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YIELDS AND YIELD COMPONENTS OF MAIZE (*Zea mays* L.) AND SOYBEAN (*Glycine max*) AS AFFECTED BY DIFFERENT TILLAGE METHODS

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Abstract

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At the experiment station of the Krizevci College of Agriculture, yield and yield components of maize (*Zea mays* L.) and soybean (*Glycine max*) grown in rotation under five different methods of tillage were investigated. The aim of this study was to determine the effect of different tillage methods on yield and yield components of maize and soybean. The results and the determined number of plants per hectare of maize and soybean show that more favorable conditions for germination are in variants where ploughing performed in the autumn (variants C, D and E). During a four-year study, the minimum number of plants per hectare of maize and soybean was found in variant A. The dry season in panicle stage of maize in 2006 has lowered yields compared to 2008, and the drought in 2007 during the seed-filling period reduced the yield and the 1000 kernel weight of soybean compared with 2009 in all variants of tillage methods. The highest grain yield of maize was recorded in variant B. During 2006, with the unfavorable weather conditions, the lowest grain yield of maize was recorded in variant E with intensive tillage treatment. The highest yield of soybean was recorded in variant E, but there were no statistically significant differences compared to variants with the reduction of additional tillage interventions (variant B, C and D). With respect to maize grain and soybean seed yield, variant A was the lowest. Considering the achieved yields of maize grain, there is a possibility of reducing additional tillage interventions, whilst for achieving higher yield of soybean seed intensive tillage is recommended.

Key words: yield, tillage, maize, soybean, climatic conditions.

Introduction

The yields of crops are affected by environmental, site and agronomical factors and the level of the basic production techniques. As is known, less precipitation and high temperatures in summer reduce yields of maize and soybean (Wilhelm, Wortmann, 2004). Falloon, Betts

(2010) and Olesen et al. (2011) stated the negative impact of climate change on crop yields in the Pannonia region. In the attempt to maintain the yields of maize at current levels, the sources of irrigation water could become questionable because the water needs will increase by 60–90% in the future (Oseni, Masarirambi, 2011; Southworth et al., 2000; Tubiello et al., 2000). In the area of the town Krizevci, because of high air temperature and lower precipitation in the past 16-year period, soil water deficiencies compared with the two previous 30-year periods were proved by the Thornthwaite and Palmer method (Špoljar et al., 2004). These data are clearly supporting the need to adapt the methods and timing of tillage to extreme climatic conditions. In order to preserve soil moisture needed by the crops during the dry season, conservation tillage is increasingly being introduced (Birkás et al., 2008). Preserving soil moisture content and water retention in soil satisfying the demand of the crops are important expectation in soil and water conservation tillage systems (Birkás et al., 2008).

Significant influence of the applied tillage systems on yield and yield components of maize grain is determined (Franchini et al., 2012; Baloyi, 2013; Mohseni et al., 2013; Partokazemi et al., 2012). After 15 years of research into different ways of tillage on Stagnic Luvisols in central Croatia have determined a significantly lower yield of grain of maize and soybean and a smaller number of plants compared with the no-tillage method (Kisić et al., 2010). Considering the negative effects of intensive, conventional tillage, Birkás et al. (2004) recommended to realize adaptable tillage systems suitable for climatic and site conditions and crops grown, preserving natural soil fertility. Therefore, the objective of this study was to determine the effect of different tillage methods in the changed climatic conditions on yield and yield components of maize and soybean.

Materials and research methodology

The research was conducted at experiment station at the College of Agriculture at Krizevci (N 46^{0}01'12"; E 16^{0}34'28") in the period from 2006 to 2009. Field experiment was set up on Stagnic Luvisols (IUSS-WRB, 2006). With the application of various methods of tillage, maize and soybean were grown in crop rotation. The study included five different methods of tillage (Table 1).

The experiment was executed at a trial area of 0.8 ha, with five different tillage methods (variants) in four replications, and the area of each plot was 280 m^2 (20x14 m). In all the variants of tillage, fertilization, planting and weed

T a b l e 1. Variants of tillage methods.

Autumn	**Spring**
A	Primary tillage at 30–35 cm depth, additional tillage by multi-tiller (one tillage pass), four-row seeder was used for planting maize (*Zea mays* L.) and wheat sowing machine for soybean (*Glycine max*), herbicides according to the type of weed.
B	Primary tillage, sowing and herbicides as in variant A, additional tillage by rotary harrow (one tillage pass).
C – Primary tillage at 30–35 cm depth	Additional tillage by spike and rotary harrow, sowing and herbicides as in variant A.
D – Primary tillage at 30–35 cm depth	Additional tillage by spike harrow and multi-tiller, sowing and herbicides as in variant A.
E – Primary tillage at 30–35 cm depth	Additional tillage by spike harrow, disc harrow and multi-tiller, sowing and herbicides, as in variant A. (intensive tillage).

control were consistent. Corn hybrid Pioneer PR 38 A 24 was grown in 2006 with the planned number of plants of 102 000 ha^{-1} and in 2008 with 90 000 plants ha^{-1}. Soybean cultivar Višnja (maturity group 00) was grown in 2007 and 2009. Sowing rates were 130 kg seed ha^{-1} with rows spaced 36 inches on all variants of tillage. Maize sowing was performed on May 3, 2006, and April 30, 2008, and soybean sowing was performed on April 25, 2007, and April 23, 2009. After the full germination, the number of soybean plants was determined by counting on the area of 1 m^2 and the number of maize plants on the area of 10 m^2 (20 replications per tillage variant). We calculated seed set on the area of 1 ha. Maize grain yield in each variant was measured in four replications by weighing grain of manually crowned pistons harvested from the area of 10 m^2. Soybean seed yield was measured by weighing seeds harvested using combine harvester from each variant with four replications.

After maize harvest and soybean harvest, samples were taken for measurement of moisture content in grain and seed, test weight and 1000 kernel weight. Test weight of grain was determined by the Schopper scale (20 replications per variant), and 1000 kernel weight by manual counting and weighing (20 replications per variant). The yield of maize and soybean, test weight and 1000 kernel weight were calculated on the basis of 14% moisture. All data were analysed statistically using analysis of variance. Mean values were compared through Dunkan's test for multiple comparisons, using the statistical software Statistica StatSoft, Inc. 2007.

Results

Mean monthly temperatures and monthly precipitation for the stated years and a multi-year period, in the growing season, from April to September, are presented in Table 2. Annual course of monthly precipitation and mean monthly air temperature in the area of Krizevci for the period from 1927 to 2005 and examined years of 2006, 2007, 2008 and 2009 are shown in Walter Climate diagrams (Figs 1–5). The determined numbers of plants per hectare of maize and soybean after the full germination are shown in Table 3, and the achieved yields of maize and soybean in Table 4. 1000 kernel weight and test weight are shown in Tables 5 and 6.

Walter Climate diagrams have not indicated drought in the multi-year period from 1927 to 2005 (Fig. 1). Annual precipitation and temperature in the investigated years from 2006 to 2009 indicate the occurrence of extreme climatic conditions, that is, dry periods, with no regularities in their occurrence over the years (Tables 2–6).

The increase of mean annual air temperature in comparison with multi-year average has been determined in the amount of 1 °C in 2006, 1.8 °C in 2007 and 1.6 °C in 2008 and 2009. Also, during the growing season of the investigated years, an increase in air temperature and decrease in precipitation have been determined compared to the period from 1927 to 2005.

T a b l e 2. Average monthly air temperature and monthly precipitation for the studied years and multi-year average for the period from 1927 until 2005.

Year/month	2006	2007	2008	2009	1927–2005	2006	2007	2008	2009	1927–2005
	Average monthly temperature, ^{0}C					Total monthly of precipitation, mm				
April	11.9	13.0	11.6	14.0	10.3	61.7	8.0	30.8	27.4	60.3
May	15.2	17.5	17.0	17.4	15.0	106.0	81.2	27.3	62.4	76.9
June	19.5	21.5	20.4	18.8	18.5	46.5	77.7	154.0	52.1	90.8
July	22.7	21.6	21.0	21.6	20.1	22.9	67.7	66.8	60.6	80.9
August	18.3	20.5	20.6	21.3	19.3	124.6	56.3	51.9	93.2	74.7
September	16.8	13.7	14.5	17.8	15.3	71.2	148	69.0	39.3	73.7
IV–IX	17.4	18.0	17.5	18.5	16.4	432.9	438.9	399.8	335.0	457.3

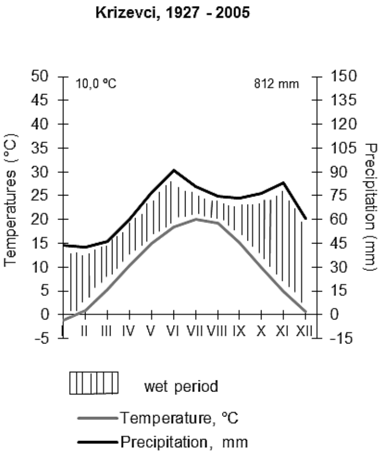

Fig. 1. Water climate diagram multi-year.

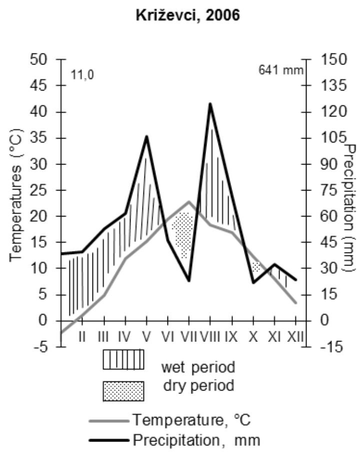

Fig. 2. Water climate diagram for 2006.

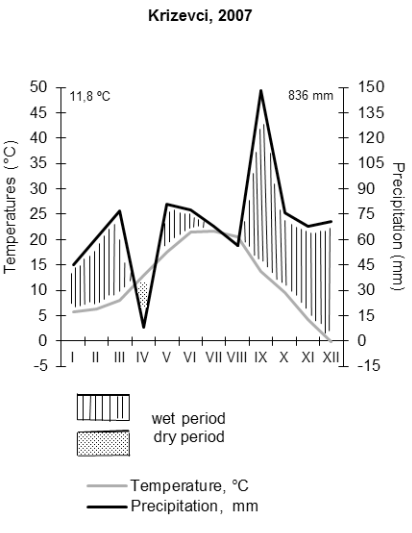

Fig. 3. Water climate diagram for 2007.

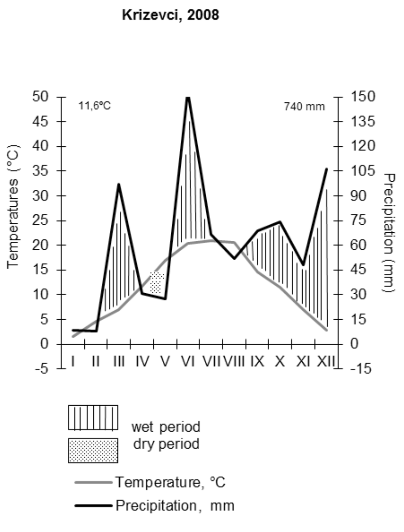

Fig. 4. Water climate diagram for 2008.

The average air temperature in the vegetation of maize and soybean in 2006 from April to September – compared with previously investigated period – was higher by 1.3 °C, in 2007 by 1.6 °C, in 2008 by 1.1 °C and in 2009 by 2.1 °C (Table 2). Compared with multi-year average, the precipitation was lower in 2006 by 24.4 mm, in 2007 by 18.4 mm, in 2008 by 57.5 mm and in 2009 by 122.3 mm (regarding to the multi-year average).

It is evident from Table 3 that in comparison with the spring ploughing variants A and B in 2006, variants C, D and E have a statistically significantly greater number of plants per hectare of maize after the full germination. In 2008, a significantly greater number of plants per hectare of maize was found only in the variant E in relation to variant A.

As with maize, a greater number of plants per hectare of soybean was counted in variants where tillage was conducted in autumn compared with spring ploughing variants. In 2007 and 2009, the largest number of plants per hectare of soybean was recorded in variant E in comparison to other investigated tillage methods. Also, in 2009, compared with 2007, a greater number of plants per hectare was identified in all the investigated variants of tillage. In both studied years, there was a statistically significant minimum number of plants per hectare of soybean in the tillage variant A.

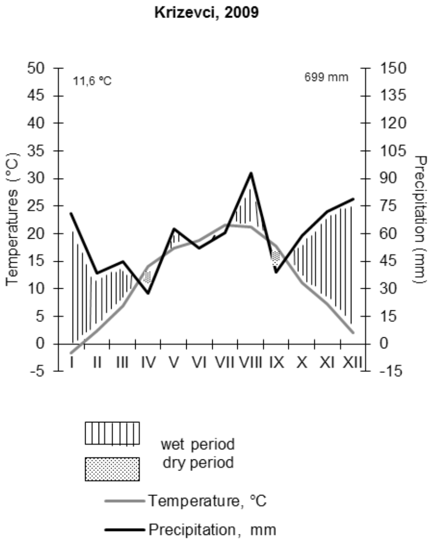

Fig. 5. Water climate diagram for 2009.

T a b l e 3. Plants per hectare of maize (*Zea mays* L.) and soybean (*Glycine max*) in different tillage variants.

Crop, year	Tillage variant				
	A	B	C	D	E
Maize (*Z. mays* L.), 2006	73 750^{b}	75 100^{b}	98 500^{a}	98 500^{a}	98 000^{a}
Maize (*Z. mays* L.), 2008	77 250^{b}	78 650^{ab}	78 000^{ab}	78 050^{ab}	81 900^{a}
Soybean(*G. max*), 2007	505 000^{d}	594 500^{c}	534 000^{d}	644 000^{b}	749 500^{a}
Soybean (*G. max*), 2009	667 500^{d}	757 000^{b}	828 000^{ac}	786 500^{bc}	812 500^{ab}

* Values within rows indicated by different letters are significantly different (p<0.05).

T a b l e 4. Grain yield of maize (*Zea mays* L.) and soybean (*Glycine max*) (t ha^{-1}) by tillage variant.

Crop, year	Tillage variant				
	A	B	C	D	E
Maize (*Z. mays L.*), 2006	10.79^{ab}	12.67^{a}	11.85^{ab}	10.14^{b}	9.93^{b}
Maize (*Z. mays L.*), 2008	10.49^{b}	13.83^{a}	13.53^{a}	13.17^{a}	13.57^{a}
Soybean (*G. max*), 2007	1.71^{c}	2.09^{ab}	1.99^{b}	2.00^{b}	2.24^{a}
Soybean (*G. max*), 2009	2.96	3.05	2.86	2.99	3.51

* Values within rows indicated by different letters are significantly different (p<0.05).

The highest grain yield in both studied years was determined in variant B, and the lowest in 2006 was in variant E and in 2008 in variant A (Table 4). The highest seed yield of soybean in both studied years was found in the intensive tillage variant (variant E) in the years. In 2006, the 1000 kernel weight of maize, as an indicator of grain size, was the largest in tillage variant D and in 2008 in tillage variant C (Table 5).

T a b l e 5. The 1000 kernel weight of grain and seeds (in g) of maize (*Zea mays* L.) and soybean (*Glycine max*).

Crop, year	Tillage variant				
	A	B	C	D	E
Maize (*Z. mays* L.) 2006	397.03[a]	398.83[a]	388.20[b]	400.26[a]	397.52[a]
Maize (*Z. mays* L.) 2008	358.90[b]	377.98[ab]	390.56[a]	373.08[ab]	354.97[b]
Soybean (*G. max*) 2007	164.41	165.06	161.50	166.34	166.49
Soybean (*G. max*) 2009	180.69[bc]	186.98[a]	183.15[ab]	185.44[ab]	177.12[c]

* Values within rows indicated by different letters are significantly different ($p<0.05$).

However, in 2007, no significant differences were determined in the 1000 kernel weight of soybean seeds in relation to the applied method of tillage. In 2009, a higher 1000 kernel weight of seed was recorded compared with 2007 in all tillage variants. In the very last year of the investigation, the greatest 1000 kernel weight of soybean seeds was found in tillage variant B.

T a b l e 6. Test weight of grain and seeds (kg) of maize (*Zea mays* L.) and soybean (*Glycine max*).

Crop, year	Tillage variant				
	A	B	C	D	E
Maize (*Z. mays* L.), 2006	84.93[a]	84.50[a]	83.58[bc]	83.63[b]	82.96[c]
Maize (*Z. mays* L.), 2008	66.53[d]	69.30[bc]	73.41[a]	67.53[cd]	71.67[ab]
Soybean (*G. max*), 2007	68.44[b]	68.82[a]	69.13[a]	69.03[a]	69.23[a]
Soybean (*G. max*), 2009	66.37[b]	66.73[b]	65.24[c]	66.64[b]	69.51[a]

* Values within rows indicated by different letters are significantly different ($p<0.05$).

In 2006, regarding the test weight of maize grain, the best tillage method was variant A, and in 2008, variant C (Table 6). The highest test weight of soybean seeds in both investigated years was in variant E.

We found the climatic conditions as important factor for yield, yield components and success of the applied methods of tillage. In 2006, because of the abundant precipitation in the last 10 days of April and in early May and poor preparation of the sowing layer, a smaller number of plants per hectare of maize was determined in the spring ploughing variants (variants A and B) compared to the variants ploughed in the autumn (variants C, D and E). With regarding to the determined number of plants per hectare of maize, in both studied years, the lowest number was determined in the variant prepared by spring ploughing and additional tillage by multi-tiller (variant A). As with maize, a generally larger number of plants per hectare of soybean was determined in autumn ploughing variants (Table 3). In 2007 and 2009, the largest number of plants per hectare of soybean was determined in variant E. The results of a four-year study of a number of plants per hectare of maize and soybean indicate that more favorable conditions for germination can be reached by ploughing in autumn (variants C, D and E).

Discussion

In the four years of investigation, the minimum number of plants per hectare of maize and soybean was found in variant A. In all four studied years, the minimum number of plants per hectare of maize and soybean was determined in variant A. Kvaternjak et al. (2008) have determined the worst results regarding the number of plants per hectare of maize and soybean in a variant of spring ploughing and additional tillage by multi-tiller compared to other investigated variants of tillage methods. Máthé-Gáspár, Rátonyi (2008) noted a significantly higher number of plants per hectare of maize in a variant where ploughing was done in the autumn compared to the spring ploughing variant. However, using deep tillage, a larger number of plants per hectare of maize and soybean was obtained (Kisić et al., 2010; Najafinezhad et al., 2007). In contrast, Carter et al. (2002) and Olson et al. (2013) have not found significant differences in the number of plants per hectare of maize in relation to the applied tillage systems and the cultivation in crop rotation.

We found that the largest number of plants per hectare has not led to the highest grain yield of maize. In 2006, regarding the grain yield, variant B was the best, whilst the worst was a variant of intensive tillage (Špoljar et al., 2009). In contrast, the highest grain yield of maize were achieved in a variant of deep and conventional tillage (Kisić et al., 2002; Jug et al., 2006). In 2008, in respect of grain yield, the best variant was variant B (Table 4). The highest yields of grain of maize and soybean and number of plants per hectare reached in varieties where ploughing and additional tillage by rotary harrow were applied was found in the research by Rusu (2005) and Rusu et al. (2011). Lower yields of maize in 2006 compared to 2008 in all tillage variants, except for variant A, can result from less precipitation and high mean monthly air temperature in June and July (Table 2), that is, the occurrence of the longer dry period (Fig. 2). The unfavorable climatic conditions during the growing season of maize in 2006, that is, the dry period in June and July, may be the probable cause of lower yield compared to the situation in 2008 in all tillage variants, except for variant A. Also, Wilhelm and Wortmann (2004) and Oveysi et al. (2010) have found a lower test weight of grain of maize and soybean in years with less precipitation during summer. In 2007, the drought period ensued in soybean seed-filling stage, and for this reason, both yield and the 1000 kernel weight were lowered compared with the same parameters in 2009. Nouri-Ganbalani et al. (2009) and Pospišil et al. (2009) also obtained a lower weight of seeds per plant and a lower 1000 kernel weight in the year of unfavorable weather conditions (high temperatures and unfavorable distribution of precipitation). Significantly lower yields and lower grain weight per plant of maize because of a lack of water in the soil during the grain-filling stage were determined by Gambin et al. (2007).

In our research, in 2007 and 2009, the highest yield of soybean was obtained in the variants of intensive tillage, but it was not statistically significantly higher compared to variants with the reduction of additional tillage procedures B, C and D. In the variant of conventional tillage compared to reduced one, increased soybean yield with no statistically significant differences were obtained by Pikul et al. (2001). With respect to the grain yield of maize, it is possible to reduce the interventions of additional tillage, whilst for achieving higher seed yield of soybean, intensive tillage is recommended.

Conclusion

The influence of tillage methods and climatic conditions on yield and yield components of maize and soybean was determined. Regarding maize yields, the best variant of tillage was spring plowing and harrowing with rotating harrow in one pass (variant B). Higher soybean yields were determined in variant E of intensive tillage, but these differences were not statistically significant compared to reduced tillage in variant B. Autumn primary tillage, variants C, D and E, are better options for germination of maize and soybean. The number of plants determined in these variants of tillage was significantly higher compared with the spring primary tillage, variants A and B. Dry period in June and July 2006 and droughts during the grain-filling stage in 2007 caused lower yields and lower 1000 grain weights of maize and soybean in all tillage variants compared to climatically more favorable 2008 and 2009.

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