# RESPONSE OF MAIZE AND WINTER WHEAT TO LIMING WITH HYDRATIZED LIME

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**Abstract:** The field experiment with an application of white hydratized lime was started in November 13, 2007 on Podgorac acid soil. The experiment was set up on three plots with 630 $m^2$ each for lime rates 0 (the control), 5 and 20 t $ha^{-1}$, respectively. The plots were divided in four sub-plots per replicates. The crop sequence maize (2008-2009-2010) - winter wheat (2011) was used. Maize responded to liming by yield increases up to 32%, 51% and 18%, for 2008, 2009 and 2010, respectively. By applications two rates of lime yield increases of wheat were for 43% (5 t $ha^{-1}$) and 64% (20 t $ha^{-1}$). As affected by liming significant differences compared to the control for phosphorus (+47%), magnesium (+23%), manganese (-27%), zinc (-20%) and cadmium status (-12%) in maize grain were found. However, effects of liming on grain status of wheat was considerably lower because of differences only for P (+9%), Mg (+21%) and Sr (-50%).

**Keywords:** maize, winter wheat, liming, yield, grain nutritional status

## Introduction

Acid soils are widespread in Croatia and cover a large area of arable land (Loncaric et al., 2005). Amelioration of acid soil by different liming materials can raise soil pH, benefiting soil properties and plant growth. Liming experiments under conditions of the eastern Croatia and the northern Bosnia showed mainly positive effects on soil fertility.
The grain yield of maize was influenced by liming by dolomite from 15 to 44% (Kovacevic and Rastija, 2010), winter barley to 33% (Rastija et al., 2010), maize for 48% (Markovic et al., 2008). Also, liming with calcite (Andric et al., 2012) resulted with yield increase for 35% (maize) and for 44% (soybean) and by non-significant differences of maize yield (Kovacevic et al., 2011). By application the hydrated lime maize yields were increased up to 24% (Kovacevic et al., 2010). Aim of this study was testing of hydratized lime effects on yields of maize and winter wheat.

## Material and methods

*The field experiment, chemical and statistical analysis*
The field experiment with an application of white hydratized lime was started on November 13, 2007 on the Anagalis d.o.o.Stipanovci (Osijek-Barannya County) soil. The experiment was set up on three plots with 630 $m^2$ each for lime rates 0, 5 and 20 t $ha^{-1}$, respectively. Uniform distribution of the lime was made manually. At early growth stage, each plot was divided into four sub-plots (replicates). The crop sequence maize (2008 -2009 - 2010; the hybrid OsSK499) - winter wheat (2011: cultivar Golubica) was used. Fertilization of the trial for maize was (kg $ha^{-1}$) 130 N + 70 $P_2O_5$ + 90 $K_2O$. NPK 7:20:30 and urea (46% N) were ploughed in autumn, NPK 15:15:15 was added in bands at sowing term and CAN (calcium ammonium nitrate 27% N) was added at 5-6 leaves stages by cultivation.

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Maize was sown at the second half of April by pneumatic sowing machine (distance in row 21 cm and interrow spacing 70 cm = theoretical crop density 68027 plants $ha^{-1}$). Maize was harvested manually (four internal rows from each sub-plot) in the second half of October. Mass of cob was weighed by precise Kern electronic balance. Ten cobs from each treatment were used for determination of grain moisture and grain share in cob. Grain moisture was determined by electronic grain moisture instrument (WILE-55, Agroelectronics, Finland). Yields were calculated on 14% grain moisture basis.
Grain nutritional status was determined using ICP after their microwave digestion by conc. $HNO_3$+$H_2O_2$. Plant analyses were made by Jobin-Yvon Ultrace 238 ICP-OES spectrometer in the laboratory of the RISSAC, Budapest. The data were statistically analyzed by ANOVA and treatment means were compared using t-test and LSD at 0.05 and 0.01 probability levels.

*Weather and soil characteristics*
The growing seasons 2008 and 2010 were mainly favorable for maize growing of adequate precipitation, especially in July and August. However, the growing season 2009 was unfavorable for maize: in two-months period April-May 2009 precipitation were inadequate, only 40% of long-term average. Additional aggravating circumstance was moderate soil reserves of water in the sowing term. Also, drought in July (about 20% precipitation compared to the long-term mean) was accompanied with monthly air-temperature for 2.2 $^{o}$C higher in comparison to the usual value (*Table 1.*). In general, the higher yields of maize were found in the growing seasons characterizing the higher precipitation and the lower temperatures, especially in July and August (Shaw, 1988; Kovacevic et al., 2007, 2009; Maklenovic et al., 2009; Markulj et al., 2010).

*Table 1.* Precipitation and mean air-temperatures (Osijek Weather Bureau)

| Period | Osijek Weather Bureau (LTM = long-term averages 1961-1990) | | | | | | | April - Sept. | |
|---|---|---|---|---|---|---|---|---|---|
| | Jan.-March | April | May | June | July | Aug. | Sept. | Total | Mean |
| | Precipitation (mm) | | | | | | | mm | $^{o}$C |
| 2008 | 123 | 50 | 67 | 76 | 79 | 46 | 86 | 404 | |
| 2009 | 115 | 19 | 39 | 63 | 14 | 61 | 10 | 206 | |
| 2010 | 165 | 71 | 121 | 234 | 32 | 111 | 108 | 677 | |
| LTM | 132 | 87 | 58 | 88 | 65 | 59 | 45 | 402 | |
| | Mean air-temperature ($^{o}$C) | | | | | | | | |
| 2008 | 4.6 | 12.5 | 18.1 | 21.5 | 21.8 | 21.8 | 15.7 | | 18.6 |
| 2009 | 2.7 | 14.6 | 18.3 | 19.2 | 23.2 | 22.9 | 19.1 | | 19.6 |
| 2010 | 2.5 | 12.4 | 16.5 | 20.4 | 23.1 | 21.7 | 15.6 | | 18.3 |
| LTM | 2.2 | 12.7 | 16.5 | 19.5 | 21.0 | 20.3 | 16.6 | | 17.8 |

*Table 2.* Precipitation and mean air-temperatures (Osijek Weather Bureau)

| | Osijek Weather Bureau: precipitation (mm) and mean-air-temperature (°C) | | | | | | | | | Σ | X |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct. | Nov. | Dec. | Jan. | Feb. | March | Apr. | May | June | | |
| | The 2010/2011 growing season | | | | | | | | | | |
| mm | 67 | 56 | 73 | 24 | 18 | 37 | 20 | 81 | 50 | 426 | |
| °C | 9.1 | 8.9 | 0.3 | 1.1 | 0.7 | 6.4 | 13.2 | 16.7 | 20.8 | | 8.6 |
| | Long-term (30-y) averages (1961-1990) | | | | | | | | | | |
| mm | 41 | 57 | 52 | 47 | 40 | 45 | 54 | 58 | 88 | 492 | |
| °C | 11.2 | 5.4 | 0.9 | -1.2 | 1.6 | 6.1 | 11.3 | 16.5 | 19.5 | | 7.9 |

The growing season 2010/2011 was favorable for wheat growing. Precipitation in October-June period was for 13% lower while air-temperature was for 1.7 °C higher than usual. Winter was mild (*Table 2.*). Under conditions of Croatia moderate and good distributed precipitation as well as mild winter is more favorable for wheat (Josipovic et al., 2005; Marijanovic et al., 2010). Drought and high air-temperature stress frequently limiting wheat yield under semiarid climate in Hungary (Pepo and Kovacevic, 2011).

## Results and discussion

Maize responded to liming by yield increases up to 32%, 51% and 18%, for 2008, 2009 and 2010, respectively. In the first year of testing, by application of the lower lime rate yield was in level of the control, while in the third year of testing between two lime rates yield difference was non-significant. Only in the second year of testing significant differences of yield among all treatments were found as follows: yield increases for 33% and 50% by applications of lime in amounts 5 and 20 t ha$^{-1}$, respectively (*Table 3.*). Plant density realization in 2009 was for about 20% lower in comparison with planned plant density because of unfavorable weather conditions in emergence stage (*Table 1.*). Gran moisture at harvesting was independent on liming.

*Table 3.* Impacts of liming on grain yield, plant density realization and grain moisture

| Lime t ha$^{-1}$ | The Anagalis trial: grain yield, plant density realization (PDR) in % of planned plant density (PPD: 100% = 68027 plants ha$^{-1}$ ) and grain moisture at harvesting (GM) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2008 (maize) | | | 2009 (maize) | | | 2010 (maize) | | | 2011 (wheat) | |
| | Yield | Percent | | Yield | Percent | | Yield | Percent | | Yield | Ears |
| | t ha$^{-1}$ | PDR | GM | t ha$^{-1}$ | PDR | GM | t ha$^{-1}$ | PDR | GM | t ha$^{-1}$ | per m$^2$ |
| 0 | 9.10 | 88.6 | 22.9 | 6.14 | 80.6 | 20.7 | 8.33 | 85.5 | 27.7 | 4.29 | 378 |
| 5 | 9.38 | 90.1 | 23.0 | 8.19 | 80.9 | 19.7 | 9.86 | 90.5 | 27.6 | 6.15 | 432 |
| 20 | 12.02 | 95.5 | 23.1 | 9.25 | 79.5 | 20.9 | 9.59 | 89.0 | 29.0 | 7.04 | 478 |
| | Statistics (LSD ) | | | Statistics (LSD ) | | | Statistics (LSD ) | | | Statistics (LSD) | |
| P 5% | 1.33 | | ns | 0.61 | | ns | 0.73 | | ns | 0.65 | 43 |
| P 1% | 2.20 | | | 0.92 | | | 1.01 | | | 0.84 | ns |
| Mean | 10.17 | 91.4 | 23.0 | 7.86 | 80.3 | 20.4 | 9.26 | 88.3 | 28.1 | 5.83 | 429 |

*Table 4.* Impacts of liming on grain composition of maize and wheat

| Lime t ha$^{-1}$ | Grain composition (mg kg$^{-1}$ on dry matter basis) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | P | K | Mg | Fe | Mn | Zn | Cu | B | Cd | Sr |
| | Maize (hybrid *OsSK499*) grain (the growing season 2008) | | | | | | | | | |
| 0 | 2315 | 3506 | 916 | 41.9 | 63.8 | 37.4 | 3.65 | 0.74 | 0.117 | 0.73 |
| 5 | 2849 | 3706 | 1012 | 38.4 | 53.5 | 35.3 | 4.22 | 0.71 | 0.121 | 0.63 |
| 20 | 3397 | 3718 | 1130 | 38.6 | 46.4 | 30.1 | 4.48 | 0.69 | 0.103 | 0.66 |
| P 5% | 286 | ns | 91 | ns | 11.3 | 4.2 | ns | ns | 0.007 | ns |
| P 1% | 475 | | 151 | | ns | ns | | | 0.012 | |
| Mean | 2854 | 3643 | 1019 | 39.6 | 54.6 | 34.2 | 4.11 | 0.71 | 0.114 | 0.67 |
| | Winter wheat (cultivar *Golubica*) grain (the growing season 2010/2011) | | | | | | | | | |
| 0 | 2860 | 2980 | 757 | 22.6 | 5.07 | 26.0 | 1.94 | 2.01 | 0.031 | 0.26 |
| 5 | 2820 | 3180 | 767 | 22.6 | 4.77 | 27.7 | 1.86 | 2.01 | 0.028 | 0.21 |
| 20 | 3130 | 3070 | 917 | 25.7 | 5.27 | 28.0 | 1.93 | 1.87 | 0.031 | 0.13 |
| P 5% | 253 | ns | 87 | ns | ns | ns | ns | ns | ns | 0.05 |
| P 1% | ns | | 113 | | | | | | | 0.09 |
| Mean | 2937 | 3077 | 814 | 23.6 | 5.04 | 27.2 | 1.89 | 1.96 | 0.030 | 0.20 |

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Response of wheat to liming was more effective in comparison with response of maize because by applications two rates of lime yield increases were for 43%. Also, ears density per unit of area was significant higher by using of lime (*Table 3*.).
As affected by liming significant differences of phosphorus (+47%), magnesium (+23%), manganese (-27%), zinc (-20%) and cadmium status (-12%) in maize grain was found. With that regard, significant differences in comparison to the control for phosphorus, magnesium and manganese were found by using the lower lime rate (*Table 4*.). However, effects of liming on grain status of wheat was considerably lower because significant differences only for P (+9%), Mg (+21%) and Sr (-50%) were found and for this differences application of the higher lime rate was needed (*Table 4*.).

## Conclusions

Liming was useful soil management practice with aspect of maize and wheat yield increases and increases of grain P and Mg status. With that regard, application of the lower lime rate in amount of 5 t $ha^{-1}$ was mainly adequate.

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