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INFLUENCE OF ARBUSCULAR MYCORRHIZAL FUNGI ON PLANT GROWTH PROMOTION AND BIOLOGICAL CONTROL OF VERTICILLIUM WILT OF TOMATO (*LYCOPERSICON ESCULENTUM*).

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ABSTRACT

Tomato (*Lycopersicon esculentum* Mill) is an important vegetable crop and is known as productive as well as a protective food because of its therapeutic values. Arbuscular mycorrhizal fungi are known to enhance plant growth mainly through nutrient uptake. Indigenous arbuscular mycorrhizal fungi *Glomus fasciculatum* (Thaxt.) Gerd. & Trappe, was inoculated in field conditions using three different cultivars of tomato viz., PKM-1, Gaurav and Monarch. Various morphological parameters, nutrient levels and disease incidence were evaluated. A significant increase in shoot and root leaf lengths, shoot and root fresh, dry weights, biomass, dry matter production and nutrient levels NPK were recorded in AM fungi treated plants over controls. There was a maximum reduction of disease incidence by 53.18% in Monarch cultivar in the plants inoculated with AM fungi in combination with the pathogen *Verticillium dahliae* compared to only pathogen inoculated plants. This was followed by 49.55% and 45.48% in Gaurav and PKM-1 cultivars respectively. All the three cultivars have shown positive response to *Glomus fasciculatum* recording significant increase in plant growth and reduction in percentage of disease incidence.

KEYWORDS: Arbuscular mycorrhizal fungi, *Glomus fasciculatum,* plant growth, tomato, *Verticillium dahliae.*

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INTRODUCTION

Arbuscular mycorrhizal fungi are beneficial soil microorganisms that form symbiotic association with the fine roots of plants, used as bio-fertilizers for plant growth, especially in soils of low fertility, are well documented. In a natural ecosystem, mycorrhizal plants exhibit greater uptake of phosphorus and trace elements when these nutrients are sparingly soluble in soils[1,2]. They can also show improved resistance to drought, environmental stress and also fight against the root borne pathogens[3]. As a result, mycorrhizal plants frequently exhibit increased growth, yield and survival over non-mycorrhizal controls[1]. The studies on mycorrhizae gained importance due to its practical use as a low input technology for managing soil fertility and plant nutrition. The Verticillium wilt caused by the pathogen *Verticillium dahliae* effects wide range of economically important host plants including vegetables (eggplants, pepper, potato and tomato), fruits (grapevine, olive and strawberry), flowers (*Chrysanthemum*), oilseed crops (sunflower), fibre crops (cotton, flax) and woody perennials[4]. There is no chemical control for the disease, but crop rotation, use of resistant varieties and deep ploughing, may be useful in reducing the spread of the disease. The use of AM fungi to protect crops from soil borne diseases eventually inducing healthy growth of plants with high yields at lower cost and minimum risk to humans and environment is a promising strategy. Tomato (*Lycopersicon esculentum* Mill) is an important vegetable crop and its cultivation is worldwide. It is known as productive as well as protective food because of its therapeutic values. They contain lycopene, a natural and powerful antioxidant. The present study was carried out to test the role of AMF in plant growth promotion and bioprotection against the verticillium wilt pathogen in three cultivars of tomato.

MATERIALS AND METHODS

(i) Inoculum of AM fungi

AM fungus *G. fasciculatum* was observed to be most predominantly occurring in the tomato cultivated agricultural field soils. Spores of *G. fasciculatum* were extracted from soil by wet sieving and decanting technique[5] and mass multiplied in pot cultures using sand and soil mixture in the ratio 1:1 with sorghum as the host plant. As soon as 70 to 80% of infection is established, the root bits and soil sample mixture was harvested and used as inoculum. The inoculum consisted of spores, pieces of hyphae and infected root material. One gram of soil containing 20 spores and one gram of roots containing 70 to 80% root infection were the standard units used for inoculating the field cultivars. Hoagland[6] plant nutrient solution without phosphorus was added at regular intervals.

(ii) Maintenance of the Pathogen

The pathogen *Verticillium dahliae* was procured from IMTECH, cultured on potato-carrot agar (PCA) (20g of carrot, 20g potato, 250ml dist. water, cooked and strained) plates as per IMTECH guidelines. The fungus was purified by the single sclerotial isolation method. Pure culture of *V. dahliae* was maintained on PCA slants by regular sub culturing and stored at 24 to 25^{o}C in Biochemical Oxygen Demand (BOD) incubator.

(iii) Inoculum development of the pathogen

The inoculum was prepared by multiplying the pathogen *V. dahliae* in potato-carrot broth medium. The broth (100ml in 250ml flask) was inoculated with discs of mycelium (pure culture) of 5d old culture, and incubated at 23±2^{o}C for 10 d in BOD incubator. This inoculum broth was used in field experiments for the pathogen group.

(iv) Pathogenicity test of V. dahliae

Pathogen was further confirmed by conducting pathogenecity test in green house conditions.

Field Experiment

The three cultivars of tomato viz., PKM-1, Gaurav and Monarch were screened under field conditions using *G. fasciculatum* as bioinoculant. The field was prepared and furrows were laid down in 100 sq. mts. area. There were four treatments used such as uninoculated control (C), *Glomus fasciculatum*

(AM), *G. fasciculatum* + *Verticillium dahliae* (AM+P) and *V. dahliae* (P), consisting of 20 plants in a row. The field soils were red sandy loam type, deficient in phosphorus and moisture content. No fertilizer was applied to the field soil. A layer of AMF inoculum was laid out in furrows, similarly pathogen and AMF plus pathogen inoculum also. The 22 days old seedlings of three tomato cultivars from nursery bed were transplanted. The plants were uprooted on 30th, 60th, 90th and 120th day of crop growth after transplantation and evaluated for the following plant growth parameters such as shoot, root lengths, shoot and root fresh and dry weights, biomass and dry matter production and N, P, K status, fruit yield (fruit weight/plant), changes/alterations in the nutritive value of fruits and percentage of disease incidence.

(i) Percentage of mycorrhizal root colonization

The collected root samples were washed under tap water and suitably processed by clearing and staining technique[7] and percentage of root colonization was calculated by morphometric technique[8].

(ii) Plant growth studies

Shoot and root lengths, shoot and root fresh weights and dry weights (shoot and root samples were oven dried at 70^{o}C for 72 hours till constant weights were recorded).

(iii) Dynamics of growth

The growth characteristics in respect of biomass increment and mean rate of dry matter production were calculated as:

a. Biomass increment- as an index of growth character, increase in biomass (W) was expressed in terms of dry weights[9]. The increase in shoot biomass and root biomass was calculated using the following formula: $W = W_2 - W_1$ (sub scripts 1 and 2 indicate the values of W on two occasions).
b. Rate of dry matter (G)- The mean rate of dry matter production is the mean growth rate (G) over an interval of time from D_1 to D_2 given by:

$$G = \frac{W2 - W1}{D2 - D1}$$

(iv) NPK status

Nitrogen (Kjeldahl method), Phosphorous (Fiske and Subbarow Method (Colorimetric method) on spectroscopy, AnalytikaJena, Specord S600) and Potassium (atomic absorption spectroscopic method on varian spectra AA220) were determined.

(v) Fruit yield

Fruit weight of three plants was estimated for each treatment and the average yield was recorded.

(vi) Estimation of nutritive value

Total Dietary Fibre, moisture content, protein, fat, ash, crude fibre and carbohydrate were determined[10].

(vii) Statistical analysis

IBM SPSS version 19 was used for statistical analysis. The descriptive statistics like mean and SD were calculated for all parameters like shoot and root lengths, fresh and dry weights of shoot and root and biomass increase across groups, varieties, time points and field conditions. Comparison of mean values across groups as well as time points were assessed with repeated measures ANOVA for given variety and field condition. T-test was also used for comparison of two mean values. Level of significance was considered as 0.05.

RESULTS

Root Colonization

The results of percentage of AM fungal root colonization in three different cultivars at different stages of plant growth period is presented in Table 1. The uninoculated control plants and pathogen inoculated cultivars of tomato showed least AM fungal root colonization ranging from 4-38%. The percentage of AM root colonization in *G. fasciculatum* (Fig. 1A) inoculated plants ranged from 15 to 89% in three cultivars during 30 to 120d crop growth and heavily colonized by vesicles and arbuscules (Fig. 1B & C). However, in dual inoculated plants with AMF in combination with the pathogen the root colonization ranged from 8 to 69%. The mycorrhizal and dual inoculated plants in all the three cultivars showed a gradual increase with increase in plant growth period[11]. The

data in the table indicates that Monarch cultivar was more responsive to *G. fasciculatum* showing maximum (89%) root colonization followed by PKM-1 (78%) and least by Gaurav (72%) in 120 days crop.

Table 1
Effect of Glomus fasciculatum on percentage root colonization in PKM-1, Gaurav and Monarch cultivars

	PKM-1				Gaurav				Monarch			
	30 d	60 d	90 d	120 d	30 d	60 d	90 d	120 d	30 d	60 d	90 d	120 d
Control	0	12.0	23.0	35.0	0	14.0	19.0	28.0	0	12.0	25.0	38.0
AM	16.0	38.0	65.0	78.0	10.0	36.0	57.0	72.0	20.0	46.0	71.0	89.0
AM+pathogen	0	15.4	35.0	55.0	0	21.0	41.0	64.0	08.0	24.0	48.0	69.0
Pathogen	0	0	4.0	19.0	0	0	8.0	17.0	0	0	8.0	18.0

AM- Glomus fasciculatum, Pathogen- Verticillium dahliae, d- days after transplantation

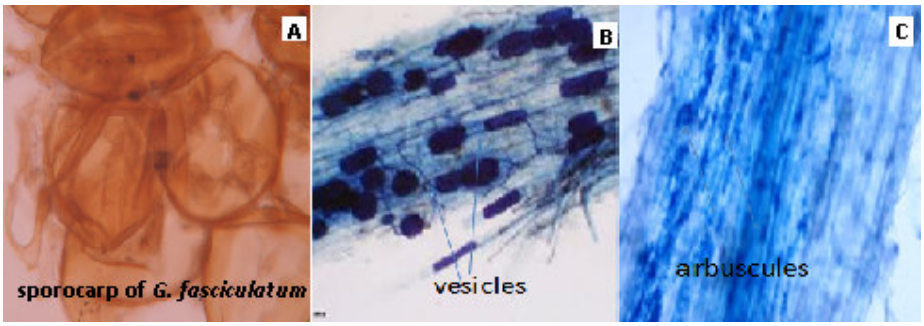

Figure 1
A. sporocarp of Glomus fasciculatum, B & C- Root colonization by G. fasciculatum showing vesicles and arbuscules

Plant growth

The results of shoot and root growth in terms of length (cms) in different cultivars of tomato studied at different growth intervals (30, 60, 90 and 120d) as affected by inoculation with different treatments are presented in Table 2. *G. fasciculatum,* the test inoculant was more effective in all the three cultivars showing significant increase in shoot and root lengths compared to uninoculated control plants. Plant growth in all the cultivars showed gradual increase with increase in age of the crop, recording maximum in 120 d growth period. Shoot and root length of different cultivars showed significant increase in AM inoculated plants followed by dual inoculation, control and minimum in pathogen inoculated plants. These three cultivars showed good response to AM inoculation. PKM-1 variety recorded maximum shoot and root lengths (205 cm and 48 cm respectively) followed by the Monarch (185 and 46 cm) and finally Gaurav (177.66 and 39.21 cm) in mycorrhizal inoculated plants. All the three varieties across the days and treatments were statistically significant. These results agree with the earlier reports[12,13,14,15].

Fresh and dry weights

The shoot and root fresh and dry weights in different cultivars studied at different growth intervals as influenced by different treatments are presented in Table 3 and 4. All the three cultivars showed positive response to *G. fasciculatum* recording significant increase in shoot and root fresh and dry weights over non mycorrhizal plants. Among the three cultivars Monarch recorded maximum shoot and root fresh and dry weights. The univariate analysis of variance for fresh and dry weights in all the three cultivars of tomato was significant between treatments and between time intervals. The data on the analysis of variance showed highly significant differences among the treatments and also among the time intervals. The results of our study proved that the indigenous AM fungi *G. fasciculatum* acted as a biofertilizer in all the three cultivars as evidenced by significant increase in shoot

and root fresh and dry weights similar to the observations made earlier[16,17,18,19].

Biomass and dry matter production

One of the important parameters in estimating the responses of the plants to AM fungi is the value pertaining to biomass and dry matter production. The effectiveness of AM inoculation studied in relation to biomass per plant and dry matter production per day were estimated at the end of 30th, 60th, 90th and 120th day after transplantation of the plants and presented in Tables 5. The data revealed that the mycorrhizal inoculated plants significantly enhanced shoot and root biomass and dry matter production over dual inoculated and control plants. The data indicates that AM inoculated plants of all the three cultivars showed greater biomass and dry matter production values compared to non mycorrhizal plants recording maximum between 90 and 120 days growth period. Many researchers have established the increase in biomass and dry matter production where mycorrhiza is involved earlier[20,21,22].

NPK status

The results of nitrogen, phosphorus and potassium levels in the shoot and root of three different cultivars of tomato crop at two intervals of crop growth i.e., 30d and 120d are presented in Table 6. The shoots and roots of AM inoculated plants significantly increased N, P, K levels over.

Table 2
Effect of Glomus fasciculatum on shoot and root length (cm) of PKM-1, Gaurav and Monarch cultivars of tomato

	Shoot length						Root length					
	PKM-1		**Gaurav**		**Monarch**		**PKM-1**		**Gaurav**		**Monarch**	
	'F' Ratio	p	'F' Ratio	p	'F' Ratio	p	'F' Ratio	p	'F' Ratio	p	'F' Ratio	p
Between Days	40868.060	0.000	151248.810	0.000	29782.734	0.000	5224.277	0.000	20603.034	0.000	8529.620	0.000
Between Treatment	24099.639	0.000	38347.869	0.000	28321.610	0.000	4478.204	0.000	13099.941	0.000	7740.432	0.000
Days & Treatment	2817.884	0.000	7834.176	0.000	3624.057	0.000	735.999	0.000	1494.361	0.000	956.279	0.000

Table 3
Effect of Glomus fasciculatum on shoot and root fresh weights (gm/plant) of PKM-1, Gaurav and Monarch cultivars

	Shoot fresh weight						Root fresh weight					
	PKM-1		**Gaurav**		**Monarch**		**PKM-1**		**Gaurav**		**Monarch**	
	'F' Ratio	p	'F' Ratio	p	'F' Ratio	p	'F' Ratio	p	'F' Ratio	p	'F' Ratio	p
Between Days	477037.707	0.000	183664.582	0.000	48335.834	0.000	252391.070	0.000	1575118.878	0.000	674891.078	0.000
Between Treatment	53946.309	0.000	13165.966	0.000	19085.588	0.000	90035.793	0.000	343406.276	0.000	95008.583	0.000
Days & Treatment	8643.212	0.000	1929.339	0.000	3826.647	0.000	14461.388	0.000	43987.393	0.000	26839.348	0.000

Table 4
Effect of Glomus fasciculatum on shoot and root dry weights (gm/plant) of PKM-1, Gaurav and Monarch cultivars

	Shoot dry weight						Root dry weight					
	PKM-1		**Gaurav**		**Monarch**		**PKM-1**		**Gaurav**		**Monarch**	
	'F' Ratio	p	'F' Ratio	p	'F' Ratio	p	'F' Ratio	p	'F' Ratio	p	'F' Ratio	p
Between Days	227901.999	0.000	93539.967	0.000	106995.664	0.000	56382.553	0.000	158881.126	0.000	85995.286	0.000
Between Treatment	9859.492	0.000	6576.193	0.000	4331.459	0.000	6663.566	0.000	3140.389	0.000	2468.487	0.000
Days & Treatment	3928.851	0.000	1455.120	0.000	1469.140	0.000	2815.230	0.000	6270.547	0.000	3472.907	0.000

Table 5
Effect of Glomus fasciculatum on shoot and root biomass and dry matter production (gm/plant) in PKM-1, Gaurav and Monarch cultivars

	Shoot →			PKM-1			Gaurav						Monarch					
	B1	B2	B3	D1	D2	D3	B1	B2	B3	D1	D2	D3	B1	B2	B3	D1	D2	D3
	(gm/plant)																	
Cont	4.81	3.81	21.85	0.16	0.13	0.73	4.09	3.32	19.42	0.136	0.110	0.647	4.81	4.788	25.220	0.160	0.159	0.840
AM	6.30	5.60	35.49	0.21	0.19	1.18	6.92	3.82	31.96	0.230	0.127	1.065	6.85	3.760	31.520	0.228	0.124	1.050
AM+P	6.86	4.27	29.60	0.22	0.14	0.99	6.86	3.71	30.00	0.228	0.123	1.000	6.29	5.607	36.125	0.209	0.186	1.200
P	3.80	3.90	19.28	0.12	0.13	0.64	3.80	3.86	19.32	0.127	0.128	0.644	4.72	3.010	20.285	0.157	0.100	0.676
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Root																		
Cont	0.53	0.580	3.320	0.017	0.019	0.110	0.55	0.38	2.46	0.018	0.012	0.082	0.53	0.69	3.463	0.017	0.023	0.115
AM	1.59	1.370	7.137	0.053	0.043	0.240	1.30	0.98	5.92	0.043	0.032	0.197	1.50	1.31	7.34	0.050	0.043	0.244
AM+P	0.73	0.078	4.000	0.024	0.026	0.133	0.75	0.86	4.22	0.025	0.028	0.140	0.73	0.876	4.472	0.024	0.290	0.149
P	0.49	0.780	2.900	0.016	0.026	0.096	0.40	0.68	2.96	0.013	0.022	0.098	0.50	0.747	3.320	0.016	0.024	0.110
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Biomass for the period- B1= D_2-D_1, B2= D_3-D_2, B3= D_4-D_3, Dry Matter production D1= W_2-W_1 / D_2-D_1, D2= W_3-W_2 / D_3-D_2, D3= W_4-W_3 / D_4-D_3, D_1, D_2, D_3, D_4- 30, 60, 90 and 120 days respectively; W_1, W_2, W_3, W_4- Weight at 30, 60, 90 and 120 days after transplantation respectively, AM- Glomus fasciculatum, P- Verticillium ahlia

Table 6
Effect of Glomus fasciculatum on NPK contents in shoot and root of PKM-1, Gaurav and Monarch cultivars

Treatment	PKM-1 (120 DAT)			Gaurav (120 DAT)			Monarch (120 DAT)		
	N	P	K	N	P	K	N	P	K
ControlS	21.133	3.2383	6.733	20.443	2.2533	6.738	22.033	3.183	7.117
R	4.483	1.9533	3.2483	4.322	2.0083	3.1733	9.117	2.1667	3.0833
AMS	26.953	7.4383	9.043	26.763	6.4583	8.983	38.473	7.6550	10.237
R	9.772	3.4733	4.1533	9.673	2.7483	4.1833	10.433	3.9833	4.4183
AM+PS	23.433	4.0967	8.008	22.818	2.4633	7.018	28.157	5.3267	7.257
R	7.553	3.4333	3.8733	7.962	2.2767	3.4633	9.538	3.0600	3.5833
PS	18.583	3.0833	5.653	18.238	2.1733	6.232	20.143	3.0433	6.573
R	4.367	1.8583	3.0833	4.115	1.9833	3.1467	9.007	2.0667	2.9533
'F'value S	68628.773	6261.358	17189.02	90422.449	17850.648	7968.737	7482318.011	17429.095	33681.004
R	64920.410	1347.776	3377.719	42574.013	303.514	1849.521	13194.581	309.226	109280.48
P value S	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

DAT- days after transplantation, AM- Glomus fasciculatum, Pathogen- Verticillium dahliae

uninoculated plants indicating that these three elements were efficiently transported by *G. fasciculatum*. All the cultivars tested showed higher levels of N, P, K in mycorrhizal inoculated plants compared to uninoculated plants followed by dual inoculated plants indicating AM fungi helped the cultivars in absorption capacity of nutrients by the roots and accumulate in the shoot tissues. Our observations are in agreement with the earlier findings of [23,24,25,26,27].

Micronutrients

The mycorrhizal plants recorded high micronutrient status than dual inoculated and non-inoculated plants in all the three cultivars (Table 7) and the results were significant between treatments and between groups. The data showed the evidence to the absorption and accumulation of enhanced amounts of micronutrients viz., iron, zinc, copper and manganese in AM inoculation over control and also showed gradual increase in the levels of micronutrients from 30 to 120d crop growth. Among the micronutrients studied, iron absorption into the plant (shoot and root) tissue was highest followed by manganese, zinc and finally copper. Similar trend was observed with AMF inoculation in the presence of pathogen (dual inoculation) showing the AM fungi to be beneficial in the absorption of micronutrients.

Table 7
Effect of Glomus fasciculatum on micronutrient levels (g/mg) in shoot and root systems of tomato cultivars at 120 days after transplantation

Cultivars		PKM-1				Gaurav				Monarch			
Treatments		Fe	Zn	Cu	Mn	Fe	Zn	Cu	Mn	Fe	Zn	Cu	Mn
Control	S	5.70	0.512	0.180	0.78	5.81	0.524	0.183	0.75	6.11	0.558	0.188	0.81
	R	1.15	0.289	0.030	0.24	1.12	0.293	0.032	0.24	1.23	0.312	0.033	0.26
AM	S	12.65	0.572	0.24	1.60	12.75	0.600	0.240	1.69	13.10	0.614	0.250	1.78
	R	2.70	0.500	0.20	0.62	2.74	0.580	0.200	0.64	2.81	0.545	0.220	0.72
AM+ Pathogen	S	10.58	0.518	0.179	0.77	10.62	0.541	0.180	0.78	10.72	0.562	0.183	0.83
	R	1.22	0.550	0.032	0.22	1.18	0.590	0.031	0.24	1.24	0.420	0.030	0.25
Pathogen	S	4.35	0.418	0.120	0.70	4.22	0.426	0.128	0.65	4.13	0.490	0.140	0.70
	R	0.85	0.300	0.024	0.20	0.90	0.300	0.023	0.18	0.86	0.282	0.024	0.20

AM- Glomus fasciculatum, Pathogen- Verticillium dahlia, S – Shoot, R – Root

Nutritive Value

The results of nutritive values in three cultivars of tomato as influenced by *G. fasciculatum* showed enhanced levels of nutritive values (Table 8) such as proximate principles, minerals and vitamins. Among the three varieties, the nutritive values were not much altered except in few cases the protein content varied. There was a slight variation in the mineral content. It is clear from the results presented that irrespective of the treatments the nutritive values were not altered much.

Fruit yield

The results of yield performance as influenced by the inoculation of mycorrhizal alone and in combination with the pathogen are given in Table 9. In the present study, the mycorrhizal inoculated plants alone and in combination with the pathogen recorded significantly high yield over only pathogen inoculated and control plants. AM inoculated plants showed two and half folds increased yield in Monarch cultivar and more than two folds in PKM-1 and Gaurav cultivars over corresponding uninoculated plants. Earlier studies[28,29] are in support of our observation. The analysis of variance (ANOVA) of the measured parameters indicated that AM fungi enhanced the growth, development and yield of tomato.

Disease incidence status

The results of disease incidence on three cultivars of tomato as influenced by the inoculation of AM fungi alone and in combination with the pathogen are presented in Table 9. The data indicate that there was a significant reduction in the percentage of disease incidence in AM fungal inoculated plants. The results showed that there was maximum reduction of disease incidence by 53.18% in Monarch cultivar when treated with AM fungi plus pathogen compared to only pathogen treated plants. This was followed by 49.55% and 45.48% in Gaurav and PKM-1 cultivars respectively. The plants inoculated with AM fungal symbiont exhibited increased resistance to the fungal root pathogen *V. dahliae* as reported earlier[30]. All the three cultivars of tomato have shown

Table 8
Effect of Glomus fasciculatum on nutritive values of PKM-1, Gaurav and Monarch cultivars of tomato

S. No	Treatments →	PKM-1				Gaurav				Monarch			
		Con	AM	P	AM+P	Con	AM	P	AM+P	Con	AM	P	AM+P
	A) Proximate Principles												
1	Moisture	93.32	92.30	93.54	93.30	92.66	92.55	93.04	92.62	92.31	91.64	93.51	92.45
2	Protein	0.99	1.00	0.85	1.02	0.82	1.06	0.75	0.90	1.16	1.58	0.99	1.10
3	Total Ash	0.75	0.80	0.81	0.76	0.75	0.80	0.70	0.73	0.66	0.75	0.60	0.70
4	Fat	0.43	0.60	0.40	0.42	0.39	0.44	0.30	0.38	0.45	0.48	0.30	0.42
5	Total Dietary Fiber	1.45	1.40	1.40	1.43	1.41	1.48	1.38	1.40	1.46	1.50	1.20	1.40
6	Insoluble Dietary Fiber	1.08	1.01	1.10	1.08	1.11	1.15	1.10	1.11	1.13	1.16	1.08	1.10
7	Soluble Dietary Fiber	0.37	0.39	0.30	0.35	0.3	0.33	0.28	0.29	0.33	0.34	0.22	0.30
8	Carbohydrates	3.06	3.36	3.00	3.07	3.97	3.67	3.83	3.97	3.96	4.05	3.40	3.93
9	Energy (KJL)	87	99	82	87	97	98	90	98	105	115.00	87.00	102.00
	B) Minerals (mg/100g)												
1	Calcium	5.56	5.63	5.40	5.58	9.05	10.05	8.95	9.00	6.21	6.30	6.00	6.18
2	Magnesium	14.93	15.00	12.86	15.10	11.44	11.56	10.30	11.40	13.26	13.53	13.50	13.15
3	Copper	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.14	0.16	0.10	0.16
4	Manganese	0.12	0.14	0.10	0.13	0.09	0.09	0.09	0.09	0.12	0.14	0.08	0.10
5	Iron	0.78	0.70	0.60	0.74	0.51	0.55	0.40	0.48	0.54	0.54	0.34	0.50
6	Zinc	0.16	0.14	0.12	0.16	0.16	0.15	0.10	0.16	0.23	0.20	0.16	0.22
7	Phosphorus	31.99	37.30	20.96	30.96	27.14	34.35	20.05	25.24	34.5	41.55	27.32	33.96
8	Potassium	288.92	292.50	273.96	286.96	289.39	292.50	240.42	284.59	288.96	292.07	236.33	285.99
C) Vitamins (mg/100g)													
1	Thiamine	0.34	0.03	0.34	0.34	0.032	0.04	0.03	0.03	0.037	0.39	0.33	0.036
2	Niacin	0.54	0.54	0.54	0.54	0.56	0.62	0.47	0.60	0.57	0.60	0.44	0.52
3	Riboflavin	0.6	0.06	0.06	0.06	0.066	0.07	0.06	0.07	0.062	0.06	0.06	0.060
4	Beta carotene	0.51	0.50	0.52	0.52	0.63	0.68	0.59	0.65	0.71	0.71	0.68	0.69
5	Total carotenoids	6.95	6.89	6.94	6.94	6.24	6.45	6.00	6.38	6.93	6.94	6.64	6.89
6	Lutein	0.09	0.07	0.09	0.09	0.08	0.10	0.05	0.07	0.09	0.09	0.06	0.08
7	Lycopene	4.36	4.35	4.36	4.36	4.72	4.76	4.66	4.71	4.74	4.76	4.50	4.70

Con- control, AM- Glomus fasciculatum, P- Verticillium dahliae

Table 9
Effect of G. fasciculatum on fruit yield and disease incidence in PKM-1, Gaurav and Monarch cultivars of tomato

	PKM-1		Gaurav		Monarch	
Treatments	Fruit yield (g/plant)	DI (%)	Fruit yield (g/plant)	DI (%)	Fruit yield (g/plant)	DI (%)
Control	626	0	640	0	636	0
AM	1462	0	1423	0	1619	0
AM + Pathogen	727	38.3	701	44.5	727	41.8
Pathogen	330	84.2	377	89.8	317	78.6

AM- Glomus fasciculatum, Pathogen- Verticillium dahliae, DI- disease incidence

positive response to *Glomus fasciculatum* recording significant reduction in percentage of disease incidence. Hence, the results indicate mycorrhiza acts as a biocontrol in minimizing the pathogen effect of plant diseases as evidenced by the authors[29,31]. The potential in biological suppression of soil borne pathogen gives a wider vision of AM fungi, in that they act as an alternative strategy for the host plant in conditions that are deleterious to root growth. Therefore, the introduction and consequent management of such symbiotic colonization could be employed for the advantage of the crop.

CONCLUSION

The results revealed that the indigenous mycorrhizal fungi *Glomus fasciculatum* inoculation was more effective in enhancing plant growth, biomass and accumulation of N, P, K in the host shoot and root tissues. Further, the plants inoculated with AM fungal symbiont exhibited increased resistance to the fungal root pathogen *V. dahliae*. All the three cultivars of tomato have shown positive response to *Glomus fasciculatum* recording significant reduction in percentage of disease incidence. Therefore, the introduction and consequent management of such symbiotic

colonization could be employed for the advantage of the crop.

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