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FULL-LENGTH RESEARCH ARTICLE

Arbuscular Mycorrhizal Fungi Status of Mango (*Mangifera indica*) Cultivars Grown in Typic Quartzipsamments Soil

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Abstract The role of Arbuscular mycorrhizal fungi (AMF) in improving plant health is well established. To understand the AMF status of mango cultivars in Typic Quartzipsamments soil, experiments were carried out in the mango orchard located at College of Agriculture, Padannakkad, Kerala Agricultural University. Five improved varieties and two hybrid varieties of mango were selected for AMF analysis. All the varieties selected for the study exhibited AMF root colonization, arbuscules and inter or intracellular vesicles. A total of ten AMF species belonging to five genera viz. *Acaulospora, Gigaspora, Claroideoglomus, Glomus* and *Sclerocystis* were isolated. Among the species identified, four species were of *Glomus*, two species of C*laroideoglomus* and *Sclerocystis* and one species each of *Acaulospora* and *Gigaspora.* The Simpson's index, Shannon index and evenness ranged from 0.80 ± 0.020 to 85 ± 0.02; 1.89 ± 0.03 to 2.09 ± 0.06; 0.74 ± 0.02 to 0.84 ± 0.04, respectively. The spore count showed a significant negative correlation with percentage of root colonization. There was no correlation observed with soil phosphorus content. These results revealed that arbuscular mycorrhizas are an important constituent in mango orchard and the high spore density and root colonization were most likely a selective adaptation toward sandy loam soil. All the species or each one of the species appeared to be generalists in Indian soil.

Keywords Typic Quartzipsamments soil · Mycorrhiza

Introduction

The advancing crop production technology, development of high fertilizer responsive crop varieties and pressure for intensive farming demand huge inputs, of which phosphatic fertilizers take a major share. Convincing evidences have pointed out that the mycorrhizal technology, which is relatively simple, low cost, easy to execute and largely of renewable sources, has a tremendous role to play in the present agriculture. Mango (*Mangifera indica* L.) is one of the most important perennial fruit crops cultivated in the Typic Quartzipsamments soil. Orchards are raised by directly planting seedlings in the main field or by planting grafts of improved varieties. In the process of production of grafted plants, the rootstocks are raised in nurseries in a controlled environment. This situation makes an ideal condition for manipulating the AM colonization in the rootstock and later benefits the entire plantation. To exploit the full potential of this technology, it is essential to evaluate the native biocoenosis of the fungi. This paper describes the experiments designed to assess the presence and diversity of Arbuscular mycorrhizal fungi (AMF) associated with mango trees naturally grown in Typic Quartzipsamments soil.

Materials and Methods

Study area

The mango orchard in the farm of College of Agriculture, Padannakkad, Kerala Agricultural University, was the

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Table 1 Physicochemical characteristics of sandy soil in Kasaragod district, Kerala

Physicochemical characteristics	
Soil order	Typic Quartzipsamments
Soil texture	Loamy sand
Sand	87.3%
Silt	3.1%
Clay	9.6%
pH	5.32
EC	0.1 dS/m
Organic carbon	0.48%
N	102.8 kg/ha
P_2O	537.7 kg/ha
K_2O	68.4 kg/ha

experimental site. The trees are more than 50 years old. The soil is Typic Quartzipsamments soil. The physiochemical characteristic of the soil is presented in Table 1. The average annual rainfall is 3633 mm. The minimum and maximum temperatures range from 23.6 to 31.2 °C.

Soil Sampling

Samples of rhizosphere soil and terminal feeder roots of mango trees of five improved varieties (Banganapalli, Alphonso, Firangiludva, Kalapadi and Neelum) and two hybrids (Himayuddin × Neelum and Himayuddin × Kalapadi) were collected from the orchard during the month of April 2017 for AMF analysis. The samples were collected from four corners on the base of each mango tree and mixed thoroughly, and the homogenized composite soil sample of approximately 500 g was made for analysis. The experiment was replicated thrice.

Root Colonization and Spore Count

The root samples were fixed in FAA solution and stored at room temperature until sample could be processed. The root samples were washed in running tap water, cut into small pieces (ca. 1 cm) and stained with 0.05% trypan blue as per the procedure described by Kormanik and McGraw [17]. The stained root samples were observed under ZEISS compound microscope for the presence of AM fungi. The AMF spores and sporocarps were extracted from 10 g rhizosphere soil using the wet sieving and decanting method [9] and count expressed as spores per 10 g of soil. The morphological properties of the spores and their subcellular structures were determined in spores mounted on a slide in a drop of polyvinyl alcohol/lactic acid/glycerol (PVLG) and in a mixture of PVLG/Melzer's reagent. Observation of AMF spore characteristics was performed using a ZEISS compound microscope. The identification was based on spore color, size, surface ornamentation, and wall structure [2, 20] with reference to the identification manual of Schenk and Perez [28] and originally published species descriptions and emendation and also new classifications available at http://invam.wvu.edu/collection,http://schuessler.userweb.mwn.de/amphylo/,http://www.zor.zut.edu.pl/Glomeromycota/index.html [23].

Diversity Indices

The diversity of AM fungi was assessed based on diversity indices: Relative abundance is expressed as the number of spores of different AMF species as percentage of the total number of spores. Frequency occurrence was calculated as the percentage of soil samples in which a species occurred, which revealed the extent of distribution of a given AMF species in an ecosystem [5]. Simpson's index (Ds) = $1 - (\Sigma ni(ni\text{-}1)/N(N-1)$ where 'ni' is the number of individual species 'ith' species and N is the total number of species [31]. Shannon index $H' = -\Sigma piln(pi)$ where pi' is the proportion of individual that species contribute to total [30], and evenness was expressed by $J = H'/H'max$, where H'max is the maximum value of diversity for the number of species present [24].

Soil Physicochemical Factors

Soil physical and chemical analyses were performed in triplicate for all soil samples. Soil moisture content was measured using the drying method, soil pH was determined with a glass electrode in a ratio of soil to distilled water of 1:2.5, soil organic carbon was evaluated with the potassium dichromate oxidation method [35], total nitrogen content was evaluated using the Kjeldahl procedure [21], and available phosphorus was extracted with 0.5 mol/L of sodium bicarbonate and determined using the Mo–Sb spectrophotometry method [22].

Correlation Analysis

Pearson correlation analysis was used to determine the relationship between AMF spore count, root colonization, diversity indices and soil physicochemical factors using SPSS Base 20.0 (SPSS, Cary, N.C.).

Results

Root Colonization and Spore Count

Microscopic observation of root samples showed the presence of extensive hyphal, vesicular and arbuscular

Table 2 Spore count and root colonization of AM fungi (mean ± S.E.) associated with seven mango varieties from the orchards at College of Agriculture, Padannakkad, Kasaragod district, Kerala, India

Cultivar	F%	M%	m%	Spore count
Banganapalli	$78.67 \pm 3.67_{ab}$	29.27 ± 9.59	35.80 ± 12.32	$129.67 \pm 12.19_{abc}$
Alphonso	$84.00 \pm 3.67_{a}$	27.70 ± 9.59	32.60 ± 12.32	$122.33 \pm 12.19_{bc}$
Firangiludva	$65.33 \pm 3.67_{c}$	16.33 ± 9.59	25.40 ± 12.32	$157.33 \pm 12.19_{ab}$
Kalapadi	$80.00 \pm 3.67_{ab}$	26.53 ± 9.59	35.40 ± 12.32	$110.00 \pm 12.19_{c}$
Neelum	$70.67 \pm 3.67_{bc}$	21.00 ± 9.59	29.80 ± 12.32	$168.00 \pm 12.19_{a}$
Himayuddin x Neelum	$70.67 \pm 3.67_{bc}$	17.5 ± 9.597	24.80 ± 12.32	$117.00 \pm 12.19_{c}$
Himayuddin x Kalapadi	$78.67 \pm 3.67_{ab}$	30.50 ± 9.59	38.37 ± 12.32	$104.00 \pm 12.19_{c}$

F% Root colonization of percentage; *M%* intensity of the mycorrhizal colonization in the root system; *m%* intensity of the mycorrhizal colonization in the root fragments

Values in the same column followed by different letters are significantly different from each other ($p < 0.05$). Values in columns without letters are not significantly different ($p < 0.05$)

stages of AMF colonization. The presence of AM fungal spores was also detected within the roots of some samples. All the seven varieties selected for the study exhibited AMF root colonization arbuscules and inter- or intracellular vesicles. Frequency of root colonization of AMF, intensity of the colonization in the root system and intensity of the mycorrhizal colonization in the root fragments significantly varied. The frequency of root colonization of AMF in the roots of different cultivars ranged from 65.33 to 84 percent, the intensity of the mycorrhizal colonization in the root system (M %) ranged from 16.33 to 30.5 percent, and intensity of the mycorrhizal colonization in the root fragments (m %) ranged from 24.8 to 38.37 percent. The extent of occurrence of vesicles, arbuscules and hyphal infection formed in the roots varied in mango varieties. According to the frequency of percentage of root colonization of AMF on the roots of mango varieties, rated as Alphonso > Kalapadi >Banganapalli = Himayuddin × Kalapadi > Neelum = Himayuddin × Neelum > Firangiludva. The total spore count of AM fungi varied significantly in different mango varieties, ranging from 104 to 168 per 10 g soil. The highest spore count was observed in the rhizosphere soil of the variety, Neelum. Least spore count was observed in Himayuddin × Kalapadi. The data are presented in Table 2.

Species Diversity

Morphological characterization of AMF spores based on the new classification of Schubler and Walker [29] revealed a total of ten AM fungal species belonging to five genera viz. *Acaulospora, Gigaspora, Claroideoglomus, Glomus* and *Sclerocystis* (Fig. 1). Among the species identified, four species were *Glomus*, two species of C*laroideoglomus* and *Sclerocystis* and one species each of *Acaulospora* and *Gigaspora.* The list of all species identified and their frequencies of occurrence and relative abundance are presented in Table 3. Among the species of AM fungi recorded, *Acaulospora scorbiculata, Gigaspora margarita, Claroideoglomus etunicatum, Glomus boreale, G. aggregatum, Sclerocystis sinuosa* and *S. liquidambaris* had 100 percent species occurrence followed by *Glomus macrocarpum* (85.7%) and then by *Glomus flavisporum* (71.4%). *Claroideoglomus claroideum* (57.1%) had low level of occurrence. The relative abundance of AM fungal species in the rhizosphere region of mango varieties varied significantly. *Clarideoglomus etunicatum* was the most dominant species isolated from all the mango varieties.

Diversity indices

The data on Simpson's index of diversity (Ds), Shannon's diversity index (Hs) and Shannon evenness (J) are presented in Table 4. The result showed that diversity index varied significantly except Shannon's evenness in mango varieties. The index of Ds, Hs, and J varied from 0.80 ± 0.020 to 85 ± 0.02; 1.89 ± 0.03 to 2.09 ± 0.06; 0.74 ± 0.02 to 0.84 ± 0.04, respectively. In cases of general diversity indices, values of 2.09 ± 0.06 observed in the rhizosphere mango variety Firangiludva and the values of general diversity indices of other varieties are on par with Firangiludva except the varieties Banganapalli and Neelum. Thus, diversity of AMF species was on par with all four mango varieties, except Banganapalli and Neelum. There was no significant difference observed in the species evenness in mango varieties.

Rhizosphere soil samples showed the presence of abundant population of bacteria, fungi and actinomycetes. The different functional groups of bacteria such as nitrogen fixing bacteria, phosphate-solubilizing bacteria and fluorescent Pseudomonas were present in the soil. The population of soil microflora varied significantly in the mango varieties. The data are presented in Table 5.

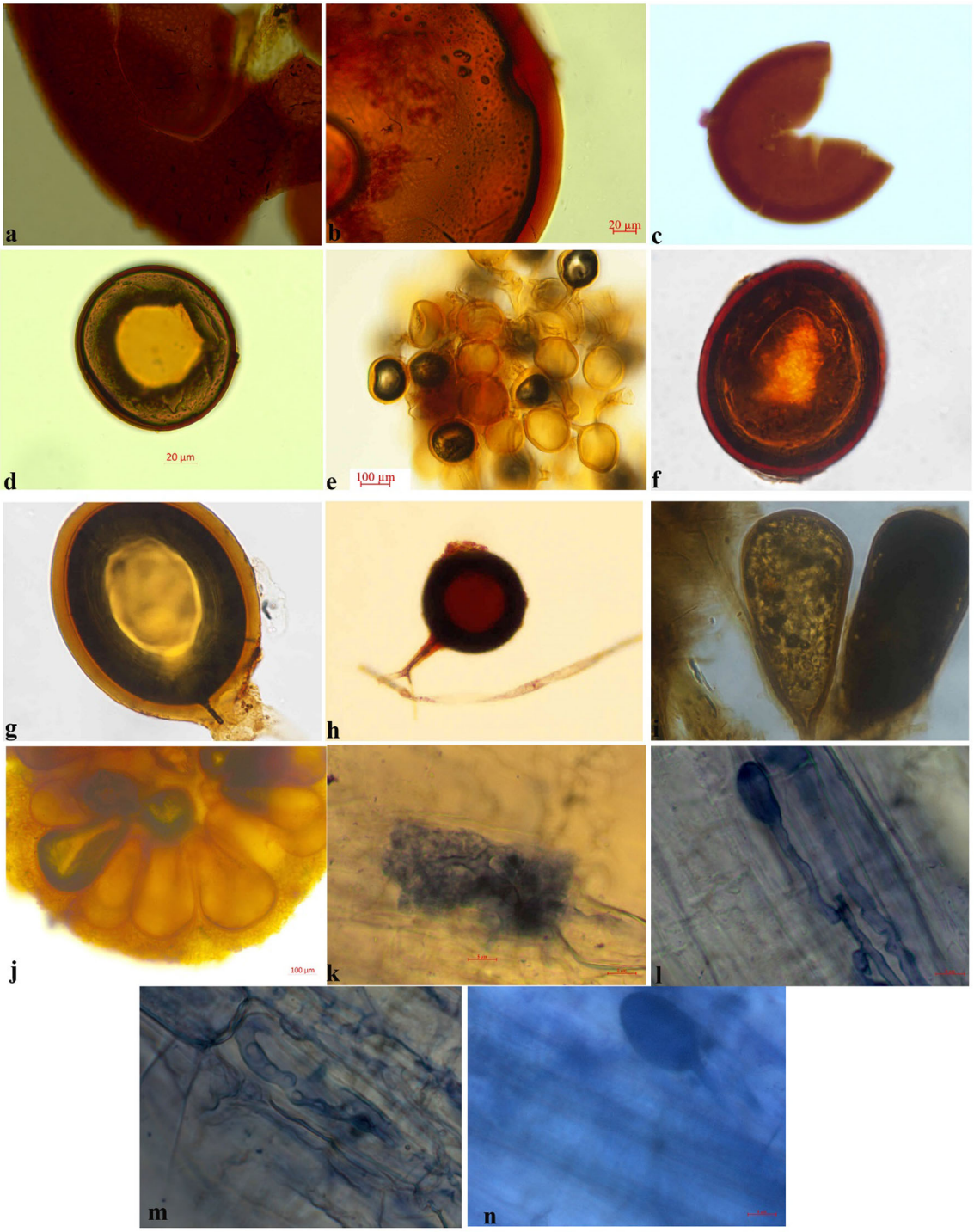

Fig. 1 **a** *Acaulospora scorbiculata,* **b** *Gigaspora margarita,* **c** *Claroideoglomus claroideum,* **d** *Claroideoglomus etunicatum,* **e** *Glomus aggregatum,* **f** *Glomus boreale,* **g** *Glomus flavisporum,* **h** *Glomus macrocarpum,* **i** *Sclerocystis sinuosa,* **j** *Sclerocystis liquidambaris,* **k** arbuscules, **l**, **n** vesicles, **m** coiled hyphae

Soil Edaphic Factors

The physicochemical properties of soil sample collected from the seven mango varieties significantly varied from each other. The data are presented in Table 6. The soils were slightly acidic in reaction (the pH between 6.17 and 6.6). Soil moisture content ranged from 1.03 ± 0.32 to 5.87 ± 0.15. The electrical conductivity (EC) ranged from 26.7 to 63.3 µs, salinity from 0.02 to 0.04, total dissolved solid from 13.53 to 31.3, organic carbon from 0.21 ± 0.01% to 1.23 ± 0.04%,

Table 3 Frequency of occurrence and relative abundance of AM fungal species associated with seven mango varieties from the orchards in the College of Agriculture, Padannakkad, Kasaragod district, Kerala, India

AM fungal species	Frequency of occurrence of AM fungal species	Relative abundance of AM fungal species						
		M1	M2	M3	M4	M5	M6	M7
Acaulospora scorbiculata	100.0	7.2c	7.1b	6.3cd	8.7bc	4.8c	5.4cd	4.5d
Gigaspora margarita	57.1	5.3c	5.3b	4.0d	6.6bc	5.9bc	5.4cd	4.1d
Claroideoglomus claroideum	71.4	4.6c	–	–	5.2c	6.7bc	5.7cd	–
Claroideoglomus etunicatum	100.0	25.3a	33.3a	33.3a	25.0a	28.9a	36.0a	31.1a
Glomus aggregatum	100.0	20.2b	11.5b	8.1bcd	12.3bc	10.6bc	6.8bcd	6.7d
Glomus boreale	100.0	7.9c	11.4b	7.0bcd	8.1bc	7.9bc	4.4d	3.8d
Glomus flavisporum	85.7	8.1c	6.5b	6.1cd	6.5bc	–	–	4.3d
Glomus macrocarpum	100.0	7.8c	8.6b	12.4b	–	9.9bc	10.9bcd	12.5c
Sclerocystis sinuosa	100.0	6.9c	8.9b	10.9bc	13.2b	13.0b	12.0bc	15.2bc
Sclerocystis liquidambaris	100.0	6.7c	11.5b	12.0b	14.3b	12.3bc	13.5b	17.9b

M1 Firangiludva, *M2*- Alphonso, *M3* Himayuddin x Neelum, *M4* Kalapadi, *M5* Himayuddin x Kalapadi, *M6* Banganapalli, *M7* Neelum

Values in the same column followed by different letters are significantly different from each other ($p < 0.05$). Values in columns without letters are not significantly different ($p < 0.05$)

Table 4 Diversity indices of AM fungal species associated with seven mango varieties from the orchards in the Collage of Agriculture, Padannakkad, Kasaragod district, Kerala, India

Cultivar	Species richness	Simpson_1-D(Ds)	Shannon_H(Hs)	Evenness_e^H/S (J)
Banganapalli	9	0.80 ± 0.02b	1.89 ± 0.03b	0.74 ± 0.02a
Alphonso	9	0.83 ± 0.03ab	1.99 ± 0.10ab	0.81 ± 0.08a
Firangiludva	10	0.85 ± 0.02a	2.09 ± 0.06a	0.81 ± 0.05a
Kalapadi	9	0.85 ± 0.01a	2.02 ± 0.05ab	0.84 ± 0.04a
Neelum	9	0.82 ± 0.02ab	1.92 ± 0.05b	0.76 ± 0.04a
Himayuddin x Kalapadi	9	0.84 ± 0.03ab	1.99 ± 0.11ab	0.82 ± 0.10a
Himayuddin x Neelum	9	0.82 ± 0.02ab	1.96 ± 0.06ab	0.79 ± 0.05a

Values in the same column followed by different letters are significantly different from each other ($p < 0.05$). Values in columns without letters are not significantly different

Table 5 Beneficial microflora of rhizosphere soil sample of seven mango varieties from the orchards in College of Agriculture, Padannakkad, Kasaragod district, Kerala, India

Cultivar	Bacteria	Actinomycetes	Bacillus sp	N fixer	P solubilizer	F Pseudomonas	Fungi
Banganapalli	7.6 ± 08ab	2.5 ± 07b	4.1 ± 05c	3.3 ± 06bc	3.3 ± 11bc	3.3 ± 06a	3.3 ± 06c
Alphonso	7.3 ± 08bc	2.5 ± 07b	4.3 ± 05ab	3.2 ± 06bc	2.9 ± 11c	3.2 ± 06bc	2.9 ± 06d
Firangiludva	7.2 ± 08c	2.7 ± 07ab	4.3 ± 05a	3.3 ± 06b	2.9 ± 11bc	3.3 ± 06ab	2.9 ± 06bc
Kalapadi	7.3 ± 08c	2.7 ± 07ab	4.2 ± 05abc	3.1 ± 06bc	3.4 ± 11a	3.1 ± 06c	3.4 ± 06abc
Neelum	7.6 ± 08a	2.5 ± 07b	4.2 ± 05abc	3.6 ± 06a	3.3 ± 11a	3.6 ± 06abc	3.3 ± 06a
Himayuddin x Kalapadi	7.2 ± 08c	2.9 ± 07a	4.1 ± 05bc	3.1 ± 06bc	3.1 ± 11abc	3.1 ± 06a	3.1 ± 06ab
Himayuddin x Neelum	7.4 ± 08ab	2.5 ± 07b	4.2 ± 05abc	3.1 ± 06c	2.5 ± 11d	3.1 ± 06a	2.5 ± 06bc

Values in the same column followed by different letters are significantly different from each other ($p < 0.05$). Values in columns without letters are not significantly different ($p < 0.05$)

nitrogen content from 0.084 % to 0.34 %, available phosphorous from 45.68 ± 0.47 ppm to 76.34 ± 0.64 ppm, available potassium from 20.40 ± 0.21 ppm to 34.08 ± 0.29 ppm. Significant differences were observed in the soil physicochemical properties.

Correlation Analysis

The correlation between spore count and root colonization parameters with soil edaphic factors is given in Table 7. The spore count showed a significant negative correlation

Table 6 Physiochemical characteristics of root region of soil sample of seven mango varieties from the orchards in College of Agriculture, Padannakkad, Kasaragod district, Kerala, India

Mango variety	PH	Soil moisture content (%)	EC (µs)	TDS mg/l	Salinity (µs)	OC (%)	N (%)	P (ppm)	K (ppm)
Banganapalli	$6.40 \pm 0.03_b$	$3.20 \pm 0.10c$	$34.53 \pm 0.39_d$	$17.27 \pm 0.28_d$	$0.02 \pm 0.001_c$	$1.23 \pm 0.04a$	0.250ab	$52.66 \pm 0.70e$	$32.71 \pm 0.27a$
Alphonso	$6.30 \pm 0.03_c$	$1.47 \pm 0.38e$	$26.70 \pm 0.39f$	$13.53 \pm 0.28_e$	$0.02 \pm 0.001_c$	$0.45 \pm 0.03d$	0.094b	$55.18 \pm 1.13d$	$21.79 \pm 0.31e$
Firangiludva	$6.60 \pm 0.03_a$	$2.50 \pm 0.30d$	$39.30 \pm 0.39_c$	$19.10 \pm 0.28_c$	$0.03 \pm 0.001_b$	$0.21 \pm 0.01f$	0.084b	$45.68 \pm 0.47f$	$23.65 \pm 0.23d$
Kalapadi	$6.40 \pm 0.03_b$	$5.87 \pm 0.15a$	$63.30 \pm 0.39_a$	$31.30 \pm 0.28_a$	$0.04 \pm 0.001_a$	$1.22 \pm 0.02a$	0.340a	$76.34 \pm 0.64a$	$29.78 \pm 0.28b$
Neelum	$6.30 \pm 0.03_c$	$1.20 \pm 0.10e$	$41.83 \pm 0.39_b$	$20.90 \pm 0.28_b$	$0.03 \pm 0.001_b$	$0.95 \pm 0.03b$	0.109b	$73.12 \pm 0.69b$	$19.82 \pm 0.51f$
Himayuddin x Neelum	$6.60 \pm 0.03_a$	$3.83 \pm 0.35b$	$28.73 \pm 0.39_e$	$14.37 \pm 0.28_e$	$0.02 \pm 0.001_c$	$0.35 \pm 0.03e$	0.095b	$69.84 \pm 0.25c$	17.44 ± 0.20 g
Himayuddin x Kalapadi	$6.17 \pm 0.03_d$	$1.03 \pm 0.32e$	$27.37 \pm 0.39_f$	$13.57 \pm 0.28_e$	$0.02 \pm 0.001_c$	$0.55 \pm 0.03c$	0.233ab	$45.80 \pm 0.67f$	$25.13 \pm 0.45c$

EC Electrical conductivity, *TDS* total dissolved solids, *OC* organic carbon, *N* nitrogen, *P* phosphorous, *K* potassium

Values in the same column followed by different letters are significantly different from each other ($p < 0.05$). Values in columns without letters are not significantly different ($p < 0.05$)

with the percentage of root colonization. The percentage of root colonization showed a negative correlation with soil pH, electrical conductivity, salinity, but a positive correlation was observed in organic carbon, potassium and moisture content. There was no correlation observed with soil phosphorus content. The spore count showed a positive correlation with soil edaphic factors pH, electrical conductivity, total dissolved solid content and salinity. The soil nitrogen, potassium and soil moisture content showed a negative correlation with spore count. The relation between soil microflora and AM fungal status is given in Table 8. The root colonization showed a positive correlation with population of Actinomycetes, Bacillus and P solubilizers; on the other hand, it showed a negative correlation with population of bacteria, nitrogen fixers, fluorescent Pseudomonas and fungi. Spore count showed a significant positive correlation with nitrogen fixers. The population of actinomycetes showed a negative correlation with spore count.

Discussion

Spore Density and Root Colonization

The results obtained in this study are in agreement with the earlier report of AMF root colonization (67.43%) from the roots of naturally occurring mango trees in hills of Aliyar, Anamalai range of Western Ghats, Southern India [34], but in contrast with Lakshman et al. [18], Abul and Khan [10] and Khanam [16] who observed 25%, 27% and 30% root colonization of mango species, respectively, from deciduous forests of Karnataka, India, Mango orchards in UP, India, and the horticultural farm in Bangladesh.

The results of the present study show that the frequency of root colonization of AMF in the mango cultivars ranged from 65.33 to 84 percent. One of the possible reasons could be the maintenance of a higher inoculum potential in the surrounding soil as reported by Pagano et al. [23]. Furthermore, the degree of AM fungal root colonization by native AMF was significantly varied among the mango varieties, similar to the findings of Karangiannidis et al. [13]. As far as the percentage of AM fungal root colonization in the roots of woody plants is concerned, it differs with respect to locality [8]. Moreover, the differential performance of the native AMF species to mango cultivars could be attributed to the significant variation of root colonization [15]. Researchers have established that the root colonization of AMF is genetically controlled [14, 19, 26].

In the study, there is no significant correlation in the AMF root colonization parameters and available soil P, which was in agreement with the previous study of Songachan and Kayang [32], Ruotsalainen et al. [27] and

Table 7 Pearson correlation coefficients of spore count, percentage of root colonization, with soil physicochemical characteristics of soil sample

	Spore count	pH	EC	TDS	Salinity	OC	N	P	K	Soil moisture content
F %	− 0.318	− 0.42	− 0.02	0.011	− 0.05	0.31	0.31	0	0.33	0.05
M %	− 0.529*	− 0.23	− 0.043	− 0.046	− 0.08	0.2	0.43	− 0.08	0.20	− 0.02
m %	− 0.508*	− 0.12	0.01	− 0.002	− 0.03	0.2	0.41	− 0.046	0.16	0.01
Spore	–	0.18	0.07	0.082	0.15	− 0.1	− 0.42	0.02	− 0.20	− 0.31

EC Electric conductivity, *OC* organic carbon

Statistically significant results are indicated with asterisks (*$p < 0.05$; **$p < 0.01$)

Table 8 Pearson correlation coefficients of AMF with other rhizosphere microflora

	Bacteria	Actinomycetes	Bacillus	N fixer	P solubilizers	Fluorescent pseudomonas	Fungi
F %	− 0.04	0.11	0.08	− 0.15	0.01	− 0.29	− 0.27
M %	− 0.2	0.09	− 0.14	− 0.17	0.08	− 0.08	− 0.26
m %	− 0.22	0.09	− 0.16	− 0.16	0.1	-0.08	− 0.20
Spore count	0.38	− 0.19	0.41	0.78**	0.32	0.10	0.20

Statistically significant results are indicated with asterisks (**$p < 0.01$)

Becerra et al. [4]. One reason for the lack of correlation could be that the plants took up P from a larger soil volume when part of the fine roots were likely to have reached a larger volume than the sample size. AM colonization also may be affected by plant internal P status. Where this is sufficient, there is no need for effective uptake through mycorrhiza. The plant internal N/P ratio may also influence symbiosis, because if N is a limiting factor, there may be no need to invest in AM, which mainly enhances P uptake [33].

AMF spore densities recorded in the study showed a significant variation in different mango varieties ranging from 104 to 168 per 10 g soil. The highest spore count was observed in the rhizosphere soil of the variety, Neelum, and the least spore count was observed in Himayuddin × Kalapadi. Johnson et al. [12] reported that high spore count is an indication of soils mycorrhizal inoculum potential. Spore density level reported in this study is much higher than the value reported by Abul and Khan [10] who recorded from 6.4 to 31.44 per 10 g soil in mango orchards of different age groups in six districts of Uttar Pradesh, India. In another study on AM fungi associated with six varieties of *Carica papaya* L. in tropical agro-based ecosystem of Goa, India, Khade and Rodrigues [15] reported that variation of AMF spore density may be seen. The difference in AM fungal spore density between the samples could be due to difference in microclimate and edaphic properties and host specificities between fungi and woody plants, disturbance and differential sporulation ability of AM fungal taxa [11].

Species Diversity

Below ground diversity is an essential component of a healthy ecosystem [6]. More diverse AMF communities would be able to exhibit greater adaptability and flexibility in response to variation of environmental conditions over space and time [7]. Our result showed that the mango cultivar orchard harbors diverse AMF communities. The number of AM fungal species recovered from the cultivars ranged from 9 to 10. Species richness was highest in cultivar Firangiludva. There are five AM fugal genera, namely *Acaulospora, Gigaspora, Claroideoglomus, Glomus* and *Sclerocystis* isolated from the rhizosphere soil of mango cultivars.

In the present study, the presence of AM fungal species agrees with the other study reports conducted at different parts of India. The AMF species recorded in the present study are commonly occurring in Kerala and have wide distribution in India [3, 25]. Seven species, i.e., *Acaulospora scorbiculata, Gigaspora margarita, Claroideoglomus etunicatum, Glomus boreale, G. aggregatum, Sclerocystis sinuosa* and *S. liquidambaris*, were identified from all the mango cultivars. The results when compared with the previous studies indicted all the species or each species alone appeared to be generalists in Indian soil [25]. *Claroideoglomus etunicatum* was the dominant species recorded in our study. The knowledge of the AMF species diversity in mango varieties in sandy soil is important for the reason that the AMF species may significantly contribute in the functionality of the ecosystem and these ecosystem which are an important source of AMF germplasm [1]. These species grow well under sandy soil. These

results reveals that arbuscular mycorrhizas are an important constituent in mango orchard and the high spore density and root colonization were most likely a selective adaptation toward sandy loam soil.

Conclusions

The present study reveals the abundance of AMF colonization in mango trees grown in Typic Quartzipsamments soil. A total of 10 species of AM fungi belonging to five genera viz. *Acaulospora, Gigaspora, Claroideoglomus, Glomus* and *Sclerocystis* were detected in the rhizosphere soil of mango. All the species or each species alone appeared to be generalists in Indian soil. There was no significant difference observed in the species richness and diversity indices in mango varieties. This study also reveals that there is no correlation with soil phosphorus content. The AMF species may significantly contribute to the nutrient mobilization in mango as well as to the functionality of ecosystem and crop diversity observed in the tropical climate.

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