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MAIZE AND SUNFLOWER PRODUCTION IN POSAVINA, CROATIA INFLUENCED BY DIFFERENT SOIL TILLAGE SYSTEMS

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Abstract: The paper presents results of the two years experiment in maize and sunflower production with four different soil tillage systems carried out in Western Slavonia, at agricultural company "PK Nova Gradiska" in village Staro Petrovo Selo, located 150 km south-east from Zagreb (45° 10' N, 17° 30' E). Energy requirement comparison showed that CT system had the highest fuel consumption of 62.93 L ha^{-1} (maize) and 57.96 L ha^{-1} (sunflower). In maize production the best energy saving system was RT2 with 36.30 L ha^{-1}, while in sunflower production was RT1 with 36.41 L ha^{-1}. Comparison regarding labour requirement unveiled that conventional tillage (CT) required 2.62 h ha^{-1} and 0.35 h Mg^{-1} in maize, while in sunflower it required 2.63 h ha^{-1} and 0.35 h Mg^{-1}. The lowest labour requirement in maize production of 1.48 h ha^{-1} and 0.19 h Mg^{-1} achieved RT2 followed by RT1 with 1.49 h ha^{-1} and 0.15 h Mg^{-1}, while in sunflower the lowest requirement achieved RT1 with 1.35 h ha^{-1} and 0.14 h Mg^{-1}. The highest average yield obtained system RT1 in both crops, while the lowest yield was with RT3 in maize and CT in sunflower production.

Key words: *fuel consumption, energy and labour requirement, income/costs ratio.*

INTRODUCTION

Maize (*Zea mays* L.) and Sunflower (*Helianthus annuus* L.) are among the most important arable crops in Croatia. The mainly utilised soil tillage system in these crops production is conventional system, based on mouldboard ploughing as primary tillage operation, followed with secondary tillage performed by disc harrow and seed-bed implement. This tillage technology is, from one side, the most expensive, complicated, organisationally slow, with high fuel consumption and labour requirement, and, from another side, ecologically unfavourable (Zugec et al., 2000). Pellizzi et al. (1988) reported that 55-65% of direct field energy consumption could be accounted to soil tillage. According to Conservation Technology Information Center (2000) no-till system in USA is applied to almost 40 % of arable land. Many authors from Central Europe, Borin and Sartori (1995), Kornmann and Köller (1997), Knakal and Prochazkova (1997), Malicki et al. (1997), Tebrügge et al. (1998), pointed out of ecological and economical benefits, which can be achieved by using non-conventional tillage systems instead of conventional. Although it is known that non-conventional tillage systems in comparison to conventional tillage system can save enormous quantity of energy and labour, decreasing thus environment pollution and production costs, currently 93.7% of the fields in Croatia are being tilled by the conventional tillage system (Zimmer et al., 2002).

MATERIALS AND METHODS

The experiment was performed at agricultural company "PK Nova Gradiska" in village Staro Petrovo Selo, located 150 km south-east from Zagreb (45° 10’ N, 17° 30’ E). Experimental field was consisted of 12 plots with dimension length 250 m x width 56 m each, organized as randomized blocks with three replications. The tillage with different systems was performed on the Hypogley-vertic type of soil, (Anonymous, 1998). Its texture in ploughed layer according to Anonymous (1975) belongs to the silty clay loam (Table 1). Implements, which were included in different tillage systems, are as follows:

- Conventional tillage - plough, disc harrow, seed-bed implement (CT);
- Conservation tillage 1 - chisel plough, disc harrow, seed-bed implement (RT1);
- Conservation tillage 2 - chisel plough, rotary harrow, drill (RT2);
- Conservation tillage 3 - plough, rotary harrow, drill (RT3).

Depth of tillage for mouldboard plough was in average 23.6 cm, disc harrow 10.2 cm and seed-bed implement 6.8 cm. Chisel ploughing was done to 26.6 cm in average.

The energy requirement of each tillage system was determined by tractor’s fuel consumption measurement for each implement in each tillage system applying volumetric method. Energy equivalent of 38.7 MJ L^{-1} (Cervinka, 1980) was presumed. In this experiment 4WD tractor with engine power of 141 kW was used. The working width of the tillage implements was chosen according to the pulling capacity of the tractor. The labour requirement was determined by measuring the time for finishing single tillage operation at each plot of the known area (14000 m^2). The yields were determined by weighing grain mass of each harvested plot.

Table 1. Soil particle size distribution and soil type (Hypogley-vertic)

Soil layer (cm)	0.2-2 µm (%)	0.05-0.2 µm (%)	0.002-0.05 µm (%)	<0.002 µm (%)	Soil type*
0-35	16.0	28.0	22.0	34. 0	SCL
36-55	13.0	32.0	26.0	29.0	SCL - SL
56-85	13.0	31.0	28.0	28.0	SCL
86-170	16.0	31.0	24.0	29.0	SCL

*SCL=Silty clay loam, SL=Silty loam

Air temperatures in cropping period 2005-2007 were generally within twenty year's average (Figure 1), except of noticeably warmer winter 2006/07. During maize growing period the significant lack of precipitation occurred in July 2006 (37 % of average), while in August 2006 more than double quantity of monthly precipitation was recorded (Figure 2). So, weather conditions regarding precipitation for maize flowering were unfavourable. During sunflower growing period the significant lack of precipitation occurred in time of sowing in April 2007 (only 23 % of average), and again in July 2007 (38 % of average), while great excess of precipitation was recorded before harvest in September 2007 (almost twice of average quantity).

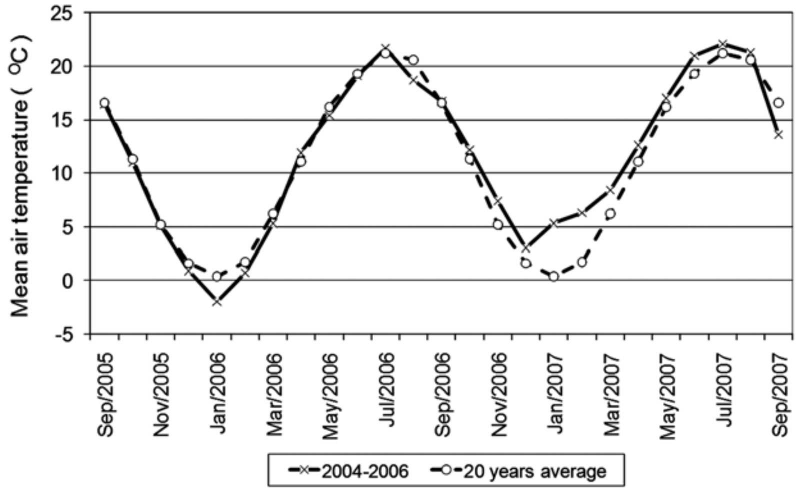

Figure 1. Mean air temperature during cropping period

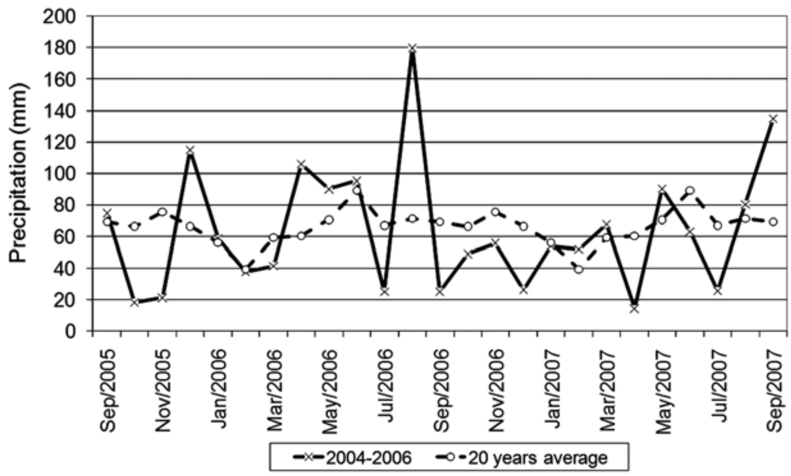

Figure 2. Precipitation during cropping period

Schedule of the field operations (tillage, fertilizing, sowing, crop protection, harvesting) and soil moisture content at the moment of tillage are shown in Table 2. On the experimental field previous crop was winter barley. Working conditions regarding soil moisture content, soil compaction and post-harvest residues at the beginning of experiment were equal for all tillage treatments.

Table 2. Date of field operations, soil moistures and application rates

Description	Maize 2005/2006	Sunflower 2006/2007
Tillage & Sowing		
Primary tillage	5th – 7th November 2005	20th November 2006
Soil moisture (%) at 5; 15; 30 cm depth	24.7; 45.6; 47.3	27.4; 39.1; 40.8
Secondary tillage	18th May 2006	17th April 2007
Soil moisture (%) at 5; 15; 30 cm depth	28.0; 46.3; 47.3	26.7; 42.8; 40.2
Sowing date	18th May 2006	19th April 2007
Crop (cultivar)	PR 37H24	PR 63A90
Fertilizing		
Application date	4th November 2005	19th April 2007
Fertilizer-rate (kg ha^{-1})	NPK (17.8-22.5-22.5)	Urea 46% (50); NPK (22.5-22.5-22.5)
Application date	16th May 2006	22nd May 2007
Fertilizer-rate (kg ha^{-1})	Urea 46% (250)	CAN 27% (150); NPK (86-22.5-22.5)
Application date	18th May 2006	
Fertilizer-rate (kg ha^{-1})	NPK 15:15:15 (150)	
Application date	22nd June 2006	
Fertilizer-rate (kg ha^{-1})	CAN 27% (150)	
Crop protection		
Application date	20th May 2006	22nd June 2007
Chemical-rate (l ha^{-1})	terbuthylazine + acetochlor + dichlormid (5)	alphametolachlor (1.3); fluchloridon (1.6); oksifluorfen (0.6)
Application date	14th June 2006	16th July 2007
Chemical-rate (l ha^{-1})	dicamba (0.5)	triazole (2); carbendazin (0.35)
Harvest		
Harvesting date	2nd November 2006	25th September 2007

RESULTS AND DISCUSSION

Yield

In the first experimental season differences among average maize yields obtained by different soil tillage systems were statistically significant according to ANOVA. The greatest average yield obtained by RT1 (9.65 Mg ha^{-1}) was significantly different from all other tillage systems at probability level of $p<0.05$. Differences of average yields between RT2 (7.95 Mg ha^{-1}) and RT3 (6.84 Mg ha^{-1}) were also significant at probability level of $p<0.05$, while average yield of CT (7.48 Mg ha^{-1}) wasn't significantly different from yields obtained by RT2 and RT3 (Table 3). Bakhsh, Kanwar et. al. (2000) experimenting with different tillage systems in maize and soybean production found that average corn yield on chisel plots was significantly (p=0.05) higher then with no tillage system. On the contrary, Kosutic, Filipovic et. al. (2001) reported of the greatest maize yield achieved by CT system in comparison to non-conventional tillage systems. Results of Tolimir, Veskovic et. al. proved that conventional tillage yields were 24 % and 84 % higher compared to reduced and zero tillage, respectively.

In the second experimental season the greatest average sunflower yield of 3.70 Mg ha^{-1} achieved RT1 system. RT2 system obtained average yield of 3.65 Mg ha^{-1} and RT3 system 3.31 Mg ha^{-1}. CT system had the lowest average yield of 3.26 Mg ha^{-1}. In spite of noticed average yield differences, statistical analysis showed they were not significant. Diaz-Zorita et. al. (2002) results of long-term tillage trials have also showed that average crop yields (sunflower, maize, soybean and wheat) with use of no-till system are similar to those observed with other tillage systems.

Table 3. Energy and labour requirement of different soil tillage systems

	Maize 2005/2006				**Sunflower 2006/2007**			
Tillage system	Fuel L ha^{-1}	Energy MJ Mg^{-1}	Productivity h ha^{-1}	h Mg^{-1}	Fuel L ha^{-1}	Energy MJ Mg^{-1}	Productivity h ha^{-1}	h Mg^{-1}
CT	Average Yield = 7,48 Mg ha^{-1} bc (1)				Average Yield = 3,26 Mg ha^{-1} a			
Plough	42,45	219,6	1,72	0,23	39,52	469,4	1,64	0,22
Disc harrow	10,34	53,5	0,31	0,04	11,32	134,5	0,49	0,06
Seed-bed impl.	6,68	34,6	0,23	0,03	3,72	44,2	0,15	0,02
Drill	3,46	17,9	0,35	0,05	3,34	40,4	0,36	0,05
Total	**62,93**	**325,5**	**2,62**	**0,35**	**57,96**	**688,5**	**2,63**	**0,35**
RT 1	Average Yield = 9,65 Mg ha^{-1} a				Average Yield = 3,70 Mg ha^{-1} a			
Chisel	18,26	73,2	0,60	0,06	21,27	222,5	0,50	0,05
Disc harrow	10,34	41,5	0,31	0,03	8,02	83,9	0,35	0,04
Seed-bed impl.	6,68	26,8	0,23	0,02	3,72	38,9	0,15	0,02
Drill	3,46	13,9	0,35	0,04	3,4	35,6	0,36	0,04
Total	**38,74**	**155,4**	**1,49**	**0,15**	**36,41**	**380,9**	**1,35**	**0,14**
RT 2	Average Yield = 7,95 Mg ha^{-1} b				Average Yield = 3,65 Mg ha^{-1} a			
Chisel	18,26	88,8	0,60	0,07	21,27	225,6	0,50	0,06
Rotary harrow	14,58	70,9	0,53	0,07	15,68	166,3	0,67	0,08
Drill	3,46	16,8	0,35	0,04	3,4	36,1	0,36	0,04
Total	**36,3**	**176,6**	**1,48**	**0,19**	**40,35**	**427,9**	**1,52**	**0,19**
RT 3	Average Yield = 6,84 Mg ha^{-1} c				Average Yield = 3,31 Mg ha^{-1} a			
Plough	42,45	240,1	1,72	0,25	39,52	461,5	1,64	0,24
Rotary harrow	14,58	82,5	0,53	0,08	14,65	171,1	0,68	0,10
Drill	3,46	19,6	0,35	0,05	3,4	39,7	0,36	0,05
Total	**60,49**	**342,2**	**2,61**	**0,38**	**57,57**	**672,3**	**2,67**	**0,39**

(1) Different letters indicate significant ($p \le 0.05$) differences

Energy requirement

The conventional tillage system (CT) was expectantly the greatest fuel consumer with 62.93 L ha^{-1} in maize and 57.96 L ha^{-1} in sunflower production. The RT3 system enabled saving of 4 % of energy per hectare in maize and 0.7 % in sunflower production. The greatest energy saving per hectare in maize production of 42.3 % was obtained by RT2 system, while in sunflower production it was 37.2 % by RT1 system. Bowers (1992) showed a composite of average fuel consumption and energy expended, based on data from different countries around the world and reported that average fuel consumption for mouldboard ploughing is 17.49±2.06 L ha^{-1}, chisel ploughing 10.20±1.50 L ha^{-1}, while no-till planter required 4.02±1.03 L ha^{-1}. In comparing these data to other sources, wide variations can be expected due to soil types, field conditions, working depth, etc. On the other hand, Köller (1996) reported that the fuel consumption was 49.40 L ha^{-1} for mouldboard ploughing, 31.30 L ha^{-1} for chisel ploughing and 13.40 L ha^{-1} for no-till. Hernanz and Ortiz-Cañavate (1999) presented data that coincide between previously mentioned results.

Economic analysis

Total costs include all the inputs (labour, machine costs, seed, fertiliser and plant protection chemicals) from soil tillage to harvest, including grain transport within field. Storage and handling costs weren’t taken into account since its great variability.

In both seasons CT system resulted in the highest costs with 633 € ha^{-1} (maize) and 638 € ha^{-1} (sunflower). In maize production the income/costs ratio differences showed that RT1 system obtained the best economic result, while the next was RT2 followed by CT and RT3 (Table 4). ANOVA unveiled that differences of income/costs ratio in maize production were statistically significant at probability level $p<0.05$. In sunflower production the best income/costs ratio achieved RT2 system, the next was RT1 followed by RT3 and CT with differences statistically significant at probability level $p<0.05$.

Table 4. Total cost, gross income and gross margin for maize and sunflower

Tillage	**Maize**				**Sunflower**			
	Gross income € ha^{-1}	Total costs € ha^{-1}	Gross margin € ha^{-1}	Income/ Costs ratio	Gross income € ha^{-1}	Total costs € ha^{-1}	Gross margin € ha^{-1}	Income/ Costs ratio
CT	1674	633	1042	2.65 c[(1)]	978	638	339	1.53 b
RT 1	2120	605	1514	3.50 a	1068	611	457	1.75 a
RT 2	1771	564	1207	3.14 b	1058	570	488	1.86 a
RT 3	1543	592	951	2.61 c	989	597	392	1.59 ab

[(1)] Different letters indicate significant ($p \leq 0.05$) differences

CONCLUSIONS

Summarizing results of the short term experiment results together with previously acquired experience following could be concluded:

1. In comparison to conventional tillage (CT) the greatest energy saving per hectare of 42.3 % in maize production was obtained by RT2 system, while in sunflower production it reached 37.2 % by RT1 system.

2. The lowest labour consuming soil tillage system in maize production was RT2 that enabled savings of 43 %, while in sunflower production it was RT1 system that enabled savings of 48.5 %.

3. In maize production soil tillage systems obtained statistically significant different yields, so the best solution would be RT1 system, due to its highest yield and best income/costs ratio.

4. The soil tillage systems in sunflower production didn't obtain statistically significant yield differences, but non-conventional tillage systems RT1 and RT2 showed significantly better income/costs ratio in comparison to CT system, so RT2 system could be right choice, due to its lowest total costs.

This short-term experiment showed that non-conventional tillage systems due to their lower energy and labour requirement could be economically important tool to decrease production costs.

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PROIZVODNJA KUKURUZA I SUNCOKRETA U POSAVINI RAZLIČITIM SUSTAVIMA OBRADE TLA

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Sadržaj: U radu su prikazani rezultati dvogodišnjih pokusa proizvodnje kukuruza i suncokreta s četiri načina obrade tla provedenih u zapadnoj Slavoniji, na proizvodnim površinama poljoprivredne tvrtke PK Nova Gradiška, lokacija Staro Petrovo Selo (45° 10' N, 17° 30' E) smješteno 150 km jugoistočno od Zagreba. Usporedbom utroška energije, najviša potrošnja goriva od 62.93 L ha^{-1} u proizvodnji kukuruza i 57.96 L ha^{-1} kod suncokreta, utvrđena je kod konvencionalnog sustava obrade tla (CT). Najveću uštedu energije u proizvodnji kukuruza omogućio je sustav RT2 s 36.30 L ha^{-1}, a kod suncokreta sustav RT1 s 36.41 L ha^{-1}. Usporedbom radnog vremena utvrđeno je da je CT sustavom u proizvodnji kukuruza utrošeno 2.62 h ha^{-1} odnosno 0.35 h Mg^{-1}, a kod suncokreta 2.63 h ha^{-1} te 0.35 h Mg^{-1}. Najniži utrošak radnog vremena u proizvodnji kukuruza ostvario je sustav RT2 s 1.48 h ha^{-1} i 0.19 h Mg^{-1}, potom RT1 s 1.49 h ha^{-1} i 0.15 h Mg^{-1}, dok je u proizvodnji suncokreta najmanji utrošak radnog vremena ostvario sustav RT1 s 1.35 h ha^{-1} i 0.14 h Mg^{-1}. Najviši prosječni urod oba usjeva postignut je sustavom RT1, a najniži urod kukuruza imao je sustav RT3, dok je najniži urod suncokreta imao sustav CT.

Ključne riječi: *utrošak energije i radnog vremena, proizvodni troškovi.*