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The effect of different tillage methods on grains quality of soybean under different weather conditions

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Abstract
In the northeastern Croatia mainly use conventional tillage to soybean production. Such a tillage system requires a high energy input and may also causes water loss and long-term soil physical degradation. The aim of this study was to assess tillage methods which are able to maintain high soybean yield and satisfactory grain quality properties, based on differences in oil content, protein content, crude fibre % and ash % under different weather conditions. For this purpose four tillage treatments (CT: Conventional tillage; DH: Disc harrowing (fine till); CH: Chisel ploughing; NT: No-tillage) were studied during four years (2002-2005) in the Baranya region of northeastern Croatia. The soybean oil, protein content, crude fibre content, ash content, plant density and grain yield were under very significant influenced of weather conditions and soil tillage treatments.

Key words*:* Soybean, soil tillage, yield, protein, oil, crude fiber, ash

Introduction

In general, NT systems have reduced cost of labor, fuel and machinery inputs but increased costs of pesticides and increased management to maintain or increase yields (Yin and Al-Kaisi, 2004). But, uncontrollable factors such as weather still play an important role and should be considered (Popp et al., 2002). Conventional tillage (CT) has adverse effects on the soil, including soil erosion, soil nitrate leaching, and subsoil compaction; as a consequence, the quality of the soil may deteriorate and the crop yield may be low (Samarejeewa, 2004). In the most of undeveloped countries, the conventional tillage treatments and lake of efficient information about no tillage methods which have lower energy requirement, lower soil erosion and lower soil moisture losses, led to more abiotic stress impact on the crop productivity (Abdipur et al., 2012). In dry conditions using appropriate tillage methods according to climate and soil properties is very important, because the effect of different tillage methods on soil properties varies from region to region (Mujdeci et al., 2010).

Grain legumes are widely recognized as important sources of food and feed proteins (Duranti and Gius, 1997). Farmers have been encouraged to adopt no-tillage (NT) because of its environmental advantages compared with other conservation tillage systems (Yin and Al-Kaisi, 2004). Soybean [*Glycine max* (L.) Merr.] plants grown with no-tillage (NT) often appear smaller than those grown with conventional tillage (CT), yet they produce a similar grain yield (Yusuf et al., 1999). No-tillage production results in changes in soil physical properties, including increases in soil organic matter content (Douglas and Goss, 1990), aggregate stability (Heard et al., 1988) and macroporosity (Lal et al., 1990). The changes may be detrimental, neutral or beneficial for crop growth and yield, depending on the soil texture and structure (Dick and VanDoren, 1985) and on climatic factors such as rainfall (Morrison et al., 2000). According to Wilhem and Wortmann (2004) the soybean grain yield was less responsive environments with a soil loosening than in other tillage treatments.

Soybean is known for its high protein and oil contents, with typical US cultivars averaging 410 and 210 g kg $^{-1}$ for protein and oil, respectively, on a dry weight basis (Leffel and Rhodes, 1993) However, Breene et al. (1988) reported a gradual decline in the protein content of soybean grown in the northern latitudes over a period of 10 to 15 years. Because of this decline, more emphasis has been placed on increasing the soybean protein content, but this goal has faced setbacks such as the negative relationship between seed and protein content (Escalante and Wilcox, 1993).

Nitrogen is considered to be a yield-determining factor in soybean production (Frederick and Hesketh, 1994; Sinclair, 1998) postulated that the high demand for N in growing seeds, of high protein grain crops, such as soybean, cannot be satisfied by the daily N accumulation rates, so N must be remobilized from vegetative tissue. Most grain crops remobilize some vegetative N into the seed: In soybean, remobilized N has been estimated to contribute 20 to 60% of the N in the seed (Egli et al., 1988; Zeiher et al., 1982).

The aim was to assess tillage methods which are able to maintain high soybean yield and satisfactory grain quality properties, based on differences in oil content, protein content, crude fibre % and ash %.

Materials and methods

Field experiments were conducted at Kneževo, in the Baranya region of northeastern Croatia (N:45°82′97.80″, E:18°64′31.93″, 90 m evolution). The study was conducted over a 4–year period (2002 and 2005) as a monofactorial trail with randomized plots divided into blocks within four replications, and with a basic plot area of 900 m^2 (18 x 50 m), on a chernozem soil the dominant soil type of the Baranya region, with pH / 8.1 ($pH_{(KCl)}$ /7.53), 2.61% organic matter, 187.0 mg kg^{-1} P and 284.2 mg kg^{-1} K, determined by Egner-Riehm Domingo method (Page, 1982) and 2.12% $CaCO_3$. The total precipitation (mm) and temperature (ºC) from October to March (winter) and during growing season (April to September at the Kneževo site during 2002 and 2005 are shown in Table 1.

The conventional tillage consisted of autumn ploughing (30-35 cm deep), the summer disking of wheat residues (7-10 cm deep), spring disc harrowing (15 cm deep), and disc harrowing to a depth of 10 cm and field cultivation in preparation for soybean. The disc harrowing (fine till) consisted of spring disc harrowing to a depth of 10-15 cm and followed by seeding. The chisel ploughing (DH) consisted of autumn disc harrowing performed with a soil loosening to a depth of 25-30 cm, spring disc harrowing to a depth of 15 cm and seeding. The no-tillage treatment by definition, involves no tillage or cultivation. A Johan Deer 750A grain drill was used for all tillage systems at a depth of 4 cm. The soybean cultivar Tisa was planted on 27 April 2002, 24 April 2003, 29 April 2004 and 3 May 2005 in 16.5-cm rows at a seeding rate of 100 kg ha^{-1}. In 2002 soybean emerged on May 17, in 2003 May 13, in 2004 May 12, in 2005 May 17. Fertilization was uniform for all tillage systems and both years (40 kg ha^{-1} N, 130 kg ha^{-1} P and 130 kg ha^{-1} K as basic dressing). In all experimental years the forecrop was winter wheat.

The grain yields of soybean for determent of oil and protein content were sampled in harvested at maturity. The grain yield was adjusted to 13.2% moisture. Several hundred seeds were selected randomly from the harvested grain of each plot and dried in a forced-air oven at 60ºC for 24 h. A 12-seed sub sample from each experimental unite was than ground to pass through a 1-mm screen. The total N of the seed was determined using a micro-Kjeldahl digestion procedure (Nelson and Sommers, 1980) and grain protein was estimated as 6.25 x N. The oil content of the grain from each tillage systems was determined using a Soxhlet extraction method (AOAC, 1985). The crude fiber and ash of the grain was determined using conventional methods (Šuko and Petek, 1970).

Quality traits of soybean grains [*Glycine max* (L.) Merr] under different reduced soil tillage treatments was investigated by variance analysis and tested using the F-test (P<0.01**; P<0.05*).

Results and discussion

The long-term monthly precipitation and air temperature means at Kneževo, in the Baranya region, and the average total precipitation and temperature during the growing season of 2002 to 2005 are presented in Table 1. In general, 2002 was wetter and cooler than the long-term mean. In contrast, with the exception of April, 2003 was drier than the mean during the growing season and slightly warmer than the mean, particularly in May and September (Table 1).

Table1. Total precipitation (mm) and average temperature (^{o}C) from October through March (winter season) and from April through September (growing season) at Kneževo in period 2002-2005 year.

	2002	2003	2004	2005	25-yr average	2002	2003	2004	2005	25-yr average
	Precipitation (mm)					Temperature (^{o}C)				
Winter season	182	222	332	384	266	4.8	3.5	4.3	3.8	4.5
April	64	9	119	54	43	11.4	11.2	12.0	11.5	11.0
May	86	33	77	55	56	18.8	20.0	14.9	17.0	16.6
June	49	19	114	88	90	21.7	24.5	19.5	20.4	19.7
July	61	61	41	168	60	23.8	22.8	21.9	21.4	21.2
August	111	23	52	155	45	21.5	24.7	21.6	19.7	21.3
September	63	34	43	82	53	15.9	16.4	15.9	17.5	16.6
Growing season	434	179	447	602	346	18.9	19.9	17.6	17.9	17.7

The increased drought stress in 2003 was probably responsible for the lower seed yields observed in 2003 (Table 2), by exacerbating the negative effects of NT on soybean yield. Analysis of variance indicated that the soybean yield was affected the main effects of all the year and the tillage system (Table 2). Grain yields were similar for the CT and NT treatments in the study of Yusuf et al. (1999). In the present study the yield of soybean was significant lower under NT than in the CT, DH and CH treatments in all years (Table 2). No-tillage is detrimental to early-season plant growth, but does not usually substantially decrease the grain yields of soybean (Kladivko et al., 1986).

The soybean protein and oil contents were similar in all the tillage systems over a 4-year average, which is in accordance with previous experiments (Yusuf et al., 1999). The soybean protein content and oil content was significantly affected by the main effects of all year and all tillage systems (Table 2). Oil content was the highest in 2005, when the yield was the best, and the lowest was in dry 2003, but not significantly lower in comparison with 2002 and 2004 (Table 2).

Soybean grain contained more protein and oil in 2005 than in other years investigated (Table 2). The inverse relationship between grain oil and grain protein is well known (Scott and Aldrich, 1983). Differences in the grain protein and oil responses between the years were probably due to the temperature. Cool conditions during grain fill generally results in a decrease in grain oil and an increase in grain protein (Calvin, 1965). In the present study the air temperature during the grain-filling period (mid - to late August and early September) and during the wet period in September was cooler in 2002, 2004 and 2005 than in 2003 (Table 1).

Table 2. Analysis of variance and means for examined parameters and soybean grain yield by reduced tillage at East Croatia in the 4-yr average period (2002 – 2005)

Variable		Grain protein (%)	Grain oil (%)	Crude fiber (%)	Ash (%)	Number of plant spacing per sq m	Grain yield kg ha^{-1}
Year							
	2002	32.47a[†]	20.40a	5.73a	4.97a	60a	4.27a
	2003	30.36b	20.06a	5.71a	5.05ab	22b	3.01b
	2004	31.73c	20.43a	5.78a	5.06b	41c	3.77c
	2005	36.14d	22.74b	6.39b	5.54c	53ad	3.39d
LSD	0.01	0.2141	0.5390	0.2848	0.0892	9.3576	0.2634
	0.05	0.1490	0.3752	0.1982	0.0621	6.5129	0.1834
Tillage							
	CT	33.13a	20.90a	5.56a	5.03a	49a	3.83a
	DH	32.34b	20.49b	5.91ab	5.11a	46a	3.60b
	CH	32.92a	21.08a	5.82ab	5.27b	44a	3.87a
	NT	32.31b	21.15a	6.32b	5.22b	36b	3.14c
Average		32.68	20.91	5.90	5.16	44	3.61
LSD	0.01	0.2953	0.3450	0.5160	0.1222	5.5906	0.1588
	0.05	0.2244	0.2621	0.3920	0.0928	4.2472	0.1207
F – values							
Year		2811.150**	110.604**	28.035**	179.203**	65.008**	87.415**
Tillage		25.938**	9.934**	5.045**	10.252**	13.062**	58.916**
Year×tillage		2.857*	n.s.	n.s.	n.s.	n.s.	5.518**

Abbreviations: CT: Conventional tillage; DH: Disc harrowing (fine till); CH: Soil loosening (chisel); NT: No-tillage; Y x TS: Year x tillage system; Ash: Mineral content.
** Significant at the 0.01 level; *Significant at the 0.05 level; [n.s.] No significant.
† – means with the same lower case letters are not significantly different at P<0.01 level

Tillage method showed to be also very significant for all tested parameters. The highest impact was on grain yield and protein content. CT and CH variants of tillage gave the best yield and the lowest was obtained in no-till (NT). Norwood (1999) stated that among four tested crops (soybean, sunflower, corn, grain sorghum) soybean seems the least likely to show a yield increase with no-till and that soybean responded least often to no-till, in contrary to corn. However, Yin and Al-Kaisi (2004) reported that in their long-term research, no-tillage soybean grain yields were similar to those under MP, RT, CP or other tillage systems on well-drained soils, with differences usually within 5%. In our research, NT resulted with 14.6% lower yield compared to DH, and 22% or 23% lower compared to CT and CH, respectively.
Regarding tillage, the highest oil content was obtained by NT, and the lowest with DH. Differences among NT, CT and CH were not significant.

The crude fibre (%) was affected by main effect of tillage. Averaged over 4-years the crude fibre (%) of soybean grain was greater under NT than in the CT, DH and CH treatments (Table 2). The crude fibre content was the highest in the most humid year 2005, while in other years was lower without significant differences among years. NT gave the highest grain crude fibre content which was significantly higher than that obtained with CT. Ash content was also the highest in 2005 and the lowest in the CT.

Crop density expressed by number of stems per sq m was the lowest in driest year (2003) and NT (Table 2). However, other tillage methods increased crop density but there was no significant difference among them regarding the number stem per sq m. Vyn et al. (1998) observed delayed growth and reduced yields in no-till soybean and assumed that unfavorable in-row seedbed conditions were influenced by wheat residues. The no-till treatments with wheat residues took the longest time to achieve 50% emergence and resulted with the lowest biomass yield 5 week after planting. However, fall tillage treatments tended to have an average of 10% higher plant densities compared with no-till. In our investigation, stem number per sq m was 22% higher in the CH, 28% higher in the DH and 36% higher in the CT, in comparison with NT.

It is questionable if the previous crop residues in no-till influences crop density and yield through delayed emergence or later throughout the soybean vegetation. In the research of Pedersen and Lauer (2004), management system did not affect time of emergence, but did affect subsequent DM accumulation. They stated that yield stability in the no-tillage system at Arlington compared with the conventional tillage systems were achieved through maintenance of a greater LAI, CGR, LER and total DM accumulation during the seed filling period.

After Wilhelm and Wortmann (2004), planting corn and soybean without tillage results in increased yield in some environments but less in other environments. In their research, the main effects of rotation and year, as well as the tillage x year and rotation x year interactions, were significant for soybean yield. On the contrary, in the research of Yusuf et al. (1999) soybean yield was not affected by either the main effects of tillage and year or by the year x tillage interaction.

The year had greater influence than tillage in all tested parameters in our research. The strongest influence of year was detected by protein content, which was the highest in grain harvested in 2005 (Table 2) (the highest moisture and average temperature Table 1). Dry conditions in 2003 resulted with the lowest protein content and yield. The yield was the highest in 2002, when the precipitation and temperature were above 25-years average (Table 1). Year significantly affected soybean oil and protein content in the research of Yusuf et al. (1999), who stated that differences in grain oil and protein response between years was probably due to temperature.

Year x tillage system interaction was significant for grain yield and for soybean protein. The other parameters were not influenced by this interaction (Table 2).

This indicates that the ranking of the soybean cultivars for protein and oil content, crude fiber and ash was unaffected by the tillage system (Table 2). The response of soybean quality traits to the tillage system, varied with the prevailing weather conditions in the particular growing season.

Conclusions

The dry conditions experienced in 2003 have caused exacerbated any negative effects of no-tillage on soybean yield. The 4-year average yield of soybean was significantly lower under no-tillage (NT) than in the conventional tillage (CT), chisel plow (CH) and disc harrowing (DH) treatments. The soybean oil and protein contents significantly varied in all of investigated tillage systems over the 4-year average. Soybean crude fibre (%) was affected by the main effect of tillage. Averaged over 4–years the crude fibre (%) of soybean grain was greater under NT than in the CT, DH and CH treatments. The ash (%) generally increased as tillage declined. Chisel plow treatment compared with other tillage treatments, especially conventional tillage with save soil moisture and prevent to high impact of moisture and heat stress on soybean at the end of the season has led to yield stability. Seems, chisel plow treatment compared with conventional tillage is suitable tillage treatment for soybean under different weather conditions.

References

Abdipur, M, Heidarpur, N.A, Vaezi, B, Bavei, V, Ghanbari, A.H, Talaee, S. (2012): The Effect of Different Tillage Methods on Yield and Yield Components of Bread Wheat Under Rainfed Conditions, American-Eurasian J. Agric. & Environ. Sci., 12 (9): 1205-1208.

Association of Official Analytical Chemists (1985): Official Methods of Analysis, 14th edition. AOAC, Wasinghton, DC.

Breene, W.M., Ling, S., Hardman, L.L., Orf, J. (1988): Protein and oil content of soybean from different geographic regions. *Journal American Oil Chem. Soc*., 65, 1927 – 1931.

Calvin, D.T. (1965): The effects of temperature on the oil content of fatty acid composition of the oils from several oil seed crop. *Canadian Journal of Botany*, 43, 63-69.

Dick, W.A., VanDoren, D.M. (1985): Continuous tillage and rotation combinations effects on corn, soybean and oat yields. *Agronomy Journal*, 77, 459-465.

Douglas, J.T. Goss, M.J. (1982): Stability and organic matter content of surface soil aggregates under different methods of cultivation and I n grassland. *Soil Tillage Research*, 2, 155-175.

Duranti M., Gius C. (1997). Legume seeds: protein content and nutritional value. Field Crops Research. 53:31-45.

Egli, D.B. (1988): Plant density and soybean yields. *Crop Sci*., 28, 977-981.

Escalante, E.E., Wilocox, J.R. (1993): Variation in seed protein among nodes of normal and high protein soybean genotypes. *Crop Sci.*, 33, 1164-1166.

Frederick, J.R., Hesketh, J.D. (1994): Genetic improvement in soybean: Physiological attributes. Pp -237-286. In: Slafer, G. A. (ed.), Genetic Improvement of Filds Crops. Marcel Dekker, Inc., New York.

Heard, J.R., Kladivko, E.J., Mannering, J.R. (1988): Soil macro-porosity, hydraulic conductivity and air permeability of silty soils under long-term conservation tillage in Indiana. *Soil Tillage Research*, 11, 1-18.

Kladivko, E.J., Griffith, D.R., Mannering, J.V. (1986): Conservation tillage effects on soil properties and yield of corn and soybean in Indiana. *Soil Tillage Research*, 8, 277-287.

Lal, R., De Vleeschauwer, D., Ngaje, R.M. (1990): Changes in properties of a newly cleared tropical Alfisol as affected by mulching. *Soil Science Soc. Am. J.*, 44, 823-827.

Leffel, R.C., Rhodes, W.K (1993): Agronomic performance and economic value of high- seed – protein soybean. *Journal Production Agricultural*, 6, 365-368.

Morrison, M.J., Voldeng, H.D., Cober, E.R. (2000): Agronomic changes from 58 years of genetic improvement of short-season soybean cultivars in Canada. *Agron. J.*, 92, 780-784.

Mujdeci, M., Kara, B., ISiIdar, A.A. (2010): The 14. Mohammadi, K.H., K. Nabi Allahi, M. Aghaalikhani effects of different soil tillage methods on soil and F. Khormali, 2009. Study on the effect of different water dynamic. Scientific Research and Essays, tillage methods on the soil physical properties, yield 5(21): 3345-3350.

Nelson, D.W., Sommers, L.E. (1980): Total nitrogen analysis of soil plant tissues. *Journal Association Official Analytical Chemists*, 63, 770-778.

Norwood, C.A. (1999): Water use and yield of dryland row crops as affected by tillage. Agron. J. 91:108–115.

Page, A.L. (1982): Methods in soil analysis. Part 2: Chemical and microbiological properties. Madison, Wisconsin.

Pederson, P., Lauer, J.G. (2004): Response of soybean yield components to management system and planting date. *Agron. J.*, 96, 1372-1381.

Popp, M.P., Keisling, T.C., McNew, R.W., Oliver, L.R., Dillon, C.R., Wallace, D.M. (2002): Planting Date, Cultivar, and Tillage System Effects on Dryland Soybean Production. *Agronomy J.* 94:81-88.

Samarajeewa, K.B., Horiuchi, T., Oba, S. (2004): The Effects of Subsoil Compaction on Nodulation, Growth and Yield of Soybean [Glycine max (L) Merr.]. *Nippon Sakumotsu Gakkai Koenkai Yoshi*, *Shiryoshu,* Vol. 217:92-93.

Scott, W.O., Aldrich, S.R. (1983): *Modern Production Soybean*, 2nd ed. S & A Publications, Champaign, IL. pp.- 26-48.

Sinclair, T.R. (1998): Historical changes in harvest index and crop nitrogen accumulation. *Crop Sci*., 38, 638-643.

Šuko, A., Petek, M. (1970): Analiza i poznavanje stočne hrane. Zagreb.

Vyn, T.J., Opoku, G. Swanton, C.J. (1998): Residue management an minimum tillage systems for soybean following wheat. Agronomy Journal, 90:131–138.

Wilhelm, W.W., Wortmann, S.C. (2004): Tillage and rotation interactions for corn and soybean grain yields as affected by precipitation and air temperature. *Agronomy Journal*, 96:425-432.

Yin, X., Al-Kaisi, M.M. (2004): Periodic response of soybean yields and economic returns to long-term no-tillage. *Agronomy Journal*, 96:723-733.

Yusuf, R.I., Siemens, J.C., Bullock, D.G. (1999): Growth analysis of soybean under no-tillage and conventional tillage systems. *Agronomy Journal*, 91, 928-933.

Zeiher, C., Egli, D.B., Leggett, J.E., Reicosky, D.A. (1982): Cultivar differences in N redistribution in soybean. *Agronomy Journal*, 74, 375-379.