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TWO YEARS EXPERIMENT WITH DIFFERENT SOIL TILLAGE SYSTEMS IN PRODUCTION OF WINTER BARLEY AND MAIZE IN POSAVINA

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Abstract: The paper presents results of the two years experiment in winter barley and maize 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 in both crops production had the highest fuel consumption of 56.07 L ha^{-1} (winter barley) and 62.93 L ha^{-1} (maize). The best energy saving system in winter barley was RT1 with 37.58 L ha^{-1} and RT2 with 36.30 L ha^{-1} in maize production. Soil tillage systems comparison regarding labour requirement unveiled that conventional tillage required 2.39 h ha^{-1} and 0.52 h Mg^{-1} in winter barley, while in maize production required 2.62 h ha^{-1} and 0.35 h Mg^{-1}. The lowest labour requirement of 1.35 h ha^{-1} and 0.32 h Mg^{-1} obtained RT2 in winter barley, while in maize production RT2 achieved 1.48 h ha^{-1} and RT1 0.15 h Mg^{-1}. The highest average yields were obtained by CT system in winter barley and RT1 in maize production, while the lowest yields were with RT1 in winter barley and RT3 in maize production.

Key words: tillage, energy consumption, barley, maize.

INTRODUCTION

Winter Barley (Hordeum vulgare L.) and maize (Zea mays 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:

1. Conventional tillage - plough, disc harrow, seed-bed implement (CT); 2. Conservation tillage 1 - chisel plough, disc harrow, seed-bed implement (RT 1); 3. Conservation tillage 2 - chisel plough, rotary harrow, drill (RT 2); 4. Conservation tillage 3 – plough, rotary harrow, drill (RT 3). In winter barley production an integrated implement consisted of rotary harrow and drill was used. Depth of tillage for mouldboard plough was in average 20.6 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 m2). 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 2004-2006 were generally within twenty year's average (Figure 1). Total precipitation during cropping period of winter barley was within twenty years average with no significant deviations recorded (Figure 2). During maize growing period the significant lack of precipitation occurred in July 2006 (37% of average), while in August 2006 more then double quantity of monthly precipitation was recorded. So weather conditions regarding precipitation for maize flowering were unfavourable.

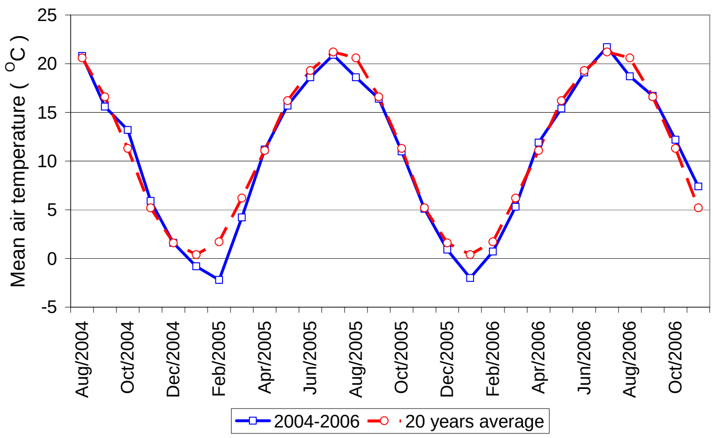

Figure 1. Mean air temperature during cropping period

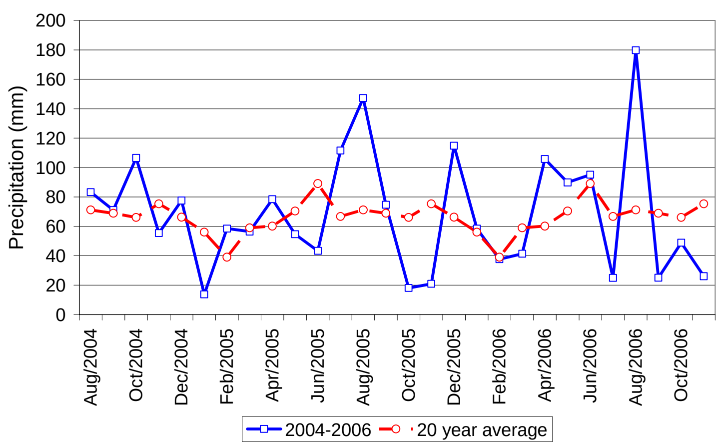

Figure 2. Precipitation during cropping period

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 wheat. 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	Winter Barley 2004/2005	Maize 2005/2006
Tillage & Sowing		
Primary tillage	1st September 2004	5th – 7th November 2005
Soil moisture (%) at 5; 15; 30 cm depth	22.3; 31.8; 32.7	24.7; 45.6; 47.3
Secondary tillage	8th October 2004	18th May 2006
Soil moisture (%) at 5; 15; 30 cm depth	26.4; 30.8; 32.2	28.0; 46.3; 47.3
Sowing date	8th October 2004	18th May 2006
Crop (cultivar)	Regina C1	PR 37H24
Fertilizing		
Application date	8th October 2004	4th November 2005
Fertilizer-rate (kg ha^{-1})	NPK (90-41-60); MAP (80); KCl (100)	NPK (17.8-22.5-22.5)
Application date	2nd March 2005	16th May 2006
Fertilizer-rate (kg ha^{-1})	CAN 27% (150)	Urea 46% (250)
Application date	5th April 2005	18th May 2006
Fertilizer-rate (kg ha^{-1})	CAN 27% (150)	NPK 15:15:15 (150)
Application date		22nd June 2006
Fertilizer-rate (kg ha^{-1})		CAN 27% (150)
Crop protection		
Application date	25th October 2004	20th May 2006
Chemical-rate (l ha^{-1})	alphacypermethrin (0.1)	terbuthylazine + acetochlor + dichlormid (5)
Application date	18th April 2005	14th June 2006
Chemical-rate (l ha^{-1})	bentazon (1.5); fluoroxypyr (0.4)	dicamba (0.5)
Application date	13th May 2005	
Chemical-rate (l ha^{-1})	metaconazole + azoxystrobin (0.5); epoxyconazole (0.5)	
Application date	5th July 2005	
Chemical-rate (l ha^{-1})	carbendazim (0.5)	
Harvest		
Harvesting date	5th July 2005	2nd November 2006

RESULTS AND DISCUSSION

Yield

In the first experimental season the greatest average winter barley yield of 4.58 Mg ha^{-1} achieved CT system. RT3 system obtained average yield of 4.50 Mg ha^{-1} and RT2 system 4.21 Mg ha^{-1}. RT1 system had the lowest average yield of 4.17 Mg ha^{-1}. In spite of noticed average yield differences, statistical analysis showed they were not significant. Moret, Arrue et. al. (2007) experimenting with different tillage systems in winter barley production during three consecutive cropping seasons reported that no clear differences in crop yield were observed among the tillage treatments in the study period. Chatskikh and Olesen (2007) reported that spring barley dry matter grain yields were reduced by 14% for RT and 27% for DD (direct drill) compared to CT.

In maize production RT1 achieved the greatest average yield of 9.65 Mg ha^{-1} followed by RT2 with average yield of 7.95 Mg ha^{-1} and CT with 7.48 Mg ha^{-1}. The lowest average maize yield obtained RT3 with 6.84 Mg ha^{-1}.

According to ANOVA differences among average maize yields obtained by different soil tillage systems were statistically significant. So, the greatest average yield obtained by RT1 was significantly different from all other tillage systems at probability level of $p<0.05$. Differences of average yields between RT2 and RT3 were also significant at probability level of $p<0.05$, while average yield of CT 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.

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

	Winter Barley Cropping period 2004/2005				Maize Cropping period 2005/2006			
Tillage system	Fuel L ha^{-1}	Energy MJ Mg^{-1}	Productivity h ha^{-1}	Productivity h Mg^{-1}	Fuel L ha^{-1}	Energy MJ Mg^{-1}	Productivity h ha^{-1}	Productivity h Mg^{-1}
CT	Average Yield = 4,58 Mg ha^{-1} a[(1)]				Average Yield = 7,48 Mg ha^{-1} bc			
Plough	35,96	303,9	1,54	0,34	42,45	219,6	1,72	0,23
Disc harrow	12,24	103,4	0,38	0,08	10,34	53,5	0,31	0,04
Seed-bed impl.	4,53	38,3	0,23	0,05	6,68	34,6	0,23	0,03
Drill	3,34	28,2	0,25	0,05	3,46	17,9	0,35	0,05
Total	56,07	473,8	2,39	0,52	62,93	325,5	2,62	0,35
RT 1	Average Yield = 4,17 Mg ha^{-1} a				Average Yield = 9,65 Mg ha^{-1} a			
Chisel	20,43	189,6	0,74	0,18	18,26	73,2	0,60	0,06
Disc harrow	9,28	86,1	0,38	0,09	10,34	41,5	0,31	0,03
Seed-bed impl.	4,53	42,0	0,23	0,05	6,68	26,8	0,23	0,02
Drill	3,34	31,0	0,25	0,06	3,46	13,9	0,35	0,04
Total	37,58	348,8	1,59	0,38	38,74	155,4	1,49	0,15
RT 2	Average Yield = 4,21 Mg ha^{-1} a				Average Yield = 7,95 Mg ha^{-1} b			
Chisel	20,43	187,8	0,74	0,17	18,26	88,8	0,60	0,07
Rotary harrow	20,34	187,0	0,61	0,15	14,58	70,9	0,53	0,07
Drill					3,46	16,8	0,35	0,04
Total	40,77	374,8	1,35	0,32	36,3	176,6	1,48	0,19
RT 3	Average Yield = 4,50 Mg ha^{-1} a				Average Yield = 6,84 Mg ha^{-1} c			
Plough	35,96	309,3	1,54	0,34	42,45	240,1	1,72	0,25
Rotary harrow	12,27	105,5	0,63	0,14	14,58	82,5	0,53	0,08
Drill					3,46	19,6	0,35	0,05
Total	48,23	414,8	2,17	0,48	60,49	342,2	2,61	0,38

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

Energy requirement

The conventional tillage system (CT) was expectantly the greatest fuel consumer with 56.07 L ha^{-1} in winter barley and 56.07 L ha^{-1} in maize production. RT3 system enabled saving of 14% of energy per hectare in winter barley and 4% in maize production. The greatest energy saving per hectare in winter barley production of 33% was obtained by RT1 system, while in maize production it was 42 % by RT2 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 705 € ha^{-1} (winter barley) and 633 € ha^{-1} (maize). In winter barley production the income/costs ratio differences showed that RT3 system obtained the best economic result but there were no statistically significant differences among tested tillage systems (Table 4). On the contrary, ANOVA unveiled that difference of income/costs ratio in maize production were statistically significant at probability level $p<0.05$. The best economic result obtained RT1 system, while the next was RT2 followed by CT and RT3.

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

Tillage	Winter Barley				Maize			
	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	1669	705	964	2,37 a(1)	1674	633	1042	2,65 c
RT 1	1540	678	862	2,27 a	2120	605	1514	3,50 a
RT 2	1552	637	916	2,44 a	1771	564	1207	3,14 b
RT 3	1644	664	980	2,47 a	1543	592	951	2,61 c

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

CONCLUSIONS

Summarizing results of 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 33% in winter barley production was obtained by RT1 system, while in maize production it reached even 42% by RT2 system.

2. The lowest labour consuming soil tillage system in both cropping seasons was RT2, enabled savings of 44% in winter barley and maize production too.

3. Since soil tillage systems in winter barley production didn't obtain statistically significant yield differences, the system with the best income/costs ratio could be right choice, due to its lowest total costs.

4. 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.

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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DVOGODIŠNJI EKSPERIMENT S RAZLIČITIM SISTEMIMA OBRADE TLA U PROIZVODNJI OZIMOG JEČMA I KUKURUZA U POSAVINI

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Sadržaj: Rad prikazuje rezultate dvogodišnjeg eksperimenta u proizvodnji ozimog ječma i kukuruza različitim sistemima obrade tla provedenim u zapadnoj Slavoniji na površinama poduzeća "PK Nova Gradiška" u mjestu Staro Petrovo Selo (45° 10' N, 17° 30' E), smještenom 150 km istočno od Zagreba. Usporedba sistema prema utrošku energije pokazuje da je najveći potrošač CT sistem koji je trebao 56.07 L ha^{-1} u ozimom ječmu i 62.93 L ha^{-1} u kukuruzu. Energetski najštedljiviji sistemi obrade tla bili su: u ozimom ječmu RT1 sa 37.58 L ha^{-1}, a u kukuruzu RT2 sa 36.30 L ha^{-1}. Usporedba sistema obrade tla prema utrošku ljudskog rada pokazuje da konvencionalni system (CT) treba 2.39 h ha^{-1} i 0.52 h Mg^{-1} u ozimom ječmu, a u kukuruzu 2.62 h ha^{-1} i 0.35 h Mg^{-1}. Najmanji utrošak ljudskog rada od 1.35 h ha^{-1} i 0.32 h Mg^{-1} postigao je sistem RT2 u ozimom ječmu, a u kukuruzu je ovaj sistem postigao 1.48 h ha^{-1}, dok je RT1 postigao 0.15 h Mg^{-1}. Najveći prosječni urod ozimog ječma postignut je CT sistemom, a kukuruza RT1 sistemom. Najniže urode postigli su: RT1 sistem u ozimom ječmu i RT3 sistem u kukuruzu.

Ključne riječi: *obrada tla, utrošak energije, ozimi ječam, kukuruz.*