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THE EFFECT OF LIMESTONE AND STABILIZED NITROGEN FERTILIZERS APPLICATION ON SOIL PH VALUE AND ON THE FORAGE PRODUCTION OF PERMANENT GRASSLAND

Pavel Ryant[1], Petr Škarpa[1], Lenka Detvanová[1], Lucie Taušová[1]

[1]Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition, Faculty of AgriSciences, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic

Abstract

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The changes of soil pH and dry forage yield of permanent grassland after application of dolomitic limestone and stabilized nitrogen fertilizers are described in this paper. The small-plot experiment was located on semi-natural grassland at Bohemian-Moravian Highlands, near village Kameničky (Czech Republic), with poor and acidic soil. The experiment was divided into two blocks, within one of whose dolomitic limestone was applied in autumn 2013. In each block, 4 experimental treatments were applied: 1. control (untreated), 2. Urea, 3. Urea with inhibitor of urease, 4. Urea with inhibitor of nitrification. After liming, the pH/$CaCl_2$ soil values increased in both the first as well as the second year after application. Fertilizing by urea, namely urea with inhibitors, did not significantly influence the pH/$CaCl_2$ values. Dry forage productions in both years were comparable. In comparison to the untreated variants, significant increase in dry forage yield was achieved after application of urea and urea with urease inhibitors. The impact of stabilized fertilizers on the yield was not proven. In case of the limed variants, yield drop by 1.12 t/ha (average of both years) was observed; the yield decrease may be connected with disturbance of production potential of the stable community of plant species that had been adapted to acidic locations.

Keywords: liming, acidic soil, soil pH, stabilized nitrogen fertilizers, urease inhibitors, nitrification inhibitors, dry forage yield.

INTRODUCTION

Minimal inputs have been recorded on permanent grassland in the Czech Republic, mainly in regard to fertilizers application or lime substances.

Since the 90s, the development of soil properties has indicated an increase in land area of strongly acidic (7 %) and acid soil (61 %) as a result of the steep reduction in the use of liming materials (Smatanová *et al.*, 2015). Soils become acidic especially in areas of high rainfall, because base cations (Ca^{2+} and Mg^{2+}) are relatively easy to leach from soils. The rate of acidification in agricultural soils may be influenced by the form and amount of N fertilizer applied. Soil acidification is frequently inevitable in agriculture that relies on either N_2 fixation or cheaper (ammonium-containing) N fertilizers (Mahler and Harder, 1984; Bezdicek *et al.*, 1988; Rengel, 2003).

Soil acidity expressed as a pH value can importantly influence plant growth in grassland. Many agricultural plants actively grow in the pH range between 4.0 and 8.5 but not at the same rate throughout the interval (Whitehead, 2000). The optimum pH for semi-natural grasslands is in a wide range from 5.0 to 6.5. Cultivated grasses can stand the soil pH of up to 7.5. If soil pH drops below 5.0, liming should be performed (Hrabě and Buchgraber 2004).

The effect of nitrogenous fertilizing on grassland production is generally well known. However, the utilization rate of N in mineral fertilizers is about 50–60 % in the first year (Finck, 1992; Cassmann *et al.*, 2002; Galloway *et al.*, 2003). The unused nitrogen has negative impact on ecosystem (nitrates wash out of soil, eutrophication in surface water, soil acidification, gas emissions), undesirable impact on the climate and loss of soil biological diversity (Beever *et al.*, 2007). One of the possibilities to limit these losses and achieve a more effective utilization of nitrogenous fertilizers is the application of stabilized fertilizers, fertilizers associated with nitrification or urease inhibitors that delay either the nitrification of ammonia or the ammonification of urea (Trenkel, 2010, Dawar, *et al.* 2011, Singh *et al.* 2013). Decreasing the wash out of nitrates into underground waters and nitrogen oxides emissions into the atmosphere which results in the increased utilization of applied N with subsequent increase in productivity of grasslands have been described by, for example, Merino *et al.* (2002), who applied inhibitors of urease and nitrification in combination with nitrogenous fertilizers, including cattle slurry.

The aim of this work was to evaluate the impact of liming and the application of urea and urea with urease inhibitor and nitrification inhibitor on the value of exchangeable soil acidity (pH/$CaCl_2$) and dry forage yield of permanent grassland.

MATERIALS AND METHODS

Experimental locality

The small-plot experiment was located at Bohemian-Moravian Highlands (Czech Republic), near village Kameničky (49°43'30"N, 15°58'38"E) at the altitude of 650 m a. s. l. The site has a SW aspect and is situated on a slope with the gradient of 3°. Mean annual temperature (1951–2000) is 5.8 °C and mean annual precipitation amount is 758 mm. Medium high meadows with a coverage above 90 % occur here. The predominant species are *Festuca rubra* L., *Holcus lanatus* L. and an inter-genus hybrid *Festulolium (Felina)*. Soil type is acidic Luvic Stagnosol on the gneiss diluvium. Agrochemical soil properties are presented in Table I.

Experimental design

I: *Agrochemical soil properties on locality Kameničky before establishment of field trial*

Soil	pH/ $CaCl_2$	Available nutrients (mg/kg)			
		P	K	Ca	Mg
loamy	4.43	55	85	1575	102

The trial plot was divided into two blocks. In on one of these blocks, dolomitic limestone in the dose of 1.8 t/ha was applied in October 2013. Within each block, variants with varied nitrogenous fertilizing were randomly placed. The variants were as follows: 1. control (untreated), 2. Urea, 3. Urea with inhibitor of urease, 4. Urea with inhibitor of nitrification. For variant 3, the fertilizer UREA Stabil (46 % N, NBPT – urease inhibitor N-(n-butyl) thiophosphoric acid triamide) was used, and for variant 4, the fertilizer ALZON 46 (46 % N, nitrification inhibitor 1H-1,2,4 triazole) was employed. The dose of nitrogen was 100 kg/ha and was applied once on March 26, 2014 and April 24, 2015. Each variant was repeated 6 times and each small plot was the size of 15 m² (1.5 × 10 m).

Cuts and analyses

The first cut was carried out on July 7, 2014, and June 6, 2015, the second cut on September 18, 2014 and September 16, 2015. The plots were harvested by a self-propelled mowing machine with an engagement of 1.25 m. The harvested area was 12.5 m² and the stubble height was 7 cm. All harvested biomass was weighed and the amount expressed by t/ha.

After the first cut, soil samples were taken in order to establish exchangeable soil acidity (pH/$CaCl_2$). The representative soil samples (from each replication) were collected at a depth of 20 cm.

Dry soil samples were sieved through a 2-mm mesh. Soil pH was determined in 0.01 mol/l $CaCl_2$ 1:5 w/v according to the methodology of the Central Institute for Supervising and Testing in Agriculture (Zbíral, 2002). Each sample was measured two times. The exchangeable soil acidity was measured using a pH meter MS 22 (Laboratory appliances Prague, Czech Republic).

Statistical analyses

Results are expressed as a mean ± standard deviation. The obtained results were further analyzed using the multi-factor analysis of variance with a subsequent verification based on the Tukey Test. The data were processed using the STATISTICA Cz 12 (StatSoft, Inc., USA).

RESULTS AND DISCUSSION

The established average values of soil pH are displayed in Tables II and III and the graphical comparison is presented in Figure 1. After application of dolomitic limestone in autumn 2013, a gradual increase of soil pH from 4.43 to 4.67 was found after the first cut in 2014, and to 4.81 in 2015. Increase of soil pH upon liming was reported also by Belesky *et al.* (1991) or Adams (1986). The annual average increase from 4.67 to 4.81 is conclusive although it has been presented that the effect of liming on soil pH is usually decectable as late as in the third and the following years (Kulhánek *et al.*, 2013).

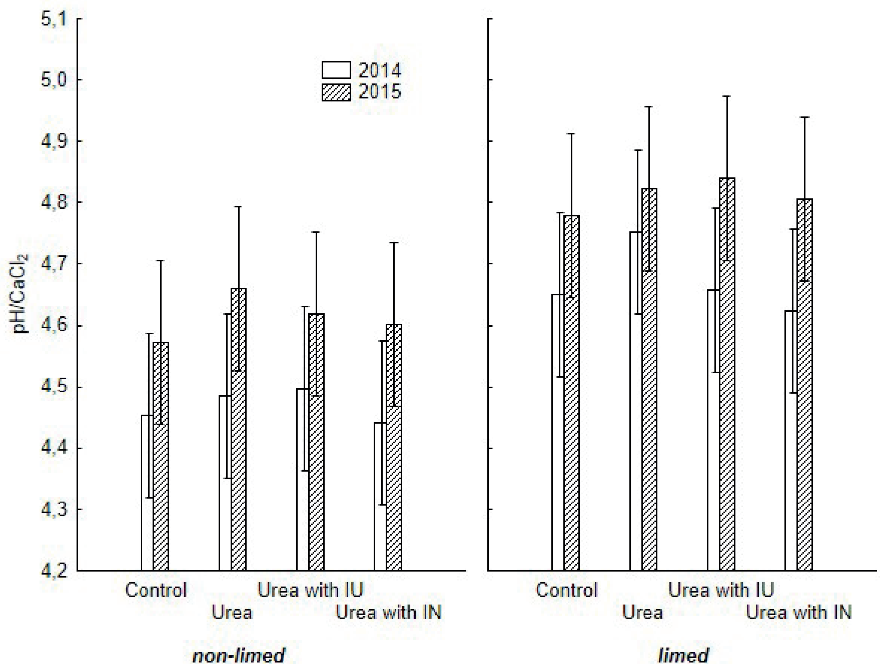
After liming, improved plant growth (Belesky *et al.*, 1991) and increase of forage yield (Haken, 1992; Poozesh *et al.*, 2010) are usually reported. On the

II: *Soil pH and dry forage yield after liming and nitrogen fertilization (mean ± standard deviation)*

	$pH/CaCl_2$	Dry forage yield (t/ha)	
		First cut	Total
2014	$4.57^{a} \pm 0.18$	$4.69^{a} \pm 0.99$	$6.43^{a} \pm 1.34$
2015	$4.71^{b} \pm 0.14$	$4.63^{a} \pm 1.20$	$6.44^{a} \pm 1.63$
control	$4.61^{a} \pm 0.14$	$3.94^{a} \pm 1.04$	$5.57^{a} \pm 1.42$
urea	$4.68^{a} \pm 0.23$	$5.00^{b} \pm 1.10$	$6.94^{b} \pm 1.55$
urea with IU	$4.65^{a} \pm 0.14$	$5.06^{b} \pm 0.89$	$6.88^{b} \pm 1.18$
urea with IN	$4.61^{a} \pm 0.15$	$4.64^{ab} \pm 1.03$	$6.36^{ab} \pm 1.43$
non-limed	$4.54^{a} \pm 0.12$	$5.06^{b} \pm 1.05$	$7.00^{b} \pm 1.45$
limed	$4.74^{b} \pm 0.14$	$4.26^{a} \pm 1.00$	$5.88^{a} \pm 1.32$

III: *Soil pH after application dolomitic limestone (mean ± standard deviation)*

		$pH/CaCl_2$
non-limed	2014	$4.47^{a} \pm 0.12$
	2015	$4.61^{b} \pm 0.09$
limed	2014	$4.67^{b} \pm 0.18$
	2015	$4.81^{c} \pm 0.08$



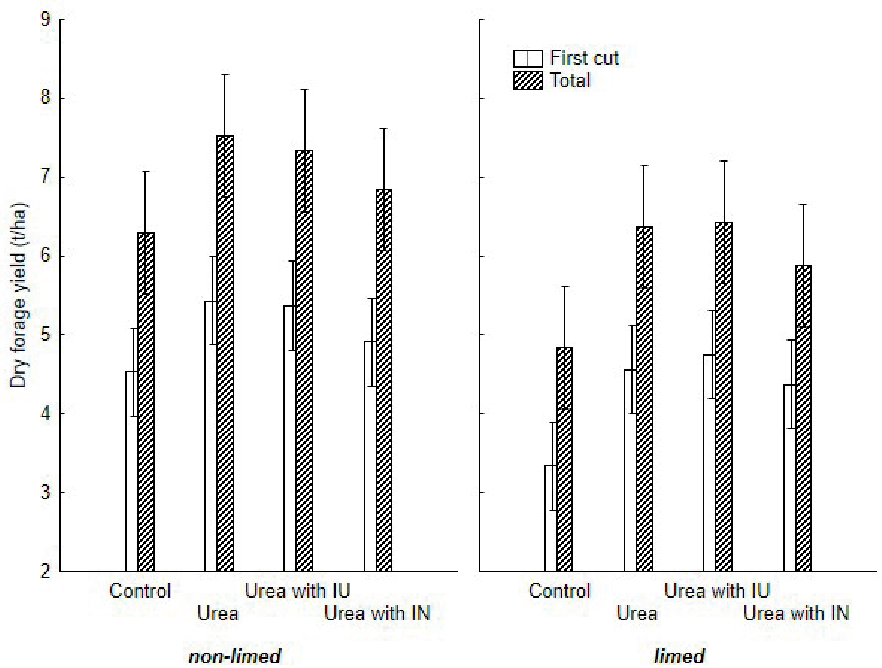
1: *Soil pH after application of dolomitic limestone and N fertilizers*

other hand, forage yields achieved on semi-natural grassland in Kameničky are conclusively lower after liming (see Tables II and IV, Figure 2). Liming of grasslands with semi-natural vegetation frequently on poor and acid soils did not always reflect in a higher forage yield. The cause of this inefficiency is the plant composition of the grassland. Thus, many grassland plants with relatively high production potential have adapted to acid soil conditions (Čop, 2014).

Positive effects of liming were observed on sown grasslands and, moreover, with perennial ryegrass (*Lolium perenne* L.) which is sensitive to Al toxicity (Wheeler *et al.*, 1992; Poozesh *et al.*, 2007). This grass species had only negligible share (%) in the semi-natural grassland of our experiment. On the contrary, on fertilized grasslands with a complex semi-natural flora, surface liming often has no effect on yield (Pinto *et al.*, 1995) or only a limited effect (Stevens and Laughlin, 1996; Poozesh *et al.*, 2010).

IV: *Dry forage yield after application of dolomitic limestone*

		Dry forage yield (t/ha)	
		First cut	**Total**
non-limed	2014	$5.05^{bc} \pm 1.00$	$6.94^{b} \pm 1.39$
	2015	$5.07^{c} \pm 1.12$	$7.05^{b} \pm 1.53$
limed	2014	$4.32^{ab} \pm 0.86$	$5.92^{a} \pm 1.10$
	2015	$4.19^{a} \pm 1.14$	$5.84^{a} \pm 1.53$



2: *Dry forage yield after liming and nitrogen fertilization*

Impact of fertilizing by urea and urea with inhibitors on dry forage yields is shown in Table II and Figure 2. Significant increase in dry forage yield as compared to the untreated variant was achieved after application of urea or urea with urease inhibitors. The impact of stabilized fertilizers on the yield was not proven.

According to Yadvinder-Singh and Beauchamp (1988), liming promotes urea hydrolysis which may encourage volatilization of ammonia in variants 2 and 4 and thus lower utilization of nitrogen from urea. Also Trenkel (2010) describes higher ammonia volatilization if fertilizers amended with a nitrification inhibitor are not incorporated into the soil immediately or soon after application. This corresponds with our finding that the variant of urea with nitrification inhibitor achieved the lowest yield out of the treated variants. Take Prasad and Power (1995) and Davies and Wiliams (1995) found zero or variable effect of nitrification inhibitors on nitrogen losses and the yield of grown crops. Ammonia losses by volatilization are connected with the higher value of soil pH. However, the soil on the experimental plot showed relatively low pH values, namely between 4.54 on the non-limed part and 4.74 on the limed one in 2015. Beyrouty *et al.* (1988) studied the impact of the initial soil pH values on the degree of urea hydrolysis inhibition in 4 different urease inhibitors. In all the monitored lengths of incubations, significant drop in the effect of urease inhibitors in case of a more acidic soil pH occurred. In the described trial, the values of the initial soil pH were 7.4 and 5.6, which is considerably higher than in our experiment.

CONCLUSION

The presented results make it obvious that liming had conclusively increased the exchangeable soil acidity (pH/$CaCl_2$) in the course of the two-year study. Fertilizing by stabilized urea significantly impacted the values of soil pH. Significant increase of dry forage yield as compared to the untreated variant was achieved after application of urea or urea with urease inhibitor. The increase of yield after application of urea with nitrification inhibitor was not statistically conclusive. The impact of urease inhibitor and nitrification inhibitor on the dry forage yield was not proven. In the limed variants, drop in the yield by 1.12 t/ha in both years was found. This may be connected to the disturbance of the production potential of the stable community of plant species that had been adapted to acidic localities.

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Contact information

Pavel Ryant: pavel.ryant@mendelu.cz