Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2009, 5 (3), 241 - 245

Effect of Minimum Tillage Systems on the Soil Conservation and Sustainability of Agricultural Production

Teodor RUSU, Petru GUS, Ileana BOGDAN, Paula Ioana MORARU, Adrian POP, Ioan PACURAR, Doina CLAPA, Doru Ioan MARIN, Lavinia Ioana POP
University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Manastur Street, 400372, Cluj-Napoca, Romania,
rusuteodor23@yahoo.com

Abstract:The minimum tillage soil systems – paraplow, chisel or rotary grape – are polyvalent alternatives for basic preparation, germination bed preparation and sowing, for fields and crops with moderate loose requirements being optimized technologies for: soil natural fertility activation and rationalization, reduction of erosion, increasing the accumulation capacity for water and realization of sowing in the optimal period. By continuously applying for 4 years the minimum tillage system in a crop rotation: corn – soy-bean – wheat – potato / rape, an improvement in physical, hydro-physical and biological properties of soil was observed, together with the rebuilt of structure and increase of water permeability of soil.

The minimum tillage systems ensure an adequate aerial-hydrical regime for the biological activity intensity and for the nutrients solubility equilibrium. The vegetal material remaining at the soil surface or superficially incorporated has its contribution to intensifying the biological activity, being an important resource of organic matter. The minimum tillage systems rebuild the soil structure, improving the global drainage of soil which allows a rapid infiltration of water in soil. The result is a more productive soil, better protected against wind and water erosion and needing less fuel for preparing the germination bed.

The productions obtained by applying the minimum tillage systems show very differentiated results, choosing the working variant being related to the cultivated plant thus, compared to the conventional tillage variant, the productions obtained in the minimum tillage variants represented: 92.1-97.9% in corn, 96.4-101.6% in soy-bean, 95.1-98.2% in wheat, 82.4-93.4% in potato and 94.8-97.8% in the rape crop.

Key words: minimum tillage, agricultural production, soil conservation.

INTRODUCTION

The sustainable development of agriculture has stated that there is no universally applicable system for soil tillage because of the local differences, especially climate and soil type and also the technical level of endowment. The soil conservative systems in different areas have to show specific features according to ecological properties and to cultivated plants characteristics; thus, this systems must be applied in different ways (Horn and Arvidsson, 2000; Riley et al., 2005; Jitareanu et al., 2006).

The influence of soil tillage system on soil properties is proved by indices important to conservation of soil fertility and to evaluate the sustainability of agricultural system (Rusu, 2001; Mark and Mahdi, 2004; Rusu et al., 2006; Ulrich et al., 2006). The conservation of soil fertility requires a tillage system that optimizes the plant needs in accordance with the soil modifications, that ensures the improvement of soil features and the obtainment of big and constant crops. Thus, the conservation of soil fertility is tied to maintaining and improving the soil fertility indices and to the productivity of tillage system in work

MATERIAL and METHODS

The data presented in this paper were obtained on molic aluviosol (SRTS, 2003), at University of Agricultural Sciences and Veterinary Medicine in Cluj Napoca, within the Research Center for Minimal Systems and Sustainable Agricultural Technologies. The field is a class II quality type, having 73 points for arable use. The soil profile is of type: Amp – Am – A/C – C_{Ca}. The clay content on 0-40 cm depth varies between 46.6 and 51.1%. On 0-20 cm depth, soil has an reaction at the limit neutral-weak basic, with a value of 7.25. The presence of carbonates in the next horizon, the 20-40 cm depth determines an increase of pH value to 7.35. The base saturation degree of 96% frames this soil type in the eubasic soils, meaning base saturated. As for the humus content, the soil is appreciated as medium, namely 3.01% in the first 20 cm and 2.96% in the 20-40 cm depth. The field is plane, with the ground water level at 2-3 m depth.

The experimental variants chosen were:

A. Conventional system: V_1 *– classic plough + disc –2x.*

B. Minimum tillage system: V_2 *– paraplow + rotary grape,* V_3 *– chisel + rotary grape,* V_4 *– rotary grape.*

The experimental variants were studied in the 4 years crop rotation: corn – soy bean – autumn wheat – potato / rape. The analyses and determinations were done according to acting methodology and standards (SRTS, 2003; MESP, vol. I-III, 1987, Guide to Agrotechnics and Experimental Technology).

RESEARCH RESULTS

The influence of minimum tillage systems on ecological determinants: structure and texture. Soil fertility is very tight related to its structural state. The structure crushing and the physical properties are the first changes directly induced by the tillage system. The solid phase / porous space ratio regulates the thermal, chemical and biological regime of the soil. The minimal tillage systems, through a reduced number of interventions on soil and a bigger amount of organic material remaining on the soil surface, has an essential contribution to rebuilding its structure. The mulch on the soil surface has a protection function and a structure amelioration function (by transforming under the micro and macro-organisms in soil). The content of hydro stable macro-aggregates increases in all minimum tillage variants – with 0.1-2.2% in 0-10 cm depth and with 4.9-5.2% in the 10-30 cm depth – compared to the classic system (Table 1).

The soil texture has not changed by applying the minimum tillage system (Table 2).

The influence of minimum tillage systems on water reserve in soil. The soil infiltration determinations – done at soil surface, with an field permeameter – show the value of 5.7 l/m^2/minute of water in soil in the plough tillage variant and of 6.5-7.9 l/m^2/minute in the minimum tillage variants (Table 3). Related to this soil feature, the water reserve, accumulated in the 0-50 cm depth is with 1-32 m^3/ha higher in the minimum tillage variants.

Table 1. Evolution of hydro-stability degree of soil structure under the influence of tillage system

Variant / Feature	Depth cm	Classic plough + disc 2x	Paraplow + rotary grape	Chisel + rotary grape	Rotary grape
Hydro-stability degree, %	0-10	69.2	69.6	69.3	71.4
	10-20	71.3	79.0	79.5	79.2
	20-30	73.6	79.4	79.6	78.5

Table 2. The influence of tillage system on soil texture

Variant / Feature	Initial	Final			
		Classic plough + disc 2x	Paraplow + rotary grape	Chisel + rotary grape	Rotary grape
Clay (< 0,002 mm), %	51.1	50.1	51.0	51.1	50.9
Dust (0,02-0,002 mm), %	16.0	15.0	16.4	16.5	16.1
Sand (2-0,02 mm), %	32.9	34.9	32.6	32.4	33.0

Table 3. Evolution of physical properties of soil under the influence of tillage system

Variant / Feature	Depth cm	Classic plough + disc 2x	Paraplow + rotary grape	Chisel + rotary grape	Rotary grape
Infiltration, l/m^2/minut	0-5	5.7	7.9	6.5	6.8
Water reserve, m^3/ha	0-50	936	968	954	937

The influence of minimum tillage on agrochemical properties of soil. The soil reaction and base saturation degree remain practically unchanged, no matter the way the soil was tilt. Still, a tendency in pH decreasing is observed (leading to soil acidifying), as a result of increasing the hydrolytic acidity and decrease of bases sum. The pH changing tendency is justified by phosphorous stratification at soil surface and by the intensification of biological activity (including of fungi's).

The influence of minimum tillage systems on humus and mineral nutrients content. The soil content in phosphorous and mobile potassium changes significantly under the influence of tillage system because of the applied fertilizers which are located in different depths in soil (Table 4). Thus, the rotary grape tillage fixed large amounts of mobile phosphorous in the first 10 cm of tilt soil; the paraplow and chisel tillage do the same thing, bringing the phosphorous in the same amount as the plough tillage in the 10-20 cm depth. The intensity of aeration and the large density of plants are justifications for the smaller amounts of mobile phosphorous in the classic plough tillage.

The humus content of soil has a tendency to grow by applying the minimum tillage systems. This is first because of the bigger quantities of remaining vegetal material (minimum 30%), in different decomposition stages, at the soil surface and in the first 10-20 cm; secondly, because of the trimming in the mineralization / humification ratio, done in a specific physical, thermal and biological regime. By determining the humus content after 4 years, it can be observed an increasing tendency when applying the minimum tillage systems (the increase is up to 0.41%). The registered values were 3.11% in the plough variant and 3.12-3.52% in the minimum tillage variants.

The influence of minimum tillage systems on fuel consumption. The tilt furrow ploughing is one of the most expensive operations (meaning big fuel consumer). More, when soils have an average-fine to fine texture and the tillage is done in the depth. Replacing this operation, at least partially, and working the soil after two or three years, especially if the crop production is the same, is a solution to reduce the fuel consumption. Replacing the classic tillage system with a minimum one, with paraplow, chisel and rotary grape, leads to a reduction in fuel consumption to 64.1-91.4% in the wheat cultivation to 52.7-91.6% in the corn cultivation and to 58.6-97.0% in the soy-bean cultivation.

The influence of minimum tillage systems on crop production. The tillage system has an influence on the cultivated species productivity and finally on the obtained crop. The cultures within the crop rotation have a different reaction to the minimum tillage systems application (Table 5). Thus, in the wheat, soy-bean and rape crops, the productions obtained by applying the minimum tillage systems were very close to those obtained in the conventional tillage system, the differences being not statistically assured (except for the rotary grape variant in the wheat crop). Under these conditions, the productions obtained were: 2747-2867 kg/ha for soy-bean, 3282-3451 kg/ha for wheat and 1505-1588 kg/ha for spring rape.

The corn crop and especially the potato crop gave smaller productions by applying the minimum tillage systems. In the corn cultivation there are significant differences between the variant applied also; thus in the classic plough variant were obtained 5857 kg/ha, in the chisel and paraplow variant were obtained 5704-5737 kg/ha (97.3-97.9% of the witness production). The production was smaller, very significantly negative in the rotary grape variant (92.1% of the witness production). In the potato crop, the productions obtained by applying the minimum tillage systems were 82.4-93.4% of the witness production (plough variant).

The influence of minimum tillage systems on bonitation index. The soil quality is expressed by bonitation indices (Table 6) for the arable use in crop rotation: corn – soy-bean – wheat – potato - rape.

DISCUSSION and CONCLUSIONS

The minimum tillage systems represent alternatives to the conventional system of soil tillage, due to their conservation effects on soil features and to the assured productions.

By continuously applying for 4 years the same tillage system in a crop rotation: corn – soy-bean – wheat – potato / rape, an improvement in physical, hydro-physical and biological properties of soil was observed, together with the rebuilt of structure and increase of water permeability of soil.

The productions obtained by applying the minimum tillage systems show very differentiated results, choosing the working variant being related to the cultivated plant thus, compared to the conventional tillage variant, the productions obtained in the minimum tillage variants represented: 92.1-97.9% in corn, 96.4-101.6% in soy-bean, 95.1-98.2% in wheat, 82.4-93.4% in potato and 94.8-97.8% in the rape crop.

Table 4. The influence of tillage system on humus and mineral nutrients content (0-20 cm)

Variant / Feature	Initial	Final			
		Classic plough + disc 2x	Paraplow + rotary grape	Chisel + rotary grape	Rotary grape
Humus, %	3.02	2.84	2.93	3.12	3.15
Mobile P, ppm/100g soil	130	108	125	135	142
Mobile K, ppm/100 g soil	165	170	165	182	183
Total N, % 0-10 cm	0.210	0.214	0.236	0.246	0.236
10-20 cm	0.230	0.254	0.214	0.236	0.256
20-30 cm	0.252	0.263	0.211	0.214	0.196

Table 5. The influence of mollic alluvial soil tillage system on productions obtained in corn, soy-bean, wheat, potato and rape crops

Technological variant	Classic plough + disc 2x	Paraplow + rotary grape	Chisel + rotary grape	Rotary grape
Corn kg/ha	5857	5737	5704	5395
%	100	97.9	97.3	92.1
Diff.±	Mt.	- 120	- 153	- 462
Significance	Mt.	-	-	000
	DL 5%= 180.04 kg/ha, DL 1%= 261.88 kg/ha, DL 0.1%= 392.82 kg/ha			
Soy-bean kg/ha	2848	2867	2860	2747
%	100	101.6	100.4	96.4
Diff.±	Mt.	+ 19	+ 12	- 101
Significance	Mt.	-	-	-
	DL 5% = 136.74 kg/ha, DL 1% = 198.89 kg/ha, DL 0.1% = 298.34 kg/ha			
Wheat kg/ha	3451	3387	3391	3282
%	100	98.1	98.2	95.1
Diff.±	Mt.	- 64	- 60	- 169
Significance	Mt.	-	-	0
	DL5% = 140,11 kg/ha, DL1% = 203,80 kg/ha, DL0,1% = 305,70 kg/ha			
Potato kg/ha	39428	36853	36317	32521
%	100	93.4	92.1	82.4
Diff.±	Mt.	- 2 575	- 3 111	- 6 907
Significance	Mt.	0	00	000
	DL5% = 1 827.94 kg/ha, DL1% = 2 658.83 kg/ha, DL0.1% = 3 988.24 kg/ha			
Rape kg/ha	1588	1532	1552	1505
%	100	96.5	97.8	94.8
Diff.±	Mt.	- 56	- 36	- 83
Significance	Mt.	-	-	-
	DL5% = 166.94 kg/ha, DL1% = 252.80 kg/ha, DL0.1% = 406.11 kg/ha			

Table 6. The influence of tillage system on global quality of soil (Bonitation index)

Variant / Feature	Initial	Final			
		Classic plough + disc 2x	Paraplow + rotary grape	Chisel + rotary grape	Rotary grape
Bonitation index	73	70	75	74	73
Quality class	II	II	II	II	II

REFERENCES

Horn, R., J.J.H. van den Akker and J.Arvidsson, 2000, Subsoil compaction. Disstribution, Processes and Consequences. Advances in GeoEcology 32, Germany.

Jitareanu, G., C. Ailincai and D.Bucur. 2006. Influence of Tillage Systems on Soil Phsical and Chemical Caracteristics and Yield in Soybean and Maize Grown in the Moldavian Plain (North – Eastern Romania). In Soil Management for Sustainability, 370-379 pp, IUSS, Catena Verlag, Germany.

Mark, A. Licht and Mahdi Al-Kaisi, 2004, Strip-tillage effect seedbed soil temperature and other soil physical properties. Soil and Tillage Research, volume 80, Issues 1-2, 233-249 pp.

MESP, 1987. Podologic Studies Elaboration Metodology. Pedologic and Agrochemical Ins. Bucharest. Vol. 1-3.

PoliFact, 2002. ANOVA and Duncan's test pc program for variant analyses made for completely randomized polifactorial experiences. USAMV Cluj-Napoca.

Riley, H.C.F., Bleken, M.A, Abrahamsen, S., Bergjord, A.K. and Bakken, A.K., 2005. Effects of alternative tillage systems on soil quality and yield of spring cereals on silty clay loam and sandy loam soils in the cool, wet climate of central Norway. Soil and Tillage Research, volume 80, Issues 1-2, 79-93 pp.

Rusu, T., 2001, The influence of Minimum Soil Tillage upon the soil, yield and efficiency. PhD Thesis, University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca.

Rusu, T., P. Guş, Ileana Bogdan, I. Oroian and Laura Paulette. 2006. Influence of minimum tillage systems on physical and chemical properties of soil. Journal of Food, Agriculture & Environment, vol. 4(3-4/2006), p. 262-265, Helsinki, Finlanda.

SRTS, 2003. Romanian System of Soil Taxonomy. Ed. Estfalia, Bucharest, 182 pp.

Ulrich, S., B. Hofmann, S.Tischer and O.Christen, 2006, Influence of Tillage on Soil Quality in a Long Term Trial in Germany. In Soil Management for Sustainability, 110-116 pp, IUSS, Catena Verlag, Germany.