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Mycorrhizae of Desert Plants

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ABSTRACT

Mycorrhizal associations were found to be a common phenomenon in Chihuahuan Desert plants. Endomycorrhizal fungi were found in 18 of 26 genera and 20 of 28 species examined. Seven of the eight species that did not harbor mycorrhizal fungi were examined on only one date throughout the year. There was indication that tertiary roots of *Larrea tridentata*, *Prosopis glandulosa* and *Ephedra trifurca* were more involved with mycorrhizal associations than were the secondary roots of these plants. In contrast to this, the secondary roots of *Yucca elata* and *Opuntia* spp. appeared more commonly involved with mycorrhizal fungi than tertiary roots. Mycorrhizal associations were more common on *P. glandulosa*, *E. trifurca*, *Y. elata* and *Opuntia* spp. during the spring and fall than during the summer. The opposite appeared to be true for *L. tridentata*. Initiation of mycorrhizal development in *Y. elata* seedlings is diagrammatically represented as are some of the early findings of mycorrhizal associations on more mature *L. tridentata* plants.

INTRODUCTION

Many fungus species are inhabitants of the soil and therefore in close proximity to plant roots. When the appropriate species of microorganism and plant root are in close association they could interact in a positive, neutral or negative maner. Changing environmental conditions could exert negative pressures on the fungus and plant roots independently. If these pressures are reduced through fungus-root associations, these associations would probably come into existence and persist as a survival mechanism.

The arid and semiarid areas of the United States support a wide variety of plants with various and unique survival problems (MacDougal and Spalding 1910, Shreve 1914, Cloudsley-Thompson and Chadwick 1964). Studies have been conducted on desert plants to develop an understanding of adaptation and the scientifically interesting phenomena which occur in these habitats (Al-Ani et al. 1972, Batanouny and Ziegler 1971, Barbour 1969, Cunningham and Strain 1969).

The presence or absence of mycorrhizae on desert plants is distinctly limiting (Khudairi 1969). An understanding of plant growth and survival in the arid and semiarid climate with less than optimal soil conditions might be better attained if a knowledge of the presence and effects of mycorrhizae on these plants could be determined.

OBJECTIVES

1. Determine the extent of mycorrhizal development on the roots of predominant Jornada desert plants.
2. Determine if any seasonal changes take place in establishment or proliferation of mycorrhizae and evaluate the possible causes of the observed changes.
3. Construct comparative root diagrams and determine the relationships that may exist between similar types of plant-fungal relationships.
4. Begin the evaluation of specific beneficial influences derived from the plant-fungal associations.

METHODS

Roots were removed from 28 different desert plant species which were growing in the Chihuahuan Desert. Most of the continuous or more frequent seasonal collections were taken on the Jornada range adjacent to the IBP validation site. Other collections were obtained from an area between Socorro and Las Cruces, New Mexico, defined as Chihuahuan Desert by Barbour (1968).

In some instances, entire root systems were removed from the soil and sequential segments of the primary, secondary and tertiary roots were excised, stained and examined for the presence of the mycorrhizal fungus. In contrast to the above, other plant roots were excised, stained and examined with emphasis on the presence of the mycorrhizal fungus in the secondary and tertiary roots. Prior to root removal the depth below the soil surface and the diameter of the root were determined.

Each type of root was stained using a variation of the Phillips and Hayman (1970) technique. The roots were cut into segments approximately 1 cm in length and heated to 90 C in 10% KOH for 2 hr to remove the cytoplasm. After washing in fresh 10% KOH, the roots were placed in an alkaline solution of hydrogen peroxide until bleached. The time in hydrogen peroxide was dependent upon the original color and density of the root, which varies with size, age and plant species. These roots were then rinsed thoroughly in distilled water to remove all the hydrogen peroxide. Staining was accomplished by placing and soaking the roots overnight in the chloral hydrate-acid fuchsin (chloral hydrate, 250 g; acid fuchsin, 35 mg; distilled water, 100 ml). Excess stain was removed with clear lactophenol.

The root segments were placed in a drop of lactophenol on a glass slide, a slip cover was placed over the root segment and pressure was exerted on the slip cover to flatten the root segment as evenly as possible. Each segment was then microscopically examined to detect the presence or absence of the mycorrhizal fungus. When the vesicular-arbuscular fungus was detected, the percentage of the surface area occupied by the fungus was compared with the root area lacking the fungus and the percentage of involvement was recorded.

Seedlings of desert plants were removed when available to determine how early this plant-fungus association can become established. The techniques employed on seedlings were essentially the same as those described above.

RESULTS

Plants representing 26 genera and 28 species were examined for possible involvement in mycorrhizal associations. Endomycorrhizae were observed in the roots of 18 genera and 20 species of desert plants (Table 1). Seven of the eight species in which mycorrhizal fungi were not observed were removed from the field only once during this investigation. In most species where observations have been fairly numerous, *Ephedra trifurca*, *Larrea tridentata*, *Opuntia engelmannii*, *Prosopis glandulosa* and *Yucca elata*, roots have been observed with a high concentration of fungal mycelium and vesicles. This high concentration of fungus has not been frequent when fewer observations have been made, and *Rhus microphylla* was the exception.

The overview presented in Table 1 (DSCODE A3USF01) indicates that endomycorrhizal fungi were found in 70% of the desert plant species examined, but it does not indicate other aspects of the study. When plant roots were removed during the season, it was found in *Larrea tridentata* (Table 2) that more tertiary roots (45%) possessed endomycorrhizal fungi than did the secondary (18%) or primary roots (6%). In fact, the only primary root found to be involved in a mycorrhizal association was removed from a plant 4 cm tall. The greatest concentration of fungus in the root occured in the tertiary roots, and this concentration appeared most common from June through August of 1974. The secondary roots possessed a low number of infections and generally a low concentration of the fungal mycelium and vesicles.

Some of the aspects observed for *Larrea tridentata* were also observed for *Prosopis glandulosa* and *Ephedra trifurca* (Tables 3 and 4, respectively). Again tertiary roots were more commonly infected by the endomycorrhizal fungi than were the secondary or primary roots. This varied from 40, 31 and 6% in *P. gladulosa* to 26 and 16% in *E. trifurca*. No readings for primary roots were obtained for the latter plant because mature roots could not satisfactorily be subjected to the technique employed and no seedling plants could be found. There is an indication that a greater concentration of fungi occurs in the roots of *P. glandulosa* in March, May and November rather than the warmer months as in *L. tridentata*. Highest concentrations in the roots of *E. trifurca* occurred in May and September.

Occurrence of the endomycorrhizal fungus was not as prevalent in the tertiary roots as in the secondary roots of *Yucca elata* (Table 5) or *Opuntia* spp. (Table 6). They differed from the three previously discussed species in this aspect and the type of root system also differed. Samples of secondary roots examined exhibited 45% involvement in *Y. elata* and 28% in *Opuntia* spp., while the tertiary roots were infected only 27 and 16%, respectively. The concentration of mycelium and vesicles in the root tissue was higher in the secondaries than the tertiary roots. Combinations of occurrence and concentration appeared to be greater in March, May and November with less involvement being observed during the warmer and wetter months.

Table 1. The occurrence of endomycorrhizae in roots of 28 species of desert plants

Species	Occurrence of mycorrhizae in roots		% Area of roots covered by mycorrhizae, range
	Sampled	Infected	
Acacia constricta	8*	1	0-72
Acleisanthus longiflora	1*	0	0
Atriplex canescens	6*	0	0
Bouteloua eriopoda	16	8	0-30
Brickellia californica	11	0	0
Cucurbita foetidissima	8	1	0-1.0
Dalea formosa	11*	1	0-6.0
Datura stramonium	4*	0	0
Dithyrea wislienii	5*	3	0-10
Dyssodia acerosa	4*	1	0-5.0
Ephedra trifurca	50	10	0-50
Fallugia paradoxa	7*	1	0-10
Flourensia cernua	13*	0	0
Fouquieria splendens	5*	1	0-6.7
Gutierrezia microcephala	5*	1	0-1.0
Gutierrezia microphylla	12*	1	0-10
Hoffmanseggia densiflora	6*	2	0-10
Koeberlinia spinosa	2*	0	0
Larrea tridentata	89	20	0-70
Lycium sp.	5*	1	0-1.0
Mendora scabia	2*	0	0
Opuntia leptocaulus	6*	0	0
Opuntia engelmannii	38	10	0-70
Parthenium incanum	3*	1	0-10
Prosopis glandulosa	61	15	0-50
Rhus microphylla	16	4	0-60
Sloysia lycioides	6*	3	0-30
Yucca elata	40	15	0-60

*Plant roots were removed on a single day during the season.

Additional data were collected on root diameter and the depth of the root below the soil surface. This information, however, does not appear to correlate well with the presence or absence of mycorrhizal fungi in the roots examined. Relationships might become more apparent after the accumulation of additional data.

Continuous available soil moisture during the fall of 1974 induced a profusion of seedlings in some plant species. A number of these seedlings were transplanted and taken to the greenhouse while others were examined to determine the early establishment of mycorrhizal fungi in plant roots. Seedlings of *Yucca elata* were readily available and were studied in greater detail than other seedlings to date. Infection by the mycorrhizal fungi appeared to be random and possibly sporadic during the examination of the *Y. elata* seedlings. None of the 7- to 10-day-old seedlings was found to contain either mycelium or vesicles (Fig. 1). A number of the roots in the 21-day-old seedlings contained expression of the endomycorrhizal fungus but no infections were found close to the soil surface. This same observation was made on the 30-, 45- (Fig. 2) and 60-day-old (Fig. 3) seedlings. It was unusual to remove a 60-day-old seedling, excise and stain the entire root system, and not find indication of a mycorrhizal association, but this does occur.

In more mature *Larrea tridentata* plants, mycorrizal fungi were found in roots much closer to the surface (Fig. 4) than found in *Y. elata* seedlings. There was a much greater concentration of mycorrhizal fungi on one side of the plant in comparison to the other. Additional plants need to be examined as well as other parameters before this interrelationship can be more factually evaluated.

Table 2. Occurrence and concentration of endomycorrhizal fungi observed in the primary, secondary and tertiary roots of *Larrea tridentata*, Jornada, 1974

DATE	PRIMARY ROOTS			SECONDARY ROOTS			TERTIARY ROOTS		
	Sampled	Infected	Range	Sampled	Infected	Range	Sampled	Infected	Range
13 March	6	0	0	4	1	0-40	-[2]	-	-
11 May	3	0	0	2	0	0	1	1	5
28 June	-	-	-	3	1	0-2	2	2	1-40
31 July	-	-	-	7	1	0-20	5	3	0-60
7 August[3]	-	-	-	6	1	0-20	4	1	0-6.6
7 August[4]	-	-	-	3	1	0-40	3	2	0-45
7 August[5]	-	-	-	6	0	0	3	1	0-1
17 September	-	-	-	6	1	0-10	3	0	0
6 November[6]	7	1	0-15	4	2	0-15	1	0	0
26 November[6]	1	0	0	9	1	0-70	-	-	-
TOTAL	17	1		50	9		22	10	

1. Range = % Area of roots on the slide covered by fungal mycelium or vesicles.
2. - No observation made.
3. Plants removed at Hillsboro, New Mexico.
4. Plants removed at Garfield, New Mexico.
5. Plants removed at Socorro, New Mexico.
6. Seedling plant removed on the Jornada.

Table 3. Occurrence and concentration of endomycorrhizal fungi observed in the primary, secondary and tertiary roots of *Prosopis glandulosa*, Jornada, 1974

DATE	PRIMARY			SECONDARY			TERTIARY		
	Sampled	Infected	Range[1]	Sampled	Infected	Range	Sampled	Infected	Range
13 March	1	0	0	4	1	0-1.0	1	1	50
11 May	3	0	0	4	4	5-40	1	1	50
31 July	-[2]	-	-	5	1	0-1.0	1	0	0
13 August	-	-	-	2	0	0	2	0	0
6 November[3]	8	1	0-35	5	3	0-50	-	-	-
26 November[3]	5	0	0	19	3	0-25	-	-	-
TOTALS	17	1		39	12		5	2	

1. Range = % Area of roots on the slide covered by fungal mycelium or vesicles.
2. - No observations made.
3. Seedling plants removed.

Table 4. Occurrence and concentration of endomycorrhizal fungi observed in the primary, secondary and tertiary roots of *Ephedra trifurca*, Jornada, 1974

DATE	PRIMARY			SECONDARY			TERTIARY		
	Sampled	Infected	Range[1]	Sampled	Infected	Range	Sampled	Infected	Range
13 March	-[2]	-	-	2	0	0	3	1	0-3.0
11 May	-	-	-	4	4	1-20	2	2	30-50
31 July	-	-	-	10	1	0-6	7	0	0
7 August	-	-	-	10	0	0	6	1	0-5.9
17 September	-	-	-	5	0	0	1	1	30
			TOTALS	17	5		19	5	

1. Range = % Area of roots on the slide covered by fungal mycelium or vesicles.
2. - No observations made.

Table 5. Occurrence and concentration of endomycorrhizal fungi observed in the primary, secondary and tertiary roots of *Yucca elata*, Jornada, 1974

DATE	PRIMARY			SECONDARY			TERTIARY		
	Sampled	Infected	Range[1]	Sampled	Infected	Range	Sampled	Infected	Range
13 March	-[2]	-	-	4	2	0-30	3	0	0
11 May	-	-	-	4	2	0-10	1	1	5
28 June	-	-	-	6	1	0-1	1	0	0
31 July	-	-	-	2	2	2-5	-	-	-
7 August[3]	-	-	-	5	0	0	-	-	-
17 September	-	-	-	1	1	1	-	-	-
1 November[4]	-	-	-	7	4	0-60	6	2	0-45
			TOTALS	29	12		11	3	

1. Range = % Area of roots on the slide covered by fungal mycelium or vesicles.
2. - No observations made.
3. Plants removed at Socorro and Garfield, New Mexico.
4. Smaller plants used.

Table 6. Occurrence and concentration of endomycorrhizal fungi observed in the primary, secondary and tertiary roots of *Opuntia* spp., Jornada, 1974

DATE	PRIMARY			SECONDARY			TERTIARY		
	Sampled	Infected	Range[1]	Sampled	Infected	Range	Sampled	Infected	Range
11 May '74	-[2]	-	-	4	4	30-70	2	1	0-60
28 June '74	-	-	-	4	0	0	4	2	0-53
31 July '74	-	-	-	4	0	0	4	0	0
7 Aug. '74[3]	-	-	-	8	3	0-6.7	4	0	0
17 Sept. '74	-	-	-	5	0	0	5	0	0
			TOTALS	25	7		19	3	

1. Range = % Area of roots on the slide covered by fungal mycelium or vesicles.
2. - No observations made.
3. Plants removed from Hillsboro, Garfield and Socorro, New Mexico.

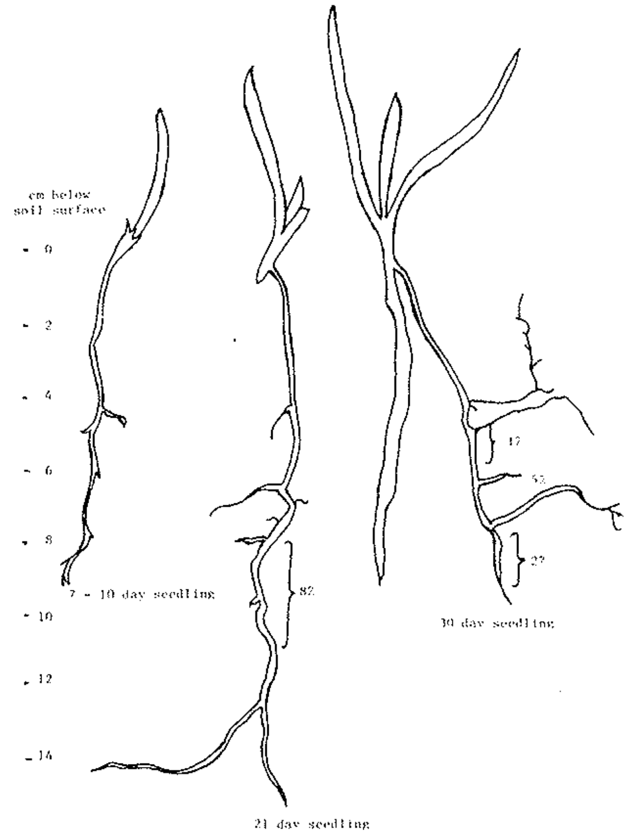

Figure 1. Diagrammatic representation of *Yucca elata* seedlings indicating where mycorrhizal fungi were observed in the roots.

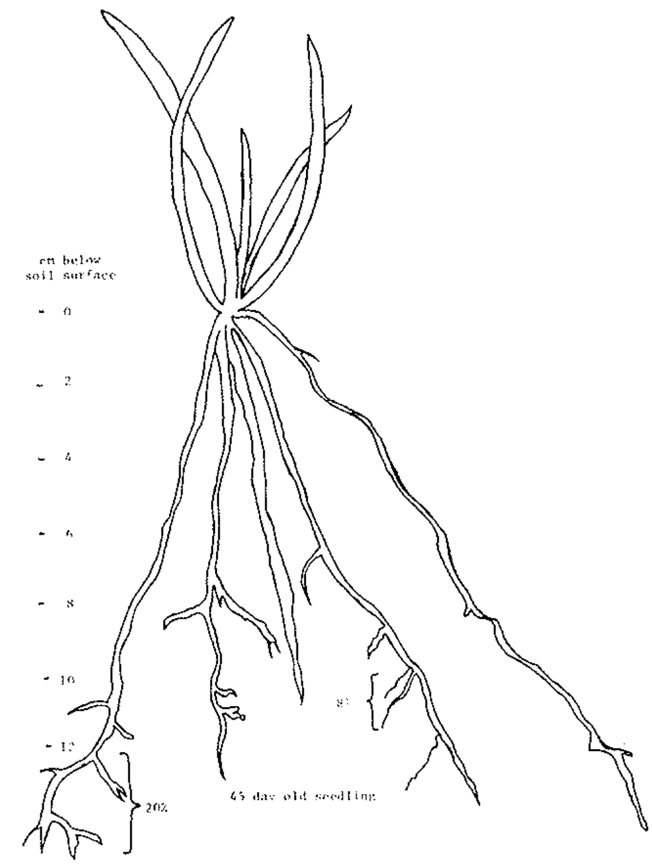

Figure 2. Diagrammatic representation of *Yucca elata* seedling indicating where mycorrhizal fungi were observed in the roots.

DISCUSSION

More Chihuahuan Desert plants were found to have entered into mycorrhizal associations than were found to be devoid of them. It is believed that, of the representatives of the eight genera and species which did not possess mycorrhizal fungi, some will probably exhibit this association when additional plants are studied. Some trends were observed during this study; one was the high concentration and occurrence of mycorrhizal fungi in the tertiary roots of *Larrea tridentata, Prosopis glandulosa* and *Ephedra trifurca*. If this is a common occurrence with plants possessing either the generalized root system of *L. tridentata* or the specialized taproot system of *P. glandulosa* or *E. trifurca* (Ludwig in press) then some groupings could be constructed and generalizations made. Additional data could be collected on *Fallugia paradoxa*, *Chilopsis linearis*, *Parthenium incanum* or other similar plants which correspond to Ludwig's root system type for desert plant species. Secondary roots of *Y. elata* and *Opuntia* spp. possessed higher occurrence and concentration of mycorrhizal fungi than did the tertiary roots examined. This aspect requires further examination because many tertiary roots may have been lost during sampling or removal in the field.

Increased occurrence of mycorrhizal fungi in the roots of *L. tridentata* during the summer months does not correspond with the changes in mycorrhizae on the other four desert plants examined and may indicate a different interaction between the roots of this plant and the fungus. This will have to be studied at another time.

Investigations on the *Y. elata* seedlings indicate that desert plants can and do enter into mycorrhizal relationships relatively early in plant development. The lack of mycorrhizal fungi in all of the 7- to 10-day-old seedlings would indicate that the fungus is not seed-borne. This fact is further substantiated by the random and sporatic infections that occur in the roots of the 21- to 45-day-old seedlings. If the mycorrhizal fungus was seed-borne, many more infections should occur closer to the soil surface where the inoculum potential might be higher next to the seed coat.

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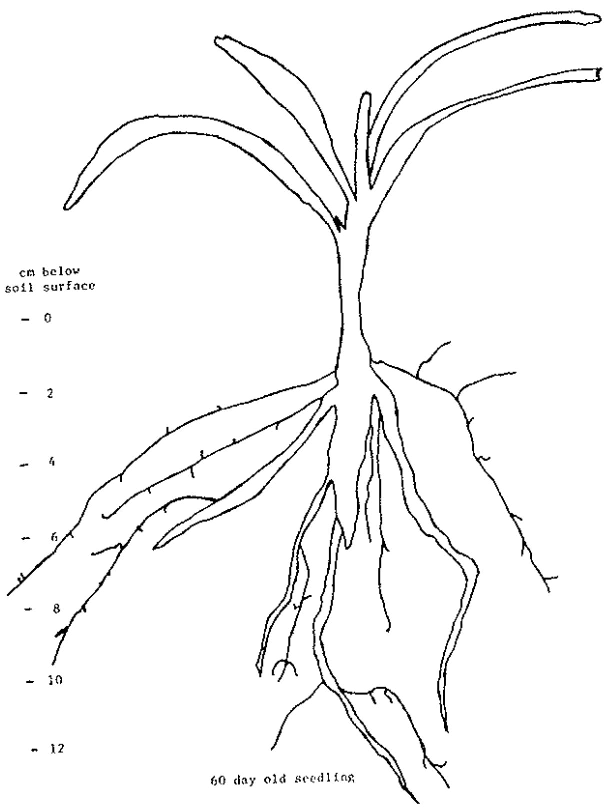

Figure 3. Diagrammatic representation of *Yucca elata* seedling forming main taproot and containing no mycorrhizal fungi in the root system.

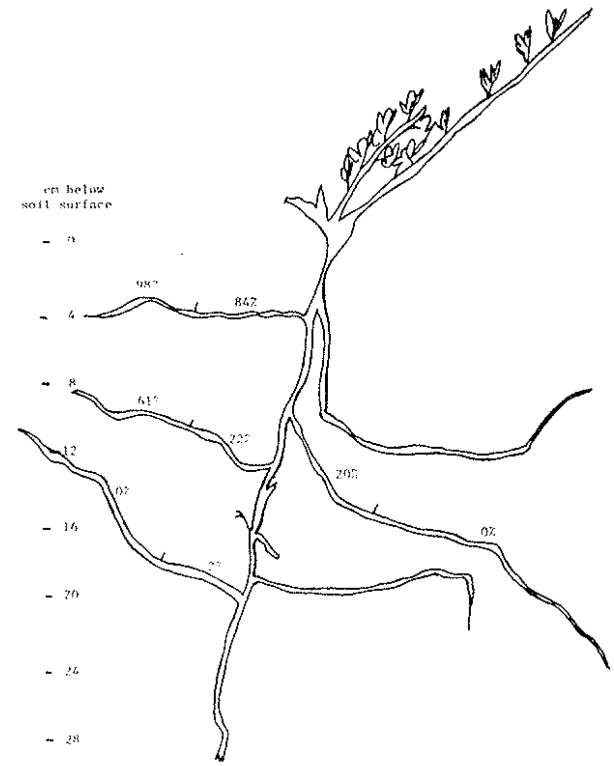

Figure 4. Diagrammatic representation of *Larrea tridentata* root showing areas of mycorrhizal involvement.

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