10.7251/AGSY1303153S

EFFECTS OF FERTILISING SYSTEMS ON MAIZE PRODUCTION IN LONG-TERM MONOCULTURE

Milena SIMIC[1]*, Vesna DRAGICEVIC[1], Igor SPASOJEVIC[1], Dusan KOVACEVIC[2], Milan BRANKOV[1], Zivota JOVANOVIC[1]

[1]Maize Research Institute, Zemun Polje, Belgrade, Serbia
[2]University of Belgrade, Faculty of Agriculture, Zemun, Serbia
*(Corresponding author: smilena@mrizp.rs)

Abstract

Maize monoculture is still present in Serbia and usually increases weed and pest infestation and decreases yield. It can also deteriorate physico-chemical and biological properties of soil. The objective of the study was to evaluate effects of an applied fertiliser system in long-term maize monoculture on soil properties and yield.
The experiment was set up at the Maize Research Institute (MRI), Zemun Polje, in 1972 and since then, the late maturing maize hybrid ZPSC 684 Ultra was continuously grown in the same field with the application of cattle manure each fifth year. The crop residues were ploughed down in the whole and half of the amount, and they were removed from the third variant. The mineral fertiliser application included three variants: without mineral fertilisers, the application of NPK fertiliser in autumn and of N in spring, and the application of only N fertiliser in spring. The content of N, P and K and organic matter in the soil was evaluated twice per maize growing season - at the beginning and at the harvest time, during the last two seasons - 2011 and 2012. The maize grain yield was evaluated and calculated at 14% moisture.
Crop residues increased the N, P, K and organic matter contents in the soil especially in the variant without application of cattle manure. In both years, the highest average maize yield was achieved with the application of cattle manure, whole amount of crop residues, and N fertiliser distributed over the soil surface at the beginning of the growing period. Nevertheless, although the late maturing hybrid potential and fertiliser rates were high in the maize monoculture, the highest yield amounted to not more than 10.4 t/ha. This underlines the importance of all cropping practices (crop rotation, fertilization, and hybrid type), their interaction and integrated effects on maize production.

Key words: monoculture, maize, fertilisers, soil properties, yield quality

Introduction

Yield stability is an important characteristic to be considered when estimating the value of a cropping system. Maize monoculture and another two cropping systems are present in Serbia: maize continuous cropping (15%), two crop rotation (maize-winter wheat - 60% and maize-soybean - 15%) and three crop rotation (maize-winter wheat-soybean - 5%) (Jovanović et al., 2004; Kovačević et al., 2005).
Growing just one crop in the same field for many years has some disadvantages. Maize monoculture usually increases weed and pest infestation and decreases crop yield. Furthermore, monoculture can deteriorate physic-chemical and biological properties of soil. On the other hand, maize is one of the crops tolerant to continuous cropping (Todorović and Božić, 1995). According to global market demands, maize is a very profitable crop. But,

intensive and high yielding crop production implies the application of the cropping practices that will show results during a longer period of time. Studies carried out by Stranger and Lauer (2008) show that extended rotations involving forage crops, reduce N inputs, increase maize yield and are more agronomically sustainable than short-terms rotations or monoculture. Results from the long-lasting study conducted at Zemun Polje, showed that the 21-year average grain yield of maize was the lowest in monoculture (6.75 t ha^{-1}), (Videnović et al., 2007). Maize cultivation in continuous cropping with the application of the conservation tillage system and with leaving crop residues on the soil surface can possibly result in reduction of soil erosion (Papendick and Elliot, cit. Bulock, 1992).
It is known that each crop utilises different amounts of nutrients from the soil. Additionally, the composition and abundance of microflora differ among various individual crops, which affect the scope of transformation of organic and mineral matters into forms available to plants. According to studies conducted at Zemun Polje, the fertiliser application was the most effective in maize monoculture when yield has been increased by 0.76 t ha^{-1} (12.4%) after the application of 160 kg N ha^{-1}, even though the chernozem as a naturally fertile soil does not require intensive fertiliser systems (Videnović et al., 2007). Effects of monoculture on microbiological processes is deleterious, which is particularly pronounced on less fertile soils, but the activity of micro-organisms in chernozem and similar soils is high in rhizosphere despite maize monoculture (Kovačević, 2010). Adiku et al. (2009) state that the crop rotation and residue management practices can significantly affect maize performances.
Based on a long-term experimental study, the aim was to establish advantages and disadvantages of maize growing in continuous cropping. Besides, the objective was to determine the effects of the applied fertiliser system in long-term monoculture on soil properties and maize yield.

Material and Methods

The experiment was set up at the Maize Research Institute (MRI), Zemun Polje, in 1972 with the aim to evaluate effects of maize growing in monoculture on crop production and soil properties. The late maturing maize hybrid ZPSC 704 was continuously grown in the same field with the application of cattle manure each fifth year. In the last three years the recently developed late maturing hybrid ZPSC 684 Ultra was grown in the experimental field in order to suppress perennial grass weeds by applying cycloxydim. The soil type in the experimental field is slightly calcareous chernozem with 53% sand, 30% silt, 17% clay; with good fertility and 3.3% of organic matter and moderate drainage. The pH in water is 6.9 and the soil structure is silty clay loam.
The cattle manure application is the first factor in the experiment and there were two variants of fertilisation: 1080 kg cattle manure ha^{-1} applied in 2008 and without application of cattle manure. The crop residues management is the second factor with three levels: ploughing down the whole (CR1) and the half amount (CR2), and they were removed from the third part of the experimental plot (CR3). The mineral fertiliser application, as the third factor, included three variants: F1 - application of NPK fertiliser in autumn (N:P:K= 15:15:15, 1709 kg ha^{-1}) and N in spring (UREA, 320 kg ha^{-1}), F2 - the application of only N fertiliser in spring (UREA, 237 kg ha^{-1}) and F3 - without mineral fertilisers.
The content of N, P and K and organic matter in the soil was evaluated twice per a growing season - at the beginning and at the harvest time, during the last two seasons - 2011 and 2012. The maize grain yield was recorded and calculated at 14% moisture. The yield data were processed by standard deviation (SD).
Meteorological conditions

Meteorological conditions during growing seasons were different in 2011 and 2012. The precipitation was higher in 2011 (273.3 mm) than in 2012 (210.6 mm), while the mean daily temperatures were 20.1 °C and 22.1 °C, respectively. The year of 2012 was extremely dry (June - 30.7 mm; August - 5.8 mm and September - 26.0 mm) and unfavourable for maize production. A dry spell during the June-September period in 2012 year was especially important since it coincided with maize pollination and yield formation, Figure 1.

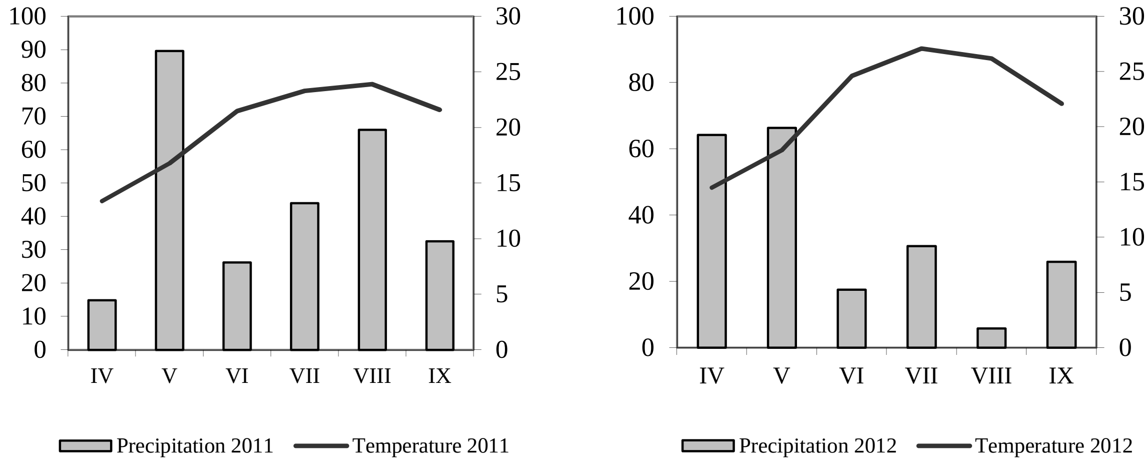


Figure 1. Meteorological conditions in 2011 and 20112

Results and Discussion

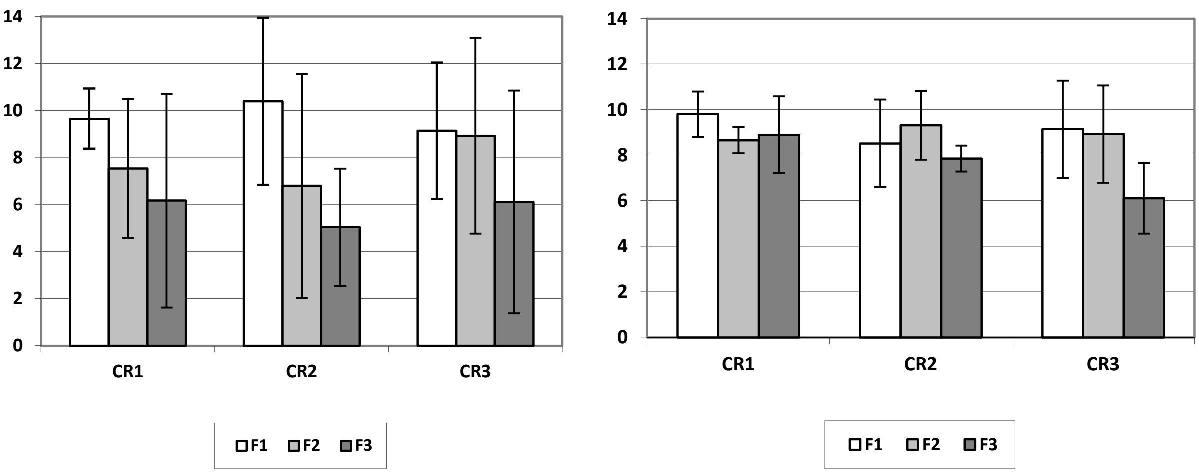
Application of cattle manure and crop residues increased the N, P, K contents in the soil especially at the beginning of the 2011 growing season (Table 1). In the plot without application of cattle manure, ploughing down of the whole amount of residues contributed to the increase of the organic matter content even up to 0.5% (F3), while in the plot with the application of cattle manure the organic matter content did not depend on the return of crop residues. The content of analysed mineral nutrients and organic matter was also increased after the application of higher amounts of fertilisers (F1), in the variant with cattle manure.

The content of the available N was reduced until the end of the growing season, whether it is related to outtake with yields or losses. The highest N loss or the highest difference in N content in the soil between the beginning of the growing season and harvest, was recorded in F2 and CR2 in the variant without application of cattle manure (149.2 kg ha^{-1}). The highest P and K losses were in the variant F1, regardless of the level of crop residue returns. On the other hand, the application of cattle manure led to the increase of organic matter and nutrient contents in the soil, as well as to their greater outtake in all trial variants.

Table 1. Effects of different fertilising treatments on N, P, K (kg/ha) and organic matter (%) contents in the soil in long-term maize monoculture (2011)

		Beginning of growing season				Harvest			
		N	P	K	OM	N	P	K	OM
Without cattle manure									
Crop residues	F1	656.7	441.5	537.0	3.3	569.9	209.5	535.6	3.0
	F2	269.1	133.1	169.5	3.2	119.9	50.7	104.3	2.5
	F3	111.4	276.6	324.7	3.3	52.3	130.4	216.9	2.8
	Av.	**345.7**	**283.7**	**343.7**	**3.3**	**247.4**	**130.2**	**285.6**	**2.8**
½ of crop residues	F1	549.4	397.6	473.7	3.1	513.1	178.8	341.4	2.7
	F2	173.4	122.0	201.9	3.1	99.5	50.7	73.0	2.6
	F3	110.0	145.3	178.3	3.0	38.6	81.9	135.7	2.7
	Av.	**277.6**	**221.6**	**284.6**	**3.1**	**217.1**	**103.8**	**183.4**	**2.7**
Without crop residues	F1	417.9	299.0	531.3	2.8	308.2	157.0	276.7	2.6
	F2	161.0	78.9	124.2	2.9	97.6	58.6	70.4	2.5
	F3	61.8	153.5	209.8	2.6	28.0	57.1	131.9	2.5
	Av.	**213.6**	**177.1**	**288.4**	**2.8**	**144.6**	**90.9**	**159.7**	**2.5**
Average		279.0	227.5	305.6	3.1	203.0	108.3	209.6	2.7
Cattle manure									
Crop residues	F1	709.6	666.5	442.9	3.2	497.1	380.6	936.8	3.2
	F2	277.8	518.2	654.6	4.1	256.8	333.3	366.6	2.6
	F3	361.4	542.6	707.4	3.6	153.1	242.3	338.8	2.6
	Av.	**539.6**	**575.8**	**601.6**	**3.6**	**302.3**	**318.7**	**547.4**	**2.8**
½ of crop residues	F1	615.9	590.9	238.1	4.0	545.7	466.6	746.2	3.5
	F2	423.4	550.0	507.2	3.0	256.0	330.8	295.5	2.9
	F3	314.5	449.7	450.7	3.3	188.4	346.3	313.8	3.3
	Av.	**451.3**	**530.0**	**398.7**	**3.4**	**330.0**	**381.2**	**451.8**	**3.2**
Without crop residues	F1	603.5	459.9	557.0	3.7	418.7	418.0	510.4	3.4
	F2	413.5	576.9	679.1	4.4	241.5	425.8	463.7	3.0
	F3	223.4	332.0	258.0	5.4	126.0	118.2	139.6	2.8
	Av.	**413.5**	**456.3**	**498.0**	**4.5**	**262.1**	**320.7**	**371.2**	**3.1**
Average		468.1	520.7	499.4	3.8	298.1	340.2	456.8	3.0

Alongside stated trends, maize yield also varied (Figure 2). Cattle manure increased the maize average yield to the greatest extent (871 kg ha^{-1}) in the variant in which the whole amount of crop residues was ploughed down and in the variant without application of mineral fertilisers.



Without cattle manure Cattle manure

Figure 2. Maize grain yield (t ha^{-1}) in dependence on crop residue management (CR) and the level of fertilising (F) in 2011 (mean value ± SD)

The statistical analysis of data indicates that the yield variation in 2011 in dependence on the application of mineral fertilisers and the return of crop residues was much less pronounced in the area in which cattle manure was applied. However, the highest yield was achieved in the variant without cattle manure with the return of a half of crop residues and with the application of NPK (CR2-F2- 10.4 t ha^{-1}).

In unfavourable year of 2012, the macroelements and the organic matter content exchange was less intensive than in previous year because of extremely dry conditions. The N content was reduced with the maize yields and losses. According to analysis, the N content in the soil was lower on average by 57.7 kg ha^{-1} at harvest (157.2 kg ha^{-1}) than in the beginning of the growing season (214.9 kg ha^{-1}) in the part of the plot in which cattle manure was not incorporated). Similarly, in the part of the plot in which cattle manure was applied, the N amount in the soil was reduced by 95.4 kg ha^{-1} (Table 2). The outtake of P and K was significantly lower: 30.7 and 21.3 kg ha^{-1}, respectively, in the part of the plot in which cattle manure was applied.

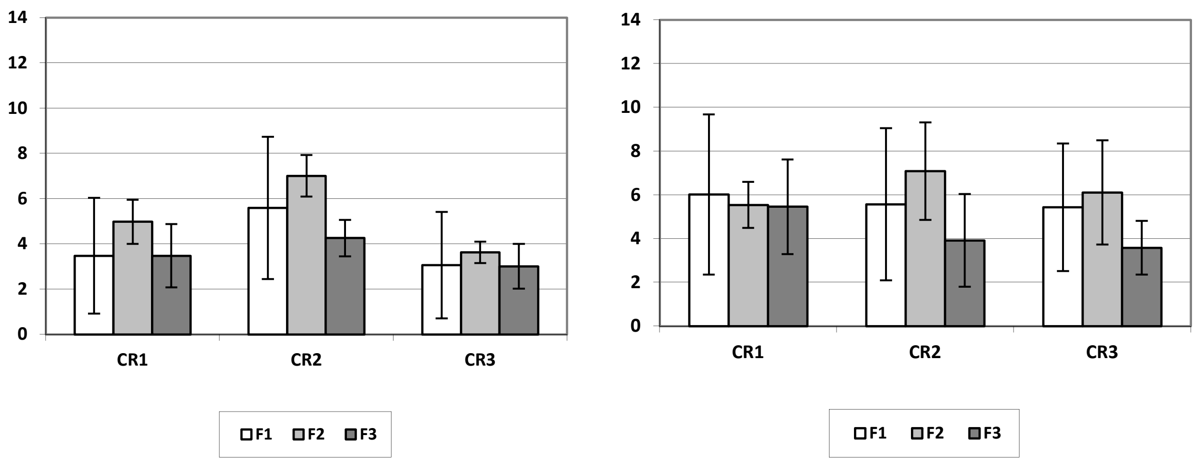
Table 2. Effects of different fertilising treatments on N, P, K (kg/ha) and organic matter (%) contents in the soil in long-term maize monoculture (2012)

		Beginning of growing season				Harvest			
		N	P	K	OM	N	P	K	OM
		Without cattle manure							
Crop residues	F1	178.9	170.6	56.8	2.9	127.9	154.0	39.6	4.7
	F2	285.3	84.7	26.1	3.2	219.0	80.8	22.4	5.0
	F3	112.8	48.7	24.4	3.0	94.2	26.7	17.9	5.0
	Av.	**192.3**	**101.4**	**35.8**	**3.1**	**147.0**	**87.1**	**26.6**	**4.9**
½ of crop residues	F1	201.4	367.4	131.7	3.6	203.4	223.9	51.1	4.8
	F2	376.7	97.1	57.1	3.5	291.8	49.3	17.2	4.5
	F3	176.7	47.1	28.9	4.1	173.3	41.8	11.3	6.6
	Av.	**251.6**	**170.5**	**72.6**	**3.7**	**222.9**	**105.0**	**26.5**	**5.3**
Without crop	F1	144.9	213.4	59.8	3.4	147.2	203.0	55.5	5.1
	F2	382.6	66.6	21.0	3.8	96.8	57.9	9.6	5.2

residues	F3	74.9	49.3	25.4	3.1	60.9	31.2	15.3	4.6
	Av.	**200.8**	**109.7**	**35.4**	**3.4**	**101.7**	**97.4**	**26.8**	**4.9**
Average		214.9	127.2	47.9	3.4	157.2	96.5	26.6	5.0
Cattle manure									
Crop residues	F1	372.1	314.7	82.9	3.1	155.4	312.1	50.6	4.3
	F2	380.3	291.6	53.7	3.6	352.6	194.0	18.5	4.4
	F3	308.3	234.8	52.1	3.6	147.6	142.0	34.5	4.7
	Av.	**353.6**	**280.4**	**62.9**	**3.4**	**218.5**	**216.0**	**34.5**	**4.5**
½ of crop residues	F1	314.9	318.2	63.4	3.6	266.3	335.5	35.4	4.8
	F2	436.8	233.1	33.9	4.0	378.0	194.0	25.6	7.5
	F3	259.3	189.4	32.4	2.8	208.8	196.6	19.9	4.5
	Av.	**337.0**	**246.9**	**43.2**	**3.5**	**284.4**	**242.1**	**27.0**	**5.6**
Without crop residues	F1	315.8	424.1	73.4	4.2	188.4	365.0	36.0	4.5
	F2	308.6	159.5	30.5	4.3	278.6	197.0	20.2	5.8
	F3	296.0	196.9	34.4	4.6	157.9	189.8	22.8	5.2
	Av.	**306.8**	**260.2**	**46.1**	**4.4**	**208.3**	**250.6**	**26.3**	**5.2**
Average		332.5	262.5	50.7	3.8	237.1	236.2	29.3	5.1

Unlike analysed macroelements, the content of organic matter increased to a smaller extent in all experimental variants and treatments during the growing season, probably as a result of the activation of soil microorganisms after rainfalls that occurred at the end of the growing season.

In 2012, under conditions of extreme drought, the application of cattle manure contributed to slightly higher maize yields (Figure 3). Regardless of the fact that stress conditions (high temperatures and lack of precipitation) prevailed during the growing season, the highest yield of over 7 t ha^{-1} was obtained in the treatment CR2-F2 due to good nitrogen supply. This means that the optimum nitrogen supply with a prolonged effect of smaller amounts of ploughed down crop residues could provide substantial yields in maize continuous cropping (Kovačević, 2010). The statistical analysis showed that the yield recorded in dry 2012 similarly varied in dependence on applied cropping practices in the variant with and without application of cattle manure.



Without cattle manure

Cattle manure

Figure 3. Maize grain yield (t ha^{-1}) in dependence on crop residue management (CR) and level of fertilizing (F) in 2012 (mean value ± SD)

The presented results indicate that crop residues and amount of applied fertilisers, influence the rates of N, P, K and organic matter in the soil in maize monoculture. The present trend of increasing percentage of maize acreage emphasises the importance of developing improved procedures for achieving optimum N and other elements use. Generally, the basic information required in predicting the optimum use of N includes the internal N requirement by the crop for the expected yield, the amount of soil N mineralised during the cropping season, the amount of residual mineral N present in the root zone early in the cropping season, and the expected efficiency of recovery of the plant –available N supply (Stanford, 1973). At higher than optimum rates, a significant portion of the nitrate remains mobile and susceptible to loss by leaching or denitrification especially during optimally wet seasons.
In both years, the highest average maize yield was achieved with the application of cattle manure, whole amount of crop residues and N fertiliser distributed over the soil surface at the beginning of the growing season. The maize grain yield was significantly higher in both fertilising treatments (F1 and F2 – 9.44 and 8.36 t ha^{-1}, respectively) in comparison to control (F3 - 6.70 t ha^{-1}) in 2011 and also in 2012 (4.86, 5.73 and 3.95 t ha^{-1}, respectively). On the other hand, there are no significant differences among applied rates of fertilisers, which is a result of the effects of meteorological conditions. Unfavourable meteorological conditions during 2012 reduced effects of fertilisers on maize yield in favourable year, 2011, but obtained differences were not significant. According to models integrating rainfall, fertiliser N and P rates, soil N and P, previous crop and tillage system accounted for 51 % of maize yield variability. Soil organic matter was not included in the models, but the indirect effect on yield was detected as organic matter correlated with initial soil N levels (Alvarez and Grigera, 2005).
Average maize yields were not the highest in the treatment with the highest amount of fertilisers (F1). It means that the application of the great rates of mineral fertilisers under the Zemun Polje conditions on slightly calcareous soil is not economically justified (Videnović et al., 2007).
Regardless of the late maturing hybrid potential and high levels of the fertiliser application in maize monoculture the highest yield was lower than 10.4 t ha^{-1} (CR2-F1 in 2011). This underlines the importance of all cropping practices (crop rotation, fertilizing, and hybrid type), their interaction and integrated effects on maize production.

Acknowledgements

This study was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia through the Project TR-31037.

References

Adiku, S.G.D, Jones, J.W., Kumaga, F.K., Tonyigah, A. (2009): Effects of crop rotation and fallow residue management on maize growth, yield and soil carbon in a savannah-forest transition zone in Ghana, Journal of Agricultural Science, Vol. 147, 313-322.

Alvarez, R., Grigera, S. (2005): Analysis of Soil Fertility and Management Effects on Yields of Wheat and Corn in the Rolling Pampa of Argentina, Journal of Agronomy and Crop Science, Vol. 191, No. 5, 321-329.

Bulock, G.D. (1992): Crop rotation. Critical Reviews in Plant Sciences, Vol. 11, No. 4, 309-326.

Jovanović, Ž., Vesković, M., Jovin, P., Kovačević, D. (2004): Effect of Different Growing Systems on Maize Yield According to The Concept of Sustainable Agriculture. Proceedings of the 8th ESA Congress, Copenhagen, Denmark, 611-612.

Kovačević, D., Oljača, S., Dolijanović, Ž., Jovanović, Ž., Milić, V. (2005): Influence of crop rotation on the yield of some important crops. International Conference TEMPO, October 6-8, Čačak, Serbia, 422-428. (*In Serbian*)

Kovačević, D. (2010): Crop Science. 1. ed. Faculty of Agriculture, Belgrade, Serbia, 771p. (*In Serbian*)

Stranger, F.T., Lauer, G.J. (2008): Corn grain yield response to crop rotation and nitrogen over 35 years, Agronomy Journal, Vol. 100, 643-650.

Todorović, J., Božić, D. (1995): Crop Science. Faculty of Agriculture Banja Luka, Faculty of Agriculture, Belgrade, 395p. (*In Serbian*)

Videnović, Ž., Ž. Jovanović, G. Cvijanović, L. Stefanović, M. Simić, 2007. The Contribution of Science to the Development of Contemporary Maize Growing Practices in Serbia, pp. 267-285. In: Science as a Basis of Sustainable Development, eds. Konstantinov K., Anđelković V., Saratlić G. and Piterson P.A., Genetic Society of Serbia, Belgrade, Serbia (*In Serbian*)