

RESPONSE OF BARLEY TO AMELIORATIVE FERTILIZATION

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Abstract

Winter barley were grown under field conditions during the 2004 growing season and residual influences of liming with carbocalk (waste of sugar factory) and phosphorus fertilization with MAP (monoammonium phosphate) were tested. By using the lowest lime rate (15 t ha⁻¹) barley yield was increased by 30%. Overliming (90 t ha⁻¹) resulted by significant yield decreases in comparison with application 15 and 30 t of lime. Using of 45 and more lime per hectare protein contents was significantly increased. In general, liming considerably influenced on grain composition of barley. For example, by application of the lowest lime rate, grain P, K, Ca, Mg, Fe, Cu, Mo and Na significantly increased in comparison with the control. Differences of grain composition among lime treatments were mainly non-significant. Ameliorative P fertilization significantly increased grain yields of barley up to 25% in comparison with the control. In general, grain composition differences among applied treatments were mainly non-significant because significant differences only for P and Mn (increasing trend due to P application) as well as for Zn and Mo (decreasing trend) were found.

Key words: liming, phosphorus fertilization, barley, grain yield, grain composition

Introduction

Soil acidity is certainly one of the most damaging soil conditions affecting the growth of most crops. Plant growth-limiting factors in acid soils include deficiencies (N, P, Ca, Mg, Mo, Zn) and toxicities (Al, Mn, Fe, H) elements. The efficiency of added fertilizers (N, P, K) is very low in acid soils. Naturally occurring minerals which are commonly used to raise soil pH are limestone and dolomite. Also, waste products from manufacturing processes using limestone or similar raw materials can be used for neutralising soil acidity (for example, waste from sugar factories). Soil acidity is in many cases limiting factor of the arable crops yield in Croatia (Grgic, 1991; Kovacevic et al. 1993; Antunovic et al., 2001). Also, low levels of plant available phosphorus (P) alone or in combination with potassium (K) are limiting factor of some field crops yields, especially maize (Kovacevic and Vukadinovic, 1992, Kovacevic, 1993). Aim of this study was testing of barley response to liming and P fertilization.

Material and methods

The field experiments

Field experiment with increased rates of carbocalk (waste of Osijek Sugar Factory, 39% CaO) was conducted in term November 8, 2000 on albeluvisol (Ap-E/E-Btg-C profile: pH in KCl in 0-30 cm of depth = 3.89) of Kutjevo Agricultural Holding (Pozega-Slavonian County). Liming treatments were as follows (t ha⁻¹): 0, 15, 30, 45, 60 and 90. The field trial was conducted in four replicates (experimental plot of fertilization 64.3m²). Crop rotation for the 2001-2004 period on the experimental field was as follows: maize (2001) – maize (2002) –

sunflower (2003) – winter barley (2004). Yields of these crops and soil properties were elaborated in the study Kovacevic et al. (2006).

The field experiment with three rates of P fertilization was conducted in spring 2003 on Okucani hydromorphic soil (pH in KCl = 5.63; AL-soluble P_2O_5 = 7.2 mg 100 g⁻¹). P was added as monoammonium phosphate (MAP: 52% P_2O_5 and 12% N). N was equalized for all treatments by addition of correspondingly rates of CAN (calcium ammonium nitrate: 27% N). Maize was grown for the 2003 growing season. In the next year we tested residual influences of P (ordinary fertilization of the experiment) on winter barley (cultivar Lord) status.

Chemical and statistical analyses

The total amounts individual elements in the barley grain were determined using ICP technique after their microwave digestion by concentrated $HNO_3+H_2O_2$. Plant analyses were made by Jobin-Yvon Ultrace 238 ICP-OES spectrometer in the laboratory of the Research Institute for Soil Science and Agricultural Chemistry Budapest, Hungary. Statistical calculations of the data (analysis of variance) were made according Mead et al. (1996).

Weather characteristics

In general, the 2004 growing season was less favorable for winter barley because precipitation was considerable higher in comparison with the long-term means (Table 1). Under these conditions considerable reduction of plan density was found in the Okucani experiment because of lowland positioned the experimental plot.

Table 1. Weather characteristics (Slav. Brod* Weather Bureau)

	Precipitation (mm) and mean air-temperatures (°C)									Total	Mean
	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.	May	June		
The growing season 2003/2004											
mm	167	56	27	81	56	39	170	74	86	756	
°C	9.5	7.7	1.3	-1.0	2.4	6.0	12.2	14.8	15.7		7.6
The long-term means (20-years: 1971-1990)											
mm	61	59	46	44	39	46	56	74	82	467	
°C	10.3	4.5	1.2	-0.6	1.8	6.4	10.7	15.9	18.8		7.7

* 20 km (SE-direction) and 60 km (toward E) air-distanced from Pleternica and Okucani, respectively.

Results and discussion

Liming with carbokalk resulted with considerable increases of winter barley. For example, by using the lowest lime rate barley yield was increased by 30%. Overliming (90 t ha⁻¹) resulted by significant yield decreases in comparison with application 15 and 30 t of lime. Using of 45 and more lime per hectare protein contents was significantly increased. However, starch contents were similar and independent on liming treatments (Table 2). As affected by liming maize yields were increased up to 50% and 36%, for the 2001 and 2002 growing season, respectively. In both years using of 60 t/ha was the most effective treatment. Sunflower (the 2003 growing season) also responded with yield increases but optimal level was treatment 45 t of lime ha⁻¹ (Kovacevic et al. 2006). In general, liming considerably influenced on grain composition of barley. For example, by application of the lowest lime rate, grain P, K, Ca, Mg, Fe, Cu, Mo and Na significantly increased in comparison with the control. Differences of grain composition among lime treatments were mainly non-significant (Table 2).

Table 2.: Response of winter barley to liming (the 2004 growing season)

Property	Liming (carbocalk t ha ⁻¹ : November 8, 2000)						LSD	
	0	15	30	45	60	90	5%	1%
The fourth year of testing (2004): winter barley (cultivar Lord)								
Grain yield (t ha ⁻¹)	5.79	7.50	7.29	6.82	7.05	6.51	0.76	1.06
Realized density (%)*	68.0	95.8	97.5	95.5	89.2	90.8	10.2	14.0
Protein (%)	9.08	9.80	10.14	11.08	10.93	12.15	1.05	1.45
Starch (%)	62.81	63.00	62.96	62.64	62.27	61.92	n.s.	
Grain composition (mg kg ⁻¹ on dry matter** basis)*	Phosphorus (P)	3499	4210	4465	4658	4571	352	488
	Potassium (K)	4401	5463	5533	5444	5633	351	487
	Calcium (Ca)	283	324	327	357	371	44	61
	Magnesium (Mg)	1057	1176	1240	1237	1205	83	115
	Sulphur (S)	1013	1038	1044	1079	1180	n.s.	
	Zinc (Zn)	17.7	18.4	21.1	22.4	21.4	n.s.	
	Manganese (Mn)	21.7	21.2	19.4	19.2	20.0	n.s.	
	Iron (Fe)	22.6	27.0	28.8	32.6	32.0	4.4	6.1
	Copper (Cu)	2.75	4.39	4.76	4.88	4.78	0.99	1.36
	Molybden (Mo)	0.06	0.21	0.25	0.32	0.34	0.07	0.09
	Strontium (Sr)	0.92	0.87	0.86	0.87	0.82	n.s.	
	Sodium (Na)	5.24	9.13	9.42	7.88	8.44	1.80	2.49
	Barium (Ba)	18.2	19.9	17.3	17.9	17.6	7.3	n.s.
** <u>under detectable limit</u> (DL): cadmium (0.02), arsenic (0.40), mercury (0.12), selenium (0.004), cobalt (0.04), lead (0.30)								

* 100% = 600 ears per square meter

Table 3.: Residual influences of phosphorus fertilization on winter barley properties

	P ₂ O ₅ (kg ha ⁻¹) in the spring 2003				LSD						
	125	625	1125	1625	5%	1%					
The second year of testing (2004): winter barley											
Yield (t ha ⁻¹)	3.31	3.26	3.96	4.15	0.55	0.93					
Protein (%)	12.9	12.8	13.2	13.4	n.s.						
Starch (%)	60.7	60.5	60.4	60.7	n.s.						
Realized density (100 % = 600 ears m ²)	50.4	46.6	54.0	56.9							
Grain composition of barley (mg kg ⁻¹ on dry matter basis; n.s. = non-significant)*											
	P ₂ O ₅ (kg ha ⁻¹)				LSD		P ₂ O ₅ (kg ha ⁻¹)				LSD
	125	625	1125	1625	5%		125	625	1125	1625	5%
P	4436	4858	5077	4844	304	Zn	36.0	27.8	29.8	27.5	5.0
K	482	4977	5124	5026	n.s.	Mn	13.2	14.7	16.5	17.3	2.3
Ca	375	414	408	404	n.s.	Fe	33.1	35.8	34.0	34.6	n.s.
Mg	1281	1291	1304	1255	n.s.	Cu	6.15	6.05	5.44	5.03	n.s.
S	1335	1341	1383	1380	n.s.	Mo	0.78	0.76	0.69	0.59	0.11
Cr	0.24	0.17	0.2	0.16	n.s.	* <u>under detectable limit</u> (DL): arsen (0.40), mercury (0.12), selenium (0.004), cobalt (0.04), lead (0.30), nickel (0.76), boron (0.05), aluminium (1.3)					
Sr	1.79	1.85	1.86	1.84	n.s.						
Cd	0.05	0.03	0.03	0.04	n.s.						
Ba	2.25	2.36	2.73	2.26	n.s.						
Na	16.9	17.0	14.0	12.4	n.s.						

Ameliorative P fertilization significantly increased grain yields of barley up to 25% in comparison with the control, while protein and starch contents were independent on the fertilization (Table 3). In general, grain composition differences among applied treatments were mainly non-significant because significant differences only for P and Mn (increasing trend due to P application) as well as for Zn and Mo (decreasing trend) were found (Table 3). Influences of P fertilization on Zn, Mn and Mo status are mainly in accordance with the literature data (Blasl and Mayr 1978; Bergmann, 1992; Mengel and Kirkby, 2001). In both experiments, low levels of harmful elements in barley were found (Bergmann, 1992; Mengel and Kirkby, 2001) and their levels were mainly under detectable limits of the method. Kovacevic et al. (2002) tested impacts of P and K fertilization up to 1500 kg P₂O₅ and/or K₂O ha⁻¹ (the soil I and the soil II) on the harmful elements status in maize. In general, the concentrations of Sr, Cd, and Ni in the ear leaves at silking stage were significantly higher under conditions of the soil I (22.5 ppm Sr, 0.361 ppm Cd and 0.284 ppm Ni, compared to 16.8 ppm Sr, 0.217 ppm Cd and 0.154 ppm Ni, respectively). Applied fertilization had not effects on Pb and Ni concentrations in maize leaves. However, using of ameliorative quantity of P fertilizer resulted by increase of Sr and Cr, while Cd concentrations in maize leaves increased as affected by both MAP and KCl fertilization. However, by this study was found non-toxic levels of the elements.

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