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IMPACT OF MINIMUM TILLAGE SYSTEMS IN CONSERVATION OF WATER IN THE SOIL IN THE CASE OF PEA CROPS

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Abstract

Climate change is one of the most important factors influencing agricultural production, by natural energy flows blocking the work of the plant systems. Human activity, primarily the use of fossil fuels as the main energy source, contributes with over 40% increase greenhouse gas emissions. The principles of conservation agriculture include practices that retain soil undisturbed, conservation of soil fertility, minimum loss of organic matter and reduce the amount of water lost from the soil, conservation and use of water by plants spread throughout the growing season. The purpose of this paper is researching the influence of the minimum tillage systems application and climate conditions on the momentary soil moisture reserves and yield in the case of pea crops. The experimental factors were: factor A - tillage system, a_1 = classical tillage system (with plowing), a_2 = minimum tillage system (chisel variant), a_3 = no-tillage system (direct sowing); factor B - experimental years, b_1 = 2014, b_2 = 2015, b_3 = 2016. The afila pea variety cultivated was Tudor. Momentary soil moisture reserves were determined by the oven drying method. The average annual temperature increased during 2014-2016 by 0.9-2.0^{0}C from the annual average of the past 59 years of 9.1^{0}C recorded at the Meteorological Station Turda. Rainfall monthly registered over the three years were higher than the average on 59 years by 127.6 mm in 2015, 227.9 mm in 2014 and 303.2 mm in 2016. Soil reserve moisture determined between March and July at pea crop was higher in 2016 both the depth of 0-20 cm and 0-50 cm, the pea yield was 4210 kg/ha, compared to 2015 when the moisture reserve was close to the minimum limit and the yield obtained was 2360 kg/ha. Momentary soil moisture reserves calculated on 0-20 cm and 0-50 cm of depths were influenced by the soil tillage processing, in the minimum tillage systems and no-tillage the momentary soil moisture reserves are preserved better than in the classical tillage system. Reserve momentary soil moisture and pea yield are influenced by climate conditions and the processing of soil.

Key words: *climate conditions, water conservation, tillage systems, yield, peas.*

INTRODUCTION

Climate changes are one of the biggest economical, social and environment threats and one of the most important factors which influence agricultural production by blocking natural energy flows to the plant's working systems (Rusu et al., 2015); it's necessary to adapt applied technologies and to make the works in the optimal period (Simon et al., 2016), so as the result should be an efficient use of available water but also the increase of the water reserve in the soil (Teka, 2002; French, 2004; Mihailovic and Mikic, 2010; Marin et al., 2015; Chetan et al., 2016).
The result of keeping at the soil surface vegetal debris in the case of minimum tillage (Mcphee, 2003) is an increase of the content of organic mass in the soil (Malecka et al., 2012), the protection of soil against water erosion during heavy rain and wind (Assayehegne, 2002), the reduction of water quantity evaporated from the soil and surface leaks (Rukavina et al., 2002). The principles of conservative agriculture include practices which keep the soil undisturbed, preserve soil fertility, minimum losses of organic mass, preserve and use in steps of water by plants during the entire vegetation period (Rusu et al., 1999; Simon et al., 2015).
How soil is processed affects significantly the soil structure and moisture during the vegetation period of the crop, in general these changes are related to the type of soil, the soil

processing equipment, the cultivating depth and climate changes (Szajdak et al., 2003; Simon et al., 2014). The quantity of water stocked in the soil depends not only on a good management of technology but also on the crop, the most reduced water deficit in the soil appears to be after the pea crop (Sopterean and Puia, 2012; Velykis and Satkus, 2012).

Minimum tillage has numerous positive effects on soil, such as improvement of water content, reduction of soil erosion and fuel economy, but minimum tillage can also lead to soil compaction, which could affect seed germination, root growth and crop yield (D'Haene et al., 2008).

Penetration resistance of soil is an important parameter that influences to the root growth and water movement, therefore, penetration resistance is mostly associated with soil moisture changes (Quang et al., 2012). The soil penetration resistance is influenced by soil moisture and is necessary when using this parameter on soil property, the values be supplemented by the information of soil moisture value (Cara et al., 2008).

Pea is a plant which is cultivated in regions with cold climate (Simon et al., 2015) but it is tolerant to different environment conditions, different types of soil and it has a short vegetation period, taking into account all of the above it can be easily introduced in crop rotations.

The purpose of this paper is the research of the influence of applying minimum tillage systems and climate conditions on the current moisture reserve in the soil and the production of pea crop.

MATERIALS AND METHODS

The experiment was made during 2014-2016, at the Agricultural Research and Development Station Turda (ADRS Turda), on a vertic phaeosiom type of soil, with neutral pH, clayey-loamy texture, average humus content and good supply of nitrogen, phosphorus and mobile potassium.

Pea was sowed in the third decade of March, with a quantity of 100 germinable grains per 1 m^2, at a distance between lines of 18 cm, with Gaspardo Directa 400 sowing machine.

The experimental factors are:

Factor a - Soil tillage system: a_1-conventional tillage system which includes plowing 25 cm deep after the harvest of the pre-emerging crop and soil processing with rotary harrow before sowing; a_2-Minimum tillage system with chisel 30 cm deep after the harvest of the pre-emerging crop and soil processing with rotary harrow before sowing; a_3-No-tillage system.

Factor b - climate conditions during experimental years: b_1-2014, b_2-2015, b_3-2016.

In order to assess the pea production cultivated in all three soil tilalge systems, we have studied an afila pea genotype: Tudor. Pea was cultivated in a 3 years rotation crop, the pre-emerging plant was autumn wheat.

After having sowed, a pre-emerging herbicidation with Glyfos (glyfosat 360 g/l) - 4 l/ha was made in all three systems. The control of monocotyledonous and dicotyledonous weeds per vegetation was made with Tender (S-metolaclor 960 g/l) - 1.5 l/ha, Pulsar (imazamox 40 g/l) - 1.0 l/ha and Agil (propaquizafop 100 g/l) - 1.0 l/ha herbicides in the rosette phenophase of dicotyledonous weeds and 3-4 leaves at monocotyledonous.

In order to protect pea crop against pests during early bloom, a treatment with insecticide (tiacloprid 480 g/l) - 0.1 l/ha was made and 10 days after blooming the treatment was repeated.

Determine the reserve of momentaneous moisture: in order to determine these indices, monthly samples have been taken from each soil tillage system during all vegetation period with the help of the Tetha drill, 50 cm deep by using the gravimetric method with drying oven at 108°C for 8 hours.

Determine the soil resistance to penetration: it was made after harvesting the crop, with the help of the Digital Field Scout Penetrometer 900 SC, 0-45 cm deep, from each experimental variant.

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).

RESULTS AND DISCUSSIONS

The climate conditions during 2014-2016 are presented according to ARDS Turda Weather Station (Figures 1 and 2). During the last 59 years, the annual temperature average recorded was 9^0C and the annual amount of rainfall was 520.6 mm. The average temperatures recorded during the months from the vegetation period of pea crop have varied during all three years, but they were higher than the average during 59 years by 1.4^0C in 2014, characterized as the hottest year during the last 59 years, by 1.1^0C in 2015, being considered a hot year and by 1.2^0C in 2016, being considered a warm year.

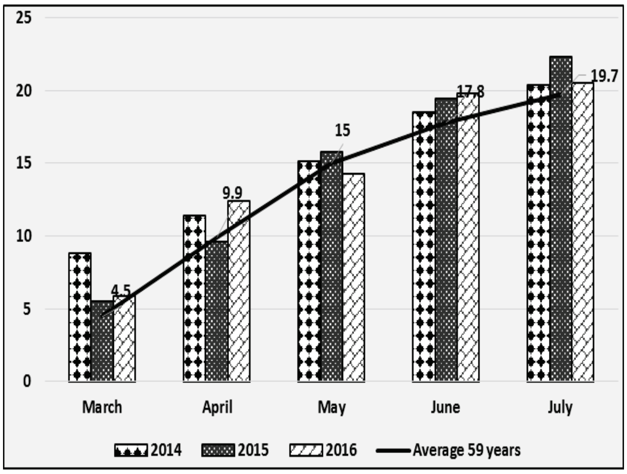

Figure 1. Thermal regime during the vegetation period of pea crop, ARDS Turda 2014-2016

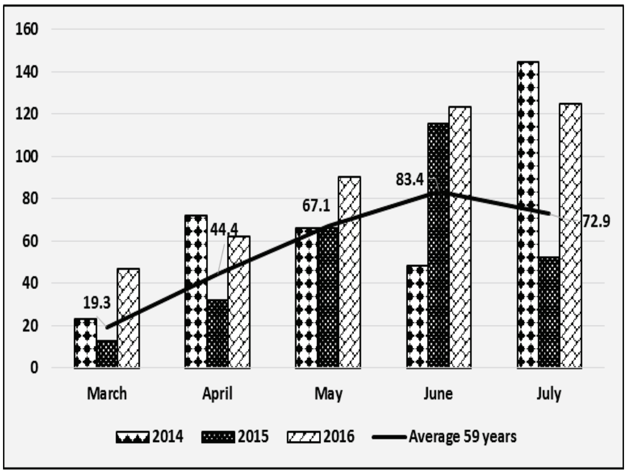

Figure 2. Rain regime during the vegetation period of pea crop, ARDS Turda, 2014-2016

The amount of rainfall recorded in 2014 was higher than the average during 59 years, being considered an excessively rainy year, the rainfall during the first half of 2015 was under the monthly amount during the last 59 years and pea had to suffer from the drought installed in spring, in 2016 the amount of rainfall was higher than the average during 59 years, being considered an excessively rainy year. In 2015, the rainfall was more reduced, and its absence during the optimal moments for the development of the crop resulted in a significant production loss. In 2014 and 2016, temperatures and rainfall were beneficial for the pea crop, the productions obtained were the result of the interaction between optimal climate conditions.

The rainfall from the winter months and those from the vegetation period contributed to the increase of soil moisture, which resulted in the creation of favorable conditions for the uprise and development of pea crop.

The relief from the research area is represented 71% by a hill orographic frame, with slopes submitted to an increased process of surface erosion. This, together with the degree of soil coverage with vegetation influences the process of erosion especially when they are strongly connected to rain, temperature and wind.

The lack of rain corroborated with the increase of annual average temperature offer a tendency of aridization of the climate in the area, which imposes taking measures to prevent erosion for the agricultural fields by introducing some variants of soil tillage systems according to the effects of global warming.

The main aim of introducing the new variants of soil tillage systems is the reduction of soil erosion, but in the areas lacking rain it is highly important to reduce the effects of the atmosphere and pedological drought by accumulating and keeping rain water in the soil for a higher period of time.

The vegetal debris from the soil surface reduce the degree of soil erosion produced by wind and surface leaks but also prevent the evaporation of water from the soil exposed from the first phases of vegetation of agricultural crops, but also after the harvest of the plants, especially those which are harvested early, like it is the case of pea, when it is very important that the soil should preserve a quantity of water as high as possible for the crops which are going to be sown in the fall.

The current moisture reserve of the soil recorded 0-20 cm deep is higher than the minimum limit of 503.1 m^3/ha in all three soil tillage systems, the highest values are recorded in the conservative soil tillage systems, as these systems have a higher capacity of accumulating and keeping water in the soil. In the system with direct sowing, the water reserve recorded is significantly higher than the one from the

classical soil tillage system, as one can notice in Table 1.
The results obtained by Su et al. (2007), showed that the water reserve in the soil is growing by 25% when applying the system of direct sowing compared to the classical system, over a period of 6 years.
The level of field capacity of 590.6 m^3/ha 0-20 cm deep was reached during the period when recordings were made, the values recorded in the conservative systems were higher than this level compared to the classical system, where the moisture value records a deficit compared to the field capacity, of 7.8 m^3/ha.

Table 1. Influence of the soil tillage system on the moisture reserve of the soil 0-20 cm deep, Turda 2014-2016

Variant	Moisture reserve (m^3/ha)	Difference, ± (m^3/ha)	Significance
Conventional system (witness)	582.8	Mt.	-
Minimum tillage	593.4	10.6	-
No-tillage	600.0	17.2	*
LSD (p 5%) 13.1	LSD (p 1%) 30.2	LSD (p 0.1%) 96.1	

The rainfall during the vegetation period of the pea crop in 2016 determined a very significant growth of the water reserve in the soil compared to the average of all three years studied, the plants could benefit from a higher quantity of accessible water. As one can notice in Table 2, during 2014 and 2015 the water quantity from the soil was significantly lower than the witness, rainfall during this period was scarce and more non-uniform than in 2016, some of it torrential.

Table 2. Influence of the experimental years on the moisture reserve of the soil 0-20 cm deep

Variant	Moisture reserve (m^3/ha)	Difference, ± (m^3/ha)	Significance
Average (witness)	592.0	Mt.	-
2014	575.3	-16.7	000
2015	559.7	-32.3	000
2016	641.1	49.1	***
LSD (p 5%) 3.9	LSD (p 1%) 5.9	LSD (p 0.1%) 9.5	

During the vegetation period of the pea crop, the recorded moisture reserve from the soil varied, the smallest value being recorded in March, with a very significant difference compared to the average of the 5 months when the recordings were made and the highest in April and May with very significant differences compared to witness (Figure 3), as Moraru and Rusu (2012) states, the water content in the soil is growing during all development season of plants, especially when conventional soil tillage systems are being replaced by conservative soil tillage systems, this water is used more efficiently during all vegetation period.
The current moisture reserve from the soil recorded 0-50 cm deep is higher after having applied conservative soil tillage systems, with a significant difference of 11.5 m^3/ha in the case of applying minimum tillage system and with a distinct significant difference of 19.6 m^3/ha in the case of direct sowing system compared to the classical soil tillage system considered as a witness (Table 3).

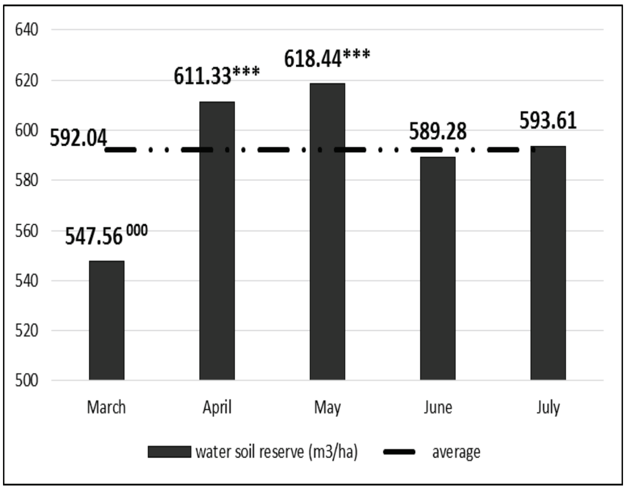

Figure 3. Monthly average of the current moisture reserve of the soil 0-20 cm deep, Turda 2014-2016

Table 3. Influence of the soil tillage system on the moisture reserve of the soil 0-50 cm deep, Turda 2014-2016

Variant	Moisture reserve (m^3/ha)	Difference, ± (m^3/ha)	Significance
Conventional system (witness)	1873.9	Mt.	-
Minimum tillage	1885.4	11.5	*
No-tillage	1893.5	19.6	**
LSD (p 5%) 7.7	LSD (p 1%) 17.9	LSD (p 0.1%) 56.9	

Following the research made with regards to the moisture reserve from the soil recorded at the wheat crop in Turda area, Chetan et al. (2016) specify the fact that in general, the higher values of the accessible water reserve in the soil were found in the classical soil tillage system, but from which it was lost easier than in the no tillage system, that in the conservative soil tillage systems water accumulates with more difficulty in the soil but it is lost slower and in the classical system it accumulates easier but it is also lost easier.

The moisture reserve from the soil 0-50 cm deep was also influenced by the rainfall during the vegetation period, the water reserve was over the minimum limit of 1734.8 m^3/ha in all three years studied, but in 2016 the moisture value recorded was significantly higher than the average of all three years (Table 4).

Table 4. Influence of experimental years on the moisture reserve of the soil 0-50 cm deep

Variant	Moisture reserve (m^3/ha)	Difference, ± (m^3/ha)	Significance
Average (witness)	1884.3	Mt.	-
2014	1847.9	-36.4	000
2015	1817.0	-67.3	000
2016	1987.9	103.7	***
LSD (p 5%) 11.7 LSD (p 1%) 17.7 LSD (p 0.1%) 28.4			

As one can notice in Table 5, in the case of interaction between the two experimental factors (soil tillage systems and climate conditions), the highest quantity of water from the soil was determined in 2016, in the case of applying the system with no-tillage system, with a very significant positive difference of 52.7 m^3/ha compared to witness.

Table 5. The interaction between year and tillage system factor on the moisture reserve of the soil 0-20 cm deep

Variant*	Moisture reserve (m^3/ha)	Difference, ± (m^3/ha)	Significance
b_0a_1	582.8	0	Mt.
b_1a_1	565.2	-17.6	000
b_2a_1	554.6	-28.2	000
b_3a_1	628.5	+45.7	***
b_0a_2	593.4	0	Mt.
b_1a_2	579.7	-13.7	00
b_2a_2	558.3	-35.1	000
b_3a_2	642.1	+48.7	***
b_0a_3	600.0	0	Mt.
b_1a_3	581.1	-18.9	000
b_2a_3	566.2	-33.8	000
b_3a_3	652.7	+52.7	***
LSD (p 5%) 6.7 LSD (p 1%) 10.2 LSD (p 0.1%) 16.4			

*b_0-years average; b_1-2014; b^2-2015; b_3-2016.
a_1- conventional system; a_2- minimum tillage; a_3- no-tillage.

Although in 2015 there was a deficit of rain during the vegetation period of the pea crop (March-July), there weren't recorded values of the soil moisture under 333 m^3/ha, representing the value of the fading coefficient.

The rain from March-July in 2016 resulted in the reserve of useful water in the soil exceed the level of field capacity 590.6 m^3/ha, by 37.9 m^3/ha in the conventional soil tillage system, by 51.5 m^3/ha when applying the minimum soil tillage system and by 62.1 m^3/ha in the case of the system with no-tillage.

The level of field capacity hasn't been reached during the vegetation period of the pea crop in 2014, respectively in 2015, in the case of the conventional soil tillage system, but after applying the conservative soil tillage systems, the value of the soil moisture determined in 2014 was close to this value, with a deficit of -10.9 m^3/ha in the case of minimum soil tillage system and by 9.5 m^3/ha in the case of the system with no-tillage.

How soil is processed influences a lot productions recorded in the case of pea crops, the highest production being recorded in the classical soil tillage system, after having applied the minimum soil tillage system it drops with a distinct significant difference and after having applied the direct sowing system, production decreases very much compared to the conventional system, as one can see in Table 6.

According to the research made by Jitareanu et al. (2006), in the case of the pea crop, the biggest productions are recorded in the conventional soil tillage system, that is almost 40.8% higher than the herbicide system. From the experiments made by Marin et al. (2011), the grain production obtained in the conventional system is higher compared to the chisel variants at different depths.

Table 6. The influence of the tillage system on the yield of pea

Variant	Yield (kg/ha)	Difference, ±
Conventional system (witness)	3683	-
Minimum tillage	3608^{00}	-74
No-tillage	2459^{000}	-1223
LSD (p 5%) 53	LSD (p 1%) 73	DL (p 0.1%) 99

As one can notice in Table 7, in 2015 the lack of rainfall in the first half of June (blooming time-formation of pods) led to a very significant decrease of production by - 890 kg/ha compared to the average of the years and compared to the other two years (2014 and 2016) when rainfall was more uniformly distributed during the 5 months, the biggest production of 4210 kg/ha was recorded in 2016, the difference compared to the average of the three years being statistically ensured as very important.

Table 7. The influence of experimental years on the yield of pea

Variant	Yield (kg/ha)	Difference, ±
Average (witness)	3250	-
2014	3181	-69
2015	2360^{000}	-890
2016	4210***	959
LSD (p 5%) 73	LSD (p 1%) 110	LSD (p 0.1%) 177

The soil resistance to penetration was influenced by the climate conditions from all three experimental years (moisture), thus in 2015 when rain was lower than in the other two years, the values recorded when harvesting the crop were higher than the average for three years, the difference of 145 kPa is very significantly positive, still the value of 1450 kPa hasn't prevented the development of the radicular system in the case of the pea.

The values of resistance to penetration recorded in 2014 were slightly more reduced than the average considered witness, the difference of only -39 kPa is insignificant, the results are presented in Table 8.

In 2016, the quantity of rain fallen during the entire vegetation period of the pea crop resulted in the soil resistance to penetration determined when the crop was harvested, should record the lowest values in all three years studied, the difference of -105 kPa is considered from a statistically point of view distinct significantly negative.

Table 8. Influence of the experimental years on soil penetration resistance

Variant	Soil penetration resistance (kPa)	Difference, ± (kPa)	Significance
Average (witness)	1305	-	Mt.
2014	1266	-39	-
2015	1450	145	***
2016	1200	-105	00
LSD (p 5%) 46	LSD (p 1%) 69	LSD (p 0.1%) 111	

From the data presented in Table 9 it results that the soil tillage system influences the soil resistance to penetration, in the case of applying the two conservative systems (minimum soil tillage and no-tillage system) the value of resistance increases with very significant differences (90 kPa respectively 156 kPa) compared to the conventional soil tillage system considered as witness.

The soil from the research area is slightly compactable, but even when applying minimum soil tillage systems during more than 5 years we didn't record very high values of the soil resistance to penetration, values which can prevent the natural development of the radicular system of crop plants.

Table 9. The influence of the tillage system on soil penetration resistance

Variant	Soil penetration resistance (kPa)	Difference, ± (kPa)	Significance
Conventional system (witness)	1224	-	Mt.
Minimum tillage	1313	90	***
No-tillage	1379	156	***
LSD (p 5%) 39	LSD (p 1%) 54	LSD (p 0.1%) 73	

Table 10 presents the influence of the depth of the soil layer on the soil resistance to penetration, as it has a really big influence on it, as one can notice on the depth of 0-10 cm the values recorded don't exceed 800 kPa, the differences compared to the average of the values on the depth of 0-45 cm being considered very significantly negative, on the depth of 10-15 cm the value increases up to 1223 kPa, the value is lower than the average, still the difference of -83 kPa is considered significantly negative.

Table 10. Influence of the soil depth on soil penetration resistance

Variant	Soil penetration resistance (kPa)	Difference, ± (kPa)	Significance
Average (witness)	1305	-	Mt.
0-5	368	-937	000
5-10	770	-535	000
10-15	1223	-83	0
15-20	1354	48	-
20-25	1546	241	***
25-30	1617	312	***
30-35	1632	327	***
35-40	1636	331	***
40-45	1602	297	***
LSD (p 5%) 64	LSD (p 1%) 85	LSD (p 0.1%) 109	

After the depth of 20 cm the values of the soil resistance to penetration increase with highly significant differences compared to the witness, the highest value of resistance is recorded on the depth of 35-40 cm, this value reaching over 1636 kPa.

The values of the soil resistance to penetration increase up to the depth of 30 cm, the depth of the soil processing, stabilizes on the depth 25-40 cm then begin to decrease after the depth of 40 cm.

CONCLUSIONS

The water quantity in the soil available to plants is one of the most important factors which determines the production of a crop. Even if the amount of rainfall from the vegetation period corresponds to the value necessary for a good development of pea plants, the non-uniformity of rainfall and its lack during important periods lead to an important decrease of the production.

The soil tillage system influences a lot the moisture reserve of the soil, the conservative soil tillage systems are an important factor for the accumulation and preserve of the soil moisture.

Both in the conventional system and in the conservative systems, the water is over the minimum limit of 503.1 m^3/ha, the highest value is recorded in the case of the minimum systems. In the case of applying the conservative systems, the water reserve is kept better than in the conventional soil tillage system. The highest quantity of water was recorded in 2016. The closest values of the water reserve were set in 2015 when rainfall was very low.

The pea production is influenced by several factors, the most important ones being the climate conditions through the quantity of water necessary for the best development and how soil is processed.

At 30-40 cm depth, the highest value of soil resistance to penetration of 1636 kPa is recorded, the depth reached by the machines' working parts.

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