	10.94	10.98		1.12	1.05	1.09
$A_4B_1C_1$	10.79	10.65	10.72		1.09	0.99	1.04
$A_4B_1C_2$	10.20	10.06	10.13		0.99	0.90	0.95
$A_4B_2C_1$	9.61	9.03	9.32		0.87	0.80	0.84
$A_4B_2C_2$	8.74	8.25	8.50		0.82	0.73	0.78
$A_4B_3C_1$	10.16	9.88	10.02		0.96	0.88	0.92
$A_4B_3C_2$	9.81	9.28	9.55		0.88	0.83	0.86
SEm±	0.18	0.17	0.19		0.01	0.01	0.01
CD (P=0.05)	0.56	0.50	0.53		0.03	0.03	0.03
Controlvz Rest	7.93	7.64	7.79		0.73	0.68	0.71
SEm± (Control)	0.65	0.69	0.63		0.04	0.03	0.03
CD (P=0.5) (Control)	1.86	1.75	1.82		0.10	0.10	0.10
CV%	10.23`	5.20	5.20		5.80	5.20	5.50

Table.4 Straw yield, seed yield and biological yield of Ajwain as influenced by organic manures, plant growth promoting rhizobacteria and micronutrients

	Straw yield (g m^{-2})				Seed yield (Kg ha^{-1})				Biological yield (Kg ha^{-1})		
	2017-18	**2018-19**	**Pooled**		**2017-18**	**2018-19**	**Pooled**		**2017-18**	**2018-19**	**Pooled**
Organic manures (A)											
A_1	313.81	300.80	307.30		1229.34	1214.06	1221.70		4367.47	4222.01	4294.74
A_2	220.25	213.43	216.84		1055.37	1014.98	1035.17		3257.85	3149.23	3203.54
A_3	317.09	304.38	310.73		1246.36	1231.65	1239.00		4417.23	4275.40	4346.31
A_4	238.77	226.00	232.38		1090.65	1069.96	1080.31		3478.30	3329.98	3404.14
SEm±	2.88	2.57	2.91		15.21	12.11	13.56		28.58	27.51	28.82
CD (P=0.05)	8.20	7.55	8.82		43.25	36.24	40.58		81.27	82.43	86.35
Plant Growth Promoting Rhizobacteria (B)											
B_1	301.68	287.76	294.72		1218.38	1203.71	1211.04		4235.13	4081.29	4158.21
B_2	242.56	233.42	237.99		1087.67	1049.24	1068.45		3513.23	3383.43	3448.33
B_3	273.20	262.27	267.74		1160.24	1145.05	1152.64		3892.27	3767.75	3830.01
SEm±	2.50	2.16	2.61		13.17	12.77	14.24		24.75	25.12	27.16
CD (P=0.05)	7.10	6.32	7.86		37.46	38.16	42.63		70.39	75.22	81.45
Micronutrients (C)											
C_1	290.02	277.43	283.73		1191.87	1170.77	1181.32		4092.04	3945.11	4018.58
C_2	254.94	244.86	249.90		1118.98	1094.56	1106.77		3668.38	3543.20	3605.79
SEm±	2.04	1.42	1.68		10.20	11.27	10.89		20.21	20.72	21.71
CD (P=0.05)	5.80	4.21	4.90		30.59	33.71	32.14		57.47	62.13	65.08

Treatment details		
A-Organic manures	**B- Plant Growth Promoting Rhizobacteria**	**C-Micronutrients**
A_1: 50% of RDN through FYM	B_1: Azospirillum	C_1: Zn @ 0.5%
A_2: 75% of RDN through FYM	B_2: Phosphorus Solubilising Bacteria (PSB)	C_2: Fe @ 0.5%
A_3: 50% of RDN through VC	B_3: Potash Mobilizing Bacteria (KMB)	
A_4: 75%of RDN through VC		

Table.4 Contd...

	Straw yield (g m^{-2})				Seed yield (Kg ha^{-1})				Biological yield (Kg ha^{-1})		
	2017-18	2018-19	Pooled		2017-18	2018-19	Pooled		2017-18	2018-19	Pooled
A x B x C (Organic manures x PGPR x Micronutrients)											
$A_1B_1C_1$	356.50	332.87	344.69		1321.48	1315.43	1318.46		4886.48	4644.13	4765.31
$A_1B_1C_2$	324.45	314.19	319.32		1228.89	1213.87	1221.38		4473.39	4355.77	4414.58
$A_1B_2C_1$	320.89	314.62	317.76		1224.36	1195.55	1209.96		4433.26	4341.75	4387.51
$A_1B_2C_2$	259.26	246.33	252.80		1142.96	1117.98	1130.47		3735.56	3581.28	3658.42
$A_1B_3C_1$	334.37	325.21	329.79		1282.04	1274.34	1278.19		4625.74	4526.44	4576.09
$A_1B_3C_2$	287.41	271.55	279.48		1176.28	1167.21	1171.75		4050.38	3882.71	3966.55
$A_2B_1C_1$	277.34	265.31	271.33		1173.33	1155.09	1164.21		3946.73	3808.19	3877.46
$A_2B_1C_2$	229.04	216.44	222.74		1091.31	1075.34	1083.33		3381.71	3239.74	3310.73
$A_2B_2C_1$	214.22	196.35	205.29		1016.70	923.14	969.92		3158.9	2886.64	3022.77
$A_2B_2C_2$	148.45	174.12	161.29		925.90	864.78	895.34		2410.4	2605.98	2508.19
$A_2B_3C_1$	237.33	224.56	230.95		1093.10	1089.09	1091.10		3466.4	3334.69	3400.55
$A_2B_3C_2$	215.11	203.77	209.44		1031.85	982.45	1007.15		3182.95	3020.15	3101.55
$A_3B_1C_1$	359.11	340.33	349.72		1345.19	1327.67	1336.43		4936.29	4730.97	4833.63
$A_3B_1C_2$	327.41	318.46	322.94		1274.07	1265.90	1269.99		4548.17	4450.5	4499.34
$A_3B_2C_1$	299.26	283.22	291.24		1189.63	1179.33	1184.48		4182.23	4011.53	4096.88
$A_3B_2C_2$	268.74	253.46	261.10		1164.07	1134.24	1149.16		3851.47	3668.84	3760.16
$A_3B_3C_1$	336.30	328.65	332.48		1308.15	1298.09	1303.12		4671.15	4584.59	4627.87
$A_3B_3C_2$	311.70	302.13	306.92		1197.04	1184.67	1190.86		4314.04	4205.97	4260.01
$A_4B_1C_1$	289.18	278.63	283.91		1179.26	1170.56	1174.91		4071.06	3956.86	4013.96
$A_4B_1C_2$	250.37	235.84	243.11		1133.49	1105.78	1119.64		3637.19	3464.18	3550.69
$A_4B_2C_1$	218.07	210.60	214.34		1066.28	1024.77	1045.53		3246.98	3130.77	3188.88
$A_4B_2C_2$	211.56	188.65	200.11		971.46	954.12	962.79		3087.06	2840.62	2963.84
$A_4B_3C_1$	237.63	228.86	233.25		1102.96	1096.21	1099.59		3479.26	3384.81	3432.04
$A_4B_3C_2$	225.78	213.43	219.61		1090.47	1068.34	1079.41		3348.27	3202.64	3275.46
SEm±	5.39	3.62	5.21		11.62	8.81	10.65		38.43	39.11	40.22
CD (P=0.05)	16.09	10.57	15.43		35.10	26.34	31.87		115.24	117.22	120.54
Control vz Rest	213.63	202.18	207.91		881.49	852.64	867.07		3017.79	2874.44	2946.12
SEm± (Control)	24.81	22.91	23.86		37.48	33.99	36.48		70.39	61.56	68.52
CD (P=0.5) (Control)	74.93	68.56	71.75		112.38	101.96	109.40		211.16	184.66	205.48
CV%	4.53	5.20	4.87		5.64	5.38	5.51		3.15	4.20	3.68

In conclusion, the integrated nutrient management practices by substituting inorganic source with organics was found to be significantly influential on the growth, flowering and yield aspects of Ajwain. Among the organic sources, 50% of RDN through VC and 50% of RDN through FYM was found superior in improving the vegetative traits, yield and its attributes in Ajwain. Among the PGPR, seed priming with *Azospirillum* found significantly superior in promoting growth, yield and its attributes and quality components. Among the micronutrients application, foliar spray of Zn @ 0.5% was found promising with better vegetative growth, yield and its attributes and quality parameters.

Among the combined effect of organic manures, PGPR and micronutrients, application of 50% of RDN through vermicompost +seed priming with *Azospirillum*+foliar spray of Zn @ 0.5% and with 50% of RDN through FYM + seed priming with *Azospirillum*+ foliar spray of Zn @ 0.5% was found on par with superior morphological growth, yield and its attributes.

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