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THE INFLUENCE OF THE TILLAGE SYSTEM AND THE CROP ROTATION ON THE SOIL AVAILABILITY IN THE MAIN NUTRIENTS AND THE YIELDS OBTAINED IN TURDA AREA

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Abstract

The research on the application of different soil tillage systems enjoys considerable worldwide popularity, and this can be explained by the effect of soil tillage on the conservation of water resources of the soil, as well as on the production costs. Yet, the main objective of this kind of research is the identification of an appropriate balance between the effects of soil tillage systems on soil quality and on yield. After 12 years of experimentation at ARDS Turda, changes in soil pH, from low acid and neutral to low alkaline in all experimental variants. In the case of the classical system (CS) there is a slight reduction of the humus content in the surface layer of the soil on the first cm at both levels of fertilization but instead there are increases on the deeper layers in the variant with additional fertilization. In the MT system there is a slight increase of total N in the first cm in both fertilization variants. Increases content in phosphorus in the MT system, from a weak content to low content. There is an increase in the K content, especially in the arable layer in the MT system compared to CS. The average yields recorded at crops had lower values especially in the conservative system on the first years.

Key words: *tillage system, crop rotation, nutrients, clime condition, yield.*

INTRODUCTION

Conservative tillage restores the soil structure and improves global soil drainage, resulting in a more productive soil, protected against water and wind erosion and requiring less fuel for the preparation of the germinating bed (Cociu, 2011; Cheţan et al., 2011; 2016). Poor rotation on crops can favor soil compaction by limiting the plants root system and the major role it plays in restoring physical features of the soil and even breaking the deep compacted layers. Ciontu et al. (2012) found that the three - four years rotation play an important role in achieving safe and stable yields and Šeremeši et al. (2013) found that the effect of crop rotation on maize yield was inversely proportional to the ratio of the maize in the crop rotation.

When mineral nitrogen fertilizers are applied, it is necessary to consider not only the production of superior quantities in terms of quantitative and quality, but also the evolution of the physical, chemical and biological characteristics of the soil. Comparing the "minimum tillage" and "no-tillage" systems with the conventional tillage, which involves the ploughing and/or the disc harrowing for the preparation of the seedbed, it can be concluded that there is a reduction in the content of organic material, mainly under tropical and subtropical conditions (Balota et al., 2003).

MATERIALS AND METHODS

The experiments were conducted 2007-2018 at ARDS Turda, located at 23°47′ longitude and 46°35′ latitude on 345-493 m altitude, in West of the Transylvanian Plain, Turda town.

The relief is represented by a hilly orthographic framework, with a dominant proportion of 71% and specific with low altitude of 345-493 m, with different exhibitions and inclinations and an advanced erosion stage. The valleys between these hills, representing 11%, are relatively narrow, oriented mainly in the East-West direction and have a poor natural drainage. The groundwater is at different depths, depending on the relief, reaching 1.5-2 m on the valleys, 15-20 m on the plateaus and 0-18 m on the slopes. The experiment was designed as a randomized complete block. The experience was based on a Phaeozem (SRTS, 2012), with clay-clay texture with good hydrophobic properties, 59% porosity on the surface and 47% in depth, high water retention capacity of 32% and Co 18%.

The experimental factors are:

- *factor (A)* the soil tillage system with three graduations: a_1- conventional system (CS); a_2 - minimum tillage system (MT); a_3- no-tillage system (NT);
- *factor (B)* the fertilization level with two graduations: b_1- basic fertilization with $N_{40}P_{40}$ (at same with sowing); b_2- basic fertilization with $N_{40}P_{40}$ + N_{40} on vegetation (at wheat on resumption of vegetation in spring; soybean at 3-5 trifoliate leaves, maize at 4-6 leaves);
- *factor (C)* the agricultural year with 12 graduations: c_1 - 2007, c_2 - 2008, c_3 - 2009, c_4 - 2010, c_5 - 2011, c_6 - 2012, c_7 - 2013, c_8 - 2014, c_9 - 2015, c_{10} - 2016, c_{11} - 2017, c_{12} - 2018.

The soil system were included three variants of the processing of the land: classic with plow; minimum tillage and no-tillage. The wheat was cultivated in a classic system in parallel with the no tillage system; soy and maize in a classic system in parallel to the minimum tillage system.

In this experiment (three years rotation with winter wheat - maize - soy) in the first year it was sown directly in the stubble of the previously cultivated plant, in this case winter wheat after soy, two years after the soil was processed with the chisel.

At experimental factor B - fertilization, there are two graduation of application to all three crops (winter wheat - maize - soybean), only the application moment differs.

The sowing was done with the Directa-400 machine (at the same time as sowing was applied the fertilization) at 18 cm distance between the rows, the seed introduced at 5 cm depth, winter wheat density 550 b.g./m^2 and soybean 55 b.g./m^2. In the maize culture, sowing was performed with MT-6 machine at distance between rows 70 cm, density 65,000 plants/ha, of 22.5 cm distance between seed/row, the seed incorporation 5 cm depth.

The soil samples for chemical analyses were collected along a depth of 0-20 and 20-40 cm before instalated the experiments (2007) and after harvesting the soybean culture (2018). The method used in 2007 for determining the pH was the Potentiometric method; the nitrogen content was measured through the Kjeldhal method; the phosphorous content was measured through the Colorimetric method, whereas the Flame Photometric method determined the content of potassium in the soil (Pedological and Agrochemical Studies Office, Cluj). After soybeans have been harvested in 2018 the availability of soil in nutrients was determined with the laboratory equipment compact photometer PF12-Plus (with Visocolor Eco test kit and Nanocolor teste tube) from the Agricultural Research and Development Station Turda.

The results obtained were statistically processed according to the method of analyzing the variant and establishing the lowest significant differences, LSD (5%, 1% and 0.1%) (ANOVA, 2015).

The weed control was based on the use of herbicides: in soybean and maize culture infested with weeds was applied treatments out in two stages: pre-emergence and post-emergence in both system using of the present products exist on the market that can be applied individually or in combination, depending on the weed spectrum present: pre-emergence for soybean: Sencor (*metribuzin* 600 g/l) 0.35 l/ha + Tender (960 g/l *S-metolachlor*) 1.5 l/ha and post-emergence: Pulsar 40 (40 g/l *imazamox*) in dose 1.0 l/ha (for dicotyledonous and some monocotyledonous weeds) + Agil 100 EC (100 g/*l propaquizafop*) in dose 1.5 l/ha for the *Agropyron repens* control (izolated present); pre-emergence for maize: Merlin Flexx (240 g/ha *isoxaflutol* 240 g/l and *ciprosulfamida* (safener) 0.4 l/ha + Tender (960 g/l *S-metolachlor*) 1.5 l/ha and post-emergence: Cerlit (*fluroxipir* 250 g/l) 1.0 l/ha for control of dicotyledonous weeds (especially *Rubus caesius*) + Astral 40SC (*nicosulfuron* 40 g/l) 1.5 l/ha for the monocotyledonous weeds; on vegetation at winter wheat culture: 0.15 l/ha Sekator Progres OD (*amidosulfuron* 100 g/l + *iodosulfuron-metyl-Na* 25 g/l + *mefenpyr dietyl* 250 g/l (safener) + 0.6 l/ha DMA 6 (660 g/l *acide* from 2.4% D *dimethyl amine salt*: 825 g/l 2.4 *D dimethyl amine salt*).

The weather conditions during the 12 years of trials (measured at Turda Meteorological Station, 23°47′ longitude; 46°35′ latitude; 427 m altitude) are shown in Figures 1 and 2.

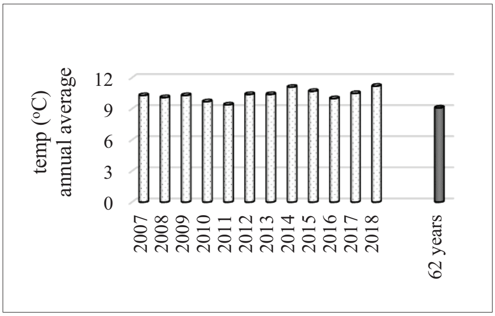

Figure 1. The thermic regime at Turda (°C), 2007-2018

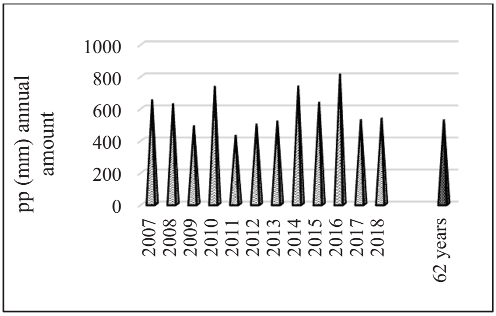

Figure 2. The rainfall regime at Turda (mm), 2007-2018

Of the 12 years considered in terms of the thermal regime, 6 were warm, 4 warm and only 2 normal and the precipitation was in 4 years excessive rain, 2 years very rainy, 5 years normal and just only 1 dry year 2011 with an annual rainfall of 433 mm). Annual mean values refer to multiannual averages (62 years) with average temperature 9.1°C and precipitation 531 mm. Also during this period the most rainy year was recorded in 2016 with 816.8 mm, the deviation is + 303.2 mm but with a non-uniform distribution of precipitation. The rainfall regime has increased in the Turda area in the last years, during the experimentation period, the most rain was 2010, 2014 and 2016. The average value of 609.8 mm, for the last 12 years, is maintained in the area with medium aggressiveness.

Specifically for the 12 years was the uneven distribution of precipitation (2009, 2011, 2012, 2017, 2018), drought prolonged was followed by torrential rains, which although they had large quantities of water, did not have often managed to restore the water reserve in the soil and the drought dominating this whole period. During the last years the climate in the Transylvanian Plain has changed, with the increase of the annual average temperature as well as the non-uniformity of rainfall, that is why the agrotechnique applied must be adapted to more oscillating ecological conditions.

REZULTS AND DISCUSSIONS

The soil reaction in the ARDS Turda area is neutral, on the ground where the experience was located, the soil reaction is weakly acidic in the first 20 cm and neutral on the depth of 20-40 cm. After 12 years, can be seen from Table 1, changes in soil pH, from weakly acid (0-20 cm) and neutral (20-40 cm) to low alkaline in all experimental variants and on both of them (7.7-8.4).

Table 1. The influence of the soil tillage system, crop-rotation and fertilization upon the soil pH (ARDS Turda 2007, 2018)

Year	Tillage system/ crop rotation/fertilization	Deepth sample	pH_{H2O}
2007	Classic $N_{40}P_{40}$	0-20 cm	6.30
		20-40 cm	7.00
2018	Classic $N_{40}P_{40}$	0-20 cm	7.7
		20-40 cm	8.4
	Minimum tillage $N_{40}P_{40}$	0-20 cm	7.6
		20-40 cm	8.3
	Classic $N_{40}P_{40+}N_{30}$	0-20 cm	7.8
		20-40 cm	7.8
	Minimum tillage $N_{40}P_{40+}N_{30}$	0-20 cm	7.5
		20-40 cm	8.3

The soil on the experiment have an average supply of N (0.162) in the 0-20 cm layer and low in the 20-40 cm (0.124) layer. Comparing the N content from 0-20 cm to 0.162% in 2007, 0.147 % came in 2018 by talking about SC + a fertilization and 0.150% on the same level with the supplementary fertilization. In the deeper layers of soil the nitrogen content decreases in the CS, while in the MT there is a slight increase on 0-20 cm in both fertilization variants (0.178 with basic fertilization and 0.183 with additional fertilization) as shown in Table 2. Similar reports on the increase of total N content by application of systems for soil preservation and direct sowing were also presented in other studies. The results obtained by Neugsghwandtner et al. (2014) in Austria under similar condition to Turda area, presented values of the N content total (%): classic system with a 25-30 cm, the total N content was 0.194 (0-10 cm) and 0.195 (20-30 cm); conservative system 0.231 (0-10 cm), 0.198 (20-30 cm) in the NT system and 0.220-0.231 (0-10 cm), 0.206-0.192 (20-30 cm).

Table 2. The influence of the soil tillage system, of the crop-rotation and fertilization on the availability of soil in N (ARDS Turda 2007, 2018)

Year	Tillage system/ crop rotation/fertilization	Deepth sample	Total N (%)
2007	Classic $N_{40}P_{40}$	0-20 cm	0.162
		20-40 cm	0.124
2018	Classic $N_{40}P_{40}$	0-20 cm	0.147
		20-40 cm	0.126
	Minimum tillage $N_{40}P_{40}$	0-20 cm	0.178
		20-40 cm	0.153
	Classic $N_{40}P_{40+}N_{30}$	0-20 cm	0.150
		20-40 cm	0.122
	Minimum tillage $N_{40}P_{40+}N_{30}$	0-20 cm	0.183
		20-40 cm	0.134

The changes recorded in the phosphorus content, from the low values of 5 ppm and 9 ppm recorded in 2007 the highest increase was registered in the minimum tillage in both variants of fertilization in the 20-40 cm (45 ppm, 49 ppm) in 2018 (good supply). Also, in the classic system, the highest increase in the same depth of 20-40 cm was achieved (42 ppm, 27 ppm), the content being medium to good (Table 3).

Table 3. The influence of the soil tillage system, of the crop-rotation and fertilization on the availability of soil in P (ARDS Turda 2007, 2018)

Year	Tillage system/ crop rotation/fertilization	Deepth sample	P (ppm)
2007	Classic $N_{40}P_{40}$	0-20 cm	5
		20-40 cm	9
2018	Classic $N_{40}P_{40}$	0-20 cm	8
		20-40 cm	42
	Minimum tillage $N_{40}P_{40}$	0-20 cm	10
		20-40 cm	45
	Classic $N_{40}P_{40+}N_{30}$	0-20 cm	10
		20-40 cm	27
	Minimum tillage $N_{40}P_{40+}N_{30}$	0-20 cm	12
		20-40 cm	49

The soil on which the experiment was placed have a good supply of K (140 ppm) for the arable layer 0-20 cm and middle (126 ppm) for the layer 20-40 cm, the values determined in 2007. An increase of the K content can be ascertained, especially in the layer 0-20 cm in the MT (207 ppm-219 ppm) compared to CS (159 ppm -167 ppm) as show in Table 4.

The yield obtained at winter wheat cultivated in MT system, was slightly higher than those from conventional soil cultivation and at maize the yield was 5-11% lower, results obtained by Marin et al. (2015) from the research carried out at the Moara Domnească.

Average yields recorded in winter wheat, maize and soybean crops (included in the three-year rotation) had lower values especially in the NT and MT on the first year (Table 5).

Table 4. The influence of the soil tillage system, of the crop-rotation and fertilization on the availability of soil in K (ARDS Turda 2007, 2018)

Year	Tillage system/ crop rotation/fertilization	Deepth sample	K (ppm)
2007	Classic $N_{40}P_{40}$	0-20 cm	140
		20-40 cm	126
2018	Classic $N_{40}P_{40}$	0-20 cm	159
		20-40 cm	242
	Minimum tillage $N_{40}P_{40}$	0-20 cm	207
		20-40 cm	195
	Classic $N_{40}P_{40+}N_{30}$	0-20 cm	167
		20-40 cm	201
	Minimum tillage $N_{40}P_{40+}N_{30}$	0-20 cm	219
		20-40 cm	253

Table 5. The influence of the soil tillage system and the crop-rotation on the yield during 2007-2018, ARDS Turda

No.	Cultivar	Preceding crop	Year	Tillage system	Yield ($kgha^{-1}$)
1.	winter wheat	soybean	2007	Classic	4988^{Ct}
				No tillage	4830^{Ct}
			2010	Classic	5373^{**}
				No tillage	5448^{***}
			2013	Classic	5000^{ns}
				No tillage	5076^{*}
			2016	Classic	7198^{***}
				No tillage	7245^{***}
LSD (p 5%) = 188; LSD (p 1%) = 285; LSD (p 0.1%) = 458					
2.	maize	winter wheat	2008	Classic	5668^{Ct}
				Minimum tillage	5459^{Ct}
			2011	Classic	4851^{000}
				Minimum tillage	4783^{000}
			2014	Classic	6718^{***}
				Minimum tillage	6600^{***}
			2017	Classic	7919^{***}
				Minimum tillage	7726^{***}
LSD (p 5%) = 123; LSD (p 1%) = 186; LSD (p 0.1%) = 299.					
3.	soybean	maize	2009	Classic	1967^{Ct}
				Minimum tillage	1850^{Ct}
			2012	Classic	2096^{ns}
				Minimum tillage	2158^{**}
			2015	Classic	3163^{***}
				Minimum tillage	3295^{***}
			2018	Classic	2217^{**}
				Minimum tillage	2388^{**}
LSD (p 5%) = 135; LSD (p 1%) = 289; LSD (p 0.1%) = 432.					

^{Ct}-control; ^{ns}-not significant.

We believe that the largest production recorded in conservative systems is due to better accumulation and storage of water in the soil, as is shown by the research conducted by Şimon et al. (2018), the highest quantity of water from the soil was determined the case of applying NT, with a very significant positive difference of 52.7 m^3/ha compared to CS. The tillage system influences a lot the moisture reserve of the soil, the NT and MT systems are an important factor for the accumulation and preserve of the soil moisture.

CONCLUSIONS

After 12 years of experimentation, changes in soil pH, from low acid (0-20 cm) and neutral (20-40 cm) to low alkaline in all experimental variants and on both depth (7.6-8.4).

In the MT there is a slight increase of total N in the 0-20 cm layer in both fertilization variants (0.178% with $N_{40}P_{40}$ and 0.183% with $N_{40}P_{40+}N_{30}$) and decrease in the 20-40 cm (0.153% - 0,154%).

Increase content in phosphorus in the MT, from a weak content of 5 ppm and 9 ppm in 2007 to good content (0-20 cm) and very good on the 20-40 cm depth, in 2018.

The K content increase in arable layer of 0-20 cm in the MT (207 ppm -219 ppm) compared to CS (159 ppm-167 ppm).

The winter wheat in the four years where it occupied the place in the rotation set only in 2007 realized a lower yield (4830 kg/ha) in NT than CS (4988 kg/ha).

The yield obtained at soybean in MT has values close to those obtained in the CS, on the four years it occupied the rotation place the yield was higher in MT (2012, 2015, 2018) compared with CS.

Maize it is pretentious by cultivation in MT in the Turda area, during the whole experimental period, the yields were lower than the yields obtained in CS.

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