Research Article (Open access)

Correlation of Soil Physico-chemical Factors with AM Fungal Diversity in *Ailanthus excelsa Roxb.* Under Different Agroecological Zones of Western Rajasthan

Neelam Verma[1], Jagadish Chandra Tarafdar[2*], Krishna Kant Srivastava[1], Bhawana Sharma[1]
[1]Arid Forest Research Institute, Jodhpur, Rajasthan, India
[2]Emeritus Scientist, ICAR-Central Arid Zone Research Institute, Jodhpur, Rajasthan, India

[*]**Address for Correspondence:** Dr. J.C. Tarafdar, Emeritus Scientist, Former Principal Scientist and National Fellow, ICAR-Central Arid Zone Research Institute, Jodhpur, Rajasthan, India
Received: 27 April 2016/Revised: 16 May 2016/Accepted: 13 June 2016

ABSTRACT- Arbuscular mycorrhizal (AM) fungi associated with *Ailanthus excelsa Roxb* (Ardu) were assessed for their qualitative and quantitative distribution from eight districts of Rajasthan. A total of three species of *Acaulospora,* two species of *Gigaspora,* fourteen 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* and *G. mosseae* were found to be the most predominant AM fungi in infecting *A. excelsa*. *G. fasciculatum*, *Sclerocystis* was found in all the fields studied, while *Gigaspora* species and *Scutellospora* species were found only in few sites. The maximum number (22) of AM fungal species were isolated and identified from Sikar whereas, only ten species (10) were found from Nagaur. The spore density varied between 195 to 682 propagules (100 g^{-1}) soil. The percent root colonization was varied (47 to 79 %) from place to place. The pH of the study area ranged between 7.82 to 8.79; EC was recorded from 0.13 to 0.62 (dSm^{-1}); Percent OC ranged from 0.22 to 0.39 and available P content varied from 4.1 to 5.36 mg kg^{-1} for *A. excelsa.* A significant correlation of AM population was observed with root colonization, percent organic carbon and pH while other variables under study had a non-significant correlation with total AM population.

Key-Words: Arbuscular mycorrhizae, Arid agroecosystems, Diversity, Root colonization, Correlation, *Ailanthus excelsa*

----------IJLSSR----------

INTRODUCTION

Ailanthus excelsa Roxb. (Simaroubaceae) also known as "Indian Tree of Heaven" is a multipurpose tree species (MPTS) of arid region because of its ability to grow well at low rainfalls (from 400 to 1900 mm) and in strong light conditions [1,2]. Therefore, semi arid areas of Rajasthan are quite suitable for this species. The genus name *Ailanthus* comes from *ailanthos* (tree of heaven), the Indonesian name for *Ailanthus moluccana*. It is commonly known as Mahanimba, Ardu is indigenous to India and in Rajasthan spread in dry tracts of Barmer, Jodhpur, Sirohi, Banswara, Tiwri, Churu, and Mt. Abu. It can attain a height of 18 to 25 m and girth of 2.5 m and has a cylindrical bole. It is fast growing species with a small whitish trunk. It is sensitive to drought and is moderately frost tender, being killed by frost in exposed situations. It is a suitable species for introduction as a plantation tree in social forestry, agroforestry, avenue plantation, industrial plantation and wasteland afforestation. The species has been extensively used for soil conservation purposes. Even in arid regions of Rajasthan it has been planted as an avenue tree along the road side.

This tree is useful to mankind in various ways. The wood is white and very light (433 kg/m^3 at 12% Moisture content). The timber can be used where lightness is the priority, especially for making catamarans for fishing, packing cases, sword sheaths and matchboxes. The leaves of this tree are excellent sources of fodder in Rajasthan. It is also important for meeting the demand of plywood, match stick, toys and packing material Industries of Rajasthan [3]. The species are having medicinal importance and it is used as astringent, febrifuge, stomachic, anthelmintic,

Access this article online	
Quick Response Code:	Website: www.ijlssr.com
ISSN 2455-1716	DOI: 10.21276/ijlssr.2016.2.4.3

antispasmodic, expectorant and used for the treatment of bronchitis, cold, cough, skin diseases, trouble of rectum, diarrhoea, dysentery, dropsy, fever due to tridosha, guinea- worms, snakebite and also is proven an effective contraceptive [4]. Ardu is used as fodder, fuel, making matchwood boxes and match splints. Wood is used as timber, poles, pulp and paper etc. The species has been extensively used for soil conservation purposes. Even in arid regions of Rajasthan it has been planted as an avenue tree along the road side. It yields the gum of inferior quality.

Arbuscular mycorrhizal (AM) fungi are major component of rhizosphere micro-flora in natural ecosystems. Accumulating evidence indicate that the mycorrhizal association plays a significant role in decomposition of soil organic matter, mineralization of plant nutrients and nutrient recycling [5,6]. Mycorrhizal plants have greater ability to absorb nutrients and water, which may lead to better survival under stressed environmental conditions [7]. 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 [8]. Plants infected with AM fungi get most easily established on disturbed sites through improved mineral nutrition [9] and provide a primary mechanism for phosphorus uptake from the soil [10]. The geographic distribution of AM fungal species influenced by edaphic factors plays an important role in 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 *Ailanthus excelsa* along with their diversity and their correlation with soil physico-chemical factors.

MATERIALS AND METHODS

The study was conducted in natural and planted stands of *A. excelsa* located in different parts of western Rajasthan in India. Periodical survey for *A. excelsa* plantations were undertaken to collect rhizosphere soil samples and roots from ecologically different sites *viz.*, Barmer, Bikaner, Jodhpur, Ganganagar, Hanumangarh, Sikar, Nagaur and Pali district of western Rajasthan state. The sample collection sites are presented as Table 1.

Table 1: Collection of rhizosphere soil samples in plantation of *A. excelsa* from various sites of different districts of western Rajasthan

Zone	Districts	Sites
Zone I A	Barmer (4)	Tapra (site-1, site-2, site-3 & site-4), Bore (Dhorimana)
	Bikaner (1)	61RD-KYD (Khajuwala)
	Jodhpur (2)	Chokha, Osian
Zone I B	Ganganagar (5)	134 RD (site-1 & site-2) , 0 RD (Nirvana distributary), 4KSD (site-1 & site-2)
	Hanumangarh (5)	5LK (Lakhuwali), 22AG, Bhompura , Chaia minor (site-1 & site-2)
Zone II A	Sikar (5)	Badahala Ki Dhani (Palsana), Chandrpura, Laxmangarh, Ranoli ki dhani, Samota Ka Bas
	Nagaur (1)	Nallawas (Nagri); Kathoti
Zone II B	Pali (5)	Dadia, 802 RD, 9 MD, 19 KJD, Sojat

Fifteen samples were taken from each place. The samples were processed for isolation, identification of Arbuscular mycorrhizal (AM) fungi associated with *A. excelsa*. 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 2011), when the spore built up is the maximum [11]. 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 phosphorus (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 [12]. 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 [13]. AM spores were isolated by wet sieving and decanting technique [14]. 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 the spore cell wall and hyphal attachment with the help of synoptic keys [15,16]. The soil samples were analysed for Physico-chemical properties *viz.*, pH, EC, organic carbon by Walkley-Black method [17] and phosphorus by Olsen's method [18]. The relationship between AM propagules and nutrient status of soil under different sites were also worked out.

The important climatological features of various districts growing the plants were depicted as Table 2.

Table 2: Important climatological features of various districts of Western Rajasthan growing *A. excelsa* plantation (Source: Raj. Govt. Official website)

District	Latitude and longitude	Area Sq. Km.	Rainfall (mm)	Mean maximum temperature (^{0}C)	Mean minimum temperature (^{0}C)	No. of rainy days
Barmer	25° 45' N, 71° 25' E	28,309	270	49	3	11
Bikaner	28° 01' N, 73° 22' E	30,356	260	47	2	16
Jodhpur	26° 17' N, 73° 1' E	22,892	330	45	3	18
Ganganagar	29° 49' N, 73° 50' E	11.003	200	41	6	16
Hanumangarh	29° 35' N, 74° 21' E	9,672	250	40	5	15
Sikar	27° 36' N, 75° 15' E	7,739	460	46	4	30
Nagaur	27° 00' N, 73° 40' E	17,696	388	47	3	22
Pali	25° 46' N, 73° 25' E	12,355	490	41	10	22
Sirohi	24°.61' N, 72°.52' E	5,135	562	47	23	29

RESULTS AND DISCUSSION

The main purpose of this study was to isolate and identify the arbuscular mycorrhizal (AM) fungi associated with *A. excelsa*. The infection and spread of endophytes in root tissues, and percentage of root colonization as influenced by as 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. excels* in different agro climatic regions/based systems of the arid regions of Rajasthan. A high diversity of AM fungi was observed and it varied at different study sites (Table 3).

Table 3: Distribution of Genera and species of the Glomeromycotain at various districts of western Rajasthan of India

Genus	No.	AMF species	Barmer	Bikaner	Jodhpur	Ganganagar	Hanumangarh	Sikar	Nagaur	Pali
			1	2	3	4	5	6	7	8
Acaulospora	1	*Acaulospora bireticulata*	✓	-	✓	-	✓	-	-	✓
	2	*Acaulospora rugosa*	-	✓	-	✓	-	✓	-	✓
	3	*Acaulospora sp.*	-	-	-	-	-	-	✓	-
Gigaspora	4	*Gigaspora albida*	-	✓	✓	✓	-	✓	-	✓
	5	*Gigaspora sp.*	✓	-	-	-	✓	✓	✓	✓
Glomus	6	*Glomus aggregatum*	-	✓	✓	✓	✓	✓	✓	✓
	7	*Glomus citricolum*	-	-	-	✓	✓	✓	✓	✓
	8	*Glomus constrictum*	✓	-	✓	-	✓	✓	-	-
	9	*Glomus convolutum*	-	-	✓	-	-	✓	-	✓
	10	*Glomus deserticola*	✓	✓	-	✓	✓	✓	-	-
	11	*Glomus fasciculatum*	✓	✓	✓	✓	✓	✓	✓	✓
	12	*Glomus geosporum*	-	-	-	-	-	✓	✓	-
	13	*Glomus macrocarpum*	✓	-	✓	✓	-	✓	-	✓
	14	*Glomus microcarpum*	-	✓	-	✓	✓	✓	✓	✓
	15	*Glomus mosseae*	✓	✓	✓	✓	✓	✓	✓	✓
	16	*Glomus multicaulis*	✓	-	✓	✓	-	✓	-	✓
	17	*Glomus multisubstensum*	✓	✓	-	-	✓	✓	-	✓
	18	*Glomus reticulatum*	-	-	-	✓	-	✓	-	✓
	19	*Glomus tenerum*	✓	-	✓	✓	✓	✓	✓	-
Sclerocystis	20	*Sclerocystis dussii*	-	✓	✓	✓	-	✓	✓	✓
	21	*Sclerocystis indica*	✓	✓	✓	-	✓	-	-	-
	22	*Sclerocystis rubiformis*	✓	-	✓	-	✓	✓	-	-
	23	*Sclerocystis sinuosa*	-	-	✓	-	✓	✓	-	✓
Scutellospora	24	*Scutellospora. nigra*	-	✓	✓	-	✓	✓	-	✓
	25	*Scutellospora.*	-	-	-	-	-	✓	-	-

The important genera were identified as *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, three species of *Acaulospora,viz., A. bireticulata, A. rugosa, Acaulospora* sp., (1); two species of *Gigaspora viz. ,G. albida, Gigaspora* (1); fourteen species of *Glomus viz., G. aggregatum, G. citricolum, G. constrictum, G. convolutum, G. deserticola, G. fasciculatum, G. geosporum, G. macrocarpum, G. microcarpum, G. mosseae, G. multicaulis, G. multisubstensum, G. reticulatum, G. tenerum*; four species of *Sclerocystis viz., S. dussii, S. indica, S. rubiformis, S. sinuosa*; and two species of *Scutellospora viz., S. nigra, Scutellospora sp.* (1) were frequently found in the rhizosphere soil of *Ailanthus excelsa*. 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 (22) of AM fungal species were isolated and identified from Sikar whereas, only ten (10) species were found from Nagaur (Table 3). The total four species of *Sclerocystis* were identified, *Sclerocystis sinuosa* reported from Barmer, Bikaner, Hanumangarh Jodhpur, Sikar and Pali. AM fungal species identified in *A. excelsa* in various districts of western Rajasthan varied from site to site was presented (Table 3). As far as the distribution of AM fungal species in *A. excelsa* in various districts of western Rajasthan concerned it varied from site to site (Table 3). In general, *G. fasciculatum* was found to be most abundant species. The different AM spores identified under *A. excelsa* of different sites are presented as Plate 1.

Plate 1: Overall picture of identified AM spores under *A. excelsa*

The results of the study of AM population (Table 4) showed that maximum spore density was recorded in tree rhizosphere from (Chandrpura & Ranoli ki dhani) Sikar (682 spores 100 g^{-1} soil) and minimum (195 spores 100 g^{-1} soil) from (62RD-KYD, Khajuwala) Bikaner (Table 4) in *A. excelsa*. The maximum percent root colonization (79 %) was recorded in (Samota ka Bas) Sikar whereas, the minimum colonization of (47 %) was recorded from (62RD-KYD, Khajuwala) Bikaner.) in *A. excelsa* (Table 4).

Table 4: Physico-chemical properties, phosphorus (P) content, AM population and root colonization (%) in plantation of *A. excelsa* 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**						
	Tapra, site-1	8.43	0.61	0.25	4.22	310	40
	Tapra, site-2	8.61	0.59	0.22	4.25	335	57
	Tapra, site-3	8.79	0.62	0.26	4.18	324	51
	Bore, Dhorimana	8.57	0.54	0.27	4.19	315	52
	Mean	8.60	0.59	0.25	4.21	321	50
Zone I A	**Bikaner**						
	61RD-KYD, Khajuwala	8.52	0.13	0.28	4.1	195	47
	Mean	8.52	0.13	0.28	4.10	195	47
Zone I A	**Jodhpur**						
	Chokha	8.18	0.14	0.37	5.09	391	59
	Osian	8.2	0.18	0.35	5.21	399	62
	Mean	8.19	0.16	0.36	5.15	395	57
Zone I B	**Ganganagar**						
	134 RD, site-1	8.19	0.4	0.38	5.36	485	67
	134 RD, site-2	8.17	0.37	0.34	5.3	499	72
	0 RD, Nirvana Distributary	8.22	0.35	0.32	5.26	486	66
	4KSD, site-1	8.18	0.35	0.32	5.27	488	65
	4KSD, site-2	8.19	0.43	0.39	5.36	492	70
	Mean	8.19	0.38	0.35	5.31	490	68
Zone I B	**Hanumangarh**						
	5LK, Lakhuwali	7.9	0.27	0.23	4.9	379	53
	22AG	7.92	0.24	0.25	5.5	372	51
	Bhompura	7.93	0.27	0.23	5.7	391	62
	Chaia minor site-1	7.94	0.25	0.26	5.2	386	59
	Chaia minor site-2	7.96	0.27	0.28	4.7	367	50
	Mean	7.93	0.26	0.26	5.20	380	55
Zone II A	**Sikar**						
	Badahala Ki Dhani	7.91	0.14	0.38	4.39	658	73
	Chandrpura	7.89	0.16	0.36	4.37	682	76
	Laxmangarh	7.88	0.15	0.35	4.47	658	73
	Ranoli ki dhani	7.85	0.17	0.37	4.44	682	76
	Samota Ka Bas	7.82	0.18	0.39	4.38	670	79
	Mean	7.91	0.14	0.37	4.39	670	76
Zone II A	**Nagaur**						
	Nallawas, Nagri	8.67	0.17	0.35	5.49	303	42
	Kathoti	8.43	0.21	0.23	3.71	317	56
	Mean	8.55	0.19	0.29	4.60	310	49
Zone II B	**Pali**						
	Dadia	8.21	0.13	0.34	4.21	421	60
	802 RD	8.22	0.15	0.31	4.15	419	58
	9 MD	8.2	0.23	0.23	4.23	433	69
	19 KJD	8.19	0.23	0.22	4.16	427	65
	Sojat	8.18	0.21	0.25	4.15	425	63
	Mean	8.20	0.19	0.27	4.18	425	63

The soil samples were analysed for soil pH and it varied from 7.82 to 8.79, minimum being at (Samota ka Bas) Sikar and maximum at (Tapra, Site-3) Barmer (Table 4). Minimum EC 0.13 (dSm^{-1}) was recorded at (62RD-KYD, Khajuwala) Bikaner and maximum EC 0.62 (dSm^{-1}) at (Tapra Site-3) Barmer. Percent organic carbon ranged from 0.22 at (Tapra, Site-2) Barmer to 0.39 at (Samota ka Bas) Sikar. Available P content varied from 4.1 ($mg\ kg^{-1}$) to 5.36 ($mg\ kg^{-1}$).

Linear regression equation for AM population with their characteristics (*A. excelsa*)

$Y_{i(am)} = -236.72398 + 11.04004\ X_{i\ (RC)}$
r = 0.89095 P Value for a =0.00152 P Value for b = 9.36E-11)……1.1
$Y_{i(am)} = 402.05300 + 7.72004\ X_{i\ (AP)}$
r = 0.03426 P Value for a =0. 05972 P Value for b = 0.859941)……1.2
$Y_{i(am)} = 27.74017 + 1355.86959\ X_{i\ (OC)}$
r = 0.63259 P Value for a =0.78037 P Value for b = 0.00023)……1.3
$Y_{i(am)} = 515.15290 + -274.00911\ X_{i\ (EC)}$
r = 0.32502 P Value for a =4.2E-11 P Value for b = 0.08536)……1.4
$Y_{i(am)} = 3144.33495 + -330.63709\ X_{i\ (pH)}$
r = 0.69388 P Value for a =3.45E-06 P Value for b = 2.99E-05)……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 worked out considering AM population of *A. excelsa* (plantation) with other variables *viz.*, root colonization, available P, percent organic carbon (% OC), electrical conductivity (EC) and value of pH. The regression equations no. 1.1 to 1.5 was written as above for the *A. excelsa* along with the estimated parameters intercept and slope. Also, the value of the correlation coefficient and the P values of estimated parameter were given in parenthesis. A perusal of above regression equations shows that there is good relationship between AM population with percent root colonization followed by with pH and OC. However, it can be seen that there is no significant relationship of AM population with EC and available P (Table 5).

Table 5: 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 (^{0}C)	Mean min. temperature (^{0}C)	No. of rainy days
Zone I A	**Barmer**	321	50	8.60	0.59	0.25	4.21	270	49	3	11
	Bikaner	195	47	8.52	0.13	0.28	4.10	260	47	2	16
	Jodhpur	395	57	8.19	0.16	0.36	5.15	330	45	3	18
Zone I B	**Ganganagar**	490	68	8.19	0.38	0.35	5.31	200	41	6	16
	Hanumangarh	380	55	7.93	0.26	0.26	5.20	250	40	5	15
Zone II A	**Sikar**	670	76	7.91	0.14	0.37	4.39	460	46	4	30
	Nagaur	310	49	8.55	0.19	0.29	4.60	388	47	3	22
Zone II B	**Pali**	425	63	8.20	0.19	0.27	4.18	490	41	10	22
	Correlation (r)		**0.963****	**0.757***	**0.103**	**0.675**	**0.234**	**0.414**	**0.301**	**0.357**	**0.669**

Correlation between AM fungi and different edaphoclimatic factors for *A. excelsa*

The number of AM propagules presents in the soil, may be the resultant effect of various climatic, physical and chemical properties of soils. In case of tree rhizosphere a significant correlation of AM population was observed with % root colonization (r = 0.963) and pH (r = 0.757), while other variables under study had a non-significant correlation with total AM population Table 5. Large variation occurred in the spore population within the same plant species were found in the present study, which may be attributed to the variation in edaphic [19] and climatic factors [20]. The present study revealed that the rhizosphere soils of *A. excelsa* in Sikar have high AM diversity (Table 3), as compared to other districts *i.e.*, Barmer, Bikaner, Jodhpur, Ganganagar, Hanumangarh, Nagaur and Pali.

The study revealed that the *Glomus* has been the most dominant genus in arid regions (Table 3). 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 [21]. The present study revealed that *G. fasciculatum* was the most dominant AM fungal species under *A. excelsa*. The similar observations were also made [22,23]. Perhaps, it may be due to the ability of fungi to produce excellent inoculum under *A. excelsa* in this environment. The pH of our study area was very narrow *i.e.* from 7.82 to 8.79 and we got good relationship of AM population with available pH. Effects of pH are particularly difficult to evaluate since many chemical properties of the soil vary with changes in pH. The maximum spore density (682 propagules 100 g^{-1} soil) was recorded from (Chandrpura & Ranoli ki dhani) Sikar and minimized (195 propagules 100 g^{-1} soil) from (62RD-KYD, Khajuwala) Bikaner in *A. excelsa*. The main reason for lower spore count in Bikaner might be due to very low rainfall (260 mm approx.) and high temperature (upto 47-49^{0}C) than Sikar (460 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 Bikaner, available water recedes to smaller pores resulting in decreased contact between the spores and water films in the soils. Leeper [24] shows similar views in this context. The higher number of AM fungi in Sikar and lower in Bikaner 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 [25].

In Sikar, 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. excelsa* trees growing in this area might be because of the adaptability of AM fungi to the native soils. Under optimum conditions, as in Sikar, the climate provides favourable conditions for colonization, and therefore nearly the entire lengths of roots were found to be colonized by this myco-symbiont [26].

The present study clearly demonstrated for the first time that at least 25 species from five genera are associated with *A. excelsa* and revealed that both AM fungal population and percentage of root colonization are affected by organic carbon (OC) and pH. Species of *Acaulospora, Glomus, Gigaspora,* and *Sclerocystis* were found in alkaline soils, with EC from 1-19.9 dSm^{-1} in some areas of the Unites States [27]. 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 [28]. This demonstrates the importance of soil fertility in influencing the population of AM fungi [29,30]. It has been observed that in tree rhizosphere soil, phosphorus had no significant relationship with AM population (lack of relationships with P) may be due to relatively low levels of P, since generally no fertilizer application in the vicinity of the tree roots in crop fields is practiced. Similar observations were also reported from [22,31]. Mycorrhizae are an important consideration in maximizing land productivity, which can be managed by using appropriate AM and a complete understanding of the profile of AM associated with the plant can be useful in finding AM symbiosis in particular host species.

ACKNOWLEDGMENT

We thank Shri N. K. Vasu, Director, AFRI for his keen interest in the present work. We are also thankful to Head, Forest Ecology Division, AFRI for soil analysis work. We are highly thankful to (Late) Dr. Sunil Kumar, Scientist F, AFRI for statistical analysis.

REFERENCES

[1] Seth, S.K., Raizada, M.B, Khan, W.M.A. 1962. Trees of Vana Mahotsava F.R.L and Collges, Dehradun.

[2] Bhimya, C.P., Kaul, R.N, Gangul, B. N. 1963. Species suitable for afforestation of different arid habitats of Rajasthan. Ann. Arid Zone 2: 162-68.

[3] Jat, H.S., Singh, R.K., Mann, J.S. 2011. Ardu (*Ailanthus* sp.) in arid ecosystem: A compatible species for combating with drought and securing livelihood security of resource poor people. *Ind. J. Tradi.* Know. 10: 102-13.

[4] Kumar, D.; Bhat, Z.A.; Singh, P.; Shah, M.Y, Bhujbal, S.S. 2010. *Ailanthus excelsa* Roxb. is Really a Plant of Heaven. *Int. J. Pharmacology* 6 (5): 535-50.

[5] Tarafdar, J.C. and Rao, A.V. 1997. Response of arid legumes to VAM fungal inoculation. *Symbiosis* 22, 265-74.

[6] Pare, T.; Gregorich, E.G, Nelson, S.D. 2000. Mineralization of nitrogen from crop residues and N recovery by maize inoculated with vesicular arbuscular mycorrhizal fungi. *Plant and Soil* 218, 11-20.

[7] Sylvia, D.M, Williams, S.E. 1992. Vesicular arbuscular mycorrhizal and environmental stress. In: Bethlenfalvay, G.L. Lindermann, R.G. (Eds.), *Mycorrhizae in Sustainable Agriculture. American Society of Agronomy*, Madison, pp. 101-24.

[8] Mc Gonigle, T.P, Miller, M.N. 1996. Development of fungi below ground in association with plants growing in disturbed and undisturbed sorts. Soil Biology and Biochemistry 28, 263-69.

[9] Shiffestin, W.C, Medve, R.J. 1979. Growth performance and Mycorrhizae of native and exotic hardwoods on bituminous stripmine spoils. *Ohio Journal of Science*, 79: 274-79.

[10] Hayman, D.S. 1982. Influence of soil and fertilizer on activity and survival of vesicular-arbuscular mycorrhizal fungi. *Phytopathology*, 72: 1119-25.

[11] Verma, N. 2005 "Dependency, evaluation and selection of efficient strains of a-mycorrhizal fungi for *Prosopis cineraria* (L.) Druce. in western rajasthan." Ph.D. thesis, Forest Research Institute, Dehradun, India.

[12] Phillips, J.M. and Hayman, D.S. (1970). Improved procedure for clearing roots and staining parasitic and Vesicular Arbuscular Mycorrhizal fungi for rapid assessment of infection. *Trans. Brit. Myco. Soc.* 55: 158-61.

[13] Giovannetti, M, Mosse, B. 1980. An evaluation of techniques for measuring vesicular arbuscular mycorrhizal infection in roots. *New Phytol.* 84: 489-500.

[14] Gerdemann, J.W, Nicolson, T.H. 1963. L. Spores of mycorrhizal *Endogone* species extracted from soil by Wet Sieving and Decanting. *Trans. Brit. Myco. Soc.* 73: 261-70.

[15] Schenck, N.C, Perez, Y. 1987. *Mannual for identification of VA-mycorrhizal fungi.* Univ. of Florida Gainesville. Florida, USA.

[16] Raman, M, Mohankumar, V. 1988. *Techniques in mycorrhizal research*. Centre for Advanced Study in Botany, Univ. of Madras, Madras. Dept. Sci. Technology, Govt. of India.

[17] Walkley, A, Black, I.A. 1934. An examination of the Degtiareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Sci.* 37: 29-38.

[18] Olsen, S.R.; Cole, S.C.W.; Wantabe, P.S, Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *U.S. Dept. AgrilCircular* 939: 18.

[19] Rabatin, S.C, Stinner, B.R. 1991. The significance of vesicular arbuscular mycorrhiza fungi macroinvertebrate interactions in agroecosystems. *Agric. Ecosyst. Environ.* 27: 195-204.

[20] Stahl, P.D, Christensen M. 1991. Population variation in the mycorrhizal fungus *Glomus mosseae* breadth of environmental tolerance. *Mycol. Res.* 95: 300-07.

[21] Ho, I. 1987. Vesicular arbuscular mycorrhizae of halophytic grasses in the Alvord desert of Oregon. *Northwest Sci.* 61: 148-51.

[22] Pande, M. 1999. Studies on VAM associations in neem based agroforestry systems in arid zone of Rajasthan. *Ph.D. thesis.* FRI Deemed University, Dehradun.

[23] Verma, Neelam; Tarafdar, J.C.; Srivastava, K.K. and Jitendra Panwar 2008. Arbuscular Mycorrhizal (AM) diversity in *Prosopis cineraria* (L.) Druce under arid agroecosystems. *Agricultural Sciences in China* 7(6): 754-61.

[24] Leeper, G.W. 1964. *Introduction to soil science* (4th Edition). Melbourne University Press.

[25] Sieverding, E. 1980. Einflub der Bodenfeuchte auf Entwicklung und Effektivitat der vesicular-arbuskularen Mykorrhiza, Gottingen.

[26] Hepper, C.M. 1977. A calorimetric method for estimating the vesicular-arbuscular mycorrhizal infection in roots. *Soil Biol. Biochem.* 9: 15-18.

[27] Pond, E.C.; Menge, J.A, Jarrell, W.M. 1984. Improved growth of tomato in salinized soil by vesicular-arbuscular mycorrhizal fungi collected from saline soils. *Mycologia* 76: 74-84.

[28] Stahl, P.D, Williams, S.E. 1986. Oil shale process water affects activity of vesicular-arbuscular fungi and *Rhizobium* 4 years after application to soil. *Soil Biol. Biochem.* 18: 451-55.

[29] Abbott, L.K, Robson, A.D. 1985. Formation of external hyphae in soil by four species of vesicular-arbuscular mycorrhizae fungus. *New Phytol.* 97: 437-46.

[30] Hayman, D.S, Tavares, M. 1985. Plant growth responses to vesicular- arbuscular mycorrhiza XV. Influence of soil pH on the symbiotic efficiency of different endophytes. *New Phytol.* 100: 367-77.

[31] Harley, J.L, Smith, S.E. 1983. *Mycorrhizal symbiosis.* Academic Press, London. pp. 483.

