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PRODUCTIVITY ELEMENTS IN CONSERVATIVE AND CONVENTIONAL TILLAGE SYSTEMS

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Abstract

We have studied productivity elements - soil moisture, agro-physical properties, soil disturbance, edaphic volume and the root system in the conservative non-tillage system as compared to the traditional system - ploughing.
The experiments included 7 soles and 3 agrocoenoses - winter wheat, maize as a repeated culture (34 years), rotation of maize and beans. The soil from the studied agricultural ecosystem is sandy loam carbonate chernozem, the content of physic loam (<0.01 mm) is 22-25%.
It was stated that soil moisture in the conservative no-tillage system is directly influenced by agrocoenoses, the stage of plant development and more compact horizons (20-30 cm) greatly favour the location of the root system closer to the surface, which causes the inhomogeneity of water content available on the soil profile. The data showed that we should study water on the whole humified profile in the conservative tillage system.
We found out that the no-tillage conservative system increases water reserves in soil during the periods subject to pedologic droughts. It is more evident, when cultivated crops, such as maize, are planted. There was identified a close correlation between penetration resistance and bulk density of the ecosystem soil - winter wheat (r = 0.73-0.78).
We have also noticed that the weight of winter wheat roots in the conservative tillage system is 1266 g/m^2, as compared to the traditional ploughing (1017 g/m^2).
In the farming year 2014-2015, a year of great droughts according to hydrothermal indices (Seleaninov), the agricultural ecosystem of winter wheat, preceded by winter barley showed a higher level of productivity (2809 kg/ha) in the no-tillage system as compared to the ploughing (1789 kg/ha).
We have found out that crop productivity and moisture in agrocoenoses are influenced by a forecrop, tillage system and conditions of the root system.

Key words: *agricultural ecosystems, no-tillage works, soil moisture, root system, crop structure.*

INTRODUCTION

The conservative system of agriculture requires scientific harmonious combination and application of all anthropogenic components of sustainable agriculture: soil tillage; crop rotation; control of weeds and diseases; conservation of resources - soil, water, air, biodiversity, energy (Cerbari, 2011; Jigau, 2011; Rusu et al., 2013; Boincean, 2013).
We need to study the conservative no-tillage system as compared to the traditional system in various climatic zones, including the Republic of Moldova, where the conservative system is used without any detailed scientific grounding of the benefits and problems that may arise.
You may often find contradictory and incoherent information on the production and average performance of the conservative no-tillage system in the scientific literature.
The conservative tillage system requires specific adaptation to soil conditions, climate, humidity, crop rotation, weed control, maintaining soil biological activity and vitality and developing some environmental conditions that will be favourable to agricultural crops and stimulate crop formation. Even if the conservative system does not increase the productivity of the agricultural ecosystem through harvest, its application is justified (if it is scientifically recommended), taking into consideration those environmental benefits which accompany it: reduced time for sowing; reduced fuel and energy consumption (by 30-40%); reduced number of purchased agricultural machinery; reduced soil compaction; restructuring; reduced surface and subsurface erosion; improved water in soil; favourable development of the root system; increased microbial activity.

The elements of efficient fertility play an important role, when the conservative tillage system is applied, special components of the agricultural ecosystem, which greatly contribute to the development of plants and crop formation.

The following ecological productive determinants of the conservative tillage system were studied during the growing season in different experimental variations: soil moisture, agro-physical properties, the root system, structural elements of the crop.

The conservative no-tillage system (the first year of application) mobilized the upper layer of 0-30 cm, providing more favourable conditions to winter wheat root systems, which resulted in an increased yield by 1.1-1.5 times, as compared to the conventional tillage system – the ploughing.

MATERIALS AND METHODS

The research was conducted in the agricultural year 2014-2015 at the educational and experimental station of SAUM "SDE Chetrosu". The case study included 7 soles with 3 agrocoenoses - winter wheat (2 soles, Antonovca variety), maize (Porumbeni 458) as a repeated culture (34 years), rotated maize I and II (2 soles) and beans (2 soles). The experiments were distributed to long-term research variants - ploughing and conservative activities - paraplow.

According to agro-ecological monitoring methods that were applied (Cerbari, 1997, 2010) there were determined: soil texture; physical and chemical indices; soil moisture (% and mm); wilting coefficient; soil density, bulk density and total porosity; resistance to penetration both in the field and in the laboratory. Root systems of winter wheat, maize and beans were studied by taking the organic mass of the 0-50 cm layer on the area of 0.25 m^2 in four repetitions. In July we conducted a biometric research of the studied cultures: winter wheat and maize grains. The production of the agricultural ecosystem was appreciated by structural elements of the crop and field crops.

The assessment of agricultural climatic conditions for the station Chetrosu in 2014-2015 showed that the annual average temperature was 11.2^{o}C, by 1.8^{o}C higher than the multiannual average temperature (9.4^{o}C). The annual amount of deposition was reduced by 50.8 mm (472.2 mm) as compared to the annual average (523 mm). The amount of precipitations during the summer period was 52% of the multiannual average: in May - 48%; in June - 80%; in July - 61% and in August – 0.6% respectively.

According to the hydrothermal index (HTI) and the temperature regime over 10^{o}C, the agricultural year 2014-2015 was extremely dry, especially during the active growing season, an extremely dry year as the annual average air temperature exceeded the multiannual average air temperature.

The hydrothermal index (HTI after Seleaninov) during the active growing season (from May to September) deviates significantly from the multiannual average, which during the last 50 years (1946-1995) used to decrease from March to May, from 2.71 (III) to 1.00 (IV) and 0.89 (V), while in June, due to the increased precipitation, it equals to 1.14, and, then, it decreases as temperatures rise: 1.14 (VI), 0.96 (VII) and 0.72 (VIII) at the educational station Chetrosu. According to our calculations, the agricultural year 2014-2015 was characterized by the semi-arid climate, the hydrothermal index (HTI) ranged from 0.5 to 0.94. In March it was 2.66, in April – 0.94 and in May it was half as much as compared to the multiannual average.

The detailed assessment showed that plants had long periods of climatic stress, they were forced to adapt to HTI great deviations in summer, when it deviated significantly, in June, July and August respectively: 0.93; 0.53; 0.4 - a huge shortage of rainfall. Climatic conditions in March deviated from the multiannual average significantly.

RESULTS AND DISCUSSIONS

The soil of the studied agricultural ecosystems (year 2015) is represented by calcareous black soil under moderate humified moderately deep sandy loam to sandy loam, which is characterized by the under moderate humus content (2.2-2.5%), the class of total cation exchange the capacity being average, the amount of adsorbed cation is from 22 to

25 me/100 g of soil in the upper part of the profile. Carbonates are present throughout the profile, ranging from 1.0-1.4% in the upper layer to 6-8% at a depth of 110-120 cm. Soil reaction is slightly alkaline.

Soil moisture. We have also studied the humidity in dynamics as deep as 120 cm. The results showed that at the early stages of the biological active development of winter wheat (the first decade of May), the moisture of ploughed soil was 18-20% (Figure 1), in the conservative tillage system it was about 2% lower, as the plants here were better developed. In a month (in June) moisture in the upper soil profile from the agrocoenoses of winter wheat, the ploughing variant had 9-15% or 72 mm in the layer of 0-50 cm. Moisture in May-June, mm is reflected in Figure 2. Comparative data of soil moisture in mm do not highlight water conservation in the layer of 0-50 cm. However, the data evaluation for the depth of 60-120 cm showed that moisture had been used more productively, by 2-3% higher in the no-tillage variant as compared to the ploughing variant (Figures 1 and 2). The coefficient of soil constant wilting was 11-13%, and in June soil moisture was close to the wilting coefficient, in the no-tillage variant reserves of water available to plants were greater at the depth of 60-120 cm.

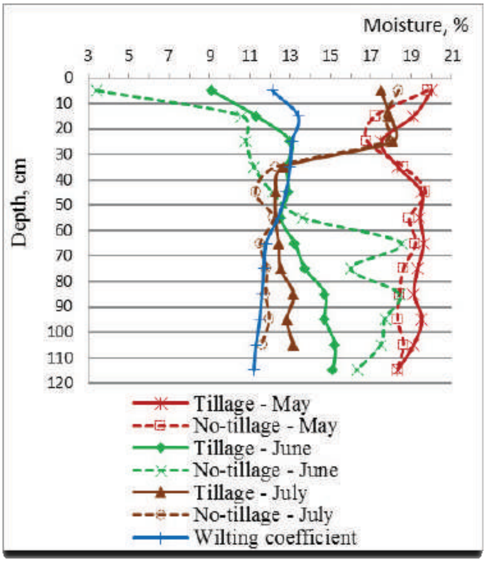

Figure 1. Soil moisture (%) in the traditional (ploughing) and conservative tillage (no-tillage) systems

The results of soil moisture changes with the development of agrocoenoses are most visible, when soil moisture is presented in mm (Figure 2). The comparative assessment of moisture reserves in soil at the beginning of the active growing season (May) for various agrocoenoses showed the following: 113-114 mm by winter wheat, Figure 2; 123-137 mm by maize repeated culture; 112-116 mm by beans. The data obtained in June indicated preservation of soil moisture (102 mm as compared to 94 mm) in maize, the conservative no-tillage variant. The results showed different water conservation degrees, depending on the agricultural system that was applied and agrocoenoses, the type of the root system. It should be noted that the assessment of soil moisture should be expressed both in % and mm, and the content of soil moisture requires thorough research not only in the upper layer (0-50 cm), but throughout the whole layer of soil (Figure 1), as water from the surface layer is actively consumed by root systems.

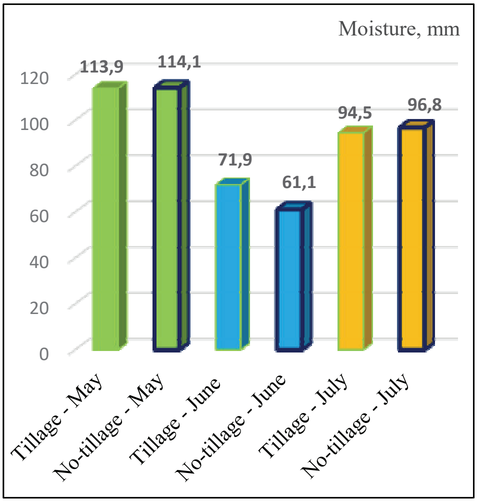

Figure 2. The variation of soil moisture, mm in the winter wheat agrocoenoses in May-July, 2014-2015

The bulk density. It was found that the bulk density reflects significantly the forecrop and the tillage system. The soil density in the layer of 0-50 cm is higher in agrocoenoses of the conservative no-tillage system (1.21-1.33 g/cm^3) as compared to the ploughing system, and namely: 1.21 g/cm^3 - winter wheat; 1.22 g/cm^3 - maize, repeated culture; 1.16g /cm^3 -

beans (Figure 3). We observed compaction of the layer of 20-30 cm by winter wheat both in the ploughing and no-tillage systems; this fact was also reflected in the data regarding penetration resistance (Figure 4). It was found out that soil moisture influences directly the penetration resistance. We identified a strong correlation between the bulk density and penetration resistance of the soil. The correlation coefficient is r = 0.78 for the variant winter wheat - ploughing, and r = 0.73 for the variant winter wheat - no-tillage.

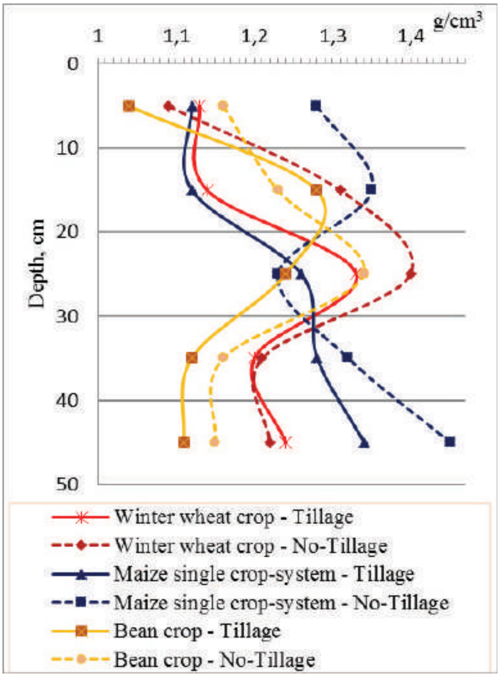

Figure 3. Comparative evaluation of soil density depending on the agrocoenoses and soil tillage

Penetration resistance. The data on the soil penetration resistance from the agricultural ecosystem of winter wheat in May and June show that ploughing contributes to the formation of a loose layer of 0-20 cm (5-9 kgf/cm^2) and in the no-tillage variant at the depth of 10-20 cm the penetration resistance is 19 kgf/cm^2 (Figure 4). The same thing was observed in the agrocoenoses of maize as a permanent crop, before sowing. Penetration resistance of both arable and under-arable layer in rotated maize was more homogenous, with the values that were lower than the arable and under-arable layer of maize as a permanent crop. In June, moisture decreases and penetration resistance increases for virtually all the agrocoenoses of the studied variants, yet the maximum values of penetration resistance was recorded in the upper layer (0-10 cm deep) and in the layer of 30-40 cm in agrocoenoses of winter wheat, where resistance equalled to 29 kgf/cm^2.

Soil penetration resistance was studied for all agrocoenoses depending on moisture. We observed an increase in penetration resistance in the no-tillage variant in July, which is explained by the root system that was better developed under the conditions of the conservative tillage system and the increased amount of consumed water.

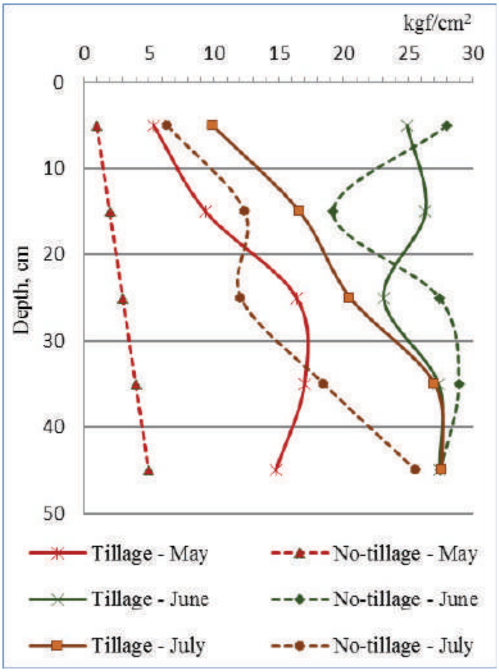

Figure 4. The dynamics of the soil penetration resistance change depending on the tillage system in winter wheat

We have also carried out some biometric assessments of fully ripened winter wheat, maize as a permanent crop and maize as a rotated crop at the flowering stage, beans at the stage of ripening. The data on agrocoenoses of maize under both the conservative system and ploughing (Table 1).

The data show that the maximum height of maize plants as well as the number of cobs was recorded in rotated maize under ploughing. The smallest stem diameter (2 cm) was registered in maize as a permanent crop in the ploughing variant, in other variants the stem diameter was from 2.3 to 2.4 cm and the plants were more vigorous.

The crop structure. We have also studied structural elements of the winter wheat crop, including the mass of roots (Table 2) in both maize as a permanent culture and in rotated maize (Table 3) according to their morphological characteristics. There was assessed crop productivity in the field, depending on the tillage system that had been applied (Table 4). The crop structure was assessed on the plots with the area of 0.25 m^2 and 1 m^2 each.

The technological harvest (productivity) of winter wheat in fields 1 and 7, both tillage systems correlate with the biological crop structure, determined per 1m^2. The parallel determination of structural elements of winter wheat harvest on the surface of 1m^2 and 0.25 m^2 by four repetitions, shows the use of only one crop gathered from the parcels of 1 m^2.

Table 1. Biometric features of the studied maize, July, 2015

Biometric measurements	The variant			
	Maize as a permanent crop (34 years)		Maize (1) - rotation	
	Ploughing	No-tillage	Ploughing	No-tillage
Height, cm	204	211.6	221.5	202.5
Number of leaves	13.0	11.4	12.6	12.1
Number of cobs	2.0	1.8	2.1	1.5
The length at the height of the 4th leaf, cm	62.7	76.2	71.3	70.6
The width at the height of the 4th leaf, cm	7.6	8.4	8.6	9.3
Stem diameter, cm	2.0	2.4	2.3	2.3

Table 2. Structural elements of winter wheat (1 m^2), 2014-2015

The variant	The number of stems	The mass of stems, grams	The number of heads	The mass of grains per 1 m^2, g	The mass of 1,000 grains, g	Harvest, kg/ha	The mass of roots, g
Ploughing	430	201.7	405	186.3	35.4	1863	1017
No-tillage	543	265.7	508	281.4	34.7	2814	1266
$DL_{0,05}$	366	72.0	320	76.0	2.2	756	448

Table 3. Structural elements of maize (6 cobs), 2015

The agrofond	The length of cobs (cm)	The cob diameter (cm)	The number of rows per cob	The number of grains per row	The total mass of cobs (g)	The total mass of grains (g)	The share of grains in the mass of cobs (%)	The mass of 1,000 grains (g)
Maize as a permanent crop (Field 3)								
Ploughing	20.8	4.2	13	43	1216.7	999.3	82.1	316.6
No-tillage	22.3	4.6	15	41	1488.5	1232.1	82.8	348.7
Rotation of maize (Field 4)								
Ploughing	20.3	4.2	14	41	1277.7	1051.9	82.3	349.9
No-tillage	20.7	3.5	14	39	1243.5	1020.1	82.0	354.0

The studied productivity of field crops. The results showed that the productivity of crops studied in the agricultural year 2014-2015 was directly influenced by forecrops, the tillage system (Table 4), and the conditions of the root system development (Table 2). The agricultural ecosystem of winter wheat (Table 4), preceded by winter wheat, the no-tillage variant showed a higher level of productivity (2809 kg/ha) as compared to the ploughing variant (1789 kg/ha).

The data on field crops correlate with the data on the harvest of winter wheat (Tables 2 and 4).

The data show a positive influence of the no-tillage system on the productivity of maize as a monoculture and as a rotated crop (Table 4).

Table 4. The productivity of field crops by the tillage system (kg/ha) within Rotation 1, Chetrosu, 2014 -2015

The culture	The variant	Harvest, kg/ha	$DL_{0.05}$
Winter wheat (the forecrop winter wheat - Field 1)	Ploughing	1789	188
	No-tillage	2809	
Beans (1) (the forecrop maize, the 3rd year - Field 2)	Ploughing	695	477
	No-tillage	634	
Maize as a permanent crop (34 years) - Field 3	Ploughing	4203	78
	No-tillage	4791	
Maize (1) (the forecrop maize, the 3rd year - Field 4)	Ploughing	5266	496
	No-tillage	6093	
Beans (2) (the forecrop maize, the 2nd year - Field 5)	Ploughing	792	385
	No-tillage	524	
Winter wheat (the forecrop winter wheat - Field 7)	Ploughing	3278	795
	No-tillage	3243	

CONCLUSIONS

The application of the conservative no-tillage system in the Republic of Moldova requires comprehensive adaptation to soil conditions, climate, agrocoenoses, plant protection technologies and the surface of the agricultural ecosystem, technological conditions and methods of water conservation in soil.

We found out that disturbance of soil from the agricultural ecosystem, expressed by the bulk density, penetration resistance and moisture significantly reflects the forecrop and the conservative tillage system offers more favourable conditions for the root system of plants with high density as compared to row crops (maize, beans). Water conservation in the conservative tillage system of carbonate chernozem (no-tillage) occurs at the depth of 60 cm.

As to the assessment of water available to plants in the conservative tillage system, water reserves at the depth of 1 m play a significant role here.

There were less water reserves in soil during the active growing stage of winter wheat in compacted layers as compared to adjacent horizons.

We stated a positive correlation between the bulk density and soil penetration resistance under winter wheat (r = 0.73-0.78). In case of moisture available to plants (17-20%) as compared to the wilting coefficient of 12-13%, soil moisture and penetration resistance correlated negatively (r = 0.6-0.7).

During the period of pedological drought the conservative no-tillage system has greatly preserved water available in agrocoenoses with maize as a repeated culture.

Biometric features of maize by the studied variants demonstrated that the maximum height of plants and the greatest number of cobs were observed in the variant, where ploughing was applied and maize was used as a rotated culture.

The agricultural ecosystem of winter wheat, the no-tillage variant, the forecrop is winter wheat showed a higher level of productivity (2809 kg/ha) as compared to the ploughing variant (1789 kg/ha).

The variant of no-tillage winter wheat provided more favourable conditions for the development of agrocoenoses expressed by the number and mass of stems, the number of heads, the mass of grains and the total mass of roots per 1 m^2.

The harvest of winter wheat was significantly high in the no-tillage variant (the forecrop winter wheat), while there was registered no crop increase in the winter wheat ploughing variant, (the forecrop winter wheat).

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