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The Effect of Agricultural Practices on the Spatial Variability of Arbuscular Mycorrhiza Spores

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Abstract: The main objective of this paper is to assess the spatial variability of arbuscular mycorrhizal (AM) spore numbers in following two contrasting soil uses. Adjacent plots, one irrigated farmland and the other dry farmland, were marked on a transect (300 m long), with 10-m spacing. Soil samples were collected at 0–30 and 30–60 cm depth and were then analyzed for AM spore numbers and some other soil properties. The analytical results were submitted to different kinds of analysis: classical statistical and geostatistical analysis which showed that coefficient of variations (CV's) and standard deviations for spore numbers in both farmlands were considerably low. Variations of spore numbers in irrigated farmland was lower than those in dry farmland. The soils of irrigated farmland was found to be much more homogeneous than the adjacent dry farmland soil. The results showed that in both farmland, CV's of spores numbers in topsoil horizon were lower than those of subsoil horizon. The pattern of spatial variability of this soil property was found to be different for the two lands. Spore numbers of AM fungi in topsoil and subsoil of irrigated farmland exhibited spatial dependence at the sampled scale and their experimental semivariograms were adjusted to a spherical and linear model respectively. However these data for dry farmland did not exhibit spatial dependence.

Key Words: Spatial variability, AM spore numbers, irrigated and dry farmlands

Introduction

Spatial variability in soils occurs naturally from pedogenetic factors. In addition, much variability can occur as a result of land use and management. As a consequence, soils can exhibit marked spatial variability at the macro- and micro-scale. Geostatistical analysis have been done for a number of chemical, physical and morphological soil properties. In many instances spatial variation is not random but tends to follow a pattern in which variability decreases as distance diminishes between points in space (1). Spatial dependence has been observed for a wide range of soil physical, chemical, and biological properties and processes (2-10). Incorporation of functions that relate distance and variance among points (e.g. semivariograms) into spatial analysis of soils data results in more accurate estimates of soil properties and processes than those that consider only spatial independence between points (1). Semivariograms for soil properties can also be used to reduce the need for expensive and intensive sampling, as in the case of precision agriculture (11).

Our understanding about the soil organisms has not advanced at the same rate as other properties, mostly because of their cryptic nature which makes them difficult to monitor (12). More recently, geostatistics have been used to describe the spatial distribution of soil organisms (13-16), illustrating that they are structured at various spatial scales. There are many reports about biology of AM fungi, obligate symbionts potentially useful in sustainable agriculture. It has been reported that soil properties, management, fertilization and farming system have significant effects on AM activities in soils (17-24). However, there is not much work on variability of these fungi in soils. The main objective of this paper was to assess the spatial variability of arbuscular mycorrhizal fungi of a landscape in two contrasting soil uses, irrigated and dry farmlands.

Materials and Methods

The present investigation was made in the dry and irrigated farmlands of Bahar region in northwestern of Hamadan, Iran. In autumn after harvesting of wheat sampling was carried out on a transect (300 m long), in north-south direction with a separation distance of 10 m, thereby providing 30 actual sampling location for each farmland. Sampling was carried out at depths of 0-30 cm and 30-60 cm to assess the variability in the vertical direction. Spores of AM fungi were isolated from 50 cm^3 sub-samples by wet sieving (25) and centrifugation (26), and counted. Data statistically analyzed for standard deviation (s) and coefficient of variation (CV) to assess the variability of this soil property. Mean was calculated and t-student test was made to assess the nature of distribution and to estimate the number of samples required for this property. Data geostatistically analyzed for semivariance, semivariograme, nugget variance, sill, range of spatial dependence, and stability of spatial structure.

In addition soil samples were analyzed for clay, silt, and sand contents using the hydrometer method (27). Mean weight diameter (MWD) and geometric mean diameter (GMD) were analyzed by wet sieving (28). Soil equivalent $CaCO_3$ was analyzed by back titration procedure. Soil pH and electrical conductivity in a 1:2 soil: water extract after shaking for 30 min (29) were measured. Organic carbon (OC) was analyzed by dichromate oxidation and titration with ferrous ammonium sulfate (30). Available phosphorus was extracted with 0.5 M $NaHCO_3$ (pH 8.5) and determined colorimetrically as blue molybdate-phosphate complexes under partial reduction with ascorbic acid (31). Basal respiration was measured by jar methods as CO_2 evolved in 5 days. Acid and alkaline phosphatase was analyzed according to the methods of Eivazi and Tabatabai (32). These analyses were according to methods of soil analysis parts 1 and 2: published by SSSA, and applied methods in soil biology and biochemistry (33). The correlations between AM spore numbers with these soil parameters were also studied.

Results and Discussion

Results of correlation analysis in Table 1 show that there are strongly significant positive correlation between AM spore numbers and silt, EC, organic carbon, basal respiration, acid phosphatase and alkaline phosphatase in total samples of farmlands. However, spore numbers has a negative significant (at the 0.05 level) correlation with sand and equivalent $CaCO_3$ in these calcareous soils. Organic carbon and biological activities in topsoil of irrigated farmlands are relatively high with compare to those of dry farmlands in semi-arid region. It has been

Table 1. Pearson correlation coefficients of AM spore numbers and some other soil properties.

Soil properties	Correlation coefficients
Clay	-0.094
Silt	0.526**
Sand	-0.201*
MWD	0.038
GMD	0.125
EC	0.376**
pH	-0.073
Eq. $CaCO_3$	-0.214*
Organic carbon	0.409**
Basal respiration	0.646**
Av. Phosphorus	0.175
Acid Phosphatase	0.296**
Alkaline Phosphatase	0.367**

** Correlation is significant at the 0.01 level.
* Correlation is significant at the 0.05 level.

reported that the addition of organic matter to soils increases AM activities (17,23).

Strikingly there was not a significant correlation between soil available phosphorus and AM spore numbers in total samples of farmlands. This finding may be related to heterogeneity of soil available phosphorus (Results have not been shown). High concentration of available P in soils is well recognized as a deterrent in the formation of VA mycorrhizae (34-37). However Zahka *et al*(38) showed that Pearson correlation coefficients of AM spore numbers and available P are positive and significant. Our finding is in accordance with the later report.

Results in Table 2 show that spore numbers in both layers of the irrigated farmland were significantly higher than those of the dry farmland. Spore numbers in topsoil of both farmlands with compare to subsoil of them were significantly high. It may be related to higher organic carbon content and root biomass in topsoil of the farmlands and especially that of irrigated farmland (results have not been shown).

Spore numbers in both layers of irrigated farmlands exhibit low standard deviations (<2.82) and coefficients of variation (<5.97%). This homogeneity for topsoil of irrigated farmland is high. So, the number of required samples calculated with less than 5, 10 and 15 % error

Table 2. Classical statistical and geostatistical analysis of AM spore numbers in 10 g of soil of farmlands.

Land use Soil depth (cm)		Irrigated farmland		Dry farmland	
		0-30	30-60	0-30	30-60
Range		65-76	40-55	54-65	29-46
Mean*		69.43[a]	47.23[c]	61.63[b]	39.1[d]
Standard deviation		2.73	2.82	2.79	6.23
Coefficient of variation		3.93	5.97	4.52	15.93
The number of sample required	5 % error	3	6	4	43
	10 % error	1	2	1	11
	15 % error	1	1	1	5
Nugget variance		3.168	2.88	7.8	39
Sill		3.528	-	-	-
Range of spatial dependence		27.2	-	-	-
Stability of spatial structure		0.52	-	-	-
Model of semivariance		Spherical	Linear	Nugget effect	Nugget effect

* There are significant ($P<0.01$) differences between means

in estimating, for determining AM spore numbers in irrigated farmland were considerably low (<6). Spore numbers in both layers of dry farmland with compare to those of irrigated farmland exhibit higher standard deviations and coefficients of variation (CVs) especially in the subsoil horizons (Table 2). So, the number of required samples calculated with less than 5, 10 and 15 % error in estimating, for determining AM spore numbers in dry farmland were relatively high (to 43). These differences may be related to the farming system and tillage homogenization of fungal spores in soils.

The variograms analyses of spore numbers suggest the presence bounded variogram for topsoil (spherical model) and linear model for subsoil of irrigated farmland. These models have relatively large nugget variances (Figure 1). The observed structures were pure nugget effect for spore numbers in both layer of dry farmland in the scale of study due to measurement error and/or micro-variation within the smaller sampling interval. However, spore numbers in topsoil of irrigated farmland has the strongest spatial stability structure with range of spatial dependence 27.2 m, which may be related to spore redistribution by surface irrigation.

Conclusion

This study showed that soil texture is one of the most important factor affecting AM spore numbers in soils. All of the studied indices of soil biological activities exhibited significant correlation with AM spore numbers. Although, high concentration of available P in soils is well recognized as a deterrent in the formation of VA mycorrhizae (34-37), the correlation of AM spore numbers with soil available phosphorus was positive, but not significant.

It has been reported that spatial variability of subsoil horizons seems to be governed by pedogenic processes. At topsoil horizons of farmlands, one of the underlying physical processes would be the tillage homogenization plus irrigation and run off water erosions and redistribution. The kind of human activities on topsoil of irrigated farmland with compare to dry farmland are different. Although, tillage homogenization increases the rage spatial dependence on topsoil of both farmlands, surface water displaces and more reduces the range spatial dependence of spores on topsoil of irrigated farmland.

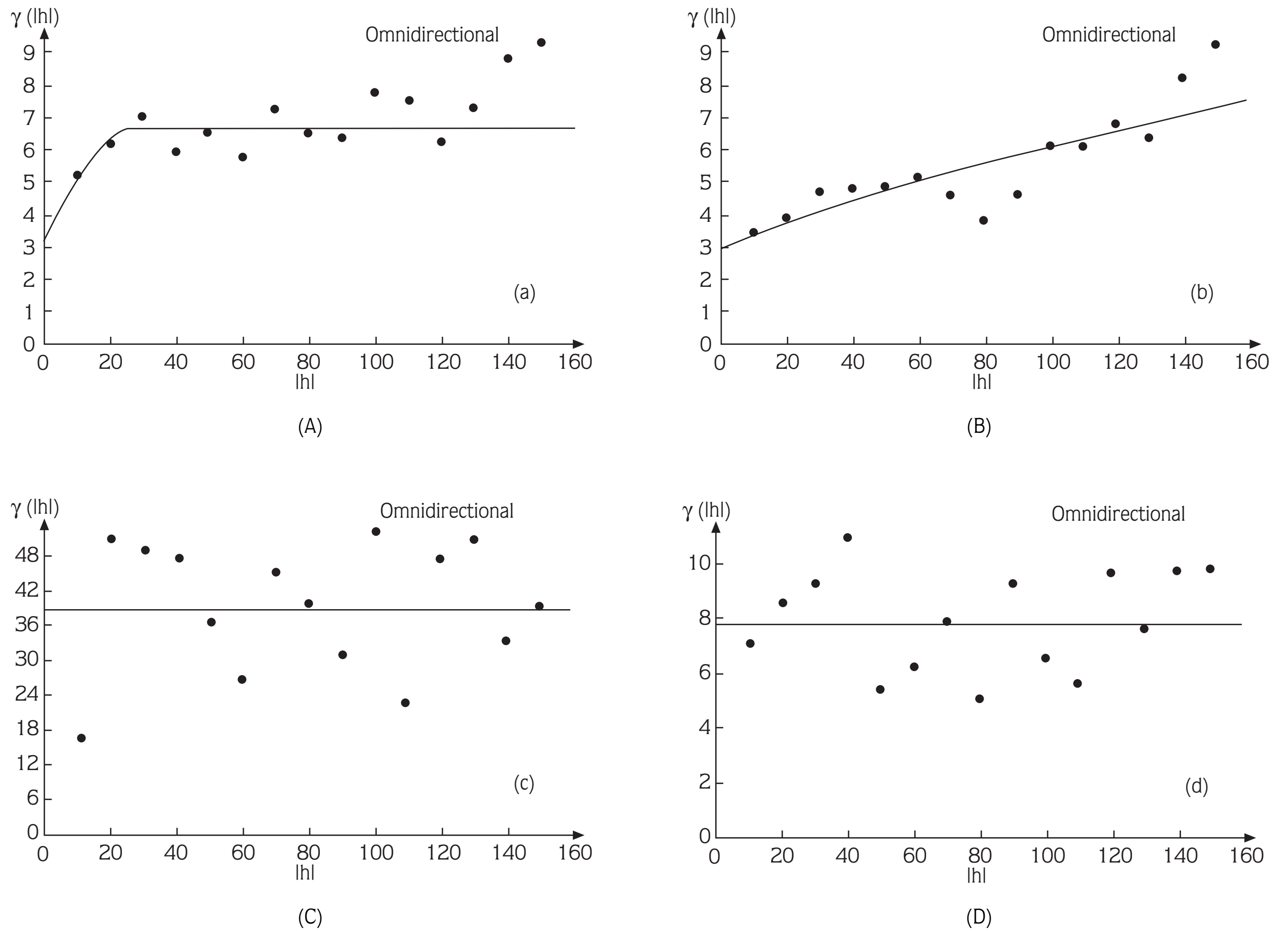

Figure 1. Experimental semivariograms (dots) and their model fits (solid lines) for spore numbers of A) topsoil of irrigated farmland, B) subsoil of irrigated farmland, C) topsoil of dry farmland, and D) subsoil of dry farmland.

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