



## Implications of minimum tillage systems on sustainability of agricultural production and soil conservation

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### 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 – soybean – 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-hydric regime for the biological activity intensity and for the nutrients solubility equilibrium. The plant 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 yields 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 yields obtained in the minimum tillage variants represented: 92.1-97.9% in corn, 96.4-101.6% in soybean, 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<sup>1, 2, 4, 6, 7</sup>. 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<sup>3, 5-8</sup>. 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 mollic aluviosol<sup>11</sup>, 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<sub>ca</sub>. The clay content on 0-40 cm depth varies between 46.6 and 51.1%. At 0-20 cm depth, soil has a 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 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<sub>1</sub> – classic plough + disc – 2x; B. Minimum tillage system: V<sub>2</sub> – paraplow + rotary grape, V<sub>3</sub> – chisel + rotary grape, V<sub>4</sub> – rotary grape. The experimental variants were studied in the 4 years crop rotation: corn – soybean – autumn wheat – potato/rape. The analyses and determinations were done according to acting methodology and standards<sup>9, 11, 12</sup>.

### Results and Discussion

**The influence of minimum tillage systems on ecological determinants, soil structure and texture:** Soil fertility is very closely 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 higher amount of organic material remaining on the soil surface, have an essential contribution to rebuilding its structure. The mulch on the soil surface has a protection and 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 was 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 a field permeameter – show the value of 5.7 l/m<sup>2</sup>/minute of water in soil in the plough tillage variant and 6.5-7.9 l/m<sup>2</sup>/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<sup>3</sup>/ha higher in the minimum tillage variants.

**The influence of minimum tillage on agrochemical soil properties:** The soil reaction and base saturation degree remained practically unchanged, no matter the way the soil was tilled (Table 4). Still, a tendency in pH decrease was observed (leading to soil acidifying) as a result of increase in the hydrolytic acidity and decrease of bases sum. The pH changing tendency is justified by phosphorus 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 nutrient contents:** Soil contents of phosphorus and mobile potassium changed significantly under the influence of tillage system because of the applied fertilizers located in different depths of soil (Table 5). Thus, the rotary grape tillage fixed large amounts of mobile phosphorus in the upper 10 cm of tilled soil; the paraplow and chisel tillage do the same thing, bringing the phosphorus 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 phosphorus 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 plant material (minimum 30%) in different decomposition stages at the soil surface and the depth of 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 was 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 tilled 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 (Table 6), 52.7-91.6% in the corn cultivation (Table 7) and 58.6-97.0% in the soybean cultivation (Table 8).

**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 had different response to the minimum tillage systems application (Table 9). Thus, in the wheat, soybean and rape crops, the yields 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 in the wheat crop). Under these conditions, the yields were 2747-2867 kg/ha for soybean, 3282-3451 kg/ha for wheat and 1505-1588 kg/ha for spring rape.

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

**The influence of minimum tillage systems on bonitation index:** The soil quality is expressed by bonitation indices (Table 10) for the arable use in crop rotation: corn – soybean – wheat – potato – rape.

## 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 – soybean – 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 yields obtained by applying the minimum tillage systems show very differentiated results, the working variant being related to the cultivated plant. Thus, compared to the conventional tillage, the yields obtained in the minimum tillage variants represented 92.1-97.9% in corn, 96.4-101.6% in soybean, 95.1-98.2% in wheat, 82.4-93.4% in potato and 94.8-97.8% in the rape crop.

## References

- <sup>1</sup>Horn, R., van den Akker, J.J.H. and Arvidsson, J. (eds) 2000. Subsoil Compaction - Distribution, Processes and Consequences. Advances in GeoEcology 32, Catena Verlag GMBH, Reiskirchen, Germany, 470p.
- <sup>2</sup>Jitareanu, G., Ailincăi, C. and Bucur, D. 2006. Influence of tillage systems on soil physical and chemical characteristics and yield in soybean and maize grown in the Moldavian Plain (North-Eastern Romania). In Soil Management for Sustainability, IUSS, Catena Verlag, Germany, pp. 370-379.

- <sup>3</sup>Licht, M. A. and Al-Kaisi, M. 2004. Strip-tillage effect seedbed soil temperature and other soil physical properties. *Soil and Tillage Research* **80**(1-2):233-249.
- <sup>4</sup>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* **80**(1-2):79-93.
- <sup>5</sup>Rusu, T. 2001. The Influence of Minimum Soil Tillage upon the Soil, Yield and Efficiency. PhD. thesis, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca.
- <sup>6</sup>Rusu, T., Gus, P. and Bogdan, I. 2006. The influence of minimum soil tillage systems on weed density, frequency of phytopatogenous agents and crop yields of soybean, wheat, potato, rape and corn. *Journal of Food, Agriculture & Environment* **4**(1):225-227.
- <sup>7</sup>Rusu, T., Gus, P., Bogdan, I., Oroian, I. and Paulette, L. 2006. Influence of minimum tillage systems on physical and chemical properties of soil. *Journal of Food, Agriculture & Environment* **4**(3&4):262-265.
- <sup>8</sup>Ulrich, S., Hofmann, B., Tischler, S. and Christen, O. 2006, Influence of tillage on soil quality in a long-term trial in Germany. In *Soil Management for Sustainability*. IUSS, Catena Verlag, Germany, pp.110-116.
- <sup>9</sup>MESP 1987. *Pedologic Studies Elaboration Methodology*. Pedologic and Agrochemical Ins., Vol. 1-3, Bucharest.
- <sup>10</sup>PoliFact 2002. ANOVA and Duncan's Test Pc Program for Variant Analyses Made for Completely Randomized Polyfactorial Experiences. USAMV, Cluj-Napoca.
- <sup>11</sup>SRTS 2003. *Romanian System of Soil Taxonomy*. Estfalia, Bucharest, 182 pp.
- <sup>12</sup>Guide to Agrotechnics and Experimental Technology.

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

	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.

	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
Silt (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.

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

**Table 4.** The influence of soil tillage on agrochemical properties of soil.

Feature (0-20 cm)	Initial	Final			
		Classic plough + disc 2x	Paraplow + rotary grape	Chisel + rotary grape	Rotary grape
CaCO <sub>3</sub> , %	1.60	2.00	1.50	1.55	1.60
SB, me/100g sol	26.22	27.00	26.90	27.31	26.83
SH, me/100g sol	1.10	1.07	1.10	1.05	1.20
T, me (SB+SH)	27.30	28.07	28.00	28.36	28.03
V, %	95.94	96.18	96.07	96.29	95.72

**Table 5.** The influence of tillage system on humus and mineral nutrient contents (0-20 cm).

	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/100 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 6.** The fuel consumption (l/ha), by technology variants, in wheat cultivation.

Specific consumption Variant	l/ha	%	Difference	Difference significance
Ploughing	61.60	100	Mt.	Mt.
Paraplow	56.33	91.4	- 5.27	***
Chisel	51.32	83.8	- 10.28	***
Rotary grape	39.50	64.1	- 22.10	***
DL (5%) = 1.46 l/ha; DL (1%) = 2.21 l/ha; DL 0.1% = 3.54 l/ha				

**Table 7.** The fuel consumption (l/ha), by technology variants, in corn cultivation.

Specific consumption Variant	l/ha	%	Difference	Difference significance
Ploughing	95.62	100.0	Mt.	Mt.
Paraplow	87.58	91.6	- 8.04	***
Chisel	71.69	75.0	- 23.93	***
Rotary grape	50.36	52.7	- 45.26	***
DL (5%) = 1.22 l/ha; DL (1%) = 1.84 l/ha; DL 0.1% = 2.96 l/ha				

**Table 8.** The fuel consumption (l/ha), by technology variants, in soy-bean cultivation.

Specific consumption Variant	l/ha	%	Difference	Difference significance
Ploughing	67.63	100.0	Mt.	Mt.
Paraplow	65.59	97.0	-2.04	*
Chisel	51.74	76.5	-15.89	***
Rotary grape	39.63	58.6	-28.00	***
DL (5%) = 1.79 l/ha; DL (1%) = 2.71 l/ha; DL 0.1% = 4.35 l/ha				

**Table 9.** The influence of mollic alluvial soil tillage system on yields 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
	%	100	97.9	97.3
	Diff.±	Mt.	- 120	- 153
Significance		Mt.	-	-
	DL 5% = 180.04 kg/ha, DL 1% = 261.88 kg/ha, DL 0.1% = 392.82 kg/ha			
	kg/ha	2848	2867	2860
Soy-bean	%	100	101.6	100.4
	Diff.±	Mt.	+ 19	+ 12
	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
	%	100	98.1	95.1
	Diff.±	Mt.	- 64	- 60
Significance		Mt.	-	-
	DL 5% = 140.11 kg/ha, DL 1% = 203.80 kg/ha, DL 0.1% = 305.70 kg/ha			
	kg/ha	39428	36853	36317
Potato	%	100	93.4	92.1
	Diff.±	Mt.	- 2 575	- 3 111
	Significance	Mt.	0	00
DL 5% = 1 827.94 kg/ha, DL 1% = 2 658.83 kg/ha, DL 0.1% = 3 988.24 kg/ha				
Rape	kg/ha	1588	1532	1552
	%	100	96.5	97.8
	Diff.±	Mt.	- 56	- 36
Significance		Mt.	-	-
	DL 5% = 166.94 kg/ha, DL 1% = 252.80 kg/ha, DL 0.1% = 406.11 kg/ha			

**Table 10.** The influence of tillage system on quality of soil (Bonitation index).

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