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Next generation organic inputs on the soft rot disease, growth, yield and quality of ginger, *Zingiber officinale* L., grown in Sikkim Himalaya

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Abstract

Ginger is one of the major cash crops of Sikkim and being an organic state, maintaining sustainability in ginger cultivation is a challenge especially in the changing climate scenario. Soft rot caused by *Pythium aphanidermatum* is a major problem in ginger cultivation and the disease has resulted into reduction in the acreage under the crop in this Himalayan state. Conventional exhaustive organic inputs, self renewable organic inputs like plant growth-promoting rhizobacteria (PGPR) were tested against the soft rot incidence in ginger for two consecutive years. Two local varieties, namely, Bhaise and Majouley were used with conventional organic inputs and PGPR, alone and in combinations. The disease causing organism was challenge inoculated. The disease symptoms were assessed by visual scoring. In addition, growth and yield parameters were recorded. The results revealed that PGPR along with the other organic inputs have significant effect on disease suppression in addition to promoting the growth and yield parameters like plant height, number of leaves, number of tillers, leaf area and yield per plant. The information generated can act as a readily available environmentally safe method for the management of soft rot in ginger through organic means.

Key words: Growth, yield, ginger, PGPR, organic inputs, Bhaise, Majauley

Introduction

Ginger (*Zingiber officinale* Rosc.) is an important spice crop that supports the livelihood of many farmers in Kerala, Karnataka, Himachal Pradesh, Meghalaya, Sikkim, West Bengal and other North Eastern states of India (Kumar and Sharma, 2004).

Sikkim, with an area of about 7096 sq. km, where farming is done in about 10.20 %, is declared as an Organic state. Ginger being one of the major cash crops of Sikkim plays a vital role in the state's economy in terms of direct and indirect income and employment generation. The crop is a good source of income for small and marginal farmers and is growing up to an elevation of 1500 m above MSL, occupying an area about 8000 ha. producing 44,000 tons of ginger (Yadav *et al.,* 2014). The productivity of ginger in Sikkim has increased from 4.8 tonnes ha^{-1} in 2002-03 to 5.3 tonnes/ha in 2010-11.

Ginger is affected by several diseases. Among them the most serious one is a soft rot disease. Soft rot is also called rhizome rot or *Pythium* rot. Butler (1907) recorded the incidence of this disease for the first time from Surat (Gujarat) in India. The disease is prevalent in India, Japan, China, Nigeria, Fiji, Taiwan, Australia, Hawaii, Sri Lanka, and Korea. In India, this disease has been reported from almost all states, including, Kerala, Rajasthan, Himachal Pradesh, Orissa, Maharashtra, Tamil Nadu, Andhra Pradesh and Sikkim. Soft rot reduces the potential yield to a great extent in the field, storage, and market and may cause losses of even more than 50 percent (Joshi and Sharma, 1980). Crop loss depends on the growth stage at which infection starts. Total loss results if the infection occurs in the early stage of crop growth. In Kerala, the loss was as high as 90 percent during heavy infection (Rajan and Agnihotri, 1989).

Sikkim being declared an organic state, not only supply of nutrients, but also the control of pest and diseases have to be without agro chemicals. Application of different organic amendments in combinations and in a cumulative manner can supply the nutrient requirement of the plant. Like any other plant, ginger requires the right kind of nutrients to sustain its growth and maximum yield. Some of the new organic inputs like PGPR manipulate the ginger growing environment and prevents the plant diseases in addition to promoting plant growth and development. Next generation organic inputs are the new set of technology where the beneficial microbes are packed in such a way that it is easy to handle, carry and transport. Its effectiveness is quite high as compared to the other organic inputs.

There is an ample scope for further improvement of organic production and productivity of ginger for increasing the incomes of the farming community of the state. Hence, the present study has been carried out to know the effect of the different combinations of next generation organic inputs on the soft rot disease, growth and yield of ginger grown in the Sikkim Himalaya.

Material and methods

Two different commercial varieties of ginger, *i.e.*, Bhaise and Majauley were collected and planted in the farmer's field at Khamdong, East Sikkim located at the latitude of 27°15′0′′N and longitude of 88°28′32′′E for two consecutive years. The

Table 1. Different combinations of treatments of organic inputs and PGPR

Treatment		Treatment	
T1	Control*	T23	Cap 1+ 2
T2	Farm Yard Manure (FYM)	T24	Cap 1+3
T3	Vesicular Abuscular Mycohriza (VAM)	T25	Cap 2+3
T4	Vermicompost	T26	Cap 1+ Trichoderma
T5	Capsule 1	T27	Cap 2+ Trichoderma
T6	Capsule 2	T28	Cap 3 + Trichoderma
T7	Capsule 3	T29	FYM+VAM+Cap 1
T8	Trichoderma	T30	FYM+VAM+Cap 2
T9	Vermicompost+VAM	T31	FYM+VAM+Cap3
T10	Vermicompost+Cap 1	T32	FYM+VAM+Trichoderma
T11	Vermicompost+Cap 2	T33	Vermi+VAM+Cap1
T12	Vermicompost+Cap 3	T34	Vermi+VAM+Cap2
T13	Vermicompost+Trichoderma	T35	Vermi+VAM+Cap3
T14	FYM+Cap 1	T36	Vermi+VAM+Trichoderma
T15	FYM+Cap 2	T37	FYM+VAM+Cap1+Trichoderma
T16	FYM+Cap 3	T38	FYM+VAM+Cap2+Trichoderma
T17	FYM+Trichoderma	T39	FYM+VAM+Cap3+Trichoderma
T18	FYM+VAM	T40	Vermi+VAM+Cap1+Trichoderma
T19	VAM+Cap 1	T41	Vermi+VAM+Cap2+Trichoderma
T20	VAM+Cap 2	T42	Vermi+VAM+Cap3+Trichoderma
T21	VAM+Cap 3	T43	Check**
T22	VAM+Trichoderma		

*Control: No organic inputs
**Check: Recommended dose of NPK (75:50:50 kg/ha supplied in the form of Rich Fertiplus
Capsule 1 GRB-35 (*Bacillus amyloliquefaceins*)
Capsule 2 FL-18 (*Microbacterium paraoxydans*)
Capsule 3 BRB (*Micrococcus* sps)

soil analysis of the field was done in the soil testing lab, Tadong, Gangtok. The experiment was laid down in a Factorial Randomized Block Design with 43 treatments having three replications each (Table 1). The recommended dose of NPK *i.e.*, 75:50:50 kg ha^{-1} was taken as check and no input was taken as control. Each treatment was adopted in 1 m^2 plot. Spacing was kept at 25 cm eitherway, making 16 plants/plot. Each plot was treated with different treatments as per design. The rhizome was treated with appropriate organic inputs as per treatment design. Three PGPR capsule namely Capsule1: GRB-35 (*Bacillus amyloliquefaceins*), Capsule2 : FL-18 (*Microbacterium paraoxydans*), Capsule 3: BRB (*Micrococcus* sp.) and Trichoderma capsule was used in the study. One capsule from each different PGPR were suspended in 10 L water and dissolved properly and the rhizomes which were to be treated were soaked in it for about 30 minutes before sowing. FYM, vermicompost and VAM were given 3 g, respectively for each rhizome. It was planted in the month of March 2017 for 1st season and March 2018 for 2nd season and harvesting of the rhizomes was done after nine months of planting when all the leaves had changed its color from green to yellow and shriveled down indicating its harvest time. Cultures of *Pythium aphanidermatum* a causal organism of soft rot disease of ginger was obtained from the Indian Type Culture Collection Centre (ITCC), IARI, New Delhi and it was challenged inoculated in the month of July 2017 for 1st season and July 2018 for 2nd season as it was the peak season for the soft rot infestation coinciding with South West monsoon.

Plant height and number of tillers were recorded from 60 days after planting and continued at 40 days interval till harvest. Plant height was measured from the base of the plant to the apex using measuring tape. Number of leaves, number of tillers was measured by counting manually. Leaf area was measured using the leaf area meter. The disease incidence was estimated according to the symptoms shown by the plant using the visual scoring method. After the harvest the yield of the ginger rhizome was taken per plant.

Results and discussion

The pre-plant soil analysis showed that the soil was neutral with a pH of 6.3. The organic carbon was 2.23 %, nitrogen content was medium (330.75 kg ha^{-1}), phosphorus was high (29.89 kg ha^{-1}) and potassium was medium (285.64 kg ha^{-1}) in range.

Morphological characters

Plant height: The height of the plant started to increase rapidly from the 100 days of planting in both the varieties. Plant height got to its highest peak of 68.89 cm in T40 *i.e.*, Vermico mpost+VAM+Cap1+Trichoderma in the variety Bhaise and the least increase of height was observed in T1 *i.e.*, control. In Majouley,T37 *i.e.*, FYM+VAM+Cap1+Trichoderma was significantly superior than all the other treatments. According to the varieties involved in the study the highest peak was observed in the variety Bhaise than the variety Majouley (Table 2).

Number of leaves: The highest number of leaves in Bhaise was 21.25 which was observed in T40 *i.e.*, Vermicompost+VAM+ Cap1+Trichoderma. In Majouley, it was T37 FYM+VAM+Cap1+Trichoderma which had 22 number of leaves on an average for both the seasons (Table 2).

Number of tillers: Irrespective of the treatment applied, the number of tillers ranged from 4-2 in both the varieties.

Leaf area: The variety Bhaise was having the highest leaf area among the two varieties. The T40 *i.e.*, Vermicompost+VAM+Cap1+Trichod erma has shown the highest leaf area among the different treatments.

Disease development (visual scoring): The disease development was recorded at 90th, 120th and 180th days after the inoculation of the disease. Based on the visual observation of the incidence of the soft rot shown by the plant they were scored on 1 to 10 scales. 1 for little effect and 10 was given to a greater effect (Table 3).

Table 2. Growth parameters as affected by organic inputs and PGPR in Season 1 and Season 2.

Treatment	Plant height (cm)			Number of leaves (number)			Tillers (number)			Leaf area (cm^2)		
	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
T1	30.87	35.96	33.41	12	13.75	12.87	2.75	2.75	2.75	15.00	18.75	16.87
T2	35.74	35.92	35.83	13.50	13.50	13.50	2.75	2.75	2.75	21.25	21.50	21.37
T3	32.95	36.07	34.51	15.00	15.75	15.37	3.15	3.00	3.07	21.50	24.50	23.00
T4	36.37	33.98	35.17	13.50	13.50	13.50	3.25	3.15	3.20	23.00	23.00	23.00
T5	40.59	37.17	38.88	15.25	14.25	14.75	2.75	2.50	2.62	26.00	25.75	25.87
T6	39.35	38.99	39.17	14.75	14.75	14.75	2.75	2.70	2.72	29.75	27.75	28.75
T7	32.44	30.07	31.25	15.25	15.00	15.12	2.25	2.15	2.20	30.00	29.00	29.50
T8	40.60	33.95	37.27	15.25	14.75	15.00	2.25	2.25	2.25	37.75	30.75	34.25
T9	42.09	39.33	40.71	16.50	14.25	15.37	3.25	3.00	3.12	31.75	35.50	33.62
T10	44.03	41.85	42.94	15.50	13.50	14.50	3.00	3.10	3.05	32.00	32.50	32.25
T11	39.77	33.12	36.44	15.75	13.25	14.50	2.75	2.75	2.75	35.00	31.25	33.12
T12	35.20	33.73	34.46	15.25	13.00	14.12	3.25	3.00	3.12	36.25	38.75	37.50
T13	44.68	31.46	38.07	16.25	14.00	15.12	3.25	3.00	3.12	31.75	30.75	31.25
T14	54.76	36.91	45.83	15.25	15.50	15.37	3.25	3.00	3.12	30.00	32.25	31.15
T15	48.67	32.04	40.35	15.75	15.50	15.62	3.15	3.15	3.15	32.50	33.50	33.00
T16	35.52	31.45	33.48	15.75	16.75	16.25	3.10	3.20	3.15	36.00	34.25	35.12
T17	36.88	34.19	35.53	16.00	15.75	15.87	3.15	3.20	3.17	39.75	38.75	39.25
T18	34.69	32.61	33.65	14.50	15.75	15.12	3.00	3.15	3.07	31.50	32.00	31.75
T19	34.42	38.74	36.58	14.00	13.00	13.50	2.75	3.05	2.90	38.50	35.75	37.12
T20	36.37	42.09	39.23	14.00	16.75	15.37	3.25	3.00	3.12	35.75	32.75	34.25
T21	46.77	43.02	44.89	16.00	15.25	15.62	2.50	3.10	2.80	32.00	33.00	32.50
T22	38.84	45.88	42.36	17.75	15.50	16.62	3.10	3.15	3.12	39.50	34.50	37.00
T23	31.58	35.94	33.76	16.00	14.00	15.00	3.25	3.05	3.15	36.75	38.00	37.37
T24	39.44	38.96	39.20	16.25	16.00	16.12	3.20	3.20	3.20	31.25	36.75	34.00
T25	45.50	38.39	41.94	15.75	15.75	15.75	3.20	3.15	3.17	32.25	32.75	32.50
T26	32.45	43.76	38.10	15.00	14.50	14.75	3.00	3.10	3.05	33.00	34.00	33.50
T27	41.09	41.10	41.09	14.75	13.75	14.25	3.00	3.00	3.00	32.75	35.50	34.12
T28	43.97	43.16	43.56	14.25	14.00	14.12	3.25	3.00	3.12	35.50	32.25	33.87
T29	40.93	46.44	43.68	15.25	15.00	15.12	3.15	3.05	3.10	36.00	31.50	33.75
T30	40.18	47.23	43.70	16.00	14.50	15.25	3.20	3.00	3.10	37.75	30.00	33.87
T31	45.99	29.84	37.91	16.70	16.50	16.60	3.00	3.15	3.07	30.25	35.25	32.75
T32	42.50	46.15	44.32	14.50	14.75	14.62	3.25	3.05	3.15	35.75	36.00	35.87
T33	37.80	39.56	38.68	13.50	14.75	14.12	3.20	3.10	3.15	34.25	38.50	36.37
T34	40.35	40.22	40.28	15.00	15.00	15.00	3.15	3.15	3.15	31.25	38.50	34.87
T35	52.45	46.44	49.44	15.75	15.00	15.37	3.10	3.10	3.10	34.75	37.75	36.25
T36	50.43	48.12	49.27	17.25	15.25	16.25	3.15	3.15	3.15	36.25	38.00	37.12
T37	54.93	62.11	58.52	17.25	22.00	19.62	3.25	3.85	3.55	33.25	45.75	39.50
T38	58.46	50.24	54.35	18.25	16.00	17.12	3.00	3.15	3.07	34.50	36.75	35.62
T39	50.08	48.73	49.40	17.00	15.00	16.00	3.20	3.10	3.15	37.75	35.50	36.62
T40	68.89	51.67	60.28	21.25	16.20	18.72	4.00	3.20	3.60	48.75	36.25	42.50
T41	49.98	50.03	50.00	18.10	16.25	17.17	3.15	3.20	3.17	38.00	36.50	37.25
T42	55.24	51.77	53.50	18.00	16.25	17.12	3.20	3.15	3.17	39.00	38.75	38.87
T43	52.11	51.55	51.83	17.25	17.00	17.12	3.25	3.20	3.22	40.25	38.85	39.55
Mean	42.69	40.69		15.71	15.12		3.06	3.02		33.38	33.47	
LSD Treatment (A)	1.34			0.43			0.93			0.90		
LSD Varieties (B)	0.29			0.93			0.20			0.19		
LSD A x B	1.90			0.61			0.13			1.27		

Among the varieties, Bhaise had shown a more tolerance to the disease development as compared to Majouley. The rhizome of Bhaise which was treated with Vermicompost+VAM+Cap1+T richoderma had more disease tolerance capacity than the other treatment combinations.

Fresh weight: The fresh weight of harvested ginger (Table 3) at 240 DAP produced significantly highest yield of 390.50 g in Bhaise which was treated with Vermicompost+VAM+Cap1+Tri choderma (T40) and in Majouley the highest yield was 387.25 g which was seen in the T37 (FYM+VAM+Cap1+Trichoderma).

Discussion

The results revealed that the T40 (Vermicompost+VAM+Cap 1+Trichoderma) and T37 (FYM+VAM+Cap1+Trichoderma) were the most superior treatments than all the other treatment combinations. These treatments had the highest tolerance towards the disease infestations as well as significantly superior effect on other parameters like height, rhizome weight, number of leaves and leaf area. In these treatments VAM and trichoderma were common input along with the PGPR *i.e.*, Cap 1 , GRB-35

Table 3. Yield, quality and disease incidence as affected by organic inputs and PGPR in Season 1 and Season 2

Treatment	Rhizome weight (g) of individual plant			Volatile oil (%)			Crude fiber (%)			Visual scoring of disease		
	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean	Bhaise	Majouley	Mean
T1	132.50	138.75	135.62	1.49	1.27	1.38	2.79	2.13	2.46	6.75	6.50	6.62
T2	147.50	145.20	146.35	2.35	1.49	1.92	3.49	2.50	2.99	5.50	5.50	5.50
T3	152.65	155.75	154.20	2.32	2.25	2.28	3.11	3.20	3.15	5.00	4.25	4.60
T4	146.25	150.25	148.25	2.22	2.20	2.21	3.42	3.29	3.35	5.50	5.00	5.25
T5	152.50	161.75	157.12	2.20	2.48	2.34	3.32	3.33	3.32	4.00	4.25	4.12
T6	168.75	165.25	167.00	2.48	2.30	2.39	3.74	3.41	3.57	4.00	4.00	4.00
T7	161.25	166.50	163.87	2.46	2.21	2.33	3.21	3.20	3.20	4.75	4.00	4.37
T8	200.00	145.25	172.62	2.75	2.17	2.46	3.19	3.18	3.18	4.50	4.75	4.62
T9	184.00	150.00	167.00	2.10	2.49	2.29	3.17	3.15	3.16	5.00	4.50	4.75
T10	216.75	154.50	185.62	2.26	2.47	2.36	3.18	3.44	3.31	4.50	4.50	4.50
T11	170.50	161.20	165.85	3.20	2.75	2.97	3.82	3.41	3.61	4.00	4.00	4.00
T12	150.25	165.25	157.75	3.09	2.32	2.70	2.29	3.19	2.74	5.50	4.00	4.75
T13	253.75	155.50	204.62	2.26	2.28	2.27	2.48	3.13	2.80	3.50	4.50	4.00
T14	245.50	165.25	205.37	2.99	2.72	2.85	3.46	3.18	3.32	3.75	4.25	4.00
T15	263.75	162.00	212.87	2.41	2.32	2.36	3.39	3.23	3.31	3.50	4.00	3.75
T16	175.00	150.75	162.87	2.35	2.51	2.43	3.29	3.20	3.24	4.00	4.50	4.25
T17	170.00	152.50	161.25	2.25	2.27	2.26	3.54	3.18	3.36	4.25	4.50	4.37
T18	165.25	155.00	160.12	3.35	2.46	2.90	3.64	3.09	3.36	4.75	4.50	4.62
T19	180.25	163.75	172.00	3.38	2.66	3.02	3.87	3.14	3.50	4.00	4.00	4.00
T20	182.25	168.00	175.12	3.20	2.25	2.72	3.48	3.15	3.31	5.00	4.00	4.50
T21	255.75	170.25	213.00	3.42	2.18	2.80	3.76	3.07	3.41	3.25	4.00	3.62
T22	174.25	215.00	194.62	2.48	2.58	2.53	3.27	3.13	3.20	4.25	3.75	4.00
T23	170.50	230.75	200.62	2.39	2.67	2.53	3.96	3.25	3.60	4.25	3.50	3.87
T24	192.25	169.25	180.75	2.16	2.61	2.38	3.19	3.26	3.22	4.00	4.25	4.12
T25	253.50	172.75	213.12	3.49	2.21	2.85	3.23	3.24	3.23	3.75	4.25	4.00
T26	180.00	177.50	178.75	3.11	2.37	2.74	3.19	3.17	3.18	4.25	4.00	4.12
T27	257.50	240.75	249.12	3.29	2.83	3.06	2.46	3.27	2.86	3.50	3.50	3.50
T28	272.00	230.00	251.00	3.45	3.20	3.32	3.80	3.92	3.86	3.25	3.75	3.50
T29	264.75	235.75	250.25	3.25	3.15	3.20	3.87	3.76	3.81	3.75	3.50	3.62
T30	272.25	242.50	257.37	3.37	3.22	3.29	3.28	3.26	3.27	3.75	3.50	3.62
T31	285.50	245.75	265.62	3.32	3.20	3.26	3.60	3.24	3.42	3.50	3.50	3.50
T32	262.50	185.25	223.87	3.45	2.73	3.09	3.92	3.27	3.59	3.75	4.00	3.87
T33	195.25	235.75	215.50	2.69	2.60	2.64	3.46	3.25	3.35	4.25	3.75	4.00
T34	200.50	180.25	190.37	2.27	2.63	2.45	3.04	3.76	3.40	4.00	4.00	4.00
T35	312.25	235.25	273.75	3.61	3.13	3.37	3.28	3.88	3.58	3.50	3.75	3.62
T36	300.50	225.50	263.00	3.58	3.10	3.34	3.31	3.78	3.54	3.25	3.25	3.25
T37	325.75	387.25	356.50	3.41	3.84	3.62	4.00	4.72	4.36	3.15	2.75	2.95
T38	330.25	320.25	325.25	3.65	3.18	3.41	4.08	3.34	3.71	3.00	3.50	3.25
T39	310.50	315.25	312.87	3.71	2.40	3.05	3.91	3.19	3.55	3.50	4.00	3.75
T40	390.50	310.25	250.37	4.46	3.19	3.82	4.87	3.03	3.95	2.50	3.00	2.75
T41	315.20	300.75	307.97	3.50	3.18	3.34	4.10	3.23	3.66	3.15	3.00	3.07
T42	325.00	315.50	320.25	3.60	3.15	3.37	3.15	3.25	3.20	3.20	3.25	3.22
T43	315.75	325.75	320.75	3.75	3.20	3.47	3.46	3.62	3.54	3.55	3.25	3.40
Mean	227.46	204.64		2.94	2.61		3.44	3.29		4.04	4.01	
LSD Treatment (A)	6.87			0.75			0.95			0.13		
LSD Varieties (B)	1.48			0.16			0.20			0.28		
LSD AXB	9.72			0.10			0.13			0.18		

(*Bacillus amyloliquefaceins*). Similar results were obtained by earlier workers in different crops. According to the study of Kumar and Gupta (2018) study on the effect of bio-Fertilizers, vermicompost and *Trichoderma* on yield and economics of strawberry (*Fragaria* x *annanasa* Duch.) *cv.* Sweet Charlie had revealed that the highest yield per plant was recorded in the combination of 5 kg ha^{-1} *Trichoderma* + 2.5 ton ha^{-1} vermicompost + 7 kg ha^{-1} *Azotobactor* + 6 kg ha^{-1} PSB + 10 kg ha^{-1} VAM. The maximum cost benefit ratio of 1:3.97 was also found in the same treatment.

In another study by Dohroo *et al.* (2014), on the effect of bioagents on the management of rhizome diseases, plant growth parameters and nematode population in ginger stated that combined applications of bioagents were more effective in reducing the disease incidence than the individual treatments. *T. harzianum*+ *Pseudomonas fluorescens* + *Bacillus subtilis* gave minimum disease incidence on rhizomes (8.64 %) as well as on tillers (12.50 %). Combined treatment also proved more effective in increasing the plant growth parameters, *i.e.* number of tillers, plant height, fresh rhizome weight along with more recovery of old rhizome. Similarly a study was carried out to see the influence of vesicular arbuscular mycorrhiza (VAM), vermicompost and *T. harzianum* on vegetative growth parameters of banana, *cv.*

Rajapuri by Sabarad *et al.* (2004) and it was found that VAM inoculated banana plants showed increased plant height, plant girth, number of leaves and number of suckers as compared to uninoculated plants. Among sub-treatments, the plants supplied with in situ vermiculture produced significantly maximum plant height, plant girth and leaf area as compared to other treatments.

Sarma *et al.* (2010) revealed that the role of vermicompost (VC) in plant growth promotion is largely believed to be due to its nutrient rich composition as well as its ability to modify soil physical and chemical properties suitably in a way to favor plant growth and development. Among its role in suppression of plant pathogens and nematodes, it is believed that it modulates a plant's innate resistance response to resist microbial attack. Apart from this, VC-mediated soil physicochemical properties also favors growth and multiplication of saprophytic soil microbes, including the biocontrol agents and thus helps in enhancing the performance of most biocontrol agents against a wide range of phytopathogens.

Apart from the effect of VC the trichoderma has the ability to inhibit the pathogens and promote the beneficial microorganism like the applied PGPR and VAM. This creates a favorable environment for the growth and development of plants at the micro climate of rhizosphere modified by the trichoderma known as 'trichorhizosphere' (Umadevi *et al.,* 2017a and b). The trichorhizosphere environment along with the additional benefit of PGPR, VC and VAM were available in the best treatments of our study, which had promoted the yield and growth parameters of ginger while significantly reducing the soft rot incidence.

Application of PGPR suppressed the disease incidence may be by selectively recruiting the beneficial organism in the rhizosphere. In this process trichoderma, VAM and vermicompost play a vital role either directly occupying the space and utilizing the resources available due to the suppression of pathogens or aiding the PGPR in its multiplication, ultimately resulting in better growth and yield of ginger.

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