THE YIELD AND SUGAR CONTENT OF SWEET CORN CULTIVATED IN ORGANIC PRODUCTION SYSTEM

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Abstract: *In organic and integrated production systems, application of biofertilizers and different species of microorganisms plays an important role, and its activity can influence the increase of total soil fertility, and therefore the yield and quality of safe food products. A two-year research (2011 and 2112) was conducted on the experimental field of the Institute of Field and Vegetable Crops, in the Department of organic agriculture and biodiversity in Backi Petrovac site, in order to determine whether different treatments with Azotobacter chroococcum and different concentrations of organic fertilizer Guana have influence on yield and total sugar content in the sweet corn grain. Applied concentrations of Azotobacter and foliar application of Guana did not affect the significant differences in the yield and the moisture of grain, however, significant differences were observed in the total sugar content. Increasing concentrations of Azotobacter resulted in an increase in sugar content. Also, on the average, foliar application of Guana increased the total sugar content for 1.8%.*

Key words: *sweet corn, sugar content, organic farming, Azotobacter*

INTRODUCTION

Number of organic producers and areas under certified organic food production in Serbia, and especially in Vojvodina has been constantly increased due to growing demands of market for safe food products. In systems of organic production, production of sweet corn that is used for only for human nutrition can be of high importance.

Sweet corn (*Zea mays* L. var. *saccharata*), as well as other corn varieties, originates from Central America, where it has been grown for over 7000 years. The United States of America are the greatest producers of sweet corn in the world, however, lately it has become more popular in Europe, and year after year, in our country consumption has been increasing as well. Sweet corn is used in the milk stage of maturity, fresh, i.e. directly in ears, boiled or roasted, as a side dish or dessert; or for industrial processing (canning or freezing), when uniform size and shape of the ears are demanded. Sweet corn for industrial processing can be canned in whole grains, by canning of the corn cream, by freezing of the sawn grain, or by freezing of the whole ear.

Sweet corn differs from other corn types by presence of one or more recessive genes that change synthesis of starch in endosperm, and corn is used as vegetable (PAJIĆ *et al.,* 2008). In human nutrition it is used in the milky stage of endosperm development, when grain is sweet, soft and juicy, i.e. contains high level of starch that gives it sweet taste. Grain quality of this corn therefore primarily depends upon sugar content, and for consumption of fresh sweet corn especially appreciated are taste (sweetness), as well as appearance, shape and uniformity of ears. Besides, very important feature of sweet corn is also uniformity in ears ripening (MARSHALL, 1987). According to FLORA AND WILEY (1974), primary components of sweet corn in nutrition are linked with consumers' demands such as grain taste, texture and flavor. In sweet corn grain endosperm are deposited sugars, that later transit into starch. Saccharose, glucose and fructose are three main components contributing to the total content of the soluble sugar in grain (EVENSEN AND BOYER, 1986). The highest quality of the sweet corn is during highest saccharose content in grain, 21-24 days after fertilization, during the optimum harvest time – technological maturity of sweet corn (JUGENHEIMER, 1976). Harvest is performed by ripping of ears with cob in order not to hurt grains. From the same reason, all hybrids for industrial processing should be adapted to mechanized harvesting, husking and cutting of the grain.

In systems of organic plant growth, use of *biofertilizers,* i.e. different types of microorganisms that by their activity can have impact on increase of soil biogeny and its fertility in whole, plays an important role. Application of some bacterial species could reduce use of certain quantities of nitrogen and phosphorous mineral fertilizers and in such a manner profitability of corn production could be increased *(*GOVEDARICA *et al.*, 2001). Further, soil biogeny would also be increased and ecological and highly valuable product would be produced. Application of biofertilizers can result in cheaper, ecological and highly valuable food (HAJNAL AND GOVEDARICA, 2004). Microorganisms-diazotrophs play a key role in the process of fixation of elemental nitrogen, translating it into an organic form that is available to plants and other microorganisms (HAJNAL et al., 2004), and production of certain active substances, such as hormones and vitamins, can also have effect on yield increase and quality. *Azotobacter* is aerobic nitrogen fixing bacteria in the soil, whose existence is of special importance for plant nutrition with nitrogen. The same authors report the results of field and laboratory trials in which they showed that a diazotrophs have significant impact on increasing in grain quality, biomass, soil structure, nitrogen content in the soil, as well as on corn yield.

The aim of this research was to determine whether there are differences in the content of total sugars in grain corn, depending on different treatments with *Azotobacter chroococcum* and different concentrations of organic fertilizer Guana.

MATERIAL AND METHODS

During 2011 and 2012, researches were conducted on the experimental field of the Institute of Field and Vegetable Crops, in the Department of organic agriculture and biodiversity in Backi Petrovac site. The trial was set up on a plot certified for organic production, as two factorial split-plot design in four replications. In the trials four corn hybrids were tested, of which only one sweet corn - ZP 555su. Before sowing corn seed was treated by pure *Azotobacter chroococcum* culture in three descending concentrations: A1 ($1x10^8$), A2 ($1x10^6$) i A3 ($1x10^4$ cell/ml inoculum), plus control – untreated variant (C). Four corn rows were sown with inter row distance of 75 cm, with 24.6 cm distance between plants in a raw. Preceding crop to corn was soybean. Sweet corn was sown in optimal cropping practices deadline for conditions in Vojvodina; on 20th April, 2011, i.e. 23rd April, 2012. In the phase of corn intensive growth, fertilizer *Guana* (FG) was folliary applied in 2% solution (treatment A1), 4% (treatment A2) and in 6% solution (treatment A3). Corn harvest was performed in optimal agrotechique deadline, i.e. in the milk stage of maturity (technological ripening for sweet corn), to ensure high sugar content in grain. Sweet corn milk stage of maturity is short, which among other things depends also from the air temperature, so that the optimal time for harvests lasts only a few days. After the harvest, ear yield was determined (t ha^{-1}) and the average grain samples from ten ears per each variant and replication were taken, total sugar content (%) was determined in absolute dry matter of the grain according to the method of Luff – Schoorl (MATISSEK et al., 1992) and moisture content in grain was established by the method of drying in the owen at 105 ^oC. Statistical data analysis (ANOVA) was performed by the software Genstat Release 9.1. (Rothamsted Experimental Station, Trial version).

Weather conditions in the analyzed years (Table 1) indicate that both years were very dry. In comparison to several years lasting average values (LTA – Long-term averages for period 1964-2012); in 2011 growing season there were only 212 mm of precipitations, i.e. for 148 mm less than in LTA (360 mm). In 2012 growing season, in relation to the LTA, precipitations were for 130 mm lower. However, in 2011, winter reserves of moisture in the period October-March were somewhat more convenient, i.e. 266 mm in comparison to 2012 with only 200 mm; i.e. 55 mm less in relation to the LTA values.

Temperature conditions in the analyzed years also did not favor growing of sweet corn. In both years the mean temperature values for all growing season were higher in comparison to LTA; which was particularly pronounced in three critical summer months (June, July, August) when mean monthly air temperatures significantly exceeded the LTA values (Table 1).

Table 1.

Precipitation and temperature conditions at Rimski Šančevi experimental station (N 45° 19`, E 19° 50`)

Year		Month												GS[1]	WP[2]	Yearly (1st Oct-30th Sept)
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec			
T (°C)	2011	0,1	-0,2	6,0	13,2	16,8	20,9	22,1	23,0	20,4	10,7	2,8	4,2	**19,4**	**-**	**11,7**
	2012	2,0	-5,0	8,0	13,0	17,2	22,5	25,0	24,3	20,5	13,7	9,9	2,7	**20,4**	-	**12,8**
	LTA[3]	**-0,4**	**1,5**	**6,3**	**11,6**	**16,9**	**20,0**	**21,7**	**21,2**	**16,9**	**11,5**	**6,1**	**1,4**	**18,1**	-	**11,2**
P (mm)	2011	25	37	26	23	63	37	62	2	25	35	2	49	**212**	**266**	**478**
	2012	43	67	4	83	51	31	48	4	14	48	36	55	**230**	**200**	**430**
	LTA[3]	**39**	**34**	**38**	**48**	**60**	**87**	**68**	**58**	**47**	**47**	**50**	**50**	**360**	**255**	**617**

[1]GS – Growing season (Apr-Sept); [2]WP – Winter precipitation (Oct-Mar), [3]LTA – Long-term averages (1964-2012)

RESULTS AND DISCUSSIONS

F-test from the Analysis of variance of the studied properties (Table 2) show that only conditions of the year (Y) had statistically high influence on ear yield and moisture content in sweet corn grain, while effects of the applied treatments (T) and Y x T interactions were insignificant. However, concerning the total sugar content in grain, beside conditions of the year, applied treatments had highly significant influence (F-pr. = 0,008**). In total variability of the sugar content in grain, conditions of the year proved dominant (78%) with the impact of the treatments of 6% (s.s.(%) - percentage of individual variation sources in sum of squares).

Table 2

Analysis of variance (ANOVA) of ear yield, moisture content and total sugar content in grain of sweet corn

Analysis of variance		Ear yield			Moisture content			Total sugar content		
Source of variation	**d.f.**	**s.s.**	**s.s (%)**	**F-pr.**	**s.s.**	**s.s (%)**	**F-pr.**	**s.s.**	**s.s (%)**	**F-pr.**
Replication	3	29.64	2		35.345	19		6.943	1	
Years (Y)	1	976.56	68	**<.001****	20.942	11	**0.003****	906.612	78	**<.001****
Treatments (T)	7	12.96	1	0.983^{ns}	17.879	10	0.321^{ns}	75.115	6	**0.008****
Y x T	7	7.31	1	0.997^{ns}	12.869	7	0.541^{ns}	27.104	2	0.350^{ns}
Residual	45	409.91	29		95.573	52		151.522	13	
Total	63	1436.37	100		182.608	100		1167.296	100	

d.f. – degrees of freedom, s.s. – sum of square, F-pr. – probability of the F-test of ANOVA

** - Significant at the level α=99%; ^{ns} - not statistically significant

In 2011, ear yield in all trial treatments was significantly higher in comparison to 2012, but within certan treatments, statistically significant differences were not observed in any year (Table 3). In 2011 the average yield of 19.81 t ha^{-1} was for 7.81 ha^{-1} higher in comparison to 2012 (12.00 ha^{-1}), which can be explained by somewhat more convenient climatic conditions in 2011, i.e. lower temperatures in the critical period for corn – Jun, July and August; as well as significantly higher reserves of winter moisture in the soil (Table 1).

Analysis results of the moisture content during ear harvest show that moisture content in grain was rather equalized in test variants, and in 2011 it was within a range of 66.6% (C+FG) to 68.3% (in variant A2+FG); i.e. in 2012 it was 67.4-70.3%. The applied concentrations of *Azotobacter* and foliar application of Guana did not have effect to significant differences in grain moisture content in any of the analyzed years.

Table 3

Effect of various concentrations of Azotobacter (A1-A3) and foliar application of Guana (FG) on the Ear yield, Moisture content and Total sugar content in absolute dry matter of sweet corn grain

Treatments (T)	**Ear yield (t ha^{-1})**			**Moisture content (%)**			**Total sugar content in absolute dry matter (%)**		
	Year (Y)		**Average (T)**	**Year (Y)**		**Average (T)**	**Year (Y)**		**Average (T)**
	2011	**2012**		**2011**	**2012**		**2011**	**2012**	
C	19.31	12.00	**15.66**	67.7	68.4	**68.1**	15.4	21.7	**18.6**
C+FG	19.39	11.44	**15.42**	66.6	68.4	**67.5**	16.8	25.1	**21.0**
A1	20.36	12.67	**16.52**	67.3	67.4	**67.3**	17.2	22.6	**19.9**
A1+FG	19.17	12.44	**15.81**	67.9	70.3	**69.1**	16.4	24.4	**20.4**
A2	20.58	11.31	**15.95**	67.6	69.5	**68.6**	14.7	23.8	**19.3**
A2+FG	20.03	12.11	**16.07**	68.3	68.0	**68.1**	17.4	23.4	**20.4**
A3	20.56	12.64	**16.60**	67.3	68.5	**67.9**	13.5	22.1	**17.8**
A3+FG	19.11	11.39	**15.25**	67.4	68.8	**68.1**	16.9	25.3	**21.1**
Average (Y)	**19.81**	**12.00**	**15.91**	**67.5**	**68.7**	**68.1**	**16.0**	**23.6**	**19.8**
LSD	Y	T	YxT	Y	T	YxT	Y	T	YxT
0,05	1.52	3.04	4.30	0.7	1.5	2.1	0.9	1.8	2.6
0,01	2.03	4.06	5.74	1.0	1.9	2.8	1.2	2.5	3.5

However, significant differences between treatments were observed in the total sugar content in grain (Table 3).

In 2011, the average sugar content in absolute dry matter of sweet corn grain was 16.0%, within a range of 13.5 to 17.4%. The highest total sugar content was obtained in variant with medium concentration of Azotobacter and with foliar application of 4% Guana solution (A2+FG), while the lowest content (13.5%) was recorded in treatment with the lowest Azotobacter concentration (A3), without foliar application of Guana. Similar results were obtained by LATKOVIĆ *et al.* (2012).

Descending concentrations of Azotobacter had impact on almost linear decline in sugar content (Figure 1, left), while simultaneous increase of Guana concentration led to increase in the total sugar content in grain, mostly in combination with medium Azotobacter concentration (A2+FG). In 2011, in average, foliar application by Guana increased total sugar content for 1.7%.

In 2012, statistically significantly higher sugar content was obtained (in average 23.6%; Table 3), i.e. almost 7.6% higher in comparison to the previous year. Such results can be explained by differences in prevailing climatic conditions in two years, for it is known that in dry conditions majority of cultivated plants concurrently with lower yields mostly provide higher quality, in this case expressed through increase in the total sugar content in grain.

In 2012 the highest total sugar content (25.3%) was obtained in variant with the lowest Azotobacter concentration and with foliar application of 6% Guana solution (A3+FG), as well as in variant C+FG (25.1%). In 2012, in average, foliar application by Guana increased the total sugar content for 2.0% (Figure 1, right).

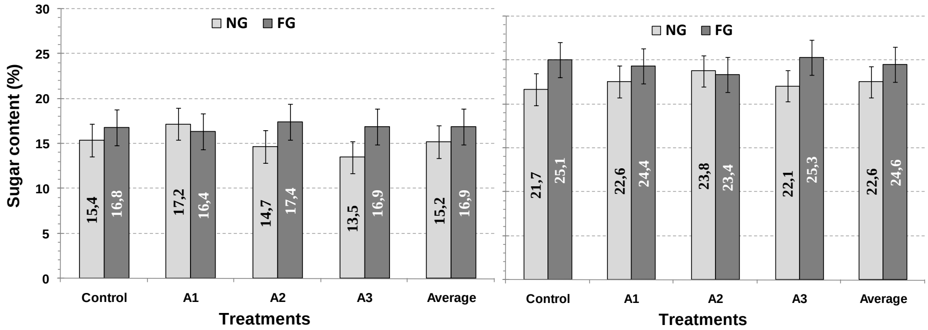

Figure 1. Sugar content at different variants with (FG) and without (NG) foliar application of Guana in 2011 (left) and 2012 (right)

For both of the analyzed years, in average, foliar application by Guana increased the total sugar content in grain for 1.8% (Figure 2). Statistically significant differences in the total sugar content in variants with and without Guana application occurred in control variant and in variant in combination with the lowest Azotobacter (A3), in which use of Guana increased the total sugar content for 2.4, i.e. 3,3%, respectively.

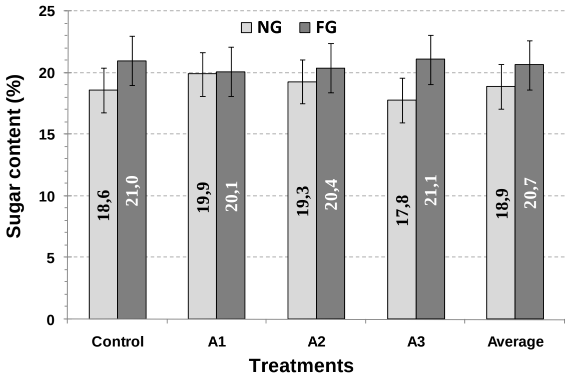

Figure 2. Sugar content at different variants with (FG) and without (NG) foliar application of Guana in average for two years (2011 and 2012)

In researches of GOVEDARICA *et al.* (2001) it was established that tested bacteria species *Azotobakter chrococcum* and *Bacillus megaterium*, individually or in combination, caused increase in yield in two corn hybrids, which was not confirmed by our researches. However, authors also reported that the total number of microorganisms, number of ammonifiers, actinomycetes, Azotobacter, oligonitrophilic bacteria and dehydrogenase activity in the soil increased, but number of fungi decreased; which in longer terms can have possitive effect to the soil quality and overall soil fertility, and therefore to the height of crop yield. In their research on effects of five strains of *Azotobacter chroococcum* and *Bacillus megaterium*, as well as efficiency of their combinations, HAJNAL *et al.* (2004) and HAJNAL AND GOVEDARICA (2004) reported that bacterization of corn seed with individual or joint strains of these bacteria affected increase in corn yield and increase in mycrobiological activity in the soil.

CONCLUSIONS

Statistically significant effect to ear yield and moisture content in sweet corn grain showed only conditions of the year, while effects of the applied treatments were not significant. However, relative to the total sugar content in grain, beside conditions of the year, the applied treatments also showed significant effect, especially foliar application of Guana.

In 2011, ear yield was significantly higher in comparison to 2012, in between different treatments statistically significant differences in any year were not observed. However, in 2012 statistically significantly higher sugar content was recorded (in average 23.6%), i.e. for 7.6% higher in comparison to 2011.

For both of the analyzed years in average, foliar application of Guana increased the total sugar content for 1.8%. Statistically significant differences in the total sugar content in variants with and without Guana application were observed in control and in variant in combination with the lowest Azotobacter (A3) concentration, in which application of Guana increased sugar content for 2.4, i.e. 3.3%, respectively.

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