COMPARISON OF ENERGY CONSUPTION AND MACHINERY WORK WITH VARIOUS SOIL TILLAGE PRACTICES AT SOYBEAN PRODUCTION

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Abstract: *An annual investigation of energy consumption and machinery work with three various soil tillage practices at soybean production, variety Tisa (Ist group) was conducted in east Croatia area (latitude 45^{O}30 and longitude 18^{O}07). Conventional, conservation and no till were tillage practices applied. Energy comparison indicates a markedly energy consumption at the conventional soil tillage (ploughing, disking and seeding) with 56.86 kg ha^{-1} and 18.85 kg t^{-1} of the gas oil D-2 (diesel). More convenient variant is conservation soil tillage (shovel loosening, disking, seeding) demanding 45.51 kg ha^{-1} and 16.88 kg t^{-1} being 20% i.e. 10.5% less compared to the conventional practice. The most favourable variant, in terms of energy, is no till with only 5.71 kg ha^{-1} and 1.86 kg t^{-1} of diesel D-2 being 90% less compared to the conventional practice. Comparison of the investigated variants productivity indicates that conventional practice requires 1.97 h ha^{-1} and 0.65 h t^{-1}, conservation 1.40 h ha^{-1} and 0.52 h t^{-1} being 29% i.e. 20% whereas no till demands only 0.29 h ha^{-1} and 0.09 h t^{-1} being 85.3% i.e. 86.2% less compared to the conventional one. Direct soybean seeding resulted in reducing production costs of (130.74 € ha^{-1}), primarily due to soil tillage and chemical protection mission. The lowest yield of 2.70 t ha^{-1} was accomplished with a conservation tillage and the highest one of 3.07 t ha^{-1} by no till application.*

Key words: soil tillage, energy consumption, productivity, soybean

INTRODUCTION

The largest world soybean producers (*Glycine max L.*) are USA accounting for 48% followed by Brazil 20% and China 9% of the total world soybean production. Experiences with unconventional soil tillage practices in soybean production go back to USA in late 60's of the 20th century. Those first experiences and results indicate that no-till soybean seeding or with reduced tillage was justified on drained soils and those characterized by lighter mechanical composition, high fertility and sufficient precipitations during the growing season. In 1997, according to Johnson (1987), 2% of the total sown areas was no-till seeded, 12% with reduced tillage and 86% applying conventional soil tillage. Ten years later, in 1982 no-till areas were increased to 7%, reduced tillage to 38% whereas conventional ones were reduced to 55%. More recent data (http://www.ctic.purdue.edu/CTIC/CTIC.html) indicate that no till sowing reached 21.1% of total areas (USA) in 2000 followed by impressive 33% i.e. 9.340.187 ha in 2002.

In Croatia, according to Vratarić and Sudarić (2000) most soils require conventional tillage for soybean growing since otherwise it is not possible to secure normal conditions for production plants growth and development. Zimmer et al., (2001) stated that direct sowing accomplished (with saving) soybean yield 6% higher, primarily in soil tillage of HRK 975 ha^{-1}, compared to the conventional soil tillage in eastern Slavonia area in the very dry 2000 year.

This paper presents results of the first year experiment with various soil tillage in a soybean production on productive areas of the firm “Hana” Našice, Lila.

METHODS AND MATERIAL

Three soil tillage practices (conventional, preservation and direct sowing –no-till) in soybean production were conducted in the period 2002/2003 in the production fields of “Hana” Našice p.l.c , Lila. The trial was set up by the randomised design in three replicates. July 2000 was characterized by conservative soil tillage practice. Namely, soil loosening, conducted on 3 plots, was done using the rotary tiller by a=30.3 cm on the average. On 28 November basic fertilization of the total plot was carried out with KCL (60%) at a dose of 150 kg ha^{-1} and urea 100 kg ha^{-1}.

Basic tillage, ploughing of three plots with conventional tillage practice was conducted by a three way plough by depth of a=28.2 cm. Soil flattening done by a disk harrow in a conventional and conservative practice was done on 29 November 2002. Secondary i.e. preseeding soil tillage conducted on the plots of conventional and conservative tillage practice was performed on 26 March 2003 by only one disk harrow pass. Sowing of Tisa variety soybean (I^{st} vegetation group) was done on 29 April 2003 by the sowing machine Great Plains, B_r=440 cm of 20 cm inter-row space with sowing rate of 140 kg ha^{-1}. Weed crop protection was performed on 5 May 2003 applying Dancor (0.75 l ha^{-1} and Dual gold (1.3 l ha^{-1}) on the conventional and conservative tillage and on 7 May 2003 using Boom effect (4 l ha^{-1}) on no-till plots. Soil tillage was accomplished by the tractor John Deere 4755, plough Rabewer Super Taube 180 MX IV/85-42 with lattice mould boards, rotary tiller Pegporaro Drag 5 and disk harrow OLT-Tara B_r =300 cm.

Texture soil determination of the experimental plots was conducted at Department of pedology at Faculty of Agronomy of Zagreb University. Meteorological data required for Lila area was provided at Croatian State Weather Bureau in Zagreb. On 19 September 2003 soybean harvest was accomplished by the combine Đ. Đ. M1620 of header cut range 5, 6 m. Yield was determined by weighing some combine passes by electronic scales.

RESULTS

1. Pedological climatic conditions

The investigation was conducted on a mechanical composition soil ranging from loam to powdery clay loam which represents average conditions of Lila p.l.c production areas.

Table 1. Soil particle size distribution and soil type

Sample	Coarse gravel (%) 0.2-2 µm	Fine gravel (%) 0.05-0.2 µm	Silt (%) 0.002-0.05 µm	Clay (%) <0.002 µm	Soil type
A	0.80	28.80	44.60	25.80	a Loam
B	2.20	8.60	69.40	19.80	Silty loam
C	1.00	10.20	58.00	30.80	Silty clay loam

Total rate of precipitations in the observed period (October 2002 – September 2003) was by 34% lower compared to 10-year average for Lila area, being unfavourable for soybean growth and development. Vratarić and Sudarić (2000) reported that, according to many authors, it is critical for June , July and August to have precipitations level from 150 to 170 mm. In 2003 Lila was characterized by precipitations ratio of only 136.1 mm in the above mentioned critical months. Thus, it was 10.0% lower compared to total precipitations limit for the aforesaid months. Only 47.5% of many years' average (1981-2000) precipitated in August. Regardless very dry 2003 it was found out by Vratarić and Sudarić (2000) that soybean was capable of using efficiently available air humidity as well as morning dew (as a water source) in the period of critical growth and development phases. Air temperatures characterized by the growing season in 2003 show that this year was still within common years compared to 20–year average. Namely, there were some deviations as follows: April- minimal temperature of 1.6 ^{o}C

being lower compared to the average one but maximal on the average being totally sufficient for germination. In May maximal temperature was even 4.5 ^{o}C higher than the average one whereas June and August were warmer compared to the average, especially in maximal temperatures being inconvenient for blooming and grain formation phase.

Table 2. Weather conditions during period October 2002- September 2003. and average for period 1981-2000

Month	Precipitation (mm) 2002-2003.	Precipitation (mm) 1981-2000.	Mean minimal air tempetarure (ºC) 2002-2003-1981-00		Mean maximal air temperature (ºC) 2002-2003-1981-00.	
October02	58.4	66.1	6.2	6.3	18.4	17.4
November	64.0	75.3	n.m.	1.3	14.5	9.6
December	24.6	66.2	-3.2	-1.7	4.3	5.2
January03	94.5	56.0	-7.0	-3.1	2.5	4.0
February	20.9	39.0	n.m.	-2.8	0.7	6.3
March	5.8	59.0	0.4	1.4	13.1	11.0
April	12.9	60.1	3.8	5.4	17.1	17.0
May	34.9	70.4	n.m.	10.1	26.6	22.1
June	59.1	89.1	11.8	13.3	33.9	25.2
July	43.2	66.7	15.6	14.7	29.0	27.7
August	33.8	71.2	16.6	14.4	32.3	27.5
Septemb.	73.5	68.9	10.0	11.1	23.2	23.4
Total	525.6	787.9				

2. Consumption of energy and machinery work for soil tillage and sowing

Three soil tillage practices with appertaining tools were compared in this investigation:

A- Conventional tillage: a ploughshare application, disking, harrowing by a combined tool, Seeding by a sowing machine;
B- Conservation tillage: loosening by a rotary tiller, seeding by a sowing machine;
C- No-tillage, seeding by a no-till sowing machine;

Conventional soil tillage was found to consume most energy i.e.fuel. Comparison with a conservation tillage shows that it is capable to save 20% and at the same time 29% of machinery work per ha. No-tillage is, for sure, the most efficient variant since it saves even 90% of energy and 85% of machinery work per ha. Statistical comparison of the obtained yields (table 4) shows that yield differences, in spite of being present, are not significant from the statistics aspect. Data provided by “Hana” Našice shows that price for ploughing was HRK 468 ha^{-1} (EUR 62.4), disking (2 passes) HRK 390 ha^{-1} (EUR 52) and for seed harrow work HRK 117 ha^{-1} (EUR15.6). Thus, in this year no-tillage contributed to saving of HRK 780 i.e. EUR 104 ha^{-1} (EUR 1=HRK 7.50 in 2002). Chemical protection costs should also be taken into account in soybean production. Thus, Dancor and Dual were applied in the conventional and conservation tillage at costs of HRK 429.93 (EUR 57.32) ha^{-1} whereas Boom effect was used at costs of HRK 229.36 (EUR 30.48) ha^{-1}. So, protection saving accounts for HRK 200.57 (EUR 26.74) ha^{-1}. If the fact that saving provided by no-till reached HRK 980.57 (EUR 130.74) ha^{-1} is

followed by another one whereby this variant obtained 376 kg ha^{-1} higher yield compared to the conventional tillage, no-tillage advantages are more pronounced.

Table 3. Energy requirement, work rate and productivity of different soil tillage systems

Tillage	Implements	Fuel consumption kg ha^{-1}	kg t^{-1}	Work rate ha h^{-1}	Productivity h ha^{-1}	h t^{-1}
Conventional	Plow	27.50	9.12	0.97	1.03	0.34
	Discharrow (Ix)	17.50	5.80	2.28	0.44	0.15
	Seedbed implement	6.51	2.16	4.60	0.22	0.07
	Planter	5.35	1.77	3.52	0.28	0.09
Total		56.86	18.85		1.97	0.65
Conservation	Chisel plow	22.30	8.27	1.50	0.67	0.25
	Discharrow (Ix)	17.50	6.49	2.28	0.44	0.16
	Planter	5.71	2.12	3.48	0.29	0.11
Total		45.51	16.88		1.40	0.52
No-till	No-till planter	5.71	1.86	3.45	0.29	0.09

Table 4. Soybean yield (13% H_2O) at different soil tillage systems

	Soil tillage system		
	Conventional	Conservation	No-till
Yield t ha^{-1}	2.95 – 3.12	2.17 – 2.99	3.02 – 3.11
Average yield t ha^{-1}	3.02	2.70	3.07
L.S.D. p<0.05=0.540 L.S.D. p<0.01=0.818	0.3199 -	-	0.3766 5.666 E-02

CONCLUSION

One year investigation and former experiences led to the conclusions as follows:

- Climatic conditions were not favourable for soybean production in the area of "Hana" Našice, Lila in 2003 since April – September period was known for 39% of precipitations less compared to many years' average whereas average maximal air temperatures were unusually high.
- Conservation tillage brought about 20% soil tillage energy saving per ha and no-tillage 90% compared to the conventional one.
- Machinery work saving per ha was 29% by conservation tillage and even 85% by no-tillage.
- No-tillage obtained highest average soybean grain yield of 3.07 t ha^{-1} (with 13% H_2O), followed by conventional of 3.02 t ha^{-1} and conservation of 2.70 t ha^{-1}.
- Production soybean costs reduced by HRK 780 ha^{-1} were obtained by applying no-tillage.

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