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Biomass Production, Nutrient Uptake and Nodulation in *Prosopis cineraria* by Indigenous VAM Fungi

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Abstract : The incidence of root infection by indigenous VAM fungi and its consequence on biomass production, nodulation and nutrition of *Prosopis cineraria* were studied in pots in five different soils of Indian Thar desert. Soil sterilization completely inhibited root colonization by indigenous VAM fungi. However, considerable root colonization occurred in roots of the plants in unsterilized soils. Root colonization by indigenous VAM fungi resulted in improved nodulation. The indigenous VAM fungi also improved uptake of N, P, K, Cu, Mn, Fe and Zn in all the five soil types. VAM infection resulted in increased biomass production and the plant showed field mycorrhizal dependency for its biomass.

Key words : *Prosopis cineraria*, *Rhizobium leguminosarum*, VAM fungi, nodulation, nutrient uptake, nodule formulation, root infection.

P. cineraria, locally known as 'khejri', is an important multipurpose leguminous tree of arid and semi-arid regions. It is a source of fuel and fodder. Mostly the plant is grown in nutrient deficient sandy soils of drought prone areas. Primary stresses imposed on vegetation by the arid environment are lack of water and nutrients (Fisher and Turner, 1978). VAM fungi may be of particular significance in coping with nutrient deficiency stress in natural ecosystems (McArthur and Knowles, 1993). Due to their beneficial effects, VA mycorrhizae receive considerable attention in agriculture and forestry (Peterson *et al.*, 1984). VAM fungi are frequently associated with *P. cineraria* in arid and semi-arid regions of India (Mathur and Vyas, 1994). Due to obligate symbiotic nature it is very difficult to artificially culture the VAM endophytes, hence mass multiplication is not possible. In view of these facts, present study was undertaken to evaluate the potentiality of indigenous VAM fungi on biomass production, nutrient uptake and nodulation of *P. cineraria* in five Indian desert soils.

Materials and Methods

Five different soils of arid and semi-arid regions of India were used. Some of the basic characteristics of these soils are presented in Table 1. Samples (500 g from each soil) were sieved (Gerdemann and Nicolson, 1963) and passed through set of sieves to collect VAM spores. The number of spores were counted under a light microscope by floating them in 100 ml water.

There were two sets of experiments, one with sterilized soils and the other with non-sterilized soils. Soils were sterilized by twice autoclaving them at 15 lb atm pressure with 24 h gap. pH of soils varied from 8.4-8.7. Pots used during the study were of 30 cm diameter containing 10 kg soil. Each pot was fertilized with 25 kg ha^{-1} nitrogen and 45 kg ha^{-1} potassium. The seeds were pre-inoculated with *Rhizobium leguminosarum*. The seeds were not inoculated with VAM as the

Table 1. Some characteristics of the soils under study

Soil	Sand (%)	Silt (%)	Clay (%)	pH	Organic matter (%)	Total P	Total N
						mg kg^{-1}	
Jodhpur	92.0	3.5	4.5	8.4	0.07	6.20	9.15
Osian	92.4	1.8	5.8	8.6	0.06	6.00	9.00
Bikaner	92.2	3.4	4.4	8.6	0.08	7.15	10.25
Nagaur	93.8	2.7	3.5	8.7	0.11	7.30	10.70
Churu	94.6	2.2	3.2	8.5	0.13	6.82	10.15

experiment was set up to evaluate the efficacy of indigenous VAM fungi following the method of Khan *et al.* (1988). The pots were randomly arranged in a greenhouse having 25-30°C day light temperature, 60% relative humidity, with 12-14 h day length. One week after the emergence of seedlings the plant density was thinned to five per pot. There were twenty replicates for each treatment.

Sampling and Analyses

The plants were sampled 90 days after emergence of seedlings. Dry weight of plants was recorded after drying them in hot air oven at 60°C to a constant weight. The roots of the plants were dug out very carefully to get most of the finer roots. The number of nodules per plant was counted. Root samples were then cleaned and stained according to the method of Phillips and Hayman (1970). Percentage of root colonization was calculated by the grid line intersect method (Giovanetti and Mosse, 1980). Nutrient contents in leaves of plants were analysed following method of Dhir *et al.* (1984). Relative field mycorrhizal dependency (RFMD) was calculated for each mycorrhizal plant (Plenchette *et al.*, 1983).

Results and Discussions

Root infection

Although the five soil types used during the present study had different mycorrhizal populations (Table 2), considerable good VAM infection occurred in the plants grown in unsterilized soils. In general, the root infection ranged form 62-64% in different soil types. Root infection by VAM fungi was not observed in the plants grown in sterilized soils. Plants grown in sterilized soils were designated as 'non mycorrhizal plants' and those grown in unsterilized soils were designated as 'mycorrhizal' plants.

Nodule formation

Root infection by indigenous VAM fungi improved nodulation in *P. cineraria*. There were significant differences in number of nodules between mycorrhizal and non mycorrhizal plants. Mycorrhizal plants produced almost two-fold increase in nodule number as

Table 2. Spore population and precentage of root colonization by indigenous VAM fungi in rhizosphere of Prosopis cineraria.

Soil series	VAM spores (per 100 g soil)	Percentage root colonization
Jodhpur	322.24 ± 1.82	62.26 ± 0.39
Osian	310.20 ± 1.76	63.12 ± 0.37
Bikaner	318.56 ± 2.12	64.10 ± 0.63
Nagaur	404.16 ± 2.20	65.38 ± 0.48
Churu	386.28 ± 1.53	64.82 ± 0.56

Each value represents mean ± S.D. of twenty samples.

Table 3. Biomass production, nodulation and relative field mycorrhizal dependency of P. cineraria

Soil	Sterilization	Plant dry weight g plant^{-1}	Number of nodules plant^{-1}	RFMD (%)
Jodhpur	-	24.80 ± 1.15	21.62 ± 1.13	48.70
	+	12.72 ± 0.14	10.76 ± 0.20	–
Osian	-	25.0 ± 0.18	24.82 ± 1.15	49.32
	+	13.10 ± 0.12	12.24 ± 0.15	–
Bikaner	-	25.55 ± 0.32	24.66 ± 1.72	49.74
	+	12.84 ± 0.22	11.62 ± 0.16	–
Nagaur	-	27.62 ± 0.15	24.97 ± 1.24	52.06
	+	13.24 ± 0.22	12.36 ± 1.24	–
Churu	-	24.86 ± 1.75	23.20 ± 1.35	50.40
	+	12.32 ± 0.26	11.32 ± 0.12	–

Each value represents mean ± SD of 20 samples.

compared to the non mycorrhizal plants (Table 3).

Biomass production

The plant dry weights of mycorrhizal and non mycorrhizal *P. cineraria* are presented in Table 3. Marked differences were observed between plant biomass of mycorrhizal and non mycorrhizal *P. cineraria*. The difference was also almost two-fold in all the soil types.

Nutrient uptake

Table 4 represents nutrient levels in mycorrhizal and non mycorrhizal *P. cineraria* in five soil types. Mycorrhizal plants showed more than two-fold increase in P and K and more than three-fold increase in N as compared with the non mycorrhizal plants. The indigenous VAM fungi also increased significantly uptake of other nutrients, viz., Cu, Mn, Fe and Zn.

It is quite evident from the present investigation that substantial number of effective VAM spores exist in many Indian arid soils used for successful plantation of *P. cineraria* for better biomass production, more particularly in areas where nutrient deficiency is a determining factor.

Root infection by indigenous VAM fungi greatly improved uptake of N, P, K, Cu, Mn, Fe and Zn from all the five soil types. The effect of mycorrhizal infection on uptake of

Table 4. Nutrient contents (mg kg^{-1}) of mycorrhizal and non mycorrhizal Prosopis cineraria in different soil types

Soil	N	P	K	Cu	Mn	Fe	Zn
Jodhpur	45.15±0.33	24.10±0.26	32.20±0.05	42.20±0.65	42.15±0.72	41.00±0.50	30.40±0.16
	(36.20±0.21	16.20±0.22	24.16±0.06	30.42±0.15	33.26±0.12	34.10±0.17	25.12±0.12)
Osian	44.20±0.56	24.80±0.45	33.42±0.12	40.75±0.80	42.20±0.75	41.80±0.60	30.85±0.18
	(36.00±0.30	17.30±0.16	24.30±0.09	30.30±0.25	33.50±0.28	34.35±0.54	26.15±0.10)
Bikaner	44.62±0.59	25.25±0.42	33.80±0.88	40.90±0.56	42.56±0.60	42.60±0.65	31.10±0.06
	(35.10±0.27	17.15±0.44	24.25±0.06	30.45±0.42	33.72±0.19	35.24±0.20	25.72±0.15)
Nagaur	45.50±0.48	25.70±0.37	34.15±0.10	41.12±0.35	42.80±0.70	43.20±0.55	31.50±0.24
	(36.45±0.36	17.92±0.07	25.10±0.14	31.15±0.40	33.00±0.25	35.12±0.30	26.25±0.08)
Churu	44.87±0.25	24.54±0.75	32.65±0.07	41.20±0.26	43.10±0.64	43.92±0.45	31.90±0.27
	(35.00±0.22	16.72±0.12	24.00±0.12	31.20±0.42	34.25±0.30	34.80±0.12	26.60±0.13)

Each value represents mean ± S.D. of twenty samples.
Nutrient contents of plants grown in sterilized soil are presented in parenthesis.

N, P, and K was more pronounced. However, differences in the uptake of Cu, Mn, Fe and Zn between mycorrhizal and non mycorrhizal plants were also marked.

The improved biomass production of *P. cineraria* by the VAM symbiosis were concomitant with an enhanced mineral nutrient accumulation. Improvement in nutrient uptake by VAM fungi in different plant species in well known (Koide and Schriener, 1992; McArthur and Knowles, 1993). By enhancement of the concentration of nutrients in plant, the VAM symbiont appeared to play a role in stimulating the development of plant photosynthetic surface area (Radin and Boyer, 1982). This might have ultimately led to increased biomass production by the indigenous VAM fungi observed in the present investigation. Further support for this conclusion comes from tremendous relative field mycorrhizal dependency of *P. cineraria* on indigenous VAM fungi for its biomass production in all the five soil types (Table 4).

The marked differences in number of nodules between mycorrhizal plants must not be due to the effect of sterilization on the activity of rhizobium strain on root infection as all the plants were properly inoculated. The increased nodulation of mycorrhizal plants was, in all likelihood, the outcome of the beneficial effects of indigenous VAM associations, probably through a better utilization of nutrients, particularly P, which is required for effective nodulation.

It is thus concluded that the indigenous VA mycorrhizal spores present in the Indian arid soils are capable of infecting the *P. cineraria*, thereby improving its biomass production, nutrient uptake and nodulation. This beneficial association ultimately leads to the establishment of better plantation of this tree, particularly in areas where nutrient deficiency is a determining factor.

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