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Spatial variation of arbuscular mycorrhizal fungi in two vegetatiob types in gurbantonggut desert*

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ABSTRACT

Geostatistical techniques were used to assess the spatial patterns of spores densities and biovolume of arbuscular mycorrhizal fungi (AMF) in soils from two contrasting vegetation communities: an *Ephedra distachya*-ephemeral plant vegetation community and an *Eremurus anisopteris* vegetation community. Also evaluated was the relationship between the spatial distribution of spore densities and biovolume of AMF and soil properties. Spatial dependence of spore densities and biovolume of AMF were exhibited further by kriged maps. The results showed spore density and biovolume indicated strong spatial autocorrelation and a patchy distribution within both sites. However, the patch size of genera and biovolume of AMF differed between the two communities. The correlation between distribution of spore and biovolume of AMF and distribution of soil parameters was expressed by Spearman rank-correlations coefficients. These results suggest that spore or biovolume distribution of AMF was affected significantly by some soil properties.

Key words: arbuscular mycorrhizal fungal spores, arbuscular mycorrhizal fungal biovolume, Desert, soil properties, spatial distribution.

It is well known that spatial heterogeneity is a general feature of soil. It embraces all kinds of aspects of soil, for example soil properties [1–4], vegetation structure [5] and diversity of soil organisms [6–10] in natural ecosystems. Spatial heterogeneity arbuscular mycorrhizal fungi (AMF) have intrigued ecologists [7, 11–13]. And their studies have documented that spores of AMF are in aggregated distribution. Moreover, there is growing evidence that the diversity and distribution of AMF is related to plant mineral nutrition and community structure, ecosystem processes and function [14–17].

AM fungal spores are very important in determining AM fungal species distribution because they are the major form that can be identified accurately to species [16]. In some situations, AM fungal spore abundance has been shown to be affected by environmental factors, such as soil moisture [11], organic matter [9],

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soil P [18], pH [19, 20] and electrical conductivity [19]. However, these relationships are not always firm. For instance, Anderson et al. did not observe a relationship with soil organic matter and pH [21]. Friese and Koske in a small spatial scale study also did not find any correlation between AM fungal spore density and root location [13].

AM fungi are known to benefit plant establishment by increasing resistance to environmental stresses, enhancing plant nutrient acquisition and improving soil quality [22, 23]. AMF are of great interest because of their potential influence on ecosystem processes, structure and functioning, their role in determining plant diversity in natural communities and the capacity of AM fungi to induce a wide variety of growth responses in coexisting plant species [24–28]. Conversely, the composition of plant communities may affect the structure of AM fungal communities through differential survival and reproduction (e.g., sporulation rates) of AMF [29–31]. There is evidence suggesting that plant species can influence the multiplication pattern of AMF in the rhizosphere [32–34]. Moreover, environmental factors and host plants affected the volume of AMF [35–38]. Thus, there might be a relationship between AM fungal spores and plant community.

We hypothesized that the strength of the relationship between AM fungal spatial distribution and AM plant distribution may vary among vegetation communities in relation to their structure (composition and volume of AM fungal spores and spatial pattern of plant species). Anderson et al. [11, 21] and Johnson et al. [39] found that AM fungal spore density can be related to plant cover. Klironomos et al., in a spatial distribution study, found that spore abundance of some AM fungal taxa was related to shrub location [7]. Carvalho et al. studied the spatial variability of AM fungal spores in two contrasting natural plant communities including a salt marsh and a marsh [12]. In desert ecosystems, Titus et al. researched the spatial heterogeneity of AMF in course of studying soil resource heterogeneity in the Mojave Desert [40]. Thus, it is still unclear if soil properties or plant variables are most important in explaining the spatial distribution of community and volume of AM fungal spores in desert ecosystem. In this work, we assess the importance of plant spatial distributions and soil properties on the distribution of community and volume of AM fungal spores in two different vegetation communities of dissimilar structure. The approach used sampling and statistical procedures that permitted evaluation of AM fungal spore distributions across many plant communities. The two different vegetation communities chosen were in an *Ephedra distachya*-ephemeral plant vegetation community and an *Eremurus anisopteris* vegetation community.

The objectives of this study were to quantify the variability in numbers and volume of AMF spores, and to evaluate the relative importance of plant distribution and soil properties for the spatial distribution of AM fungal spores. To accomplish these goals, geostatistical techniques and correlation analysis were employed to assess the influence of edaphic conditions on spore spatial distribution and volume. Semivariance has been verified that it is a effective way to quantify soil spatial heterogeneity [2–4, 41–43]. Furthermore, semivariance has also recently been used to describe spatial patterns in mycorrhizal fungi [7, 12, 44]. When combined with correlations analysis, soil factors affecting the spatial patterns of AMF can be assessed.

MATERIAL AND METHODS

Study Sites. The two vegetation communities were located in Gurbantonggut Desert. The *Ephedra distachya*-ephemeral plant vegetation community was situated at Sanhaodian (44°22.233′ N 87°52.916′ E) at the altitude of 442 m and the *Eremurus anisopteris* vegetation community was located in Wutonggou (44°32.44′ N 88°16.777′ E) at the elevation of 507 m. The sampling plots in both sites were selected in the interridge of dunes. The altitudinal difference is less than 20 cm.

Gurbantonggut Desert, located in the hinterland of the Junggar Basin at the northwesternmost part of the desert zone of northern China, lies between 44°11′–46°120′ N and 84°31′–90°00′ E. It covers an area of 48,800 km^2 and is the largest fixed and semi-fixed desert in China. Main morphological dune types in the desert are balk-hollow dune ridge and dentrit-

ic dune ridge, which are generally a few hundred meters to more than 10 km in length, 10–50 m in height and orientate from north to south. Interridge and middle to lower parts of a dune are stabilized but the crests of dune often have a 10–40 m wide mobile zone. Under the action of bi-directional winds, sand materials move leftward and rightward and extend along the crest line of dune [57]. Annual accumulated temperature varies between 3000 and 3, 500 °C, annual precipitation 70–150 mm and annual evaporation exceeds 2,000 mm. It belongs climatically to the typical inland arid zone. There is a stable accumulated snow with a thickness of 20 cm in winter. Precipitation distribution is better in spring and summer than in autumn and winter. So such water and heat allocation pattern creates favourable conditions for the growth and development of ephemeral plants. *Haloxoylon persicum* is a widespread species in the Gurbantunggut Desert and it generally occupies the middle to upper parts of dunes. Interdune depressions and middle to lower parts of sand dune are occupied by *Ephedra distachya* in Sanhaodian, and their understories are widely distributed by ephemeral plants and black cryptobiotic crusts. In Wutonggou, the ephemeral plant *Eremurus anisopteris* is the dominant taxon; and there are >150 entries per m^2 (unpublished). Soil profile differentiation is invisible and surface layer is poor in organic matter. Interridge consists of mixed sand that includes coarse, medium, fine and silt sand and there is little organic matter on soil surface. Dominant winds over the region are NW and NE winds caused by westerly circulation and Mongolian high pressure. Threshold wind (≥ 6 m/s) occur from April to September, mainly in April, May and June.

Sampling Design. On March 28, 2004, a 10 × 10 m experimental plot was established at each site at a randomly selected location within representative vegetation. In each 10 × 10 m experimental plot ('macrogrid') 1 × 1.4 m grids were marked. Samples were collected in the centre of 1 × 1.4 m cells. Total 70 samples were taken in each site. Soil of 0–20 cm depth was collected in each 1 × 1.4 m grid.

Sample Analysis. Spores of AMF were extracted from 30 g of each soil sample by wet-sieving followed by sucrose gradient centrifugation. Water was added to 30 g of soil per sample and the solution passed through a sequence of sieves (2000, 600 and 53 μm). The fraction collected in the last sieve (53 μm) was centrifuged in a 60 % (w/v) sucrose solution for 2 min at 3000 rpm. Spores were collected from the water-sucrose interface, poured through a sieve, rinsed with distilled water and quantified under a dissecting microscope at × 45 magnifications. Spores were counted at genus level and permanent slides of some selected spores from different samples were made and examined at × 400–1000 magnification. Spores were identified at least to a genus level according to Schenck and Pérez [45] and information published by INVAM (http//:invam.caf.wvu.edu) and the *Banque Européenne des Glomales* (www.ukc.ac.uk/bio/beg/) on the internet. Spore density was expressed as a number of spores per 100 g dry soil. Gravimetric soil water content was calculated for each sample as percent oven-dry weight of soil by drying at 110° for 72 h. Other soil properties were measured using methods described by Lu [46]. Total spore biovolume, in addition to spore densities, was used to compare response of total AM fungal spore production. This is to account for the large variation in spore size and numbers produced by the different AM fungal species and genera. Spore biovolume was calculated as $V = 1/6 \cdot D^3$ for species with spherical spores, or as $V = 1/6 \cdot D_1 D_2^2$ (where D_1 is the larger dimension and D_2 is the smaller dimension) for species with elongated spores.

Statistical Analysis. The geostatistics software GS+ program (Version 5.3, Gamma Design Software, Plainwell, MI) was used to calculate semi-variograms from the field data. The Spherical Model [47] showed the best fit to all the variograms. The Spherical Model is a modified quadratic function that assumes that sample points will not be autocorrelated beyond some distance; points were assumed not to be autocorrelated when the semivariance was equal to the sample variance [4]. The Spatial Dependence ($C/(C + C_0) \times 100$), relates the Structural Variance (C) with Total Variance. The Nugget Variance (C_0) is the value of the semivariogram at extremely small distances (y-intercept of curve); this variance is not zero because there are several factors (such as sampling error) that cause this displacement at the origin of the semivariogram. The Sill ($C + C_0$)

is the maximum value (plateau of semivariogram), representing the distance between points above which autocorrelation no longer exists. Coefficient of variation for samples in the experimental (10 r 10 m) was used as a measure of the magnitude of the variability among patches. Correlations were calculated for each site to relate spore density and biovolume of AMF with soil water content, organic matter, available P, pH and electrical conductivity (EC). Spearman rank-correlation coefficients between spore densities and biovolume of AMF and soil parameters were calculated by SPSS11.0.

RESULTS AND DISCUSSION

The vegetation coverage was different in the two different type vegetation communities. The coverage was higher in *Eremurus anisopteris* vegetation community (20 %) than in *Ephedra distachya*-ephemeral plant vegetation community (13 %). The two plant communities differed in plant diversity, plant mycorrhizal status, soil properties, and spore number and biovolume of AMF (Tables 1 and 2). The non-host species of AMF *Agriophyllunm squarrosum* and *Alyssum linifolium* were found in both vegetation communities. The plant densities (plant number per m^2 plot) in *Eremurus anisopteris* vegetation community were found to be higher than in *Ephedra distachya*-ephemeral plant vegetation community. However, the non-host densities in *Ephedra distachya*-ephemeral plant vegetation community were higher than in *Eremurus anisopteris* vegetation community (Table 1). The soil characteristics were similar in two vegetation communities (Table 2).

In the *Ephedra distachya*-ephemeral plant vegetation community spores of the genus *Acaulospora* and *Glomus* were found (Table 2). *Glomus* spores were the most common accounting for 95 % of the total. In the *Eremurus anisopteris* vegetation community, spores of three different AMF genera were found: *Acaulospora*, *Entrophospora* and *Glomus* (Table 2). *Glomus* spores were the most common accounting for 89 % of the total. Spore density and biovolume was 1.5 and 1.6 times higher in the *Eremurus anisopteris* vegetation community than in the *Ephedra distachya*-ephemeral plant vegetation community (Table 2).

In both vegetation communities, spores and biovolume of AMF had an aggregated spatial distribution (Table 3, Figures 1, 2 and 3). Spatial dependence was very high for all spore isolates and biovolume (except for AMF biovolume in the *Eremurus anisopteris* vegetation community) and soil available P and pH in the *Ephedra distachya*-ephemeral plant vegetation community and all soil properties (except for electrical conductivity) in the *Eremurus anisopteris* vegetation community, indicating strong autocorrelation within the plot (Table 3). Patches of some of the above variables were relatively small and well defined as reflected by higher spatial dependence and autocorrelation between samples than these of other variab-

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Plant species composition in sampling plots from each vegetation community (*Ephedra distachya*-ephemeral plant and *Eremurus anisopteris*), mean number in plot of 1 m^2 and their mycorrhizal status (M, arbuscular mycorrhizal; NM, non-arbuscular mycorrhizal)

Vegetation communities	Plant species	Plant number	Mycorrhizal status
Ephedra distachya – ephemeral plant	*Ephedra distachya*	3.3	NM
	Artemisia arenaria	0.3	M
	Erodium oxyrrhyndum	34.7	M
	Agriophyllunm squarrosum	1.3	NM
	Alyssum linifolium	10.3	NM
	Carex physodes	16.2	M
Eremurus anisopteris	*Eremurus anisopteris*	148.5	M
	Agriophyllunm squarrosum	0.8	NM
	Alyssum linifolium	6.4	NM
	Soranthus meyeri	4.7	M

Table 2

Spore densities of AM fungal genera, AM fungal biovolume, organic matter, soil available P, soil water content, soil electrical conductivity and soil pH for the samples collected in two different vegetation communities with mean ± S.D. (C.V.(%)). Spore density is expressed as spores per 100 g soil dry weight.

Veriable	Plant community	
	Ephedra distachya – ephemeral plant	*Eremurus anisopteris*
Acaulospora spore number	2 ± 1.5 (75)	4 ± 3.3 (83)
Glomus spore number	35 ± 18 (51)	50 ± 27 (54)
Entrophospora spore number	N.D.	2 ± 1.2 (60)
Total spore number	37 ± 32 (59)	56 ± 32 (57)
AMF biovolume, mm^3 per 100 g soil	0.0191 ± 0.0032 (17)	0.0304 ± 0.0286 (94)
Organic matter, g Kg^{-1}	1.75 ± 0.23 (13)	1.67 ± 0.26 (16)
Available P, mg Kg^{-1}	1.65 ± 0.54 (33)	0.88 ± 0.28 (32)
Water content, %	3.93 ±0.32 (8)	4.58 ± 0.46 (10)
Electrical conductivity, mS cm^{-1}	0.71 ± 0.05 (7)	0.52 ± 0.06 (12)
pH	7.98 ± 0.10 (1)	7.54 ± 0.11 (2)

les (Table 3). AMF spores and biovolume exhibited spatial gradients from distinctive areas of low to high activity (Fig. 1, 2 and 3). In the *Ephedra distachya*-ephemeral plant vegetation community, spore densities and biovolume of AMF and soil pH were lower than 2 m. However, for other soil parameters, the region of autocorrelation was greater than 10 m (Table 3). In the *Eremurus anisopteris* vegetation community, all variables except for AMF biovolume and soil pH had a range of autocorrelation of lower 10 m. However, AMF biovolume and soil pH had a much greater range of autocorrelation, estimated at 20.99 m. Low nugget present in all variables except for *Glomus* and total spore in the *Eremurus anisopteris* vegetation community. And their high nugget variance indicated greater small scale heterogeneity than observed for other variables.

Based on the coefficient of variation for samples collected in the two vegetation communities, there was relatively high variation for spore density and biovolume of AMF and for the soil parameters (Table 2). The coefficient of variation for *Glomus* spore density, total spore density, soil organic matter, soil available P and soil pH spore density in the *Ephedra distachya*-ephemeral plant vegetation community were

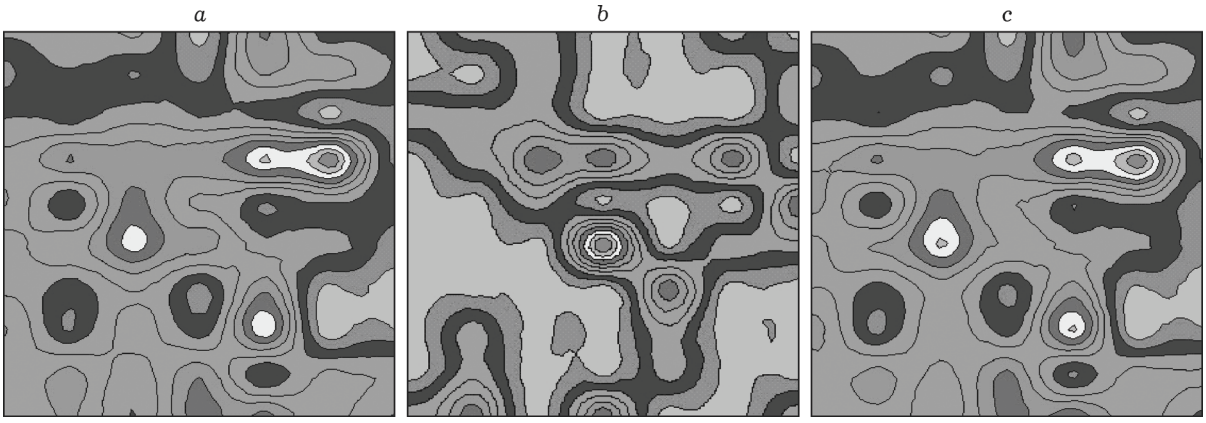

Fig. 1. Population isopleths for (*a*) total spore number, (*b*) *Acaulospora* spore number, and (*c*) *Glomus* spore number in the 10 m × 10 m plot in vegetation community of *Ephedra distachya*-ephemeral plants. Total spore number intervals >6, >144, >23, >31, >40, >48, >57, >65, >74, >82 per 100g dry soils, *Acaulospora* spore number >0, >1, >2, >3, >4, >4, >5, >6, >7, >8 per 100g dry soils, *Glomus* spore number >6, >14, >23, >31, >40, >48, >57, >65, >74, >82 per 100g dry soils

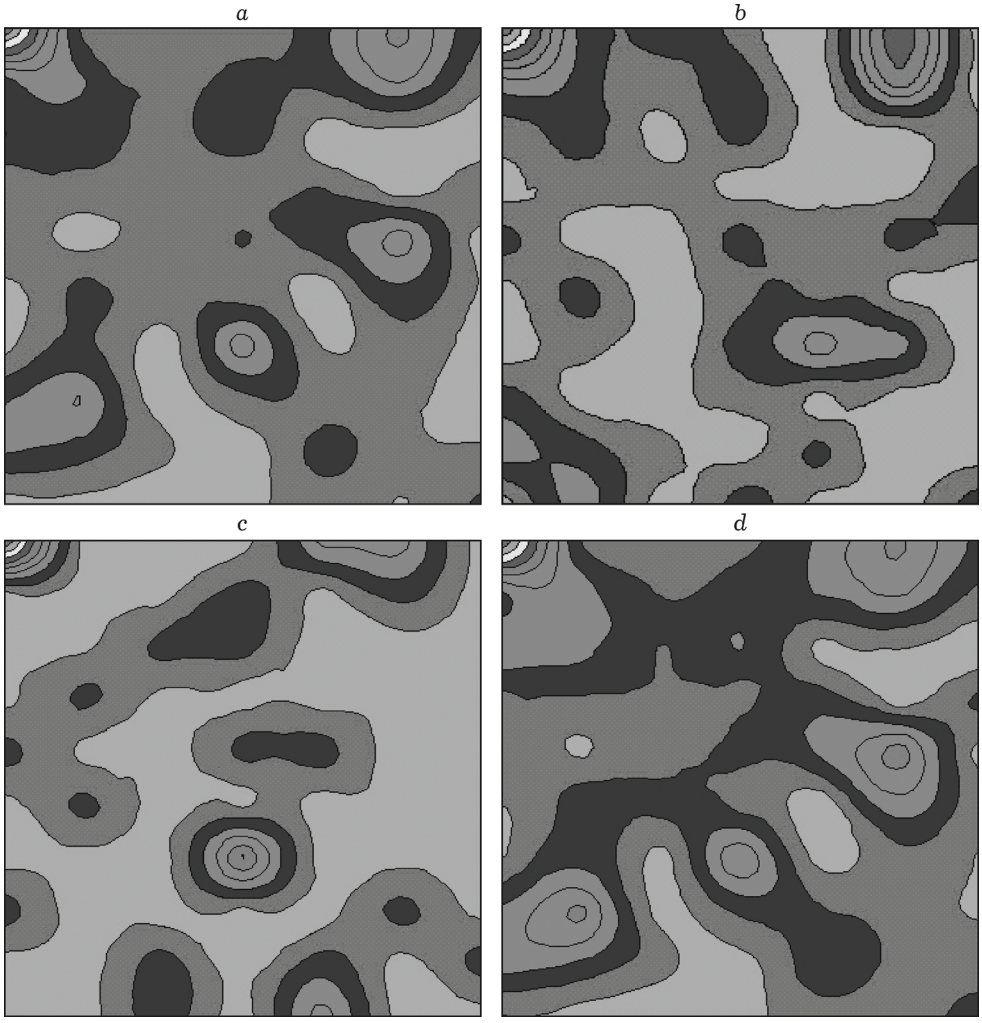

Fig. 2. Population isopleths for (*a*) total spore number, (*b*) *Acaulospora* spore number, (*c*) *Entrophospora* spore number, and (*d*) *Glomus* spore number in the 10 m × 10 m plot in vegetation community of *Eremurus anisopteris*. Total spore number intervals >18, >38, >59, >79, >100, >120, >141, >161, >182, >202 per 100 g dry soils, *Acaulospora* spore number >0, >2, >5, >8, >11, >14, >17, >20, >23, >26 per 100 g dry soils, *Entrophospora* spore number >0, >1, >2, >4, >6, >8, >9, >11, >13, >14 per 100 g dry soils, *Glomus* spore number >15, >31, >47, >64, >80, >96, >113, >129, 145, >161 per 100 g dry soils

nearly identical to those found in the *Eremurus anisopteris* vegetation community (Table 2).

Relationships between spore densities, biovolume and soil variables were calculated for samples collected in the two vegetation communities (Table 4). AMF biovolume were correlated with soil pH though it was positive in the *Ephedra distachya*-ephemeral plant vegetation community and negative in the *Eremurus anisopteris* vegetation community, respectively. In the *Ephedra distachya*-ephemeral plant vegetation community, *Glomus* density showed a significant negative correlation with soil oganic matter and pH. Positive correlation was observed between total spore density and soil electrical conductivity. However, no correlation was shown to be present between *Acaulospora* spore density and any soil parameters. In the *Eremurus anisopteris* vegetation community, no correlations between spore densities and biovolume of AMF and soil parameters were found to be present except for between *Entrophospora* spore density and soil available P and between AMF biovolume and soil pH.

In both sites variations in AM fungal spore density and biovolume were found within the sampled areas. The nugget values and spatial dependence varied from 0.00002 to 10.0 and from 55.0 to 99.9 % in both sites, respectively. The geostatistical analyses indicated that spores

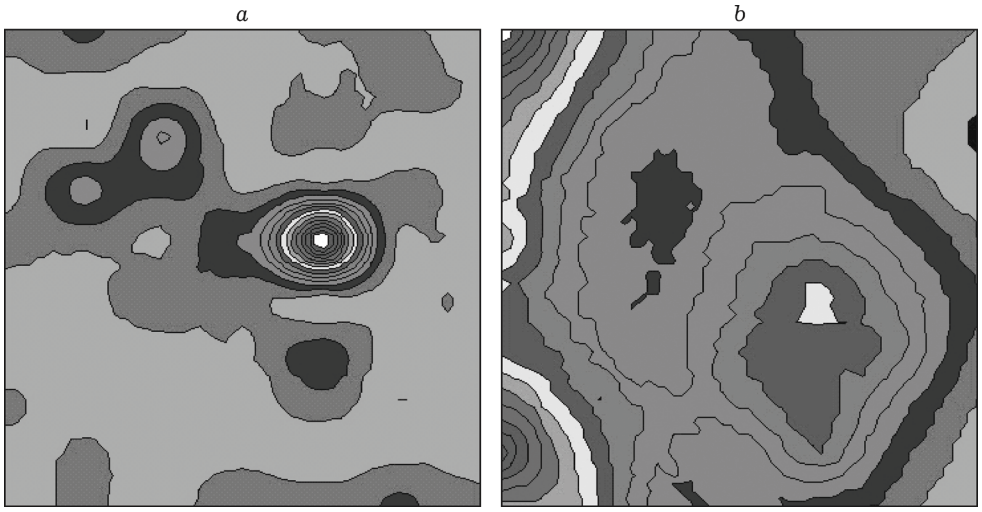

Fig. 3. Population isopleths for AM biovolume in the 10 m × 10 m plot in two vegetation community, (*a*) Vegetation community of *Ephedra distachya*-ephemeral plants. (*b*) Vegetation community of *Eremurus anisopteris*. Biovolume intervals, Vegetation community of *Ephedra distachya*-ephemeral plants >0.001,>0.016, >0.032, >0.047, >0.062, >0.078, >0.093, >0.108, >0.124, >0.139, >0.154, >0.170, >0.185, >0.200, >0.216 mm^3 per 100 g dry soil, Vegetation community of *Eremurus anisopteris* >0.012, >0.016, >0.020, >0.024, >0.029, >0.033, >0.037, >0.041, >0.045, >0.049, >0.053, >0.057, >0.062, >0.066, >0.070 mm^3 per 100 g dry soil

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Parameters for spherical model for semivariograms for spore densities of AM fungal genera, AM fungal biovolume and soil patter in sampling plots. Spatial dependence (C/(C + C0) is the ratio of structural variance to total variance

Vegetation communities	Variable	Nugget, C_0	Sill, $C + C_0$	Range, A_0	Spatial dependence, %
Ephedra distachya – ephemeral plant	*Acaulospora* number	0.03	5.98	1.45	99.5
	Glomus number	9.00	344.20	1.45	97.4
	Total spore number	10.00	373.20	1.45	97.3
	AMF biovolume, mm^3 per 100 g soil	0.00003	0.00106	1.45	97.3
	Organic matter, g Kg^{-1}	0.0298	0.093	20.99	68.0
	Available P, mg Kg^{-1}	0.001	0.773	20.99	99.9
	Water content, %	0.0358	0.1766	15.22	79.7
	Electrical conductivity, mS cm^{-1}	0.00147	0.00328	13.39	55.0
	pH	0.00002	0.01024	1.98	99.8
Eremurus anisopteris	*Acaulospora* number	0.01	26.71	2.30	99.9
	Entrophospora number	0.01	7.37	2.06	99.9
	Glomus number	1.00	688.80	2.27	99.9
	Total spore number	1.00	981.00	2.40	99.9
	AMF biovolume, mm^3 per 100 g soil	0.00038	0.00149	20.99	74.6
	Organic matter, g Kg^{-1}	0.0007	0.0653	2.16	98.9
	Available P, mg Kg^{-1}	0.0009	0.0825	2.29	989
	Water content, %	0.0197	0.2724	7.83	92.8
	Electrical conductivity, mS cm^{-1}	0.00108	0.00378	8.64	71.3
	pH	0.0001	0.0317	20.99	99.7

Table 4

Spearman rank-correlations coefficients between spore density of AM fungal genera, AM fungal biovolume and soil parameters (water content, available P, organic matter, pH and electrical conductivity) for the samples collected in the 10 m × 10 m plot of two different vegetation communities

Vegetation communities/AMF genus	Water content	Available P	Organic matter	pH	Electrical conductivity
Ephedra distachya – ephemeral plant					
Acaulospora	−0.193	−0.023	0.003	−0.012	−0.115
Glomus	0.032	0.263	−0.337**	−0.347**	0.42
Total spore	−0.174	0.102	0.161	0.012	0.278*
AMF biovolume	−0.170	0.026	−0.105	−0.276*	−0.039
Eremurus anisopteris					
Acaulospora	−0.156	0.083	−0.069	0.017	−0.022
Entrophospora	−0.059	0.262*	0.147	−0.019	−0.020
Glomus	−0.036	0.127	0.071	0.055	−0.014
Total spore	−0.074	0.140	0.060	0.059	−0.022
AMF biovolume	−0.104	0.147	0.064	0.261*	0.103

* $P < 0.05$; ** $P < 0.01$.

were not randomly distributed, but instead spatially distributed in patches independent of the type of vegetation and AM fungal genus. At the same time, spore densities and biovolume of AMF that exhibited spatial dependence were further explored by kriged maps (Fig. 1–3). Soil characteristics for both type of vegetation community were also found to exhibit spatial heterogeneity. The size of spore patches was identical with varying of AM fungal genus, and it was uniform with AMF biovolume in the *Ephedra distachya*-ephemeral plant vegetation community. However, the size of AMF spore patches was found to vary with AM fungal genus. Other studies have found highly variable spatial distributions of spores among different AM fungal genera [7, 12, 13, 29]. These differences in spatial variability may be related to ecological features of AMF. It was recently shown that dispersion of hyphal networks vary among AM fungal taxa [48], probably leading to different spatial patterns of sporulation and spore dispersion, and consequently, different patch sizes. The variation of AMF biovolume was different in two sites. The possible reasons were due to different ecological conditions. Wolf et al. showed that AMF biovolume changed with the different CO_2 concentration and host plants [49].

Our results indicated that soil properties might have an effect on the spatial distribution of AM fungal spores; however, this relationship was site- and AMF genera-dependent. Organic matters were only negatively correlated to the distribution of *Glomus* spores in the Ephedra distachya-ephemeral plant vegetative community and were independent of other AMF genera and in the *Eremurus anisopteris* vegetation community. Therefore, organic matter was not a certain reason to cause AMF spore spatial distribution. A lot of researches have showed that positive correlation was found between AMF spores and organic matter in some ecosystems [9, 12, 50]. In contrast, organic matter was apparently not an important influence on the spatial distribution of spores in the salt marsh [12]. The same result was obtained in the *Eremurus anisopteris* vegetation community in this study. Soil moisture was not related to AMF spore distribution though the amount and duration of rainfall clearly may be important to *Glomus* in arid biomes [35, 37, 38]. This finding accorded with the results obtained by Carvalho et al. [12]. Soil available P was correlated to the distribution of *Entrophospora* spores only in the *Eremurus anisopteris* vegetation community and no significant effect to other variables of AMF in both sites, although several studies showed that P availability affected mycorrhizal abundance [37, 53]. What is more, Cuenca and Menedes found that the abundance of *Glomus* species

was correlated with available phosphorus [51]. However, Allen et al. found that fertility did not influence significantly the community structure of sporulating AM fungi in tropical deciduous forests in Mexico [52]. Thus, we deduced the influence of available P on AMF was varied with the difference of ecosystem. Soil pH presented contrary correlation with AMF biovolume in both sites, indicating uncertain influence in AMF. Other studies obtained the similar results [19, 53–55]. Soil electrical conductivity affected significantly total spore densities only in the *Ephedra distachya*-ephemeral plant vegetative community. Mohammad et al. indicated that spore density of AMF had a very weak correlation with electrical conductivity (EC) in semi-arid environment of Jordan [19]. In addition, the differences of diversity and productivity of host plants maybe also lead to the different distribution of AMF in two plant communities because previous researches have supported this conclusion [56, 57].

In the present study the identification of AM fungi has traditionally relied on the morphological and developmental characteristics of their large multinucleate spores. However, identification of AMF is rather problematic due to their hidden, biotrophic lifestyle in the soil, few morphological characters, and the potential formation of dimorphic spores. Recent molecular ecological studies showed that the species described represent only less than 5% of the existing AMF diversity [58]. Thus morphologically monitoring AMF by their resting spores can lead to AMF species, phylogenetically belonging to different orders, being placed in one genus (*Glomus*) and, conversely, individual species forming different spore morphs may be described as members of different orders. Moreover, many species cannot be reliably identified at all from heterogeneous field samples, and when identifying described species similar morphotypes may be erroneously determined as a single species. To circumvent this problem, molecular approaches are necessary to define and relate taxa in the *Glomeromycota* in the future studies.

These results of present study indicate that spore or biovolume distribution of AMF was affected significantly by some soil properties. The high variation of AMF implies that the two communities are functionally and ecologically distinct. Further, AMF may have the potential to influence recruitment and host composition of desert plant communities.

The present study was conducted in two vegetation communities. Thus, our study suggested that spatial distribution of AMF genera and biovolume varied with vegetation community types and some soil parameters. Other issues that need to be resolved are: does this spatial heterogeneity change with season? And how predictable is it among years? What is the spatial variation of AMF in different positions of a dune? These questions need to be addressed in our future research.

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