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SWEET MAIZE (*ZEA MAYS* L. *SACCHARATA*) WEEDS INFESTATION, YIELD AND YIELD QUALITY AFFECTED BY DIFFERENT CROP DENSITIES

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Abstract

SIMIC, M., J. SRDIC, Z. VIDENOVIC, Z. DOLIJANOVIC, A. ULUDAG and D. KOVACEVIC, 2012. Sweet maize (*Zea mays* L. *saccharata*) weeds infestation, yield and yield quality affected by different crop densities. *Bulg. J. Agric. Sci.,* 18: 668-674

Weeds are among main limiting factors in sweet maize production. Commercially grown sweet corn hybrids (*Zea mays saccharata* Sturt.) vary widely in competitive ability against weeds which interference differentially affects yield and ear traits important to processing and fresh markets. A total of 28 sweet corn hybrids of different FAO maturity groups have been developed at the Maize Research Institute, Zemun Polje, and released by the the Commission for the Variety Releasing. In order to obtain high yields of good quality the scientists have been searching for the most appropriate growing practices. Therefore the objective of the present study was to determine the effect of four plant densities (40 000, 50 000, 60 000, and 70 000 plants/ha) on the level of weed infestation, yield and shelling percentage of four sweet maize hybrids (ZP 424su, ZP 462su, ZP 504su, and ZP 521su) in 2008 and 2009. Total fresh weight and the total number of weeds decreased with increasing sowing density, which was more prominent in 2008. Results of the analysis of variance showed that investigated factors, year, sowing density and hybrid had significant influence on fresh ear yield and shelling percentage. Sowing density affected fresh ear yield in the way that the denser sowing was, the higher yield was. Hybrids ZP 424su and ZP 462su gave higher fresh ear yields than other two. However, hybrids with less fresh ear yield (ZP 504su and ZP 521su) gave better shelling percentage. These results suggest that ZP 424su and ZP 462su can be preferable for fresh consumption and ZP 504su and ZP 521su for processing.

Key words: sweet maize (*Zea mays* L. *saccharata*), crop density, weeds, fresh ear yield, shelling percentage

Introduction

Sweet maize (*Zea mays* L. *saccharata*) is a vegetable crop with an important dietary significance. It has been consumed boiled, roasted or as adding to salads, pizzas etc. Although it has been grown on a small acreage, e.g. 5,000 ha in Serbia, it is a cash source for farmers, and furthermore expansion of growing areas is expected due to the increased usage (Pajić and Srdić, 2007).

Weeds are problem in sweet maize as well as in field maize production. Season-long weed interference resulted in 15% sweet maize yield loss in late planting and up to 85% yield loss in early planting (Williams, 2006). Furthermore, sweet maize is considered a week competitor because of its shorter and less developed habitus, which makes improved weed management systems a priority. Even low densities of weeds also caused sweet maize yield losses (Williams, 2010). As

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much as 1 *Ambrosia trifida* plant in 25 m^2 area caused 5 % loss in sweet maize ear mass (Williams and Masiunas, 2006) while 10.5 individual in 25 m^2 caused 5 % yield loss in field maize (Harrison et al., 2001). Both broadleaf and grass weeds infest sweet maize fields. In organically produced sweet maize, the most dominant weeds were *Digitaria sanguinalis* (L.) Scop., *Setaria faberi* Herrm., *Amaranthus hybridus* L. (Silvernail, 2005). *Panicum miliaceum*, *Ambrosia trifida*, and *Sinapis arvensis* are considered the most troublesome weeds in sweet maize (Davis and Liebman, 2001; Williams et al., 2008b).

Increasing environmental problems and concern on health issues has driven to develop new techniques and systems to deal with pests. Integrated weed management (IWM) is one of these approaches. IWM systems tend to efficiently use competitive ability of crops for weed suppression (Tollenaar et al. 1994; Williams et al., 2008a). Growing conditions (crop cultivation, floristic composition and weed distribution), as well as, biological traits of the crop (the growth rate and development during the growing season, maximum plant height and the leaf cover, etc.), notably affect crop competitiveness against weeds (Simić et al., 2009; Uremis et al., 2010). A correctly selected plant density in accordance with the genotype could be a mode to make a crop more competitive against weeds, while at the same time, herbicides can be applied in lower rates (Simić et al., 2007).

Sweet maize hybrids similar to standard field maize hybrids differently response to plant densities depending on genotypes and their maturity group (Turgut, 2000; Moris et al., 2000; Rangarajan et al., 2000). The longer the maturity group (FAO), the higher total aboveground biomass is (Garcia y Garcia et al., 2009). At Maize Research Institute, Zemun Polje, Serbia 28 sweet maize hybrids of different FAO maturity groups have been released since 1970, with good agronomic and excellent properties of quality (Pajić et al., 2010). It is important to determine the most suitable agronomic techniques for each variety too. The objective of the present study was to determine the effect of sowing densities and different sweet maize hybrids on weed infestation and on sweet maize fresh ear yield and its shelling percentage.

Materials and Methods

Site description

Field experiments were conducted in 2008 and 2009 at Maize Research Institute, Zemun Polje, near Belgrade (44°52’N 20°20’E) in Serbia. The soil was slightly calcareous chernozem with 47% clay and silt and 53% sand. The soil properties at 0-30-cm layer were 3.3% organic matter, 0.21% total N, 1.9% organic C, 14 and 31 mg per 100 g soil of available P and extractable K, respectively, 9.7% total $CaCO_3$ and pH 7.8, on average.

Winter wheat was the preceding crop each year. The experimental area was ploughed in autumn, followed by one pass of disk harrow and field cultivator prior to sowing. The fields received 90 kg/ha N, 90 kg/ha P and 90 kg/ha K in the mid October each year and 69 kg/ha N in the form of urea was incorporated into the soil in spring. The crop was manually sown on April 23rd in both years.

There was difference between two years in meteorological conditions. Average monthly air temperatures were similar in both years, but sum of precipitation and especially its distribution, were different in 2008 and 2009. Higher and evenly distributed precipitation in all months of cropping season was in 2008; but less precipitation was in 2009 and its distribution clearly varied among months, which was high in June and scarce in April. The high precipitation in June 2009 might be favourable for maize as well as weeds (Table 1).

Table 1
Average monthly air temperatures and monthly precipitation sums from April till September at Zemun Polje

Months	Temperature, °C			Precipitation, mm		
	2008	2009	1998-2007	2008	2009	1998-2007
April	14.1	15.8	13.3	27.3	7.3	52.6
May	19.3	19.8	18.2	39.7	27.4	44.3
June	23	21	21.7	36.3	71.9	89.6
July	23.5	24.1	22.5	46.2	31.2	56.6
August	24.2	23.9	20.5	19.7	36.6	56.8
September	17.5	20.6	17.9	54.4	4	50.9
Average/ Sum	20.3	20.9	19	223.6	178.4	320.8

Experimental design

The experiment was in factorial setting with two factors (sowing density and genotype) in RCBD with three replications. Sweet maize was sown in four different densities: D_1- 40 000 plants/ha; D_2-50 000 plants/ha; D_3-60 000 plants/ha and D_4-70 000 plants/ha. The inter-row distance was 70 cm for all plant densities, while the within-row plant distance was 35, 28, 24 and 20 cm regarding to experimental densities. In order to ensure given densities two kernels per hill were sown and then thinned to one plant in the 3-leaf stage. The two new Zemun Polje (ZP) sweet maize hybrids from FAO 400 maturity group ZP 424su (H_1) and ZP 462su (H_2) and one from FAO 500 maturity group ZP 521su (H_4) were sown. The well-known ZP 504su from maturity group FAO 500 (H_3) was used as a standard. The combination of herbicides, acetochlor + therbuthilyzine, was applied pre emergence in the rate of 1800 + 1000 a.i g/ha, respectively. A hand-held sprayer with capacity of 15 l at 300 kPa with a flat-fan nozzle (Teejet, 1.4 mm E 04-80) was used. The main plot size was 78.4 m^2 (7.0 m by 11.2 m) and sub-plot size for hybrids was 19.6 m^2 (7.0 m by 2.8 m, which consisted of 4 crop rows). Crops were harvested 22-24 days after pollination for each hybrid (Table 2).

Measurements and statistical analysis

Weed species were separately counted and uprooted to determine fresh weight in two 0.25 m^2 squares, which is placed in the middle of the each main plot a month after the herbicide application. All ears in two inner rows of each subplot were harvested and weighted without husk. Furthermore, a shelling percentage, as a kernel weight to ear without husk weight ratio, was determined in a sample of 10 randomly selected fresh ears.

Table 2
Harvest date of sweet maize hybrids in 2008 and 2009

Hybrids	Year	
	2008	2009
ZP 424su	24 July	3 August
ZP 462su	25 July	6 August
ZP 504su	25 July	6 August
ZP 521su	24 July	3 August

Fresh ear yield and shelling percentage data were calculated by ANOVA for the three factorial trial (two years, four densities and four hybrids), and differences between means were tested by the least significant difference (LSD) test (Gomez and Gomez, 1984).

Results

In sweet maize weed association, both perennial and annual species were determined. Perennial weed species were recorded in both years but they were not exactly the same: *Convolvulus arvensis*, *Sorghum halepense* and *C. sepium* in 2008 and *C. arvensis*, *S. halepense* and *Cirsium arvense* in 2009. The remaining weeds were annual species (Tables 3 and 4). The number of weed species recorded in both years was similar: ten and eleven in 2008 and 2009, respectively and seven species made the basic spectrum-*Chenopodium hybridum*, *Datura stramonium*, *Solanum nigrum*, *Hibiscus trionum*, *Sorghum halepense*, *Abutilon theophrasti* and *Convolvulus arvensis*.

The lowest total number and fresh weight of weeds were detected in D_4 in both years- 24.0 plants/m^2 and 228.9 g/m^2 (2008) and 28.0 plants/m^2 and 520.4 g/m^2 (2009). The greatest total fresh weight was 612.3 g/m^2 (D_2) in 2008 and 934.0 g/m^2 (D_3) in 2009. Even though differences in weed parameters between sweet maize sowing densities are obvious, they are not significant (Table 5). Only year had significant influence on weed biomass, which is connected with meteorological conditions.

Results of the analysis of variance (Table 6) showed that investigated factors, year, sowing density and hybrid had significant influence on the observed traits. Different metrological conditions in the two years had significant impact on the variability of fresh ear yield as well as on the quality production of sweet maize. Effect of the sowing density produced significant variations in both traits and significant differences among hybrids were found both concerning fresh ear yield and shelling percentage. All the interactions between investigated factors produced significant variations, except the Year x Hybrid interaction in fresh ear yield.

The highest average fresh ear yield was obtained from ZP 424su (11.39 t/ha) followed by ZP 462su and

Table 3
Weed species, weed number and weed fresh weight depending on sweet maize densities in 2008

Weed species	Sweet maize density							
	D_1		D_2		D_3		D_4	
	N*	B**	N	B	N	B	N	B
Solanum nigrum	18.7	95.5	10.7	95.7	12	91.7	13.3	73.6
Convolvulus arvensis	6.7	90.7	5.3	141.7	6.7	53.6	5.3	70
Sorghum halepense	2.7	70.7	4	170.7	1.3	32.5	4	77.5
Datura stramonium	2.7	150.1	1.3	61.7	-	-	1.3	7.9
Convolvulus sepium	1.3	6.5	1.3	81.5	-	-	-	-
Hibiscus trionum	1.3	26	-	-	4	56.4	-	-
Chenopodium hybridum	-	-	2.7	38.4	4	23.3	-	-
Digitaria sanguinalis	2.7	32.1	1.3	12.3	-	-	-	-
Abutilon theophrasti	1.3	15.1	-	-	-	-	-	-
Amaranthus albus	-	-	1.3	10.3	-	-	-	-
Sum	37.3	486.7	28	612.3	28	257.6	24	228.9

* N means the number of weeds per m^2
** W means biomass of weeds (g/m^2)

Table 4
Weed species, weed number and weed fresh weight depending on sweet maize densities in 2009

Weed species	Sweet maize density							
	D_1		D_2		D_3		D_4	
	N*	B**	N	B	N	B	N	B
Datura stramonium	6.7	237.9	2.7	70.5	6.7	315.9	4	75.3
Chenopodium album	8	110.4	2.7	102.7	2.7	156	4	88.4
Chenopodium hybridum	12	169.3	6.7	108.9	4	61.9	5.3	110.5
Convolvulus arvensis	4	142.3	8	143.6	1.3	30.9	5.3	108
Amaranthus hybridus	5.3	80.7	1.3	109.3	2.7	154.3	-	-
Cirsium arvense	2.7	71.2	1.3	53.5	1.3	18.4	2.7	76.5
Xanthium strumarium	1.3	17.7	1.3	48.9	1.3	108.7	1.3	31.1
Abutilon theophrasti	1.3	34.3	2.7	104.4	1.3	28.8	1.3	20.1
Sorghum halepense	1.3	19.1	2.7	9.6	2.7	47.6	1.3	6.4
Hibiscus trionum	1.3	5.3	1.3	21.2	-	-	-	-
Solanum nigrum	1.3	6.3	-	-	2.7	11.3	2.7	4
Sum	45.3	894.4	30.7	772.7	26.7	934	28	520.4

* N means the number of weeds per m^2
** B means biomass of weeds (g/m^2)

ZP 521su, while the standard ZP 504su had the lowest fresh ear yield which was significantly lower from all the others in 2008(Table 7). The ZP 462su gave the highest fresh ear yield (10.89 t/ha) and the lowest fresh ear yield was like in the previous year, produced by ZP 504su (9.10 t/ha) in 2009. Average fresh ear yield in 2008 was higher than in 2009 while it was opposite for average shelling percentage. In 2008, the highest shelling percentage produced hybrid ZP 521su which was among the lower yielding hybrids. The lowest yielding hybrid ZP 504 had the highest shelling percentage, which in 2009 was 76.70 %.

Average fresh ear yield also significantly varied over sowing densities and the higher density was the higher yield was (Table 8). Hence the highest average fresh ear yield (11.45 t/ha) was in the highest sowing density

Table 5
ANOVA for number of weed plants (No/m²) and weed biomass (g/m²)

Sources of variance	Degrees of freedom	Mean square	
		No of weed plants	Weed biomass
Year	1	0.46ns	10.25***
Sowing density	3	2.05ns	1.55ns
Year x S. density	3	0.15ns	0.83ns

** - significant at 0.001 probability level; ns – not significant

Table 6
ANOVA for fresh ear yield and shelling percentage

Sources of variance	Degrees of freedom	Mean square	
		Fresh ear yield, t/ha	Shelling percentage, %
Year	1	9.47**	1960.14**
Sowing density	3	20.77**	22.61**
Hybrid	3	17.26**	51.15**
Year x Sowing density	3	4.82**	46.81**
Year x Hybrid	3	0.63ns	145.87**
Sowing density x Hybrid	9	1.51**	13.63**
Year x S.density x Hybrid	9	2.44**	19.24**

** - significant at 0.01 probability level; ns – not significant

Table 7
Effects of the year and genotype and their interaction on fresh ear yield and shelling percentage

Hybrid	Fresh ear yield, t/ha		Shelling percentage, %	
	2008	2009	2008	2009
ZP 424su	11.39	10.61	62.66	70.92
ZP 462su	11.26	10.89	62.7	67.46
ZP 504su	9.44	9.1	60.6	76.7
ZP 521su	10.65	9.64	63.15	70.17
Average	10.67	10.06	62.27	71.31

(70 000 plants/ha). Hybrid ZP 462su had the highest average yield 11.07 t/ha and it was especially productive in sowing density of 60 000 plants per ha. The highest yield (12.24 t/ha) was recorded in the highest sowing density for the ZP 424su. The lowest yielding hybrid was ZP 504su (9.27 t/ha, average), and its yield in different sowing densities was significantly lower than yields of other hybrids. Hybrid ZP 521su had the highest shelling percentage in 2008 and ZP 504su in 2009 (Table 7). The highest average shelling percentage was recorded for the hybrid ZP 504su (68.65 %) and it was especially high in the lowest planting density (72.11%) (Table 8).

Discussion

Observed weed species belong to the *Hibisco-Eragrostietum*, Tx 1950 association which is mainly distributed in row field crops in Serbia and has been reduced due to applied cropping practices. Therefore, the distribution of terophytes is dominant while several geophytes are permanently present (Stefanović, 1984). The greatest effect of maize density is on robust, heliophilic, broad-leaf weed species, such as *D. stramonium* and *A. theophrasti* (Teasdale, 1998; Oljača, 2000). The species, *Abutilon theophrasti*, *C. sepium* and *Digitaria sanguinalis*, requiring greater amounts of light were not present in higher plant densities in 2008. Among these three species, only *A. theophrasti* was recorded in 2009 of which density was similar but fresh weight was less in higher densities. Our results are in parallel with research that indicated that the increased maize density resulted in decrease of the number of species, number of plants per species and the weed fresh weight (Tollenaar et al., 1994; Williams et al., 2007).

Lower precipitation in the April in 2009 influenced efficiency of the soil-applied herbicides and caused greater number of species, individual plants and fresh weight of weeds in 2009 than in 2008. Higher precipitations in June (71.9 mm) in 2009 also might cause higher plant emergence and growth, which was reflected in both parameters due to time of weed scoring. The number of weed species changed depending on sweet maize density. The lowest number of weed species was determined in D_4 in both years, i.e. four species in 2008 and nine in 2009 while the highest number of species was determined in D_1 in both years.

Average fresh ear yield was higher in higher sweet maize density. In fact, growing maize in higher plant densities can be a good way to reduce the level of

Table 8
Effects of sowing density and genotype and their interaction on fresh ear yield and shelling percentage

Hybrid	Fresh ear yield, t/ha					Shelling percentage, %				
	D_1	D_2	D_3	D_4	Average	D_1	D_2	D_3	D_4	Average
ZP 424su	9.85	10.43	11.48	12.24	11.00a	66.89	67.66	66.51	66.08	66.79ab
ZP 462su	9.72	10.75	12.11	11.73	11.07a	66.22	65.27	65	63.85	65.08b
ZP 504su	8.41	9.38	8.67	10.63	9.27c	72.11	69.02	64.97	68.5	68.65a
ZP 521su	9.21	9.43	10.73	11.21	10.14b	65.93	67.76	66.47	66.48	66.66ab
Average	9.30d	10.00c	10.74b	11.45a		67.79a	67.43ab	65.74b	66.23ab	
	$LSD_{0.05} = 0.49$					$LSD_{0.05} = 2.00$				

weed infestation and at the same time to achieve higher yields (Simić et al., 2007). Many studies of the effect of sowing densities also showed that increased sweet maize densities caused increase in fresh ear yields (Hao, 1999; Akman, 2002; Oktem, 2005). The effect of the increased sweet maize density was more strongly pronounced in more favourable 2008 than in 2009, which confirms the fact that meteorological conditions of the given environment affect the expression of the hybrid competitive ability. The recent studies point out that the growth rate is greater of medium (hybrids in the current study are in this group) and late maturity group hybrids under cooler weather conditions during the growing season, while this rate is greater in early maturity hybrids under warmer weather conditions (Garcia y Garcia et al., 2009).

The results show that ZP 424su and ZP 462su have higher potential to produce higher ear yields than other two hybrids. However, hybrids with less fresh ear yield (ZP 504su and ZP 521su) gave better shelling percentage. These results suggest that ZP 424su and ZP 462su can be preferable for fresh consumption and ZP 504su and ZP 521su for processing. In fact, the hybrid ZP 504su has been the best seller for years among ZP sweet maize hybrids, and the hybrid ZP 521su is a recent result of breeding of maize hybrids with specific properties of increased sugar.

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