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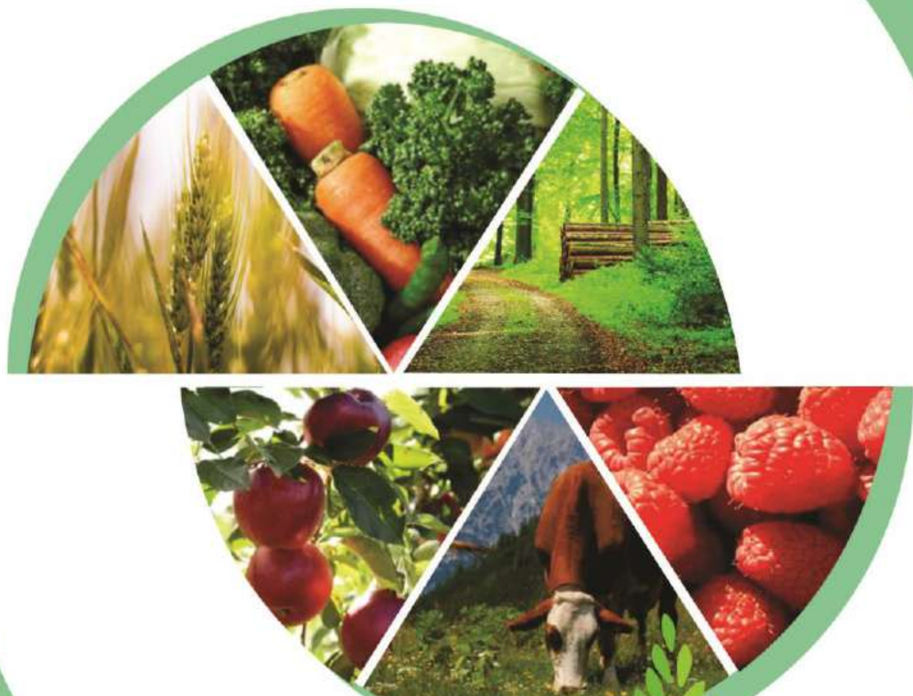

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COVER CROPS EFFECT ON STATUS OF MAIN ANTIOXIDANTS IN SWEET MAIZE

Vesna DRAGIČEVIĆ[1*], Željko DOLIJANOVIĆ[2], Biljana JANOŠEVIĆ[2], Milena SIMIĆ[1], Margarita DODEVSKA[3], Milan BRANKOV[1], Jelena MESAROVIĆ[1]

1Maize Research Institute "Zemun Polje", Slobodana Bajica 1, 11185 Zemun Polje, Serbia
2University of Belgrade, Faculty of Agriculture, Nemanjina 6, 11080 Zemun, Serbia
3Center for Food Analysis, Zmaja od Noćaja 11, 11000, Belgrade, Serbia

Abstract

Cover crops has important role in sustainability, owing to protection from soil erosion and soil enrichment with organic matter. Bio-fertilizers are important for increase of soil and crop quality. The aim of experiment was to examine nutritional quality of sweet maize, sown at experimental plots after different cover crops: T1 - common vetch (*Vicia sativa* L.), T2 - winter oats, (*Avena sativa* L.), T3 - fodder kale (*Brassica oleracea* (L.) *convar. acephala*), T4 - field pea (*Pisum sativum* L.) + winter oats, T5 - dead organic mulch, T6 - common vetch + winter oats, T7 - field pea and control - uncovered during the winter, in combination with bio-fertilizer Uniker, during 2013/2014. Content of main antioxidants: phenolics, glutathione, vitamin C, carotenoids and phytic acid were determined in technological maturity. The highest content of carotenoids (2.48 μg g^{-1}) was obtained in T1 + Uniker combination, while the highest values of glutathione and phenolics were in T2 treatment (1927 nmol g^{-1} and 716 μg g^{-1}, respectively). T3 was characterized with the highest vitamin C content in combinations with and without Uniker (29.92 and 31.09 mg $100g^{-1}$) and control had the highest phytic P content (3.69 mg g^{-1}). Correlation consigned that increased kernel yield was followed by carotenoid increase and phenolics decrease in general, while application of Uniker induced increase of P_{phy} and decrease of vitamin C, parallel with grain yield increase.

Key words: *sweet maize grain, nutritional quality, antioxidants*

Introduction

Sustainable agriculture combines various cultural practices with aim to maintain agro-ecosystem stability and high crop productivity. From this point, great responsiveness was given to the cover crops, which protect soil from erosion, maintain balance of nutrients in soil, by increasing organic matter level, together with conservation of nutrients from loosing. This is particularly important for nitrogen, since cover crops hold back nitrogen from leaching through soil profile (Restovich et al., 2012). Dolijanović et al. (2012) underlined significantly higher sweet maize kernel yield achieved from the field with cover crops in relation to kernel yield achieved from the uncovered field. Uchino et al. (2009) and Dolijanović et al. (2012) also emphasized that the highest grain yields of soybean and sweet maize were obtained when they are grown after leguminous cover crops. It is also important to underline that excessive fertilization could decline nutritive value of crops, particularly when nitrogen fertilization, which increases nitrate level and decreases the level of vitamin C, soluble sugars and Mg and Ca in some crops (Wang et al., 2008). Other than that, low input agricultural strategies contribute to increased level of vitamins in vegetables, including sweet maize (Worthington, 2004; Crinnion, 2010). Application of catch crops has advantage to application of mineral and other organic fertilizers in increased vitamin C concentration in sweet maize kernels (Rosa, 2015).

What is more, by incorporation of cover crops residues into soil, microbiological activity is increasing. Microorganisms, present naturally in soil or introduced by application of microbiological fertilizers contribute to maintenance of soil fertility together with increase of crop yields (Mahdi et al., 2010).

Sweet maize, rich in carbohydrates is also good source of fibers, vitamins and minerals and it could have many health benefits, what is important in particular since it is mainly consuming fresh (Arnarson, 2015). It is also high in phenolics, with high antioxidant activity expressed among other maize genotypes (Das et al., 2014).

The aim of experiment was to test the reaction of sweet maize to application of different cover crops from the point of nutritional quality, i.e. variation in concentration of antioxidants like vitamin C, carotenoids, water soluble phenolics, glutathione and phytic acid expressed as phytic phosphorus.

Material and methods

A field experiment was carried out over 2013/14, at the Experimental Field of Maize Research Institute in Zemun Polje (44°52'N 20°20'E). The experiment was established as a block design with four replications with winter cover crops as treatment: T1 - common vetch (*Vicia sativa* L.), T2 - winter oats, (*Avena sativa* L.), T3 - fodder kale (*Brassica oleracea* (L.) *convar. acephala*), T4 - field pea (*Pisum sativum* L.) + winter oats, T5 - dead organic mulch, T6 - common vetch + winter oats, T7 - field pea and control - classical variant, uncovered during the winter.

The cover crops were sown at the end of October or in early November. Green mass of the cover crops were incorporated in the soil in early May. After that bio-fertilizer – Uniker (containing proteolytic and cellulolytic bacteria) was applied to accelerate mineralization of cover crops, which was followed by sweet maize (ZPSC 421*su*) sowing.

The kernels were harvested at the stage of milk maturity (end of August). The content of main antioxidants: phenolics, glutathione, vitamin C, carotenoids and phytic acid were determined. Phytic P (P_{phy}) and total glutathione (GSH) content were determined colorimetrically. Phytic P was determined by the method of Dragičević et al. (2011) and GSH by the method of Sari Gorla et al. (1993). Free soluble phenolics were determined by method of Simić et al. (2004), as well as carotenoids content (mainly containing of β-carotene) was also determined colorimetrically, after extraction with saturated butanol AACC (1995). Vitamin C was determined by iodometric titration (Rikovski et al., 1989). The experimental data were statistically processed by ANOVA (with LSD 5%) and by regression analysis.

Results and discussion

According to results present in Table 1, concentrations of all examined antioxidants in sweet maize kernels varied significantly toward cover crop treatment, as well as interaction cover crop x Uniker treatment. The highest variability was in carotenoid concentration, accordingly to the results of Khalid and Juvik (2009) who find high variability in carotenoid content in sweet maize kernels among various agro-ecological conditions. For GSH, the highest values were obtained at T5 treatment (with Uniker) and T7 (Ø); for phenolics, they were obtained in control (with Uniker) and T4 (Ø); for vitamin C, the highest values were acquired by T3 treatment (with Uniker) and T6 (Ø); for carotenoids, the highest values were obtained at T1 treatment (with Uniker) and T5 (Ø), and for P_{phy}, they were obtained by T6 treatment (with Uniker) and control (Ø). T1 (common vetch cover crop) was characterised with the lowest values of GSH (with Uniker) and vitamin C (in both, with and without Uniker application), while T2 (winter oats) was treatment with the lowest values of GSH and phenolics concentration (without Uniker) and P_{phy}

concentration (with Uniker) and T3 (fodder kale) is the treatment with the lowest values of carotenoids (in both, with and without Uniker application). Rosa (2015) find that cover crops were positively reflected on increase in vitamin C concentration, what is in this experiment present in treatments with fodder kale, field pea and combination of common vetch + winter oats. The positive impact of microbiological fertilizers is also observed on carotenoid lycopene and vitamin C accumulation in tomato fruits (Verma et al., 2015; Ochoa-Velasco et al., 2016). GSH content was mainly influenced by mulch and field pea, confirming that organic fertilizers, with available N forms are important for accumulation of this protein type (Dragičević et al., 2013). It is well known that fertilizers, together with other measures commonly used in organic farming, as low input agriculture contributes to increased level of vitamins in vegetables, including sweet maize, when compared to conventional farming (Worthington, 2004; Crinnion, 2010).

Table 1.Concentration of glutathione (GSH), phenolics, Vitamin C andphytic P (P_{phy}) in sweet maize grain influenced by different cover crops (T1 – T7) and bio-fertilizer (Uniker; Ø – without Uniker)

Treatment		T1	T2	T3	T4	T5	T6	T7	Cont.	Aver.	LSD 0.05	
GSH (nmol g^{-1})	Unik.	1363.8	1373.3	1415.7	1538.7	1879.7	1723.1	1487.5	1608.9	1548.8	T	190.8
	Ø	1726.3	1927.6	1374.9	1470.8	1738.3	1410.9	1218.4	1469.2	1542.0	Un.	226.3
	Av.	1545.0	1650.5	1395.3	1504.7	1809.0	1567.0	1353.0	1539.1	1545.4	TXUn.	123.3
Phenol. (μg g^{-1})	Unik.	536.8	613.2	491.1	657.5	563.9	527.5	471.0	712.5	571.7	T	90.1
	Ø	621.1	716.1	570.4	503.2	666.8	531.8	641.1	699.0	618.7	Un.	101.8
	Av.	578.9	664.7	530.7	580.4	615.4	529.6	556.1	705.7	595.2	TXUn.	76.3
Vit. C (mg $100g^{-1}$)	Unik.	21.71	27.57	29.92	28.75	26.40	24.05	22.29	27.57	26.03	T	2.47
	Ø	21.12	21.41	31.09	30.51	29.92	31.09	29.33	29.92	28.05	Un.	3.54
	Av.	21.41	24.49	30.51	29.63	28.16	27.57	25.81	28.75	27.04	TXUn.	0.66
P_{phy} (mg g^{-1})	Unik.	3.27	2.98	3.55	3.07	3.00	3.50	3.40	3.28	3.25	T	0.24
	Ø	3.54	3.28	3.24	2.94	3.53	3.31	3.16	3.69	3.34	Un.	0.27
	Av.	3.40	3.13	3.39	3.00	3.26	3.40	3.28	3.48	3.29	TXUn.	0.18
Carot. (μg g^{-1})	Unik.	2.48	1.88	1.58	1.62	1.73	2.03	2.12	1.79	1.90	T	0.21
	Ø	1.76	1.61	1.32	1.94	2.06	1.91	1.92	1.89	1.80	Un.	0.27
	Av.	2.12	1.74	1.45	1.78	1.89	1.97	2.02	1.84	1.85	TXUn.	0.10

Variations in kernel yield were connected to variability in content of main antioxidants in sweet maize kernels, having significant and positive correlation of kernel yield with carotenoids and P_{phy} (R^2=0.3518 and R^2=0.3398, respectively; Figure 1), as well as significant and negative correlation with phenolics and vitamin C (R^2=0.1764 and R^2=0.5926, respectively) in Uniker treatment. In parallel, Verma et al. (2015) find positive impact of effective microorganisms on yield and lycopene content of tomato fruits. Other than that, in treatment without Uniker, significant and positive correlation between kernel yield and carotenoids and vitamin C (R^2=0.2404 and R^2=0.5967, respectively; Figure 2) was observed, while significant and negative correlation was between kernel yield, phenolcs and GSH (R^2=0.2963 and R^2=0.4415, respectively). In the case of vitamin C, results obtained in the part of experiment without Uniker application indicate that proper nutrition reflects positive on increase of kernel yield and vitamin C concentration in kernels (Wang et al., 2008), as improved quality. This was especially underlined in treatments with fodder kale, field pea and combination of common vetch + winter oats (Table 1).

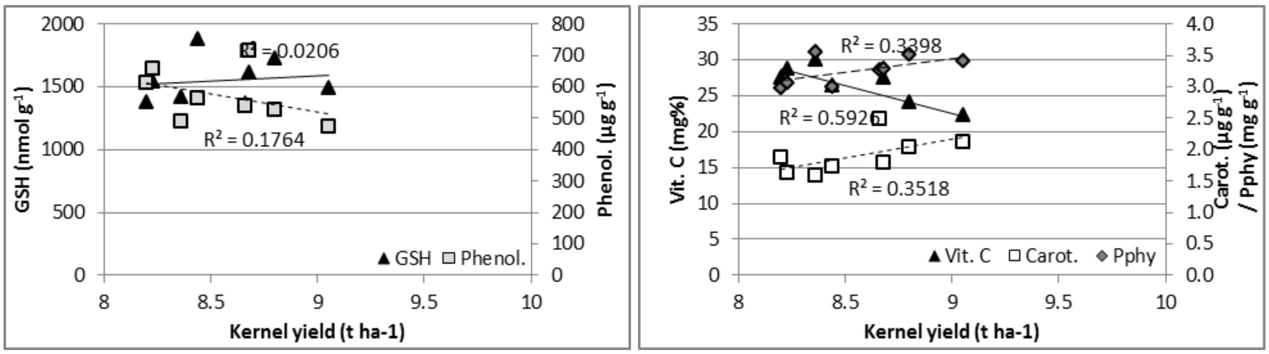

Figure 1. Interdependence between kernel yield and concentration of different antioxidants (GSH, phenolics, vitamin C, carotenoids and P_{phy}) in sweet maize grain in Uniker treatment

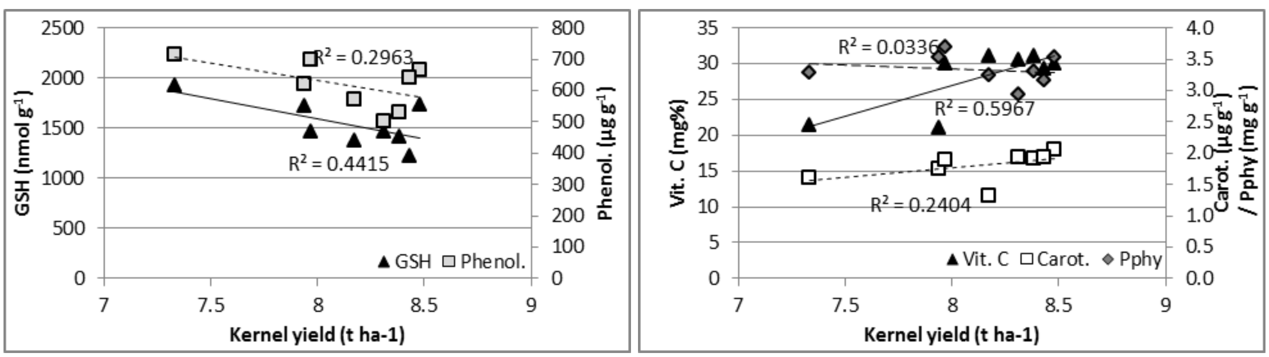

Figure 2. Interdependence between kernel yield and concentration of different antioxidants (GSH, phenolics, vitamin C, carotenoids and P_{phy}) in sweet maize grain in treatment without Uniker

Conclusion

Based on obtained results from research, it could be concluded that the highest variability was present in carotenoid concentration, among parameters examined. Uniker slightly increased carotenoid and GSH content, while it showed decreasing effect on phenolics content. Cover crop treatments expressed various effects, with the highest impact of dead organic mulch on GSH increase, fodder kale and field pea for vitamin C increase and common vetch for carotenoid increase. In general, increased kernel yield was followed by carotenoid increase and phenolics decrease, while application of Uniker showed diverse results, increasing P_{phy} and decreasing vitamin C, parallel with kernel yield increase.

Acknowledgments

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