Effects of species diversity and fungicides on organic matter and available soil phosphorus (P)

Paneris S. D.

Laboratory of Rangeland Ecology, Aristotle University, (286), Thessaloniki, 54124 Greece

Abstract

The objective of this study was to determine whether the availability of soil P and soil organic matter were affected by the plant species richness and the restriction of arbuscular mycorrhizal fungi (AMF). The research took place in Northern Greece. Availability of soil nitrogen and P was deficient for plant growth. Six C_3 grasses, three legumes and four forbs native and relatively abundant in the study area, were used. These plants were sown as monocultures and in randomly selected mixtures of 2-3-4-7-10 and 13 species. These species were planted in containers containing 30kg of soil deficient in N and P for plant growth. To restrict the AMF colonization, the fungicide benomyl at first and the combination of fungicides thiophanate methyl and carbeplus after, were applied at half of the replications. At the end of the growth season soil samples were taken to determine organic matter content and soil P concentration. The results showed that both soil characteristics were not affected by the species richness in the mixtures.. The monocultures of grasses, legumes and forbs produced the same results. However the fungicide application reduced the organic matter content and the soil P availability. These effects of fungicides are probably due to the N that they contain.

Key words: species richness, species diversity, soil phosphorus, arbuscular mycorrhizal fungies (AMF), organic matter, fungicides

Introduction

Species richness affects positively the primary productivity, contributes to the more efficient recycling of nutrients and increases the biological resistance of plant communities on biological invasions. Many researchers (Naeem et al. 1994, Naeem & Li 1997, 1998, Tilman et al. 1996) agree that a positive correlation between species diversity and effectiveness of ecosystem functions exists. However, others (Wardle et al. 1997, Berendse 1998, Grime 1997, 1998, Hooper & Vitousek 1998) believe that the attributes of the ecosystem are not necessarily determined by the richness of species, but mainly by the particular traits of the dominant species and the composition of functional groups. The published studies suggest that species richness affects the recycling of nutrients. Perhaps this is due to the positive effect of the species richness to the diversity of soil microbial community, which largely affects the rate of nutrient recycling. Mycorrhizal fungi make various contributions to plants the main of which is to the uptake of the usually limited phosphorus contributing thus, to greater plant growth (Hodge et al. 2001). The objective of this study was to determine whether the species richness and the restriction of arbuscular mycorrhizal fungi affect the availability of soil phosphorus and soil organic matter.

Materials and methods

The research was carried out in Taxiarchis Chalkidiki, 70 km southeast of Thessaloniki in an area atan altitude of 840m. The experiment was conducted in 296 pots (40×30×25 cm) filled with 30 kg soil from the research area. Some physicochemical characteristics of soil are presented in Table 1. There were two treatments (a) applying or not fungicide and (b) mixtures or monocultures of herbaceous plant species. Thirteen perennial herbaceous plant species, which represent the three main biotic forms of herbaceous groups, grasses, forbs and legumes, were used. Six of them were C_3 grasses (*Agrostis capillaris, Dactylis glomerata, Festuca ovina, Lolium perenne, Phleum pratense, Poa pratensis*), three were legumes (*Lotus corniculatus, Medicago sativa, Trifolium repens*) and four were forbs (*Cichorium indibus, Plantago lanceolata, Achillea millefolium, Rumex acetosa*). In April 240 seeds per pot were sown. There were 37 combinations of monocultures and 2-3-4-7-10 and 13 mixtures. *Plantago* roots, which were colonized by mycorrhizal fungi, were added in pots. An application of benomyl (0,6g per pot), was performed twice in July of the first year. The next year, the fungicides thiophanate methyl and carbeplus (0,15g per pot for each fungicide) were applied every 14 days.

Table 1. Physico-chemical characteristics of soil used in pots. The high value of the soil CEC is due to the involvement of fossil stretch mesh (vermiculite and montmorillonite).

soil type	**sand**	**sludge**	**clay**	**Organic Matter**	**total N**	**CEC**
	(%)	(%)	(%)	(g kg^{-1})	(g kg^{-1})	($cmol^{(+)} kg^{-1}$)
SCL	42,8	22	35,2	6,4	1,344	40,01

The soil was taken from the pots the third year, dried out at 72 C for 48 hours, weighed and then pulverized to determine the concentration of phosphorus with the Olsen extraction method, and organic matter (as organic C) with the method of Walkley & Black. The experimental design used was completely randomized blocks with two treatments and four replications. ANOVA was used to analyse the data of soil phosphorus and organic matter. Additional orthogonal comparisons were used to compare the effects of groups of species (grasses, forbs, legumes) as well as mixtures of species in both control and application of fungicide.

Results and Discussion

The application of fungicides reduced the soil P availability. However, this reduction was not significant among the species monocultures and among the biotic forms. The species as monocultures or the groups of species in both the control and the application of fungicides did not vary significantly also. Regarding the species mixtures it was obvious that species diversity did not affect the soil P availability while the fungicide application reduced it. In the mixtures of 2 and 3 species significant reduction of soil P was observed with the application of fungicides. The mixture of 4 species at control and the mixture of 2 species with the fungicide application had the lowest values. These values were significantly lower only than those in the mixture of 3 species and of monocultures respectively. Soil P did not appear to correlate with the species diversity but only with the application of fungicides.

The soil organic matter content was approximately the same in all species monocultures, and it was decreased significantly with the application of fungicides. This decrease was statistically significant in all mixtures and in the three biotic forms. Significant reduction of organic matter with the fungicide application was observed only in the monocultures of *Festuca*, *Poa*, *Achillea*, *Plantago* and *Lotus*. There was no differentiation between biotic forms in both control and application of fungicides. Soil organic matter did not appear to be affected by species diversity neither at control nor with the application of fungicides. However, at the control, the values of the mixtures of 2 and 3 species were significantly higher only from the mean value of the monocultures. At the application of fungicides the mixtures of 3 and 4 species had the highest values, which were significantly higher only from the mixture of 2 species. As averages of control and fungicide application, the mixtures of 3 and 4 species had the highest values, but these were significantly higher only compared to the average of monocultures.

Table 2. Mean squares from the ANOVA analysis for the data of soil phosphorus and soil organic matter.

source of variation	Freedom Degree	F values	
		Olsen P	**Organic**
Blocks	3	18,88***	118,35***
Fungicide treatment (A)	1	13,75**	264,19***
Species composition (B)	36	1,24	0,66
A × B	36	1,41	0,88
Error	219	1,58	0,84

** and *** shows significant effect at $p < 0,01$ and $p < 0,001$,respectively.

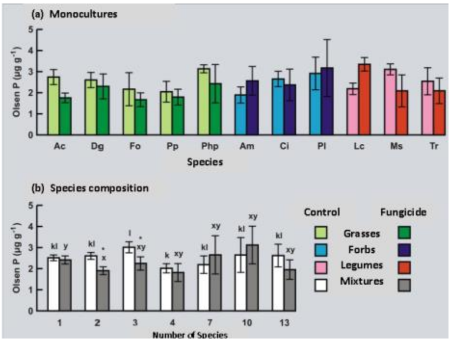

Figure 1. Effect of species, mixtures and fungicide application in the Olsen extractable phosphorus. The columns represent averages ± standard deviations. The * indicates significant difference between control and fungicide application within the same species composition, and columns at control or at application of fungicide, with the same letter are not significantly different.

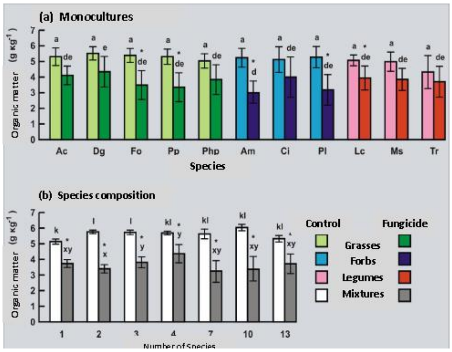

Figure 2. Effect of species, mixtures and fungicide application on soil organic matter. The columns represent averages ± standard deviations. The * indicates significant difference between control and fungicide application in the same species or same species composition, and columns at control or application of fungicide, with the same letter are not significantly different.

The results indicate that soil P and organic matter were not affected by the species diversity which participates in a plant community or from the groups of them. The applications of fungicides had an adverse effect on the two parameters of the soil (P and organic matter). These reductions could be due to the relatively high N content of fungicides. Thus, the addition of fungicides was a N source for the plants as there was a deficit at the containers, resulting in the better growth of plant biomass. Further growth of the roots seems to utilize more effectively soil P. Another factor that is likely to have influenced the use of P was the restriction of the colonization of arbuscular mycorrhizal fungies from the roots with the application of fungicides, although statistically significant (Karanika et al. 2007), it was only 21% lower compared to the control and its effect on the uptake of P is likely to be limited.

The addition of N with the application of fungicides seems to have affected the degradation of organic matter. The rate of degradation of organic matter in soil is determined by the stoichiometry and the requirements of decomposers for resources (nutrients) (Melillo et al. 1982, Hessen et al. 2004). When the ratio C:N of organic matter tends to be similar to the ratio required by decomposers, their populations are maximized and so is the rate of degradation (Melillo et al. 1982). In dry plant residues the ratio C:N is greater than 25. In decomposers the relevant ratio is much smaller than 25 (Hartley & Jones 1997). Therefore, the growth rates of decomposers and subsequently the degradation rates of organic matter increase when N is added to the organic matter. The C:N ratios of the three fungicides used are 3.0, 2.6 and 2.6, respectively. Their addition decreased the ratio C:N of soil organic matter hence the rate of degradation in pots which applied fungicides tend to be more intense and the remaining organic matter less.

Conclusions

The results of this study showed that the two features of the soil, P and organic matter were not affected by the number of plant species that participate in a plant community or by the groups of species. In some cases, significant differences between species mixtures on soil P and organic matter were observed but they do not indicate that the number of participating species is associated with the tested soil properties . The application of fungicides reduced significantly the P and organic matter of the soil. This reduction suggests that there is a severe rate of N recycling by adding fungicides.

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