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WEEDINESS OF A MAIZE AND SOYBEAN INTERCROPPING SYSTEM

Željko Dolijanović[1], Snežana Oljača[1], Dušan Kovačević[1], Milena Simić[2], Vesna Dragičević[2] and Vera Popović[3]
[1]University of Belgrade, Faculty of Agriculture, Belgrade-Zemun, Nemanjina 6, Serbia
[2]Maize Research Instiute, Zemun Polje, Belgrade-Zemun, Slobodana Bajica 1, Serbia
[3]Institute of Field and Vegetable Crops, Novi Sad, Maksima Gorkog 30, Serbia
dolijan@agrif.bg.ac.rs

Abstract

The effect of the additive intercropping system, on weediness of maize and soybean was investigated on chernozem soil type in 2004 and 2005. Intercropping was done in alternate rows and in strips. Three maize hybrids of different FAO maturity groups (FAO 500, 600 and 700) were included into the trials. The aim of this study was to determine the effects of different maize hybrids and spatial distribution intercrop patterns on the weediness of maize and soybean. The maize and soybean intercropping resulted in the decrease in parameters of weediness, especially in the number of perennial weed species and fresh biomass per area unit. The intercropping system in alternate rows expressed greater efficiency in weed control (number of species, number of plants per species and weed biomass) in comparison to the intercropping system in strips and maize monocrops. In soybean, intercropping systems were more advantageous than soybean monocrops.

Keywords: maize, soybean, monocrops, intercropping, weeds

Introduction

In the technology of growing row crops - especially in sustainable and organic farming systems - weeds are considered to be one of the biggest problems. In order to find solutions, constant education and changes in the minds of farmers are needed. One of the systems, which would be environmentally acceptable and justified in terms of weed control is intercropping system row crop with other species, especially with legumes. Cereal/legume intercropping is commonly practiced in tropics, because of yield advantages, greater yield stability, lower risks of crop failure, greater land-use efficiency, increased competitive ability toward weeds, improvement of soil fertility due to the addition of N by fixation, and some favorable exudates from legume species (Tusbio *et al.*, 2005).

Apart from crop productivity, legume-based cropping could also help to increase soil organic matter level, thereby enhancing soil quality, as well as having the additional benefit of sequestering atmospheric C (Gregorich *et al*, 2001). Incorrect choice of crops cultivation or intercrops incompatible species can lead to a crop completely choked another, ie. to reach the negative effects (competition). Park *et al.*, 2003, in his work explained the theory of competition: intra- and interspecific competition, as well as specific crop-weed competition and its practical application. According to them, there are three categories of intraspecific competition: the influence of density (reducing the survival of plants with increasing density); change of the structure of the population (hierarchical development of the plants) and the dependence of the number density of plants. In order to achieve high effects of weed control in intercropping systems, it is important to choose the most convenient shape and size of the growing area in which the competitive relationships between and within species be minimized (Dolijanović *et al.*, 2013). Basically there are three different spatial pattern arrangements: intercrop in the same row, in alternate rows and in strips (three or four rows of one, so the same number of rows of the second crop). Each of these spatial arrangement pattern has its advantages and disadvantages. The first and second arrangement patterns are acceptable in terms of explanations interspecific competition. Two crops are spatially close enough so that the relationships between them can be clearly defined and scientific explanations of their relationship as »acceptable«. When in strip intercropping can be considered only marginal (first rows) of the tapes, while more rows in the interior can be seen as a monocrop. This deficiency can be alleviated by reducing the number of rows in strips (maximum four) and reducing the distance between the rows. However, when intercrops in strips, it is possible to complete mechanization of operations, ranging from planting, care measure over until harvest.

Due to the application of various herbicides, proper crop rotation and different methods of cultivation during the 20th century, there has been a success rate of weed control (Park *et al*., 2003). On the other hand, there are proven benefits of intercrops in crop production in terms of more effective control of weeds, especially perennial. Decreasing the number and weight of weeds in intercrops than monocrops of maize and soybean, particularly marked in the drier years, thanks to the increased number of plants per unit area (Dolijanović *et al.,* 2008). Crop rotation (temporal diversification) and intercropping (spatial diversification) strategies reduce weed population density and biomass production (Liebman and Dyck, 1993; Bauman *et al*., 2000). The intercrops of maize and pumpkins are obtained, also, higher yields of monocrop, especially in conservation cropping systems (Momirović *et al*., 1998). The maize crop with pumpkins is characterized by large coverability, so there is less infestation of crops, and achieves significant savings because they do not require chemicals to protect against weeds.

The selection of hybrids and varieties of corresponding species is extremely important moment, and strongly depends on method, and the objective of the intercropping. In the additive method of intercropping, it is an important choice of the main crop and secondary crops whose density changes (due to competition). The secondary crop should be choosed based on its competitive characteristics. The method of replacement series, where both crops are equal, selected hybrids or varieties will depend largely on concerns of competition, and thus the yield. Above ground biomass yields are generally higher in the growing of maize hybrids with longer period of vegetation, especially in favorable weather conditions or growing intercrops with irrigation (Dolijanović *et al*., 2006), whereas medium early hybrids have somewhat lower yields.

In addition to numerous advantages, this cropping system encounters certain difficulties and limitations that prevent its use on large areas in general practice. There are many reasons for this: lack of mechanization for such purposes, pesticides, varieties and hybrids that would be adapted to these growing conditions and so on.

The scientific objective of this paper is to determine the advantage late maturity maize hybrids (FAO 600 and 700) compared to medium early hybrid maize (FAO 500), and the effect of spatial pattern arrangement of maize and soybean intercropping system on weed infestation.

Materials and methods

The experiment was established according to a randomized complete block design plan with four replications on the Maize Research Institute "Zemun Polje" Belgrade, Serbia. The investigations were done in 2004 and 2005 years on the chernozem soil type in conditions of natural water regime. The size of the experimental plots was 21 m^2. The sowing time was the last decade of April. The basic tillage was done in autumn at the depth of 25 cm, and spring soil preparation 10 to 15 days prior to sowing. All variants of the experiment were fertilized by mineral fertilizer NPK (15:15:15) at the amount of 80 kg/ha of active matter. Nitrogen was applied in amount of 90 kg ha^{-1} together with presowing cultivation. Two hand inter-row cultivations were done on all plots. The seeds of soybean were inoculated by microbial preparation "azotofiksin" in order to support nitrogen fixation.

Experimental design

Three experimental ZP maize (*Zea mays* L.) hybrids with different duration of vegetation (EPH2-FAO 500, EPH4-FAO 600 and EPH11-FAO 700) and soybean (*Glycine max* L. Merr) cultivar Nena from maturity group II were included in the investigation. The treatments included intercrops created according to the method of additive series and maize and soybean monocrops. In intercrops, maize as the main crop was sown in the density as in monocrops and soybeans was added at the same density as in monocrops. Preceding crop was winter wheat. In all tested years shallow plowing of stubble was done at 10 cm depth after the wheat harvest. Two different spatial designs were applied: the sowing of maize and soybean in strips and alternate rows. The treatments consisted of each maize hybrid alone (six rows) or soybean alone (six rows), and eight mixtures: 3 rows of maize and 3 rows of soybean in strips for each hybrid of maize (four variants), 3 rows of maize and 3 rows of soybean in alternated rows for each hybrid (another four variants). Maize was planted in rows 70 cm apart and within-row spacing of 40 cm (35.962 plants/ha) in monocrops and for soybean spacing was 70 cm between rows and 3.6 cm within-row spacing (400.000 plants/ha). Within-row spacing in the intercrops was twice smaller (20 cm to maize and 1.80 cm to soybean) than the monocrops.

Measurements

During the growing season of maize and soybean the number of weed species, their aboveground fresh and dry weight was determined both in monocrops and intercropping systems. All parameters of weeds were determined by the method of random squares with an area of 1 m^2. Assessment of weed infestation (summer aspect) was performed on July 13-14 (2004) and June 30 (2005). Evaluation time was determined based on the actual condition of the crop, and that was particularly affected by weather conditions during the investigation. After the evaluation of weed infestation hoeing was carried out in order to suppress weeds in monoand intercrops. The LSD was used to separate means when the F test was significant.

Meteorological conditions

Table 1. Mean monthly temperatures (^{0}C) and total monthly precipitation (mm) for the investigations period (Belgrade)

Year	Temp./ Precip.	Months												Average or Summ
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2004	^{0}C	-0,1	3,7	8,1	13,5	16,2	20,7	23,0	22,3	17,7	15,9	8,5	4,0	**12,8**
	mm	99	28	18	69	63	107	94	88	46	31	129	51	**823**
2005	^{0}C	2,1	1,0	6,0	13,1	17,7	20,2	22,9	21,4	18,9	13,8	7,1	3,6	**12,1**
	mm	53	87	32	53	48	94	90	145	56	27	23	83	**791**

Comparing the data on meteorological conditions during the years of investigation (Table 1), we note that the first test year was characterized by optimum air temperatures, especially during the vegetative period of the crops. The second year of investigation, was similar to the previous one with uneven distribution of precipitation and slightly lower average monthly air temperature at the beginning of the growing season. Precipitation sum was higher in March compared to the year 2004, what was the reason for slowly and poor germination, and greater weed infestation of the crops.

Results and disscusion

The representative conclusions about the impact of the spatial pattern arrangement of plants and different maize hybrids on the floristic composition, number of weeds, aboveground fresh and dry weight of weeds in the mono- and intercrops of the maize and soybean are shown in Table 2, 3 and 4. Summer aspect of the weed community of maize and soybean showed significantly less species, which was got earlier in similar studies (Momirović *et al.*, 1997; Simic, 2003). This aspect was fully developed after the application of agrotechnical operation (hoeing in this case) and after closing ranks and forming a characteristic pattern of the crop. In the years of investigation, the most dominant species were: *Sorghum halepense* L. Pers., *Solanum nigrum* L. and *Amaranthus retroflexus* L. in both crops. However, when we compared the number of weed species and weed plants in the two crops studied, more weeds were present in maize, as compared to those of soybean, especially in the first year (Tables 2 and

3). Fresh weight of weeds was also higher in maize, except in 2005. The therophytes were dominant as a direct consequence of the intensive application of agrotechnical measures for growing crops at this locality. Next in representation are geophytes: *Sorghum halepense* L. Pers. *Convolvulus arvensis* L. and *Cirsium arvense* L. Scop. Earlier studies of maize weed community in Zemun Polje have also pointed to the dominance of therophytes and geophytes, particularly under wet conditions (Simić, 2003).

Intercrops of maize and soybean has led to decrease the number of weed species, number of individuals and weed fresh weight per unit area compared to monocrops of maize and soybean. Analysis of weed infestation of intercropping compared to monocrops of soybeans, especially in the summer aspect showed that cultivation of mixed crops has advantage (Tables 3 and 4). And if the resulting differences, analysis of maize, were not statistically significant, these decrease parameters weedy certainly has an impact on the growth and development of maize and soybean However, when we analyze the soybean crop in the summer aspect of differences in intercropping and monocrops were statistically highly significant, primarily due to the significant impact of maize intercropping on reduction of a particular mass of weeds. What is also revealed by statistical analysis is that of maize hybrids, in terms of the number and weight of weeds, the best was the hybrid FAO 700. Differences in the structure and floristic composition of the weed community inter- and monocrops, maize and soybean, depending on the investigation hybrids were not statistically significant, it is a logical consequence of similar morphological characteristics of the studied hybrids.

Table 2. Weediness (No of weed plants m^{-2}) of monocrops maize and soybean (summer aspect)

Life forms	Weed species	2004.				2005.			
		C_1	C_2	C_3	S.	C_1	C_2	C_3	S.
T	*Amaranthus retroflexus* L.	3.5	4.2	2.0	3.5	2.0	3.0	2.0	3.2
G	*Sorghum halepense* L. Pers.	7.8	9.5	7.0	7.7	3.0	2.3	1.5	3.8
T	*Solanum nigrum* L.	11.2	7.0	9.0	9.0	1.5	2.0	2.0	3.0
T	*Chenopodium album* L.						0.2	0.5	0.8
T	*Amaranthus albus* L.	2.0	1.7	2.3	2.5	0.3			
T	*Hibiscus trionum* L.			0.5	0.7		0.2	0.7	0.7
G	*Convolvulus arvensis* L.	1.0	0.8	0.8	0.3	0.5	0.5	0.5	0.5
T	*Datura stramonium* L.	1.0	1.2	0.7	0.7	2.7	1.7	2.5	2.5
T	*Chenopodium hybridum* L	1.3	0.8		0.8	1.0	2.5	1.8	0.8
T	*Portulaca oleracea* L.								0.2

Life forms	Weed species	2004.				2005.			
		C_1	C_2	C_3	S.	C_1	C_2	C_3	S.
T	*Stachys annua* L.								0.3
T	*Amaranhus blitoides* Watson			0.2					
G	*Cirsium arvense* L. Scop.	0.5	1.0	2.7					
T	*Anagalis arvensis* L.								0.3
T	*Xanthium strumarium* L.	0.5		0.2	0.2				
G	*Cynodon dactylon* L. Pers.	0.5	0.3			0.3			
T	*Ambrosia artemisiifolia* L.					0.2			0.2
T	*Abutilon theophrasti* Med.	0.3				0.8	1.8	1.8	0.3
T	*Atriplex patula* L.		0.5	1.5	1.2		0.2		0.2
G	*Calystegia sepium* (L.) Pers.						0.3		0.3
Total number of weed species		11	10	11	10	10	11	9	15
Total number of plants per species		29.5	27.0	27.0	26.8	12.3	14.8	13.3	17.0
Number of annual weeds		7	6	8	8	7	8	7	12
Number of perennial weeds		4	4	3	2	3	3	2	3
Aboveground fresh weight of weeds (g/m2)		1925.0	1945.0	1805.0	2285.0	326.9	420.3	391.1	450.2
Aboveground dry weight of weeds (g/m2)		508.4	567.4	501.0	718.3	73.2	98.4	91.9	107.8

T-therophytes, G-geophytes
S -Soybean; C_1-maize FAO 500, C_2- maize FAO 600, C_3- maize FAO 700.

In the maize and soybean intercropping system notice the presence of a large number of species and individuals of weeds in the strips, Table 3. However, the number of perennial weed species in maize-soybean intercrops was significantly lower than in monocrops, mainly due to the increase of the number of plants per unit area. Facilitated the circulation of light in strips and less pronounced interspecific competition, it is likely the reason of better and more successful development of weed plants. Studying weed infestation of intercrop in spring, Dolijanović *et al*., 2007, determined the highest number of weed plants per species and the greatest weed biomass in alternate rows.

Table 3. Effect of plant arrangement pattern and maize hybrids on weed floristic composition (summer aspect)

Life forms	Weed species	2004.						2005.					
		Number of weed plants per m^{-2}						Number of weed plants per m^{-2}					
		B_1			B_2			B_1			B_2		
		C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3	C_1	C_2	C_3
T	AMARE	3.2	2.2	3.0	3.5	5.5	5.7	2.5	2.7	1.5	2.2	3.0	2.2
G	SORHA	6.5	7.8	5.0	5.8	6.5	5.8	3.0	3.8	2.8	3.0	1.8	2.5
T	SOLNI	10.2	10.2	10.5	10.0	11.2	13.0	2.0	2.2	3.5	3.7	2.0	1.5
T	CHEAL	0.3			0.3				0.5	0.3	0.3		
T	AMAAL	2.7	2.2	2.7	1.7	3.0	7.2	0.2			0.5		
T	HIBTR	0.5	0.5	0.8	0.3		0.3	0.8	0.3	0.8	0.8	0.5	0.5
G	CIRAR	1.2	0.7	1.2	3.7	0.7	0.7	0.5	0.2		1.0	0.2	0.2
T	DATST	0.3	0.8	1.3	2.3	2.8	1.3	2.3	2.0	2.0	1.5	1.8	2.0
T	CHEHY	0.7	2.0	0.2	0.2	2.2	2.2	0.7	0.2	0.5	0.7	1.2	1.0
T	PORTOL								0.3	0.3		0.3	0.3
T	STAAN							0.2					0.2
T	AMABL					0.3	0.3				0.3		
T	ANAAR								0.3				0.3
T	XANST	0.2			0.2	0.2							
G	CYNDA				0.3					0.3		0.5	0.8
T	AMBAR						0.2						
T	ABUTH						0.3	0.3		0.3	0.5	1.0	0.3
T	DIGSA		0.2										
T	ATRPA		0.8	0.8	0.3	1.3	1.8		0.3				0.3
T	ECHCG			0.2									
G	CALSE							0.2	0.2	0.2	0.2	0.2	
Total weed species		10	10	11	13	10	12	11	12	11	12	11	13
No of weed plants m^{-2}		26.0	27.5	25.8	28.5	33.8	38.8	12.8	13.0	12.3	14.8	12.5	12.0
Annual weed species		8	8	8	9	8	10	8	10	8	9	7	10
Perennial weed species		2	2	3	4	2	2	3	3	3	3	4	3
Fresh biomass (g m^{-2})		1875	1810	1905	2190	1950	2430	349.5	334.6	281.3	339.8	271.0	369.8
Air dried biomass (g m^{-2})		536.3	427.9	539.4	648.9	580.1	663.2	85.6	76.1	60.9	74.9	60.3	90.6

B_1- alternate rows, B_2- strips;

Table 4. Statistical analysis of weed number, fresh and air dried biomass depending on year, plant arrangement pattern and different maize hybrids

Crops	Investigation parametres	Plant arrangement patern			Hybrids			Year	
		MC	B_1	B_2	C_1	C_2	C_3	2004	2005
Maize	Total weed species	20.6	19.5	23.4	20.6	21.4	21.5	29.3	13.1
		$F = 2.19^{nsz}$			$F = 0.13^{nsz}$			$F = 110.88^{**}$	
	Fresh biomass (g m^{-2})	1135.5	1092.5	1258.4	1167.6	1121.8	1197.2	1181.7	342.7
		$F = 1.0^{nsz}$			$F = 0.19^{nsz}$			$F = 271.21$	
	Air dried biomass (g m^{-2})	306.7	287.7	353.0	321.2	301.7	324.5	552.5	79.1
		$F = 1.61^{nsz}$			$F = 0.22^{nsz}$			$F = 239.15^{**}$	
Soybean	Total weed species	21.9	19.5	23.4	21.0	21.8	22.1	28.9	14.3
		$F = 2.49^{nsz}$			$F = 0.22^{nsz}$			$F = 107.87^{**}$	
	Fresh biomass (g m^{-2})	1367.6	1092.5	1258.4	1248.2	1183.0	1286.8	2112.8	366.3
		$F = 2.97^{nsz}$			$F = 0.42^{nsz}$			$F = 354.06^{**}$	
	Air dried biomass (g m^{-2})	413.1	287.7	353.0	362.0	328.4	363.4	616.8	85.8
		$F = 7.93^{*}$			$F = 0.79^{nsz}$			$F = 426.68^{**}$	

MC-monocrops; $^{**}p<0.01$; $^{*}p<0.05$; ^{ns}no significant

Alternatively, intercrops may provide yield advantages without suppressing weed growth below levels observed in component monocrops if intercrops use resources that are not exploitable by weeds or convert resources to harvestable material more efficiently than monocrops. Significant advances in the design and improvement of weed-suppressive intercropping systems most likely to occur if three important areas of research are addressed (Liebman & Dyck, 1993). First, there must be continued attention to the study of weed population dynamics and crop-weed interference in intercropping systems. More information is needed concerning the effects of diversification of cropping systems on weed seed longevity, weed seedling emergence, weed seed production and dormancy, agents of weed mortality, differential resource consumption by crops and weeds, and allelopathic interactions. Next, there needs to by systematic manipulation of specific components of intercropping systems to isolate and improve those elements (e.g., interrow cultivation, choice of crop genotype) or combinations of elements that may be especially important for weed control. Finally, the weed-related impacts of intercropping strategies should be assessed through careful study of complex farming systems and the design and testing of new integrated approaches. Many aspects of intercrops are compatible with farming practices and could become more accessible to farmers if government policies are restructured to reflect the true environmental costs of agricultural production.

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