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POSSIBLE AVAILABILITY OF Mg, Fe, Mn AND Zn FROM ORGANICALY PRODUCED MAIZE

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Abstract

Trial was conducted during 2013 with aim to study application of different fertilizer combinations on availability of mineral nutrients Mg, Fe, Mn and Zn from organically produced maize grain. Fertilizer treatments included control (without fertilization), DIX 10 N and Italpolina 4:4:4, which were incorporated into soil, as well as foliarly applied $MgSO_4$. After harvest, grain yield, 1.000 grain weight and content of nutrients Mg, Fe, Mn and Zn, as well as inorganic phosphorus (P_i), phytate – as factor which affect availability of mineral nutrients and β-carotene – as factor which promotes availability of mineral nutrients, were determined in grains.

The highest grain yield and 1.000 grain weight were achieved in DIX treatment. $MgSO_4$ showed positive impact on phytate decrease and β-carotene increase, but in combination with Italpolina and DIX, respectively. Meanwhile, the highest content of observed mineral elements was observed in control. The highest variation in relations of phytate with examined parameters was on phytate/β-carotene content, ranging from 411.3 (DIX+$MgSO_4$) to 1825.9 (Italpolina). The desirable lowering in ratio between phytate and examined elements was achieved in DIX+$MgSO_4$ combination, for phytate/P_i, phytate/β-+carotene and phytate/Mn ratio, while Italpolina decreased phytate/Zn ratio. However, phytate/Mg and phytate/Fe ratios were the lowest in control, indicating that applied fertilizers showed negative impact on potential Mg and Fe availability. Regression analysis underlined that phytate/Fe and phytate/Zn negatively correlated with 1.000 grain weight, indicating that bigger grains could be also valuable with increased Fe and Zn availability. That could be referred to DIX as treatment with the highest β-carotene content and 1.000 grain weight.

Key words: *mineral nutrients, organic production, availability, phytate, β-carotene*

Introduction

Irrespective to generally lower yields, organically produced crops have increased nutritional value than conventionally produced crops. They have more dry matter, antioxidants (vitamin C, phenolic compounds etc.), essential amino acids, total sugars and more mineral compounds, such K, Ca, Mg and Fe (Rembiałkowska, 2007; Lairon, 2010). This means that organic agricultural systems have already proved ability to produce food with high quality standards.

Higher content of mineral nutrients in foods doesn’t mean automatically that they will be utilized in total by human and animal organisms. Plant foods can contain inhibitors, likephytate, polyphenolics, etc., which obstruct the absorption or utilization of mineral elements. Moreover, there are also enhancing substances – promoters, like ascorbic acid, *β*-carotene, S-containing amino acids, etc.,which promote bioavailability of mineral elements or decrease the effects of inhibitory substances (Luo Xie 2012). From this point of view, it is essential to decrease the content of various inhibitors in foods and to increase the content of promoters, what means that well-balanced diet, as well as staple food with distinct properties can equally improve health regardless of its organic or conventional origin (Magkos et al., 2003).

The aim of experiment was to determine nutritional quality of organically produced maize grain through potential availability of Mg, Fe, Mn and Zn, issued from their relation with phytate, as inhibitor and β-carotene, as promoter.

Material and methods

Experiment was conducted in rain-fed conditions during 2013, in ZemunPolje (44°52'N 20°20'E), in the vicinity of Belgrade, on a slightly calcareous chernozem type of soil, with: 0.0 % coarse, 53.0 % sand, 30.0 % silt, 17.0 % clay, 3.3 % organic matter, 7.40 pH KCl and 7.17 pH H_2O, 103.23 ppm N, 26.49 ppm P, 16.37 ppm K, 24.41 ppm Mg, 0.04 ppm Fe, 0.02 ppm Mn and < 0.0002 ppm Zn. Before ploughing, 2 organic fertilizers were applied: DIX 10 N (N:P:K=10:3:3, 72.5% organic matter) in amount of 500 kg ha^{-1} and Italpolina 4:4:4 (N:P:K-4:4:4, produced from the manure from several animal species), also in amount of 500 kg ha^{-1}, as well as control (without fertilization). Maize variety Rumenka was sowed on 23.04.2013. Every treatment included sub-treatments with foliar application of 1% $MgSO_4$ (in amount of 200 g ha^{-1}), on 29.05. and on 06.06., in phase 6-7 leaves (FF treatment).

After harvest, grain yield, mass of 1000 grains, and concentration of phytic P (P_{phy}), inorganic P (P_i), β-carotene, as well as mineral elements: Mg, Fe, Mn and Zn were determined in grains. P_{phy} and P_i were determined by the method of Dragičević et al. (2011); Β-carotene was determined according to AACC (1995) procedure; mineral elements were determined after wet digestion in HNO_3+$HClO_4$ by Inductively Coupled Plasma - Optical Emission Spectrometry. The obtained results were presented with standard deviation (SD). Interdependence between the 1000 grain weight and ratio between phytate and inorganic P, β-carotene, Mg. Fe, Mn and Zn were processed by regression analysis.

Results and discussion

According to results present in Table 1, grain yield varied slightly among treatments. The highest value of grain yield was obtained in DIX treatment, combined with foliar fertilizer and in control without application of foliar fertilizer, what is about 7% higher compared with control with foliar fertilizer (the lowest value of grain yield).This is in accordance with results of Thalooth et al. (2006) obtained on mungbean, with increased growth and yield components with foliarly applied Mg. In regard to the fact that phytate presents inhibitor, lowering of its content in grain could positive affect availability of mineral elements (Hunt, 2003;Dragičević et al., 2013). The lowest phytate concentration in maize grain was obtained in Italpolina + FF treatment. However, this treatment also decreased P_i accumulation in grain (it was 2.6 times lower that in DIX +FF treatment, which had the highest P_i concentration). Such situation could indicate less efficient P absorption or accumulation in grain, which could be caused by imbalanced nutrient content in soil (Nel et al., 1996). The concentration of β-carotene as promoter in grain was highly and positively affected by DIX treatment, having double higher values in DIX +FF treatment in relation to control and over 4 times higher values in relation to Italpolina without FF application.

Table 1.Grain yield and concentration of phytic P (Pphy), inorganic P (Pi) and β-carotene in maize grain, from plants treated with DIX 10 N and Italpolina 4:4:4, as well as foliarly applied $MgSO_4$ (FF) and without it (Ø).

Treatment		Grain yield $t\ ha^{-1}$	P_{phy} g/kg	P_i g/kg	β-carotene mg/kg
Control	FF	4.20 ± 0.24	3.56 ± 0.001	0.53 ± 0.04	13.21 ± 0.11
	Ø	4.52 ± 0.45	3.86 ± 0.008	0.50 ± 0.25	8.04 ± 0.23
DIX 10 N	FF	4.52 ± 0.45	3.17 ± 0.021	0.59 ± 0.12	22.26 ± 0.02
	Ø	4.25 ± 0.48	3.26 ± 0.002	0.45 ± 0.13	12.09 ± 0.21
Italpolina 4:4:4	FF	4.41 ± 0.78	2.77 ± 0.005	0.23 ± 0.28	9.74 ± 0.09
	Ø	4.31 ± 0.47	3.28 ± 0.001	0.46 ± 0.08	5.19 ± 0.11

Mean value ± SD

Irrespective to addition of organic fertilizers, which could improve soil and plant status of mineral elements, the highest concentration of Mg, Fe and Zn was observed in control, mostly with application of foliar fertilizer (Table 2). The highest variation in concentration of mineral elements in maize grain among applied treatments was noticed at the Mn level: the highest Mn concentration in grain was in DIX + FF treatment, what is almost 4 times higher in regard to combination Italpolina + FF. It was important to underline that the highest Mn concentration from DIX + FF treatment was linked with the lowest Zn concentration, possible induced by better P absorption (Ryan et al., 2004), what is evidenced by the highest $P_{phy}$and Pi concentration in grain.

Table 2.Concentration of phytic Mg, Fe, Mn and Zn in maize grain, from plants treated with DIX 10 N and Italpolina 4:4:4, as well as foliarly applied $MgSO_4$ (FF) and without it (Ø).

Treatment		Mg mg/kg	Fe mg/kg	Mn mg/kg	Zn mg/kg
Control	FF	417.5 ± 7.95	13.34 ± 0.22	2.31 ± 0.00	16.50 ± 1.59
	Ø	383.4 ± 1.33	16.31 ± 0.44	2.28 ± 0.22	17.19 ± 2.47
DIX 10 N	FF	353.1 ± 0.88	9.56 ± 0.53	2.56 ± 0.09	10.16 ± 2.43
	Ø	377.5 ± 3.54	10.69 ± 0.71	1.66 ± 0.04	13.63 ± 5.66
Italpolina 4:4:4	FF	310.6 ± 1.77	9.25 ± 0.71	0.78 ± 0.13	14.03 ± 0.66
	Ø	359.1 ± 0.44	8.31 ± 0.97	1.31 ± 0.00	15.66 ± 2.34

Mean value ± SD

Regardless to higher or lower concentration of Mg, Fe, Mn and Zn in maize grain, their availability mainly depends on their relations with inhibitor, such phytate (Walter Lopez et al., 2002; Dragičević et al., 2013). From this point, the lowest value of P_{phy}/P_i, Phy/β-carotene and Phy/Mn was noticed at DIX + FF treatment (Table 3), indicating lower phytate impact on availability of examined mineral elements, particularly Mn. The lowest Phy/Fe ratio was obtained at control and the lowest Phy/Zn ratio was observed at Italpolina + FF, treatment with the lowest P_{phy} concentration (Table 1).

Table 3.Molar ratios between phytate (Phy), inorganic P (P_i), β-carotene, Mg, Fe and Zn in maize grain, from plants treated with DIX 10 N and Italpolina 4:4:4, as well as foliarly applied $MgSO_4$ (FF) and without it (Ø).

Treatment		P_{phy}/P_i	Phy/β-carot.	Phy/Mg	Phy/Fe	Phy/Mn	Phy/Zn
Control	FF	6.75	779	1.117	80.3	455.7	76.0

	Ø	7.66	1385	1.316	71.0	499.6	78.9
DIX 10 N	FF	5.34	411	1.174	99.6	365.6	109.8
	Ø	7.21	779	1.130	91.6	581.6	84.1
Italpolina 4:4:4	FF	11.80	822	1.167	90.0	1048.2	69.5
	Ø	7.06	1826	1.195	118.5	738.3	73.7

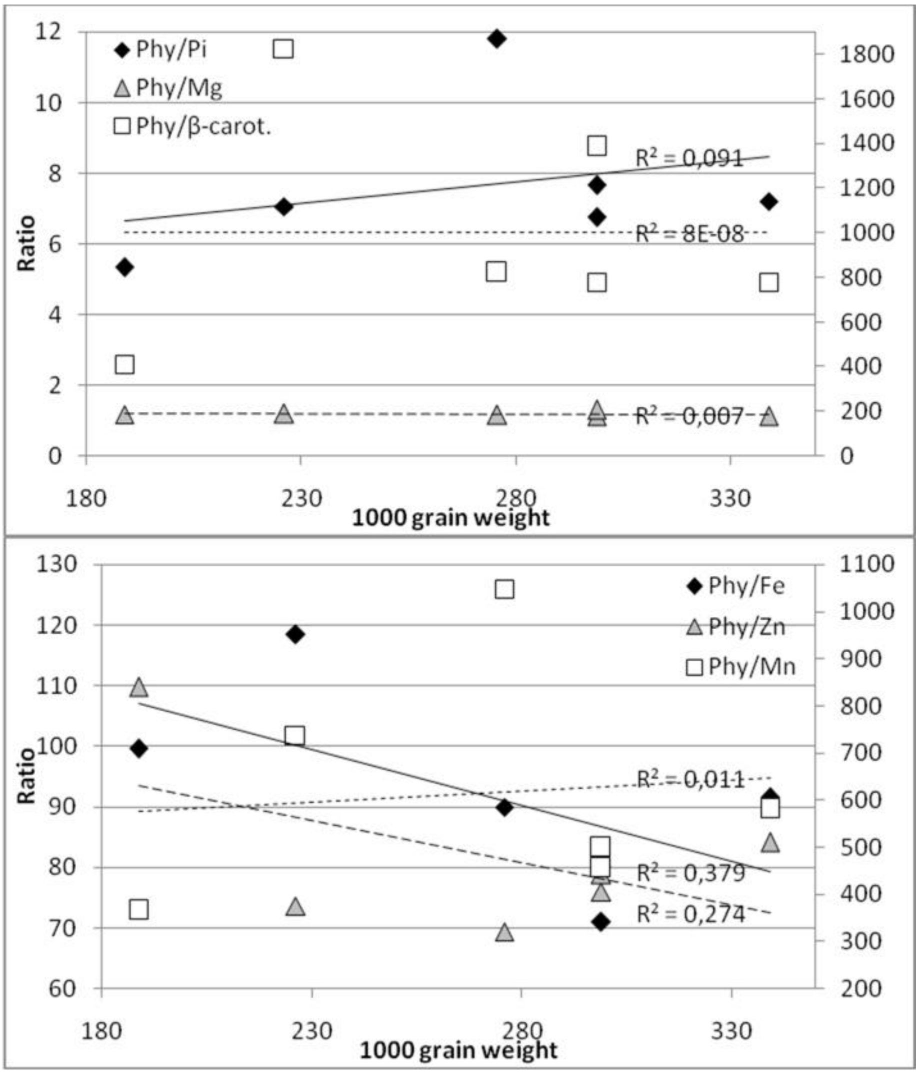

Figure 1.Interdependence between 1000 grain weight and relations between phytate (Phy), inorganic P (P_i), β-carotene, Mg, Fe, Mn and Zn

The interdependence of ratio between phytate P_i, β-carotene and mineral elements with yielding parameter, such 1000 grain weight, indicated that there was no significant dependence between P_{phy}/Pi, Phy/β-carotene and Phy/Mg (Figure 1). Other than that, Phy/Fe and Phy/Zn status have significant and negative interdependence with 1000 grain weight, indicating better availability of Fe and Zn from bigger grains.

Conclusion

Based on obtained results from preliminary research, it could be concluded that applied fertilizers DIX 10 N and Italpolina 4:4:4 slightly affected maize grain yield, in comparison with control, with higher influence of foliarly applied $MgSO_4$. Moreover, the highest Mg, Fe and Zn concentration was observed in maize grain from control, with FF application. The lowest phytate concentration in maize grain was obtained for Italpolina + FF treatment, while the highest β-carotene concentration was observed for DIX +FF treatment. Lower phytate impact on availability of examined mineral elements (mainly Mn), expressed through decreased P_{phy}/P_i, Phy/β-carotene and Phy/Mn was noticed at DIX + FF treatment, while the lowest Phy/Zn ratio was observed at Italpolina + FF. What is more important, availability of some elements could depend on yielding parameter, like 1000 grain weight. Negative interdependence between 1000 grain weight and Phy/Fe and Phy/Zn indicated better availability of Fe and Zn from bigger grains. That could be referred to DIX as treatment with the highest β-carotene content and 1.000 grain weight.

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