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Mycorrhizal perennials of the "matorral xerófilo" and the "selva baja caducifolia" communities in the semiarid Tehuacán-Cuicatlán Valley, Mexico

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Abstract We investigated the mycorrhizal status of perennial xeric plant species occurring in the "matorral xerófilo" (arid tropical scrub) and the ecotone of the "selva baja caducifolia" (tropical deciduous forest) communities in the semiarid valley of Tehuacán-Cuicatlán, south-central Mexico. The perennial species examined are dominant/codominant elements within the "matorral xerófilo" and the "selva baja caducifolia", both endangered communities in the Biosphere Reserve Tehuacán-Cuicatlán Valley. Of the 50 sampled species, 45 were mycorrhizal. To our knowledge, we report arbuscular mycorrhizae (AM) for the first time in 37 species, of which 21 are endemic to Mexico and nine are endemic to the Valley. We also report AM for the first time in three genera, *Buddleja*, *Hechtia* and *Zornia*, and in one plant family, Buddlejaceae. *Beaucarnea gracilis*, a threatened species, and *Mimosa purpusii*, a potentially rare species, are both mycorrhizal. This is the first study of the mycorrhizal status of plant species within the Valley.

Keywords Arbuscular mycorrhizae · Arid · Conservation · Endemics · Restoration

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Introduction

The Tehuacán-Cuicatlán Valley is located between 17° 20'–18° 53' N and 96° 55'–97° 44' W, and covers an area of ca. 10,000 km^2 within the states of Puebla and Oaxaca, Mexico. Parts of it were declared a Biosphere Reserve in 1998. The Valley has a very complex topography, with altitudes ranging from 500 to 3,200 m.a.s.l. The region is part of the Sierra Madre del Sur physiographic province. Rzedowski (1978) classified it as the Tehuacán-Cuicatlán floristic province within the Mexican Xerophytic phytogeographic region. The flora has Neotropical affinities with ca. 3,000 species, 30% of which are endemic to the Valley (Smith 1965; Villaseñor et al. 1990; Dávila et al. 1993).

Within the Valley, the conservation of the "matorral xerófilo" (arid tropical scrub) and the "selva baja caducifolia" (tropical deciduous forest) is of high priority because these communities house a high diversity and large number of endemics. Both communities are regarded as endangered vegetation types (Zavala-Hurtado and Hernández-Cárdenas 1998). For example, these communities have the highest diversity of columnar cacti of the tribes Pachycereeae and Cereeae, which form the most diverse and dense cacti forest in the world (Arias et al. 1997). Recent data show that thorny species are becoming the dominant/codominant species within these communities, suggesting a species replacement occurring towards the less diverse and poorer quality "matorral espinoso" (thorny scrub) (Camargo-Ricalde et al. 2002). Human activities have reduced plant diversity in the past years, especially in the matorral xerófilo and the selva baja caducifolia, where increase in unplanned agricultural fields, extensive goat overgrazing and deforestation are the main causes of degradation (Zavala-Hurtado and Harnández-Cárdenas 1998).

Though there are reports on the arbuscular mycorrhizal (AM) status of plant species from arid and semiarid regions of the world (e.g. Khan 1974; McGee 1986; Dhillion and Zak 1993; Dhillion et al. 1995; Fontenla et al. 2001), to our knowledge, only four studies have been

Table 1 Study sites, location, altitude (m.a.s.l.) and description of communities within the Biosphere Reserve Tehuacán-Cuicatlán Valley, south-central Mexico, in which 50 perennial xeric plants were examined for their mycorrhizal status. The Tehuacán-Cuicatlán Valley is located within the states of Puebla and Oaxaca, Mexico. Six sites were chosen for plant species root collection: S1, Azumbilla; S2, Coxcatlán; S3, Caltepec; S4, Tehuacán; S5, Atexcoco; S6, Los Reyes Metzontla. The study sites are grouped according to their range of distribution within the Valley. For seasonal temperature and precipitation, see Table 2. Within the study sites, we registered 24 plant families, 51 genera and ca. 70 species (5% of the total flora estimated in the Valley). Disturbance caused by farming, goat grazing, deforestation, urban pressure with concomitant road construction, salt mining, and commercial poultry are the major factors of environmental disturbance within both the matorral xerófilo (*MX*) and the selva baja caducifolia (*SBC*). Although environmental disturbance is caused by the simultaneous action of diverse agents, in the table we only refer to the main disturbance factor for each site. Slope: flat (0°–15°), medium (15°–30°), steep (30°–45°)

Site	Location	Munici-pality	Alti-tude	Community	Species within the study site	Distur-bance	Slope
S1	18°41'31'N, 97°24'01.3''W	Chapulco	2,232	MX	[a] *Agave marmorata*, [a] *Agave salmiana*, [a] *Agave triangularis*, *Bursera fagaroides*, *Calliandra eriophylla*, [a] *Coryphanta radians*, *Dalea* sp., *Dasylirion* sp., *Erythroxylon compactum*, *Hechtia* aff. *podantha*, *Leucophyllum* sp., *Mimosa lacerata*, *Mimosa purpusii*, *Nolina longifolia*, [a] *Opuntia pilifera*, *Yucca periculosa*	Farming	Medium
S4	18°24'9.8''N, 97°26'19.2''W	Tehuacán	1,720	MX	[a] *Agave kerchovei*, [a] *Agave marmorata*, *Buddleja* sp., *Calliandra eriophylla*, *Croton ciliato-glanduliferus*, [a] *Echinocactus platyacanthus*, [a] *Ferocactus flavovirens*, *Forestiera* sp., *Gymnosperma glutinosum*, *Hechtia* sp., *Lantana* sp., *Lippia* sp., *Mimosa calcicola*, *Mitrocereus fulviceps*, *Morkilia mexicana*, [a] *Myrtillocactus geometrizans*, [a] *Pedilanthus cymbiferus*, *Yucca periculosa*	Salt mining	Medium
S6	18°16'29.4''N, 97°30'12.9''W	Caltepec	1,670	MX	*Acacia constricta*, [a]*Agave kerchovei*, [a]*Agave marmorata*, *Beaucarnea gracilis*, *Cercidium praecox*, *Cnidosculus* sp., [a]*Hechtia* sp., *Ipomoea arborescens*, *Lippia graveolens*, *Mimosa luisana*, [a]*Myrtillocactus geometrizans*, [a]*Neobuxbaumia tetetzo*, [a] *Pedilanthus cymbiferus*, *Zapoteca* sp.	Roads	Medium
S3	18°10'31.3''N, 97°28'45.8''W	Caltepec	1,890	An ecotone between SBC and *Quercus* forest	*Acacia cochliacantha*, *Acacia farnesiana*, [a] *Coryphanta radians*, *Croton ciliato-glanduliferus*, *Eysenhardtia polystachya*, *Gymnosperma glutinosum*, *Ipomoea* sp., *Lippia* sp., *Lamourouxia rhinanthifolia*, *Mimosa adenantheroides*, [a] *Opuntia streptacantha*, *Plumeria rubra*, *Prosopis laevigata*, *Senna uniflora*, [a] *Stenocereus stellatus*, *Tecoma stans*, *Viguiera eriophora*, *Zanthoxylon* sp., *Zornia* sp	Urban pressure	Medium
S5	18°12'0.46''N, 97°31'28.6''W	Caltepec	2,050	An ecotone between SBC and *Quercus* forest	*Acacia constricta*, *Acacia farnesiana*, *Ageratina espinosarum*, *Baccharis* sp., *Cordia curassavica*, *Croton ciliato-glanduliferus*, *Dodonaea viscosa*, [a] *Escontria chiotilla*, [a] *Ferocactus latispinus*, *Gymnosperma glutinosum*, *Ipomoea* sp., *Mammilaria* sp., *Mimosa biuncifera*, *Mimosa texana* var. *filipes*, [a] *Opuntia streptacantha*, *Penstemon* sp., *Piqueria trinervia*, *Randia capitata*, *Senecio praecox*	Farming	Flat
S2	18°15'23.7''N, 97°09'03.3''W	Coxcatlán	1,140	MX	*Acacia cochliacantha*, *Bursera* sp., *Celtis* sp., [a] *Escontria chiotilla*, *Gomphrena decumbens*, *Gomphrena dispersa*, *Gomphrena pringlei*, *Lippia graveolens*, [a] *Mammilaria carnea*, *Mimosa luisana*, *Mimosa polyantha*, [a] *Opuntia decumbens*, [a] *Opuntia pilifera*, [a] *Opuntia velutina*, [a]*Stenocereus pruinosus*	Goat grazing	Flat

[a] Plants also reported under the canopy of *Mimosa* species (for more details on the communities see Camargo-Ricalde et al. 2002)

carried out in Mexico: two in the desert scrub (Sonoran desert) of Baja California (Rose 1981; Carrillo-García et al. 1999), one in the semiarid rangelands of the Actopan Valley in central Mexico (Montaño-Arias 1999), and one in the sand dunes of La Mancha, Veracruz (Corkidi and Rincón 1997).

Here we report on the arbuscular mycorrhizal (AM) status of 50 perennial plant species of the matorral xerófilo and the ecotones of the selva baja caducifolia and the oak (*Quercus*) forest within the Tehuacán-Cuicatlán Valley. A previous study registered 70 tree and shrub species (5% of the total flora) within these communities (Camargo-Ricalde et al. 2002). Thus, we were able to sample ca. 70% of the trees and shrubs at the sites. Twenty-one of the species examined are endemic to Mexico and nine are endemic to the Valley.

Materials and methods

Study sites and plant communities

Six sites within the Valley were selected; four within the matorral xerófilo (S1, S2, S4, S6) and two within the ecotone of the selva baja caducifoli (S3, S5) communities. For each site, a 300-m^2 quadrat was sampled during early November 2001 (start of the dry season). Plants were still green and fine roots were present in all plants (Tables 1, 2).

Mycorrhizal status

Root samples of shrubs, trees and cacti within the quadrats were collected. At least, three individuals per species were sampled. Shrubs and trees were excavated and the main root was tracked to lateral and fine roots; when possible, the entire root system was collected. Plant species voucher specimens are deposited at the Herbario Metropolitano (UAMIZ).

Fine-root samples of the 50 species in the quadrats were examined. Roots were washed and fixed in 50% ethanol, cleared with 10% KOH solution and stained with trypan blue according to Phillips and Hayman (1970) modified by Koske and Gemma (1989). Stained root segments (approximately 135 root segments per sample) were examined for mycorrhizal associations. Internal hyphae, vesicles and arbuscules were documented. Permanent slides and a photographic record are deposited at the Laboratory of Legume Biosystematics, Department of Biology, Autonomous Metropolitan University-Iztapalapa.

Results and discussion

Mycorrhizal plants

To our knowledge, we report AM for the first time in 37 species (Table 3); of which 21 are endemic to Mexico and nine to the Tehuacán-Cuicatlán Valley. We also report AM for the first time in three genera, *Buddleja* L., *Hechtia* Kl. and *Zornia* Gmel. Of the 16 families recorded, we add Buddlejaceae as possessing AM. In the Buddlejaceae family, Harley and Harley (1987) reported only one species, *Buddleja davidii* Franchet, as non-mycorrhizal.

Most of the mycorrhizal species reported here are dominant/codominant species within their communities and have a high importance value (IV), e.g. *Acacia cochliacantha* (IV=34.88), *Agave* spp. (IV=27.25), *Calliandra eriophylla* (IV=91.47), *Hechtia* spp. (e.g. *Hechtia* sp. IV=61.16), *Mimosa* spp. (e.g. *M. luisana* IV=97.74, *M. texana* var. *filipes* IV=117.35), *Morkilia mexicana* (IV=27.40), *Neobuxbaumia tetetzo* (IV=48.63), *Opuntia* spp. (IV=105.93) and *Tecoma stans* (IV=24.67) (Camargo-Ricalde et al. 2002). Furthermore, all the examined species of the Cactaceae and the Fabaceae families are mycorrhizal. A number of studies within the Mexican arid and semiarid ecosystems, e.g. Valiente-Banuet et al. (1991), Carrillo-García et al. (1999), Montaño-Arias (1999), have pointed out the importance of legumes forming resource islands and the role these species can play within the nurse-nursling association, where nursling plants are cacti (e.g. *Neobuxbaumia tetetzo*, Valiente-Banuet et al. 1991); however, the potential role of AM is still not well understood. Plants associated with *Mimosa* species that may be important to investigate are *Coryphanta radians*, *Escontria chiotilla*, *Ferocactus flavovirens*, *Ferocactus latispinus*, *Mammilaria carnea*, *Myrtillocactus geometrizans*, *Opuntia pilifera*, *Opuntia streptacantha* and *Stenocereus stellatus*, all of them members of the Cactaceae family and either endemic to Mexico or to the Valley (Tables 1 and 2). In another study, we found that the number of AM fungal spores was significantly higher under the canopy of *Mimosa* species than in non-vegetated areas (Camargo-Ricalde and Dhillion 2002).

Both *Beaucarnea gracilis*, a threatened species (Mexican Official Diary 2000) and *Mimosa purpusii*, a

Table 2 Monthly mean temperature (T °C) and precipitation (P mm) and annual total at the study sites. Values were recorded for at least 16 years at

Site		Month													Annual Total
		J	F	M	A	M	J	J	A	S	O	N	D	Mean	
S1,S4	T	15	17	19	20	21	21	20	20	20	19	17	16	19	
	P	2	3	4	8	69	90	75	59	118	32	4	5		480
S6	T	17	18	22	24	24	24	23	23	23	21	20	17	21	
	P	12	6	7	34	61	92	45	60	89	36	6	3		450
S3,S5	T	15	16	19	21	21	20	19	19	19	18	17	15	18	
	P	5	3	16	23	40	97	55	49	86	29	7	4		412
S2	T	20	22	25	27	28	26	25	25	24	24	22	21	24	
	P	4	2	4	13	41	92	76	78	92	31	5	3		440

Table 3 The arbuscular mycorrhizal status (ratio AM/NM) of 50 perennial xeric plants from six study sites within the Biosphere Reserve Tehuacán-Cuicatlán Valley, south-central Mexico. Study sites: S1, Azumbilla; S2, Coxcatlán; S3, Caltepec; S4, Tehuacán; S5, Atexcoco; S6, Los Reyes Metzontla. Sites S1, S2, S4 and S6 belong to the matorral xerófilo and sites S3 and S5 to the ecotone of the selva baja caducifolia and the oak (*Quercus*) forest. For percentage root colonized (*Col*), 135 root segments per sample were considered as 100% (*low* 1–10%, *medium* 11–20%, *high* >20%). The references report the presence (+) or absence (–) of AM [*1* first report in this paper, *2* Fontenla et al. (2001), *3* McGee (1986), *4* Corkidi and Rincón (1997), *5* Carrillo-García et al. (1999), *6* Khan (1974), *7* Logan et al. (1989), *8* Bloss and Walker (1987)] (*CS* Conservation status, *Ph* phenology, *fl* flowering, *fr* fruiting, *v* vegetative, *AM* mycorrhizal, *NM* non-mycorrhizal)

Site	Family	Species	Distribution/CS	Ph	AM/NM	Col	References
S1, S4, S6	Agavaceae	*Agave marmorata* Roezl	[a] Mexico	v	7/2	Medium	+, 1
S1		*A. salmiana* Otto & Salm-Dyck	[a] Mexico	v	1/2	Low	+, 1
S1, S4		*Yucca periculosa* F. Baker	[a] Mexico	v	5/1	Low	+, 1
S5	[f] Asteraceae	*Ageratina espinosarum* (A. Gray) King & H. Rob.	[a] Mexico	fl	2/1	Low	+, 1
S5		*Baccharis* sp.	American Continent	fl	1/2	Low	+2
S3, S4, S5		*Gymnosperma glutinosum* (Sprengel) Less.	USA, Mexico, Guatemala	fl	7/2	Low	+, 1
S5		*Senecio praecox* (Cav.) D.C.	[a] Mexico	v	0/3	NM	–, 1, +2[e], +3[e]
S3		*Viguiera eriophora* Greenman	[a] Mexico	fl	2/1	Low	+, 1
S3	Bignoniaceae	*Tecoma stans* (L.) Juss. ex Kunth.	USA to South America	fr	3/3	Low	+4, +5
S5	[f] Boraginaceae	*Cordia curassavica* (Jacq.) Roemer & Shultes	USA to Panama, West Indies	v	2/1	Low	+, 1
S1	Bromeliaceae	*Hechtia* aff. *podantha* Mez	[a] Mexico	fl	3/0	Low	+, 1
S4		*Hechtia* sp.	[b] USA to Nicaragua	v	3/0	Low	+, 1
S6		*Hechtia* sp.	[b] USA to Nicaragua	v	3/0	Medium	+, 1
S4	[g] Buddlejaceae	*Buddleja* sp.	Pantropical	v	1/2	Low	+, 1
S1	Burseraceae	*Bursera fagaroides* (Kunth) Englem.	USA, Mexico	fr	0/3	NM	+5[e]
S1, S3	Cactaceae	*Coryphanta radians* (DC.) Britton & Rose	[a] Mexico	v	4/2	Low	+, 1
S2, S5		*Escontria chiotilla* (F.A.C. Weber) Rose	[a] Mexico	v	4/2	Low	+, 1
S4		*Ferocactus flavovirens* (Scheidw.) Britton & Rose	[c] T-C Valley	v	2/1	Low	+, 1
S5		*Ferocactus latispinus* (Haworth) Britton & Rose	[a] Mexico	v	1/2	Low	+, 1
S2		*Mammilaria carnea* Zucc. ex Pfeiffer	[a] Mexico	v	2/1	Low	+, 1
S5		*Mammilaria* sp.	USA to Venezuela, West Indies	v	2/1	Low	+5
S4, S6		*Myrtillocactus geometrizans* (C. Martius) Console	[a] Mexico	v	3/3	Low	+, 1
S6		*Neobuxbaumia tetetzo* (F.A.C. Weber) Backeb.	[c] T-C Valley	v	2/1	Low	+, 1
S1, S2		*Opuntia pilifera* F.A.C. Weber	[c] T-C Valley	v	3/3	Medium	+, 1
S3		*O. streptacantha* Lemaire	[a] Mexico	v	2/1	Medium	+, 1
S3		*Stenocereus stellatus* (Pfeiffer) Riccob.	[a] Mexico	v	2/1	Low	+, 1
S6	[f] Convolvulaceae	*Ipomoea arborescens* G. Don	Mexico, Central America	v	3/0	Low	+, 1
S3, S5		*Ipomoea* sp.	[b] Pantropical	v	4/2	Medium	+4, +6, +7
S1	Erythroxylaceae	*Erythroxylon compactum* Rose	[c] T-C Valley	v	0/3	NM	–, 1
S3, S4, S5	[f] Euphorbiaceae	*Croton ciliato-glanduliferus* Ortega	Mexico, Central America, Cuba	fl, v	6/3	Low	+, 1
S4, S6		*Pedilanthus cymbiferus* Schltdl.	[a] Mexico	v	0/6	NM	+5[e]
S2, S3	[f] Fabaceae	*Acacia cochliacantha* Humb. & Bonpl. ex Willd.	Mexico, Central and South America	v	2/4	Low	+, 1
S6		*A. constricta* Benth.	USA and Mexico	fr, v	2/1	Low	+, 1
S3, S5		*A. farnesiana* (L.) Willd.	Pantropical	v	2/4	Low	+, 1
S1, S4		*Calliandra eriophylla* Benth.	[a] Mexico	fr	5/1	Low	+, 1
S3		*Eysenhardtia polystachya* (Ortega) Sarg.	USA, Mexico	v	2/1	Low	+, 1
S3		*Mimosa adenantheroides* (M. Martens & Galeotti) Benth.	[a] Mexico	fr	2/1	Low	+, 1
S5		*M. biuncifera* Benth.	USA, Mexico	v	2/1	Low	+8
S4		*M. calcicola* B.L. Rob.	[c] T-C Valley	v	1/2	Low	+, 1
S1		*M. lacerata* Rose	[a] Mexico	v	3/0	Low	+, 1
S2, S6		*M. luisana* Brandegee	[c]T-C Valley	fr	4/2	Medium	+, 1

Table 3 (continued)

Site	Family	Species	Distribution/CS	Ph	AM/NM	Col	References
S2		*M. polyantha* Benth.	[a]Mexico	fr	2/1	Low	+, 1
S1		*M. purpusii* Brandegee	[c,d]T-C Valley, rare	v	3/0	Low	+, 1
S5		*M. texana* (A. Gray) Small var. *filipes* (Britton & Rose) Barneby	[c]T-C Valley	fr	2/1	Low	+, 1
S3		*Zornia* sp.	Pantropical	v	1/2	Low	+, 1
S6	Nolinaceae	*Beaucarnea gracilis* Lem.	[c]T-C Valley, threatened	v	1/2	Low	+, 1
S1		*Dasylirion* sp.	[b]USA, Mexico	v	1/2	Low	+8
S3	[f]Scrophulariaceae	*Lamourouxia rhinanthifolia* Kunth	[a]Mexico	fl	0/3	NM	–, 1
S2,S6	[f]Verbenaceae	*Lippia graveolens* Kunth	USA, Mexico, Central America	v	2/4	Low	+, 1
S4	Zygophyllaceae	*Morkillia mexicana* (Mociño & Sessé) Rose & Painter	[a]Mexico	fr	1/2	Low	+, 1

[a]Endemic to Mexico, [b]genus distribution, [c]endemic to the Valley, [d]rare according to vegetation community data (Camargo-Ricalde et al. 2002), [e]genera and/or species reported forming AM, [f]families reported mycorrhizal and non-mycorrhizal by Harley and Harley (1987)

potentially rare species, were mycorrhizal. Though *M. purpusii* is not yet officially registered as a rare species, parallel studies point to its rarity and narrow endemism within the Valley (Camargo-Ricalde et al. 2002).

We also collected species of three genera already reported to be mycorrhizal: *Baccharis* L. from Patagonia, Argentina (Fontenla et al. 2001), *Dasylirion* Zucc. from Arizona, USA (Bloss and Walker 1987) and *Ipomoea* L. from Mexico (Corkidi and Rincón 1997), Pakistan (Khan 1974) and New South Wales, Australia (Logan et al. 1989). Furthermore, AM are reported for the first time in *Ipomoea arborescens*, *Croton ciliato-glanduliferus* and *Lippia graveolens*, though Corkidi and Rincón (1997) reported AM in related species, *C. punctatus* Jacq. and in *L. nodiflora* (L.) Greene from a sand dune in the Gulf of Mexico.

For arid and semiarid regions, other known mycorrhizal genera also reported by us are *Acacia* Willd. (Khan 1974; McGee 1986; Bethlenfalvay et al. 1984; Dhillion et al. 1995), *Agave* L. (e.g. Bloss and Walker 1987; Bethlenfalvay et al. 1984; Cui and Nobel 1992; Carillo-García et al. 1999), *Opuntia* (Tourn.) Mill. (Miller 1979; Rose 1981; Bethlenfalvay et al. 1984; Cui and Nobel 1992; Corkidi and Rincón 1997; Carrillo-García 1999) and *Yucca* L. (Rose 1981; Bethlenfalvay et al. 1984).

Of all the investigated species, only *Mimosa biuncifera* and *Tecoma stans* have been reported as forming AM: *M. biuncifera* from Arizona (Bloss and Walker 1987) and *T. stans* from the Gulf of Mexico (Corkidi and Rincón 1997) and from Baja California Sur, Mexico (Carrillo-García et al. 1999).

No AM fungal structures were observed in *Bursera fagaroides*, *Erythroxylon compactum*, *Lamourouxia rhinanthifolia*, *Pedilanthus cymbiferus* or *Senecio praecox*. However, Carrillo-García et al. (1999) reported AM in two species of *Bursera* and in one species of *Pedilanthus* from the desert scrub in Baja California Sur, Mexico. Fontenla et al. (2001) registered AM in five *Senecio* species from Patagonia, Argentina, and McGee (1986) in two species from South Australia. More plants of these species should be sampled to determine their AM status.

There is a need to conduct more seasonal observations of AM in these communities, given that mycorrhizal association can vary over space and time (Dhillion and Zak 1993) and that, in this case, roots were collected during the start of the dry season (early November) (Table 2). Within the arid and semiarid ecosystems, intermittent periods of favorable temperature and moisture, so-called “windows of opportunity”, strongly regulate the mechanisms controlling fungal activity and dynamics (Dhillion and Zak 1993; Zak et al. 1995), moisture being the main limiting factor in desert ecosystems.

The low percentage of AM colonization found in the species examined (Table 3) may be related not only to seasonality, but also to environmental disturbance. It is well known that the type, degree and intensity of environmental disturbance (e.g. Allen 1991; Dhillion and Zak 1993; Dhillion et al. 1994; Dhillion 1999;

Carrillo-García et al. 1999) can affect AM fungal population dynamics as well as plant communities in the Valley (Camargo-Ricalde et al. 2002). Though environmental disturbance is caused by the simultaneous action of diverse agents (Tables 1, 2), goat grazing is more intense at site S2. Deforestation for creating new agricultural fields is increasing at sites S1 and S5, soil and rock extraction for a mill as part of a salt mine is close to site S4, and urban growth pressure impacts sites S3 and S6, mainly through the opening of new dirt roads in the latter. More research is needed to understand how disturbance is affecting both the above-ground plant communities and the below-ground microbial communities established in the Valley.

Management needs in the Tehuacán Cuicatlán Valley Biosphere Reserve

There is no doubt that mycorrhizae are important in both plant establishment and restoration in arid and semiarid ecosystems (e.g. Allen et al. 1981; Allen and Allen 1986; Cui and Nobel 1992; Dhillion and Zak 1993; Roldán-Fajardo 1994; Whitford 1996), and their importance in maintaining plant diversity and ecosystem functioning has been reported (e.g. Van der Heijden et al. 1998; Hartnett and Wilson 1999; Koide et al. 2000). However, reports to date on the mycorrhizal status of plants of arid and semiarid regions of the world (e.g. Khan 1974; El-Giahmi et al. 1976; Singh and Varma 1981; McGee 1986; Dhillion et al. 1995; Requena et al. 1996) have focused mainly on the North American deserts (e.g. Williams and Aldon 1976; Miller 1979; Pendleton and Smith 1983; Bethlenfalvay et al. 1984; Bloss and Walker 1987). The mycorrhizal nature of 45 of the 50 plant species examined, of which 37 are reported for the first time, and of which 21 are endemic to Mexico and nine endemic to the Valley, clearly indicates that AM fungi must be considered in rehabilitation programs within the Valley. More research on above- and below-ground interactions and biodiversity is needed in the arid and the semiarid regions. In developing countries, like the Tehuacán-Cuicatlán Valley of Mexico, many xeric plant species are also used and managed by local people. Therefore, equally important in developing countries is an integrative approach for conservation of land and use management with local needs and participation.

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