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Forage yield of a grass-clover mixture on an acid soil in the third year after soil liming

Prinos travno-detelinske smeše na kiselom zemljištu u trećoj godini nakon kalcizacije

Dalibor TOMIĆ[1]*, Vladeta STEVOVIĆ[1], Dragan ĐUROVIĆ[1], Nikola BOKAN[1], Branka POPOVIĆ[1] and Jasmina KNEŽEVIĆ[2]

[1]University of Kragujevac, Faculty of Agronomy, Cara Dušana 34, Čačak, Serbia, *correspondence: dalibort@kg.ac.rs

[2]University of Priština, Faculty of Agriculture, Kopaonička bb, 38219, Lešak, Serbia

Abstract

Soil acidity is one of the most common reasons for low yields of forage crops. This paper analyzes the long-term effect of liming (control - without CaO; 3 t*ha^{-1} CaO; 6 t*ha^{-1} CaO) applied to an acid soil (pH_{H2O} 4.8) before stand establishment on the productivity of a mixture of red clover (*Trifolium pratense* L.) and tall oat grass (*Arrhenatherum elatius* L.) during the third year of production. Soil liming significantly increased hay yields in the first and second cuts by 17-25% and 46%, respectively, which resulted from an increase in the total yield and dry matter content of forage. In the third cut, soil liming had no effect on forage and hay yields due to the lower amount of precipitation in the second part of the growing season. Both lime application rates led to a significant reduction in the percentage of red clover in the first and second cuts, thus favoring the percentage of tall oat grass. In the third cut, only the percentage of weeds was lower in both lime treatments, as it decreased by more than 55% compared to the control.

Keywords: forage yield, red clover, soil liming, tall oat grass

Sažetak

Kiselost zemljišta je jedan od najčešćih razloga za niske prinose krmnih useva. U radu je analiziran produžen uticaj primene kalcizacije (kontrola – bez CaO; 3 t*ha^{-1} CaO; 6 t*ha^{-1} CaO) na kiselom zemljištu pH 4,8, pre zasnivanja useva, na produktivnost smeše crvene deteline (*Trifolium pratense* L.) i francuskog ljulja (*Arrhenatherum elatius* L.) tokom treće godine proizvodnje. Kalcizacija zemljišta je uticala na značajno povećanje prinosa sena u prvom i drugom otkosu za 17-25%, odnosno 46% po redosledu. To je posledica povećanja ukupnog prinosa krme i sadržaja suve materije u krmi. U trećem otkosu, kalcizacija zemljišta nije ostvarila

uticaj na prinos krme i sena, zbog manje količine padavina u drugom delu vegetacije. Primena oba nivoa kalcizacije zemljišta je uticala na značajno smanjenje udela crvene deteline u prvom i drugom otkosu, na račun povećanja udela francuskog ljulja. U trećem otkosu je jedino udeo korova bio manji na obe varijante kalcizacije za više od 55% u odnosu na kontrolu.

Ključne reči: crvena detelina, francuski ljulj, kalcizacija, prinos krme

Introduction

The production of sufficient amounts of high quality forage is a prerequisite for the intensification of livestock production. Grasslands of different floristic composition significantly differ in productivity. On the other hand, growing legumes and grasses in mixtures provides greater profitability and improves forage quality (Nešić et al., 2007). The introduction of legumes to forage grass stands reduces the need for nitrogen fertilizer and, hence, losses of nitrogen from the soil by leaching or gas emissions (Ledgart et al., 1999), thus contributing to environmental protection (Janzen and McGinn, 1991). Symbiotic N_2 fixation in legumes is a fundamental process for maintaining soil fertility and continuous productivity of organic growing systems (Vinther and Jensen, 2000). The total yield, quality and seasonal distribution of forage can be increased by growing mixtures of tall grasses and clovers (Tekeli and Ateş, 2005).

The incidence of weeds in grass-legume mixtures is much lower than in pure grass or legume stands (Sleugh et al., 2000).

The most common reason for low unstable yields and poor forage quality is the absence of proper cultural practices (Dubljević, 2007). Soil acidity is one of the factors which hamper the growing of both legumes and grasses (Edmeades et al., 1981; Wheeler, 1998). Soil pH affects all plant growth stages, resistance to diseases and low temperatures, stand life, and forage yield and quality. In acid soils, many nutrients are not readily available to plants, although they are present in sufficient quantities (Su and Evans, 1996). Satisfactory crop yields on acid soils can be achieved by soil liming (Grewal and Williams, 2003). However, the effect of lime application at 3 $t*ha^{-1}$ before alfalfa seeding on alfalfa yield decreases over the years (Lazarević, 2011).

Given that acid soils occupy significantly large areas in the Republic of Serbia, the aim of this study was to examine the prolonged effect of soil liming on the forage yield of a red clover/tall oat grass mixture on an acid soil.

Materials and methods

The experiment was conducted in 2014-2016 in Čačak (43°54'39.06" N, 20°19'10.21" E, 242 m a.s.l.), on a leached vertisol having an acidic reaction (pH_{H2O} 4.8), 3.18% organic matter, 0% $CaCO_3$, 22.1 mg P_2O_5 and 30 mg K_2O per 100 g soil. Along with tillage, 300 $kg*ha^{-1}$ $N_{15}P_{15}K_{15}$ was incorporated into the soil. The experiment was laid out in a completely randomized block design with three replications, with a plot size

of 5 m^2 (5 m x 1 m). Red clover cv. 'Kolubara' (Institute of Field and Vegetable Crops, Novi Sad) and tall oat grass cv. 'K-12' (Institute of Forage Crops, Kruševac) were used. The cultivars were sown at a row spacing of 0.2 m (tall oat grass and red clover sown in the same rows), and at a seeding rate of 12 kg*ha^{-1} for both crops. Lime treatments included control (without CaO), 3 t*ha^{-1} CaO and 6 t*ha^{-1} CaO. The lime material was incorporated by surface application immediately before seedbed preparation. Mechanical weed control was performed on two occasions. The crop mixture was grown without irrigation.

Data on mean monthly temperatures and rainfall were recorded throughout the experiment, at a weather station located near the experimental site. The average annual temperature during 2016 was 12.4 °C (0.4 °C higher than the 10-year average). Total rainfall was 767 mm (87 mm above the 10-year average). The total amount of precipitation during the growing season of 2016 (April-October) was 441.5 mm.

Cutting was made at red clover budding. Analyses were performed on all three cuts in 2016. Green forage yield was determined by measuring the total weight of the plot immediately after cutting. The cutting operation was conducted at the optimum stage of plant growth and development. The total weight was recalculated to green forage yield in t*ha^{-1}. After drying the samples (1,000 g) at 65 °C, hay yield (t*ha^{-1}) and the percentage (%) of tall oat grass, red clover and weeds were determined.

The results were subjected to a single-factor analysis of variance (ANOVA) using the SPSS 4.5 software. Significant differences between mean values were tested by the LSD test.

Results and discussion

Applying lime (3 t*ha^{-1}) before sowing significantly increased the first-cut green forage yield of the red clover/tall oat grass mixture in the third year of cultivation (Table 1). Forage yield was increased by 19% compared to the control. First-cut hay yield in the third year of cultivation was significantly higher under both liming treatments compared to the untreated control, as the result of the positive effect of liming on both total yield and dry matter content of forage. Soil liming helps to reduce the amount of easily mobile and toxic forms of aluminum, iron and manganese. It also increases the amount of readily available phosphorus in the soil for clovers and grasses (Wheeler, 1998). The incorporation of calcium also promotes the microbial activity of the soil (Agarwal et al., 1972) and nitrogen mineralization (Edmeades et al., 1981). By reducing soil acidity, favorable conditions are provided for the development of symbiotic nitrogen-fixers. The numbers and microbial activity of symbiotic nitrogen-fixers in perennial legumes are limited by low pH values (Jarak et al., 2002). In acid soils, the survival of nodule-forming bacteria is hampered, and their reproduction is slowed down; therefore, legume yields are reduced (Nutman, 1976).

In the second cut, during the third year of cultivation, liming at 3 t*ha^{-1} did not lead to a significant increase in forage yield, but the yield was higher than in the control, as the result of the positive effect of liming on the dry matter content of forage. Under treatment with 6 t*ha^{-1} lime, there was no significant increase in forage and hay yields compared to the control. The better response of the crops to the lower amount of lime

can be explained by different interactions between different nutrient concentrations in the soil. As found by Hinsinger (2009), as soil pH increases, the solubility of iron and aluminum phosphate increases, but that of calcium phosphate decreases, except when the soil pH is above 8.

Table 1. Effect of liming (Ø - control, 3 t*ha^{-1} CaO and 6 t*ha^{-1} CaO) on forage yield (FY), hay yield (HY), and dry mater content in green forage (DMC) of a red clover/tall oat grass mixture, two years after liming

		FY (t*ha^{-1})	HY (t*ha^{-1})	DMC (%)
1st cut	Ø	5.27^{b}	1.173^{b}	22.3
	3 t*ha^{-1}	6.28^{a}	1.473^{a}	23.1
	6 t*ha^{-1}	5.27^{b}	1.379^{a}	26.3
2nd cut	Ø	13.41	5.04^{b}	37.6^{b}
	3 t*ha^{-1}	15.77	7.38^{a}	46.8^{a}
	6 t*ha^{-1}	13.63	5.67^{b}	42^{ab}
3rd cut	Ø	6.09	1.898	31.1
	3 t*ha^{-1}	6.51	2.036	31.3
	6 t*ha^{-1}	7.01	2.138	30.5

The values followed by different lowercase letters within columns for cultivation method and liming are significantly different (P<0.05) in accordance with the LSD test.

However, in the third cut in the third year of production, soil liming had no effect on forage and hay yields. A possible reason for the low yield response to liming in the second and third cuts, when compared to the first cut, was the lower amount of precipitation in the second part of the growing season.

In the first cut in the third year of cultivation, both lime application rates led to a significant reduction in the percentage of red clover in the mixture, while that of tall oat grass increased (Table 2). Also, in the second cut, the treatment with 3 t lime*ha^{-1} significantly increased the percentage of tall oat grass in the mixture, while reducing the percentage of red clover. This indicated that the response to the prolonged effect of soil liming was better in tall oat grass than in red clover. The reason behind this finding may be that tall oat grass exhibits a higher competitive ability and faster growth in relation to red clover, which is more tolerant to acidic soils than most other legumes (Mc Kenny et al., 1993). The competitive ability of ryegrass is more pronounced than that of clover (Thomas, 1984). Liming induced a significant increase in plant height of grass species in *Poetum violaceae*-type natural grasslands (Prentović et al., 2007).

Table 2. Effect of liming (Ø - control, 3 t*ha^{-1} CaO and 6 t*ha^{-1} CaO) on the percentage of tall oat grass (TOG), red clover (RC) and weeds (W) in the hay of a red clover/tall oat grass mixture, two years after liming

		TOG (%)	RC (%)	W (%)
	Ø	90.5	2.49^{a}	7
1st cut	3 t*ha^{-1}	94.6	0.61^{b}	4.8
	6 t*ha^{-1}	97,5	0.31^{b}	2.2
	Ø	72.3^{b}	24.3^{a}	3.45
2nd cut	3 t*ha^{-1}	99.3^{a}	0.1^{b}	0.62
	6 t*ha^{-1}	87.7^{ab}	10.4^{ab}	1.9
	Ø	69.6	16.1	14.25^{a}
3rd cut	3 t*ha^{-1}	83.3	10.8	5.89^{b}
	6 t*ha^{-1}	77.5	16	6.5^{b}

The values followed by different lowercase letters within columns for cultivation method and liming are significantly different (P<0.05) in accordance with the LSD test.

In the third cut in the third year of cultivation, only the percentage of weeds was reduced in both liming treatments compared to the control. The weed percentage was higher in the third cut than in the previous two cuts. This was due to the progressive thinning of the red clover stand in the third year of cultivation. In thin stands, weeds occur massively, consume nutrients and water, and reduce crop yields, whereas dense stands “suffocate” weeds and prevent their massive occurrence (Živanović-Katić, 2004).

The percentage of red clover was higher in the second and third cuts than in the first cut. This was attributed to a higher tolerance of red clover to the low amount of precipitation during the period. The results indicate that red clover was more tolerant to drought than tall oat grass, possibly owing to the better supply of nitrogen (through nitrogen fixation), whose uptake from the soil was decreased under water deficit conditions.

Conclusions

Soil liming prior to sowing led to a significant increase in the hay yield of the red clover/tall oat grass mixture in the first cut in the third year of production. The reason for this is the positive effect of soil liming on both total forage yield and dry matter content of forage. Compared to the control, the application of lime at 3 t*ha^{-1} significantly promoted hay yield in the second cut, while liming had no effect on

forage and hay yields of the third cut. A possible reason for the low yield response to liming in the second and third cuts, when compared to the first cut, was the lower amount of precipitation in the second part of the growing season.

Both lime application rates caused a significant reduction in the percentage of red clover in the mixture, while that of tall oat grass increased in the first and second cuts. This indicated that the response to the prolonged effect of soil liming was better in tall oat grass than in red clover. In the third cut, only the percentage of weeds was reduced in both liming treatments compared to the control. Also, the percentage of weeds was higher in the third cut than in the previous two cuts. This was due to the gradual thinning of red clover in the third year of cultivation.

Applying lime to acid soils and growing red clover in mixtures with fast-growing grasses such as tall oat grass, along with proper crop utilization and management, can ensure the stability of forage production.

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