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IMPACT OF AMMONIA-LOADED ZEOLITE ON ITALIAN RYEGRASS GROWTH AND YIELD*

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SUMMARY: The structure of natural zeolite of clinptilolite type is ideal for sorption and ion exchange processes. In this study the influence of zeolite and ammonia-loaded zeolite on growth and yield of Italian ryegrass (Lolium multiflorum Lam.) was investigated on two types of soil: Planosol and Dystric Cambisol. Pot experiment carried out in greenhouse included four different treatments: a) soil (control); b) soil+zeolite; c) soil+ammonia-loaded zeolite; d) nitrogen application by mineral fertilizer; all in 4 replications. Our results show that there is a significant difference in yields obtained on the two types of soil, but the difference between treatments was not significant up to 3rd cut when the optimal yield was obtained in pots containing ammonia-loaded zeolite. The results are yet to be tested in field conditions.

***Key words:** zeolite, ammonia-loaded zeolite, Italian ryegrass, fertilizing.*

INTRODUCTION

Italian ryegrass (*Lolium italicum* L. syn *L. multiflorum* L.) is an important short duration grass in Serbia. High palatability and digestibility make this species highly valued for forage/livestock systems from early spring to late summer. It is used in many environments where fast cover or quick feed is required. Italian ryegrass is well-adapted to high rainfall, but can be grown where a minimum of about 500 mm rainfall occurs during the growing season (Evers et al., 1997). In Serbia, it is a dense-growing winter crop characterized by fast growth that secures quick tillering, high yield potential, fitness for reduced cultivation and good adaptability to heavy and moist soils. There are reports of ryegrass preference for ammonium nutrition over nitrate (Griffith and Streeter, 1994).

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Zeolite is used traditionally in agriculture as soil conditioner and as nitrogen retaining medium for nitrogen fertilizing improvements (Polat et al., 2004). The structure of natural clinoptilolite is ideal for sorption and ion exchange processes. Due to its structure and properties this natural, inert and non-toxic material can be used as a slowly releasing carrier of fertilizer, it can improve physical properties of soils and it can be used for treatment of contaminated soils (Reháková et al., 2004). Our experiment was conducted with a natural zeolitic tuff (from "Zlatokop" mine in south Serbia, containing ~70wt. % of clinoptilolite) and ammonia-loaded zeolite (formed by binding of ammonia ions from aqueous solution). The results of studies implicitly suggest that plants may have a good response if clinoptilolite is used as a fertilizer carrier while such method of fertilization is ecologically advantageous since the active compounds and nutrients are washed out into the soil slowly and gradually (Malekian et al., 2011). Clinoptilolite can also influence bioavailability of other plant nutrients and there are some indications that it contributes to releasing phosphorus in the first 24h for about 60%, while modified NH_4^+ -zeolite increases the release of phosphorus for additional 150% when added to the rock phosphate (Lopičić et al., 2013). Furthermore it has been reported that zeolites, with their specific selectivity for ammonium, can take up this specific cation from either farmyard manure, composts, or ammonium-bearing fertilizers, thereby reducing losses of nitrogen to the environment (Sparks et al., 2011). Based on the results of research, natural zeolite can be recommended for agricultural purposes in terms of sustainable fertilizing and improving system cattle farm - manure - organic fertilizer for forage crops (Simić et al., 2013).

MATERIAL AND METHODS

The soils used for the experiment were Pseudogley (*Planosol*) collected from the site in Varna (West Serbia) and Dystric brown soil (*Dystric Cambisol*) collected from the site in Vlasina (South-east Serbia). Soil samples collected at the sites were pooled and homogenized whereas stones and roots were removed. The pots were filed with 2 kg of air-dried soil and the ryegrass seed was sown on 12 December 2013. at a rate of 50 seeds per pot.

The experiments carried out in greenhouse included four different treatments: a) soil (control); b) soil+zeolite CLI (10 g kg^{-1}); c) soil+ammonia-loaded zeolite NH_4^+-CLI (10 g kg^{-1} equivalent to nitrogen application of 100 kg ha^{-1} N); d) nitrogen application by mineral fertilizer Calcium ammonium nitrate CAN (100 kg ha^{-1} N, CAN contains 27% nitrogen); all in 4 replications.

The pots were placed in an unheated greenhouse and were thoroughly watered, while the growth of the plants was monitored. The temperature in greenhouse was above 10°C during the experiment and it can be considered as optimal for Italian ryegrass since it is physiological active when temperature rises above 0°C (Griffith and Chastain 1997). Plants were cut back three times in all the individual experimental pots, about 2-3 cm above soil level, on 34th, 61st and 84th day after planting when the experiment was terminated. The foliage was collected for determination of fresh and dry weight per cut and the harvested material was left to dry at room temperature for a few days before it was dried in an oven at 60°C until constant mass. Plant tissue was examined for changes in weight and the data were analysed by analysis of variance (ANOVA). The treatment effect was determined according to Fischer's least significant difference procedure.

The main chemical characteristics of the soils were determined: pH (in water and in aqueous solution of $CaCl_2$) and the contents of P_2O_5, K_2O, total C and total N. For pH measurement distilled water and 0.01 M $CaCl_2$ were used; the pH is measured in suspension by Orion pH meter connected to a Ross combined pH electrode. Loss on ignition is calculated in percent of soil dried at 105°C. The extractions of elements were done in ammonium lactate (AL) solutions; the ammonium-lactate extraction is performed according Egner et al. (1960) and the elements are measured by use of ICP-OES. For determination of elements the inductively coupled plasma optical emission spectrometer (ICP-OES), model Perkin-Elmer Optima 5300 DV, was used. The contents of sand, silt and clay were measured and the textural classes were determined according to USDA Soil Survey manual.

The ammonia-enriched zeolitic tuff (grain size in the range 0.063-0.1 mm) was prepared as described in details by Milovanović et al. (2013).

RESULTS AND DISCUSSION

The soils selected for the experiment are traditionaly used for extensive forage production since their phisical and chemical properties (Table 1) could be restrictive for an intensive agricultural production. Planosol is marked as conditionally productive soil whereas Dystric Cambisol is marked to serious restrictions (Protic et al., 2003).

The soils have low nitrogen contents. This could considerably reduce yields since the leaves of plants grown with a limiting nitrogen supply are smaller, compared with these of plants grown with an optimum nutrient supply (Griffith and Streeter, 1994). Yield quality could also be affected since nitrogen stress decreases the concentration of protein and enhances that of (hemi) cellulose and lignin (Lambers et al., 2008). Italian ryegrass reacts rapidly to increased N application doubling the yield of proteins in relation to control (Simić et al., 2009).

Table 1. Soil properties

Soil type / *Tip zemljišta*	Textural class / *Teksturna klasa*	Chemical properties / *Hemijske osobine*					
		pH		$AL\text{-}P_2O_5$ mg kg^{-1}	$AL\text{-}K_2O$ mg kg^{-1}	Total C %	Total N %
		in H_2O	in $CaCl_2$				
Planosol / *Pseudoglej*	Sandy loam / *Peskovita ilovača*	5.73	5.07	19.8	115.1	1.37	0.16
Dystric Cambisol / *Distrično smede zemljište*	Clay loam / *Glinovita ilovača*	5.10	4.18	6.7	63.0	1.10	0.096

Number of seedlings and plant height were mesaured before the first cut (Table 2). There was no significant effect of treatment or soil type on germination rate.

Table 2. Number of seedlings and plant height (Standard Deviations appear in parentheses)

	Control	CLI	NH_4^+– CLI	CAN
Seedlings (Number pot^{-1}) / *Klijanci (Broj po posudi)*				
Planosol	44.5^{a*} (1.12)	43.5^{a} (1.80)	44.5^{a} (1.50)	44.8^{a} (2.86)
Dystric Cambisol	41.2^{a} (2.86)	46.8^{a} (2.05)	43.0^{a} (1.22)	44.5^{a} (1.11)
Plant height (cm) / *Visina biljaka (cm)*				
Planosol	24.33^{a} (0.78)	24.82^{a} (2.68)	24.45^{a} (0.35)	24.10^{a} (1.02)
Dystric Cambisol	22.60^{b} (1.35)	22.2^{b} (1.30)	22.13^{b} (0.62)	22.31^{b} (0.62)

* Means with differing superscripts are significantly different ($P<0,05$).

* *Vrednosti sa različitim superskriptama se statistički značajno razlikuju ($P<0,05$).*

Average germination rate of 88 % corresponds with the literature (Jovanović and Tešić-Jovanović, 1972) and therefore it can be concluded that addition of zeolite or ammonia-loaded zeolite doesn't have a negative effect on the germination of Italian ryegrass seeds. Soil type did have a significant influence on plant height. In relation to the plants grown on Dystric cambisol the plants grown on Planosol were 8.3 % higher in average. Soil acidity of Dystric cambisol could have an inhibitory effect on plant growth and leaf elongation. Plant height was not affected by nitrogen-source, as well as nitrogen content.

Although Italian ryegrass is tolerant of low soil pH the yield decreases when the pH is below 5.5 (Hart and Mellbye, 2009). Our results show that there is a significant difference in yields obtained on the two types of soil in each cut (Table 3). Acidity is a major limitation to soil productivity and soil pH values below 5.0 to 5.5 warn that soluble levels of certain metals, particularly Al_3^+ and Mn_2^+, may be high enough to be biologically toxic (McBride, 1994).

Table 3. Dry matter yield, in grams (Standard Deviations appear in parentheses)

	Control	CLI	NH_4^+– CLI	CAN
I cut / *I otkos*				
Planosol	0.2649^{a} (0.0197)	0.2423^{a} (0.0295)	0.2847^{a} (0.0082)	0.2652^{a} (0.0153)
Dystric Cambisol	0.1835^{b} (0.0087)	0.1888^{b} (0.0209)	0.1455^{b} (0.0259)	0.1571^{b} (0.0026)
II cut / *II otkos*				
Planosol	0.4628^{a} (0.0121)	0.4166^{a} (0.0482)	0.4948^{a} (0.0518)	0.4565^{a} (0.0664)
Dystric Cambisol	0.2381^{b} (0.0211)	0.2677^{b} (0.0269)	0.2504^{b} (0.0155)	0.2321^{b} (0.0248)
III cut / *III otkos*				
Planosol	0.5071^{b} (0.1143)	0.3748^{b} (0.0444)	0.7684^{a} (0.1006)	0.6841^{a} (0.0773)
Dystric Cambisol	0.3827^{c} (0.0438)	0.4103^{c} (0.0198)	0.4247^{b} (0.0265)	0.5053^{b} (0.0615)

* Means with differing superscripts are significantly different ($P<0,05$).

In the first two cuts there were no significant differences in yields between the treatments. The addition of nitrogen was proven to have effect on yield in third cut. A marked increase in the dry matter yield was seen for NH_4-CLI additive, compared to control, while CLI additive did not have a favourable effect on it. As expected, commercial fertilizer CAN significantly increased Italian ryegrass yield compared to control.

The delayed effect of the treatments could be explained by the limiting effect of irradiance. Both the total level of irradiance and the photoperiod, spectral composition and direction of the light affect plant development (Lambers et al., 2008). Furthermore, low red/far red ratio might preclude morphogenic responses in Italian ryegrass even before an important depletion in energy availability takes place (Casal et al., 1987).

CONCLUSION

The results implicitly suggest that plants may have a good response if clinoptilolite is used as a nitrogen fertilizer carrier. Such method of fertilization is ecologically advantageous since the active compounds and nutrients are washed out into the soil slowly and gradually. On the basis of results obtained in pot experiments on the yield of Italian ryegrass under the influence of different N application, it can be concluded that this grass species reacts to N supply increasing the yield of dry weight in relation to control. Italian ryegrass dry matter quality could be good indicator of ammonia intake and is yet to be analysed. Why the yield of Italian ryegrass was not significantly different until the third cut was not determined. Further research is need for testing the proposed hypothesis. The next stage of our research will be testing the results in field conditions.

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