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Effect of microbial bio-inoculant (VAM- *Glomusfa sciculatum*) and bio-formulations on growth, yield and quality of turmeric (*Curcuma longa* L.)

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Abstract: A field trial was carried out during 2012-13. Among the different treatments, inoculation with *G. fasciculatum* recorded significantly higher pseudostem girth (53.02 mm), number of leaves per clump (8.64), number of tillers per clump (8.64) and cured yield (9.25 t/ha) than the control (uninoculated). Processing percentage (30.45), curcumin content (4.42 %) and volatile oil content (1.17 %) were highest in turmeric crop inoculated with *G. fasciculatum*. Among nine bio-formulation treatments, the highest pseudostem girth (65.62 mm), number of leaves per clump (87.64), number of tillers per clump (8.93) and cured yield (9.79 t/ha) was recorded by T_9 receiving the application of RDF + panchagavya + amritpani + mulch (Sugar cane trash) + *Trichoderma* spray (2.5 %) on mulch + agnihotra ash + triambakamhoma ashfollowed by T_8 (8.91 t/ha) receiving RDF + panchagavya + amritpani + mulch (Sugar cane trash) + *Trichoderma*spray (2.5 %) on mulch compared to the lowest in T_1(5.45 t/ha) receiving only RDF (180:90:90 kg NPK/ha and 25 t FYM/ha). Eventhough turmeric is a nutrient exhaustive crop, the results confirm possibility of production of turmeric with maximum yield and good quality produce by applying *G. fasciculatum* and bioformulations as against applying only synthetic fertilizers.

Key words: Turmeric, Bioinoculants, Bioformulations, RDF, VAM

Introduction

Turmeric (*Curcuma longa* L.) belonging to the family Zingiberaceae is an important tropical rhizomatous spice crop, native to tropical South-East Asia. It has been a well-known condiment and coloring agent since time immemorial. It is cultivated for its underground rhizome which is used as spice and condiment, dye stuff and in cosmetic and drug industry, particularly in the preparation of anticancer medicines.It is also used as herbal medicine 'Amraharidra', which gives a cooling, aromatic effect and promotes digestion (Srivastava *et al.*, 2003).The pungent aromatic flavor is mainly due to the presence of colouring agent 'Curcumin'.

The use of bio-fertilizers and bio-formulations occupy an important place 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). It is reported that 10 to 20 per cent of crop yield can be increased with biofertilizer application (Brown, 1972). 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. Therefore, chemical free traditional farming technologies such as organic, biodynamics, agnihotrahoma, panchagavya, amritpani, rishi krishi, jeevamrutha *etc.*, are gaining a new momentum not only in India, but also world over (Singh *et al.*, 2007). These systems offer a means to address self- reliance, rural upliftment and conservation of natural resources. Keeping these points in view, the present investigation was undertaken with the objectives to know the influence of VAM on growth, yield and quality in turmeric and to assess the effect of microbial bio-inoculant (VAM) and bio-formulations on growth, yield and quality of turmeric.

Materials and Methods

The experiment was laid out in split-plot design with two main (with VAM and without VAM) and nine sub-treatments (Bio-formulations) at the Department of Plantation, Spices, Medicinal and Aromatic Crops, Kittur Rani Channamma College of Horticulture, Arabhavi ($16^0$15' N latitude and $74^0$45' E longitude, at an altitude of 612 m above mean sea level), Karnataka during 2012-2013. The main plot treatments were M_1-With VAM and M_2-Without VAM and sub-plot treatments were T_1: RDF (180: 90: 90 NPK kg/ha and 25 t/ha FYM), T_2: T_1 + Vermiwash at 10% dilution (Drenching), T_3: T_1 + PG at 3% dilution (Drenching), T_4: T_1 + AP at 3% dilution (Drenching), T_5: T_1 + Vermiwash at 10% dilution (Drenching and spraying)T_6: T_1**+** PG at 3% dilution (Drenching and spraying), T_7: T_1 **+** AP at 3% dilution (Drenching and spraying), T_8: T_1 + PG + AP + Mulch (Sugar cane trash) + TH (2.5 %) spray on mulch, T_9: T_8 + Agnihotra ash + Triambakam homa ash, T_2 to T_7 - Drenching/spraying was done at monthly intervals from beginning of the crop. PG= Panchagavya (3%), AP=Amritpani (3%), TH= *Trichoderma*

harzianum(2.5%). An isolation distance (No crop/ weed) of 10 m was given between main plots *i.e*. with VAM and without VAM.

A spacing of 45 cm between rows and 22.5 cm between the plants (ridge and furrow method) was followed and Farm yard manure (25 t/ha) was applied to all the beds before planting the seed rhizome and mixed well with the soil. Fertilizers (N: P_2O_5: K_2O) were applied in the form of urea, single super phosphate and muriate of potash. The recommended dose of fertilizers (*i.e.*, 180, 90 and 90 kg NPK/ ha) was applied in two splits. Half dose of nitrogen and full dose of phosphorus and potassium were applied as basal dose. Remaining half dose of nitrogen was top dressed at 45 days after planting after completion of weeding.Shade dried, healthy seed rhizomes were used for planting. Theinoculation of VAM fungus (*Glpmus fasciculatum*)to turmeric was done during planting by applying five grams per rhizome.Thousand ml of vermiwash diluted in 10 litre water (10%) was applied to soil and on foliage in each plot (4.86 m^2) at monthly intervals from beginning of the crop. Bioformulations (Panchagavya @ 3%, Amritpani @ 3%) and sugar cane trash was used as mulching material as per the treatment details. *Trichoderma harzianum*culture was sprayed over sugar cane trash (mulch) at 2.5 per cent concentration on the day of planting. Agnihotra and Triambakam homa ash were applied at the rate of five gram per plant at monthly intervals from the beginning of the crop. Farm yard manure (25 t/ha) was applied to all the beds before planting the seed rhizome and mixed well with the soil. The recommended dose of fertilizers (*i.e.*, 180, 90 and 90 kg NPK/ ha) was applied in two splits. Half dose of nitrogen and full dose of phosphorus and potassium were applied as basal dose. Remaining half dose of nitrogen was top dressed at 45 days after planting after completion of weeding. All cultural practices were carried out uniformly. The data was recorded for different growth and yield parameters from five tagged plants and was statistically analyzed.

Results and Discussion

The different bioformulations treatments with combination of VAM (*Glomus fasciculatum*) significantly influenced the growth and yield of turmeric (Table 1 and 2).

Vegetative parameters: Growth attributes such as plant height, pseudostem girth, number of leaves per clump, number of tillers per clump and leaf area index at 180 DAP were higher in VAM inoculated plants (M_1) compared to uninoculated control (M_2). Inoculation of VAM (*Glomus fasciculatum*) might have enhanced the uptake of nutrients by the plant and increased the plant growth by increasing the uptake of 'P' and other minor elements like Mg, Mn, Zn, Cu and Fe (Borea, 1991). Jackson and Brown (1966) reported that VAM fungus is also known to help in the synthesis of growth promoting substances like IAA and GA. Further, VAM fungi are known to influence on water uptake (Tinker, 1975). The inoculation with different species of VAM recorded a significant increase in growth compared to uninoculated turmeric plants (Kumar, 2004).

Vegetative parameters were higher in T_9 (RDF + Panchagavya + Amritpani + Mulch (Sugar cane trash) + *Trichoderma* (2.5 %) spray on mulch + Agnihotra ash + Triambakam homa ash) which was *on par* with T_8 (RDF + Panchagavya + Amritpani + Mulch (Sugar cane trash) + *Trichoderma* (2.5 %) spray on mulch) compared to the treatment T_1 (RDF). Among interaction treatments, T_9M_1*i.e.*, application of VAM and RDF + Panchagavya + Amritpani + Mulch (Sugar cane trash) + *Trichoderma* (2.5 %) spray on mulch + Agnihotra ash + Triambakam homa ash showed higher growth attributes compared to rest of the treatments. The increased growth attributes is mainly due to theearly and higher sprouting percentage leading to rapid development of root system and successful establishment of turmeric crop in the field. Further, *Trichoderma harzianum* and bio-formulations, *viz.*, panchagavya, amritpani, agnihothra ash and Triambakam homa

Table-1: Effect of microbial bio-inoculant (VAM- *Glomus fasciculatum*) and bio-formulations on vegetative parameters in turmeric cv. Salem at 180 days after planting

Treatment (S)	Plant height (cm)		Mean	Pseudostem girth (mm)		Mean	No. of leaves /clump		Mean	No. oftillers /clump		Mean	Leaf area index		Mean
	M_1	M_2		M_1	M_2		M_1	M_2		M_1	M_2		M_1	M_2	
T_1	7.60	7.07	7.33	44.24	37.90	41.07	66.95	57.53	62.24	7.60	7.07	7.33	4.47	3.94	4.20
T_2	7.93	7.13	7.53	47.50	44.54	46.02	70.93	60.92	65.93	7.93	7.13	7.53	5.47	4.64	5.05
T_3	8.13	7.20	7.67	48.33	45.93	47.13	74.67	62.00	68.33	8.13	7.20	7.67	5.62	4.95	5.28
T_4	8.40	7.27	7.83	49.28	46.14	47.71	78.97	63.35	71.16	8.40	7.27	7.83	5.69	5.27	5.48
T_5	8.53	7.33	7.93	49.85	46.74	48.29	83.00	63.49	73.25	8.53	7.33	7.93	6.09	5.38	5.74
T_6	8.60	7.60	8.10	53.28	47.40	50.34	85.55	68.44	76.99	8.60	7.60	8.10	6.23	5.62	5.92
T_7	9.00	7.80	8.40	55.01	52.99	54.00	88.19	71.39	79.79	9.00	7.80	8.40	6.59	5.65	6.12
T_8	9.60	7.87	8.73	56.26	53.82	55.04	95.84	71.40	83.62	9.60	7.87	8.73	6.60	5.95	6.27
T_9	9.93	7.93	8.93	73.39	57.85	65.62	103.32	71.96	87.64	9.93	7.93	8.93	6.84	6.14	6.49
Mean	8.64	7.47		53.02	48.14		83.05	65.61		8.64	7.47		5.95	5.28	
For comparison of mean	**S.Em ±**	**C.D. at 5%**	**CV (%)**	**S.Em ±**	**C.D. at 5%**	**CV (%)**	**S.Em ±**	**C.D. at 5%**	**CV (%)**	**S.Em ±**	**C.D. at 5%**	**CV (%)**	**S.Em ±**	**C.D. at 5%**	**CV (%)**
M	0.10	0.59	6.26	0.62	3.80	6.41	0.55	3.33	3.82	0.10	0.59	6.26	0.05	0.29	4.46
S	0.19	0.53	5.64	1.51	4.35	7.31	1.95	5.63	6.44	0.19	0.53	5.64	0.13	0.37	5.62
S at same level of M	0.26	0.76		2.14	6.15		2.76	7.96		0.26	0.76		0.18	0.53	
S at same or different level of M	0.27	0.87		2.11	6.75		2.66	8.34		0.27	0.87		0.18	0.57	

Table-2:. Effect of microbial bio-inoculant (VAM- *Glomusfasciculatum*) and bio-formulations on yield and yield attributes in turmeric cv. Salem

Treatment (S)	No. of rhizomes /clump		Mean	Rhizome clump size (cm^2)		Mean	Fresh rhizome yield (g/clump)		Mean	Fresh plot yield (kg/4.86 m^2)		Mean	Fresh yield (t/ha)		Mean
	M_1	M_2		M_1	M_2		M_1	M_2		M_1	M_2		M_1	M_2	
T_1	22.37	20.90	21.64	12.12	11.60	11.86	288.67	284.13	286.40	11.19	10.22	10.71	23.03	21.03	22.03
T_2	26.33	25.40	25.87	12.21	11.60	11.91	369.09	309.05	339.07	13.02	10.54	11.78	26.79	21.68	24.24
T_3	28.07	26.45	27.26	13.03	11.79	12.41	393.04	327.27	360.15	13.51	10.57	12.04	27.79	21.74	24.77
T_4	30.71	29.21	29.96	13.42	12.21	12.81	397.87	331.73	364.80	13.95	10.75	12.35	28.70	22.11	25.41
T_5	34.75	30.11	32.43	14.70	12.24	13.47	402.63	346.10	374.37	14.13	10.81	12.47	29.07	22.24	25.66
T_6	35.52	31.17	33.35	14.48	13.14	13.81	413.64	374.67	394.16	15.60	12.08	13.84	32.10	24.86	28.48
T_7	38.79	33.42	36.11	19.63	18.57	19.10	414.71	379.07	396.89	16.36	12.26	14.31	33.66	25.22	29.44
T_8	39.27	33.45	36.36	21.29	18.91	20.10	416.41	379.33	397.87	16.56	12.64	14.60	34.07	26.00	30.03
T_9	44.00	36.79	40.40	21.77	19.30	20.54	423.30	389.90	406.60	17.33	12.83	15.08	35.67	26.40	31.03
Mean	33.31	29.66		15.85	14.37		391.04	346.81		14.63	11.41		30.10	23.48	
For comparison of mean	**S.Em ±**	**C.D. at 5%**	**CV (%)**	**S.Em ±**	**C.D. at 5%**	**CV (%)**	**S.Em ±**	**C.D. at 5%**	**CV (%)**	**S.Em ±**	**C.D. at 5%**	**CV (%)**	**S.Em ±**	**C.D. at 5%**	**CV (%)**
M	0.20	1.23	3.33	0.27	1.62	9.16	2.01	12.24	2.83	0.06	0.35	2.30	0.12	0.72	2.31
S	0.75	2.16	5.85	0.45	1.29	7.28	5.73	16.51	3.81	0.34	0.98	6.38	0.70	2.01	6.39
S at same level of M	1.06	3.06		0.64	1.83		8.11	23.35		0.48	1.38		0.99	2.85	
S at same or different level of M	1.02	3.19		0.66	2.17		7.90	25.04		0.46	1.41		0.94	2.90	

Table-3: Effect of microbial bio-inoculant (VAM- *Glomusfasciculatum*) and bio-formulations on curcumin and volatile oil content in turmeric cv. Salem

Treatment	Curcumin content (%)		Mean	Volatile oil (%)		Mean
	M_1	M_2		M_1	M_2	
T_1	3.89	3.63	3.76	0.93	0.89	0.91
T_2	4.04	4.00	4.02	0.99	0.92	0.96
T_3	4.08	4.07	4.07	1.03	0.97	1.00
T_4	4.18	4.12	4.15	1.19	1.05	1.12
T_5	4.42	4.27	4.35	1.25	1.05	1.15
T_6	4.57	4.33	4.45	1.26	1.05	1.16
T_7	4.78	4.38	4.58	1.26	1.04	1.15
T_8	4.86	4.41	4.64	1.29	1.09	1.19
T_9	4.96	4.45	4.70	1.34	1.15	1.24
Mean	4.42	4.19		1.17	1.02	
For comparison of mean						
	S.Em ±	**C.D. at 5%**	**CV (%)**	**S.Em ±**	**C.D. at 5%**	**CV (%)**
M	0.02	0.14	2.83	0.02	0.10	7.75
S	0.06	0.18	3.52	0.05	0.14	11.03
S at same level of M	0.09	0.25		0.07	0.20	
S at same or different level of M	0.09	0.27		0.07	0.21	

In table 1 to 3: Main plot (M); M_1: With VAM M_2: Without VAM; Sub plot treatments (S); T_1: RDF (180:90:90 kg NPK /ha and 25 t FYM / ha); T_2: T_1+ Vermiwash at 10% dilution (Drenching); T_3: T_1+Panchagavyaat 3% dilution (Drenching); T_4: T_1+Amritpaniat 3% dilution (Drenching); T_5: T_1 + Vermiwash at 10% dilution (Drenching and spraying); T_6: T_1+Panchagavya at 3% dilution (Drenching and spraying); T_7: T_1 +Amritpani at 3% dilution (Drenching and spraying); T_8: T_1 + Panchagavya + Amritpani + Mulch (Sugar cane trash) + *Trichoderma* (2.5 %) spray on mulch; T_9 : T_8 + Panchagavya + Amritpani+ Agnihotra ash+Triambakamhomaash

ash mediated to increase root geometry, nutrient mineralization, resulting in the development of sound and healthy rhizosphere with increased extramatricular hyphae which might have further contributed to improved growth resulting in increased nutrient uptake, photosynthesis and bio- chemical activities. The results obtained in the present investigation are in agreement with earlier findings (Padmapriya *et al.*, 2007 and Rajamani *et al.*,2007 in turmeric).

Yield and yield attributes: The fresh rhizome yield (yield/ plant, yield/ plot and yield/ hectare) and yield attributes such as number of rhizomes per clump and rhizome clump size were higher in plants receiving VAM application compared to the uninoculated control.

Among sub plot treatments T_9 showed higher yield attributes followed by T_8 compared to the T_1 (RDF).The number of rhizomes per clump significantly varied among treatments from 40.40 (T_9) to 21.64 (T_1). Similarly rhizome clump size varied from 20.54 cm^2 (T_9) to 11.86 cm^2 (T_1). The fresh rhizome yield was maximum in T_9 (31.03 t/ha) closely followed by T_8 (30.03 t/ha). Among interactions, the treatment combination T_9M_1 showed higher yield and yield attributes compared to rest of the treatments. Inoculation of VAM must have helped to increase the mineral phosphorous uptake in the plant and might have resulted in higher fresh rhizome yield. Similar result is reported in earlier findings in black pepper by Thanuja (2002). The good response of AM fungi in turmeric cv. Sugana was also reported by Reddy *et al.* (2003) in turmeric.The increased fresh rhizome yield and yield attributes in the treatment T_9 might be due to higher growth attributes (source) leading to formation of higher sink capacity and accumulation of more carbohydrates. It is also reported that, the rhizome treated with *Trichoderma* sp. also produces plant hormones and enzymes and thereby promotes plant growth and yield in turmeric (Sivaprasad, 2002). The results obtained in the present investigation are in agreement with the findings of Padmapriya *et al.* (2007), Velmurugan *et al.* (2008) in turmeric and Vanilarasu and Balakrishnamurthy in banana (2014).

Quality attributes: The different bioformulations treatments with combination of VAM (*Glomus fasciculatum*) significantly influenced the quality attributes in turmeric (Table 3). The quality parameters like curcumin and volatile oil content were higher in T_9 followed by T_8 compared to the lowest in the treatment T_1. Higher curcumin and essential oil content might be due to the higher vigorous growth, crop duration and higher dry matter accumulation in rhizomes. Besides, bio-inoculants and bio-formulations also increased 'P' nutrient uptake, photosynthesis, source sink relationship and bio-chemical activities in turmeric (Roy and Hore, 2011). Similar reports were also corroborated by earlier findings in turmeric by Chempakam *et al.* (2000)and Padmapriya *et al.* (2007) and in guava by Sharma *et al.* (2013). It was reported that, increase in curcumin and volatile oil content was due to increased activity of phenyl ammonia lyase enzyme which involved in curcumin biosynthesis. Uphadhyay and Mishra (1999) also opined that, greater uptake of nutrients increased the essential oil and curcumin content in turmeric rhizome.

Even though turmeric is a nutrient exhaustive crop, the results of the present investigation confirm possibility of production of turmeric with maximum yield and good quality produce by applying *G. fasciculatum* and bioformulations as against applying only synthetic fertilizers.

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