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Mycorrhizal Dependency in Certain Indian Cotton Cultivars

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Mycorrhizal dependencies of ten cotton cultivars were evaluated in the green house using completely randomized block design model. Acid-delinted seeds were sown in polybags containing natural black soil. Plant growth, nutrient content and mycorrhizal colonization levels were studied. Cotton cultivars exhibited mycorrhizal colonization ranging from 36.52 to 73.5 %. Plant dry weight and tissue Nitrogen content were positively correlated whereas tissue Potassium was not correlated with the mycorrhization. Root diameter, number of root hairs and root length were varied among the cultivars. Root diameter was highest in the cultivar NHH 44, whereas root hair number was more in Suvin. Root hair length was maximum in the cultivar Suvin. Mycorrhizal dependency was negatively correlated with root hair number and root hair length. Maximum mycorrhizal dependency was exhibited by the cultivar Surya. The results showed the existence of strong mycorrhizal dependency in the cotton cultivars.

Keywords: Arbuscular mycorrhizal, mycorrhizal dependency, *Gossypium hirsutum*, rhizosphere.

Generally, AMF show little specificity and the factors that determine mycorrhization appear to depend on the genotype of the host plant (Koide and Schreiner 1992; Klironomos 2002). Host preference may be under the genetic control of the host, the fungus or a complex of interactive effect of both symbiotic partners with edaphic factors (Sylvia and Chellemi 2001). Host-dependant sporulation among common lawn plants is also well demonstrated (Bever et al. 1996). Evidence for this is provided by the existence of non-host plant species (Giovannetti and Sbrana 1998) and Myc- mutant *Pisum sativum* plants unable to form AM symbiosis (Gollotte et al. 1993). Mycorrhizal colonization patterns in inbred lines of *Zea mays* selected for resistance to fungal pathogens indicate that they had significantly low levels of mycorrhizal colonization and larger root systems (Toth et al. 1990).

Clement and Habte (1995) reported genotypic variation in mycorrhizal dependency of pejibaye palm. Host genotype variation in root colonization and plant responses has been reported for citrus (Graham and Eissenstat 1994), wheat (Hetrick et al. 1996) and tomato (Barker et al. 1998). Earlier Krishna et al. (1985) also proved the genotype dependant variation in mycorrhizal colonization in pearl millet.

Root characters, either morphological or physiological, affect plant uptake of nutrients from soil (Muthukumar et al. 1999). The influence of root morphology on

mycorrhizal formation led to the development of "Magnolioid root hypothesis" which predicts that plants with coarse root and with no or few short root hairs develop intense mycorrhizal colonization in natural soil compared to those with fine roots and abundant long root hairs. Peat and Fitter (1993) have indicated significant differences in root characters between mycorrhizal and non-mycorrhizal plant species. Mycorrhizal associations in cotton (*Gossypium hirsutum*) have been studied by various researchers and several studies have shown that AMF can promote cotton nutrient uptake and growth (Rich and Bird 1984; Smith and Roncadori 1986). *Gossypium herbaceum* showed heavy mycorrhizal colonization with almost every cortical cell of the white roots included an arbuscule (Jeffries et al. 1988). To our knowledge studies on cultivar differences in AM association and response to AMF colonization in cotton are unknown. Hence the main objective of the present work was to study the mycorrhizal association in ten cotton cultivars and their mycorrhizal dependency.

Materials and Methods

Raising of experimental seedlings

Acid-delinted seeds of seven cotton varieties namely LRA 5166, LRK 516, PAIYUR-1, MCU-7, SUVIN, MCU 5 VT and SUPRIYA; and three hybrids, NHH 44, SAVITHA and SURYA were used for the study. The seeds were procured from Central Institute for Cotton Research (CICR) Regional Station, Coimbatore, Tamil Nadu, India.

Six cotton seeds were sown in each polybag (30 x 11 cm) containing *ca.* 1.5 kg black soil. The soil had an initial pH of 7.8 and an electric conductivity of 47.35 mS cm^{-1}. The soil contained 0.135 mg kg^{-1} of total Nitrogen, 0.017 mg kg-1 of available Phosphorus and 0.10 mg kg^{-1} of exchangeable Potassium and 4.01 % Organic carbon. The seedlings were thinned to one per polybag after their germination. For non-mycorrhizal treatments to assess the mycorrhizal dependency of each cultivar, the soil was autoclaved at 120 psi for 1 h for three subsequent days and incubated for 10 days. To reintroduce natural microflora other than AMF in these polybags, 500 ml of soil filtrate prepared by suspending 1.5 Kg soil in 5 liters of sterile water and passing it through 38 µm sieve was added.

The polybags were arranged in a completely randomized block design. Each treatment was replicated five times. Plants were watered every alternate day, throughout the experiment. The positions of the polybags were altered once in every 15 days to expose seedlings to uniform conditions.

Sampling

Rhizosphere soil samples and root samples were collected every 30 days up to 120 days after emergence (DAE) of seedlings. Rhizosphere soil was collected by removing the loose soil attached to the roots. Root samples were fixed in FAA solution (5 ml of formaldehyde, 5 ml of acetic acid and 90 ml of ethyl alcohol) and analyzed later.

Analysis of plant tissue nutrient content

The plant tissues were oven-dried (70^{O} C) and powdered in a Willy Ball mill. The total nitrogen (N) and available phosphorus (P) were determined by micro-Kjeldahl and molybdenum blue methods respectively (Jackson, 1973). Exchangeable potassium (K) was extracted from the tissue in ammonium acetate solution (pH 7) and measured with a digital flame photometer (ESICO, India)(Jackson 1973). Soil organic carbon was determined according to Piper (1966).

Preparation of roots for AM assessment

Roots fixed in FAA were washed thoroughly with distilled water to remove FAA and observed under dissection

microscope (20X) to examine AM fungal spores attached to them. After examination, the roots were cut into 1 cm bits, cleared in 2.5% KOH (Koske and Gemma 1989), acidified with 5 N HCl and stained with trypan blue (0.05% in lactoglycerol). The roots were kept overnight immersed in staining soluton. For each sample, one hundred root bits were examined. The stained root bits were examined with a compound microscope (X 200 – 400) for AM fungal structures developed inside and the percentage of root length colonization was estimated according to magnified intersection method of McGonigle et al. (1990).

Enumeration and isolation of AMF spores

One hundred gram soil was dispersed in 1L water and the suspension was decanted through a series of 710- to 38-µm sieves. The residues in the sieves were washed into beakers. The sievates were dispersed in water and filtered through gridded filter papers. Each filter paper was spread on a petridish and scanned under a dissection microscope X 40 magnification and all intact spores were counted. Sporocarps and spore clusters were considered as one unit. Intact spores were transferred using a wet needle to polyvinyl alcohol-lactoglycerol with or without Melzer's reagent on a glass slide for identification. Spores were identified based on their morphology and sub-cellular characters and compared with original descriptions of Schenck and Perez (1990). Spore morphology was also compared with the INVAM culture database (http://invam.caf.wvu.edu).

Root morphology

Root diameter was measured in fifty root bits and the average was recorded for each cultivar. The root pieces were suspended in water on a microscopic slide and the root hair number (per cm), length and diameter were measured under a binocular microscope (Itoh and Barber 1983).

Mycorrhizal dependency

Percentage of mycorrhizal dependency was calculated using the formula, (dry weight of the mycorrhizal plant – dry weight of the non-mycorrhizal plant) / dry weight of the mycorrhizal plant X 100.

Statistical analysis

All data were subjected to Analysis of Variance (ANOVA) and the means were separated using Duncan's Multiple Range Test (DMRT). Pearson's correlation analysis was used to assess the relationships between various parameters by Zar (1984) using SPSS software (SPSS 9.05 for Windows).

Results

Mycorrhizal abundance

The AM fungal species isolated from the rhizosphere of the 10 cultivars were *Glomus geosporum* (Nicol. & Gerd.) Walker, *G. fasciculatum* **(**Thaxter**)** Gerd. & Trappe emend. Walker & Koske, *G. taiwanensis* (Wu & Chen) Almeida & Schenck, *G. macrocarpum* Tul & Tul., *G. intraradices* Schenck & Smith, *Gigaspora margarita* Becker & Hall, *Scutellospora gregaria* (Schenck & Nicol.) Walker & Sanders and *Acaulospora scrobiculata* Trappe. Spores of all these species were present in the rhizosphere soil of all the cotton cultivars, but their abundance varied (Table 1).

Mycorrhizal colonization

Mycorrhizal colonization was assessed in terms of per cent root length with hyphae (%RLH), vesicles (%RLV), arbuscules (%RLA) produced inside the roots and total root colonization (%RLC) which is the cumulative of the three (%RLH + %RLV + %RLA). Result of each is described hereunder. Control treatments showed no mycorrhizal association.

Table 1. AMF spore population in the rhizosphere of ten cotton cultivars at 30-120 days after emergence (DAE)

Cultivar	**Spores** (10 grams^{-1})								
30 DAE	G.g.	G.f.	G.m.	G.i.	G.t.	A.s.	Sc.g.	Gig.m.	Total
LRA5166	54 a	60 c	12 a	64 bc	10 a	20 bc	34 a	24 d	278 a
LRK516	88 cd	52 bc	24 ab	50 abc	20 bc	10 ab	44 ab	12 b	300 b
PAIYUR-1	70 abc	50 abc	40 b	70 c	14 ab	12 ab	50 abc	10 b	316 c
MCU-7	90 cd	42 abc	30 ab	52 abc	20 bc	10 ab	60 bcd	8 ab	312 bc
SUVIN	66 ab	60 c	14 a	70 c	34 e	30 cd	80 d	20 cd	374 d
MCU5VT	80 bc	40 abc	40 b	34 a	30 de	12 ab	70 cd	10 b	316 c
SUPRIYA	90 cd	24 a	32 ab	60 abc	20 bc	40 d	42 ab	2 a	310 bc
NHH44	90 cd	30 ab	34 ab	50 abc	30 de	30 cd	40 ab	14 bcd	318 c
SAVITHA	102 d	42 abc	32 ab	48 abc	26 cd	4 a	32 a	20 cd	306 bc
SURYA	90 cd	50 abc	30 ab	40 ab	30 de	2 a	40 ab	20 cd	302 b
60 DAE									
LRA5166	64 a	40 a	20 ab	70 a	20 bc	10 a	40 bcd	10 a	274 a
LRK516	92 bcd	62 ab	14 a	82 abc	14 ab	20 b	14 a	14 ab	312 b
PAIYUR-1	104 d	50 ab	10 a	98 bc	10 a	20 b	20 a	20 bc	332 c
MCU-7	82 a-d	64 ab	44 c	92 bc	22 c	14 a	30 abc	20 bc	368 d
SUVIN	70 ab	50 ab	10 a	90 bc	40 e	30 c	42 cd	34 de	366 d
MCU5VT	90 bcd	40 b	20 ab	102 c	12 a	20 b	50 d	40 e	374 d
SUPRIYA	94 cd	72 d	32 bc	80 ab	30 d	30 c	24 ab	30 d	392 e
NHH44	102 cd	50 ab	40 bc	94 bc	30 d	38 d	20 a	22 c	396 e
SAVITHA	80 abc	42 a	40 bc	100 bc	44 e	20 b	30 abc	12 a	368 d
SURYA	100 cd	50 ab	44 c	68 a	12 a	10 a	52 d	30 d	366 d
90 DAE									
LRA5166	68 ab	12 a	32 bc	50 ab	26 b	12 a	40 a	20 b	260 a
LRK516	62 ab	54 v	30 bc	60 b	20 ab	10 a	44 ab	30 c	310 ab
PAIYUR-1	90 ab	34 b	50 d	84 d	30 c	20 c	50 c	12 a	370 d
MCU-7	48 a	18 a	40 c	70 c	40 d	42 e	70 d	10 a	338 c
SUVIN	110 b	70 d	40 c	64 bc	24 b	20 c	48 ab	24 b	400 e
MCU5VT	74 ab	28 ab	18 ab	60 b	40 d	20 c	40 a	30 c	310 ab
SUPRIYA	90 ab	50 c	30 c	64 bc	12 a	30 d	46 ab	22 b	344 c
NHH44	84 ab	64 cd	24 b	44 a	48 e	18 b	52 c	40 d	374 d
SAVITHA	100 b	52 c	12 a	62 b	40 d	10 a	40 a	30 c	346 c
SURYA	72 ab	50 c	22 b	62 b	50	10	60	10	336 c
120 DAE									
LRA5166	62 c	48 e	20 c	44 b	24 d	12 a	50 d	22 d	282 c
LRK516	70 d	36 d	22 c	36 a	10 ab	16 ab	40 c	30 e	260 b

PAIYUR-1	50 b	60 f	10 a	52 c	21 cd	30 d	36 ab	10 c	269 bc
MCU-7	70 d	72 g	40 e	62 d	8 a	10 a	50 d	20 d	332 e
SUVIN	38 a	30 c	30 d	40 b	18 c	20 c	48 d	6 a	230 a
MCU5VT	40 a	20 a	14 b	60 d	42 g	24 c	60 e	20 d	280 c
SUPRIYA	50 b	38 d	20 c	74 e	36 f	30 d	72 f	8 ab	328 e
NHH44	64 c	24 ab	38 e	82 f	22 d	30 d	40 c	10 c	310 de
SAVITHA	70 d	28 c	40 e	50 c	28 e	24 c	50 d	20 d	310 de
SURYA	62 c	50 e	32 d	62 d	22 d	10 a	30 a	36 f	304 d

G.g.-*Glomus geosporum*; G.f.-*G. fasciculatum*; G.m.-*G. macrocarpum*; G. i.- *G. intraradices*; G.t.- *G. taiwanensis*; A.s.- *Acaulospora scrobiculata;* Sc.g. -*Scutellospora gregaria*; and Gig.m.- *Gigaspora margarita*.

Average of three replicates. Means followed by a common letter(s) in a row are not significantly different at 5% level according to DMRT

Published data; Damodaran et al., 2010

% RLV

At 30 DAE Supriya had maximum %RLV followed by NHH 44. Minimum % RLV was found in MCU 7 followed by Suvin (Fig. 1. a). At 60 DAE, % RLV was found maximum in LRK 516 followed by Supriya. Minimum % RLV was observed in MCU 7 and Paiyur-1. At 90 DAE MCU 5 VT showed maximum % RLV followed by Supriya, and the minimum % RLV was found in MCU 7. At 120 DAE, MCU 5 VT showed a maximum % RLV followed by Supriya. Minimum %RLV was found in Paiyur1 (19.6%).

% RLA

Root lengths with arbuscules (%RLA) were found right from 30 DAE (Fig. 1. b). %RLA was maximum at 30 DAE in Paiyur-1 followed by LRK 516. Minimum %RLA at 30 DAE was found in Suvin and Savitha. The % RLA was maximum in LRK 516 at 60 DAE, followed by Paiyur1. Minimum % RLA at 60 DAE was exhibited by Savitha followed by MCU 7. At 90 DAE, Supriya showed a maximum % RLA followed by Paiyur1 (3.1%). A minimum % RLA was found in Savitha. At 120 DAE, maximum % RLA was recorded in Paiyur-1 followed by LRK 516. Minimum % RLA was recorded in Surya followed by Savitha.

% RLC

Total root length colonization (%RLC) exhibited more or less a similar trend as AM fungal structures (Fig. 1. c). At 30 DAE % RLC was maximum in Supriya followed by LRK 516. Minimum %RLC at 30 DAE was observed in MCU 7 and Suvin. At 60 DAE LRK 516 had maximum %RLC followed by LRA 5166. Minimum %RLC at 60 DAE was found in MCU 7. At 90 DAE MCU 5VT had maximum %RLC followed by Supriya. Minimum %RLC was recorded in MCU 7. At 120 DAE, MCU 5VT had maximum % RLC than others, followed by LRA 5166. Minimum %RLC was found with MCU 7.

Through all the harvests, MCU 7 exhibited a significantly minimum mycorrhizal colonization differing from other cultivars. Non-mycorrhizal controls lacked mycorrhizal structures in their roots.

Plant height and root length

At 120 DAE, NHH 44 plants were significantly taller followed by Paiyur-1 (Table 2). Minimum shoot length was exhibited by Surya followed by LRA 5166. Non-mycorrhizal plants were significantly shorter compared to mycorrhizal plants. At 120 DAE, root length was found maximum in Suvin followed by LRA 5166 (Table 2). Minimum root length was found in Supriya followed by MCU-7. Among the non-mycorrhizal plants, Suvin had the maximum root length followed by Paiyur-1.

Plant dry weight

All the cotton cultivars were highly dependent on AMF. Non-mycorrhizal plants had significantly less plant biomass than the mycorrhizal plants. Paiyur-1 had maximum plant dry weight followed by LRA 5166 (Table 2). Minimum dry weight was exhibited by Savitha followed by MUC 7.

Tissue nutrient concentration

Tissue nitrogen concentration varied significantly among the varieties and hybrids. Maximum tissues N was in LRA 5166 followed by MCU 5 VT (Table 2). Minimum N concentration was observed in Savitha and Supriya. Tissue Phosphorus was found maximum in MCU 5 VT followed by LRA 5166. Minimum amount of Phosphorus was observed in MCU 7 and Savitha. No significant variation was evident in the case of tissue K in response to mycorrhizal association. Maximum K was observed in Suvin followed by Surya. Minimum K content was observed in Savitha followed by NHH 44.

Table 2 Growth and nutrient content of mycorrhizal (M) and non-mycorrhizal (NM) cotton cultivars at 120 days after emergence (DAE)

Cultivar	Shoot length (cm plant^{-1})		Root length (cm plant^{-1})		N (mg g^{-1})		P (mg g^{-1})		K (mg g^{-1})		Plant dry weight (mg plant^{-1})	
	M	NM	M	M	NM	M	NM	M	NM	NM	M	NM
LRA5166	15.0 ab	13.3 a	10.2 d	8.83 h	6.8 c	3.12 f	2.17 c	7.5 bc	7.4 b	9.6 c	4112.0 h	1128 g
LRK516	18.0 c	16.5 b	9.5 cd	8.35 f	7.2 d	2.98 ef	2.6d	7.6 cd	7.8 bc	9.7 c	4078.0 f	1069 f
PAIYUR-1	20.5d	17.6 c	15.2 f	7.80 c	6.9 c	2.40 c	2.25 c	7.9 de	7.5 b	15.4 f	4276.0 i	868 a
MCU-7	14.2 a	13 a	7.9 ab	7.70 bc	6.55 ab	1.70 a	1.68 a	8.0 e	7.9 cd	7.5 a	3817.0 b	912 d
SUVIN	17.0 bc	15.5 b	21.3 g	8.20 c	7.3 d	2.87 e	2.7 de	8.4 f	8.2 e	16.25 g	3914.0 c	1378 j
MCU5VT	18.0 c	16.3 b	14.9 ef	8.65 g	7.29 d	3.26 g	2.85 e	7.7 cd	8.15 de	13.9 d	4098.0 g	1212 h
SUPRIYA	16.9 bc	13.4 a	7.8 a	7.65 b	6.45 a	3.09 f	2.65 d	7.8 cde	7.9 cd	7.9 b	4017.0 e	1067 e
NHH44	21.0 d	16.6 bc	13.9 e	8.05 d	6.7 bc	2.60 d	1.96 b	7.3 ab	7.6 bc	14.8 e	3819.0 b	818 b
SAVITHA	17.2 bc	15.7 b	8.9 bc	7.15 a	7.35 d	1.95 b	1.6 a	7.0 ab	7.1 a	9.5 a	3689.0 a	1219 c
SURYA	14.2 a	13.4 a	22.0 g	8.60 g	7.15 d	3.07 f	2.16 c	8.1e	7.85 c	18.78 h	4009.0 d	680 a

Average of three replicates. Means followed by a common letter(s) are not significantly different at 5% level according to DMRT.

Table 3. Correlation between mycorrhizal colonization, plant biomass, tissue nutrients and biochemical changes in ten cotton cultivars

	% RLA	% RLV	% RLC	Shoot length	Root length	Plant dry weight	Tissue N	Tissue P	Tissue K	Mycorrhizal dependency	Root hair number	Root hair diameter	Root hair length
% RLA													
% RLV	-	-											
% RLC	-	0.871**											
Shoot length	-	-	-										
Root length	-	-		-									
Plant dry weight	-	-	0.899 **	-	-								
Tissue N	-	-	0.786**	-	-	-							
Tissue P	-	-	0.962**	-	-	-	0.812*						
Tissue K	-	-		-	-	-							
Mycorrhizal dependency	-	-	-	-	-	-	-	-	-		-0.948**	-	-0.852*
Root hair number	-	-	-	-	-	-	-	-	-	-			
Root hair diameter	-	-	-	-	-	-	-	-	-	-	-		
Root length	-	-	-	-	-	-	-	-	-	-	-	-	

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed). - Not significant

Root morphology and Mycorrhizal dependency

Root diameter was found maximum in NHH 44 followed by Suvin and minimum in LRK 516 and Paiyur-1 followed by LRA 5166 (Fig. 2). Root hair number was maximum in Suvin followed by Savitha and minimum in Paiyur-1 and NHH 44 followed by MCU 5 VT 7. Root hair length was maximum in LRA 5166, Suvin, MCU 5 VT and Savitha followed by LRK 516 and minimum in Paiyur-1 and Surya. Root hair diameter was not varied significantly among the cultivars. It was maximum in MCU 7 and minimum in Paiyur-1 and MCU 5 VT. Surya was highly mycorrhizal dependant followed by MCU 7. In contrast Suvin followed by Savitha were least mycorrhizal dependant (Fig. 3).

Discussion

This study shows significant variation in the extent of mycorrhizal association among different cultivars of cotton. Even though AM fungi are considered to be less host-specific and the results showed some critical differences in the association. The cotton cultivars exhibited mycorrhizal colonization ranging from 36.52 % to 73.05 % over the four harvests of 30 through 120 DAE under the same environmental conditions. Similar results were reported for pearl millet (Krishna et al. 1985). Studies on maize (Toth et al. 1990) and bean (Sutton 1973) inbreds showed that the differences in host genome can control the degree of mycorrhizal colonization. The two cotton cultivars, MCU-9 and MCU-7 varied in their mycorrhizal colonization levels (62.06 % and 67.6 % respectively) when inoculated with *Glomus geosporum* (Jaganathan 1996).

Mycorrhizal dependency is defined as the degree to which a plant is dependent on the mycorrhizal condition to produce its maximum growth or yield at a given level of soil fertility. In the present study, mycorrhizal dependency varied with different cultivars. Similar results were already reported (Smith and Goodman 1999; Siqueira and Saggin-Junior 2001). Mycorrhizal dependency was not correlated with mycorrhizal colonization, but negatively correlated with root hair number ($r = -0.948$; $P<0.05$; $n = 10$) and root hair length ($r= -0.852$; $P<0.01$; $n = 10$) (Table 3). The higher number of root hairs and longer root hair length might have attributed to the less mycorrhizal dependency of the cultivars. A recent study further showed that mycorrhizal dependency can vary greatly because of differential growth responses to specific AMF (van der Heijden et al. 1998).

Plant dry weight is influenced by AMF as a result of enhanced efficiency of resource acquisition by mycorrhizal plants. It is the process which in turn allows more energy to be allocated to growth and reproduction which potentially increases plant dry weight. In the present study plant dry weight at 120 DAE was found to be positively correlated with AM colonization for all the cultivars ($r=0.899$; $P<0.01$; $n = 10$). The efficiency of AM fungi in improvement of plant dry weight is a well known response (Camprubi et al. 1995; Charron et al. 2001; Sylvia et al. 2001).

Nitrogen is the most important mineral nutrient for plant growth. In the present study, total colonization and % RLH were positively correlated with tissue nitrogen content ($r = 0.786$; $P<0.01$; $n = 10$). An indirect uptake of nitrogen by AM fungal hyphae has been well documented (Smith and Gianinazzi-Pearson 1988; Ames et al. 1984; Barea et al. 1989). Ames et al. (1983) showed that more ^{15}N applied to the hyphal compartment was transported to mycorrhizal celery plants (*Apium graveolens*) than into non-mycorrhizal plants. AMF is known to possess enzymes that are involved in the

assimilation of ammonium (Smith et al. 1985) and nitrate (Ho and Trappe 1975). AM fungal hyphae might also enhance the host plant N acquisition by competing with other soil microorganisms for N released from organic particles (Bowen and Smith 1981).

The uptake of P by plants from soil is usually limited by the rate of phosphate movement in the soil rather than by the rate of absorption at the root surface (Nye 1977). In soil culture, mycorrhizal roots absorb P from labile pool by extending extramatrical hyphae beyond the P depletion zone in the vicinity of roots. In the present study, there existed a strong positive correlation between % RLC and tissue P concentration ($r = 0.962$; $p<0.01$; $n = 10$), which is strongly supported by various earlier studies. Cultivars with higher colonization levels had increased tissue P content compared to cultivars with lower colonization levels. The increased N and P status can be attributed to the role of extramatrical hyphae of AM fungi in making available the inaccessible nutrients available to the plant roots (Muthukumar and Udaiyan 1995).

No significant variation in plant K content was observed in relation to mycorrhizal colonization levels. This is supported by earlier reports, showing that AM association may not contribute to K uptake in plants (Dubsky et al. 2002). To conclude, this study clearly shows that there exist some host-dependant variations in AMF colonization among the cultivars of cotton. Further, the study shows a strong correlation between root characters and mycorrhizal colonization, which in turn attribute to mycorrhizal dependency.

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References

Ame R, Porter LK, St. Hohn TV, Reid CPP (1984) Nitrogen source and 'A' values of vesicular arbuscular and non-mycorrhizal sorghum grown at three rates of ^{15}N ammonium-sulphate. New Phytol 97: 269-276.

Ames RN, Reid CP, Porter LK, Cambardell C (1983) Hyphal uptake and transport of nitrogen from ^{15}N labeled sources of *Glomus mosseae* a vesicular – arbuscular mycorrhizal fungus, New Phytol 95:381-396.

Barea JM, El-Atrach F, Azcon R (1989) Mycorrhiza and phosphate interactions as affecting plant development, N_2-fixation, N-transfer and N-uptake from soil in legume-grass mixtures by using a ^{15}N dilution technique. Soil Biol Biochem 21: 581-589.

Barker SJ, Tagu D, Delp G (1998) Regulation of root and fungal morphogenesis in mycorrhizal symbioses. Plant Physiol 116: 1201- 1207.

Bever JD, Morton JB, Antonovics J, Schultz PA (1996) Host dependent sporulation and species diversity of arbuscular mycorrhizal fungi in a mown grassland. J Ecol 84:71–82

Bowen GD, Smith SE (1981) The effect of mycorrhizas on nitrogen uptake by plants. In: Terrestrial nitrogen cycle: processes, ecosystem strategies and management impacts. F.E. Clarke and T.Rosswell (Eds.) Ecol. Bull. Stockholm. 33: 237-247.

Camprubi A, Calvet C, Estaun V. (1995) Growth enhancement of *Citrus reshni* after

inoculation with *Glomus intraradices* and *Trichoderma aureoviride* and associated effects on microbial populations and enzyme activity in potting mixes. Plant Soil 173: 233-238.

Charron G, and Furlan V, Bernier-Cardou M, Doyon G (2001) Response of onion plants to arbuscular mycorrhizae (Effects of inoculation method and phosphorus fertilization on biomass and bulb firmness). Mycorrhiza 11: 187-197.

Clement CR, Habte M (1995) Genotypic variation in vesicular-arbuscular mycorrhizal dependence of the pejibaye palm. J Pl Nutr 18: 1907-1916

Damodaran P N, Udaiyan K and Jee H J (2010) Biochemical changes in cotton plants by Arbuscular Mycorrhizal colonization. Res in Biotech 1: 06-14

Dubsky M, Sramck F, Vosatka M (2002) Inoculation of cyclamen (*Cyclamen persicum*) and poinsettia (*Euphorbia pulcherrima*) with arbuscular mycorrhizal fungi and *Trichoderma harzianum*. Rost Vyroba 48, 63–68.

Giovannetti M, Sbrana C (1998) Meeting a non-host: the behaviour of AM fungi. Mycorrhiza 8: 123-130.

Gollotte A, Gianinazzi-Pearson V, Giovannetti M, Sbrana C, Avio Gianinazzi S (1993) Cellular localization and cytochemical probing of resistance reactions to arbuscular mycorrhizal fungi in a 'Locus a' myc-mutant of *Pisum sativam* L. Planta 191: 12-22.

Graham J H, Eissenstat D M (1994) Host genotype and the formation and function of VA mycorrhizae. Plant Soil 159:179–185

Hetrick B A D, Wilson G W T, Todd T C (1996) Mycorrhizal response in wheat cultivars: relationship to phosphorous. Can J Bot 74: 19-25.

Ho I, Trappe J M (1975) Nitrate reducing capacity of two vesicular-arbuscular mycorrhizal fungi. Mycologia 67: 886-888.

Itoh S and Barber S A (1983) Phosphorus uptake by six plant species as related to root hairs. Agron J 75: 457-464.

Jackson M L (1973) Soil Chemical Analysis. Prentice Hall of India (Pvt.) Ltd. New Delhi.

Jaganathan C (1996) Role of *Glomus geosporum* (Nicol. .& Gerd.) Walker and *Azospirillum brasilense* Terrand et al. on plant growth and control of Verticillium wilt in cotton (*Gossypium hirsutum* L.). (Ph. D. Thesis, Bharathiar University, Coimbatore 641 046, Tamil Nadu, India).

Jeffries P, Spyropoulous T, Vardavrkis E (1988) Vesicular - arbuscular mycorrhizal status of various crops in different agricultural soils of northern Greece. Biol. Fertil. Soils. 5: 333-337.

Klironomos J (2002) Host-specificity and functional diversity among arbuscular mycorrhizal fungi. http://plato.acadiau.ca/isme/symposium26/ Klironomos.pdf

Koide RT, Schreiner RP (1992) Regulation of the vesicular-arbuscular mycorrhizal symbiosis. Ann. Rev. Plant Physiol. and Plant Mol. 43: 557-581.

Koske R E and Gemma J N (1989) A modified procedure for staining roots to detect V-A mycorrhizas. Mycological Research 92: 486-488

Krishna KR, Shetty KG, Dart PJ, Andrews DJ (1985) Genotype dependent variation in mycorrhizal colonization and response to inoculation of Pearl millet. Plant Soil 86: 113-125.

McGonigle T P, Miller M H, Evans D G, Fairchild G L, Swan J A (1990) A new method which gives on objective measure of colonization of roots by vesicular - arbuscular mycorrhizal fungi. New Phytol. 115 : 495 - 501.

Muthukumar T, Udaiyan K (1995) Influence of vesicular arbuscular mycorrhiza and Rhizobium sp. on growth responses and nutrient status of *Tephrosia purpurea* Pers. Acta Bot. Indica. 23: 75-80.

Muthukumar T, Udaiyan K, Vasantha K, Kleiner D, Manian S (1999) Mycorrhizae in sedges as related to root character and its ecological significance. Pertanika J Trop Agric Sci 22(1): 9-17.

Nye R H (1977) The rate-limiting step in plant nutrient absorption from soil. Soil Sci 123: 292-293.

Peat H J, Fitter A H (1993) The distribution of arbuscular mycorrhizas oin the British Flora. New Phytol 125: 845-854

Piper C S 1966 Soil and plant analysis. Hans publications. Bombay.

Rich J R, Bird G W (1974) Association of early-season vesicular-arbuscular mycorrhizae with increased growth and development of cotton. Phytopath 64: 1421-1425.

Schenck N C, Perez Y (1987) Manual for the identification of VA mycorrhizal fungi. INVAM, University of Florida, Gainesville, Florida.

Siqueira J O, Saggin-Junior O J (2001) Dependency on arbuscular mycorrhizal fungi and responsiveness of some Brazilian native woody species. Mycorrhiza 11:245–255.

Smith G S, Roncadori R W (1986) Responses of three vesicular-arbuscular mycorrhizal fungi at four soil temperatures and their effects on cotton growth. New Phytol 104: 89-95.

Smith K P, Goodman R M (1999) Host variation for interactions with beneficial plant-associated microbes. Phyto-pathology 37: 473–491.

Smith S E, Gianinazzi-Pearson V (1988) Physiological interactions between symbionts in vesicular-arbuscular mycorrhizal plants. Ann. Rev. Plant Physiol. Plant Mol Biol 39: 221–244.

Smith S E, St.John B T, Smith F A, Nicholas D J (1985) Activity of glutamine synthetase and glutmate dehydrogenase in *Trifolium subterraneum* L. and *Allium cepa* L.: effects of mycorrhizal infection and phosphate nutrition. New Phytol., 99: 211-227.

Sutton J C (1973) Development of Vesicular-arbuscular mycorrhizae in crop plants. Can. J. Bot., 51: 2487-2493.

Sylvia D M, Chellemi D O (2001) Interactions among root-inhabiting fungi and their implications for biological control of root pathogens. Adv. Agron. 73: 1-33.

Toth R, Toth D, Starke D, Smith DR (1990) Vesicular-arbuscular mycorrhizal colonization in *Zea mays* affecting breeding for resistance to fungal pathogens. Can. J. Botany 66: 1039-1044.

van der Heijden M G A, Bolle, T, Wiemken A, Sanders I R (1998) Different arbuscular mycorrhizal fungal species are potential determinants of plant community structure. Ecology 79: 2082-2091.

Zar J H (1984) Biostatistical analysis. Englewood cliffs, N. J. : Prentice Hall, Inc.

AM fungal identification keys, available at http://invam.caf.wvu.edu.