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Milena SIMIC, Vesna DRAGICEVIC, Branka KRESOVIC,
Živorad VIDENOVIC, Zoran DUMANOVIC [1]

ADVANCED CROPPING TECHNOLOGY OF MAIZE (*Zea mays* L.) IN SERBIA

SUMMARY

Studies on maize growing practices have been performed in the Maize Research Institute, Zemun Polje since its establishment. Numerous studies realised in accordance with contemporary global trends indicated the direction of development of maize growing practices with the aim to use the genetic potential of newly derived hybrids. Although, the genetic potential of the yield of maize hybrids grown in Serbia is 10 to 15 t/ha, the recorded average yields are significantly lower. The experimental trials with the application of standard growing practices conducted during the fifteen growing seasons showed that the maize yield varied from 10.46 to 11.38 t/ha. The obtained results indicated that, for the region of central Serbia, contemporary maize growing systems should include a correctly applied crop rotation with legumes (soybean), conventional tillage with deep autumn ploughing, precisely determined plant density and the time of sowing. Another important factor is the application of fertilisers the content and formulation of which are adjusted to the requirements of the cultivated plant and irrigation tuned to the requirements of crops and climate in terms of norms and frequency of the application.

Keywords: growing, maize, crop rotation, soil tillage, yield

INTRODUCTION

Sustainability of agricultural production is important not only for the protection of the environment, but also for the reduction in costs and other inputs. Although a complete replacement of all components of the production is not possible, e.g., replacement of mineral fertilisers with alternative sources, it is very important to pay more attention to agro-ecological measures (Council for the Environment and Infrastructure, 2013). The reduction of yield losses caused by pests, pathogens and weeds are major challenges to agricultural production. Globally, approximately 35 % of potential yield is lost to pre-harvest pests. In addition to the pre-harvest losses, transport, storage, marketing, etc. loses also occur.

With reference to the above-stated, the question that arises is whether intensive but not sustainable production in relation to environmental protection

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[1] Milena Simic, Vesna Dragicevic, Branka Kresovic, Živorad Videnovic, Zoran Dumanovic, (corresponding author: smilena@mrizp.rs): Maize Research Institute, Zemun Polje, 11185 Belgrade, Slobodana Bajića 1, SERBIA
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could contribute more to the reduction in losses than ecological agriculture, the efficient application of which is based on innovative and creative knowledge and research (Popp et al., 2014).

Maize and winter wheat, in terms of area, requirements and profit, are the two most important crops in Serbia, and on average, 50 % of arable land is cultivated with these two crops. Although the genetic potential of the yield of maize hybrids grown in Serbia is 10 to 15 t/ha, the recorded average yields are significantly lower, mainly due to frequent droughts, unfavourable soil properties in certain regions, insufficient application of mineral fertilisers, obsolete machinery, small farms, etc. However, experimental studies performed in the period from 1998 to 2012 showed that average maize yields, when standard growing practices were applied, amounted to 10.46, 10.39 and 11.38 t/ha for hybrids of FAO maturity groups 300–400, 500 and 600–700, respectively (Videnović et al., 2013a). The most important limiting factor for succesfull maize production is meteorological and irrigation and they have to perform very important measure within a cropping technology (Dragičević et al., 2015). A more significant improvement of maize production requires a long-term strategy programme that would elaborate the following: defragmentation of holdings, the construction of irrigation systems on areas as large as possible and intensification of maize growing practices. Studies on maize growing practices have been performed in the Maize Research Institute, Zemun Polje since it was founded. Numerous studies performed in accordance with contemporary global trends indicated the direction of development of maize growing practices with the aim to use, to the greatest extent, the genetic potential of newly derived hybrids. The most important maize growing practices are crop rotation, tillage, density and time of sowing, fertilisation and irrigation. These studies are aimed at better understanding of the long-term effects of these practices to soil and crop and optimisation of crop growing practices.

MATERIAL AND METHODS

All experimental results were collected from multi-year field trials conducted in the experimental field of Maize Research Institute Zemun Polje, in the vicinity of Belgrade (44°52′N 20°20′E). The soil was slightly calcareous chernozem with 47 % clay and silt and 53 % sand. The 0–30-cm layer had 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. The crop was hand sown on different dates of April and May in each year, according to the experimental design and goal. All planed experimental treatments and practices were applied on time. The maize was harvested and the yield was measured and calculated with 14 % moisture at the end of the season

RESULTS AND DISCUSSION

The importance of crop rotation

Crop rotation has direct and preventive effects not only on plant production but also on the protection of the agro-ecosystem. This is also an economically very efficient measure, because no additional investments are necessary, and advantages over continuous cropping during the shorter or a longer period are numerous and are reflected in the improvement of chemical, physical and biological properties of soil, and more efficient and secure protection of crops against weeds, diseases and pests (Videnović et al., 2007). The most important advantage of crop rotation is significant yield increases in relation to crops in continuous cropping systems (Spasojević et al., 2013). Depending on weather conditions, the yield increases achieved in maize grown in a crop rotation system can be greater by 10 % and in some cases even by 30 % in relation to crops grown in continuous cropping systems. The rotation of three or four crops is the optimum system. The crop rotation systems should not include cultivated plants that belong to the same family, but it is necessary to include small grains (wheat, barley, oats, rye), maize or sorghum, legumes (soybean, French bean), as well as industrial plants (sunflower, etc.). This allows the growing of plant species with different root architectures, various nutrient and water requirements, no common pathogens causing diseases in plants, etc.

Although the use of the crop rotation should be an integral part of current maize growing practices, there is a great problem in Serbia regarding the use of an appropriate crop rotation, since maize is sown on much larger areas than other field crops. According to the Statistical Yearbook of Serbia, the annual area cultivated with maize in Serbia ranges from 1,200,000 to 1,250,000 ha, while wheat, as the second most distributed crop, is sown on an area of 450,000 to 500,000 ha. The distribution of maize over large areas is the result of its great demand on the market, first as fodder and then as food, as well as the needs of the processing industry. Due to such a sowing structure, maize is grown in continuous cropping on a certain percentage of areas. If crop rotation is used, then the well known "Balkan crop rotation" (maize–winter wheat) is applied. The advantage of this growing system over maize continuous cropping lies in the easier suppression of weeds. Wheat is a crop of a dense stand that begins to develop in spring much earlier than weeds and therefore prevents their normal growth and development. Even in a two crop rotation, wheat contributes to efficient reduction of weediness if it is the preceding crop to maize, especially the control of perennial weeds such as Johnson grass - Sorghum halepense L. and to a lesser extent bindweed - *Convolvulus arvensis* L., (Spasojević et al., 2014b).

Soybean is a nitrogen-fixing rotation crop that can provide significant amounts of available nitrogen for the succeeding crop and as a result, the input of mineral fertilisers could be reduced. The obtained results showed that the average maize yield was higher by 11.4 % in soybean–maize rotation, despite the amount of applied nitrogen fertiliser being reduced by 50 % (Videnović et al., 2013b). Moreover, the maize yield recorded in the three-crop rotation with wheat and soybean was higher by 32.4 % than the one obtained in the two-crop rotation (maize–wheat). The lowest average maize yield (5.37 t/ha) was recorded in continuous cropping (CR1).

Three-crop rotations: soybean–wheat–maize (wheat is the preceding crop to maize) and wheat–soybean–maize (soybean is the preceding crop to maize) are the most often used variants of crop rotations. These two types of three-crop rotation are identical in relation to the crops included, but due to the sequence of crops (alternation of crops), there are significant differences, before all in their effects on the reduction of weed infestation (Spasojević, 2014b). Under Serbian agro-ecological conditions, the soya bean–wheat–maize (wheat is the preceding crop to maize) rotation very efficiently affected a reduction in the total weed infestation, even when reduced amounts of herbicides were applied, which is very important from the aspect of agro-ecosystem protection (Simić et al., 2015). In dependence on the level of herbicide application, the maize-soybean-wheat three-crop rotation had the greatest effect on the reduction of maize weeds, especially perennials species, after only one rotation of crops (Spasojević, 2012).

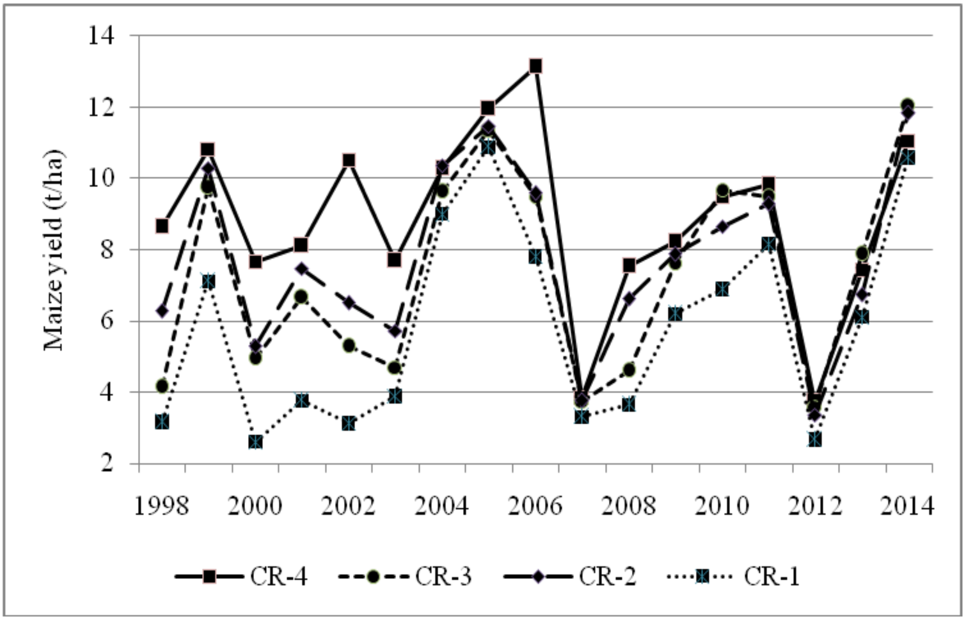

Figure 1. Significance of growing system for maize yield: CR1 – maize continuous cropping; CR2 – two-crop rotation: maize–soybean; CR3 – two-crop rotation: maize–winter wheat; CR4 – three-crop rotation: maize– winter wheat–soybean (Videnović et al., 2013b)

The most recent studies on crop rotation performed in the maize research institute, zemun polje, showed that the use of crop rotation combined with other maize growing practices might provide optimum conditions for the maximum growth of crops and efficiency of photosynthesis. When combined with herbicide application or hoeing up, crop rotation positively affected maize yields by increasing the leaf area index, content of chlorophyll and carotenoids and reduction of free energy (spasojević et al., 2014a). The effects of crop rotation are even more pronounced in years with unfavourable conditions for maize production (videnović et al., 2013a).

Soil tillage systems

Correct tillage affects the formation and renovation of a favourable soil structure, i.e., of a loosened soil layer and moisture accumulation. This improves the air–thermal soil regime, provides incorporation of organic residues of previous crops and fertilisers, and a better distribution of the herbicides applied to the soil. Under irrigation conditions, tillage has a significant role in increasing maize yield, because it enhances the effect of beneficial microorganisms, reduces erosion, and provides timely harvest and application of other cropping practices (kresović, 2003).

Considering biological and ecological relationships and environmental conservation, it is necessary to apply effective tillage practices in the maize growing systems. Conservation and reduced tillage systems have gained widespread acceptance in many countries over the past 25 years due to savings in time and economic input and reductions in environmental pollution and soil degradation (özaslan and gürsoy, 2015). With respect to this, in the recent decades, certain operations in soil tillage have been omitted (reduced tillage) or specially designed maize planters have been used to sow directly into non-tilled soil (direct sowing). Direct sowing is generally defined as sowing of crops into non-tilled soils that contain a minimum of 30 % of harvest residues. tillage applied in maize production in Serbia requires a greater number of different methods of primary tillage and pre-sowing land preparation and contributes to the achievement of the highest grain yields (Videnović et al., 2011a), Table 1. In the 2004–2008 period, the average maize grain yield in the variant with the conventional tillage, tillage with a cultivator (reduced tillage) and in the variant with direct sowing amounted to 10.6 t/ha, 9.0 t/ha (lower by 1.6 t/ha) and 6.9 t/ha (lower by 3.7 t/ha), respectively.

Table 1. Maize yield (t/ha) depending on the tillage system

Tillage method	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Average
Direct sowing	6.4	3.0	6.0	8.5	6.0	11.5	8.9	8.0	6.4	3.9	6.9
Reduced tillage	10.6	5.2	8.0	8.8	7.5	12.8	12.4	10.8	7.6	6.3	9.0
Conventional tillage	11.4	8.8	9.0	10.3	8.8	14.3	13.9	12.1	8.3	9.6	10.6
Average	9.5	5.3	7.7	9.1	7.4	12.9	11.7	10.3	7.4	6.6	8.8

Under the agro-ecological conditions of zemun polje, if reduced tillage and direct sowing are applied, greater amounts of herbicides are necessary for the suppression of weeds, particularly perennial species (simić et al., 2012a). The highest number of weed plants per species was recorded in variants with reduced tillage, which is in accordance with the significant distribution of perennial weed species that have very developed root systems and pronounced vegetative propagation.

Sowing time and density

The size and shape of the growing space in which each plant will obtain the necessary area to grow and develop are defined by sowing. Maize, belonging to the late-maturing crops germinating in spring, requires a lot of heat and is very susceptible to low temperatures. Maize sowing encompasses several operations - selection of the hybrid, preparation of the seeds for sowing, time of sowing, depth of sowing, density of sowing, i.e., the number of plants per hectare and the plant arrangement in the plot. In the recent decades, due to climatic changes, the springs have frequently been dry. Therefore, in order to ensure better use of the moisture necessary for germination and emergence, the optimum time of sowing is very often the second decade of april. The long-term results obtained in trials conducted on the slightly calcareous chernozem in zemun polje showed that the highest yields were recorded when the sowing was performed in the second decade of april, table 2 (videnović et al., 2011b). On average, the highest yield of 11.2 t/ha (100.0 %) was achieved by sowing on april 15. The yield was lower at all remaining times of sowing: april 5, 98.5 % and april 25, 97.9 %. Sowing realised in may resulted in significantly lower maize yields in comparison with sowing performed on april 15: may 5, 93.9 %; may 15, 93.3 % and may 25, 86.6 %.

Table 2. Effects of sowing time (t) on average yields (t/ha1) of zp maize hybrids (h) in the period 2003–2008 (videnović et al., 2011b).

	H1	H2	H3	H4	H5	Average	%
April 5	10.6	11.3	10.9	10.9	11.5	11.0	98.5
April 15	10.9	11.0	11.6	10.7	11.9	11.2	100.0
April 25	10.7	11.0	11.0	10.8	11.4	11.0	97.9
May 5	10.0	10.8	10.7	10.2	11.1	10.5	93.9
May 15	9.9	10.9	10.1	10.2	11.2	10.5	93.3
May 25	9.7	9.9	9.5	9.4	10.0	9.7	86.6
Average	10.3	10.8	10.6	10.4	11.2	10.7	–
%	92.3	97.0	95.3	92.8	100.0	–	–
$LSD_{0.01}$	(*T*)	0.485	(H)	0.505	(T×H)	0.765	

Minimum temperature of 10–12 °c at a 10-cm depth of the sowing layer usually provide seedling emergence within 10–15 days if the moisture is favourable. On the other hand, with favourable moisture and a temperature of 20 °c, maize seedling will emerge in 6–7 days. In the majority of years, maize sowing was performed between april 10 and april 30. The sowing depth affects not only germination and emergence, but also the development of the root system and plant productivity. An increase in the sowing depth leads to inhibition and delay of emergence. In order to mitigate adverse effects of low temperatures on the emergence rate, it is necessary to sow maize to a depth of 6–8 cm and 3–5cm in coarse textured soils and heavy soils, respectively.

The sowing density is achieved by timely sowing of the optimum number of plants for the given conditions of the habitat and the hybrid. The greater the crop density is, the higher is the total yield of the above ground weight. The increased crop density also increases grain yield, but only to a certain extend and further increases in the crop density result in the yield reduction (videnović et al., 2007; kresović et al., 2011), table 3.

Table 3. Average yield (t/ha) of hybrid zp 684 in variants with different sowing densities (Kresović et al., 2011)

Density	2006	2007	2008	2009	Average
40816	11.9	11.9	11.4	10.8	11.5
50125	12.8	12.4	13.6	12.0	12.7
59524	14.6	12.2	14.6	12.2	13.4
69686	14.2	11.1	15.9	12.7	13.5
79365	14.6	11.9	15.9	12.6	13.7
89286	13.8	12.4	16.2	12.6	13.7
98522	10.4	11.7	15.8	12.6	13.5
Average	13.7	11.9	14.8	12.2	13.2
	Year	Density	Year x	Density	
$LSD_{0.05}$	1.290	0.595	1.087		
$LSD_{0.01}$	1.808	0.722	1.443		

New Generations Of Maize Hybrids Are Characterized 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. Newer Generations Of Maize Hybrids Selected In Higher Densities (60-100,000 Plants/Ha), Have Less Robust Plants, Ears Are Placed More Lower, While The Angle Of Top Leaves In Relation To The Stalk Is Smaller (Simić Et Al., 2009). The Sowing Density Has To Be Adjusted To The Genotype, I.E., The Fao Maturity Group Of The Appropriate Hybrid, And Soil Quality, Amount Of Nutrients And Water Available To The Plants During The Growing Season. Early Maturing Hybrids (Fao 300–400) Require 70,000–80,000 Plants Per Hectare, The Hybrids Fao 500–600 Require 60,000–70,000 Plants Per Hectare, While Late Maturing Hybrids (Fao 700–800) Require 60,000 Plants Per Hectare, Which Is Significant Increase In The Number Of Plants In

Comparison To The Number In The Previous Period (Videnović Et Al., 2007). Yields Of Hybrids Characterised By A Great Height And A Powerful Habitat Are Higher At Lower Densities, While Yields Of Early Maturing And Hybrids With Shorter Plants Are Higher At Larger Densities. Newly Developed Hybrids Can Give High Yields Only When The Necessary Number Of Plants Per Unit Area Is Achieved (Simić And Stefanović, 2007). The Maize Density Directly Affects Good Crop Coverage And Consequently Increases Its Competitive Ability Against Weeds (Simić Et Al., 2009). Some Maize Genotypes May Considerably Differ From Each Other In Their Morphology And Competitive Ability Against Weeds (Simić Et Al., 2012b), Table 4.

Table 4. Effects of growing density and hybrids on yields and shelling percentage of sweet maize in the period 2008–2009 (simić et al., 2012b)

Hybrid	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	65.00	63.85	65.08b
ZP 504su	8.41	9.38	8.67	10.63	9.27c	72.11	69.02	64.97	68.50	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				

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

Fertilisation

The application of organic and mineral fertilisers, as well as certain land improvement practices (calcification, phosphatisation, humisation), significantly contribute to an improvement of unfavourable soil characteristics. It is changing chemical properties of soil, such as neutralisation of altered soil acidity, an increase of the availability of some nutrients, an increase in microbiological activities and the establishment of a favourable air and water regime in the soil. Nitrogen fertilisers can positively, but also negatively, affect soil, which indicates that fertilisation with nitrogen is very complex (Dragičević et al., 2012a). The content of available nutrients depends firstly on soil fertility (soil texture, chemical properties, organic mater content, etc.), preceding crops, weather conditions, irrigation, application of organic fertilisers, amounts of harvest residues in the soil, etc.

Previous studies conducted in Zemun Polje indicated that chernozem, as a naturally fertile soil with easily available nutrients, was less responsive to fertilisation than other soil types, especially when crop rotations with soybean were used. Such soils do not need more than 120 kg of nitrogen, 90 kg of phosphorus and 60 kg of potassium fertilisers (Videnović et al., 2007). Harvest residues of the preceding crop were crushed and ploughed down and 30–50 kgN/ha applied in autumn for easier microbiological decomposition of the organic matter. The highest yield of a late maturing hybrid in the experimental plot with long-term continuous cropping (over 35 years) was achieved when manure was applied, harvest residues ploughed down completely and N fertiliser was applied in spring at the beginning of the growing season (Simić et al., 2013). However, the highest yield of maize was not achieved when the highest amount of mineral fertiliser had been applied, and regardless of the high yielding potential of the late maturing hybrid, the yield recorded in 2011 was not greater than 10.4 t/ha. This suggests that maize production may be efficient only if the whole system of practices (crop rotation) is applied. The integrated effect of this system contributes to the achievement of record yields.

The highest maize yield in a long-term trial with three-crop rotation (maize rotated with wheat and soya bean) and the application of mineral fertilisers was achieved with 270 kgNPK/ha (Table 5). In maize continuous cropping and the maize–soybean rotation, 180 and 270 kgNPK/ha, respectively, had the best effects on yields, while higher yields in the maize–wheat rotation were obtained with greater amounts of fertilisers.

Table 5. Long-term analysis of maize yields (t/ha) in dependence on the amounts of applied mineral fertilisers and the crop sequence in the crop rotation (Zemun Polje, 1998–2009)

		Continu ous cropping	Maize–Wheat	Maize–Legume	Maize–Wheat–Legume	Average
Without fertilisation		3.64	6.53	5.85	8.52	6.14
NPK	180 t ha^{-1}	5.81	8.07	6.96	9.20	7.51
	270 t ha^{-1}	6.10	7.99	7.27	9.18	7.63
	360 t ha^{-1}	5.95	7.81	7.21	9.23	7.55
Average		5.37	7.60	6.82	9.03	7.21

The higher the maize yield is in the crop rotation, the higher is the outtake of nutrients. Hence the greatest outtake of nitrogen was recorded in the part of the plot where legume was the crop preceding maize in both rotations, with two crops (maize–legume + 270 tNPK/ha) and three crops (maize–winter wheat–legume + 360 tNPK/ha), Table 6.

The n content increased by fertilization level but has decreased during vegetation, down to harvesting phase and in higher degree in irrigation compared to rainfed cropping as well as in no-till treatment compared to conventional and reduced cropping (Dragičević et al., 2012 a).

Table 6. Effects of crop rotation on nitrogen outtake (kg/ha) with maize yield (Zemun Polje, 2013)

		Continuous cropping	Maize–Wheat	Maize–Legume	Maize–Wheat–Legume	Average
Without fertilisation		47.82	96.16	117.00	115.14	94.03
NPK	180 t ha^{-1}	88.35	94.36	136.38	128.08	111.79
	270 t ha^{-1}	92.49	93.21	141.78	131.07	114.64
	360 t ha^{-1}	98.07	89.26	129.41	144.67	115.35
Average		81.68	93.25	131.14	129.74	108.95

With the aim of protecting the agro-ecosystem, it is possible to use foliar fertilisers in maize crops, mainly for side dressing, especially if the fertiliser formulations provide its use together with plant protection products (brankov et al., 2011). Foliar fertilisers provide macro-elements and other physiologically active substances (amino acids, phytohormones, growth stimulators, etc.) Necessary for plants to overcome stress conditions more easily and to have higher yields (brankov et al., 2012; dragičević et al., 2012b). In addition to increasing the plant height and leaf area, foliar fertilisers, particularly amino acid ones, affected an increase in grain yield of maize inbred lines, table 7.

Table 7. Effects of amino acid (F1) and phosphorus (F2) foliar fertilisers on grain yield and the harvest index (Zemun Polje, average for the period 2010–2011)

	Grain yield (t/ha)						Harvest index (%)					
	L1	L2	L3	L4	L5	Average	L1	L2	L3	L4	L5	Average
K	1.86	3.11	6.09	5.6	2.81	3.89	27.2	29.4	39.3	47.6	64.1	41.5
F1	2.57	3.26	6.28	6.43	4.39	4.59	39.8	53.2	47.5	47.7	55.8	48.8
F2	1.97	3.19	6.21	5.6	5.03	4.4	36.4	58.4	52.6	50.7	51.6	49.9

L1, l2, l3, l and l5 – different inbreed lines of zp maize hybrids

Irrigation

The achievement of high yields of maize under conditions in serbia is limited by two factors: the uneven distribution and occasional deficit in precipitation. The critical period begins 15–20 days prior to tasselling and lasts until the beginning of the milk stage of maize. When the years are average in terms of weather conditions, the maize production under irrigation conditions will results in yields higher by 15–30 % or even by 50 % in seed maize. Irrigation provides the optimum water supply, activates soil microorganisms and nutrient reserves and contributes to a better utilisation of incorporated fertilisers. Grain yields of some zp maize hybrids grown under irrigation conditions showed a dependence on the amount of water that reached the soil surface (kresović et al., 2013).

Irrigation norms depend on climatic conditions, type of soil, and the type and specificities of hybrids. Water requirements of plants during the growing season under agro-ecological conditions of serbia vary from 450 to 600 mm. Guideline monthly values are as follows: 35 mm (april), 90 mm (may), 95 mm (june), 120 mm (july), 75 mm (august) and 40 mm (september). The differences between the stated amounts and amounts of effective rainfall should be compensated by irrigation. According to the obtained results, different available precipitation sums (f - 801.9051, $p < 0.01$, cv - 1.95 %) affected yields in a way that the highest yield of 15.08 t ha–1 was achieved in the variant with the greatest precipitation sum, i.e., in the variant with a pre-irrigation soil moisture of 80–85 % of field water capacity - fwc (table 8). In relation to this variant, yields were statistically very significantly lower in the other variants: 13.55 t/ha (70–75 % fwc), 12.54 t/ha (60–65 % fwc) and 10.20 t/ha (rain-fed regime).

Table 8. Average yields (t/ha) of maize in dependence on irrigation norms (Zemun Polje, 2006–2008)

Year	80–85 % FWC	70–75 % FWC	60–65 % FWC	Rain-fed regime	Average
2006	14.59	12.46	11.41	11.14	12.40
2007	16.33	14.54	13.51	10.74	13.78
2008	14.31	13.65	12.69	8.73	12.35
Average	15.08	13.55	12.54	10.20	12.84
	Year	Norm	Year x Norm		
$LSD_{0.05}$	0.236	0.210	0.364		
$LSD_{0.01}$	0.339	0.284	0.492		

Irrigation showed the best effects when it was applied together with other maize growing practices, first, with fertilising. The studies performed on slightly calcareous chernozem in the dry year of 2008 showed that the highest maize yield was obtained when conventional tillage was performed (Table 9).

The obtained yield was two-fold higher than the one obtained in the no-till variant. Irrigation increased yields, on average, by approximately 21 % in relation to those obtained under the rain-fed regime. Moreover, irrigation settled soil moisture to the similar level between tillage practices (Dragičević et al., 2012a).

The obtained results indicate the significance and contribution of certain cropping practices applied under the experimental conditions with the aim of increasing the yield of maize. Improvements of maize growing practices are possible by the correct combination and application of several practices as a system of measures adjusted to the crop-growing region and applied over a longer period. The effects of crop rotation, tillage and fertilisation on maize yields would be even greater if inputs in the application of all necessary practices regardless of the size of estates would be permanent. Therefore, an agricultural development strategy is necessary in order to regulate the defragmentation of holdings, construction of irrigation systems and an increase in the funding of improvements of maize growing practices.

Table 9. Effects of different types of tillage and fertilisation (F1, F2 and F3) on maize yields

		Irrigation					Rain-fed regime				
		2005	2006	2007	2008	$\overline{X}$	2005	2006	2007	2008	$\overline{X}$
Conventional	F1	13.18	10.54	10.86	10.69	11.32	13.13	10.08	5.72	9.64	9.64
	F2	14.53	13.51	11.88	12.20	13.03	13.80	13.51	8.57	10.27	11.54
	F3	15.68	15.06	13.00	12.99	14.18	13.92	12.72	9.10	8.78	11.13
	$\overline{X}$	14.46	13.04	11.91	11.96	12.84	13.61	12.10	7.80	9.57	10.77
Reduced	F1	10.51	11.74	11.11	7.88	10.31	10.87	9.29	5.85	3.41	7.35
	F2	12.20	12.68	12.75	9.33	11.74	12.35	10.84	9.20	8.37	10.19
	F3	12.62	13.23	11.91	11.61	12.34	13.95	12.15	8.23	7.17	10.38
	$\overline{X}$	11.78	12.55	11.92	9.60	11.46	12.39	10.76	7.76	6.32	9.31
No-till	F1	6.69	8.98	7.70	3.55	6.73	5.90	5.49	6.48	2.25	5.03
	F2	12.41	12.16	11.15	6.57	10.57	6.93	7.76	7.22	4.54	6.61
	F3	12.86	13.56	11.97	8.47	11.72	14.70	10.67	6.22	5.01	9.15
	$\overline{X}$	10.65	11.57	10.27	6.20	9.67	9.18	7.97	6.64	3.94	6.93
LSD 5 %		Year	Tillage	Fertilising			Year	Tillage	Fertilising		
		3.58	3.46	2.83			6.71	2.42	3.32		

CONCLUSION

The obtained results indicate the significance and contribution of certain cropping practices applied under the experimental conditions with the aim of increasing the yield of maize. Improvements of maize growing practices are possible by the correct combination and application of several practices as a system of measures adjusted to the crop-growing region and applied over a longer period. The effects of crop rotation, tillage and fertilisation on maize yields would be even greater if inputs in the application of all necessary practices regardless of the size of estates would be permanent. Therefore, an agricultural development strategy is necessary in order to regulate the defragmentation of holdings, construction of irrigation systems and an increase in the funding of improvements of maize growing practices.

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