10.7251/AGSY1303119K

PHOSPHORUS AND POTASSIUM AVAILABILITY CHANGE BY LIMING OF ACID SOILS

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Abstract

Soil acidification results with the chemical changes in soil, especially with availability changes of P, K, Ca, Mg, essential and potentially toxic heavy metals. The aim of this paper was to determine the influence of acid soils liming to phosphorus and potassium availabilty change and to determine plant response. Liming and fertilization pot experiment of alfalfa cultivation on acid soils was sat up with two types of acid soils with different texture, Silt loam (SiL) and Silty clay loam (SiCL) in a year 2009 and 2010. Ten liming and fertilization treatments were applied in four repetitions. Soil was sampled and analysed after first and second year of investigation and plant material was sampled in three cuttings at the beginning of blooming stage in each year and analysed. Results showed significant increase of soil pH values impacted by liming treatments. Soil pH increment by liming significantly increased phosphorus availability from 1,8 till 4,9 mg/kg per t/ha $CaCO_3$ and potassium availability from 1.3 till 1.5 mg/kg per t/ha $CaCO_3$ in both soils. Mineral and organic fertilization resulted with the same trend and expectedly raised phosphorus and potassium availability in soil. Furthermore, liming as well as mineral and organic fertilizer rates impacted on phosphorus and potassium concentrations increment in alfalfa leaf and stalk. Concentration increment in leaf dry matter was increased by liming from 31.1% till 38.5% for phosphorus and 20,2 % till 35.8% for potassium. Significant increment of phosphorus and potassium concentration was recorded for alfalfa stalk as well. Therefore, liming significantly increased phosphorus and potassium availability in the soil and their transfer into aboveground plant organs.

Key words: acid soils, liming, soil availability, plant concentrations

Introduction

Soil acidification is a slow, continuous natural process resulting in acid soils being common in areas where soil development continued for long, geological periods of time and under climatic conditions which rainfall exceeds evapotranspiration (Rengel, 2002). Soil acidification process my be accelerated by intensive agricultural production with fertilization as one of the main factors of intensification. The process of soil acidifications is aided by water leaching base cations to lower horizons and acid soils are widespread in the eastern Croatia (Loncaric, 2006).

Soil reaction affects the soil chemical properties in wide range, especially soil nutrients mobility and plant availability. Furthermore, soil acidity and elemental toxicities or deficiencies associated with it, affects crops growth and restricts yields throught the world (Rengel et al., 2003). Acid soils are usually excessive in soluble Al and Mn and deficient in P, Ca Mg and Mo, that may cause their reduced uptake and lead to nutrient imbalances in plants (Clark and Baligar, 2000). Consequently, in conditions of excessive soil acidity, numerous negative effects are present like hydrogen ions toxicity, toxicity of aluminum and manganese ions, phosphorus and molybdenum deficiency, reduction of microbiological activity and increased heavy metals availability. These unfavourable chemical properties of acid soils represent one of the main factors limiting the field crops yield.

Therefore, liming is an effective ameliorative practice that may be integrated in the overall acid soil management program to attain and maintain a suitable pH range for near-optimal crop growth and yield potential (Viscarra Rossel and McBratney, 2000). Correcting soil pH by liming can influence plant nutrient availability and plant yield and quality. Thus the lime application is common practice in amelioration of acid soils in Croatia. However, increase of soil pH can also result with negative effects, such as reduction of manganese and micronutrients availability and increase of soil organic matter decomposition. Therefore, the aim of this paper was to determine the influence of acid soils liming to phosphorus and potassium availabilty change and to determine plant response.

Material and methods

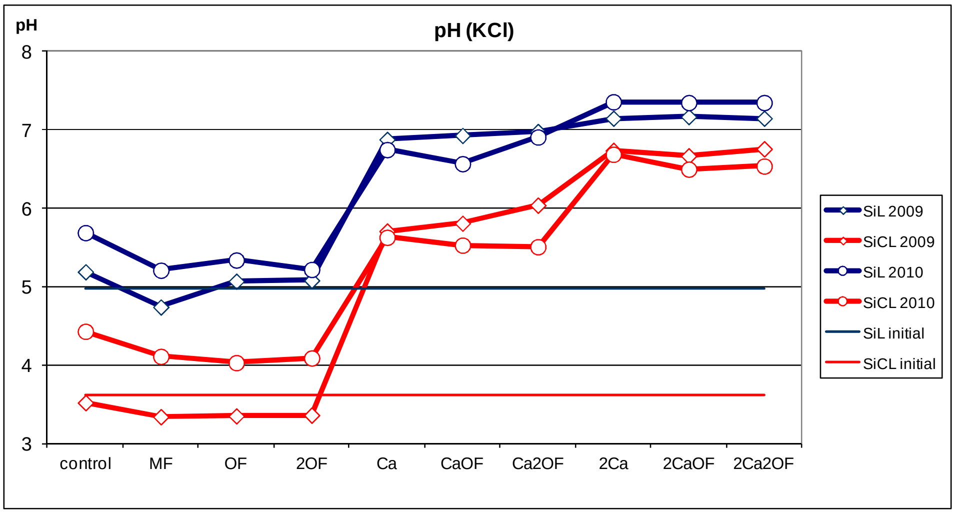
The pot experiment was conducted in field conditions, in eastern part of Croatia with two different acid soils in heavy and light textural class to investigate liming and organic fertilization effects on soil properties change as well as alfalfa mineral composition. Heavily acid silt loam soil (SiL) and extremely acid silty clay loam soil (SiCL) was set up in plastic pots of 20 L volume with 25 cm depth and 0.09 $m^2$of soil surface. Acid soils were treated with 10 liming and organic fertilization treatments in four repetitions using alfalfa as the indicator plant. Lime material was added in two rates: 7.5 and 15 t/ha of Mischkalk lime material (65% CaO, ENV = 82.5) as well as organic fertilization: 20 and 40 t/ha cattle manure and mineral fertilization 100:200:300 kg/ha N:P_2O_5:K_2O. Liming and fertilization treatments were control, mineral fertilization(MF), single (OF) and double organic fertilization (2 OF), single (Ca) and double liming (2 Ca), single liming and single organic fertilization (Ca OF), single liming and double organic fertilization (Ca 2 OF), double liming and single organic fertilization (2 Ca OF) and double liming and double organic fertilization (2 Ca 2 OF).

In order to collect soil data, soil samples were analysed before treatments and after first and second vegetation, in a year 2009 and 2010. During each year three cuttings of alfalfa were sampled and analysed to determine mineral composition and nutrient removal. Soil analyses included commonly used methods for soil fertility control in Croatia: pH (H_2O and M KCl, 1:5 v/v) (ISO, 1994), plant available phosphorus and potassium by ammonium-lactate extraction (Egner et al., 1960). Concentration of AL-P_2O_5 was measured by UV-spectrophotometer and concentration of AL-K_2O was determined by flame atomic absorption spectroscopy. Alfalfa leaf dry matter samples were wet dygested by mixture of sulphate acid and 4 % of perchloric acid and the K concentration was measured by atomic absorption spectrometer. The P leaf concentration was measured by UV-spectrophotometer. Data were statistically analyzed by ANOVA and treatment means were compared by LSD test at 0,05 probability level using Microsoft Excel and SAS 9.1 Software.

Results and discussion

Results showed significant increase of the soil pH values as well as AL-P_2O_5 and AL-K_2O soil concentrations impacted by liming treatments. Soil pH reaction was significantly influenced by liming as well as mineral and organic fertilization. Results showed significant increase of soil reaction from pH(KCl) 5.69 till 7.36 in SiL soil and from pH(KCl) 4.43 till 6.54 in SiCL soil (Graph 1). In average, single liming rate raised soil pH(KCl) value for 1.53 pH units and double liming rate raised soil pH(KCl) for 2.36 pH units. In the opposite, mineral and organic fertilization decreased soil pH for average 0.4 pH units. These results were expected since rates of applied mischkalk as liming material (CCE 116.04% and ENV

82.56%) was equal to doses of 8.7 and 17.4 t/ha of pure $CaCO_3$. Mesić et al. (2003) raised soil pH from initial pH 3.8 till pH 5.31 and till pH 5.52 by application of 10 t/ha and 20 t/ha $CaCO_3$ at the end of the first year of experiment. Rastija et al. (2008) recorded soil pH increase for 1.2 pH units as a result of application of 10 t/ha of Carbocalk (ENV 69%) in the first year of experiment.



Graph 1. Dynamics of soil pH change in 2009 and 2010.

In SiL soil initial AL-P_2O_5 concentration was 172.4 mg/kg and considerably lower, 102.2 mg/kg in SiCL soil. Mineral fertilization expeditely increased AL-P_2O_5 concentration compared to control in both years, but without statistical significance. Double level of organic fertilization significantly increased phosphorus availability. The single liming level application significantly increased phosphorus availability in both years compared to control and in second year of investigation compared to mineral fertilization treatment. Double liming level impacted on additional and statistically significant AL-P_2O_5 increment compared to single liming level on both soils, but only in a year 2010 (Table 1).

Table 1. Impact of liming and fertilization on AL-P_2O_5 (mg/kg) in 2009 and 2010.

	AL-P_2O_5 mg/kg – 2009.			AL-P_2O_5 mg/kg – 2010.		
treatments	SiL	SiCL	average	SiL	SiCL	average
control	179.0 c	100.0 f	139.50 G	135.17 g	92.67 f	113.92 H
MF	194.7 bc	122.0 ef	158.38 GF	148.50 fg	103.00 ef	125.75 G
OF	200.2 bc	129.0 def	164.63 EF	152.80 ef	107.33 def	129.92 FG
2 OF	244.0 a	149.75 cde	196.88 CD	165.00 e	114.67 de	139.83 F
Ca	231.5 ab	138.33 cde	184.92 DE	190.82 d	118.33 d	154.58 E
Ca OF	248.5 a	170.25 bc	209.38 BCD	216.50 bc	158.33 b	187.42 C
Ca 2 OF	254.3 a	166.25 bcd	210.29 BC	222.50 bc	160.33 b	191.42 BC
2 Ca	234.5 a	157.33 cde	195.92 CD	214.50 c	136.00 c	175.25 D
2 Ca OF	252.7 a	201.50 ab	227.13 AB	231.32 ab	167.33 ab	199.33 B
2 Ca 2 OF	266.5 a	209.50 a	238.00 A	245.50 a	179.00 a	212.25 A
average	230.61 A	154.39 B		192.23 A	133.70 B	

The single and double liming doses increased average AL-P_2O_5 soil concentrations from 1.8 mg/kg P_2O_5 till 4,9 mg/kg P_2O_5 per every t/ha of applied $CaCO_3$. According to the results, it is possible to determine the regularity of plant available phosphorus increase with soil pH increase or with excessive soil acidity neutralization by liming. Mineral and organic fertilization resulted with the same trend and expectedly raised phosphorus availability in the soil. Haynes (1982) reported that moderately increment of soil pH by liming impacts on phosphorus availability increment in soil, while too high liming doses could result with phosphorus availability decrement in soil.

Table 2. Impact of liming and fertilization on AL-K_2O (mg/kg) in 2009 and 2010.

	AL-K_2O mg/kg – 2009.			AL-K_2O mg/kg – 2010.		
treatments	SiL	SiCL	average	SiL	SiCL	average
control	80.95 d	130.37 c	105.66 D	60.40 d	114.07 f	87.23 F
MF	96.08 bcd	153.45 b	124.76 C	79.60 c	141.30 d	110.45 D
OF	90.68 cd	157.57 b	124.12 C	78.35 c	121.80 f	110.07 E
2 OF	102.83 abc	163.92 ab	133.37 BC	80.37 c	130.50 e	105.44 DE
Ca	109.43 abc	160.37 ab	134.90 BC	89.72 abc	150.70 c	120.21 C
Ca OF	110.63 abc	167.82 ab	139.22 AB	91.12 abc	152.95 bc	112.04 BC
Ca 2 OF	103.63 abc	161.95 ab	132.79 BC	87.70 bc	131.53 e	109.62 D
2 Ca	112.48 ab	168.22 ab	140.35 AB	97.20 ab	158.05 abc	127.62 ABC
2 Ca OF	114.40 ab	170.57 ab	142.49 AB	100.95 ab	160.37 ab	130.66 AB
2 Ca 2 OF	120.23 a	175.52 a	147.87 A	103.22 a	164.70 a	133.96 A
average	104.13 B	160.98 A		86.86 B	142.60 A	

Initial potassium availabilty (AL-K_2O) in SiL soil was 79.0 mg/kg and in SiCL soil was 124.0 mg/kg. Liming and mineral as well as organic fertilization significantly impacted on potassium availability change in soil. In SiL soil, all liming treatments significantly increased potassium availability compared to control in a year 2009 In the same soil, in a year 2010 potassium availability was lower for all treatments, but the differences between liming and control treatment became even more expressed. In the SiCL soil, double liming level with double organic fertilization resulted with significantly the highest potassium concentration compared to control in a first year of investigation. In a year 2010 this difference became more expressed, although all the concentrations of available potassium were lover (Table 2). Treatments of single liming doses minimally increased soil AL-K_2O concentrations for 1.38 mg/kg K_2O, while application of double liming doses increased potassium availability for 1.46 mg/kg K_2O per every t/ha of applied $CaCO_3$. Mineral and organic fertilization showed identical trend and expectedly raised potassium availability in soil.

Furthermore, liming as well as mineral and organic fertilizer rates impacted on phosphorus and potassium concentrations increment in alfalfa leaf. Significant increment of phosphorus and potassium concentration was recorded for alfalfa stalk as well. Therefore, liming significantly increased phosphorus and potassium availability in the soil and their transfer into aboveground plant organs.

Table 3. Impact of liming and fertilization on P (%) leaf concentration in 2009 and 2010.

	P % leaf – 2009.			P % leaf – 2010.		
treatments	SiL	SiCL	average	SiL	SiCL	average
control	0.270 d	0.257 e	0.266 E	0.232 c	0.207 d	0.219 E
MF	0.300 c	0.290 cd	0.296 D	0.267 bc	0.257 c	0.262 D
OF	0.300 c	0.287d	0.296 D	0.270 bc	0.260 c	0.265 D
2 OF	0.310 bc	0.301 bcd	0.307 BCD	0.282 abc	0.273 bc	0.278 CD
Ca	0.310 bc	0.300 bcd	0.307 BCD	0.300 ab	0.273 bc	0.287 BCD
Ca OF	0.310 bc	0.303 bc	0.309 BC	0.307 ab	0.293 abc	0.300 ABC
Ca 2 OF	0.300 c	0.293 bcd	0.299 CD	0.310 ab	0.303 ab	0.307 ABC
2 Ca	0.330 ab	0.307 b	0.317 B	0.312 ab	0.293 abc	0.303 ABC
2 Ca OF	0.330 ab	0.305 bc	0.316 B	0.317 ab	0.317 a	0.317 AB
2 Ca 2 OF	0.340 a	0.325 a	0.331 A	0.330 a	0.327 a	0.328 A
average	0.310 A	0.300 B		0.293 A	0.280 A	

As it was expected, mineral and organic fertilization significantly impacted on phosphorus leaf concentration increment compared to control treatment on the both soils in 2009. and 2010. Significance of a single liming level application on phosphorus leaf concentration was determined in comparison with control treatment in the both investigation years and on both soils. Increment of phosphorus leaf concentration under impact of a double liming level was not statistically significant compared to single liming level impact on both soils and in both years (Table 3).

Bergman (1992) specified optimal nutrient status in aboveground plant mass of alfalfa at the beginning of flowering stage. Values are expressed on the basis of dry matter mass, and range from 0.30 – 0.60% P and 2.50 – 3.80% K. Determined concentrations of alfalfa leaf dry matter mineral composition on conducted experiment were matching the mentioned values, where liming doses resulted with expressed effect of phosphorus concentration increment in alfalfa leaf dry matter as a result of soil pH increase by liming. By alfalfa growing on two acid soils, phosphorus leaf concentration was increased from 15.4% till 31.1% with single liming treatments and from 19.2% till 38.3% with double liming treatments.

Table 4. Impact of liming and fertilization on K (%) leaf concentration in 2009 and 2010.

	K % leaf – 2009.			K % leaf – 2010.		
treatments	SiL	SiCL	average	SiL	SiCL	average
control	1.85 d	1.63 g	1.74 F	1.13 f	1.05 e	1.09 G
MF	2.03 cd	1.96 f	2.00 E	1.28 e	1.18 d	1.23 F
OF	2.05 d	2.05 ef	2.05 DE	1.30 de	1.17 d	1.23 F
2 OF	2.12 bc	2.11 de	2.12 CD	1.34 cde	1.24 cd	1.29 E
Ca	2.16 bc	2.14 cd	2.15 C	1.35 cde	1.26 bcd	1.31 DE
Ca OF	2.20 abc	2.20 bc	2.20 BC	1.39 bcde	1.28 bcd	1.33 CD
Ca 2 OF	2.21 abc	2.17 cd	2.19 BC	1.41 abcd	1.34 abc	1.37 C
2 Ca	2.27 ab	2.24 abc	2.25 AB	1.43 abc	1.33 bc	1.38 BC
2 Ca OF	2.28 ab	2.27 ab	2.28 AB	1.47 ab	1.37 ab	1.42 B
2 Ca 2 OF	2.35 a	2.31 a	2.33 A	1.51 a	1.45 a	1.48 A
average	2.15 A	2.11 A		1.36 A	1.27 B	

Expectedly, mineral and organic fertilization significantly increased potassium concentration in alfalfa leaf dry matter compared to control treatment on SiCL soil in 2009 and on both soils in 2010. Application of single liming doses resulted with significant impact on

potassium leaf concentration increment compared to control treatment on both soils in 2009 and 2010. Double liming level impacted on more intensive potassium leaf concentration increment in comparison with control treatment, but on both investigated soils in 2009 and 2010 potassium leaf concentration increment was not statistically significant compared to increment accomplished by single liming doses (Table 4).
In the second year of experiment, significantly lower potassium leaf concentrations were recorded in comparison with the first year of experiment. Application of single liming doses increased average potassium leaf concentrations from 20.2% till 23.6% and double liming doses increased average concentrations from 22.6% till 26.6%.

Conclusions

Liming significantly raised soil pH in both soils and the final effect of liming on soil pH was depending on initial soil pH. In the opposite, mineral and organic fertilization impacted on soil acidity increase and partially neutralised liming effect on soil pH. Application of liming material increased phosphorus availability in soil and availability increment was higher in soils with higher initial phosphorus availability. Organic and mineral fertilization expectedly impacted on soil phosphorus availability increase. Liming also impacted on potassium availability increase in soil. Organic fertilization did not have significant impact on potassium availability change. Increment of liming material doses and organic fertilization resulted with phosphorus and potassium concentrations increase in alfalfa leaf dry matter and stalk as well.

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