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EFFECT OF LONG TERM CROP ROTATION AND FERTILISER APPLICATION ON MAIZE PRODUCTIVITY

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ABSTRACT

The effect of crop rotation and the application of fertilisers on maize yield were investigated in a 12-year study (1998-2009) on the chernozem soil type at Zemun Polje, Serbia. The treatments included four cropping systems: continuous maize cropping (CS1); two crop rotation: maize - soybean (CS2) and maize - winter wheat (CS3), and three crop rotation maize - winter wheat - soybean (CS4) and the following fertilising treatments for maize: F1 - no fertiliser, F2 - 180 kg ha^{-1} NPK, F3 - 270 kg ha^{-1} NPK and F4 - 360 kg ha^{-1} NPK. The amount of applied nitrogen fertiliser in soybean was twice lower than in maize. The grain yield, on the average for all years, was the lowest (5.37 t ha^{-1}) in continuous maize cropping. In a dominant type of the cropping system in Serbia (CS3), the maize grain yield was 6.82 t ha^{-1} and in CS2, was higher (7.60 t ha^{-1}), even though the amount of nitrogen fertilisers applied, was lower by 50%. The highest average yield was obtained in CS4 (9.03 t ha^{-1}). The application of fertilisers generally significantly influenced maize yield in comparison with control. These results favoured cropping systems with legumes preceded maize due to lower investments necessary to obtain higher yields.

Key words: cropping system, fertilizing, maize, yield

INTRODUCTION

Maize growing practices include several important measures that significantly affect the yield (Videnović et al., 2011). The crop rotation is just one of them and it, contrary to others, does not require financial investments. Only long-term planning of the production and the distribution of crops in a farm are required (Jovanović et al., 2000a, 2000b, 2004; Videnović et al., 2007). However, attention is not often paid to the preceding crops suitable to certain crops and therefore needs and prices are mainly affected by their selection and the sowing scope. In Serbia, there are three major maize growing systems: continuous maize 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, 2010). Furthermore, in smaller fields, maize was grown after some other crops such as alfalfa and other legumes, vegetables, pastures etc. (5%). Studies carried out by Stranger and Lauer (2008) showed that extended rotations involving forage crops reduce N inputs, increase maize yield and are more agronomically sustainable than current short-terms rotations.

It is known that each crop utilises nutrients from the soil to varying extent and that soybean, as a legume crop, leaves significant amounts of nitrogen in the soil for the succeeding crop (Carpenter-Boggs et al., 2000; Varvel, 2000; Jovanović et al., 2000a; Stranger et al., 2008; Riedell et al., 2009). Therefore, smaller amounts of nitrogen fertilisers are necessary in soybean cultivation. 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. Carpenter-Boggs et al. (2000) reported that the rotation and N fertilisation significantly affected the net N mineralisation in soil samples. Adiku et al. (2009) state that the crop rotation and residue management practices can significantly affect maize performances.

The cropping system level is also very important for weed control, considering that weeds can cause great damages to corps and decreased yields (Stefanović et al. 2011). The management aimed at the increasing cropping system diversity with the application of different herbicides can lead to the development of more efficient and sustainable weed and crop management practices (Smith and Gross, 2006).

Although, research in preventive methods and cropping practices have improved weed control in row crops, the effective long-term weed management should include the crop rotation, fertiliser placement, competitive varieties etc. (Melander et al., 2005).

Based on a long-term experiment, the objective of this study was to compare the advantages and disadvantages of maize growing in continuous cropping, two crops rotation with soybean or winter wheat and the three crops rotation and to determine which growing system is the most suitable for the successful and profitable production of maize in Serbia considering the effects of the application of different rates of mineral fertilisers and their interactions with observed maize growing systems.

MATERIALS AND METHODS

Site Description and Experimental Design.

The experiment was conducted at Zemun Polje, in the vicinity of Belgrade, Serbia (44°52'N 20°20'E), during the 1998-2009 period. The soil was slightly calcareous chernozem with 47 % clay and silt and 53 % sand. The trial was set up according to the split-plot arrangement with four replications. The size of the sub-plot was 14.332 m^2. The treatments included four cropping systems (CS): CS1 - continuous maize cropping; CS2 - two crop rotation: maize - soybean; CS3 - two crop rotation: maize - winter wheat; CS4 - three crop rotation: maize - winter wheat - soybean and the following fertiliser (F) treatments for the maize crop: F1 - no fertilisers, F2 - 180 kg ha^{-1} (80 kg ha^{-1} N, 60 kg ha^{-1} P_2O_5 and 40 kg ha^{-1} K_2O), F3 - 270 kg ha^{-1} (120 kg ha^{-1} N, 90 kg ha^{-1} P_2O_5 and 60 kg ha^{-1} K_2O) and F4 - 360 kg ha^{-1} (160 kg ha^{-1} N, 120 kg ha^{-1} P_2O_5 and 80 kg ha^{-1} K_2O). The amount of applied nitrogen fertiliser in soybean was twice lower: F2 - 40 kg ha^{-1} N, F3 - 60 kg ha^{-1} N and in F4 - 80 kg ha^{-1} N.

Cropping Practices and Measurements

Total amounts of P_2O_5 and K_2O fertilisers were spread over the soil surface in the autumn. Nitrogen fertilisers for all crops were applied in spring prior to the seedbed preparation. During the 12-year period of investigation two- and three-crop rotations rotated in one plot 6 and 4 times, respectively.

Shallow stubble ploughing to the depth of 15 cm was performed after wheat and soybean harvest. Ploughing was performed in autumn to the depth of 25 cm. The soil preparation was done 7-10 days prior to sowing with a seedbed tiller. The sowing density of the late maturity (FAO 700) maize hybrid ZPSC 704 was 62,111 plants per ha; of soybean late maturity cultivar Lana 500,000 plants/ha and of winter wheat variety Pobeda 600 grains per m^2. The pre-emergence application of herbicides Atrazine 500 SC in the amount of 1 L ha^{-1} (atrazine 500 g a.i.) and Harness 2 L ha^{-1} (acetochlor 900 g a.i.) had been done in maize until 2007, when atrazine was replaced with terbuthylazine. During the growing season, inter-row cultivation was performed to suppress weeds, so they would not affect the growth and the development of the plants or would not reduce the maize yields.

All observed data were processed by the analysis of variance (ANOVA) for three factors – year, Y (12), cropping system, CS (4) and amount of fertilisers, F (4). Treatment means were compared using the Fisher's least significant difference (*LSD*) test (P = 0.05) (Steal and Torrie, 1980).

Meteorological Conditions

Twelve-year meteorological conditions during the growing season (April-September) varied significantly, hence years were divided into three groups based on the precipitation sums and the suitability of conditions for maize production: Y1 - the first group of years with the precipitation up to 300 mm, Y2 - the second group of years with the precipitation sum ranging from 300 to 400 mm and Y3 - the third group of years with the precipitation sum over 400 mm, (Figure 1).

Y1 - two unfavorable years: 2000 with 203.3 mm and 2003 with 271.8 mm. These precipitation sums were not sufficient for maize production. Figure 1 shows that there were periods with the extreme precipitation deficit, especially in critical developmental stages of maize.

Y2 - five years with moderately favourable conditions: 1998 with 319.5mm; 2002 with 373.6 mm; 2007 with 364.5 mm; 2008 with 305.9 mm and 2009 with 322.6 mm. Not only the precipitation sums were greater in these years, but also their distribution was more favourable, which resulted in higher yields than in Y1 years.

Y3 - five years with favourable conditions for maize production: 1999 with 637.3 mm; 2001 with 651.0 mm; 2004 with 477.7 mm; 2005 with 487.0 mm and 2006 with 445.3 mm. These years were favourable due to both, total precipitation sums and their good distribution over the growing season.

RESULTS AND DISCUSSION

Maize grain yield was significantly affected by the investigated parameters. The statistical analysis showed that grain yield of maize varied over years, cropping systems and fertilising treatments (Tables 1 and 2). The highly significant difference in the grain yield of maize was found to be among years. The lowest yield (3.67 t ha^{-1} or 32.7%), on the average, was recorded in 2007. On the other hand, the highest yield (11.41 t ha^{-1} or 100.0%) was obtained in 2005. It is interesting to mention that there were some years with precipitation sums lower than in 2007, but with somewhat higher yields, and also there were years with precipitation sums higher than in 2005, but the yield was lower. This points out that the precipitation distribution, duration of dry spells, wind frequency, extent of evapotranspiration, as well as some other factors could significantly affect maize grain yields. In addition, it was confirmed in the trial that in Y1 years a significant difference in grain yield was not obtained between cropping systems and the application of fertiliser. In contrast, in a very favourable year of 2005, the grain yield of maize was absolutely the highest in all cropping systems and fertiliser treatments.

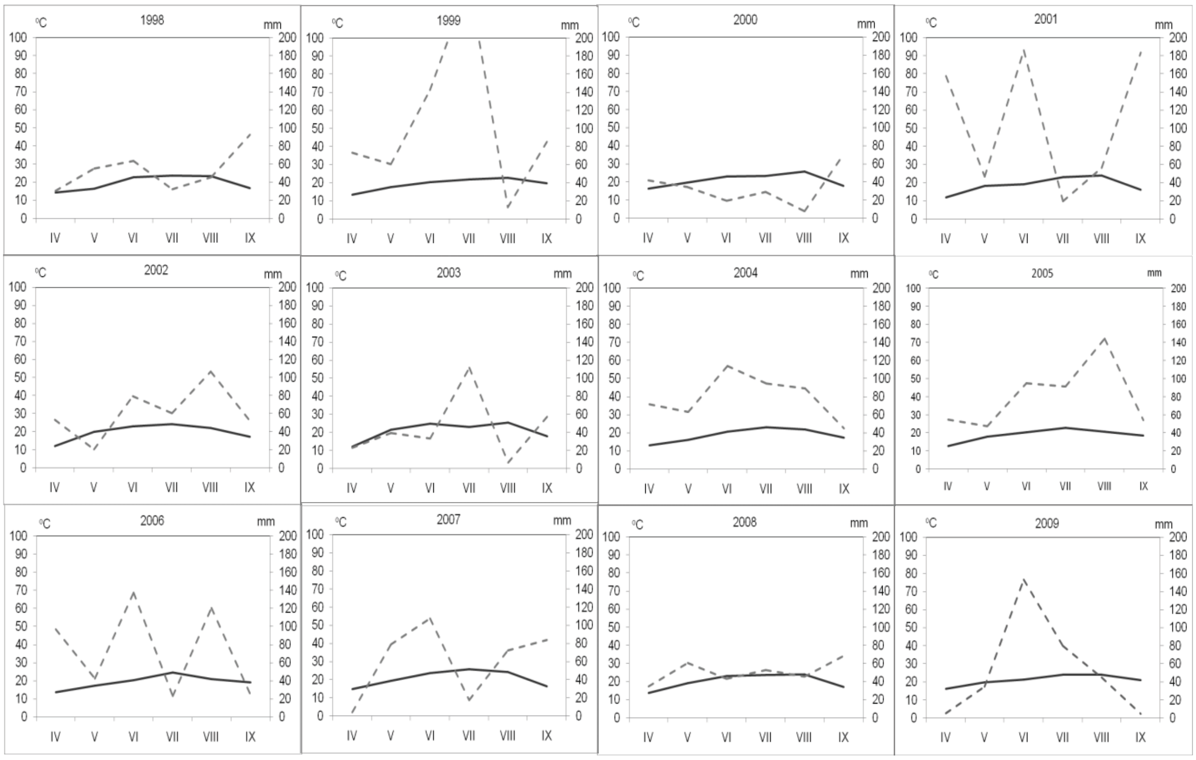

Figure 1. Walter climate diagrams of precipitation sums and average air temperatures for the April-September period during the 12-years period of investigation (1998-2009)
Climate data for Belgrade - Source: Republic Hydrometeorological Service of Serbia

Table 1. The results of the analysis of variance (ANOVA), and significance levels for maize grain yield

Sources of variance	df	F
Replication	3	1,327
Year (Y)	11	185,499*
Cropping system (CS)	3	432,329*
Y x CS	33	14,857*
Fertilisers (F)	3	208,238*
Y x F	33	18,887*
CS x F	9	12,643*
Y x CS x F	99	3,383*

* Statistically significant at P = 0.05

The studied cropping systems also significantly affected maize grain yields (Table 2, Figure 2). The yield of maize, on the average for all years and fertiliser treatments, was the lowest in CS1 (5.37 t ha^{-1}). The yields recorded in CS2, CS3 and CS4 amounted to 7.60, 6.82 and 9.03 t ha^{-1}, respectively (Table 2).

Table 2. Maize grain yield (t ha^{-1}) over the years (Y), cropping systems (CS) and levels of applied fertilizers (F), 1998-2009.

Crop systems	Fertilizer levels				Average
	F1	F2	F3	F4	
CS1	3,64	5,81	6,10	5,95	5,37
CS2	6,53	8,07	7,99	7,81	7,60
CS3	5,85	6,96	7,27	7,21	6,82
CS4	8,52	9,20	9,18	9,23	9,03
Average	6,14	7,51	7,63	7,55	7,21

$LSD_{0.05}$: Y= 0.55: CS = 0.22; C = 0.22; YxCS = 0.73; YxF = 0.49; CSxF = 0.32; YxCSxF = 0.823

In relation to maize grain yield in CS3 (6.82 t ha^{-1} or 100%), maize grain yield was 1.45 t ha^{-1} (21.3%) lower in CS1. Maize grain yield after soybean (CS2), was higher (0.78 t ha^{-1} or 11.40%) even though the 50% lower amount of nitrogen fertiliser was applied. Moreover, in CS4 grain yield was 2.21 t ha^{-1} higher than in CS3 or 32.40%. Numerous factors affected yields over tested treatments.

Reductions in yields in the continuous maize cropping were primarily recorded after dry winters, particularly if summers were also dry as it was in 1998, 2000 and 2007. Berzsenyi et al. (2000), obtained similar results. In long-term study, they found that yield-increasing effect of the crop rotation was inversely proportional to the ratio of maize or wheat in the sequence and was greatest in the Norfolk rotation and alfalfa - maize - wheat triculture that included legume crop. Varvel (2000) concluded that N, obtained from either fertiliser or legumes in continuous cropping or rotation systems, is probably one of the most, if not the most important aspect in reducing yield variability. Growing maize in extended rotations that include forage legumes may be a more sustainable practice than growing maize in either continuous cropping or two-year rotation with soybean (Riedell et al., 2009).

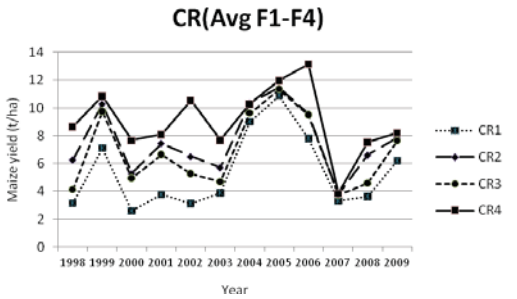

Figure 2. Effect of cropping systems on maize yield in t ha^{-1} (averagely for all fertiliser variants): CS1 - continuous maize cropping; CS2 - two crop rotation (maize - soybean); CS3 - two crop rotation (maize - winter wheat); CS4 - three crop rotation (maize - winter wheat - soybean)

The maize grain yield was significantly higher in all fertilising treatments (F2-, F3 and F4 - 7.51, 7.63, 7.55, respectively) in comparison to control (F1 - 6.14 t ha^{-1}). On the other hand, there are no significant differences among applied rates of fertilisers, due to the effects of meteorological conditions. Unfavourable meteorological conditions during the long-term studies might reduce the effects of fertilisers on maize yields in favourable years, although obtained differences were not, on the average, significant. Average maize yields were not therefore high in the treatment with the highest amount of fertilisers (F4), (Carpici et al., 2010). It could be concluded that the application of high rates of mineral fertilisers under the Zemun Polje conditions on slightly calcareous soil is not economically justified (Videnović et al., 2007).

The specificity of the obtained results was that the yield of maize grown after soybean (CS2) was higher than yield in CS3 by 0.78 t ha^{-1} (11.4%), although amounts of applied nitrogen fertilisers were 50% lower than those used for maize and winter wheat. In such a way, higher yields of maize were obtained with lower inputs. Therefore, soybean is a very suitable and desirable preceding crop for maize and thus this growing system deserves special attention. Significantly higher yields were observed at high levels of fertilisation, especially in rotations where the proportion of maize or wheat was 50% or higher (Berzsenyi et al., 2000; Ididcut and Kara, 2011). The reduced application of N fertilisers (zero N to the grain legume and less N to the following crop), improved possibilities for using reduced tillage techniques and greater diversification of the crop rotation, which helps to reduce problems caused by weeds and pathogens and therefore pesticide applications (Nemecek et al., 2008; Videnović et al., 2011).

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