IMPACT OF HYDROPOLYMER ON NITROGEN AVAILABILITY IN MEDITERRANEAN SOIL

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Abstract: Polymers are substances that are increasingly utilized in Mediterranean areas during dry seasons. Their basic property is the ability to absorb large amount of water in the rainy periods, retain the water and release it to vegetation in the periods of drought. The typical problem of Mediterranean vegetation is wilting in the dry spells. If polymer is applied to soil before the start of the rainy period, sufficient water supply for the dry season can be secured. It has been proved that polymers also have a favorable effect on a number of physical properties of soil, such as aggregate stability or infiltration. Soil is a complex system, consisting of animate and inanimate constituents, whose mutual relations and balance determine the soil fertility. The positive effect of polymer on the physical properties therefore need not entail the increase of fertility. This contribution aims to assess the impact of TerraCottem polymer on the availability of nitrogen in the soil. The results of the work suggest that the application of polymer not only improves the soil physical properties, but also influences the soil life. The experiment included work with model soils containing different amounts of polymer plus another additive. The additives applied were glucose or industrial fertilizer.

Key Words: polymers, fertilizers, Mediterranean areas, dry seasons, nitrogen

INTRODUCTION

At present, more than 2 billion ha of soil is endangered with degradation (Oldeman 1990). Soil degradation in arid areas is a principal environmental problem (Skotheim, Reynolds 2007). In these territories, soil is exposed to long periods of drought, alternating with sudden rain spells (Van Wesemael, Veer 1992). The quality and health of soil are also threatened by unsuitable crop rotation, fertilization along the slopes or excessive use of industrial fertilizers (Novara et al. 2011). The restoration of vegetation cover is an effective way of returning the soil its quality (Hueso González 2014).

Nitrogen is often associated with soil fertility as well as a threat to the environment, for instance by it's leaching into water systems (Nielson 2002).

Nitrogen is the most important limiting factor in the plant growth (Kush, Bennet 1992), and an integral part of its biochemical cycle is microorganisms (Akiyama et al. 2006). Microorganisms participate in processes essential to life on the Earth and moreover may serve as indicators of soil health (Sparling 1997).

If we gather information on the condition of soil biota and proportion of mineral nitrogen in the soil, we shall get an idea of the quality and health of the soil (Nielson 2002). Another parameter is the index, or nitrogen availability in soil, which is contingent on microbial processes, in particular on mineralization (Robertson et al. 1999).

TerraCottem is a polymeric substance consisting of more than twenty components. It has the ability to absorb and retain the amount of water corresponding to 400 times its own weight. Thus, TerraCottem is able to retain water that would leach through the soil profile or would evaporate under normal circumstances. The retained moisture is utilized by the plant roots in the dry seasons (Shahmiri et al. 2009).

Polymeric substances affect also other physical qualities, such as aggregate stability (Piccolo et al. 1990) and infiltration (Woodhouse et al. 1991). Both these parameters are closely related to soil erosion and their adjustment represents one of the methods of prevention of erosion in arid and semiarid areas (LeBissonnais 1996).

The improvement of soil water regime may also prevent the leaching of valuable nutrients which are normally distributed into the environment causing its damage, e.g. by eutrophization (Lentz et al. 1932).

According to Piccolo (1997), polymeric substances can replace the traditional additions used for the improvement of soil qualities, such as sewage sludge and compost. Moreover, polymers do not contain pathogens and other undesirable components that often make application into soil difficult or impossible.

The manufacturer describes TerraCottem as a substance which, after application to the soil, reduces the need of watering by 50%, improves the soil structure, positively influences the development of the root system of the plant and promotes biological processes in soil.

The National Action Program to Combat Desertification recommends polymeric substances as additives for the enhancement of soil quality; however their influence on soil life has not been described in detail.

MATERIALS AND METHODS

Soil properties

Soil from the Pinarillo experimental site in southern Spain was sampled in the spring 2015 (X: 424,240 m; Y: 4,073,098 m; UTM30N/ED50). The experiment involved taking disturbed soil samples from the surface (0–25 cm depth) under ČSN ISO 10 381-6 (ČSN – Czech Technical Standard).

Soil samples were sieved through a 2-mm mesh sieve. According to Food and Agriculture Organization of the United Nations (FAO) — World Reference Base for Soil Resources (2006), these soils are classified as lithic and eutric leptosols.

Their typical features are the high level of rock fragment cover on the surface (> 50%), high gravel content in the profile (total gravel content = 56%; gravel content > 10 mm = 31%; gravel content 2 fine (f) mm = 10%; gravel content 5f 1 mm = 15%), and sandy loam texture (sand = 60%, silt = 32%, and clay = 8%).

General soil properties and characteristics are summarized in Table 1.

Design of experiment

Sampling at the Pinarillo site was performed in June 2015. Each trial container was filled with 200 g of soil and 150 g of sand; an IER bag had been placed on the bottom for the purpose of measurement of nitrogen leaching.

The experiment was conducted under natural conditions and the soil humidity was replenished to the value of 15% FC.

Index of nitrogen availability

At the end of the experiment, the availability of nitrogen for soil microbes was tested. In this method, soil N availability was estimated from NH4 + - N produced at the start of the experiment and during 7 days' waterlogged incubation (Bundy, Meisigner 1994). The distillation–titration method was applied subsequently, according to the same authors.

Modes

The experiment proceeded in three modes depending on the content of polymer; 3 additives were applied. The control variant was also prepared. The variants are specified in Table 1.

RESULTS AND DISCUSSION

The main subject of our interest was to determine the effect of polymer addition on availability of mineral nitrogen for soil microbes.

To confirm or refute our hypothesis, pot experiments were conducted. The result of the experiment is the amount of mineral nitrogen, which was used by soil microbes for their development.

Table 1 Characteristic of variations

Sample	TerraCottem	Additive	Repetitions
A+	1.5 kg · m^{-3}	Control	4
A++	3.0 kg · m^{-3}	Control	4
A-	-	Control	4
B+	1.5 kg · m^{-3}	Glucose (1%)	4
B++	3.0 kg · m^{-3}	Glucose (1%)	4
B-	-	Glucose (1%)	4
C+	1.5 kg · m^{-3}	Glucose (1%) + Fertilizers (50 kg · ha^{-1} N)	4
C++	3.0 kg · m^{-3}	Glucose (1%) + Fertilizers (50 kg · ha^{-1} N)	4
C-	-	Glucose (1%) + Fertilizers (50 kg · ha^{-1} N)	4
D+	1.5 kg · m^{-3}	Fertilizers (50 kg · ha^{-1} N)	4
D++	3.0 kg · m^{-3}	Fertilizers (50 kg · ha^{-1} N)	4
D-	-	Fertilizers (50 kg · ha^{-1} N)	4

Obtained results are divided into four sections: overview of measured values; availability of N_{min} in control soil, in soil with addition of glucose, in soil with addition of mixture of glucose and mineral fertilizer and finally in soil with addition of only mineral fertilizer.

Overview of measured results – availability of mineral nitrogen in lithic and eutric leptosols

Table 2 Availability of mineral nitrogen in lithic and eutric leptosols (mean ±SD).

Variant	NH_4^+–N (mg · kg^{-1})	±SD
A-	18.81	2.81
A+	15.87	2.37
A++	23.20	3.68
B-	8.87	5.23
B+	18.74	4.48
B++	20.58	1.73
C-	20.62	5.76
C+	7.56	3.56
C++	15.90	2.35
D-	16.29	4.94
D+	14.32	3.94
D++	19.76	5.28

Statistical analysis

Potential differences in availability of mineral nitrogen for soil microbes between individual variants were tested by ANOVA in a combination with the Fischer test. All analyses were performed using Statistica 10 CZ software.

Availability of mineral nitrogen in control soil

The control series variants, which did not contain any additives, did not show any statistically significant difference. The amount of applied polymer did not affect the nitrogen availability (see Figure 1).

Availability of mineral nitrogen in soil with addition of glucose

This variant was enriched with a 1% addition of glucose. No statistically significant difference between the variants was ascertained here, eithers (see Figure 2). The values suggest that microbial activity is affected by the presence of polymer to a degree, and that it increases with the polymer representation in the soil. Glucose is an energy source for microorganisms, and soil activity is induced upon its application (Nannipieri et al. 1979). The addition of glucose in combination with polymer, containing mineral fertilizer, could lead to the increase of available nitrogen.

Table 3 The results of post-hoc Fischer LSD test.

Variants	A-	A+	A++	B-	B+	B++	C-	C+	C++	D-	D+	D++
A-		0.612	0.451	0.096	0.990	0.760	0.754	0.061	0.617	0.664	0.441	0.869
A+	0.612		0.213	0.234	0.621	0.419	0.415	0.160	0.995	0.942	0.790	0.503
A++	0.451	0.213		0.020	0.444	0.652	0.657	0.012	0.215	0.240	0.135	0.555
B-	0.096	0.234	0.020		0.098	0.052	0.051	0.821	0.231	0.208	0.351	0.069
B+	0.990	0.621	0.444	0.098		0.750	0.745	0.063	0.626	0.673	0.448	0.859
B++	0.760	0.419	0.652	0.052	0.750		0.994	0.032	0.423	0.461	0.285	0.888
C-	0.754	0.415	0.657	0.051	0.745	0.994		0.032	0.418	0.457	0.282	0.882
C+	0.061	0.160	0.012	0.821	0.063	0.032	0.032		0.158	0.141	0.250	0.044
C++	0.617	0.995	0.215	0.231	0.626	0.423	0.418	0.158		0.947	0.784	0.507
D-	0.664	0.942	0.240	0.208	0.673	0.461	0.457	0.141	0.947		0.734	0.550
D+	0.441	0.790	0.135	0.351	0.448	0.285	0.282	0.250	0.784	0.734		0.352
D++	0.869	0.503	0.555	0.069	0.859	0.888	0.882	0.044	0.507	0.550	0.352	

Legend: Significant differences at level P<0.05 are highlighted in red.

Figure 1 The availability of N_{min} in control soil (mean ±SD)

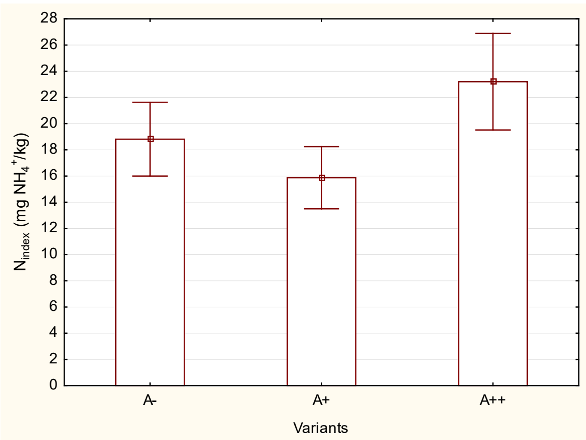
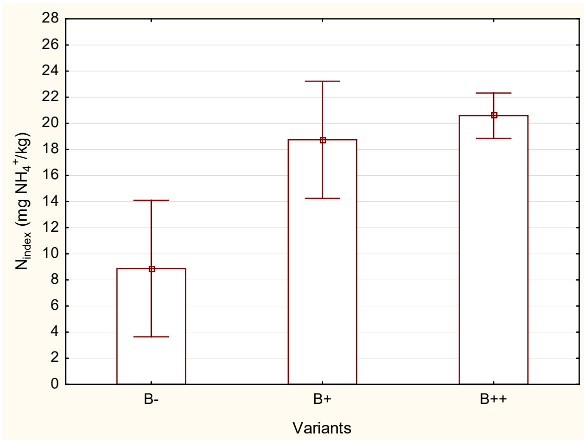


Figure 2 The availability of N_{min} in soil with addition of glucose (mean ±SD)



Availability of mineral nitrogen in soil with addition of mixture of glucose and mineral fertilizer

In this variant, glucose was applied together with mineral fertilizer. Therefore, the soil microflora had the abundance of carbonaceous and nitrogenous substances. A statistically significant difference was ascertained between the variants. The lowest value was measured in the C+ sample, which contained the recommended dose of polymer (see Figure 3). The highest value was ascertained in the C- sample, which did not contain polymer at all. This variant represented the most lucrative environment for the soil microflora, and therefore the effect of polymer was not necessary.

Availability of mineral nitrogen in soil with addition of mineral fertilizer

Figure 3 The availability of N_{min} in soil with addition of mixture of glucose and mineral fertilizer (mean ±SD).

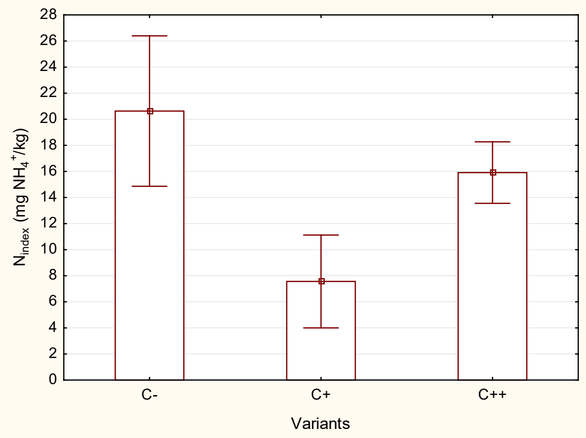
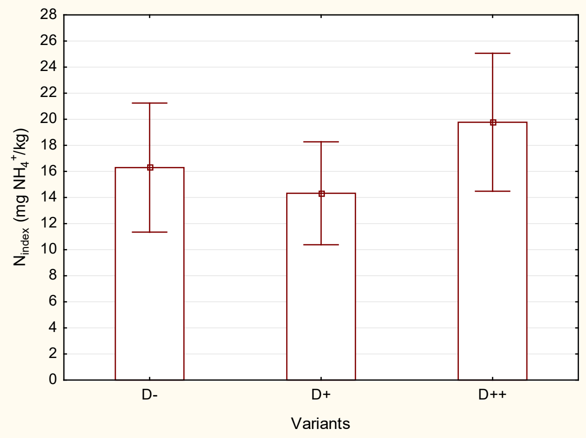


Figure 4 The availability of N_{min} in soil with addition of mineral fertilizer (mean ±SD).



No statistically significant difference was ascertained in the variant which contained only mineral fertilizer (see Figure 4).

CONCLUSION

Polymers favorably affect physical properties of soil. Their positive effect may also extend to the biotic component of soil in case they are applied together with substances promoting mineralization processes in the soil. Polymers are foreign substances introduced into soil; therefore their presence may induce stress. The prerequisite for successful application of polymers is healthy and quality soil.

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