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LONG-TERM EFFECT OF THE SOIL TILLAGE AND FERTILIZATION SYSTEMS ON CERTAIN SOIL ATTRIBUTES AND ON THE WINTER WHEAT YIELDS IN THE TRANSYLVANIAN PLAIN

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ABSTRACT

The Transylvanian Plain has a particular aspect, as the hilly areas are predominant and here the soil erosion phenomena through levigation are frequently encountered. The direct seeding in crop residues of the preceding crop (mulch), as well as the rotation of the crops are practices that reduce this phenomenon, contributing to the maintenance and amelioration of the soil quality.

Starting from these considerations, in the agricultural year 2006-2007, a polyfactorial yield trial was performed at Agricultural Research and Development Station (ARDS) Turda, for a period of ten years, during which the evolution of the main chemical characteristics of the soil and of the wheat yields under the influence of the tillage systems, fertilization, rotation, and the climatic conditions specific for this area were monitored. The content of macroelements (N, P, K) registered in time major changes in both soil tillage systems, especially in the no-tillage (NT) system along a depth of 0-20 cm.

In this area, the soil tillage systems had a rather small impact on the formation of wheat yields. Conventional soil-tillage system (CS) favoured wheat yields over the first years, but this effect gradually diminished, so that during the last three years the yields in the NT system were significantly higher.

Keywords: winter wheat, tillage methods, soil attributes, fertilization, yields.

INTRODUCTION

The conservation agriculture (CA) is widely regarded as highly beneficial for durable growth. The principles around which the concept of conservative agriculture is built include: “no-till” or the reduced disturbance of the soil, the permanent coverage of the soil, and the viable economic rotation of the crops. Based on numerous proofs, it can be stated with certainty that the CA contributes to the stabilization of the carbon and of the yields, mainly in the areas with a climate short of precipitation.

It is well-known that the world’s population shows an ascendant trend, which leads to a growth in the food demand and subsequently to the need for a growth in the food production with a minimum impact on the environment (Foley et al., 2011, quoted by Giller et al., 2015). At global level, there is a consensus (Tilman et al., 2011; Garnett et al., 2013; Vanlauwe et al., 2014, quoted by Giller et al., 2015) that the achievement of this objective supposes the durable intensification of agriculture.

The tillage systems for the conservation of the soil such as the “no-tillage” or the direct seeding in the crop residues of the preceding crop (mulch) as well as the rotation of the crops are practices that can maintain and improve the soil quality. Comparing the “minimum tillage” and “no-tillage” systems with the conventional tillage, which involves the ploughing and 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).

The soil conservation tillage reduces the soil erosion during rainy seasons and has a positive role in the increase of crop resistance to drought through the reduction of evaporation at the surface of the soil, due to the layer of mulch which is formed on the soil.

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The surface characteristics of the soil can have an important effect on the water amounts that infiltrate or leak out (Kirkham, 2005).

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.

Most of the debates and scientific reports in various domains with an impact on the environment consider the change of climate to be one of the biggest challenges of the world during the following 20-30 years. A major consequence of these climate changes could also affect the European continent, namely that there might be need for increasing the percentage of participation of Europe to the food production at global level.

Lal et al. (2007), quoted by Videnovič et al. (2011), stated that the evolution of agriculture and of farms should involve the development of some systems of handling the soil, so as to deal with the stringent problems of the 21st century: the global climate changes, the pronounced degradation of the soil and deforestation, the important decline of biodiversity, as well as the insurance of food security for an increasing population, predicted to reach about 10 billion in the year 2050.

During droughty autumns, when the soil is very dry and we can't have any plowing or the result of plowing would be clods very hard to chop, preparing the field by minimum tillage or direct sowing are preferred to ploughing in order not to delay the wheat sowing, but also from an economic point of view (Cociu and Cizmaş, 2013; Dincă et al., 2013).

Starting from these considerations, in the year 2007 a polyfactorial yield trial was performed at ARDS Turda, having as main objective to monitor the evolution of the main chemical characteristics of the soil and of wheat yield under the influence of the tillage systems, fertilization, rotation and climate conditions.

MATERIAL AND METHODS

The biological material chosen for this trial was represented by the winter wheat cultivar Arieşan (bred at ARDS Turda), which in the year 2006 (the year when the study started) was the most widespread variety of those created in Turda. The Arieşan cultivar belongs to the group of early cultivars, with a good ecological plasticity and yield stability. The crop rotation was based on balance of the main crops of grown on the farms in the area, namely maize, wheat and soybean. The starting point was the premise that the acreage cultivated with soybean registers an incontestable growth, so that an important percentage of the wheat crop can be seeded after soybean.

The three years rotation was maize-soybean-wheat, wheat being seeded in the classical and "no-tillage" systems, whereas soybean and maize in the classical and "minimum tillage" systems. The overall surface of the trial was of 0.35 ha, and the design was a split plot with three repetitions (blocks), each block being divided into three columns with a surface of 1152 m^2, corresponding to each crop of the rotation. Each column was divided into two sub-columns corresponding to the soil tillage and fertilization systems. Therefore, there were three sub-columns in three repetitions in the classical tillage system (wheat, maize, soybean) and three in the conservative system (no-tillage wheat; minimum tillage maize and minimum tillage soybean), with a surface of 576 m^2. The experimental factors were the following: factor a – the soil tillage system with two graduations: the conventional soil tillage system (CS) and the "no-tillage" (NT); factor b – the fertilization level, also with two graduations: basic fertilization with $N_{40}P_{40}$; basic fertilization with $N_{40}P_{40}$ + N_{30} on vegetation (in spring when vegetation started).

Seeding wheat in no-till system, as well as in the ploughed field, was done with the GASPARDO Directa-400 seeding machine, at the same sowing density of 550 germinating grains/m^2, 18 cm distance between the rows, the seed being treated with Yunta 246 FS (2,0 l/t).

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-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). The weather conditions during the ten years of trials (measured at Turda Meteorological Station, 23°47'longitude; 46°35' latitude; 427 m altitude) are presented in Tables 1 and 2. Comparing the multiannual averages of the ten years, the rise in temperatures is obvious, so that only during two years (2010, 2011) the annual average had values close to the multiannual one, whereas during the rest of the years registered increases more or less significant as compared to the multiannual average (Table 1). A stress factor that affects the yield considerably is represented by the heat during the spike formation period and that of the seed filling, a period that coincides approximately with the month of June in the area of Turda. In this respect, it can be noticed from Table 1 that throughout the ten years the average temperatures in this month registered smaller or greater increases as compared to the multiannual average of 17,9°C. A quite similar trend can be noticed for the months of March, April and May, especially during warmer years, as compared to the multiannual average corresponding to these months.

Table 1. Temperature regime 2007-2016

Years/ months	Temperature – monthly average (°C)												Annual average
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2007	2.4	2.5	7.3	10.8	17.0	20.3	22.0	20.1	13.7	9.3	1.9	-3.2	10.3
2008	-2.8	3.8	5.4	10.5	15.0	19.4	19.5	21.0	14.0	10.7	4.1	1.1	10.1
2009	-2.3	-0.5	3.7	13.2	16.2	18.7	21.0	20.7	17.4	10.0	5.2	0.1	10.3
2010	-3.1	1.0	4.3	10.5	15.4	18.9	20.7	21.0	14.2	7.4	7.6	-1.6	**9.7**
2011	-3.8	-3.2	5.3	10.7	15.6	19.2	20.1	20.8	18.2	8.8	0.7	0.8	**9.4**
2012	-2.3	-6.1	4.7	11.8	16.2	21.0	24.0	22.3	19.1	11.4	5.2	-2.6	10.4
2013	-2.4	2.0	3.5	12.3	16.8	19.4	20.9	22.1	13.8	11.2	7.1	-1.7	10.4
2014	0.5	3.8	8.8	11.4	15.1	18.5	20.4	19.9	16.6	10.8	5.7	1.3	11.1
2015	-0.7	0.6	5.5	9.6	15.8	19.4	22.3	21.9	17.3	9.7	6.1	0.7	10.7
2016	-2.8	4.6	5.9	12.4	14.3	19.8	20.5	19.6	17.1	8.3	2.9	-2.7	10
Average 60 years	*-3.4*	*-0.9*	*4.7*	*9.9*	*15*	*17.9*	*19.7*	*19.3*	*15.1*	*9.5*	*3.9*	*-1.4*	*9.1*

The effect of water availability on yields has been thoroughly researched, being one of the main limitative factors of the wheat yields. In this respect, we can state that generally the conditions in the area of ARDS Turda correspond to the formation of high wheat yields both in quality and quantity. However, over the last period of time, there was a significant variation in the amount of precipitations registered in the phenological phases critical to the water for wheat, as well as an important differentiation of the years in this respect (Table 2). If we relate to the annual sum of precipitations as compared to the average over a period of 60 years, only during two years (2009 and 2011) negative differences were registered, the most significant ones being in 2011. A major effect on wheat yields is represented by the precipitations in the months of April, May and June, which correspond to the straw elongation, the formation of the spike, anthesis, the formation and the filling of the grains. Calculating the coefficient of variation of the amount of precipitations registered during these months, the highest value is noticed in the month of April, namely 56%, followed by the month of June with 35%, and the month of May, namely 31%, which indicates a high fluctuation of water amounts registered in these periods throughout the ten years of trials. Therefore, the applied management practices must adjust to the conditions in the area of interest as well as to the requirements of the plants.

Table 2. The rainfall regime during 2007-2016

Years/ months	Precipitations – monthly sum (mm)												Annual sum
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2007	12.8	30.7	24.4	10.1	103.8	77.1	54.4	118.1	84.7	93.0	25.4	20.8	655.3
2008	17.3	11.2	30.3	58.4	89.0	136.8	125.2	9.0	41.0	45.4	21.1	45.9	630.6
2009	9.5	22.4	53.5	8.4	31.4	113.4	52.5	38.1	3.4	77.8	48.0	35.0	493.4
2010	39.2	30.6	17.6	52.0	87.6	172.6	121.0	49.2	67.2	31.6	30.8	40.4	739.8
2011	26.8	19.9	15.3	22.6	41.4	116.8	130.4	12.8	22.8	8.8	0.2	15.2	433.0
2012	26.2	30.7	5.3	78.4	89.2	67.4	52.4	28.0	30.2	42.0	9.6	45.0	504.4
2013	19.8	10.3	57.9	53.3	79.3	86.2	37.6	44.0	57.8	67.8	5.9	3.3	523.2
2014	51.6	15.5	23.1	72.0	66.2	48.4	144.4	83.8	48.4	67.4	34.2	86.6	741.5
2015	12.3	20.9	12.8	32.2	66	115.7	52.2	72.2	172.6	45.4	32	6.9	641.2
2016	25	23.8	47	62.2	90.4	123.2	124.9	91	24.6	152.2	45.3	7.2	816.8
CV (%)				56%	31%	35%							
Average 60 years	*21.8*	*18.8*	*20.2*	*45.9*	*68.6*	*84.8*	*76.2*	*56.6*	*42.5*	*35.6*	*33.1*	*27.1*	*518.6*

RESULTS AND DISCUSSION

a. Results regarding the soil characteristics

The pH values in the year 2007, sampled from the classical soil tillage system (Table 3) with a basic fertilization were of 6.30 along a depth of 0-20 cm and 7.00 along a depth of 20-40 cm. After 10 years, in the same system and fertilization, we can notice a growth in the pH values along both depths of sampling, namely 6.98 and 7.11. The most significant fluctuations of the pH were registered in the superficial layer of the soil along a depth of 0-20 cm; along the depth of 20-40 cm slight modifications of the pH, from 7.00 to 7.16 occurred. In all cases (tillage and fertilization) there were no decreases of the pH under the initial level from the year 2007 of 6.30 (0-20 cm), namely of 7.00 (20-40 cm). The increase of the pH over the ten years is however situated under maximum values of soil reaction of 8.3, when it is supposed that negative effects on plants appear and it would be necessary to intervene with improvements for the acidification of the soil ($CaSO_4$ or other compounds).

Table 3. The influence of the soil tillage system, of crop-rotation and fertilization upon the soil pH, (ARDS Turda, 2007, 2016)

Soil tillage system/year/fertilization		Sample depth (cm)	pH_{H2O}
2007	Classic $N_{40}P_{40}$	0-20	6.30
		20-40	7.00
2016	Classic $N_{40}P_{40}$	0-20	6.98
		20-40	7.11
	No tillage $N_{40}P_{40}$	0-20	6.79
		20-40	7.14
	Classic $N_{40}P_{40} + N_{30}$	0-20	6.66
		20-40	7.11
	No tillage $N_{40}P_{40} + N_{30}$	0-20	6.89
		20-40	7.16

The slight increase of the pH along both depths of sampling indicates that the values of soil reaction even within the same system and the same fertilization conditions (control) can undergo changes in time in a way or another. All these results strengthen the role of the chemical analyses in the monitoring the soil evolution and in taking the most adequate decisions.

The changes of the pH from the slight acid values (6.33) in the 0-20 layer towards values that are characteristic for a neutral reaction of the soil (6.66-6.98) indicate the positive effect of the doses, of the type of fertilizer and of the two systems in this study upon the soil reaction.

It is obvious that the content of humus in both systems is reduced, as well as in the fertilization levels, along the 20-40 cm layer. Moreover, the decomposition of the most significant amounts of crop residues is accomplished in the superficial soil layer (Table 4). It is important to highlight the content of organic matter of the soil after ten years in the CS and with one fertilization for the 0-20 cm tillable soil. A considerable increase in the content of humus can be noticed in this system (CS + basic fertilization) for the 20-40 depth, from 2.21 to 2.63%. This is probably due to the fact that the crop residues that were left after the soybean crop (even if most of it was removed after the harvest), still the remaining part were embedded through ploughing under the 20 cm layer where they were subject to the processes of decomposition.

Table 4. The influence of the soil tillage system, of crop-rotation and fertilization upon the content of soil humus, (ARDS Turda, 2007, 2016)

Soil tillage system/year/fertilization		Sample depth (cm)	Humus (%)
2007	Classic $N_{40}P_{40}$	0-20	2.94
		20-40	2.21
2016	Classic $N_{40}P_{40}$	0-20	2.78
		20-40	2.63
	No tillage $N_{40}P_{40}$	0-20	3.44
		20-40	1.96
	Classic $N_{40}P_{40} + N_{30}$	0-20	2.60
		20-40	2.25
	No tillage $N_{40}P_{40} + N_{30}$	0-20	3.49
		20-40	2.51

What needs to be mentioned is the positive influence of the NT system in the increase of the relative values of the humus content from 2.94 to approximately 3.5% in both fertilizations along the 0-20 cm level. If we were to establish an average of the humus content along the two depths, the highest increases can be attributed to the NT system with two fertilizations.

In the case of the CS it can be noticed that there is a slight decrease in the content of humus in the superficial layer of the soil, 0-20 cm for both fertilization levels, whereas there are increases in the deeper layers of the soil, 20-40 cm. If we referred to the primordial organic component of the soil, we can state that the type of soil on which the trials were made had an average content of humus (2.0-4.0%) according to the ICPA classification (1981) elaborated by Vidican et al., 2013.

The highest proportion of N from the soils is represented by organic N (over 90%), mineral N, namely approximately 10% out of the overall amount of N (NH_4; NO_3^+; NO_2^+), and soluble N (the dissociated ions), which represents around 1% of all the N forms, (Vidican et al., 2013). According to the degree of supply with nitrogen by the total N content (according to National Research and Development Institute for Soil Science, Agrochemistry and Environment - ICPA, 1981), quoted by Vidican et al. (2013), the soil on which the trial was performed can be characterised as having an average N supply (0.141-0.220%) at least in the 0-20 cm layer. Through a simple comparison of the N content, from the 0-20 cm depth (0.162% in the year 2007), in the year 2106 it reached 0.183% in the CS + one fertilization. In the deeper layers of the soil the N content was not subject to notable modifications in the same system. The most significant changes in the N content were noticed in the NT system for both levels of fertilization and mainly for the NT system with fractional application of Nitrogen. If we relate to the values of the total N content in 2007, in 2016 in the NT system the values (0.220% with one fertilization and 0.229% with two fertilizations) correspond to a high level of soil supply with N ranging between 0.221-0.350. Consequently, we can state that the rotation soybean – wheat – maize, along with the NT system and one fertilization with moderate doses of N, lead in time to a sustainable increase of the N content (Table 5).

Similar reports regarding the increase of the N content through the application of the NT system for soil conservation and the direct seeding were also signalled in other studies. For instance, in an study undergone in Austria in agro-ecological conditions quite similar to those in Turda (chernozem type of soil, the temperature average and the total of precipitations along 29 years being of 10°C and 538 mm) the following values were reported regarding the total N content (%): 0.231 (0-10 cm), 0.198 (20-30 cm) in the case of the NT system and 0.220-0.231 (0-10 cm), 0.206-0.192 (20-30 cm) in the case of the conservative soil tillage systems. For the classic system (CS) with tillage along a depth of 25-30 cm, the N content was of 0.194 (0-10 cm), and of 0.195 (20-30 cm).

Table 5. The influence of the soil tillage system, of the crop-rotation and fertilization on the total N content, (ARDS Turda, 2007, 2016)

Soil tillage system/year/fertilization		Sample depth (cm)	Total nitrogen (%)
2007	Classic $N_{40}P_{40}$	0-20	0.162
		20-40	0.124
2016	Classic $N_{40}P_{40}$	0-20	0.183
		20-40	0.123
	No tillage $N_{40}P_{40}$	0-20	0.220
		20-40	0.125
	Classic $N_{40}P_{40} + N_{30}$	0-20	0.186
		20-40	0.128
	No tillage $N_{40}P_{40} + N_{30}$	0-20	0.229
		20-40	0.143

We also have to mention that in that study the starting point was a complex crop rotation, where the predominant elements were wheat, sugar beet and rape, along with sunflower and soybean (Neugschwandtner et al., 2014).

The supply with phosphorous Table 6 shows a very weak initial level of this macroelement in the year 2007 (5 and 9 ppm (mg/kg of soil), at 0-20 and 20-40 sampling depth respectively). After ten years in the same system, namely the classic one, it can be noticed an obvious increase of P in the superficial layer at 20 mg/kg of soil, namely a stagnancy of the values of P content along the 20-40 cm layer. During the same period of time, still in the classic system, but with two fertilizations, the increases in the content of P are much more pronounced, reaching 43 mg/kg of soil along the 0-20 cm depth, and 10 mg/kg of soil along 20-40 cm depth. The biggest impact upon the P content along the 0-20 cm depth was found with reduced tillage in the NT system, which led to considerable increases in time, reaching 74 mg/kg of soil (NT + basic fertilization) and 54 mg/kg of soil (NT + 2 fertilizations). In the 20-40 cm layer we cannot notice a visible improvement of P for both systems and fertilization levels.

Table 6. The influence of the soil tillage system, of crop-rotation and fertilization on the P soil content, (ARDS Turda, 2007, 2016)

Soil tillage system/year/fertilization		Sample depth (cm)	P (ppm)
2007	Classic $N_{40}P_{40}$	0-20	5
		20-40	9
2016	Classic $N_{40}P_{40}$	0-20	20
		20-40	9
	No tillage $N_{40}P_{40}$	0-20	74
		20-40	11
	Classic $N_{40}P_{40} + N_{30}$	0-20	43
		20-40	10
	No tillage $N_{40}P_{40} + N_{30}$	0-20	54
		20-40	8

The positive role of the NT system as compared to the CS upon the P content in the superficial layer of the soil is also mentioned in other studies. However, they mention certain significant increases of this macroelement in the 20-40 cm layers as compared to our experience (Neugschwandtner et al., 2014). Other studies also mentioned the beneficial effect of the NT system regarding the increase of the P content in the superficial soil layers due to the crop residues at the surface (Loke et al., 2013).

According to the classification of soils by the supply with K, it can be noticed that the soil on which our study was made can be characterised as having a good K supply (132.1-2.00 ppm), at least along the 0-20 cm arable layer, bearing in mind the values determined in the year 2007.

As in the case of P, the situation of K supply highlights the fact that there was a general increase of K content, especially in the arable layer 0-20 cm in the case of the NT system, as compared to the CS. The beneficial effect of this crop rotation upon the K supply is also revealed by comparing the values from which the experience was started, 140 ppm and 126 ppm, and those registered at the end of the study, namely of 257 ppm and 198 ppm in the classic system + basic fertilization (Table 7).

Table 7. The influence of the soil tillage system, of crop-rotation and fertilization on the K soil content (ARDS Turda – 2007, 2016)

Soil tillage system/year/fertilization		Sample depth (cm)	K (ppm)
2007	Classic $N_{40}P_{40}$	0-20	140
		20-40	126
2016	Classic $N_{40}P_{40}$	0-20	257
		20-40	198
	No tillage $N_{40}P_{40}$	0-20	291
		20-40	162
	Classic $N_{40}P_{40} + N_{30}$	0-20	255
		20-40	171
	No tillage $N_{40}P_{40} + N_{30}$	0-20	246
		20-40	214

b. Results regarding the yield

The yield performances of the Arieşan cultivar during the ten years in the two systems and during the one-application stage of NP fertilizers, in autumn, at the seeding, are presented in Table 8. The biggest differences between the two systems, taking the CS as a control, were registered in the year 2009, namely a plus of 494 kg ha^{-1} in favour of the classic system (distinct significantly negative). In the other experimental years between, the two systems there are no yield differences that are statistically assured.

Table 8. The interaction of the factors soil tillage system x basic fertilization x upon the wheat yield, during 2007-2016

Year/tillage system/ fertilization		Yield (kg ha^{-1}) CS	Tillage system/ fertilization	Yield (kg ha^{-1}) NT	Difference NT-CS
2007	Classic + $N_{40}P_{40}$	4911 ^{Ct}	"No-tillage" + $N_{40}P_{40}$	4721	-191$^{n.s}$
2008		5512 ^{Ct}		5329	-183$^{n.s}$
2009		3468 ^{Ct}		2974	-494^{oo}
2010		5247 ^{Ct}		5064	-183$^{n.s}$
2011		4598 ^{Ct}		4602	4$^{n.s}$
2012		4807 ^{Ct}		4845	38$^{n.s}$
2013		4893 ^{Ct}		4714	-180$^{n.s}$
2014		6971 ^{Ct}		7064	93$^{n.s}$
2015		6988 ^{Ct}		7027	39$^{n.s}$
2016		7066 ^{Ct}		7093	27$^{n.s}$

LSD (p 5%) = 322; LSD (p 1%) = 451; n.s – not significant; Ct - control

The same similarity of yield increase in the CS as compared to the NT can be noticed in the case of the fractional application of fertilizers, with yield superiority in the CS as compared to the NT system in the first years of study (Table 9). In the year 2009, as in the previous case, we can distinguish the most important decreases of yields in the NT system (-522 kg/ha^{-1} distinctly significant negative). The trend of yield increases in the conservative soil tillage systems in the last two years of study probably suggest the positive effect of this system, cumulated in time upon the properties of the soil. In an identical rotation and over a period of 8 years, Cociu and Alionte (2017) reported average wheat yields in the NT system (5.96 t ha^{-1}), significantly superior to those in the CS (5.81 t ha^{-1}).

Table 9. The interaction of the factors soil tillage system x basic fertilization upon the wheat yield, during 2007-2016

Tillage system/fertilization/year		Yield (kg ha^{-1}) CS	Tillage system/fertilization	Yield (kg ha^{-1}) NT	Difference NT-CS
Classic + $N_{40}P_{40}$ + N_{30}	2007	5066^{Ct}	"No-tillage" + $N_{40}P_{40}$ + N_{30}	4939	-128$^{n.s.}$
	2008	5786 ^{Ct}		5522	-264$^{n.s.}$
	2009	3584 ^{Ct}		3062	-522^{oo}
	2010	5498 ^{Ct}		5232	-267$^{n.s.}$
	2011	4588 ^{Ct}		4824	236$^{n.s.}$
	2012	4928 ^{Ct}		4904	-25$^{n.s.}$
	2013	5076 ^{Ct}		4876	-200$^{n.s.}$
	2014	7155 ^{Ct}		7193	39$^{n.s.}$
	2015	7246 ^{Ct}		7341	95$^{n.s.}$
	2016	7329 ^{Ct}		7399	70$^{n.s.}$

LSD (p 5%) = 322; LSD (p 1%) = 451; n.s. – not significant; Ct- control.

Some phenological aspects during the ten years of cultivating the Arieșan cultivar and the precipitations registered in decades are presented in Table 10. It is important to mention the fact that between the two tillage systems there were no significant differences with regard to the date of reaching certain phenophases, except for the emergence which in NT system took place 5-6 days earlier. Even though there are important differences between years regarding the date of the emergence and of the tillering, these are somehow reduced during the following phenophases, the differences between the years being much smaller in this respect. The correlation coefficients between the precipitations registered in certain decades of the spring months and the yield are similar in the two systems (Table 11). It is essential to underline the fact that the Arieşan cultivar is the earliest in Turda (it reaches physiologic maturity in the last decade of the month of June and the beginning of July). Data from Table 11 show that there is a significant positive correlation between the precipitations at the end of the month of April – the beginning of May and the wheat yield. This association is also confirmed by the fact that during the last years of study, namely 2014, 2015 and 2016, when the highest yields were obtained, there was a uniform distribution of precipitations during these periods. The lack or the low amounts of precipitations in these periods negatively influenced the yields in both systems, an eloquent example being the year 2009.

Table 10. Phenological phases of the Arieșan cultivar and the amounts of precipitation (mm) in decades, during the ten years (2007-2016)

Year	Phenological phases			Precipitation (mm)									
	Emergence date	Date of the end of tillering	Boots swollen	March			April			May			June
				1-10	11-20	21-31	1-10	11-20	21-20	1-10	11-20	21-31	1-10
2007	15.XI	17.III	20.V	6.7	8.4	6.9	0	0.7	9.4	20.4	28.2	55.2	50.7
2008	22.XI	8.IV	21.V	21.7	0.3	8.3	19.2	33.4	5.8	9	30.4	49.6	20
2009	17.XI	12.IV	18.V	34	17.5	2	5.4	3	0	0.8	0.2	30.4	20.1
2010	12.XI	22.III	22.V	9.7	5.5	2.4	27.4	24.2	0.4	17.2	50.8	19.6	11
2011	12.XI	21.IV	21.V	0.8	10.7	3.8	7.6	14.8	0.2	17.8	13.4	10.2	37
2012	12.III	28.IV	23.V	0	1.6	3.7	28.4	26.2	23.8	1.4	34.4	53.4	18
2013	18.XII	24.IV	9.V	10.7	19.1	28.1	43.9	8.6	0.8	1.5	24.2	53.6	45.6
2014	16.XII	22.IV	14.V	4	10.1	9	19	38.6	14.4	19	26.8	20.4	6.2
2015	20.XI	19.III	19.V	3.2	3.2	6.4	11.8	3	17.4	14.4	20.2	31.4	0.6
2016	15.XII	23.IV	17.V	22.8	3.1	21.1	16	18.8	27.4	35.2	12.2	43	46

Table 11. The coefficients of correlation between precipitation/decade and the yields of the Arieșan cultivar during the ten years

March/decade			April/decade			May/decade			June/decade
1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20	21-31	1-10
Classic system									
-0.21	-0.51	0.31	0.08	0.35	0.64*	0.63*	0.16	-0.05	-0.26
No-tillage system									
-0.31	-0.52	0.3	0.05	0.34	0.66*	0.66*	0.14	-0.08	- 0.23

*significant for p = 5%

From the results obtained in this study we conclude that in the Transylvanian Plain, the NT system with moderate fertilizations, does not lead to major yield increases, as compared to the CS. However, besides the beneficial effects upon some of the soil properties, the NT system is economically more efficient, through the elimination of considerable costs due to the high fuel consumption, necessary for the tillage that is specific for the CS. The linear regression between the yields in the CS and the NT system (Figure 1) demonstrates that the soil tillage had a small influence on the yield of the Arieşan cultivar, regardless of the cropping year. The slope of the regression line and the presence of the three distinct year groups on the regression line indicate the big influence of years upon the yields and a smaller influence of the tillage system. It can be said that the Arieşan cultivar does not have special preferences when it comes to the soil tillage.

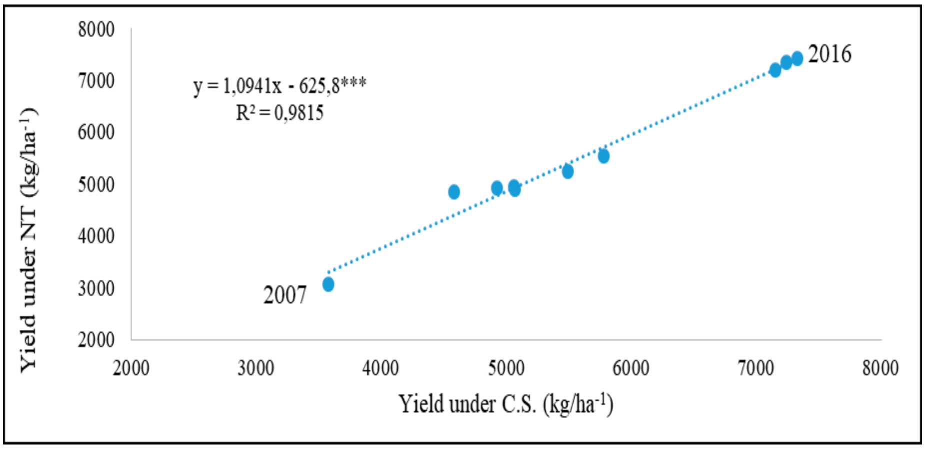

Figure 1. The relationship between yields in the CS and the NT system for the Arieşan wheat cultivar during 10 years (2007-2016)

CONCLUSIONS

The chemical properties of the soil underwent important changes in time, being considerably influenced by the soil tillage system and by fertilization. The positive role of the NT system upon the humus content of the soil, as compared to the CS, was bigger, at least for the superficial layer (0-20 cm) of the soil.

The content of macroelements (N, P, and K) registered in time major changes in both soil tillage systems, with the mention that in the NT system the increases were more pronounced, especially in the superficial soil layer. Therefore, the implementation of the conservative soil tillage methods associated to a balanced fertilization, can lead in time, in the conditions of the Transylvanian Plain, to the improvement of the chemical properties of the soil.

In the Transylvanian Plain, the level of wheat yields was tightly connected to the doses of fertilization, and to the climatic conditions of the cultivation year. The tillage system had a lower impact on the wheat yields, showing however a superiority of the CS in the first years, and an increasing superiority of the NT system in the following years.

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