Macedonian Journal of Animal Science, Vol. 5, No. 2, p-p. 69–74 (2015)
200 In print: ISSN 1857 – 6907
Received: July 7, 2015 On line: ISSN 1857 – 7709
Accepted: October 20, 2015 UDC: 633.15-157.63:581.192
Original scientific paper

IMPACT OF LIMING ON MICRONUTRIENTS STATUS IN MAIZE GRAIN

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Soil acidity is a major yield-limiting factor for crop production. Liming is the most important and most effective practice to ameliorate soil acidity constraints for optimal crop production. However, liming can be accompanied with dramatic reduction of some nutrients intake in plants. Among widely cultivated food crops, maize plays a particularly important role. Aim of this study was testing impacts of liming with fertdolomite (24.0 % CaO + 16.0 % MgO + 3.0 % N + 2.5 % P_2O_5 + 3.0 % K_2O) in five rates from 5 to 40 t ha^{-1} (spring 2008) on micronutrient status in maize grain (the growing seasons 2010 and 2011). In general, concentrations of manganese (Mn), iron (Fe), zinc (Zn) and copper (Cu) in maize grain were very low and inadequate with aspect of animal and human feed needs. The growing season characteristics (mainly precipitation and temperature regimes) were more effective factor impact on grain micronutrient status in maize compared to liming (comparison averages values in mg kg^{-1} in dry matter of all tretements in 2010 and 2011: 20.7 and 24.7 Fe, 20.6 and 25.8 Zn, 4.77 and 7.07 Mn, 1.67 and 1.46 Cu, respcetively). As affected by liming slightly decreased concentrations of Mn and Zn, while grain-Fe and -Cu were independent on liming. By comparison the control (unlimed treatment) and averages limed treatment (2-year averages: 2010 and 2011) there found values as follows (mg kg^{-1} in dry matter): 23.7 and 23.1 Fe, 23.3 and 22.5 Zn, 6.44 and 5.81 Mn, 1.55 and 1.56 Cu, respectively.

Key words: liming; maize grain; food quality; manganese; zinc; iron; copper

ВЛИЈАНИЕ НА КАЛЦИЗАЦИЈАТА ВРЗ СТАТУСОТ НА МИКРОЕЛЕМЕНТИТЕ ВО ЗРНОТО ОД ПЧЕНКА

Киселоста на земјиштето е важен ограничувачки фактор во растителното производство. Калцизацијата е најзначајната и најефикасната мерка за ублажување на ограничувањето кое киселоста го има, за добивање на оптимално растително производство. Меѓутоа, калцизацијата е поврзана со драматично намалување во примањето на некои хранливи материи во растението. Меѓу широко распространетите посеви наменети за исхрана пченката има особено важна улога. Целта на овој труд е испитување на влијанието на калцизацијата со фертдоломит (24.0 % CaO + 16.0 % MgO + 3.0 % N + 2.5 % P_2O_5 + 3.0 % K_2O), на пет нивоа од 5 до 40 t ha^{-1} (во текот на пролетта 2008), врз концентрацијата на микрохранивата во зрното од пченка во текот на вегетацијата 2010 и 2011. Генерално, концентрацијата на манганот (Mn), железото (Fe), цинкот (Zn) и бакарот (Cu) во зрното од пченка беше доста ниска и недоволна од аспект на потребите во исхраната на животните и луѓето. Карактеристиките на поединечните вегетации (главно режимот на дождови и температура) беа значаен фактор на влијание врз состојбата на микрохранивата во однос на калцизацијата (споредување на просечните вредности во mg kg^{-1} суви материи на сите третмани во 2010 и 2011: 20,7 и 24,7 Fe, 20,6 и 25,8 Zn, 4,77 и 7,07 Mn, 1,67 и 1,46 Cu, соодветно). Под влијание на калцизацијата незначително беа намалени концентрациите на Mn и Zn, додека концентрациите на Fe и Cu во зрното беа независни од калцизацијата. Со споредување на контролата (третман без калцизација) со просекот на третманот со додадениот фертдоломит (двегодишни просеци) се утврдени следните вредности (mg kg^{-1} сува материја): 23,7 и 23,1 Fe, 23,3 и 22,5 Zn, 6,44 и 5,81 Mn, 1,55 и 1,56 Cu, соодветно.

Клучни зборови: калцизација; зрно пченка; квалитет на храна; манган; цинк; железо; бакар

INTRODUCTION

Approximately forty nutrients (esential amino acids and fatty acids, water- and fat-soluble vitamins and minerals) are required by the human body (Baron, 2007). Micronutrients are substances needed in amounts of less than one hundred mg per day for good health, growth and development. They include all vitamins, as well as some minerals or trace elements (Loechl, 2014) such as iron (Fe), zinc (Zn), chromium (Cr), copper (Cu), manganese (Mn) and iodine (I). Micronutrient malnutrition becoming serious social and medical problem of human population, particularly in developing word. Widely cultivated modern field crop cultivars characterizing a high-yield capacity are poor in micronutrients, especially with Zn and Fe with aspect of daily requirements of human (Cakmak et al., 2000; Ortiz-Monasterio and Graham, 2000; Murphy et al., 2008). In addition, some food sources, as wheat grain, are rich in phytic acid and phenolic compounds that reduce bioavailability of Zn and Fe in the human digestive tract (Welch and Graham, 2004).

It is estimated that by Fe deficiency is affected about 2 billion of human population. Major Fe deficiency disorders are associated with anemia, reduced learning and work capacity, increased matrenal and infant mortality and low birth weight. On the other hand, Zn deficiency prevails in developing countries and disorders is in close connection with poor pregnancy outcome, impaired growth, genetic disorders and decreased resistance to infectious diseases (Tulchinsky, 2010).

In total, about 800 000 child deaths per year were attributable to Zn deficiency (WHO, 2002). It is important to put these disease burden estimates in perspective. Rashid et al. (2014) reported that zinc malnutrition in Pakistan has been developed to alarming magnitude: 40% children, 48% pregnant women and 41% non-pregnant women are diagnosed to be Zn-deficient. The alkaline-calcareous soils in Pakistan are conducive to Zn deficiency in crop plants. Zn supplementation can reduce morbidity from a number of common childhood infections, for example diarrhea, pneumonia, by one-third (Black 1998; Roy et al. 1999; Shankar et al. 2000). In addition, Zn deficiency is an important cause of stunting (Brown and Wuehler 2000; Umeta et al. 2000). According to WHO there are 10.8 million child deaths globally a year.

The number attributed to Zn, vitamin A, and Fe deficiencies is 2 082 000, or 19% of the total (WHO, 2002; Black 2003). Zn supplementation by food results in improved growth in children, lower rates of diarrhoea, malaria, and pneumonia, and reduced child mortality (Sazawal et al., 2001).

Mn is an essential element for humans, animals and plants and is required for normal cellular activities, but overexposure leads to toxicity. Neurons are particularly susceptible to Mn-overdose, and accumulation of Mn in the brain results in manganism that presents with Parkinson's disease-like symptoms (Santamaria and Sulski, 2010; Chen et al., 2015).

In general, malnutrition provocated by other micronutrients, like Cu and I, are considerably lower in comparison with Fe and Zn. Individual supplementation, staple food fortification, biofortification of crops and improved dietary diversification are directions for elimination or alleviation of malnutrition (Cakmak 2008; Cakmak et al., 2010).

Farming practice is also factor may considerable affects micronutrients uptake by plants. Soil acidity is a major yield-limiting factor for crop production. Liming is the most important and most effective practice to ameliorate soil acidity constraints for optimal crop production. However, liming can be accompanied with dramatic reduction of some nutrients intake in plants. Among widely cultivated food crops, maize plays a particularly important role. Aim of this study was testing impact of common effects of liming and fertilization by phosphorus and potassium on micronutrient (iron, zinc, manganese, copper and boron) status in grain of maize.

MATERIAL AND METHODS

The field experiment

The field experiment of liming and ameliorative fertilization with phosphorus (P) and potassium (K) was started at beginning of April 2008 on Badljevina (Pakrac municipality) acid soil (pH in 1nKCl 4.69). The soil was low supplied with plant available P and K determined by the AL-method (3.1 mg P_2O_5 and 8.7 mg K_2O 100 g^{-1}).

Granulated dolomite enriched with nitrogen (N), P and K (trade name fertdolomite – product of Petrokemija Fertilizer Factory in Kutina, Croatia) was applied on standard fertilization in the amounts 0 (control), 5 t ha^{-1}, 10 t ha^{-1}, 20 t ha^{-1}, 30 t ha^{-1} and 40 t ha^{-1}. Fertdolomite contained 24.0 % CaO + 16.0 % MgO + 3.0 % N + 2.5 % P_2O_5 + 3.0 % K_2O.

By the highest fertdolomite dose was added ameliorative amounts of N (1000 kg N ha^{-1}), P and K (1200 kg P_2O_5 and K_2O ha^{-1}).

The experiment was conducted by the randomized block design with four replicates (basic plot 40 m^2). In the next years the experiment was fertilized uniformly (for maize: 175 N + 50 P_2O_5 + 50 K_2O). Crop rotation in the experiment was as follows: maize (2008) – spring barley (2009) – maize (2010 + 2011) – winter wheat (2012) – maize (2013). Majority results of the experiment in the period 2008 – 2013 including weather characteristic and farming practices were elaborated in two previous studies (Kovačević et al., 2015a, 2015b).

Chemical and statistical analysis

Ten cobs of maize at maturity stage of two growing seasons (2010 and 2011) were taken from each basic plot (beginning of October) for chemical analysis. The total amounts of elements in maize grain were determined using ICP after their microwave digestion by concentrated HNO_3+H_2O_2. Grain analyses were made by Jobin-Yvon Ultrace 238 ICP-OES spectrometer in the Research Institute for Soil Science and Agricultural Chemistry (RISSAC), Budapest. The data were statistically analyzed by ANOVA and treatment means were compared using t-test and LSD at 0.05 probability level.

Weather characteristics

Weather characteristics are important factor of yield and nutrient uptake by plants. In general, the low precipitation and the higher air-temperature compared to the long-term mean (LTM), especially in summer, are oft in connection with the lower grain yield of maize (Shaw, 1988; Kovačević et al., 2013). With the aspect of this criterion, the 2010 growing season was particularly favorable for maize growth because of adequate precipitation in April-September period, Also, monthly temperature regimes were close to LTM (Table 1).

However, the 2011 growing season characterized by considerably lower precipitation bellow LTM, with exception in July, and the higher air-temperatures. Under these divergently different weather conditions, average yields of maize in the experiment were 13.22 t ha^{-1} in 2010 and 10.65 t ha^{-1} in 2011.

Table 1

The meteorological data for Daruvar (SHS, 2014)

Year	DARUVAR: Precipitation and mean air-temperatures (61–90: average 1961–1990)													
	Monthly precipitation (mm)							Monthly mean air-temperatures (°C)						
	Apr.	May	June	July	Aug	Sept	Σ	Apr.	May	June	July	Aug	Sept	X
2010	80	197	262	71	67	212	*889*	11.5	15.8	19.7	22.3	20.4	14.7	*17.4*
2011	19	55	44	121	40	27	*306*	12.6	15.6	20.3	21.7	21.6	18.7	*18.4*
61–90	77	86	99	86	91	65	*504*	11.0	15.7	18.9	20.6	19.7	16.1	*17.0*

* 10 km from the experiment site in the N direction

RESULTS AND DISCUSSION

Nutritional requirements have been most commonly expressed by recommended dietary allowances (RDAs) and according to Institute of Medicine of National Academy of Science in Washington, this value for some trace elements (mg daily, for adults male and female, respectively) are as follows (Baron, 2007): 8 and 18 Fe, 11 and 8 Zn, 9 and 9 Mn, 2.3 and 1.8 Cu, respectively.

Total body Fe ranges between 2 and 4 g, approximately 50 mg Fe kg^{-1} in men and 35 mg Fe kg^{-1} in women. The average American diet contains 10 – 15 mg Fe per day and only about 10% of this amount is absorbed (Linker, 2007).

An adult male needs to consume 4 mg, adult female needs 3 mg of Zn daily. If the diet is devoid of animal products and high in phytate, daily Zn intake requirements will increase about threefold (Hossain and Karim, 2010).

In our study, concentrations of Fe, Zn, Mn, and Cu in maize grain were very low (Table 2) and inadequate with aspect of animal and human needs in diet.

The growing season characteristics (mainly precipitation and temperature regimes) were more effective factor impact on grain micronutrient status in maize compared to liming (comparison averages values in mg kg^{-1} in dry matter of all treatments in 2010 and 2011: 20.7 and 24.7 Fe, 20.6 and 25.8 Zn, 4.77 and 7.07 Mn, 1.67 and 1.46 Cu, respectively. As affected by liming slightly decreased concentrations of Mn and Zn, while grain Fe and Cu were independent on liming. By comparison the control (unlimed treatment) and averages limed treatment (2 year averages: 2010 and 2011) there found values as follows (mg kg^{-1} in dry matter): 23.7 and 23.1 Fe, 23.3 and 22.5 Zn, 6.44 and 5.81 Mn, 1.55 and 1.56 Cu, respectively (Table 2). Regarding P, K and Mg status in maize grain (the 2010 growing season only), average values were 0.294% P, 0.334% K and 0.093% Mg and liming by fertdolomite significantly increased only grain–P for 14% (Kovačević et al., 2015a).

Table 2

Subsequent effects of liming with fertdolomite in spring of 2008 on grain yield and nutritional status of maize grain in the 2010 and 2011 growing seasons

April 2008 Fertdolomite*	Badljevina field experiment of liming with fertdolomite (April, 9, 2008) Grain yield of maize (t ha^{-1})		Nutritional status of maize (the hybrid *Drava 404*) grain at maturity (mg kg^{-1} on dry matter basis) The 2010 growing season				The 2011 growing season			
(t ha^{-1})	2010	2011	Fe	Zn	Mn	Cu	Fe	Zn	Mn	Cu
0	12.38	10.84	20.6	19.4	5.47	1.69	26.8	27.1	7.41	1.41
5	13.60	11.85	19.1	18.7	4.40	1.37	24.9	24.6	6.53	1.47
10	13.90	11.66	19.3	22.2	4.33	1.84	24.0	23.9	6.89	1.55
20	13.59	10.70	22.0	22.4	4.96	1.55	23.0	23.0	6.55	1.43
30	13.30	9.50	20.0	22.3	4.57	1.90	27,5	24.4	7.32	1.51
40	12.57	9.36	22.3	19.1	4.89	1.65	28.7	25.0	7.70	1.38
Average	13.22	10.65	20.6	20.7	4.77	1.67	24.7	24.7	7.07	1.46
LSD 5%	0.40	0.70	ns	2.6	0.70	ns	ns	2.0	ns	ns

* Fertdolomite composition: 24.0 % CaO + 16.0 % MgO + 3.0 % N + 2.5 % P_2O_5 + 3.0 % K_2O

As affected by fertdolomite application, grain yields of maize were increased for 12% (2010) and for 9% (2011) and for this effect were sufficient doses10 and less tones of fertdolomite per hectare, while by the higher rates yield were decreased mainy to level of the control particularly in 2011 (Table 2). Specific effect of „year“ on fertdolomite efficiency regarding grain yield in this experiment was found for winter wheat. For example, in the 2013/2014 growing season average grain yield of wheat in the experiment was 5.33 t ha^{-1}, with differences among treatments from 4.71 (the control) to 6.10 t ha^{-1} (40 t ha^{-1}). By use of 20 t ha^{-1} of fertdolomite yield was increased for 15%, and additionaly 15% for use of the highest fertdolomite rate. However, in the 2011/2012 average yield was 7.28 t ha^{-1} and non-significant differences of yield were found to level of 10 t ha^{-1} applied fertdolomite, while by the higher rates yield were significantly decreased for 7% (Rastija et al., 2015).

By the our earlier study (Kovačević et al., 2010), liming considerably affected decreases of Zn and Mn in maize grain as follows: 20.1 and 16.5 mg Zn kg^{-1}, 4.6 and 3.5 mg Mn kg^{-1} for the control and applied dolomite in amount 15 t ha^{-1}. However, grain–Fe status was independent on liming (20.6 and 20.7 mg Fe kg^{-1}, respectively).

Also, Jurković et al. (2008) found increase of grain yield of maize for 10% and decreases of Zn and Mn in grain as affected by liming by carbocalk (17 and 8 mg Mn kg^{-1}, 24 and 19 mg Zn kg^{-1}, respectively).

Popović et al. (2007) found considerable negative effects of liming with dolomite in amount 10 t ha^{-1} on Zn and Mn status in dry matter of alfalfa hay (41.3 and 28.9 mg Zn kg^{-1}, 50.0 and 40.2 mg Mn kg $^{-1}$). By using the higher rates of dolomite up to 40 t ha^{-1}, Zn and Mn status was similar to treatment of 10 t ha^{-1}, while for significant Fe decreases were needed the highest dolomite rate (307 and 228 mg Fe kg^{-1}, for the control and 40 t ha^{-1}, respectively). However, Cu status in alfalfa hay was similar to all applied treatments (non-significant differences from 11.7 to 12.5 mg Cu kg^{-1}).

Antunović (2008) applied liming with carbocalk. Grain yield of maize (4-year average) were 7.29 t ha^{-1}, 8.62 t ha^{-1} and 9.08 t ha^{-1}, for 0, 30 and 60 t of carbocalk per hectare. However, concentrations of Zn and Mn in maize leaves were decreased as follows (mg kg^{-1}): 49.7, 27.2 and 22.8 (Zn), 254, 64 and 74 (Mn), respectively.

CONCLUSIONS

Liming is the most important and most effective practice to ameliorate soil acidity constraints for optimal crop production. However, liming can be accompanied with dramatic reduction of some nutrients intake in plants.

Micronutrient (Fe, Zn, Mn, Cu and B) concentrations in grain of maize is very low and inadequate with aspect of human and animal requirements.

As affected by liming slightly decreased concentrations of Mn, Zn and B, while grain-Fe and -Cu were independent on liming.

In our study, the growing season characteristics (mainly precipitation and temperature regimes) were more effective factor impact on grain micronutrient status in maize compared to liming.

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