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Survival and establishment of exotic plant species in saline areas of Indian Thar Desert by application of mycorrhizal technology

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ABSTRACT

Mycorrhizal technology was applied for reclamation of saline wasteland of Indian Thar Desert. For this purpose an exotic tree species Acacia colie an endemic legume of Australia was selected. Studies revealed increased biomass production and nutrient uptake of Acacia collie by native AM fungi. Different AM fungi showed their variation towards response to this tree species. However, AM fungi resulted in survival and establishment of this exotic species in saline areas of Indian Thar Desert.

Key words: AM Fungi, saline areas, Indian Thar Desert, Acacia collie.

INTRODUCTION

The worldwide extent of saline and alkaline soil is about 322.9 million hectares, which is about 26% of the world's cultivator land. Like other hot deserts a considerable part of Rajasthan desert is also comprised of saline unproductive land in the form of saline lakes, salt depression, swamp and saline lands covered by wind blown sand. The saline areas of the Indian desert can be divided into two parts i.e. the salt lakes such as Sambhar, Deedwana and Kuchaman located in the Eastern semi arid Rajasthan and the salt basins such as Pachpadra, Luni, Baap, Phalodi, Pokran, Lunkaransar, Khajuwala located in the Western arid Rajasthan.

Saline soils are characterized by the presence of either soluble salts or exchangeable sodium or both. Salt deposition at the surface and incrustation as a result of excessive evaporation are other very distinctive characters of such soils. Salt basins of the Indian arid Zones are the inland types, which differ greatly from coastal saline areas in vegetation make-up and support relatively a smaller number of plant species capable of tolerating a high degree of salinity. In fact, only small groups of higher plants known as Halophytes can grow under these saline conditions.

Salinity effect the establishment, growth, development and production of plants in million of hectares of earth's land. This alters physiochemical and metabolic activities of host plants and it is worldwide problem. In arid and semi arid areas concentration of salts and availability of water is enough to damage the growth of plants [1] .

Indian arid zone is characterized by low fertility of soils due to lack of nutrients, poor water holding capacity of soils, high temperature and scarcity of rainfall. All these factors makes the arid climate adverse habitat for growth and survival of plants. Hence, in order to overcome these adverse conditions some technology should be applied which can benefit the plants in many fold ways.

AM Fungi are well recognized as bio fertilizers now a day[2] due to their several benefits provided to the host plants[3,4] They are being frequently used in agriculture and forest industries. By improving the nutrient uptake in water transport they help the plants to survive more efficiently under adverse climatic conditions. AM Fungi are of very common occurrence in arid and semi arid regions of Indian Thar Desert [5,6]. Plant grown in these habitats show great mycorrhizal dependency for their biomass production and survival[7,8].

Acacia colei Maslin and L. A. J. Thomson is one of the thornless species of the genus *Acacia* endemic in Australia. Spreading shrub 2–4 m high, occasionally tree to 9 m high. New shoots sericeous, the hairs pale yellow-brown soon ageing silvery. Branchlets acutely angled, silvery-sericeous. Phyllodes normally obliquely narrowly elliptic, straight but commonly shallowly recurved at apices, normally 11–20 cm long, 1–4.5 (5.5) cm wide, with knob-like mucro, silvery green or silvery grey-green, sericeous, the 3 or 4 main nerves per face confluent and contiguous with the lower margin at base, with minor nerves forming an obvious longitudinally orientated reticulum. Inflorescences rudimentary 2-headed racemes with axes to 0.5 mm long; peduncles 4–6 mm long, appressed-puberulous to sericeous, with indumentum sometimes sparse; spikes 3–6.5 cm long, golden. Flowers 5-merous; sepals united; petals hairy. Legumes openly and strongly curved dehisced valves somewhat twisted, entangled and persisting as conspicuous clumps following dehiscence, 3.5–4 mm wide, thinly coriaceous-crustaceous, glabrous or subglabrous. Seeds longitudinal, normally oblong, 4–4.5 mm long, glossy, very dark brown to black; aril bright yellow.

Widespread in northern Australia between latitudes 16^{o} and 22° S where it extends from the Pilbara and southern Kimberley region, W.A., E across the Great Sandy and Tanami Deserts, N.T., to the Gulf country and Simpson Desert in western Qld. Grows in a variety of soil types; frequently forms dense, nearly monotypic stands along dry, stony or sandy drainage lines. It is a colonising species and a component of many semi-arid, subtropical plant communities, especially the *Acacia* -dominated scrubs and tall open shrublands of north-western Australia. Dense regrowth populations often develop in disturbed sites such as road verges, gravel pits and burnt areas.

A. colei have shown potential for multipurpose use in tropical dry-zones of West Africa. In Senegal and Niger they have been grown as a source of fuel wood and for environmental rehabilitation and recently their seeds have been used as an alternative source of human food in these regions. Its wide variability in soils and climate suggest major provenance differences will occur in growth rate, drought and frost tolerance. This species have been recommended by the AFRI (Arid forest Research Institute), Jodhpur for reclamation of saline wasteland of this region.

MATERIALS AND METHODS

Site description

Major areas covered under saline habitat of Indian Thar Desert are Phalodi, Balotra , Pachpadra,Luni and Barmer. Soil samples were collected from saline areas of all the five localities

Soil parameters

Soil samples were analysed for pH and electrical conductivity on 1:2.5, soil: water suspension. Organic carbon was estimated by the method of Walkley and Black [9]using I N potassium dichromate and back titrated with 0.5 N ferrous ammonium sulphate solution. Available phosphorus in soil was determined by extraction with 0.5 M sodium bicarbonate for 30min [10]. Soil texture was estimated gravimetrically by hydrometer method [11].

Microsoft Excel 2000 was used in the statistical processing of the data (Standard errors of mean, correlation analysis).

Soil sampling

Soil samples (soil adhering to the roots) were collected at 30-90 cm depths along with root samples in five replicates from plant, which were growing in the selected sites. Before sampling, the soils from the upper layer were scrapped off to remove foreign particles and litter. The collected soil and root samples were placed in an insulated carrier for transport and immediately refrigerated at 4 °C upon arrival. The roots were processed immediately. All the soil samples collected from the rhizosphere of a particular plant species of a district were homogenized replication wise before processing by sieving (< 2 mm mesh size) to remove stones, plant material and coarse roots. Subsample of each soil was air dried and used for estimation of various physico-chemical properties and to establish successive pot cultures (trap cultures).

Trap cultures

Successive pot cultures (trap cultures) have been shown to be a useful tool in inducing sporulation of AMF from field soils in arid ecosystems to facilitate the detection of AMF species that are present in the rhizosphere and roots but do not sporulate readily in the field at the time of sampling [12]. To establish successive pot cultures, 500 g dry wt. field soil was mixed with autoclaved sand (1:1, v/v), and planted with surface-sterilized seeds (by 0.1% w/w mercuric chloride solution for 2 min and then washed with distilled water) of *Cenchrus ciliaris* L. as host.

Spore extraction

Spores of AMF were extracted from the field and successive pot culture soils by the wet sieving and decanting technique of Gerdemann and Nicolson [13]. Total spore numbers of mycorrhizal fungi in the soil samples were estimated by the method of Gaur and Adholeya [14] and spore densities were expressed as the number of spores per 100 g of soil. The isolated spores were picked up with needle under a dissecting microscope and were mounted in polyvinyl lacto glycerol (PVLG). However, PVLG was mixed with Meltzer's reagent (1:1, v/v) in case of *Scutellospora* species. All the spores (including broken ones) were examined using Medilux-20 TR compound microscope. Taxonomic identification of spores up to species level was based on spore size, spore colour, wall layers and hyphal attachments using the identification manual of Schenck and Perez [15] and the description provided by the International collection of vesicular and AMF (http:/ /invam.caf. wvu.edu).

Root colonization by AMF

To determine the percent root colonization, root samples collected from different sites were washed in tap water and staining was done by the method of Phillips and Hayman [16] for rapid assay of mycorrhizal association. The root samples were cut into pieces of 1 cm length and placed in 10% KOH solution, which was kept at boiling point for about 10min (depending upon the hardness of the root sample). The root samples were captured on a fine sieve and rinsed with distilled water until the brown colour disappeared. Post-clearing bleaching was done with alkaline hydrogen peroxide (0.5% NH_4OH and 0.5% H_2O_2 v/v in distilled water). Roots were rinsed with distilled water, treated with 1% HCl and stained with 0.05% w/v trypan blue in lactic acid-glycerol. Assessment of colonization was conducted on each sample by the glass slide method, in which 100 randomly selected root segments of each replication were determined microscopically. A segment was counted as infected when hyphae, vesicles, or arbuscules were observed. The infection percentage was determined by the method given by Biermann and Lindermann [17].

RESULTS AND DISCUSSION

Physicochemical characteristics of soil samples collected from various saline areas of Indian Thar Desert are presented in table-1. P^H at various localities varied from 8.15-9.50, which show high salinity .Soil samples revealed presence of eight species of AM fungi viz *Acaulospora morrawae* Spain & Schenck, Gigaspora gigantean *(Nicol. & Gerd.) Gerd. & Trappe, Gigaspora margarita* Becker & Hall, *Glomus deserticola* Trappe, Bloss & Menge, *Glomus fasciculatum* (Thaxter sensu Gerd.) Gerd. & Trappe, Sclerocystis rubiformis *Gerd. & Trappe, Scutellospora calospora* (Nicol. & Gerd.) Walker & Sanders, Scutellospora nigra *(Red head) Walker & Sanders* at these localities .Distribution of these fungi at various localities of saline areas of Indian Thar Desert are presented in table-2.Mycorrhizal spore population and percentage root colonization at different localities of saline areas are presented in table-3. Spore population at various localities varied from 53 to 78 per cent , while percentage root colonization varied from 46 to 65 at different localities. Acacia collie seedlings treated with different AM fungi showed increase in biomass production(table-4) and nutrient uptake (table-5). It is clear from the observations that AM fungi resulted in increase in dry weight up to 70 per cent and nutrient uptake up to 80 -90 per cent in *Acacia colei* as compare to non treated control plants.

Application of mycorrhizal fungi resulted in increasing uptake of both the nutrients, phosphorus and nitrogen irrespective of the treatment. The overall growth of mycorrhizal plants was higher as compared with corresponding control. Different mycorrhizae treated plants showed variation from 12.5 to 18.2 mg/g nitrogen content while phosphorus in different mycorrhizal treated plants varied from 13.0 to 18.7 mg/g in various treatments. Among the seven mycorrhizal fungi used during the present study, *Acaulospora morrawae* responded least efficiently while *Scutellospora calospora* responded most efficiently in the uptake of both the nutrients. Nutrient uptake by plants inoculated with mycorrhizal fungi is a well known benefits provided by AM fungi to the host plants [2,3,4,]. During present study *Scutellospora calospora* resulted in almost eighty percent increase in uptake of both the nutrients i.e. phosphorus and nitrogen as compared with non-mycorrhizal plants. This increased nutrient uptake by colonizing

roots (Plate-1) resulted in increasing biomass production of *Acacia colie* during present study. Similar trend in the potentiality of different mycorrhizal fungi was also observed in increasing plant biomass production . AM fungi bring about changes in enzymes of nitrogen metabolism [5,8] there by increasing rate of photosynthesis[7] which might be the possible mechanism of improving survival and establishment of the exotic plant species in saline areas of Indian Thar Desert.

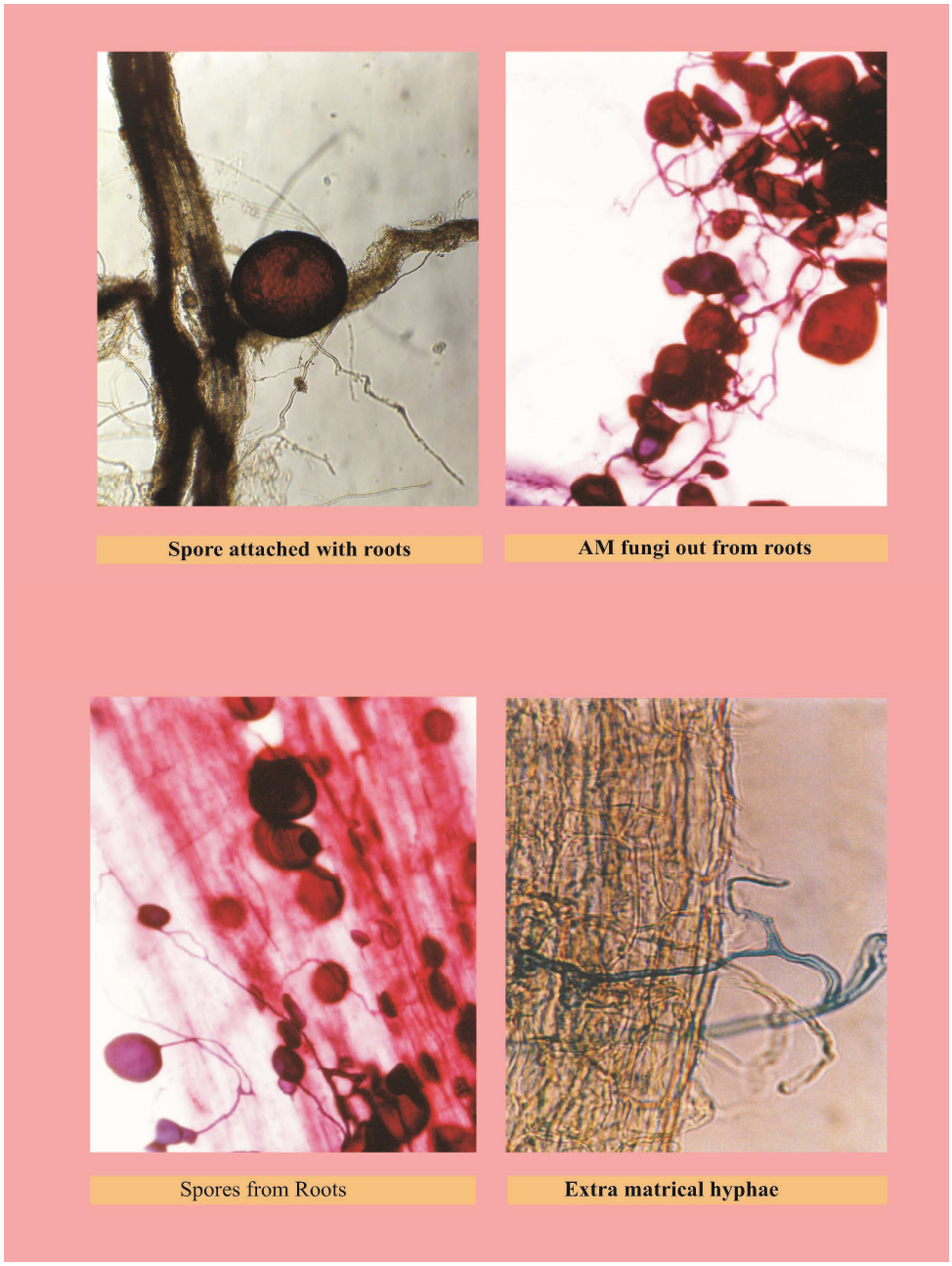

PLATE-1 Various stages of Arbuscular Mycorrhizal Association with Acacia colie

Table 1: Physicochemical characteristics of site soils for *Acacia colei*

District	pH	EC (dSm^{-1})	OC (%)	Olsen P ($mg\ kg^{-1}$)
Pachpadra	9.19±0.02	0.25±0.01	0.24±0.01	6.1±0.02
Luni	9.23±0.02	0.20±0.02	0.32±0.01	4.1±0.02
Balotra	8.15±0.01	0.16±0.02	0.31±0.01	7.2±0.03
Phalodi	9.50±0.02	0.23±0.01	0.30±0.01	5.0±0.02
Barmer	9.19±0.04	0.24±0.01	0.30±0.01	4.2±0.01

± Standard error of mean.

Table-2. Distribution of arbuscular mycorrhizal fungi at saline areas of Indian Thar Desert

S. No.	AM species	Localities				
		Pachpadra	Luni	Balotra	Phalodi	Barmer
1.	*Acaulospora morrawae*	+	-	++	+	-
2.	*Acaulospora laevis*	+	-	-	+	+
2.	*Gigaspora margarita*	++	++	++	++	++
3.	*Glomus constrictum*	++	+	-	+	-
4.	*Glomus deserticola*	+++	+++	+++	+++	+++
5.	*Glomus fasciculatum*	+++	+++	+++	+++	+++
6.	*Glomus mosseae*	+++	+++	+++	+++	+++
7.	*Sclerocystis rubiformis*	++	++	++	++	++
8.	*Scutellospora calospora*	+	+	+	++	+

\- *Absent*
\+ *Low (10-20 spore g^{-1} soil)*
++ *Moderate (20-40 spore g^{-1} soil)*
+++ *High (> 40 spore g^{-1} soil)*

Table-3: Spore population and percentage of root colonization at different localities

S. No.	Locality	AM spore population (per g soil)	Percentage root Colonization (%)
1.	Pachpadra	53	46
2.	Luni	59	52
3.	Balotra	78	65
4.	Phalodi	65	55
5.	Barmer	62	59

Table 4: Influence of different AM fungi on biomass production of *Acacia colei*

Treatment	Plant Height (cm)			Plant dry weight ($g\ plant^{-1}$)		
	Days after inoculation					
	50 days	100 days	150 days	50 days	100 days	150 days
Control	10.5	20.2	45.2	3.0	7.2	15.0
Acaulospora morrawae	11.5	25.0	62.6	3.5	7.8	16.5
Gigaspora gigantea	15.4	30.5	70.3	4.8	9.2	19.7
Gigaspora margarita	15.0	33.0	120.4	4.6	8.9	19.4
Glomus deserticola	14.7	33.0	76.2	5.2	8.5	18.2
Glomus fasciculatum	14.2	29.0	80.2	4.0	8.3	17.6
Sclerocystis rubiformis	12.5	26.0	85.8	3.8	8.0	17.0
Scutellospora calospora	16.2	38.0	90.1	5.5	10.2	25.3
Scutellospora nigra	15.8	31.5	95.4	5.0	9.7	20.2
CD at 5% level	0.22	0.26	0.78	0.17	0.19	0.24

Table 5: Influence of Arbuscular Mycorrhizae on nutrient uptake in *Acacia colei* after six months of inoculation

Treatment	Total Phosphorus (mg plant^{-1})	Total Nitrogen (mg plant^{-1})
Control	10.8	8.5
Acaulospora morrawae Spain & Schenck	13.0	12.5
Gigaspora gigantean (Nicol. & Gerd.) Gerd. & Trappe	14.3	13.8
Gigaspora margarita Becker & Hall	15.6	15.2
Glomus deserticola Trappe, Bloss & Menge	13.0	12.2
Glomus fasciculatum (Thaxter sensu Gerd.) Gerd. & Trappe	13.7	13.2
Sclerocystis rubiformis Gerd. & Trappe	12.4	12.0
Scutellospora calospora (Nicol. & Gerd.) Walker & Sanders	18.7	18.2
Scutellospora nigra (Red head) Walker & Sanders	16.8	16.2
CD at 5% level	0.22	0.20

CONCLUSION

Australian endemic leguminous tree species Acacia colie was successfully cultivated under saline habitats of Indian Thar Desert by application of AM fungi. The study can be important for introducing new exotic plant species for different purpose.

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