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THE GENOTYPE ROLE IN MAIZE COMPETITIVE ABILITY

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Growing competitive crops is an important component of the integrated weed management system, although selection of genotypes with the increased competitive ability is rather difficult. The possibility of reducing weed infestation by increasing the competitive activity of crops by growing genotypes, i.e. hybrids that better "endure" a greater density, depends on the FAO maturity group and morphological properties of a genotype, environmental conditions and the growing regions. The competition between maize and weeds varies over the modified crop arrangement pattern. The greatest weed infestation is recorded in the crops of the sparse-spaced plants, while the height and the weight of weeds are significantly lower in closely-spaced plants. The height, growth intensity in the initial stages, embryo vigour and leaf area of the plant are important for a greater competitive ability, as they are components of competitive effects of crops on weeds.

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Weed infestation and maize hybrids yielding were studied in dependence on the hybrids arrangement pattern and the application of herbicides.

Obtained results show statistically significant differences in the weed fresh weight, but only in certain years and in accordance with differences in the height and the leaf area of ZP maize hybrids.

Key word: competition, genotype, maize, weeds

INTRODUCTION

Some crops can significantly suppress weeds by their ability to grow faster than weeds or to endure greater sowing densities. These are "dense crops" (RADOSEVICH *et al*., 1997; MASON *et al*., 2007; ZERNER *et al*., 2008). The plant competitive ability can be expressed in the following two modes: 1) the crop weed suppressive ability that results in the reduction of weed biomass and 2) the crop tolerance - ability of crops to tolerate weed effects and to have high yields at the same time (BUSSAN *et al*., 1997; DALLEY *et al*., 2006; WILLIAMS II *et al*., 2007). The intensity of competitive effects of crops, especially broadcast crops such as maize and soya bean, is manly determined by the crop density (number of plants per ha) and the plant arrangement pattern (inter-row distance and within-row plant distance), (MURPHY *et al*., 1996; MOHLER, 2001; KNEŽEVIĆ *et al*., 2003; DALLEY *et al*., 2006; SIMIĆ and STEFANOVIĆ, 2007).

The long-term studies carried out in the USA show that the further yield increase in maize can be more easily achieved by increasing the number of plants per area unit that by increasing the yield per plant. In regard to this, new generations of maize hybrids are characterised by a better ability of plants to be grown in denser stand, as they were selected under such conditions. The higher density results in the appearance modification of the maize genotype plant. Older generations of maize hybrids selected in lower densities have, as a rule, more robust plants and less erect top leaves. Newer generations of maize hybrids selected in higher densities (60-100,000 plants ha^{-1}), have less robust plants, ears are placed more lower, while the angle of top leaves in relation to the stalk is smaller.

The competition between maize and weeds changes with the alteration of the plant arrangement pattern. The thin-growing crops are most weed infested, while the weed height and weight are significantly lower in the thick-growing crops. The possibility of weed suppression on the basis of increasing the competitive activity of crops by growing high yielding hybrids that "endure" a greater density depends on the genotype properties, environmental conditions and growing regions (LINDQUIST and MORTENSEN, 1999; FARNHAM, 2001).

The following parameters are important for the increase of maize hybrid competitive ability: time of maize hybrids emergence in relation to weeds, seedling vigour, the growth intensity in the initial developmental stages, rapid development of a high leaf structure, larger leaves, leaves with mosaic venation for better light interception, rapid shoot prolongation and shade tolerance, as well as, the plant height, which are all components of competitive effects of maize against weeds,

(JOENJE and KROPF, 1987; FORCELLA, 1987; ZIMDAHL, 1993). Growing competitive crops is an important component of the integrated weed management, although genotype selection for the increased competitive ability is rather difficult (SWANTON and WEISE, 1991; LEMERLE *et al*., 1996). The role of the crop genotype in weed suppression has received attention over the past 30 years (MOHLER, 2001).

Growing maize hybrids in the adequate plant pattern and with the application of herbicides in lower amounts provide the advantage to the crop over weeds with the simultaneous environmental protection. Weed infestation and yielding of different maize hybrids were studied in relation to the plant arrangement pattern and the herbicides application.

MATERIAL AND METHODS

The three-replicated trial was carried out according to the split-split plot RCB design on slightly calcareous chernozem in the experimental field of the Maize Research Institute, Zemun Polje, during the 2004-2006 periods. The principal factor encompassed the following maize plant arrangement pattern: a) inter-row distance of 70 cm and within-row distance of 25 cm, b) inter-row distance of 50 cm and within-row distance of 35 cm and c) inter-row distance of 35 cm and within-row distance of 50 cm. The plant density was the same in each plant arrangement pattern - 57,143 plants ha^{-1}. The following three rates of herbicides were applied within the filed with the inter-row distance: P - the application of isoxaflutole+acetohlor after sowing but prior to maize emergence in the recommended amount (1500 g ha^{-1}+1536 g ha^{-1} a.i.), PP - the application of the same herbicides in the twofold lower amount that recommended (768 g ha^{-1}+750 g ha^{-1} a.m.) and K - control variant without the application of herbicides. The following three maize hybrids of different FAO maturity groups were grown in each of the stated variants: H_1-ZPSC 434 (FAO 400), H_2-ZPSC 578 (FAO 500) and H_3-ZPSC 735 (FAO 700). The weed samples were drawn three times during the maize growing season in each hybrid and each replicate in the following manner: a month prior to the herbicide application (spring evaluation), three weeks after the first sampling (summer evaluation) and in the period when plants were completely formed (autumn evaluation). After the second (summer) evaluation, all variants were hoed in order to provide yields in the untreated areas. The fresh weight of all weed was analysed with the 0.25 square meter area method and calculated per sample m^{-2}. Simultaneously with weed sampling, the maize plant height was measured. The leaf area per maize plant was measured when plants completed their growth at the time of the autumn evaluation of weeds.

The obtained experimental data were processed by the mathematical-statistical procedure. The analysis of variants for the factorial trials set up according to the split-split plot design for three inter-row distances, three herbicide rates and three hybrids and LSD test at the 0.05 and 0.01 probability levels in the statistical package STATISTICA 8.0 were applied to determine differences among variants.

Table 1 Average monthly air temperature (T) and monthly sum of precipitation (P) from April to September at Zemun Polje

Months	Temperature (°C)			Precipitation (mm)		
	2004	2005	2006	2004	2005	2006
April	12.9	12.4	13.4	27.2	28.2	19.4
May	16.0	17.6	16.9	53.6	3.2	15.2
June	20.3	20.1	20.0	125.0	65.0	57.8
July	21.9	22.4	17.5	66.4	44.0	6.2
August	21.0	20.6	21.1	39.4	64.0	113.1
September	15.7	19.5	19.7	35.8	21.4	17.7
Average/Sum	18.0	18.8	18.1	347.4	225.4	229.4

RESULTS AND DISCUSSION

The effect of the density and the plant arrangement pattern according to which certain hybrids are grown on their morphological and productive properties, as well as, the effect of stated factors on the competitive ability against weeds, are still studied worldwide (SARLANGUE *et al*., 2007), including our country too (SIMIĆ AND STEFANOVIĆ, 2007).

According to gained results, a month after soil herbicides had been applied, the weed fresh mass did not significantly differ among observed maize genotypes, Table 2. The determined differences for the weed fresh weight were statistically very significant only in 2004, whereby the lowest weed fresh weight was detected in the hybrid of the medium maturing group (ZPSC 578). The three year average of the weed fresh weight (g m^{-2}) was also the lowest in the hybrid ZPSC 578, although this hybrid had the lowest average height for all investigation years (Table 3). However, the determined differences in observed hybrids in the spring evaluation were statistically significant in 2004 and 2005.

These results can be explained by the fact that the hybrid ZPSC 578 has the greatest leaf area in a given developmental stage, while at the same time, hybrids ZPSC 434 and ZPSC 735 have very narrow spear-shaped leaves due to which they shade less the soil surface. The stated is also supported by the fact that the maize plant stand was not fully formed in the time of the spring evaluation and that determined differences were more a result of their belonging to a maturing group and genetic properties than of a crop competition against weeds.

Table 2. Weed fresh weight (g m^{-2}) in the spring evaluation

	ZPSC 434	ZPSC 578	ZPSC 735	
2004	630.4a	382.3b	546.0a	$LSD_{0.01}$ = 196.2
2005	194.5	219.0	164.0	ns
2006	410.8	317.6	330.3	ns
Average	411.9	306.3	346.8	

Table 3. Maize hybrid height in the spring evaluation of weed infestation

	ZPSC 434	ZPSC 578	ZPSC 735	
2004	24.9a	22.8b	24.4a	$LSD_{0.01}$ = 1.22
2005	26.7a	24.6b	26.3a	$LSD_{0.01}$ = 1.12
2006	26.0	26.1	25.2	ns
Average	25.9	24.5	25.3	

The fresh weed weight was much higher in the summer than in the spring evaluation, and differences in its value in studied genotypes were not significant, except in 2006, Table 4. The lowest weed fresh weight was registered in the earliest maturity hybrid (ZPSC 434), while the highest weed fresh weight was detected in the latest maturity hybrid (ZPSC 735), whose stages of growth and development were slower due to the duration of a vegetative cycle. The plants of the hybrid ZPSC 434 shaded more quickly the soil surface, because their development was the fastest, while it was vice versa in the late maturing hybrid. The hybrid ZPSC 735 had the shortest average plant height (60.4 cm, Table 5) in the summer evaluation. The differences in the plant height among studied hybrids were significant in 2004 and 2006, when the hybrid ZPSC 735 had a significantly lower height, especially when compared with the hybrid ZPSC 434.

Table 4. Weed fresh weight (g m^{-2}) in the summer evaluation

	ZPSC 434	ZPSC 578	ZPSC 735	
2004	2304.2	2379.5	2463.0	ns
2005	1002.8	1127.6	1140.7	ns
2006	1504.2b	1802.4ab	2068.3a	$LSD_{0.05}$ = 376.9
Average	1603.7	1769.8	1890.7	

Table 5. Maize hybrid height in the summer evaluation of weed infestation

	ZPSC 434	ZPSC 578	ZPSC 735	
2004	68.3a	66.6ab	64.8b	$LSD_{0.01}$ = 2.89
2005	63.3	64.6	62.6	ns
2006	58.2a	58.0a	53.7b	$LSD_{0.01}$ = 2.78
Average	63.3	63.1	60.4	

Weeds re-grew after summer hoeing and in dependence on meteorological conditions in the second part of the growing season had smaller or greater total fresh weight per m^2, Table 6. The highest values of the weed fresh weight were recorded in 2006, when the differences in these values were statistically very significant depending on a hybrid. The weed fresh weight in the autumn evaluation was the highest in the hybrid ZPSC 578, as a result of the smallest index leaf angle. Due to this, sunlight penetration to the soil surface was the greatest in this hybrid (RADENOVIĆ *et al*., 2008). Thereby, the growth and the development of weeds, emergence of new, late summer species were expedited to a great extent. On the average, the weed fresh weight was the lowest in the hybrid ZPSC 735 (667.2 g m^{-2}). This hybrid had the greatest value of the total leaf area per plant in the autumn evaluation, wherewith it was the most competitive against weeds, Table 7. The index leaf angle in this hybrid was the greatest in comparison to the hybrids ZPSC 434 and ZPSC 578, and thereby, shading of the soil surface was greater. In addition, the total number of leaves and top leaves was the greatest in the hybrid ZPSC 735.

Table 6. Weed fresh weight (g m^{-2}) in the autumn evaluation

	ZPSC 434	ZPSC 578	ZPSC 735	
2004	477.7	431.8	356.8	ns
2005	992.3	945.3	1067.4	ns
2006	737.9ab	1077.0a	577.4b	$LSD_{0.01}$ = 328.6
Average	736.0	818.0	667.2	

The leaf area (LA) significantly differed among studied ZP maize hybrids over all investigated years. The greatest LA values were recorded in the hybrid ZPSC 735 (7402.6 cm^2), whose plants are robust and high.

Table 7. LA of maize hybrids

	ZPSC 434	ZPSC 578	ZPSC 735	
2004	6081.7b	6028.2b	8147.2a	$LSD_{0.01}$ = 441.9
2005	5076.4c	5609.6b	6858.1a	$LSD_{0.01}$ = 316.0
2006	5201.8b	5163.1b	7202.4a	$LSD_{0.01}$ = 253.3
Average	5453.3	5600.3	7402.6	

Obtained results on grown ZP maize hybrids point out that there were statistically significant differences in the weed fresh weight only in certain years but in accordance with the height and the leaf area of the crops. Based on the previous studies (SIMIĆ, 2003; SIMIĆ *et al*., 2003), the leaf area and the leaf area index had a significant role in the competitive activity of certain maize genotypes against weeds. The maize inbred lines, although significantly lower than hybrids, can considerably differ in their morphological traits and thereby in their effects on the weed growth and development (STEFANOVIĆ *et al*., 2002). Similar results were obtained by LINDQUIST *et al*., (1998). These authors studied the competitive ability

of several maize hybrids against the species *Abutilon theophrasti* under irrigation conditions. Gained results indicated that the increase of the leaf area index, the degree of coverage or the plant height at which the maize leaf occurred, could enhance crop tolerance in relation to the weed competitive activity. These crop properties can be modified by the application of different cultivation measures such as inter-row distance, maize density and the choice of the genotype.

Good vigour during the initial developmental stages expressed via the length and the width of the first leaves, biomass formation and a favourable leaf area index, are factors that significantly affect the weed infestation level, although this level is not permanent and varies depending on the environmental conditions (ZERNER *et al*., 2008). The most recent generation of maize hybrids are characterised with a smaller index leaf angle. Such leaf position contributes to a better photosynthetic activity and in case of air and soil drought plants can promptly reduce the transpiration area of such leaves. In such a way, plants have soil moisture reserve at their disposal, which enables them to be more tolerant to drought and higher sowing densities.

Considering the standard operating width of the machines and the fact that ZP maize hybrids are selected at the inter-row distance of 70-75 cm, ZP maize hybrids should have the following properties in order to be efficiently competitive against weeds:

- to endure well earlier sowing and to have a good germination and emergence ability in moisture and cold soils
- to have rapid initial growth such as the hybrid ZPSC 434
- to have a greater leaf area in the initial growth stages, such as the hybrid ZPSC 578, hence to cover the soil surface in the 10-12-leaf stage
- to response well to the growth in the higher densities
- to have a greater index leaf angle in order to have more efficient shading of the soil and more competitive activities against weeds.

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ULOGA GENOTIPA U KOMPETITIVNOSTI KUKURUZA PREMA KOROVIMA

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I z v o d

Gajenje kompetitivnijih useva je važna komponenta integralnog sistema suzbijanja korova, iako je selekcija genotipova sa povećanom kompetitivnom sposobnošću dosta teška. Mogućnost smanjenja zakorovljenosti na osnovu povećanja kompetitivnog delovanja useva gajenjem genotipova tj. hibrida koji bolje "podnose" veću gustinu, zavisi od FAO grupe zrenja i morfoloških karakteristika genotipa, uslova spoljašnje sredine i područja gajenja. Kompeticija između kukuruza i korova se menja sa promenom gustine i rasporeda gajenih biljaka. Najzakorovljeniji su usevi retkog sklopa, dok su visina i masa korova u usevima gustog sklopa znatno niže. Za veću kompetitivnost genotipa kukuruza u odnosu na korove važni su visina, intenzitet rastenja u početnim fazama, vigor klijanaca i lisna površina biljke, koje su komponente konkurentskog delovanja useva na korove.

U radu je ispitivana zakorovljenost i produktivnost različitih hibrida kukuruza u zavisnosti od prostornog rasporeda u kome su gajeni i primene herbicida. Rezultati pokazuju da su pri gajenju ispitivanih genotipova kukuruza utvrđene statistički značajne razlike u svežoj masi korova, ali samo u pojedinim godinama, u skladu sa razlikama u visini i lisnoj površini ZP hibrida.

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