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Vesiculo arbuscular mycorrhizae associated with saltbushes *Atriplex* spp. (Chenopodiaceae) in the Chilean arid zone

Micorrizas vesículo arbusculares en poblaciones del género *Atriplex* (Chenopodiaceae) en la zona árida de Chile

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ABSTRACT

The family Chenopodiaceae is represented in arid plant communities worldwide. Chenopodiaceae have been usually defined as non-mycorrhizal; however, recently some species of the genus *Atriplex* in North America have been shown to be mycorrhizal. We determined the vesiculo arbuscular mycorrhizal (VAM) status of nine species of *Atriplex* spp., including nine populations of *A. repanda*, three of *A. atacamensis*, two of *A. madariagae* and *A. mucronata*, and one of *A. podocarpa*, *A. coquimbensis*, *A. deserticola* and *A. microphylla*, and two plantations of the exotic species *A. nummularia* in the Chilean Pacific coastal desert. Localities and species showed large differences in number of VAM spores and percentage of VAM infection. Number of VAM spores and percentage of VAM infection were positively correlated with available nitrogen in the soil. Percentage of VAM infection was also negatively correlated with soil salinity. Considering all populations, we found in the field on the average 32% infection and 45 VAM spores/100 g soil. Although the infection percentage was low, this may allow land managers to select VAM strains to inoculate *Atriplex* plants used to reclaim disturbed Chilean aridlands.

Key words: vesiculo-arbuscular mycorrhizae, *Atriplex*, Chile, aridlands, halophytes.

RESUMEN

La familia Chenopodiaceae se encuentra representada en las comunidades de plantas de zonas áridas de todo el mundo. Se ha definido frecuentemente como no micotrófica, sin embargo, recientemente algunas especies del género *Atriplex* en Norte América se han documentado como micotróficas. Nosotros determinamos el status micorrícico vesículo arbuscular de nueve especies de *Atriplex* spp., incluyendo nueve poblaciones de *Atriplex repanda*, tres de *A. atacamensis*, dos de *A. madariagae* y de *A. mucronata*, y una de *A. podocarpa*, *A. coquimbensis*, *A. deserticola* y *A. microphylla*, y dos plantaciones de la especie exótica *A. nummularia*, en la zona costera árida de Chile. Tanto las localidades como las diferentes especies presentaron grandes diferencias en el número de esporas VAM y porcentaje de infección VAM de raíces. El número de esporas y el porcentaje de infección VAM se correlacionó positivamente con el nivel de fósforo disponible y negativamente con el nitrógeno disponible del suelo. El porcentaje de infección VAM también se correlacionó negativamente con la salinidad del suelo. Considerando todas las poblaciones, se encontró en promedio un 32% de infección y 45 esporas VAM/100 g de suelo en el terreno. A pesar que el porcentaje de infección fue bajo, esto podría permitir seleccionar cepas VAM para inocular plantas de *Atriplex* que son usadas en la actualidad para recuperar suelos áridos degradados de Chile.

Palabras clave: micorrizas vesículo-arbusculares, *Atriplex*, Chile, zonas áridas, halófitas.

INTRODUCTION

Vesicular-arbuscular micorrhizae (VAM) live in endophytic symbiosis with the roots of the majority of plant species in arid regions (Newman & Reddell 1987, Torres 1990). These microorganisms belong to the family Endogonaceae and to the class Zygomicetes (Newman & Reddel 1987, Allen 1991). VAM formation on roots have a positive effect on the host plant by enhancing phosphorus absorption. The

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hyphae of the fungal mycelium increases the absorptive surface of plant roots allowing them to take up phosphorus from a large soil volume, thus increasing plant growth rates, especially in phosphorus-poor soil (Azcon & Barea 1980, Fogel 1980, Hardy & Leyton 1981, Dhillion & Zak 1993). The plant provides the fungi with carbohydrates coming from photosynthesis, and a protected place against the microbial antagonism in the rhizosphere.

The shrubby species of the family Chenopodiaceae are important members of plant communities in arid environments in north-central Chile (Aguilera et al. 1989) and their productivity vary spatially as well as temporally. The VAM status of the species belonging to this family is controversial. The Chenopodiaceae is one of the few families defined as non-mycorrhizal. However, recently some species in this family have been reported as mycorrhizal (Hirrel et al. 1978, Newman & Reddel 1987, Dhillion & Zak 1993, Dhillion et al. 1995).

A survey of the endomycorrhizal status of North American shrubs reported that 68% of the species in the family Chenopodiaceae showed some degree of association with VAM, and three out of five epecies of *Atriplex* (Linneaus, 1753) had VAM associated with their roots (Lindsey 1982). On the other side, using inoculation techniques it has been possible to induce infection in *Chenopodium quinoa* (Selwad et al. 1982). The presence of VAM vesicles and hyphae in *Atriplex canescens* enhanced its growth and survival (Williams et al. 1974). The VAM association may be important for the use of these species in reclamation plans. The productivity of *Atriplex gardeneri* was increased when plants were inoculated with VAM spores or with soil containing VAM spores (Allen 1983).

Studying the VAM status of woody plants with potential value for reclaiming low production lands in the Chilean arid zone, Torres (1990) found that *Atriplex nummularia,* a species introduced to Chile from Australia, shows a low percentage of VAM infection in its roots, which varied seasonally. The maximun infection value was 26% in summer. In Chile, a few studies about the mycorrhizal status of plants have been conducted mainly in forest ecosystems (Godoy et al. 1989, 1994a, 1994b). The information available on VAM in arid ecosystems is limited to the study on VAM status of herbs and shrubs in the fog-free Pacific coastal desert of Chile by Dhillion etal. (1995). The plants examined in that study included endemic species, endangered and rare geophytes. Over 90% of the 38 species analyzed (19 families), including four species of *Atriplex* (*A. coquimbensis, A. deserticola, A. madariagae and A. repanda*) had VAM associations. Given the apparently increasing findings of the association between VAM and species in the genus *Atriplex*, we will assess here the VAM status of eigth out of twenty-one (Rosas 1989) *Atriplex* species native to Chile and one introduced species. The hypotheses tested were as follows: (1) there will be significant associations between the occurrence of VAM fungal symbionts and *Atriplex* spp. and (2) the differences in abundance of spores and percentage of infection VAM fungi of *Atriplex* rhizospheres will be related to differences in soil nutrient availability in the study sites.

MATERIALS AND METHODS

Location of Atriplex populations

We studied nine species of *Atriplex* in twenty localites along the coastal Pacific desert of Chile. Overall, we sampled nine populations of *Atriplex repanda* (between 27°30' and 31°55' S), three populations of *A. atacamensis* (between 23°15' and 25°30' S), two populations of *A. madariagae* and *A. mucronata*, (27°30' and 26°15' S), and one population of *A. podocarpa* (29°52' S), *A. coquimbensis* (29°23' S), *A. deserticola*

(28°23' S) and *A. microphylla* (29°54' S) (Fig. 1). No other Atriplex species were present in the study sites. In general, *Atriplex* populations occurred in open, stony, and high radiation sites with a sparse plant cover and low species richness. All sites had evidences of recent intense human disturbance (mining and/or agricultural activity). Site elevation varied between 50 and 2,200 m, with slopes between 0 and 35°, soil texture ranged from sandy-clay loam to sandy-clay (Table 1). Annual precipitation varies between 330 mm in Los Vilos (the southernmost locality) to <5 mm in Camarones (the northenmost locality).

Soil sampling

In each locality, we collected, in the summer season of 1995, five 1kg-soil samples, from the top 20 cm of soil directly below the canopy of five randomly chosen *Atriplex* plants, where most of the VAM were presumably present (Trape 1981). The samples were stored in plastic bags and within 24 hours transported to the laboratory for chemical and fungal analyses. pH was determined in a 1:5 (w/v) suspension of soil in water. Organic matter was calculated from the percent organic carbon estimated by oxidization with dichromate in presence of H_2SO_4, without application of external heat. Electrical conductivity was determined by a saturated-paste method (Dewis & Freitas 1984). Available nitrogen (ammonium, nitrite and nitrate) was extracted with 2M KCl. Available phosphorus was extracted with 2M ammonium acetate at pH 7.0. Soil texture was determined by the Boyoucos' densimeter method (Dewis & Freitas 1984).

VAM spores were isolated employing a wet-sieving density gradient procedure (Anderson & Liberta 1989) and intact spores with filled-cytoplasm were counted and identified following Schenck & Perez (1990). One-way ANOVAs were used to compare estimated number of VAM spores, and percentage of VAM in soil and root samples collected from underneath saltbushes. Prior to the analyses, percentage data were arcsine square-root transformed. Number of VAM spores and percentage of VAM in soil samples were related to soil characteristics by multiple regression analysis.

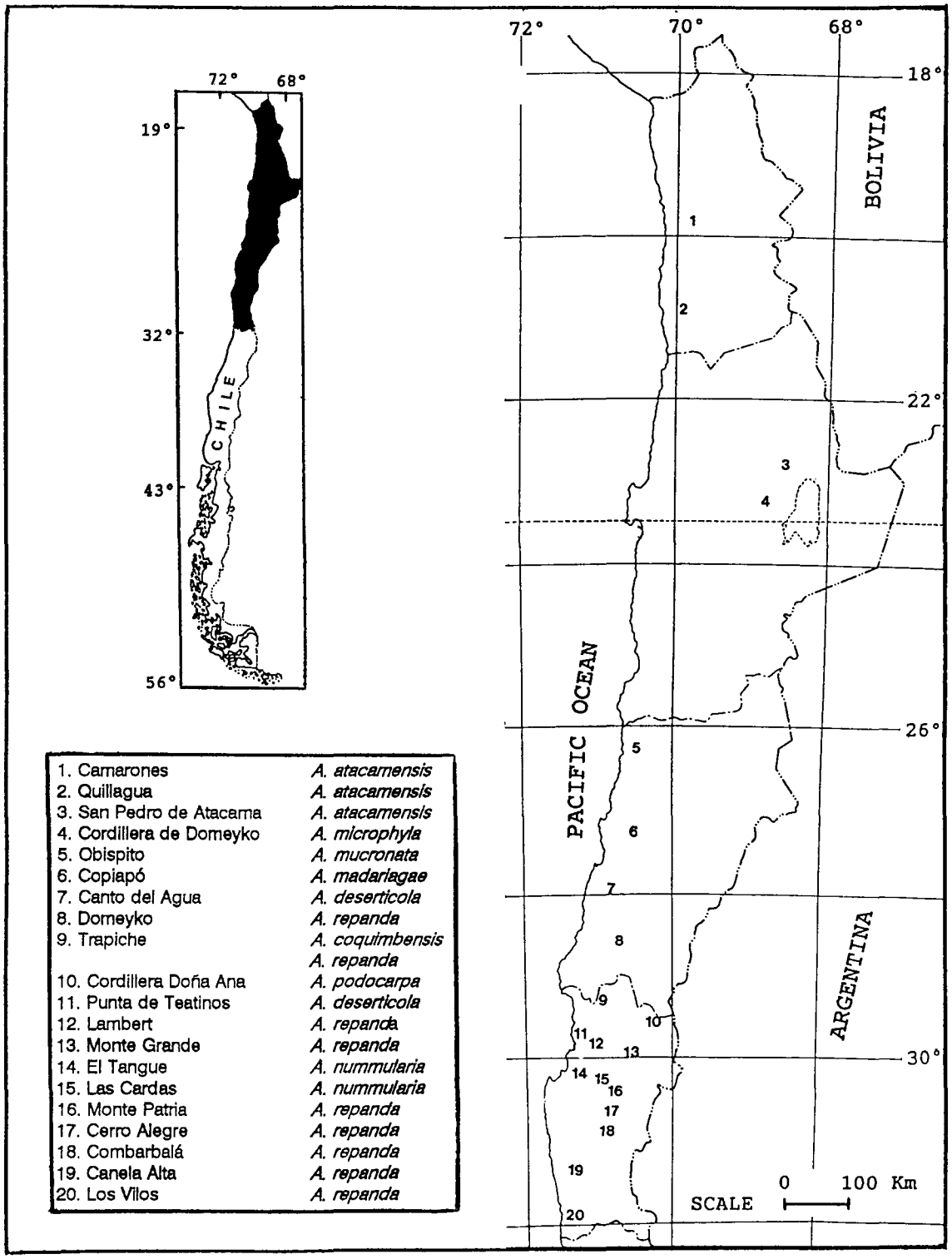
Root collections and analysis

In each locality, 20 cm of roots 1-2 mm in diameter were collected from five randomly chosen plants of the species of interest. In each root sample, the VAM infection was determined by the Phillips & Hayman's method (Phillips & Hayman 1970).

RESULTS AND DISCUSSION

The general physico-chemical characteristics of the soils for each locality are shown in Table 2. Soil pH ranged from neutral to alkaline. Despite generally *Atriplex* species have been considered as halophytes, with more than 50% of the species living in saline to high salinity soils (Hall & Clements 1923, Osmond et al. 1980) most soils were non-saline, except for Quillagua, San Pedro de Atacama and Trapiche which were saline and Juntas del Toro which was moderately saline. All the soils were poor in organic matter, with low concentrations of available nitrogen and phosphorus. Soil from the southermost site, Los Vilos, showed the highest values of organic matter, nitrogen and phosphorus.

In the rhizosphere of 15 out of 21 *Atriplex* populations had VAM spores and in two other ones there were not evidence for VAM infection (Figs. 2 and 3). The localities of Quillagua, San Pedro de Atacama, and El Tangue showed the highest spore abundance (70, 70, and 64.6 spores/100 g soil, respectively). There was a positive correlation between the percent of VAM infection in root systems and the concentration of spores in the rhizosphere ($r = 0.65$; $P < 0.0001$).



1. Camarones	*A. atacamensis*
2. Quillagua	*A. atacamensis*
3. San Pedro de Atacama	*A. atacamensis*
4. Cordillera de Domeyko	*A. microphyla*
5. Obispito	*A. mucronata*
6. Copiapó	*A. madariagae*
7. Canto del Agua	*A. deserticola*
8. Domeyko	*A. repanda*
9. Trapiche	*A. coquimbensis*
	A. repanda
10. Cordillera Doña Ana	*A. podocarpa*
11. Punta de Teatinos	*A. deserticola*
12. Lambert	*A. repanda*
13. Monte Grande	*A. repanda*
14. El Tangue	*A. nummularia*
15. Las Cardas	*A. nummularia*
16. Monte Patria	*A. repanda*
17. Cerro Alegre	*A. repanda*
18. Combarbalá	*A. repanda*
19. Canela Alta	*A. repanda*
20. Los Vilos	*A. repanda*

Fig. 1: Geographical location of twenty-one *Atriplex* populations within the arid region of Chile.

Ubicación geográfica de veintiuna poblaciones de *Atriplex* dentro de la región árida de Chile.

TABLE 1

Sites and soil characteristics where *Atriplex* species roots were collected.

Sitios y características de suelos donde se colectaron raíces de las especies de *Atriplex*.

Study site/ species	Latitude	Altitude (masl)	Slope (degree)	Annual precipitation (mm)	Soil type
Los Vilos	31°55'	100	0	330	Sandy-clay-loam
A. repanda					
Canela Alta	31°19'	450	0	251	Sandy-clay-loam
A. repanda					
Combarbalá	31°05'	500	0	267	Sandy-clay
A. repanda					
Cerro Alegre	31°01'	550	15	267	Sandy-clay-loam
A. repanda					
Monte Patria	30°35'	300	5	137	Sandy-clay
A. repanda					
Las Cardas	30°20'	350	0	120	Sandy-clay
A. nummularia					
El Tangue	30°14'	200	0	120	Sandy-clay
A. nummularia					
Monte Grande	30°05'	1200	20	189	Sandy-clay-loam
A. repanda					
Lambert	29°55'	50	0	116	Sandy-clay-loam
A. repanda					
Pta. Teatinos	29°53'	50	0	116	Sandy
A. deserticola					
C. Doña Ana	29°52'	2200	35	145	Sandy-clay-loam
A. podocarpa					
Trapiche	29°23'	200	0	95	Sandy-clay
A. coquimbensis					
A. repanda					
Domeyko	27°30'	700	0	65	Sandy-clay
A. repanda					
Cto. del Agua	28°23'	600	0	20	Sandy
A. deserticola					
Copiapó	27°30'	550	0	20	Sandy-clay
A. madariagae					
Obispito	26°15'	50	0	20	Sandy
A. mucronata					
C. Domeyko	23°02'	2900	10	no data	Sandy-clay
A. mycrophyla					
S. P. Atacama	23°15'	2400	0	no data	Loam
A. atacamensis					
Quillagua	21°55'	750	0	<5	Sandy
A. atacamensis					
Camarones	19°54'	550	0	<5	Sandy-clay
A. atacamensis					

TABLE 2

Physical and chemical characteristics of soil samples of *Atriplex* populations. Each value corresponds to the mean of 5 replicates ± 1 SD.

Características físicas y químicas de muestras de suelos de poblaciones de *Atriplex*. Cada valor corresponde al promedio de 5 réplicas ± 1 DS.

Study site	Species	pH	O.M. (%)	E.C. (mS)	N (ppm)	P (ppm)
Los Vilos	*A. repanda*	7.0 0.2	2.1 ± 0.4	1.6 ± 0.4	16 ± 2	19 ± 4
Canela Alta	*A. repanda*	7.3 ± 0.1	1.2 ± 0.2	1.0 ± 0.1	9 ± 3	12 ± 3
Combarbalá	*A. repanda*	7.3 ± 0.1	0.8 ± 0.1	1.2 ± 0.4	5 ± 1	8 ± 2
Cerro Alegre	*A. repanda*	7.1 ± 0.2	0.9 ± 0.3	1.1 ± 0.3	6 ± 2	12 ± 2
Monte Patria	*A. repanda*	7.0 ± 0.2	1.8 ± 0.4	1.0 ± 0.1	13 ± 4	18 ± 5
Las Cardas	*A. nummularia*	7.2 ± 0.2	1.8 ± 0.6	0.6 ± 0.1	5 ± 2	11 ± 3
El Tangue	*A. nummularia*	6.3 ± 0.5	0.5 ± 0.1	0.6 ± 0.1	2 ± 1	15 ± 3
Monte Grande	*A. repanda*	7.4 ± 0.1	1.0 ± 0.3	0.4 ± 0.2	8 ± 2	10 ± 2
Lambert	*A. repanda*	7.5 ± 0.3	0.7 ± 0.2	1.2 ± 0.1	6 ± 1	13 ± 2
Pta. Teatinos	*A. deserticola*	7.1 ± 0.3	0.2 ± 0.1	0.5 ± 0.1	1 ± 0,5	5 ± 2
C. Doña Ana	*A. podocarpa*	7.8 ± 0.4	0.3 ± 0.1	1.0 ± 0.4	1 ± 0,5	4 ± 1
Trapiche	*A. coquimbensis* *A. repanda*	7.9 ± 0.4	1.0 ± 0.2	4.1 ± 0.5	6 ± 1	9 ± 1
Domeyko	*A. repanda*	7.8 ± 0.3	0.4 ± 0.2	1.3 ± 0.1	1 ± 0,5	5 ± 2
Cto. del Agua	*A. deserticola*	8.5 ± 0.4	0.5 ± 0.1	0.6 ± 0.1	2 ± 1	15 ± 2
Copiapó	*A. madariagae*	7.8 ± 0.3	0.6 ± 0.2	1.1 ± 0.3	2 ± 1	8 ± 3
Obispito	*A. mucronata*	8.6 ± 0.5	0.2 ± 0.1	1.3 ± 0.3	2 ± 1	8 ± 2
C. Domeyko	*A. microphyla*	8.4 ± 0.3	0.2 ± 0.1	0.4 ± 0.1	1 ± 0,5	4 ± 2
S. P. Atacama	*A. atacamensis*	8.0 ± 0.3	1.4 ± 0.3	17.3± 5.8	4 ± 1	21 ± 4
Quillagua	*A. atacamensis*	8.0 ± 0.4	0.6 ± 0.2	9.5 ± 2.6	4 ± 2	28 ± 6
Camarones	*A. atacamensis*	7.6 ± 0.3	0.5 ± 0.2	2.1 ± 0.5	5 ± 2	7 ± 1

O.M.: Organic Matter, E.C.: Electrical Conductivity

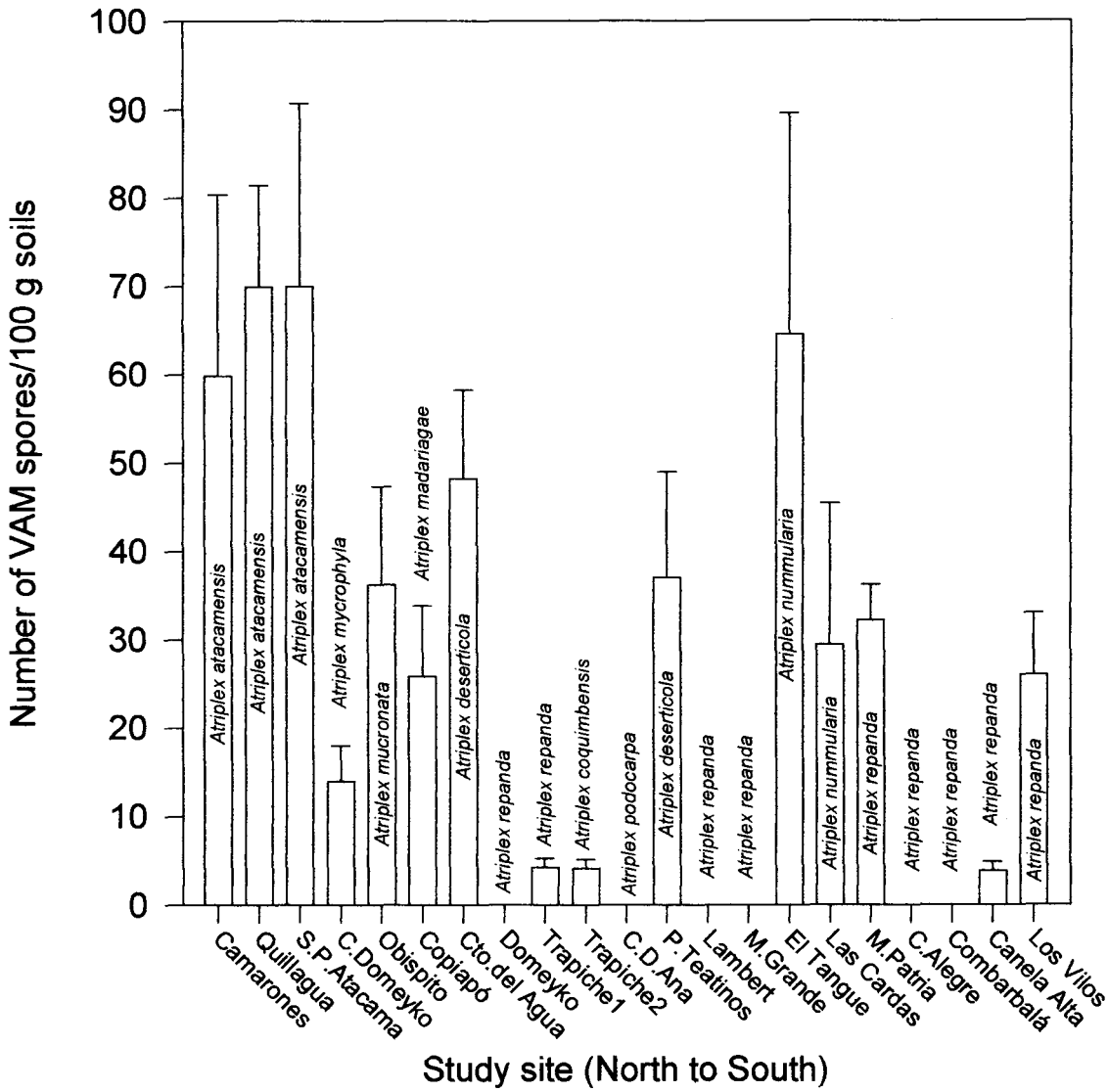


Fig. 2: Mean number of VAM spores/100 g of soil in the study sites. Sites were arranged from north (left) to south (right). Vertical lines corresponds to 1 SE.

Número promedio de esporas VAM/100 g de suelo en los distintos sitios de estudio. Las localidades fueron ordenadas de norte (izquierda) a sur (derecha). Las líneas verticales representan un error estándar.

Eigth out of the nine species of *Atriplex* studied had VAM associated with their rhizosphere and/or root systems. Although the average proportion of root infection, considering all populations, was only 32% and the mean number of VAM spores in their rhizophere was 45/100 g soil, this information would eventually allow us to select VAM strains to inoculate *Atriplex* species susceptible to fungal infection.

According to the analysis of variance we established that the number of VAM spores ($F_{(8,99)} = 23.1$, $P < 0.0001$) as well as the percentage of VAM infection ($F_{(8,99)} = 51.39$, $P < 0.0001$) differed significantly among the different species of *Atriplex* studied (Table 3). Duncan's multiple range comparisons yielded five groups of species based on the number of VAM spores and six groups based on the percentage of VAM infection (Table 4). *Atriplex atacamensis*, *A. nummularia*, and *A. deserticola* had both the higher number of

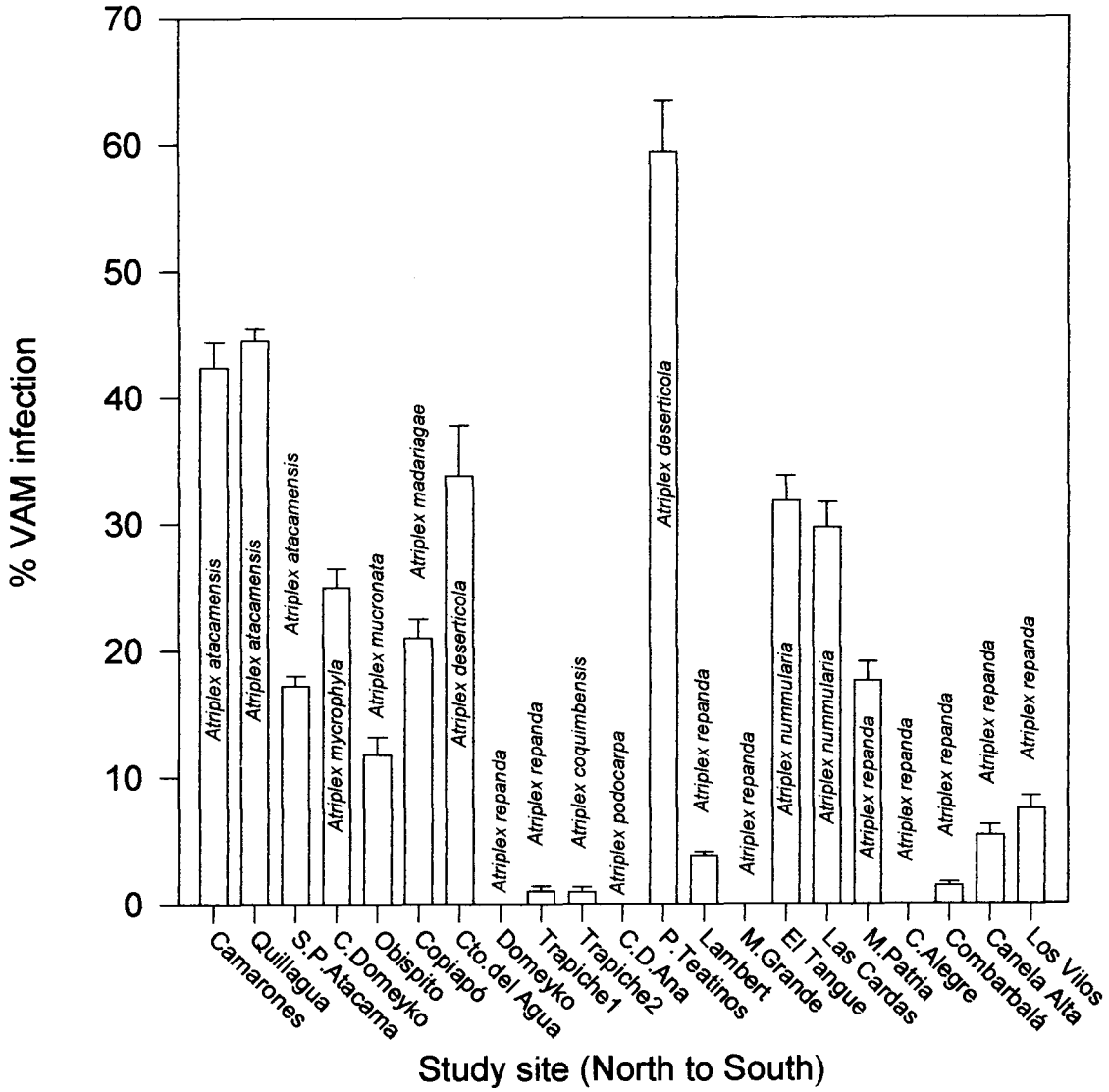


Fig. 3: Percentage of VAM infection in the study sites. Sites were arranged from north (left) to south (right). Vertical lines corresponds to 1 SE.

Porcentaje de infección VAM en los sitios de estudio. Las localidades fueron ordenadas de norte (izquierda) a sur (derecha). Las barras representan un error estándar.

VAM spores and higher percentage of VAM infection. The number of VAM spores and percentage of VAM infection were positively and significantly correlated with the level of soil phosphorus and negatively correlated with the nitrogen content of soils (Table 5). These results show that the nutrient status of soil may enhance or suppress root infection and colonization by mycorrhizas. For example, at extremely low soil phosphorus concentration, root infections by VAM fungi tends to be low (Bolan et al. 1984), because phosphorus limits the development of the fungi. With increasing root growth, the proportion of infected root length increases until an optimum level of phosphorus is approached, beyond wich infection rate is depressed to a different level, depending on VAM species (Bolan et al. 1984) and also on the host species (Davis et al. 1984). High nitrogen contents

TABLE 3

General lineal models procedure of one-way ANOVA, where number of VAM spores (a) and percentage of VAM infection (b) are the dependent variables, respectively, and the species are the treatments.

ANOVA de una vía según un modelo lineal general, donde el número de esporas VAM (a) y el porcentaje de infección (b) son las variables dependientes, y las especies son los tratamientos.

(a) Dependent Variable: number of VAM spores/100 g soil					
Source	DF	Sum of Squares	Mean Square	F	P > F
Model	8	52209.74	6526.28	23.10	0.0001
Error	91	25711.90	282.55		
Corrected Total	99	77921.64			
(b) Dependent variable: percentaje of VAM infection					
Model	8	24843.17	3105.40	51.39	0.0001
Error	91	5498.64	60.42		
Corrected Total	99	30341.81			

TABLE 4

Duncan's multiple range comparison test for number of VAM spores/100 g soil (a) and percentage of VAM infection (b), respectively. Means with the same letter are not significantly different at = 0.05.

Prueba de comparaciones múltiples de Duncan para el número de esporas VAM/100 g de suelo (a) y porcentaje de infección VAM (b). Los promedios seguidos de la misma letra no difieren significativamente para un = 0.05

Number of vam spores (a)			Percentage of vam infection (b)		
Duncan grouping	Mean	Species	Duncan grouping	Mean	Species
a	66.6	*A. atacamensis*	a	46.6	*A. deserticola*
b	47.0	*A. nummularia*	b	34.7	*A. atacamensis*
bc	42.6	*A. deserticola*	bc	30.7	*A. nummularia*
bc	36.2	*A. mucronata*	cd	25.0	*A. microphyla*
cd	25.8	*A. madariagae*	d	21.0	*A. madariagae*
de	14.0	*A. microphyla*	e	11.8	*A. mucronata*
de	7.7	*A. repanda*	ef	4.5	*A. repanda*
e	4.2	*A. coquimbensis*	f	1.1	*A. coquimbensis*
e	0.0	*A. podocarpa*	f	0.0	*A. podocarpa*

in soils depresses VAM infection, particularly in combination with high phosphorus levels (Baath & Spokes 1988, Vitousek 1994). Decreased percentage of VAM infected root associated with high phosphorus or nitrogen levels in soils are, however, not necessarily an expresion of a specific regulation mechanism, but often the result of enhanced root growth whereas that of the associated fungus lags behind. The percentage of VAM infection was negatively correlated with soil electric conductivity (Table 5), i.e. in more salty soils VAM infection is reduced. The effects of salinity on VAM fungi, which reduce plant growth in high level, is less well understood, although VAM often occur in halophytes plants (Khan 1974). Both Na and Cl reduce the infection and germination of *Gigaspora margarita* spores (Hirrel 1981), and VAM spore numbers are inversely correlated with Na in Oregon desert soils (Trape, 1981). The localities and populations also differ with respect to their contents of VAM spores ($F_{(19,99)}$ = 16.6, $P < 0.0001$) and percentage of VAM infection ($F_{(19,99)}$ = 441.98, $P < 0.0001$) (Figs. 2 and 3).

Surveys of VAM status of *Chenopodiaceae* in arid environments have shown that the number of spores in the rhizosphere and the percentage of infection of their roots are affected by soil moisture contents (Lindsey 1982, Dhillion et al. 1995). For instance, in Pakistan, the number of spores in the rhizosphere and the percentage of root infection of six halophyte species of *Chenopodiaceae* decreased during the drier months and during flooding periods (Kan 1974). Most soil and root samples of *Atriplex* in our study were collected during summer which is the dry season in the Pacific coastal desert, when temperatures are the highests of the year (Di Castri & Hajek 1976). This seasonal effect could account for the low abundance of VAM spores and percentage of root infection found in all sites. In a study on VAM status of *Adesmia bedwelii* in Parque Nacional Fray Jorge, IV Región, we found that in late winter of 1997 (August) the number of VAM spores was 3

TABLE 5

Multiple regression using the forward selection technique. Dependent variable are vam spores/100g soil (a) and % of vam infection (b). Independent variable were pH, O.M., E.C., N and P. Given values are those with significant contribution to the model for ± = 0.05.

Regresión múltiple usando el método de selección "forward". Las variables dependientes son número de esporas VAM/100 g suelos (a) y porcentaje de infección VAM (b). Las variables independientes fueron pH, M.O., C.E., N y P. Los valores dados son aquellos que contribuyen significativamente al modelo para un ± = 0.05.

Independent Variable	Dependent Variable					
	N° of VAM spores			% of VAM infection		
	Parameter estimate	F estimate	P > F	Parameter	F	P > F
P	2.961	60.8	0.0001	1.485	17.2	0.0001
N	-2.731	20.4	0.0001	-2.344	25.6	0.0001
E.C.				-1.054	4.1	0.0470

times higher than that found in the fall (April) of 1997 (Aguilera et al. in preparation). Nevertheless, 40% of the soil and root samples in our study showed some level of VAM presence.

The complete absence of VAM spores in the rhizosphere of *A. repanda* population in Combarbalá and Lambert, despite their level of VAM root infection, may be due to infection by endophytic species, producing few spores or that the spores may be too small to be detected by the technique used. Ianson & Allen (1986) point out that the methods that depend on spores floating on an aqueous medium, small spores may attach to clay particles and decanting, and large amount of debris is retained, increasing counting difficulties.

The higher concentration of VAM spores in the rhizosphere of *Atriplex* populations occurring toward the mesic end of the gradient (e.g., Los Vilos, Punta de Teatinos and San Pedro de Atacama) where soils presented higher contents of organic matter and nutrients contents suggests that soil quality and/or moisture content may have an important effect on the distribution of the fungi in arid region. However, a research about the effects of nutrients and soil moisture on infectivity and effectivity of VAM species of *Atriplex* is needed to confirm these trends.

VAM colonization also affect plant water relations directly or indirectly. An increase in drought stress tolerance has been observed in VAM plants compared with nonmycorrhizal plants (Morschner 1995). Differences in phosphorus nutritional status of the plants might account in part for this effect. The fact that VAM decreases the resistance to water transport in several crop species in soils with low hydric potentials suggests that this could be one of the important controls of VAM in dry-arid saline soils (Gianinazzi-Pearson & Gianinazzi 1983). VAM infection of roots of *Atriplex* species growing in saline soils may help these halophytes to overcome the conditions in these harsh environments.

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