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Effect of Bio-Inoculants on Growth, Dry Root Yield and Quality in Ashwagandha (*Withania somnifera* L. Dunal.)

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A B S T R A C T

An investigation was carried out to study the effect of bio-inoculants (*Azatobacter*, *Azospirillum*, PSB and VAM) on growth, yield and quality of ashwagandha by comparing with RDF at K.R.C.C.H. College of Arabhavi. The results showed that growth parameters *viz*., plant height (74.20 cm), stem diameter (0.85 cm), plant spread (N-S (37.60 cm) and E-W (38.07 cm)) and number of primary branches (8.80) recorded maximum with the application of RDF + VAM and yield parameters *viz*., number of berries per plant (219.33), seed yield (3.15 q/ha), fresh root (19.58 q/ha) and dry root yield (5.88 q/ha) recorded maximum with the application of RDF + VAM, however the organic treatment T_7 have shown on par results in growth and yield parameters. Quality parameter like root length and root diameter recorded maximum (27.07 cm, 1.88 cm, respectively) in T_3-RDF (N: P: K-40:50:40 kg/ha) + FYM (5 t/ha) + VAM (25 kg/ha), which was on par results of T_1, T_7 and T_5. Maximum total alkaloid content (0.31%) recorded in T_7-FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha) + (Panchagavya-3% + Amruthapani-3% at 15 days interval up to harvest of crop), however treatments T_3, T_1 and T_5 have shown on par results. The highest organic carbon (0.63%) was recorded in treatment T_7-FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha) + (Panchagavya-3% + Amruthapani-3% at 15 days interval up to harvest of crop. Maximum soil pH (7.72) was recorded in treatment in T_3-RDF (N: P: K-40:50:40 kg/ha) + FYM (5 t/ha) + VAM (25 kg/ha). Maximum soil electrical conductivity (0.51 dS/m) was recorded in treatment T_1-RDF (N: P: K-40:50:40 kg/ha) + FYM (5 t/ha). The available nutrient status in soil differed significantly among different treatments. The highest available nitrogen, phosphorus and potassium (159.67, 32.08 and 163.44 kg/ha respectively) recorded in T_7-FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha) + (Panchagavya-3% + Amruthapani-3% at 15 days interval up to harvest of crop). Maximum bacterial population (134×10^6), fungi (124×10^3), *Azotobacter chroococcum* (174.25×10^4), *Azospirillum brasilense* (192.23×10^4), Phosphate solubilising bacteria (178.46×10^6), root colonization (82%) and number of chlamydospores (3174.50/ 100 g of soil) were obtained in the treatment T_7-FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha) + (Panchagavya-3% + Amruthapani-3% at 15 days interval up to harvest of crop), followed by treatments T_6-FYM (5 t/ha) + Azotobacter (625g/ha) + Azospirillum (625g/ha) + PSB (625g/ha) + VAM (25 kg/ha). As bio-fertilizers are eco-friendly and helps in maintaining the harmony with the nature, at the same time helps to obtain higher yields with higher productivity.

Introduction

Ashwagandha or Asgandh (*Withania somnifera* L. Dunal.) popularly known as 'Indian Ginseng' belongs to the family Solanaceae. It is found in wild state in the Mediterranean region of North Africa. In India it is mainly cultivated in Mandsaur district of Madhya Pradesh, adjoining villages of Kota district of Rajasthan, Punjab and Karnataka. Ashwagandha roots and occasionally its leaf and seeds are used in ayurvedic and unani medicines preparations. (Majumdar, 1955). The total alkaloid content of the Indian ashwagandha roots is reported to vary between 0.13 to 0.31 per cent. Apart from roots, alkaloids have also been reported in leaves and berries (Sreerekha *et al.*, 2004). The roots are prescribed in medicines for hiccup, several female disorders, bronchitis, rheumatism, dropsy and stomach, lung inflammation and skin diseases.

They are mostly used for curing general and sexual disabilities. Roots are having anti-aging property (Savitha *et al.,* 2009). The leaves are used to cure eye boils, and swellings of hands and feet, in treatment of syphilis, to kill the lice infecting the body. The leaf decoction is used for treatment of haemorrhoids and arthritis.

Materials and Methods

The field experiment was carried out in the division of plantation, Spices, Medicinal and Aromatic Crops, college of horticulture, Arabhavi during 2016-2017. The experiment was laid out in randomized block design with 7 treatments *viz.*,T_1 -Recommended dose of fertilizers (N: P: K- 40:50:40 kg/ha) + FYM (5 t/ha), T_2- FYM (5 t/ha) + Vermicompost-1.33 t/ha (N equivalent weight), T_3-T_1 + VAM (25 kg/ha), T_4- FYM (5 t/ha) + VAM (25 kg/ha), T_5- FYM (5 t/ha) + VAM (25 kg/ha) + (Panchagavya-3% + Amruthapani-3% at 15 days' interval up to harvest crop), T_6 -FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha) and T_7- T_6 + (Panchagavya-3% + Amruthapani-3% at 15 days' interval up to harvest of crop) and 3 replications. The spacing followed was 30 x 20 cm.

Seed treatment with bio-fertlizers and sowing

Azospirillum brasilense, Azotobacter chroococcum, Phosphate solublising bacteria were obtained from Department of Agricultural Microbiology, Dharwad. *Azospirillum brasilense, Azotobacter chroococcum,* Phosphate solublising bacteria were applied as seed treatment. Bio-fertlizers culture suspension was prepared by using 625 g per ha of *Azotobacter chroococcum, Azospirillum brasilense,* Phosphate solublising bacteria and mixed in water at a ratio of 1:2 and with adding jaggary which acts as sticker. Then the seeds were shade dried overnight and then seeds were sown at a spacing of 30 × 20 cm. Light irrigation was provided immediately after sowing.

Inoculation with AM fungus

Culture of Vesicular Arbuscular Mycorrhizal fungus (VAM) *Entrophospora* sp. was obtained from Department of Agricultural Microbiology, Kittur Rani Channamma College of Horticulture, Arabhavi. The inoculum was multiplied in sterilized potting mixture using maize (*Zea mays*) as host plant in the shade house of Microbiology Department.

The inoculum used consisted of sand and soil in 1:1 proportion and root segments of maize comprising of hyphae, vescicles, arbuscules and chlamydospore of AM fungus, *Entrophospora* sp. Five grams of inoculum was applied per seed before sowing.

Results and Discussion

Maximum plant height, stem diameter, plant spread (N-S & E-W) and number of primary branches (74.20 cm, 0.85 cm, (37.60 cm, 38.07 cm) and 8.80, respectively), were recorded in the treatment T_3 -Recommended dose of fertilizers (N:P:K- 40:50:40 kg/ha) + FYM (5t/ha) + VAM (25 kg/ha), which was on par with T_1 (68.53 cm, 0.84 cm, (35.07 cm and 36.67 cm) and 8.40, respectively), T_7 (67.67 cm, 0.84 cm, (35.00 cm and 37.00 cm) and 8.20, respectively) and T_5 (63.47 cm, 0.83 cm, (34.27 cm and 33.00 cm) and 8.13, respectively). This increasing trend in morphological parameters might be due to recommended dose of fertilizer along with VAM recorded significantly higher values for morphological parameters. It could be attributed to the quick and readily availability of major nutrients like N, P and K to plants at earlier stages of plant growth. The results obtained in the present investigation are in agreement with earlier findings of Rana *et al.,* (2005), Snezana *et al.,* (2012) in buckwheat and Shinde *et al.,* (2013) in ashwagandha.

However the organic treatment T_7 -FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha)+ (Panchagavya-3% + Amruthapani-3% at 15 days interval) has also shown better result, this might be due to the reason that, their built up in the beneficial soil microbial population at the rhizosphere and regular addition of bio-formulations especially by the synergetic effect drench both of panchagavya and amrutpani have lead to the effective supply of nutrients and acting as source of PGPR (Plant Growth Promoting Rhizobacteria). This had helped to improve nutrient availability to the plants and also by arbuscular mycorrhizal fungi, due to their ability to increase nutrient uptake and water transport. The results obtained in the present investigation are in agreement with earlier findings of Sakhubai *et al.,* (2014) in buckwheat, Ravikumar *et al.,* (2012) in coleus and Vajantha *et al.,* (2014) in ashwagandha.

Number of berries per node and seed yield were significantly influenced by application of organic manures and bio-inoculants. At harvest, maximum number of berries per plant (219.33) was recorded in T_3-Recommended dose of fertilizers (N:P:K-40:50:40 kg/ha) + FYM (5 t/ha) + VAM (25 kg/ha), it was on par with T_1 (213.33/plant), T_7 (211.67/plant) and T_5 (210.13/plant).There was appreciable increase in the number of berries per plant due to excellent growth and development of root and shoot particularly more assimilatory area on account of balanced and timely supply of all the essential nutrients which in turn led to better partitioning of photosynthates from source to the sink (seeds). Similar results have been reported by Shrivatsav and Sahu (2013) in ashwagandha.

Seed yield was influenced with application of organic manures and bio-inoculants. At harvest maximum seed yield (2.83 g/plant, 0.23 kg/plot and 3.15 q/ha) was obtained in T_3-Recommended dose of fertilizers (N:P:K-40:50:40 kg/ha) + FYM (5 t/ha) + VAM (25 kg/ha), it was on par with T_1 (2.78 g/plant, 0.22 kg/plot and 3.09 q/ha) and T_7 (2.73 g/plant, 0.22 kg/plot and 3.0 q/ha).The enhanced seed yield in particular treatment might be due to availability of nutrients in the soil throughout the growing phase and also due to enhanced carbohydrates synthesis and effective translocation of the photosynthates to the sink and the results are in line with the findings of with Pakkiyanthan *et al.,* (2004), Panchabhai *et al.,* (2005) in ashwagandha. Immediate supply of plant nutrients by inorganic sources has enhanced seed yield were realized.

At harvest fresh and dry root yield were significantly influenced by treatments. The

highest fresh root yield (17.60 g/plant, 1.41 kg/plot and 19.58 q/ha) was recorded in T_3-Recommended dose of fertilizers (N:P:K-40:50:40 kg/ha) + FYM (5 t/ha) + VAM (25 kg/ha), it was on par with T_1 (17.55 g/plant, 1.40 kg/plot and 19.50 q/ha), T_7 (17.54 g/plant, 1.40 kg/plot and 19.49 q/ha), T_5 (17.25 g/plant, 1.38 kg/plot and 19.12 q/ha) and T_6 (16.77 g/plant, 1.34 kg/plot and 18.61 q/ha) recorded. Highest dry root yield (5.29 g/plant, 0.42 kg/plot and 5.88 q/ha) recorded in T_3-Recommended dose of fertilizers (N:P:K- 40:50:40 kg/ha) + FYM (5 t/ha) + VAM (25 kg/ha) it was on par with T_1 (4.75 g/plant, 0.38 kg/plot and 5.27 q/ha) and T_7 (4.69 g/plant, 0.36 kg/plot and 5.00 q/ha).

The combined application of inorganic fertilizer and organic manures (FYM) might have supplied adequate amount of nutrients, favoured metabolic rate, auxin activities in the plant, resulting in better yield attributes and higher root yield. These results are in agreement with Maheshwari *et al.,* (2000), Ajay *et al.,* (2005) in ashwagandha and Somanath *et al.,* (2005) in coleus.

The VAM fungusand bio-formulations, increased root geometry, nutrient access and supply resulting in the development of sound and healthy rhizosphere with increased extramycelial hyphae might had further contributed to improved growth resulting in increased nutrient uptake, photosynthesis and excellent biochemical activities. Similar results were also reported Sakhubai *et al.,* (2014) in buckwheat and Ravikumar *et al.,* (2010) in coleus, Vajantha *et al.,* (2014) in ashwagandha.

Significant difference was observed in root length and root diameter due to application of organic manures and bio-inoculants. At harvest, maximum root length (27.07 cm) and root diameter (1.88 cm) were recorded in T_3-Recommended dose of fertilizers (N: P: K-40:50:40 kg/ha) + FYM (5 t/ha) + VAM (25 kg/ha). It was on par with T_1 (26.47 cm, 1.84 cm of root length and root diameter, respectively), T_7 (26.13 cm, 1.83 cm of root length and root diameter, respectively) and T_5 (24.27 cm, 1.81 cm of root length and root diameter, respectively).This might be due to the favourable soil condition by the incorporation of organic manures and further, the inorganic fertilizers would have created congenial condition for better uptake of nutrients and better development of root length and root diameter. These results are in conformity with Rashmi (2013) in ashwagandha, Somnath *et al.,* (2005) and Ravikumar *et al.,* (2012) in coleus and Sandhya *et al.,* (2013) in *Marsdenia volubilis*.

Alkaloid content differed significantly due to application of organic manures bio-inoculants (Table 3). Maximum alkaloid content (0.31 %) was recorded with application of T_7 -FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha) + (Panchagavya-3% + Amruthapani-3% at 15 days interval), it was on par with T_3 (0.29%), T_1 (0.27%) and T_5 (0.26%). Favourable soil condition due to the incorporation of organic and a bio-inoculants nutrient source were congenial for better development of root. This might have resulted in higher alkaloid accumulation. The results obtained in the present investigation are in agreement with earlier findings of Rajamani *et al.,* (2007) in turmeric, Das *et al.,* (2008) in stevia, Ravikumar *et al.,* (2012) in coleus and Sandhya *et al.,* (2013) in *Marsdenia volubilis*, Rajasekar and Elango (2011) in ashwagandha.

Soil pH, electrical conductivity and organic carbon varied significantly among different treatments. Maximum soil pH (7.72) was observed in soil T_3 -Recommended dose of fertilizers (N: P: K-40:50:40 kg/ha) + FYM (5 t/ha) + VAM (25 kg/ha), it was on par with T_1 (7.70) (Table 1–6).

Table.1 Growth of ashwagandha at 150 Days After Sowing

Treatments	Plant height (cm)	Stem diameter (cm)	Plant spread		Number of primary branches
			(N-S) (cm)	(E-W) (cm)	
T_1-Recommended dose of fertilizers (control) N:P:K-40:50:40 kg per ha + FYM-5 t/ha	68.53	0.84	35.07	36.67	8.40
T_2- FYM (5 t/ha) +Vermicompost-1.33 t/ha (N equivalent weight)	54.53	0.73	24.33	25.13	7.27
T_3- T_1 +VAM (25 kg/ha)	74.20	0.85	37.60	38.07	8.80
T_4-FYM (5 t/ha) + VAM (25 kg/ha)	56.07	0.78	29.20	28.13	7.53
T_5- FYM (5 t/ha) +VAM (25 kg/ha) + (Panchagavya -3% + Amruthapani -3% at 15 days interval)	63.47	0.83	34.27	33.00	8.13
T_6- FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha)	59.40	0.82	34.00	29.07	8.07
T_7-T_6+ (Panchagavya -3% + Amruthapani -3% at 15 days interval)	67.67	0.84	35.00	37.00	8.20
Mean	**63.41**	**0.81**	**32.78**	**32.44**	**8.06**
SEm ±	**1.32**	**0.02**	**2.51**	**2.67**	**0.25**
CD at 5%	**4.08**	**0.06**	**7.74**	**8.23**	**0.78**

Table.2 Yield of ashwagandha at after harvest

Treatments	Number of berries/plant	Seed yield (q/ha)	Fresh root yield (q/ha)	Dry root yield (q/ha)
T_1-Recommended dose of fertilizers (control) N:P:K- 40:50:40 kg per ha + FYM-5 t/ha	213.33	3.09	19.50	5.27
T_2- FYM (5 t/ha) +Vermicompost-1.33 t/ha (N equivalent weight)	183.87	2.25	15.87	4.21
T_3- T_1 +VAM (25 kg/ha)	219.33	3.15	19.58	5.88
T_4-FYM (5 t/ha) + VAM (25 kg/ha)	192.33	2.38	17.03	4.41
T_5- FYM (5 t/ha) +VAM (25 kg/ha) + (Panchagavya -3% + Amruthapani -3% at 15 days interval)	210.13	2.71	19.12	4.72
T_6- FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha)	208.67	2.45	18.61	4.58
T_7-T_6+ (Panchagavya -3% + Amruthapani -3% at 15 daysinterval)	211.67	3.03	19.49	5.00
Mean	**205.62**	**2.72**	**18.46**	**4.85**
SEm ±	**3.49**	**0.13**	**0.71**	**0.32**
CD at 5%	**10.74**	**0.40**	**2.18**	**0.97**

Table.3 Root length (cm), root diameter (cm) and total alkaloid content as influenced by different nutrient sources and their combination with bio-inoculants in ashwagandha

Treatments	Root length (cm)	Root diameter (cm)	Total alkaloid content (%)
T_1-Recommended dose of fertilizers (control) N:P:K-40:50:40 kg per ha + FYM-5 t/ha	26.47	1.84	0.27
T_2- FYM (5 t/ha) +Vermicompost-1.33t/ha (N equivalent weight)	21.03	1.60	0.20
T_3- T_1 +VAM (25 kg/ha)	27.07	1.88	0.29
T_4-FYM (5 t/ha) + VAM (25 kg/ha)	22.73	1.70	0.22
T_5- FYM (5 t/ha) +VAM (25 kg/ha) + (Panchagavya – 3% + Amruthapani -3% at 15 days interval)	24.27	1.81	0.26
T_6- FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha)	23.17	1.79	0.24
T_7-T_6+ (Panchagavya -3% + Amruthapani -3% at 15 days interval)	26.13	1.83	0.31
Mean	**24.41**	**1.78**	**0.26**
SEm ±	**1.02**	**0.06**	**0.02**
CD at 5%	**3.13**	**0.18**	**0.06**

Table.4 Soil status after harvest crop as influenced by different nutrient sources and their combination with bio- inoculants in ashwagandha.

Treatments	pH	Electrical conductivity (dS m^{-1})	Organic carbon (%)
T_1-Recommended dose of fertilizers (control) N:P:K-40:50:40 kg per ha + FYM-5 t/ha	7.70	0.51	0.40
T_2- FYM (5 t/ha) +Vermicompost-1.33t/ha (N equivalent weight)	7.68	0.49	0.43
T_3- T_1 +VAM (25 kg/ha)	7.72	0.50	0.48
T_4-FYM (5 t/ha) + VAM (25 kg/ha)	7.65	0.48	0.52
T_5- FYM (5 t/ha) +VAM (25 kg/ha) + (Panchagavya -3% + Amruthapani -3% at 15 days interval)	7.62	0.46	0.60
T_6- FYM (5 t/ha) + Azotobacter (625g/ha) + Azospirillum (625g/ha) + PSB (625g/ha) + VAM (25 kg/ha)	7.64	0.47	0.54
T_7-T_6+ (Panchagavya -3% + Amruthapani -3% at 15 days interval)	7.60	0.40	0.63
Mean	**7.66**	**0.48**	**0.51**
SEm ±	**0.01**	**0.01**	**0.01**
CD at 5%	**0.02**	**0.02**	**0.04**

Table.5 Available nutrients in soil after harvest crop as influenced by different nutrient sources and their combination with bio-inoculants in ashwagandha.

Treatments	Available nutrients (kg/ha)		
	N	P	K
T_1-Recommended dose of fertilizers (control) N:P:K-40:50:40 kg per ha + FYM-5 t/ha	131.33	21.79	144.28
T_2- FYM (5 t/ha) +Vermicompost-1.33 t/ha (N equivalent weight)	136.50	23.01	151.38
T_3- T_1 +VAM (25 kg/ha)	137.66	26.26	155.68
T_4-FYM (5 t/ha) + VAM (25 kg/ha)	140.17	26.38	157.64
T_5- FYM (5 t/ha) +VAM (25 kg/ha) + (Panchagavya -3% + Amruthapani – 3% at 15 days interval)	145.83	31.15	162.07
T_6- FYM (5 t/ha) + Azotobacter (625g/ha) + Azospirillum (625g/ha) + PSB (625g/ha) + VAM (25 kg/ha)	145.50	28.16	161.46
T_7-T_6+ (Panchagavya -3% + Amruthapani -3% at 15 days interval)	159.67	32.08	163.44
Mean	**142.38**	**26.98**	**156.56**
SEm ±	**1.32**	**0.55**	**0.99**
CD at 5%	**4.08**	**1.71**	**3.05**

Maximum electrical conductivity (0.51 dS/m) was recorded in soil applied T_1-

Table.6 Isolation of inoculated microorganisms, enumeration of total count of bacteria and fungi in soil after harvest of ashwagandha

Treatments	*Azotobacter Chroococcum* No. × 10^4 CFU/ g of soil	*Azospirillum Brasilense* No. × 10^4 CFU/ g of soil	Phosphate Solubilising Bacteria No. × 10^6 CFU/ gof soil	Bacteria No. × 10^6 CFU/ g of soil	Fungi No. × 10^3 CFU/ g of soil
T_1-Recommended dose of fertilizers (control) N:P:K- 40:50:40 kg per ha + FYM- 5t/ha	14.00	10.50	12.40	49.00	32.00
T_2-FYM(5t/ha)+Vermicompost-1.33t/ha (N equivalent weight)	18.00	14.72	14.00	74.00	58.00
T_3- T_1 +VAM (25 kg/ha)	20.00	18.94	12.00	56.00	42.00
T_4-FYM (5 t/ha) + VAM (25 kg/ha)	32.00	24.00	20.12	84.00	70.00
T_5- FYM (5 t/ha) +VAM (25 kg/ha) + (Panchagavya -3% + Amruthapani -3% at 15 days interval)	100.00	83.00	78.00	110.00	85.00
T_6- FYM (5 t/ha) + Azotobacter (625g/ha) + Azospirillum (625g/ha) + PSB (625g/ha) + VAM (25 kg/ha)	166.84	176.78	168.80	129.00	108.00
T_7-T_6+ (Panchagavya -3% + Amruthapani -3% at 15 days interval)	174.25	192.23	178.46	134.00	124.00
Mean	**75.01**	**74.31**	**69.11**	**90.86**	**74.14**
SEm ±	**18.02**	**19.95**	**18.91**	**8.58**	**8.50**
CD at 5%	**55.52**	**61.47**	**58.28**	**26.45**	**26.18**

Recommended dose of fertilizers (N: P: K-40:50:40 kg/ha) + FYM (5 t/ha), which was on par with T_3 (0.50 dS/m) and T_2 (0.49 dS/m). The increase in pH might be due to increase in exchangeable aluminium in soil and application of inorganic fertilizer has reduced acidity. The increase in EC might be due to combined application of organic and inorganic fertilizers which enhanced exchangeable cations. Similar results are reported by Rajamani *et al.,* (2007) in turmeric. Maximum organic carbon (0.63%) was recorded in T_7-FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha) + (Panchagavya-3% + Amruthapani-3% at 15 days interval), which was on par with T_5 (0.60%). This might be due to the reason that, their built up beneficial soil microbial population in the rhizosphere, increased plant residue decomposition and regular addition of bio-formulations especially by the synergetic effect both drench panchagavya and amrutpani have lead to the effective supply of organic matter. The results obtained in the present investigation are in agreement with earlier findings of Rajamani *et al.,* (2007) in turmeric and Das *et al.,* (2008) in stevia.

Nutrient status in soil after harvest varied significantly due to organic manures and bio-inoculants sources of nutrients. The maximum soil nitrogen, phosphorous and potassium (159.67, 32.08 and 163.44 kg/ha, respectively) was observed in T_7 -FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha) + (Panchagavya-3% + Amruthapani-3% at 15 days interval), which was on par with T_5 (145.83 kg/ ha of N, 31.15 kg/ha of P and 162.07 kg/ha of K).

This might be due to the reason that, their built up of beneficial soil microbial population in the rhizosphere, increased plant residue decomposition and mineralization with regular addition of bio-formulations especially by the synergetic effect both drench of panchagavya and amrutpani have lead to the effective supply of nutrients. Application of VAM has lead to increased surface area for absorption and uptake of nutrients. Besides this *Entrophospora* sp. is also known to release growth hormones and enzymes, which help in translocation of insoluble nutrients to soluble form and increase their availability to plants resulting in increased content of major nutrients like N, P, K and micronutrients like Fe, Mg, Mn, Mo and Co. The results obtained in the present investigation are in agreement with earlier findings of Rajamani *et al.,* (2007) in turmeric, Das *et al.,* (2008) in stevia and Sakhubhai *et al.,* (2014) in buckwheat.

Microbial status in soil after harvest varied significantly due to organic manures and bio-inoculants sources of nutrients.

The maximum bacteria and fungi count (134.00×10^6 and 124.00×10^3, respectively) were observed in the treatment in T_7 -FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha) + (Panchagavya-3% + Amruthapani-3% at 15 days interval), which was on par with T_6 (129.00×10^6 and108.00×10^3, respectively).

The maximum population of *Azotobacter chroococcum, Azospirillum brasilense* and Phosphate solubilising bacteria (174.25×10^4, 192.23×10^4 and 178.46×10^6, respectively) was found in the treatment T_7-FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha) + (Panchagavya-3% + Amruthapani-3% at 15 days interval), which is found on par with the treatment T_6 (166.84×10^4, 176.78×10^4 and 168.80×10^6, respectively).

These findings are in agreement with Maragatham and James, 2010, the population

of *Azospirillum*, Phosphobacteria, *Pseudomonas* and VAM were higher because of the increase in microbial load due to application of bio-inoculants and panchagavya and amrutpani contain a lot of saprophytic bacteria, fungi, actinomycetes, yeasts, nitrogen fixers, 'P' solubilisers, growth promoting PGPRs, biocontrol agents and leading to microbial biotechnology in the soil. Similar results are reported by Srivatsava and Gobind (2007) in gladiolus and Sakhubhai *et al.,* (2014) in buckwheat.

Higher root colonization (82.00%) was observed in T_7-FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha) + (Panchagavya-3% + Amruthapani-3% at15 days interval), which was on par with T_6 (78.00%), T_5 (74.00%) and T_4 (60.00%). Maximum number of chlamydospores (3174.50/100 g of soil) was observed in T_7-FYM (5 t/ha) + Azotobacter (625 g/ha) + Azospirillum (625 g/ha) + PSB (625 g/ha) + VAM (25 kg/ha) + (Panchagavya -3% + Amruthapani-3% at 15 days interval), which was on par with T_6 (3121.68/100 g of soil), T_5 (2900.88/100 g of soil), T_4 (2789.56/100 g of soil). The similar findings were noticed by Sakhubhai *et al.,* (2014) in buch wheat, the single and dual inoculations of *Glomus fasciculatum* and Plant Growth Promoting Rhizobacteria, the consortium of these organisms were found superior in enhancing phosphorus content by mycorrhizal colonization and spore numbers in the root zone.

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