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Original Article

The Long-Term Effect of the Soil Tillage Systems, Fertilization and Rotation Soybean-Winter Wheat-Maize on Certain Soil Attributes and Yields Specific to Different Pedoclimatic Conditions, in Turda Area

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Abstract

The research followed by the application of the various soil cultivation systems has a considerable popularity in the world. Of course, the motivation for the attention of the soil tillage systems can be widely debated, however it also includes the conservation of soil water resources as well as the reduction of labor costs and, implicitly, the growth of economies. The main objective is still to identify an optimal balance between the systems and their effects. After 11 years of experimentation at ARDS Turda, changes in soil pH, from low acid (0-20 cm) and neutral (20-40 cm) to low alkaline in all experimental variants and on the both depth (7.55-8.1), were recorded. In the case of the classical system (CS) there is a slight reduction of the humus content in the surface layer of the soil 0-20 cm at both levels of fertilization (2.87-2.58), but instead there are increases on the deeper layers of 20-40 cm (2.33 in the variant with additional fertilization). In the MT system there is a slight increase of total N in the 0-20 cm layer in both fertilization variants (0.275 with basic fertilization and 0.175 with additional fertilization). Increases content in phosphorus in the MT system, from a weak content of 5 ppm and 9 ppm in 2007 to low content (0-20 cm) and very good on the 20-40 cm depth in 2017.There is an increase in the K content, especially in the arable layer of 0-20 cm in the MT system compared to CS. The average yields recorded in soybean, winter wheat and maize crops had lower values especially in the conservative system (NT and MT) on the first years.

Keywords: *system of work, soil, fertilization, climate, rotation.*

1. Introduction

Conservative tillage has as objective the provision of an aero-hydric regime appropriate for carrying out a biological activity and the nutrient solubility equilibrium. 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 [1, 3, 11].

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. It also increases the compaction potential at the beginning of the crop growing period due to the increased number of passes and field traffic.

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 an d biological characteristics of the soil [2]. The amount of fertilizer should be applied to each

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crop group of parts, for each type of soil, taking into account environmental conditions etc., to avoid changing the soil pH (too low or too high doses), and does not affect the evolution of the other soil nutrients. Soil cover with a layer of vegetal mulch (the remains left from the previous crop) she protect the soil of large variations in temperature and reduces the amplitude of thermal oscillations and avoids loss of water by evaporation but also suffocates the weeds [7, 10]. An adequate crop rotation is obligatory, the plants with strong root alternate with plants with superficial roots, the leguminous having a favorable effect on succeeding cultures, improving the soil in nitrogen and contributed to the development of the root system. After the soybean, the need for nitrate fertilizers is greatly reduced and, on the back ground of this culture, the efficiency of phosphor and potash fertilizing increases (economic and agro-technical efficiency).

Rotation of crops remains one of the measures with increased efficiency in combating weeds.

The specific agro-technical measures that apply to each crop (soybean-wheat-corn example) reduce the growth and multiplication of certain weed species (*Cirsium arvense* in the wheat crop, it is easier to combated). Rotation of crops automatically involves the diversification of herbicides, thus eliminating the formation of weed resistance and their perpetuation [5, 8].

By applying the conservative systems in the Turda area, the objective is to identify an optimal balance between the systems and their effects.

2. Material and Method

Field experiments were conducted during eleven growing seasons (2006/2007-2016/2017) 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 [13]. The experiment was performed in 2006 autumn, within a long-term multidisciplinary research platform based on conservative agriculture. The experiment was designed as a randomized complete block (subdivided plots).

The experimental factors were the following: 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 $N_{40}P_{40}$; 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 11 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.

At the experimental factor A - the soil system were included three variants of the processing of the land: classic with plow (return the furrow); conservative minimum tillage (with chisel) and no-tillage. The technology for each plant in the experiment was performed according to the experimental plan.

Thus the wheat was cultivated in a classic system in parallel with the system without works (the winter wheat sowed directly in the unprocessed land); soy and maize in a classic system (plow) parallel to the minimum tillage system. In this experiment (rotation of 3 years with winter wheat - maize - soy) in the first year it was sown in unprocessed soil (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 (scarification). According to the experimental scheme this applied technology is part of the sustainable agriculture.

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 plowing and the work with chisel was executed in the autumn at the depth of 30 cm.

The sowing was done with the Directa-400 machine (at the same time as sowing was applied the fertilization, avoiding repeated crossings with heavy aggregates on the soil surface), at 18 cm distance between the rows, the seed introduced at 5 cm depth, winter wheat density 550 gr/m^2 and soybean 55 g/m^2. In the maize culture, sowing (plus fertilized) 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 agricultural crops in the area are mainly infested with weed species: *Convolvulus arvense, Polygonum convolvulus, Cirsium arvense, Rubus caesius, Taraxacum officinalis, Viola arvensis, Agropyron repens, Xanthium strumarium, Erigeron canadensis, Setaria glauca, Amaranthus retroflexus, Capsella bursa pastoris, Chenopodium* sp., *Rorippa austriaca, Lepidium draba, Matricaria inodora, Sonchus arvensis, Datura stramonium* etc.

Due to the fact that in the conservative system the technological works are reduced (without plow), weed control is based more 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 (conventional and minimum tillage) 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.

- at winter wheat culture on vegetation: 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 soil samples for chemical analyses were collected along a depth of 0-20 and 20-40 cm. The method used for determining the pH was the Potentiometric method; for the humus the Walkley and Black method was used; 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). Data were processed using PoliFact program [15].

The weather conditions during the eleven years of trials (measured at Turda Meteorological Station, 23°47′ longitude; 46°35′ latitude; 427 m altitude) are shown in Fig. 1 and Fig. 2 [14].

Of the eleven years considered in terms of the thermal regime, 6 were warm, 3 warm and only 2 normal and the precipitation was in 4 years excessive rain 2 years very rainy, 4 years normal and just only 1 dry year 2011 with an annual rainfall of 433 mm). Annual mean values refer to multiannual averages (60 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.

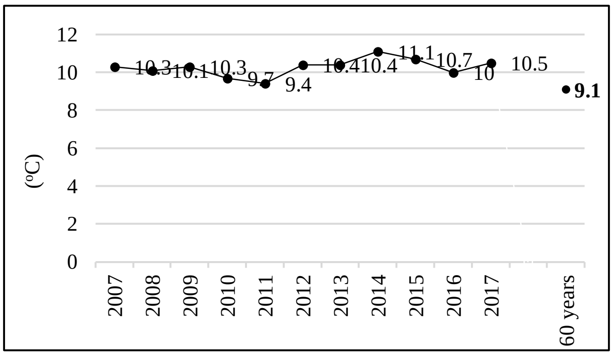

Figure 1. The thermic regime at Turda (°C), 2007-2017

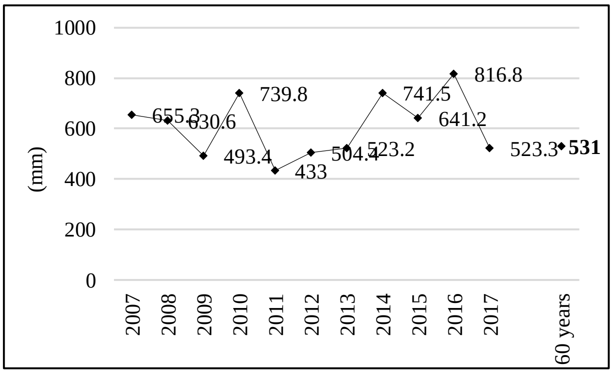

Figure 2. The rainfall regime at Turda (mm), 2007-2017

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 11 years, is maintained in the area with medium aggressiveness.

The highest rainfall values are obtained in the summer months, especially in June, which is the rainy month of the year. Specifically for the eleven years was the uneven distribution of precipitation (2009, 2011, 2012), 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.

3. Results and Discussions

Although the soil reaction in the ARDS Turda area is neutral, on the ground where the experience was located, the soil's reaction is weakly acidic in the first 20 cm and neutral on the depth of 20-40 cm.

After 11 experimental years, as 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 (7.55-8.1). The agro-biological indicator of soil, the humus, is the main energy source that has a favorable influence on soil properties.

Table 1. The influence of the soil tillage system, crop-rotation and fertilization upon the soil pH (ARDS Turda 2007, 2017)

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
2017	Classic $N_{40}P_{40}$	0-20 cm	7.69
		20-40 cm	8.07
	Minimum tillage $N_{40}P_{40}$	0-20 cm	7.8
		20-40 cm	8.1
	Classic $N_{40}P_{40+}N_{30}$	0-20 cm	7.55
		20-40 cm	7.8
	Minimum tillage $N_{40}P_{40+}N_{30}$	0-20 cm	7.68
		20-40 cm	8.03

What is necessarily mentioned is the positive influence of the MT system on increasing the relative humus content from 2.94 to 2.99 on the 0-20 cm level and from 2.21 to 2.67 on the 20-40 cm level with the basic fertilization option.

If the humus content is average, the highest growth rates are recorded in the minimum tillage system (2.99 in the basic fertilization variant on the 0-20 cm depth and 3.09 in the 20-40 cm depth).

This increase is believed to be primarily influenced by the amount of vegetal debris left on the soil surface (no-tillage system) or superficially grown (minimum tillage system for soybean and maize). In the case of the classical soil cultivation system (CS) one can notice a slight reduction of the humus content in the surface layer of soil in 0-20 cm at both levels of fertilization (2.87-2.58) but a increases on the deeper layers of the soil 20-40 cm (2.33 in the case of additional fertilization), can be seen in Table 2.

According to the degree of nitrogen supply for the total N content [12], the soil on which the experiment was placed can be characterized as with an average supply of N (0.162) in the 0-20 cm layer and low in the 20-40 cm (0.124) layer.

By simply comparing the N content from 0-20 cm to 0.162% in 2007, 0.146 % came in 2017 by talking about SC + a fertilization and 0.143% on the same level with the supplementary fertilization.

In the deeper layers of soil the nitrogen content decreases in the classical system, while in the minimum system there is a slight increase on 0-20 cm in both fertilization variants (0.275 with basic fertilization and 0.175 with additional fertilization) as shown in Table 3.

Table 2.The influence of the soil tillage system, of crop-rotation and fertilization upon the content of soil humus, (ARDS Turda 2007, 2017)

Year	Tillage system/ crop rotation/ fertilization	Deepth sample	Humus %
2007	Classic $N_{40}P_{40}$	0-20 cm	2.94
		20-40 cm	2.21
2017	Classic $N_{40}P_{40}$	0-20 cm	2.87
		20-40 cm	2.12
	Minimum tillage $N_{40}P_{40}$	0-20 cm	2.99
		20-40 cm	2.67
	Classic $N_{40}P_{40+}N_{30}$	0-20 cm	2.58
		20-40 cm	2.33
	Minimum tillage $N_{40}P_{40+}N_{30}$	0-20 cm	3.09
		20-40 cm	2.55

Table 3.The influence of the soil tillage system, of the crop-rotation and fertilization on the upon the total N content (ARDS Turda 2007, 2017)

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
2017	Classic $N_{40}P_{40}$	0-20 cm	0.146
		20-40 cm	0.109
	Minimum tillage $N_{40}P_{40}$	0-20 cm	0.275
		20-40 cm	0.149
	Classic $N_{40}P_{40+}N_{30}$	0-20 cm	0.143
		20-40 cm	0.090
	Minimum tillage $N_{40}P_{40+}N_{30}$	0-20 cm	0.175
		20-40 cm	0.109

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.

For example, experience in Austria under conditions quite similar to Turda area, presented values of the N content total (%): 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) in the case of conservative work systems of the soil.

For the classic system (CS) with a 25-30 cm, the total N content was 0.194 (0-10 cm) and 0.195 (20-30 cm) respectively [9].

Table 4 shows the changes recorded the content in phosphorus, so that from the low values of

5 ppm and 9 ppm recorded in 2007 the highest increase was registered in the system with minimal works in both variants of fertilization in the 20-40 cm (50 ppm, 52 ppm) in 2017 (good supply). Also, in the classic system, the highest increase in the same depth of 20-40 cm was achieved (43 ppm, 23 ppm), the content being medium to good.

Table 4. The influence of the soil tillage system, of the crop-rotation and fertilization on the P content (ARDS Turda 2007, 2017)

Year	Tillage system/ crop rotation/fertilization	Deepth sample	P ppm
2007	Classic $N_{40}P_{40}$	0-20 cm	5
		20-40 cm	9
2017	Classic $N_{40}P_{40}$	0-20 cm	8
		20-40 cm	43
	Minimum tillage	0-20 cm	10
	$N_{40}P_{40}$	20-40 cm	50
	Classic $N_{40}P_{40}+N_{30}$	0-20 cm	10
		20-40 cm	23
	Minimum tillage	0-20 cm	12
	$N_{40}P_{40}+N_{30}$	20-40 cm	52

According to the classification of soils according to the degree with K supply it is found that the soil on which the experiment was placed can be characterized as having a good supply of K (140 ppm) for the arable layer 0-20 cm and middle (126 ppm) for the layer 20- 40 cm, taking into account the values determined in 2007.

An increase of the K content can be ascertained, especially in the arable layer 0-20 cm in the case of the MT system compared to CS, as can be seen in Table 5.

Table 5. The influence of the soil tillage system, of the crop-rotation and fertilization on the K content (ARDS Turda 2007, 2017)

Year	Tillage system/ crop rotation/ fertilization	Deepth sample	K ppm
2007	Classic $N_{40}P_{40}$	0-20 cm	140
		20-40 cm	126
2017	Classic $N_{40}P_{40}$	0-20 cm	168
		20-40 cm	250
	Minimum tillage	0-20 cm	214
	$N_{40}P_{40}$	20-40 cm	194
	Classic $N_{40}P_{40}+N_{30}$	0-20 cm	158
		20-40 cm	204
	Minimum tillage	0-20 cm	215
	$N_{40}P_{40}+N_{30}$	20-40 cm	258

Marin et al., following the research carried out at the Moara Domnească (placed on the chromic luvisol), in 2015 presented the positive influence of the minimum tillage in the winter wheat crop yields [6]. The yield obtained was equal or slightly higher than those from conventional soil cultivation; in maize, yield was 5-11% lower, as it was a less favorable year for this crop.

As can be seen from Table 6, average yields recorded in winter wheat, maize and soybean crops (included in the three-year rotation) had lower values especially in the conservative system (NT and MT) (2007-2009) on the first years. From the experimental data obtained during the period 2007-2017, it turns out that the autumn wheat is well suited to the cultivation in the NT system, in the four years where it occupied the place in the rotation set only in 2007 realized a lower yield than CS.

Table 6. The influence of the soil tillage system and the crop-rotation on the yield during 2007-2017, ARDS Turda

No.	Cultivar	Precedin 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^{***}
LSD (p 5%) = 141; LSD (p 1%) = 233; LSD (p 0.1%) = 436.					

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

Soybean is a culture without high demands about the MT system applied in our area, so that the value of yield has values close to those obtained in the CS, on the three years the yield was higher in MT (2012, 2015) compared with CS.

Maize seems to be pretentious to cultivation on the MT system, during the whole experimental period, the yields were lower than the yields obtained in cultivation in CS.

Cociu (2019) following the research carried out within 6 years on a cambic chernozem under the conditions of the Eastern Romanian Danube Plain, show that in maize crop, the no tillage system achieved an average yield of 0.5 % higher than the classical system, and the rotation with winter wheat, although did not have significant positive effects, resulted in an average yield of 3.4 % higher than that obtained in the soybean rotation [4]. In the soybean crop, the classical system provided a insignificantly higher average yield by 2.9 % compared to the system no tillage and the rotation with winter wheat resulted in an average yield with 5.1 % superior to that obtained in the rotation with maize.

4. Conclusions

After 11 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 (7.6-8.1), were recorded.

In the case of the classical system (CS) there is a slight reduction of the humus content in the surface layer of the soil 0-20 cm at both levels of fertilization (2.87-2.58), but instead there are increases on the deeper layers of 20-40 cm (2.33 in the variant with additional fertilization).

In the MT system there is a slight increase of total N in the 0-20 cm layer in both fertilization variants (0.275 with basic fertilization and 0.175 with additional fertilization)

Increase content in phosphorus in the MT system, 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 2017.

There is an increase in the K content, especially in the arable layer of 0-20 cm in the MT system compared to CS.

By including soybeans culture on the rotation, the mineral fertilizer doses can be reduced.

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