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Arbuscular Mycorrhizal (AM) Diversity in *Acacia nilotica* subsp. *indica* (Benth.) Brenan under Arid Agroecosystems of Western Rajasthan

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Abstract

Arbuscular mycorrhizal (AM) fungi associated with *Acacia nilotica* subsp. *Indica* (Babul) were assessed for their qualitative and quantitative distribution from nine districts of Rajasthan. A total of one species of *Acaulospora*, two species of *Gigaspora*, seventeen species of *Glomus*, four species of *Sclerocystis* and two species of *Scutellospora* were recorded. A high diversity of AM fungi was observed and it varied at different study sites. Among these five genera, *Glomus* occurred most frequently. *Glomus fasciculatum*, *G. aggregatum*, and *G. mosseae* were found to be the most predominant AM fungi in infecting *A. nilotica* subsp. *indica*. *G. fasciculatum*, *Sclerocystis* was found in all the fields studied, while *Gigaspora* species and *Scutellospora* species were found only in few sites. The more number (26) of AM fungal species were isolated and identified from Pali whereas, only eleven species (11) were found from Barmer. The spore density was varied between 163 to 480 propagules (100 g^{-1}) soil. The per cent root colonization was varied (40 to 78 %) from place to place. The pH of study area was ranged between 7.58 to 8.69; EC was recorded from 0.09 to 0.73 (dSm^{-1}); per cent OC ranged from 0.09 to 0.50 and available P content varied from 3.81 to 5.12 mg kg^{-1} for *A. nilotica* subsp. *indica*. A significant correlation of AM population was observed with root colonization and per cent organic carbon while other variables studies had a non-significant correlation with total AM population.

Keywords: Arbuscular mycorrhizae; arid agroecosystems; diversity; root colonization; correlation; *A. nilotica* subsp. *Indica*.

Introduction

Acacia nilotica (Mimosaceae) locally known as Babul is multipurpose tree species occurring throughout arid and semi-arid regions of the country. The species is well adapted to the harsh bio-physical and climatic conditions. In Rajasthan, the species occurs in most part of the state (northern and central regions) but it avoids extreme arid conditions (Gupta, 1970). In its native ranges, it is widely used in agroforestry, social forestry, reclamation of wastelands, and rehabilitation of degraded forests. In traditional agroforestry systems, *A. nilotica* provides fuel, fodder, gum, tannin, and timber (Pandey et al., 1999; Pandey and Sharma, 2003). Root nodulations in this species help in biological nitrogen fixation (Dreyfus and Dommergues, 1981) and enhance soil fertility (Pandey and Sharma, 2003). Its bark has a tannin content of greater than 20 % and pods without seeds have 18-27 % tannin content. It is strong, hard and tough and it takes up a good polish. Its colour is whitish red. The young branchlets of this sub-species (indica) may vary from sub-glabrous to thinly pubescent. Pods are arranged necklace like, narrowly clogged between the seeds and are densely white-tomentose. It is used for such products as building purposes, agricultural

instruments, spokes, wheels of bullock cart, oil presses, tent pegs, tool handles, and well curbs etc. *A. nilotica* subsp. *indica* prefers alluvial soil, low to moderate rainfall and considerable amount of soil moisture for its survival and growth. However, it is drought resistant and suitable for marginal land planting.

Arbuscular mycorrhizal (AM) fungi are major component of rhizosphere micro-flora in natural ecosystems. Accumulating evidence indicate that mycorrhizal association plays a significant role in decomposition of soil organic matter, mineralization of plant nutrients and nutrient recycling (Tarafdar and Rao, 1997; Pare et al., 2000). Mycorrhizal plants have greater ability to absorb nutrients, soil water, and an increased plant fitness, which may lead to better survival under stressed environmental conditions (Sylvia and Williams, 1992). The population pattern of AM fungi varies greatly and their diversity is affected by various factors including soil, environmental condition, host plant and agricultural practices (McGonigle and Miller, 1996). Plants infected with AM fungi get more easily established on disturbed sites through improved mineral nutrition (Shiffestin and Medve, 1979) and provide a primary mechanism for phosphorous uptake from the soil (Hayman, 1982). The geographic distribution of AM fungal species influenced by edaphic factors, plays an important role for their distribution. Although a large number of factors affect in predicting levels of indigenous AM population but to understand mycorrhizal dynamics, identification and quantification are necessary. Keeping this objective in view the present study was undertaken to analyse the mycorrhizal status in *A. nilotica* subsp. *indica* and to study the number of species and population of mycorrhizal fungi present at different sites and their ability of infection on *A. nilotica*.

Materials and Methods

The study was conducted in natural and planted stands of *A. nilotica* subsp. *indica* located in different parts of western Rajasthan of India. Periodical survey for *Acacia nilotica* subsp. *indica* plantations were undertaken to collect rhizosphere soil samples and roots from ecologically different sites *viz*. ,Barmer, Bikaner, Jodhpur, Ganganagar, Hanumangarh, Sikar, Nagaur, Pali and Sirohi district of western Rajasthan state. The samples were taken from Servede, Kudi, Tapra, Badu Ka Kalan, Payla Kalan and Bhandiavas (Barmer);10KJD, 62RD-KYD-Khajuwala (Bikaner); Banar, Chopasni, Gudavishnoion, Jhalamand, Mogra (Jodhpur); Lalpura, 4KSD, 7MD, 8P and 2GSM-Gharsana (Ganganagar); Jandawali minor, 2JRK-Khunja, Rorawali, 9Chuk-Rorawali, Dholipal (Hanumangarh); Ramu ka bas, Gorian (Piprali), Ranoli, Badahala Ki Dhani (Palsana), Chohano ki dhani (Sikar); Gothari, Kathoti, Jhareli and Nagri (Nagaur) Khivandi, Sumerpur, Muth, Sojat road and Mandia (Pali); Uthman, Khambal, Rampura, Udvaria and Anadera (Sirohi) district. Fifteen samples were taken from each place. The samples were processed for isolation, identification of Arbuscular mycorrhizal (AM) fungi associated with *A. nilotica* subsp. *indica*. These data were further used to develop relationships between AM fungi and soil parameters. The collection of rhizosphere soil samples and roots were done at the time (July to September) when the spore built up is the maximum (Verma, 2005). Tree with average girth diameter at breast height 21.25 + 1.55 cm were taken for study. Samples were collected at the base of five trees, which were selected, at random. Fifteen rhizosphere soil samples were taken from each site in sealed polythene bags. The soil sampling was done at a depth of 30 cm under the canopy of the standing trees and were analysed for soil pH, Electrical conductivity (EC), organic carbon (OC) and phosphorous (P) contents.

Roots were separated from collected soil samples and assayed for AM fungal association after staining in Trypan blue as described by Phillips and Hayman (1970). A total of 100 root segments were examined for each replicate and percentage of segments with colonization was calculated. The AM fungal infection was examined by using Optiphot-2 “Nikon” compound microscope. The Percentage of root infection was determined by Giovannetti and Mosse, (1980). AM spores were isolated by wet sieving and decanting technique (Gerdemann and Nicolson, 1963). Semi-permanent slides were prepared by mounting the spores in lactophenol or polyvinyl lactophenol. The photographs were taken by Nikon Optiphot-2 compound microscope. The spore density was expressed in terms of the number of spores per 100 g of soil. The spores were identified on the basis of colour, shape, size, surface, nature of spore cell wall and hyphal attachment with the help of synoptic keys of the Schenck and Perez (1987) and Raman and Mohankumar (1988).The soil samples were analysed for Physico-chemical properties viz., pH, EC, organic carbon by Walkley-Black method (Walkley-Black 1934) and phosphorous by Olsen’s method (Olsen’s et al. 1954). The relationship between AM propagules and nutrient status of soil under different sites were also worked out.

Results and Discussion

The main purpose of this study was to isolate and identify the AM fungi associated with *A. nilotica* subsp. *indica*. The infection and spread of endophytes in root tissues, and percentage of root colonization is influenced by climatic and edaphic factors. The results of the present investigations pertain to influence of varying soil properties and climatic variations on the AM associations in *A. nilotica* subsp. *indica* in agroclimatic zones of western Rajasthan. A high diversity of AM fungi was observed and it varied at different study sites (Table 1). The important genera identified were *Acaulospora*, *Gigaspora*, *Glomus*, *Sclerocystis*, and *Scutellospora*. Among these five genera, *Glomus* occurred most frequently. The species of *Gigaspora* and *Scutellospora* were distinguished from the genera *Sclerocystis* by the presence of bulbous suspensor in the former.

In all, one species of *Acaulospora* sp. (1); two species of *Gigaspora viz., G. margarita, G. rosea*, seventeen species of *Glomus viz., G. aggregatum, G. citricolum, G. convolutum, G. etunicatum, G. fasciculatum, G. fulvum, G. geosporum, G. glomerulatum, G. magnicaulis, G. microcarpum, G. monosporum, G. mosseae, G. multicaulis, G.pachycaulis, G. pallidum, G. reticulatum, G. tenerum*; four species of *Sclerocystis viz., S. dussii, S. microcarpus, S. rubiformis, S. sinuosa*, and two species of *Scutellospora viz., S. bionarta, S. nigra* were frequently found in the rhizosphere soil of *A. nilotica* subsp. *indica*. It is evident that the occurrence of various species of AM fungi varied considerably from place to place. *G. aggregatum, G. fasciculatum* and *G. mosseae* were found to be the most predominant AM fungi in infecting tree species. *G. fasciculatum* and *Sclerocystis* was found in all the fields studied, while *Scutellospora* species were found only in few sites. The maximum number (26) of AM fungal species were isolated and identified from the rhizosphere soil of *A. nilotica* subsp. *indica* from Pali district, whereas only eleven species were found from Barmer. The total four species of *Sclerocystis* were identified, *S. sinuosa* reported from Jodhpur, Ganganagar, Hanumangarh, Sikar and Pali. As far as the distribution of AM fungal species in *A. nilotica* subsp. *indica* in various districts of western Rajasthan concerned it varied from site to site (Table 1). In general, *G. fasciculatum* was found to be most abundant species. The different AM spores identified under *A. nilotica* subsp. *indica* of different sites was presented (Plate1)

The results of the study of AM population (Table 2) showed that maximum spore density was recorded in tree rhizosphere from (Muth) Pali (492 spores 100 g^{-1} soil) and minimum (154 spores 100 g^{-1} soil) from (Tapra) Barmer in *A. nilotica* subsp. *indica*. The maximum per cent root colonization (78 %) was recorded in (Khivandi) Pali whereas, the minimum colonization of (40 %) was recorded from Tapra (Barmer) (Table 2).

The soil samples were analysed for soil pH and it varied from 7.58 to 8.69, minimum being at (Gorian, Piprali) Sikar and maximum at (Jhareli) Nagaur (Table 2). Minimum EC 0.09 dSm^{-1} was recorded at (Mandia) Pali and maximum EC 0.73 dSm^{-1} at (Payla Kalan) Barmer. Per cent organic carbon ranged from 0.09 at 62RD-KYD, Khajuwala (Bikaner) to 0.50 at (Gudavishnoion) Jodhpur. Available P content varied between 3.44 mg $kg^{-1}$and 5.48 mg kg^{-1} (Table 2).

Linear regression equation for AM population with their characteristics in (*A. nilotica* subsp. *indica*)

$Y_{i(am)}$ = -98.26463+ 6.77137 $X_{i\,(RC)}$
(r = 0.807006, P Value for a =0.04709 P Value for b = 1.0864E- 10)……1.1
$Y_{i(am)}$ = 333.51906+ - 5.06940 $X_{i\,(AP)}$
(r = 0.035811 P Value for a =0.00285 P Value for b = 0.82186)……1.2
$Y_{i(am)}$ = 138.53865+ 574.58779 $X_{i\,(OC)}$
(r = 0.65640 P Value for a =0.00014 P Value for b = 2.3584E-06)……1.3
$Y_{i(am)}$ = 390.11320+ -289.98749 $X_{i\,(EC)}$
(r = 0.60783 P Value for a =4.9637E-22 P Value for b = 1.9607E-05)……1.4
$Y_{i(am)}$ = 845.80822+ -65.42426 $X_{i\,(pH)}$
(r = 0.23535 P Value for a =0.02037 P Value for b = 0.13350)……1.5
Where, $Y_{i(am)}$ = VAM population ,
$X_{i\,(RC)}$ = Root colonization (%)
$X_{i\,(AP)}$ = Available P
$X_{i\,(OC)}$ = Organic carbon (%)
$X_{i\,(EC)}$ =Electrical conductivity
$X_{i\,(pH)}$ = value of Ph

The linear regression equations were work out considering AM population of *A. nilotica* subsp. *indica* with other variables *viz.*, per cent root colonization, available P, per cent organic carbon (% OC), electrical conductivity (EC) and value of pH. The regression equations no. 1.1 to 1.5 are written as above for the *A. nilotica* subsp. *indica* along with the estimated parameters intercept and slope. Also, the value of correlation coefficient and the P values of

Table 1 Distribution of Genera and species of the Arbuscular mycorrhizae in various districts of western Rajasthan

Genus	No.	AMF species	Barmer	Bikaner	Jodhpur	Ganganagar	Hanumangarh	Sikar	Nagaur	Pali	Sirohi
			1	2	3	4	5	6	7	8	9
Acaulospora	1	*Acaulospora* sp.	-	-	-	-	-	-	-	✓	-
Gigaspora	2	*Gigaspora margarita*	-	✓	✓ +	-	✓	✓	-	✓	✓ +
	3	*Gigaspora rosea*	✓ +	-	-	✓	-	✓	✓	✓	-
Glomus	4	*Glomus aggregatum*	-	-	✓	✓	✓	-	✓	✓	-
	5	*Glomus citricolum*	✓	-	✓	-	✓	✓	-	✓	✓
	6	*Glomus convolutum*	-	-	✓	-	✓	-	✓	✓	-
	7	*Glomus etunicatum*	-	✓	✓	✓	-	✓	-	✓	-
	8	*Glomus fasciculatum*	✓	✓	✓	✓	✓	✓	✓	✓	✓
	9	*Glomus fulvum*	✓	✓	✓	-	✓	✓	-	✓	✓
	10	*Glomus geosporum*	-	✓	✓	-	✓	✓	-	✓	-
	11	*Glomus glomerulatum*	-	-	✓	✓	-	-	✓	✓	-
	12	*Glomus magnicaulis,*				✓				✓	
	13	*Glomus microcarpum*	✓	✓		-	-	✓	✓	✓	✓
	14	*Glomus monosporum*	-	-	✓	✓	✓	-	-	✓	-
	15	*Glomus mosseae*	✓	✓	✓	✓	✓	✓	✓	✓	✓
	16	*Glomus multicaulis*	-	✓	✓	-	-	-	-	✓	✓
	17	*Glomus pachycaulis*	-	✓	✓	-	✓	✓	-	✓	-
	18	*Glomus pallidum*	-	✓	✓	✓	✓	-	-	✓	-
	19	*Glomus reticulatum*	-	✓	✓	-	✓	✓	✓	✓	✓
	20	*Glomus tenerum*	✓	-	✓	-	-	✓	✓	✓	✓
Sclerocystis	21	*Sclerocystis dussii*	✓	-	✓	✓	✓	✓	✓	✓	✓
	22	*Sclerocystis microcarpus*	✓	-	✓	✓	✓	-	✓	✓	✓
	23	*Sclerocystis rubiformis*	✓	✓	✓	✓	✓	✓	✓	✓	✓
	24	*Sclerocystis sinuosa*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Scutellospora	25	*Scutellospora bionarta*	-	-	✓	-	✓	-	-	✓	✓
	26	*Scutellospora. nigra*	-	-	✓	✓	-	-	-	-	-

estimated parameter are given in parenthesis. A perusal of above regression equations shows that there is good relationship between AM populations with root colonization followed by with per cent organic carbon and EC. However, it can be seen that there is no significant relationship of VAM population with available P and pH.

Plate 1. Overall picture of identified AM spores under *A. nilotica* subsp. *indica*

Table 2 Physico-chemical properties, phosphorous (P) content, AM population and root colonization (%) in plantation of *A. nilotica* subsp. *indica* in different Districts of western Rajasthan of India.

Zone	Districts	pH (1:2.5)	EC(dSm^{-1})	OC (%)	Available P ($mg\ kg^{-1}$)	AM Population ($100\ g^{-1}$)	Root Colonization (%)
Zone I A	**Barmer**						
	Servede	8.40	0.64	0.20	4.82	168	49
	Kudi	8.62	0.72	0.25	5.40	157	41
	Tapra	8.37	0.65	0.18	4.69	154	40
	Badu Ka Kalan	8.29	0.60	0.17	4.61	161	45
	Payla Kalan	8.55	0.73	0.24	4.89	179	53
	Bhandiavas	8.37	0.71	0.16	4.10	159	42
	Mean	**8.43**	**0.69**	**0.20**	**4.70**	**163**	**45**
Zone I A	**Bikaner**						
	10 KJD	8.7	0.17	0.11	4.70	194	65
	62RD-KYD, Khajuwala	8.3	0.11	0.09	4.10	176	51
	Mean	**8.5**	**0.14**	**0.1**	**4.40**	**185**	**58**
Zone I A	**Jodhpur**						
	Banar	7.95	0.18	.044	4.94	365	66
	Chopasni	8.10	0.20	0.48	5.09	380	75
	Gudavishnoion	8.30	0.22	0.50	5.04	375	72
	Jhalamand	8.05	0.19	0.46	4.86	370	68
	Mogra	7.70	0.17	0.43	4.62	360	64
	Mean	**8.02**	**0.19**	**0.46**	**4.91**	**370**	**69**
Zone I B	**Ganganagar**						
	Lalpura	8.47	0.44	0.38	5.42	349	78
	4KSD	8.32	0.42	0.34	5.38	341	67
	7MD	7.94	0.36	0.29	5.3	333	64
	8P	7.98	0.38	0.27	5.29	331	61
	2GSM, Gharsana	8.49	0.45	0.38	5.41	346	70
	Mean	**8.24**	**0.41**	**0.33**	**5.36**	**340**	**68**
Zone I B	**Hanumangarh**						
	Jandawali minor	7.98	0.25	0.27	5.39	310	61
	2JRK, Khunja	7.71	0.21	0.29	5.46	316	67
	Rorawali	8.11	0.26	0.30	5.48	324	72
	9 Chuk, Rorawali	7.58	0.20	0.26	5.3	305	56
	Dholipal	8.13	0.28	0.33	5.42	320	69
	Mean	**7.9**	**0.24**	**0.29**	**5.41**	**315**	**65**
Zone II A	**Sikar**						
	Ramu ka Bas	8.14	0.16	0.26	4.81	319	60
	Gorian, Piprali	7.58	0.13	0.23	4.59	315	56
	Ranoli,	8.16	0.18	0.27	5.11	322	68
	Badahala Ki Dhani, Palsana	7.59	0.12	0.23	4.12	284	52
	Chohano ki Dhani	7.99	0.11	0.26	4.37	310	64
	Mean	**7.89**	**0.14**	**0.25**	**4.6**	**310**	**60**
Zone II A	**Nagaur**						
	Gothari	8.60	0.10	0.33	5.40	289	52
	Kathoti	8.54	0.09	0.21	4.25	265	42
	Jhareli	8.69	0.11	0.27	4.19	271	46
	Nagri	8.58	0.17	0.35	4.48	295	56

	Mean	**8.6**	**0.17**	**0.29**	**4.58**	**280**	**49**
Zone II B	**Pali**						
	Khivandi	8.24	0.14	0.32	4.24	490	78
	Sumerpur	8.28	0.13	0.36	3.99	464	67
	Muth	8.19	0.12	0.44	4.26	492	75
	Sojat road	8.35	0.12	0.43	4.18	486	76
	Mandia	8.16	0.09	0.40	4.14	468	69
	Mean	**8.24**	**0.12**	**0.39**	**4.16**	**480**	**73**
Zone II B	**Sirohi**						
	Uthman	8.7	0.29	0.39	3.49	306	61
	Khambal	7.7	0.24	0.33	3.44	282	49
	Rampura	8.2	0.27	0.37	3.53	301	59
	Udvaria	7.6	0.22	0.31	3.48	286	50
	Anadera	8.3	0.28	0.35	3.47	300	56
	Mean	**8.1**	**0.26**	**0.35**	**3.48**	**295**	**55**

The number of AM propagules present in the soil, may be the resultant effect of various climatic, physical and chemical properties of soils. In case of tree rhizosphere (Table 3) a significant correlation of AM population was observed with root colonization (r = 0.824) and per cent organic carbon (r = 0.809), while other variables under study had a non-significant correlation with total AM population. Large variation occurred in the spore population within the same plant species were found in present study, which may be attributed to the variation in edaphic (Rabatin and Stinner, 1991) and climatic factors (Stahl and Christensen, 1991). The present study revealed that the rhizosphere soils of *A. nilotica* subsp. *indica* in Pali have high AM diversity (Table 1), as compared to other districts *i.e.*, Barmer, Bikaner, Jodhpur, Ganganagar, Hanumangarh, Sikar, Nagaur and Sirohi.

The study revealed that the *Glomus* has been the most dominant genus in arid regions (Table 1). The predominance of *Glomus* species varying edaphic conditions may be due to the fact that it is highly adaptable to varied soil and temperature conditions, and can survive in acidic as well as alkaline soil (Ho, 1987).The present study revealed that *G. fasciculatum* was the most dominant AM fungal species under *A. nilotica* subsp. *indica*. The similar observations were also made by Pande, 1999; Verma *et al.*, 2008. Perhaps, it may be due to the ability of fungus to produce excellent inoculum under *A. nilotica* subsp. *indica* under arid environment. The pH of our study area was very narrow *i.e.* between 7.58 and 8.69, for that we got no significant relationship of AM population with soil pH. Effects of pH are particularly difficult to evaluate since many chemical properties of the soil vary with changes in pH.

The maximum spore population was recorded from (Muth) Pali and minimum from (Tapra) Barmer in *A. nilotica* subsp. *indica*. The main reason for lower spore count in Barmer might be due to very low rainfall (270-388 mm) and high temperature (upto 47-49^{0}C) than Pali (460-490 mm rainfall and mean maximum temperature 41-46^{0}C). Aridity hampers the spore germination and thus results in the decline of spore population. In very dry situation like Barmer, available water recede to smaller pores resulting in decreased contact between the spores and water films in the soils. The higher number of AM fungi in Pali and lower in Barmer as indicated from the study may be due to a difference in moisture and thermal regimes, because an optimum level of soil and environmental conditions are required for the AM fungi to sporulate for its development and infectiveness (Sieverding, 1980).

Table 3 Correlation Coefficient *(r)* with number of AM spores and other edapho-climatic factors

Zone	Districts	AM Population ($100\ g^{-1}$)	Root colonization (%)	pH (1:2.5)	E.C. (dSm^{-1})	OC (%)	Available P ($mg\ kg^{-1}$)	Rainfall (mm)	Mean max. temperature (^0C)	Mean min. temperature (^0C)	No. of rainy days
Zone I A	**Barmer**	163	45	8.43	0.69	0.20	4.70	270	49	3	11
	Bikaner	185	58	8.50	0.14	0.10	4.40	260	47	2	16
	Jodhpur	370	69	8.02	0.19	0.46	4.91	330	45	3	18
Zone I B	**Ganganagar**	340	68	8.24	0.41	0.33	5.36	200	41	6	16
	Hanumangarh	315	65	7.90	0.24	0.29	5.41	250	40	5	15
Zone II A	**Sikar**	310	60	7.89	0.14	0.25	4.60	460	46	4	30
	Nagaur	280	49	8.60	0.17	0.29	4.58	388	47	3	22
Zone II B	**Pali**	480	73	8.24	0.12	0.39	4.16	490	41	10	22
	Sirohi	295	55	8.10	0.26	0.35	3.48	562	47	23	29
	Correlation (r)		**0.824****	**0.428** NS	**0.497** NS	**0.809** **	**-0.001** NS	**0.387** NS	**0.714***	**0.260** NS	**0.349** NS

* Significant at 5% level, ** Significant at 1% level, NS-non significant

In Pali, highest AM population was recorded which may be due to its location, which experiences optimum rainfall and temperature that are conducive for AM sporulation. Higher infection in *A. nilotica* subsp. *indica* trees growing in this area might be because of the adaptability of AM fungi to the native soils. Under optimum conditions, as in Pali, climate provides favourable conditions for colonization, and therefore nearly the entire length of roots were found to be colonized by these myco-symbiont (Hepper, 1977).

The present study clearly demonstrated for the first time that at least 26 species from five genera are associated with *A. nilotica* subsp. *indica* and revealed that both AM fungal population and percentage of root colonization are affected by organic carbon (OC) and EC. Species of *Acaulospora*, *Glomus*, *Gigaspora*, and *Sclerocystis* were found in alkaline soils, with EC from 1-19.9 d Sm^{-1} in some areas of the Unites States (Pond *et al.*, 1984). It is possible that plants and AM fungi have co-adapted to tolerate environments characterized by high salinity. It has also been shown that the increase in soil salinity changes the distribution of AM fungal species (Stahl and Williams 1986). This demonstrates the importance of soil fertility in influencing the population of AM fungi (Abbott and Robson, 1985; Hayman and Tavares, 1985). It has been observed that in tree rhizosphere soil, phosphorous had no significant relationship with AM population (lack of relationships with P) may be due to relatively low levels of P, since no fertilizer application in the vicinity of the tree roots in crop fields is practiced generally. Similar observations were also reported by Harley and Smith, (1983) and Pande, (1999). Mycorrhizae are an important consideration in maximizing land productivity, which can be managed by using appropriate AM and a complete understanding of profile of AM associated with plant can be useful in finding AM symbiosis in particular host species.

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