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TYPES OF INTERACTIONS IN INTERCROPPING OF MAIZE AND SOYA BEAN

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Abstract: Intercropping two or more crops under similar microenvironmental conditions can increase the agricultural productivity. A field study was conducted in three-year period 2003-2005 at experimental field of Maize Research Institute, Belgrade on chernozem soil type. This examination included three experimental hybrids of maize from various FAO groups of ripening (500,600 and 700) and the type of soya bean from II group of ripening (Nena). Maize and soybean was grown in pure stands and three combinations of intercrops (alternate-row and in strip intercropping). Additive design was used for creating of intercrop variants.

The paper investigated the grain yield of maize and soya bean in the intercropping, and compared with the yield of the monocrops. Comparison of the yield was carried out with the most Number indicators- Land equivalent Ratio index (LER). For individual comparisons used the standard error differences between means. Comparing with the intercropping production of monocrops production of maize and soya bean, with the index LER, the results obtained indicate that there are more intercropping production, especially in 2004. The three-year average, the increase of grain yield in the intercropping in relation to monocrops of maize and soya bean was 45% in the strip, or 49% in the alternate rows. Intra-species the intensity of competition is higher in the strip and in the pattern arrangement of the resulting lower relative grain yield, primarily due to lower maize yield.

Key words: maize, soybean, intercrops, monocrops, productivity, competition.

I n t r o d u c t i o n

One of the main reasons for growing intercrops in developing countries, in which there is a risk in production, is the stability of yield (L a m b e r t s, 1980).

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This stability is obtained in several ways, most frequently by compensation of yields of individual components. Different crops react differently to stressful conditions of the environment, so that yield decrease of one sort can be compensated by preserving yield of the other sort. It also refers to disease and pests attacks, because intercrops as special systems mainly withstand those attacks. However, in developed countries, the reasons for intercropping are the increase of the production of intercrops mainly because of different length of vegetation period, various need for resources and different time of using those resources, suitable vertical arrangement of crops, both over ground (better using of light) and underground (less intense competition for nutrients and water), leguminous nitrogen fixation and transfer of nitrogen from legumes to cereals.

A very important assumption of high and stable yields of agricultural crops is uninterrupted growth and development of single plants in time and space. The intensity of competitive relations for main factors of growth and development depends on form and size of vegetative area, and as a result the productivity of certain crops. This is very important for growing two or three sorts on the same areas (intercropping). It is generally accepted (although many details are fiercely discussed) that when two sorts occupy the same place, and involve in the actions of each other, it is little probable that there is a room for both of them (Vandermeer, 1989). It is well known principle of *competitive exclusion*, where stronger competitor excludes weaker one. However, in case that two plant sorts have similar, but somehow different needs for the most important resources, they can survive in community with lower intensity of competition (*the principle of competitive community*). The competition of grown plants is very difficult to determine, because apart from influencing each other in the community, it is also influenced by other factors of the environment so that it is difficult to determine the influence of a single plant on the other one. The result of competition mainly depends on skill in choosing kinds (sorts and hybrids) which will be intercropped, from water regime and relations among sorts in the mixture, that is on their spatial arrangement (Weigelt Alexandra and Jolliffe, P., 2003). The best combination for intercropping in crop science so far is intercrop of one sort from the grass family and the one from the legume family, e.g. maize and soya bean. Growing monocrop of maize many mineral matters are taken out and hence physical characteristics of the soil are spoilt to a certain degree (Mišković *et al*., 1980). Soya bean grown in community with maize fixes great amounts of nitrogen, and with dense structure of root system, it improves physical, chemical and biological characteristics of soil i.e. it biologically supplements maize. Mathematical indicators, made by combination of several main measures, can help researchers to sum up, interpret, and show the results of the experiment within plant competition. Many indexes are based on comparison of plant endurance in intercrops, in relation to the same one in the monocrop.

The most important and most frequently used indicator is LER index (land equivalent ratio), which is thought to be used for the first time in annual report of

the International Institute for rice in 1974 by unknown author although Willey and Osiru must be given precedence for their research in 1972 (Weigelt Alexandra and Jolliffe, P., 2003). LER index should show the area of soil which is needed for intercrop to be productive as well as each of the crops grown individually. It is important to point out that LER is differently observed in communities where the single crop is main, and the other one is secondary – additive series. Dolijanović (2002), induces that the main crop in community should not be under any competitive pressure of the secondary crop, i.e. its LER is always 1 or more than 1. The secondary crop is added in order to improve supplying of the main crop with the factors of growth and development, to protect main crop from diseases and pests or to improve the quality of fodder. Because of that, certain authors (Riley, 1984, Reddy and Chetty, 1984) introduced effective LER (eLER-*effective land equivalent ratio*) and main LER (sLER-*staple land equivalent ratio*), which are used depending on the aim of researching. If you want to achieve as better as possible yield of both sorts, eLER is used, and if the main one is the crop whose yield must not be lower than minimum, then sLER is used. The yield of monocrop is used as control one and serves for marking the efficiency of intercrops of the same sorts.

Apart from very noticeable competition between the sorts in intercrop, it is necessary to point out the fact that there are many difficulties and restrictions in applying of this system to great areas in intensive agriculture. It is because of the fact that all means of high technology (modern mechanization, protection means, sorts) which are used in the system of growing only one kind of plant, are adapted to that system. A special disadvantage of this system of growing plants is impossibility of using mechanization for performing sowing, protecting and harvesting of crops.

Material and Methods

The study of interaction between maize and soya bean was done in the period 2003-2005, on the soil type chernozem on the experimental field at the Institute for maize "Zemun polje". Field experiment was set up according to plan of random block system in three repetitions. The size of elementary lot was 21 m^2. Three experimental multi-cob maize hybrids of different length of vegetative period: EPH2-FAO 500; EPH4-FAO 600 and EPH11-FAO 700 and soya bean sort Nena (II group of maturing).

Intercropping was performed according to additive series (De Wit, 1960). Interspace between rows of maize and soya bean was 70 cm. Interspace between the maize plants was 40 cm (monocrop) and 20 cm (intercrop), and in soya bean 3,60 cm (monocrop) and 1,80 cm (intercrop). Hence the density of maize crops both in monocrops and intercrops was 35.962 plants per hectare, and the density of soya bean was 400.000 plants per hectare. Pre-crop in natural and irrigational water regime was winter wheat.

Sowing of maize and soya bean was done manually in the last decade of the month of April every investigated year. During the sowing, the seed of soya bean was treated with Azotofiksin, and the seed of maize was treated with Mesurol. Irrigation, as one of investigated factors was practised only in 2003, while meteorological conditions, first of all rainfall and distribution of precipitation during the vegetative period of crops were very suitable in 2004 and 2005. Irrigation was maintained by sprinkling of water (artificial rain) by means of tifon-device. The norm of watering was 20 mm (20 l/m^2), and the time of irrigation was based on soil moisture at the depth of 60 cm.

Obtained data were processed statistically, by means of the method of variant analysis, and for single comparisons standard errors of the differences between the means (SED) were used. For defining of efficiency of using of soil resources, LER (Land Equivalent Ratio) is used according to Willey, 1979. This coefficient was determined by formula:

$$LER = (X_i/Y_i) + (X_j/Y_j)$$

X_i – yield of i sort per unit of area in intercrop
Y_i - yield of i sort per unit of area in monocrop
X_j - yield of j sort per unit of area in intercrop
Y_j - yield of j sort per unit of area in monocrop

Results and Discussion

Performing of the experiment as well as the statistical analysis of the obtained data in the system of intercrops is a very complex issue, because inadequate analysing of the experiment can lead to a wrong interpretation of the results. Earlier, the results of similar experiments were superficially considered. The most reliable methods for interpretation of results for intercrops are those which take into consideration both yields simultaneously and equally analyse them (Dolijanović, 2008). The main form of LER was used for studying the efficiency of intercrops of maize and soya bean in period 2003-2005 (Tables 1, 2 and 3). The density of maize was constant, and yields of individual maize hybrids in intercrop were compared with the yield of equivalent maize hybrids in monocrop. All obtained yields of soya bean in intercrops were compared with the yield of soya bean in monocrop. Calculating of LER index was based on data about yield of maize aand soya bean seed (Tables 1, 2 and 3). All values of LER which were more than one indicate advantage of intercrops over monocrops. Increasing of yields in intercrops in alternate rows comparing to monocrops was from 12% (natural water regime in 2003) to even 91% (2004). In variants of intercropping in strips the incresing of seed yield was from 15% (natural water regime in 2003) to 88 % (2004). We can immediately notice, that regardless of

irrigation in 2003, the best results were obtained in 2004. Irrigation is a measure by means of which increased intensity of competition for water in crops susceptible to drought can be avoided (Snežana Oljača *et al*., 1999; Dolijanović *et al*., 2002), but our results, as well as results of Dolijanović's in 2008 show that irrigation compared with the years with sufficient amount and suitable arrangement of precipitation does not show advantages, especially regarding seed yield in intercrops.

While analyzing two investigated arrangement patterns it can be noticed that the advantage of intercropping in strips was displayed in 2003, primarily owing to the increase of yield of soya bean seed in this system of intercropping (Table 1). In intercrops in alternate rows both interspecific competition and intraspecific competition are present. Crops hardly bear that kind of competitive pressure especially in dry years (2003), which is often reflected on the quantity and the quality of the yield. When crops are intercropped in alternate rows it frequently happens that the yield of legumes is decreased with respect to the yield in monocrop, while the decrease is smaller in strips. Yunusa (1989) indicates that the reason for that is overshadowing of legumes by cereals. The lowest seed yields of maize and soya bean in 2003 were mainly achieved in intercrop with late maturity maize hybrid in both regimes of wetting (Table 1).

Tab. 1. - Land equivalent ratio (LER) for grain yield of maize and soya bean intercropping ($kg*ha^{-1}$) in 2003 Year

Crops	Hybrids	Maize		Soya bean		LER	
		A_0	A_1	A_0	A_1	A_0	A_1
Monocrops	C_1	6673.8	9452.4				
	C_2	6316.7	8197.6				
	C_3	7207.1	10642.9				
	Average	6732.5	9431.0	1777.0	2392.9		
B_1	C_1	4426.2	7700.0	735.7	1300.0	1.07	1.35
	C_2	4569.6	7961.9	897.9	1519.0	1.22	1.60
	C_3	4457.1	8628.6	788.1	1176.2	1.06	1.30
	Average	4496.3	8096.8	807.2	1331.7	1.12	1.41
B_2	C_1	4667.9	8787.6	804.8	1461.9	1.15	1.54
	C_2	4342.9	7719.1	873.8	1580.9	1.18	1.60
	C_3	4094.6	6802.4	971.4	1219.0	1.12	1.15
	Average	4368.5	7769.7	883.3	1420.6	1.15	1.43
SED		311.83	239.69	83.49	93.97	0.025	0.076

A_0-rainfed watering regimes, A_1- irrigation watering regimes; B_1-alternate rows, B_2-strip intercropping; C_1-FAO 500, C_2-FAO 600, C_3-FAO 700; SED−standard errors of the differences between the means

The production of intercrops was significantly higher with respect to other two investigated years, especially in 2004. The decrease of LER index in intercrops in 2005 in comparison with 2004, is the consequence of decreased yield of seed of maize and soya bean in this year. (Table 2). In 2005, there was no increase of the

maize yield in intercrop in comparison with monocrop, especially in strips. The highest yield of maize was produced in alternate rows with the hybrid FAO 700 (8642.9 kg/ha). In addition, the highest yield of soya bean seed was achieved in strips with above-mentioned hybrid (1571.4 kg/ha).

In mixtures with alternate rows higher yields were achieved, which were followed by significantly higher percent of maize participation. The advantages of the mixture with strips are easier harvest and application of agrotechnical measures. Besides, it is very difficult to mechanize the harvest of maize and soya bean in alternate rows. Everything that was said earlier is confirmed here: alternate rows are more suitable for maize, whereas strips are more appropriate for soya bean. Yunusa (1989) induces that it is best to sow the mixture of maize and soya bean in alternate rows using the amount of 67% of the density which is used in monocrops. The above-mentioned author termed this kind of intercropping half-additive.

Tab. 2. - Land equivalent ratio (LER) for grain yield of maize and soya bean intercropping (kg*ha^{-1}) in 2004. and 2005. Year

Crops	Hybrids	Maize		Soya bean		LER	
		2004	2005	2004	2005	2004	2005
Monocrops	C_1	9375.0	8333.3				
	C_2	9032.1	8857.1				
	C_3	10682.1	9523.8				
	Average	9696.4	8904.7	2217.9	2488.1		
B_1	C_1	9964.3	7238.1	1714.3	1523.8	1.83	1.48
	C_2	12235.7	7404.8	1235.7	1476.2	1.91	1.43
	C_3	14335.7	8642.9	1457.1	1238.0	2.00	1.41
	Average	12178.6	7761.9	1469.0	1412.7	1.91	1.44
B_2	C_1	10378.6	6642.9	1560.5	1428.5	1.81	1.37
	C_2	9788.1	6452.4	1471.4	1452.4	1.74	1.31
	C_3	13257.1	5880.9	1928.6	1571.4	2.11	1.25
	Average	11141.3	6325.4	1653.5	1484.1	1.88	1.31
SED		390.60	210.14	103.12	90.61	0.056	0.034

Based on average three-year values of LER index, it can be noticed that growing in monocrops demands 45% (strips) and 49% (alternate rows) more soil for achieving yield on a level of intercrops (Table 3). The values are approximate in two investigated arrangement patterns, in alternate rows, a relative maize yield is higher in comparison with strips and concerning soya the situation is reverse of the previous one. Lower values of LER are induced by Putnam *et al.* (1985) who determined LER index in the intercrop harvest of maize and soya bean of 1,18. Dolijanovic *et al.* (2007) indicated the increase of intercrop productivity in the first year was from 25-38% (strips) and 27-43% (alternate rows), while in the second year this increase was a little bit lower: 8-18% (strips) and 13-40%

(alternate rows). With respect to investigated hybrids regularity was displayed, i.e. the late maturity maize hybrid achieved the best result in the yield of maize seed in alternate rows, and the worst one in strips, but the case of the yield of soya bean seed is the reverse of the previous one. The system of intercrops according to additive principle, with regard to increasing the seed yield, the crop of maize was more efficient. It can be especially seen in 2003, in natural water regime, and on the basis of that, it can be concluded that maize is more tolerant of the lack of environment factors, which is in accordance with the results which were obtained by Dolijanović (2002).

The relations between maize and soya bean in intercrops can be defined as positive and in accordance with competitive-productive principle of Vandermeer (1989). In case of correctly chosen combinations of sorts which are grown in intercrop, then optimal density and hybrids/sorts of single crops, it can be surely expected that those sorts will achieve higher productivity in comparison with monocrops. Considering intensified competitive ability of late maturity hybrid (FAO 700), it is easy to conclude that it achieved the highest seed yields, especially in alternate rows. However, intensified shadowing of this hybrid, especially in time of flowering of soya bean, led to the increase of the yield of soya bean seed, especially in strips. In this arrangement pattern, the shoots of maize are sufficiently far from each other that there is no strong interspecific competition, but on the other hand they are near enough to provide optimal shadowing and nitrogen transfer.

Tab. 3. - Relative grain yield of maize and soya bean in intercropping system and Land equivalent ratio (LER) in intercropping system (Average 2003-2005)

Crops	Hybrids	2003		2004		2005		LER
		Maize	Soya bean	Maize	Soya bean	Maize	Soya bean	
B_1	C_1	0.66	0.41	1.06	0.77	0.87	0.61	1.46
	C_2	0.72	0.50	1.35	0.56	0.84	0.59	1.52
	C_3	0.62	0.44	1.34	0.66	0.91	0.50	1.49
	Average	0.67	0.45	1.25	0.66	0.87	0.57	1.49
B_2	C_1	0.70	0.45	1.11	0.70	0.80	0.57	1.44
	C_2	0.69	0.49	1.08	0.66	0.73	0.58	1.41
	C_3	0.57	0.55	1.24	0.87	0.62	0.63	1.49
	Average	0.65	0.50	1.14	0.74	0.72	0.59	1.45
SED		0.023	0.020	0.053	0.043	0.043	0.018	0.016

Conslusion

Comparing the productivity of intercrops with the productivity of monocrops of maize and soya bean, by means of LER index, we obtained the results which refer to higher production of intercrops. Comparing the yields of investigated

crops seeds, it can be noticed that variants of intercropping in alternate rows especially stand out there where was the most important increase of yield, particularly in more suitable meteorological conditions or by irrigation. The lowest value of LER index was obtained by intercropping of maize and soya bean in strips when the hybrid from FAO 600 (LER = 1,41) was grown. The yield of soya bean seed in alternate rows was always the lowest if it was intercropped with the hybrid of the longest vegetation (FAO 700), whereas the situation in strips was the reverse of the previous one- the highest yields of soya bean seed in all investigated years when intercropped with late hybrid maturity.

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TIPOVI INTERAKCIJA U ZDRUŽENOM USEVU KUKURUZA I SOJE

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R e z i m e

Gajenje dva ili više useva u sličnim mikroklimatskim uslovima može dovesti do povećanja produktivnosti. Ispitivanja združenih i čistih useva kukuruza i soje, u prirodnom vodnom režimu, su sprovedena u periodu od 2003. do 2005. godine na eksperimentalnom polju Instituta za kukuruz u Zemun polju, na zemljištu tipa černozem. Gajena su 3 eksperimentalna hibrida kukuruza iz različitih FAO grupa zrenja (EPH2-FAO 500, EPH4-FAO 600 i EPH 11 – FAO 700) i sorta soje Nena iz II grupe zrenja. Združena setva kukuruza i soje je obavljena po aditivnom metodu, a primenjivana su dva prostorna rasporeda: u trakama i u naizmeničnim redovima.

U radu su ispitivani prinosi zrna kukuruza i soje u združenim i upoređivani sa prinosom u čistim usevima. Upoređivanje dobijenih prinosa je obavljeno pomoću najpoznatijeg brojčanog pokazatelja-indeksa efikasnosti korišćenja zemljišta (LER indeksa). Za pojedinačna poređenja korišćena je standardna greška razlike aritmetičkih sredina. Upoređujući produkciju združenih sa produkcijom čistih useva kukuruza i soje, pomoću LER indeksa, dobijeni rezultati ukazuju na veću produkciju združenih useva, posebno u 2004. godini. U trogodišnjem proseku, povećanje prinosa zrna u združenim u odnosu na čiste useve kukuruza i soje iznosilo je 45 % u trakama, odnosno 49 % u naizmeničnim redovima. Intenzitet intraspecijske kompeticije je veći u trakama, pa su u tom prostornom rasporedu dobijeni niži relativni prinosi zrna, prvenstveno zbog nižih prinosa kukuruza.

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