Influence of Agro-Technical Treatments on Some Physical and Agrochemical Parameters of Haplic Vertisols

Vanya Lozanova, Ivan Dimitrov

"N. Poushkarov" Institute of Soil Science, Agrotechnologies and Plant Protection,

7 Shosse Bankya Str., Sofia 1331, Bulgaria

Corresponding Author: Ivan Dimitrov, e-mail: idspasov@abv.bg

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Abstract

By assessing basic agro-technical factors, optimal decisions can be made for good agricultural practice on soils with heavy soil texture, such as the Haplic Vertisols. The aim of the study is to identify the changes in the physical and agrochemical status of Haplic Vertisols that occur under the influence of applied agro-technical measures.

For the achievement of the purpose in the period 2016 -2019, field experiments, based on the block method in the Sofia Region on a Haplic Vertisols were carried out.

The study found out that soil moisture was a major limiting factor for crop development. The soil moisture content is influenced by the type of soil tillage, although the density of the weeds is also less affected by the parameter. The bulk density of the Haplic Vertisols is inversely correlated with the soil moisture content. In the case of deep loosening of maize, its values are reduced compared to those with plowing. Lower values were found for the parameter after plowing as a pre-sowing treatment for wheat, compared to the variants with disking.

The applied fertilization mainly affects the content of nitrate and ammonium nitrogen, the phosphorus forms remain with low values, it is clearly necessary to raise the norm and with a methodical approach it is necessary to achieve a sustainable level of absorbed phosphates. The content of the absorbed potassium is still satisfactory, and based on the data from the analysis, its reduction and export with the produced products are smaller.

Key words: Haplic Vertisols, agricultural treatment, physical and agrochemical properties

Introduction

The problems of agriculture in the separated regions are different, they are specific, especially and according to Stoinev (2004), they can be solved only through the implementation of complexes of activities united in a comprehensive ecological farming system.

The physical characteristics of the soil are essential for the development of the reproductive potential of agricultural crops (Galeva and Dilkova 1970; Kuznetsova 1990; Arvidsson et al., 2003; Yankov, 2005; Van der Akker, 2006; Schjønning et al., 2020).

In soils with heavy soil texture composition (Haplic Vertisols), the physical properties are more susceptible to negative changes, necessitating timely agrotechnical intervention (Holmberg, 1985; Dimitrov & Borisova, 1996; Radford et al., 2000; Castellini et al., 2006; Grifith et al., 2013; Moreira at al., 2016) These changes require a systematic approach to adjust the physical parameters in the range of optimal values.

The Haplic Vertisols, widespread in the country, are characterized by considerable diversity in nutritional status as a result of the different fertilization systems applied. According to studies conducted by Samalieva and Nikolova (2005) on Haplic Vertisols, the recommendable content of absorbable phosphorus is 12,9-19,8 mg/100g soil and mobile potassium - 16,1-20 mg/100g in acetate-lactate extract. Ensuring optimum crop development with minimal environmental impact involves the correct determination of fertilization rate, fertilizer form, methods and timing of application (House et al., 1984; Ivanov, P., 2004; Hou et al., 2011; Nikolova et al., 2014).

By assessing basic agro-technical factors, optimal decisions can be made for good agricultural practice on soils with heavy soil texture, such as the Haplic Vertisols.

The aim of the study is to identify the changes in the physical and agrochemical status of Haplic Vertisols - that occur under the influence of the applied agro-technical measures.

Material and methods

For the achievement of the purpose in the period 2016 -2019, a field experiment, based on the block method – standard (on the long plots) in the Bozhurishte trial base of ISSAPP "N. Poushkarov", Sofia Region, on the soil type Haplic Vertisol (according to Koinov, 1987 or WRB for soil resources) was conducted.

The field trials has a total area of 0.72 ha, includes two crop rotations of 0.30 ha (Scheme 1), each with 24 crop areas of 70 m^{-2} in size. One crop rotates the two-shelf wheat-maize crop, while the other includes other cereals with a fused surface - oats and triticale.

Scheme 1. *Crop rotation and fertilization*

Years / Crop rotation	2016-2017	2017-2018	2018-2019
First rotation	Wheat $N_0/N_{14}P_{10}K_6$	Maize $N_0/N_{16}P_{10}$	Wheat $N_0/N_{14}P_{10}K_6$
Second rotation	Oats $N_0/N_{14}P_{10}\ K_6$	Maize $N_0/N_{16}P_{10}$	Triticale $N_0/N_{14}P_{10}K_6$

Fertilization applied in crop rotation is: T_0 - no fertilization; T_1 is at a fertilizer norm according to the macroelement stock by agrochemical analysis of soil samples.

For cereals fertilization is with nitrogen, phosphorus and potassium, and for maize - without potassium. In both crop rotations, the fertilization rate is the same in order to detect changes in soil agrochemical parameters under the same conditions.

Scheme 2. *Soil tillage systems in crop rotation*

By No	Crop	Year	Soil tillage systems	
			O_1	O_2
1.	Wheat/ Oats	2016-2017	Plowing 18-20 cm	Discing 10-12cm
2.	Maize	2017-2018	Loosening 35-40cm	Plowing 28-30 cm
3.	Wheat/ Triticale	2018-2019	Plowing 15-18cm	Discing 10-12 cm

The experiments are based on a two-factor scheme of type 2x3 with four blocks (repetitions), each of which is divided into two sub-blocks corresponding to the two tillage systems (Scheme 2). One of the systems involves more intensive cultivation (O_1 variant), while the other includes a disking as a minimum soil tillage (O_2) variant.

Indicators studied:

- soil texture composition - Kachinski's method(1958) with the pyrophosphate;
- moisture content by weight% and bulk density in g/cm^{-3} - by Kachnski's weight method, in layers 10 cm deep to 60 cm from the profile with rings of 100 cm^{-3} volume;
- total porosity of the soil - by the ratio of volume and relative mass of the soil by the formula:

$$V = \frac{d - \rho}{d} \cdot 100$$

where: V - total soil porosity in%; d - relative soil mass;

ρ is the bulk density of the soil in g/cm^{-3};

- mobile forms: nitrogen - by the method of Bremner and Kiney(1966); phosphorus - by the method of P. Ivanov(1984); potassium by the method of P. Ivanov(1984);
- reaction of soil solution (pH) - potentiometrically in water (H_2O) and potassium chloride (KCl);
- carbonates - by the method of Scheibler;(Penkov et al., 1991);
- content of organic matter in soil - according to Tyurin (Penkov et al., 1991);

Productivity is determined - the main and additional production of the cultivated crop, calculated in kg/ha;

The mathematical and statistical analysis of the experimental data was performed with the SPSS statistical program.

The experiments were carried out at the Bozhurishte experimental field of ISSAPP “N. Poushkarov” on Haplic Vertisols with a deep (about 1 m), slightly clay humus horizon. Deeper clay, dark brown, transitional horizon, which changes to a depth of about 250 cm from the soil-forming materials, follows deeper into the profile.

Table 1. *Soil Texture % to air dry condition (Haplic Vertisols)*

Horizon and depth in cm	Loss from HCl	Sum > 1	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	Sum <0.01
Ap 0-26	2.5	0.0	1.9	9.1	13.0	12.1	9.1	52.3	73.5
A′ 26-40	2.6	0.0	1.7	12.0	12.1	8.2	8.1	55.3	71.6
A″ 40-56	2.2	0.0	1.6	9.7	14.0	8.7	7.3	56.5	72.5
A‴ 56-85	2.2	0.0	1.4	9.7	12.4	8.3	7.3	58.7	74.3
B_k85-100	7.8	1.6	6.6	11.9	14.1	15.7	4.4	37.9	58.0
B_{ck} 100-140	8.7	1.5	3.3	9.0	15.2	8.2	10.2	43.9	62.3
C_k 140-170	8.7	0.0	7.7	13.5	14.1	6.9	7.6	41.5	56.0

The chemical properties of the soil in the experimental field vary slightly, which is a sign of soil uniformity. The humus content of the soil is medium humus (2.5% -3.8%) There is a regular and gradual decrease of humus from the surface to 120 cm depth. Total nitrogen content is low to moderate, which gradually decreases in profile depth. The total phosphorus content of the soil is poorly preserved. There is a deep leaching of carbonates from the soil profile. They are beyond the humus and transitional horizons.

The soil has a neutral to slightly alkaline reaction in the humus horizon, alkaline in the transient and strongly alkaline in the “C” horizon (Teoharov et al., 2005).

The investigation period covers years that vary in the amount and distribution of the fallen rainfall during the growing season of the crops. During the vegetation of wheat, the sum of rainfall is 346,3 mm, which is about the average for many years. Oats growth and development also proceeded at relatively good rainfall – 212,4 mm from germination to waxy maturity. During the growing season of maize - May - September, the amount of rainfall is 373,7 mm. In quantity, it is above the average for many years, but there was also a period of drought - August is only 3.8 mm.

Results and Discussion

The instantaneous moisture content of the soil found at the beginning and end of the vegetation season of wheat is influenced by the applied agricultural techniques. More significant is the influence of the type of soil tillage applied. As a result of the plowing, a higher moisture content was found in the Haplic Vertisols – 2.15% and 1.80% for the layer 20-30 cm, 1.60% and 1.80% for the layer 30-40 cm (fig. 1). For the deeper layers, the differences are statistically proven.

At the end of the growing season, permanent drought occurs after flowering. The soil moisture content recorded during this period is low. At Vertisols, the humidity is about wilting moisture17.0-19.45%, with the exception of the deepest layer 40-60 cm in the profile, where the humidity is 59-63% of MFMC. Depending on the variants of tillage, a lower content in the deep layers of 30-40 cm and 40-60 cm of the plots with applied disking was found, which is due to increased evaporation by capillary way.

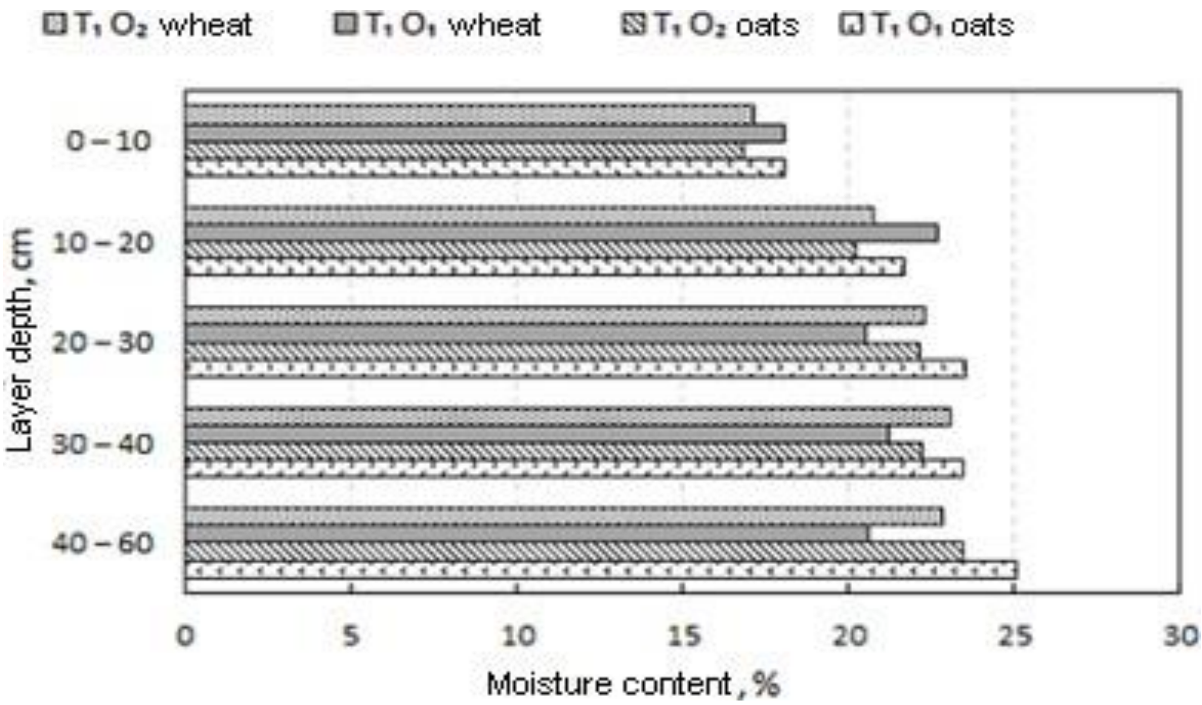
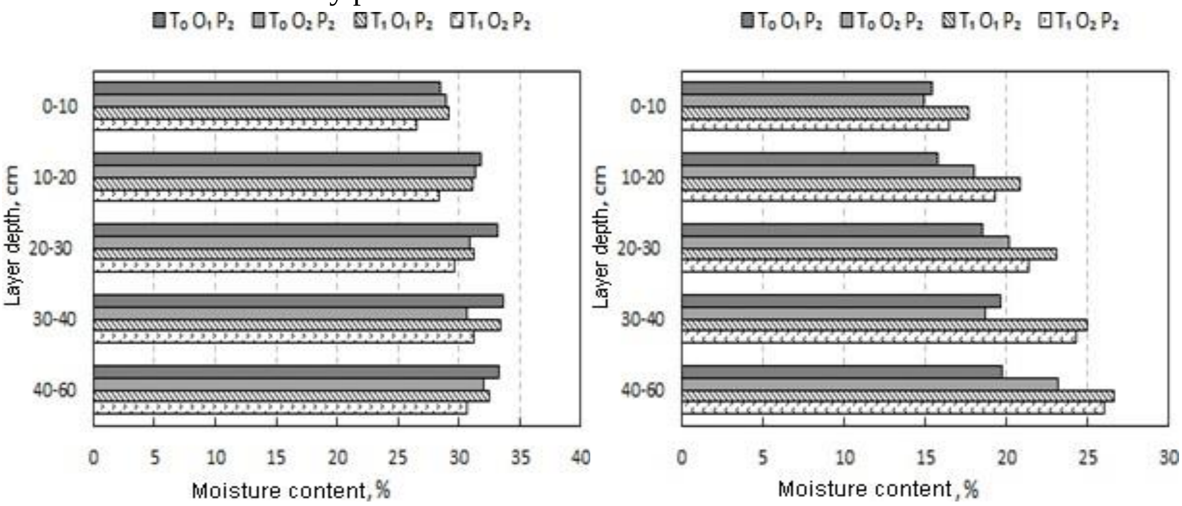


Fig. 1. *Soil moisture content in weight % - wheat and oats, 2017*

The instantaneous moisture content of the soil established at the beginning (phase "3-5 leaf") and the end of the maize vegetation season is influenced by the weather conditions and the applied agrotechnics. More significant is the influence of the type of applied tillage (fig.2,a). As a result of the basic treatment, loosening of 32-35 cm compared to 25-28 cm plowing revealed a higher moisture content of 1.41% and 2.69% for the 10-20 cm layer, respectively 2.27% and 1.64% for the 20-30 cm layer. For the deeper layers, the differences are statistically proven.



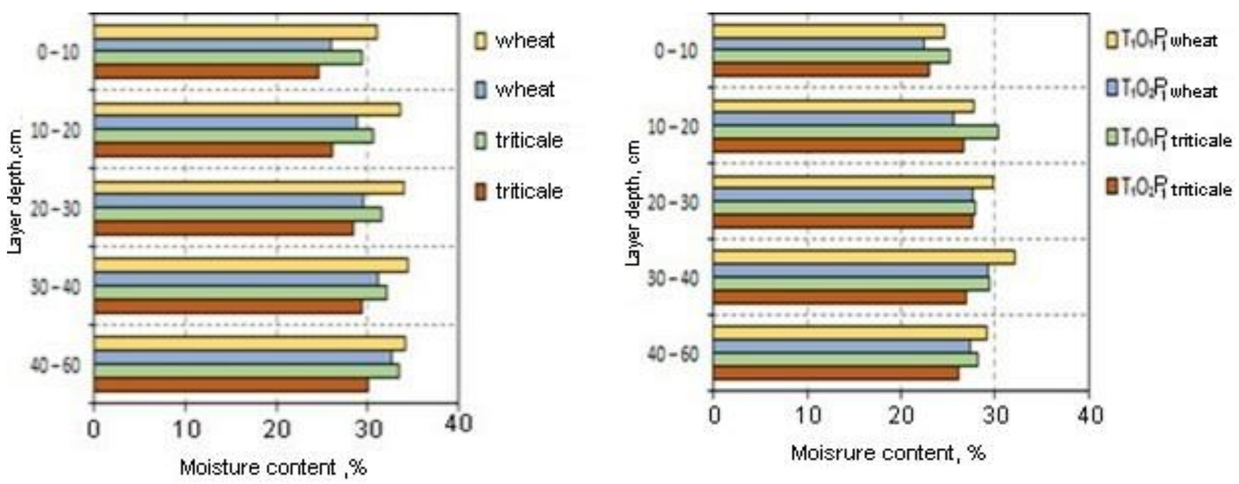
a) **b)**

Fig. 2 .*Soil moisture content in weight % - maize - 2018*

a) *phase "3-5 leaf"* ***b)*** *phase "tasseling",* After the "tasseling" phase, a permanent drought occurred, which continued until the end of the growing season. The soil moisture content recorded during this period is low. In the Vertisols, the humidity in the plow layer is below or around wilting moisture of 14.91 – 23.11% (fig. 2b). With the exception of the deepest layer of the profile 40-60 cm, where the humidity is 50-66% of the MFMC, the soil moisture deficit is strongly manifested.

Depending on the variants of tillage, a lower content in the deep layers of 30-40 cm and 40-60 cm in the plots with zero fertilization has been found, which is due to increased evaporation due to the lower vegetation coverage of the soil surface. Unlike the initial stages of maize development, the waxy maturity phase has no established effect on the type of treatment applied.

In the wheat “breeding” phase, the humidity of the soil is 75-80% of the MFMC. Significant differences in exploration options have not been identified. In the $T_1O_1P_1$ variant the 20-40 cm layer, the moisture content was 3.16 to 3.62% higher than that found in the $T_0O_2P_1$ and $T_1O_2P_2$ variants with disking, which is due to better moisture movement during plowing (fig.3,a).This thesis is confirmed by the fact that the variants with plowing are with the highest soil moisture in the layer 30-40 cm, and those with the disking in the layer 10-30 cm. There is no established difference between fertilized and non-fertilized variants.



a) **b)**

Fig. 3. *Soil moisture content in weight%-wheat and triticale - 2019*

***a)** phase “breeding”* ***b)** phase “class formation”*

In the “class formation” phase, the soil moisture content is much lower. In the plowing and fertilizing variant, $T_1O_1P_1$shows the biggest difference from the established in the ”breeding” phase, with the humidity in the 10-30 cm layer being over 10% lower than the previous reading. In this layer, the moisture content is on average 2.6% lower than that founded in the other variants. This finding can be explained by the soil composition in the plow layer. During plowing, the structure appears to be more friable, creating conditions for enhanced capillary rise and loss of moisture from evaporation.

In the “waxy maturity” phase, as a result of drought occurred, the soil moisture reserves are significantly reduced (fig.3,b). In the 0-10 cm surface layer, the humidity is about wilting moisture (WM). In all variants relatively balanced moisture content is established. Minor differences were found in the deepest layer 40-60 cm.

Bulk density of Haplic Vertisols

Bulk density is correlated with soil moisture. Parameter values that are within the range optimal for the development of the plant root mass are reported. An exception to this tendency is the values reported for the 30-40 cm layer in the variants with disking (fig. 4).

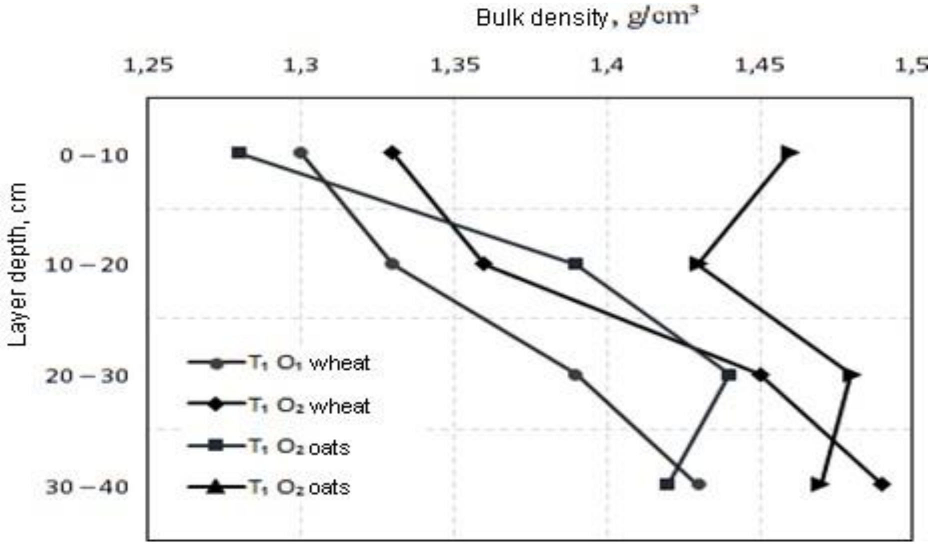
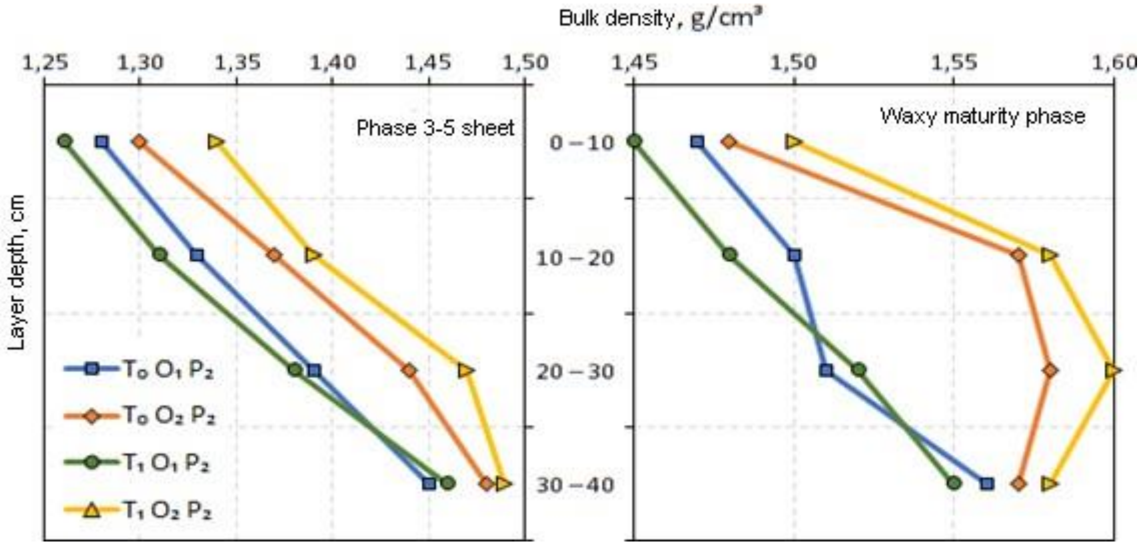


Fig. 4. *Soil bulk density in g/cm^3 – wheat and oats, 2017*

For the 30-40 cm layer, the parameter values are 0.10 g/cm^{-3} and 0.16 g/cm^{-3} higher on the plots with plowing and disking in the second crop rotation than those with the variants in the first. Although the humidity at the time of determination is about 70% of the MFMC, the values for the bulk density reach the upper limit of the optimum values (1.4 g/cm^{-3}).



a) **b)**

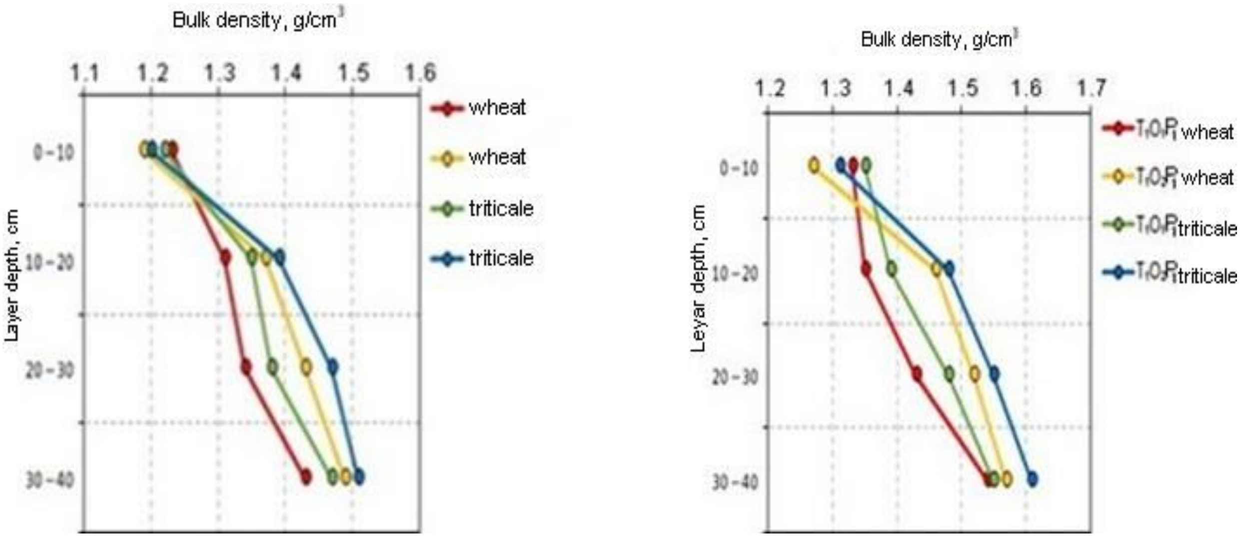
Fig. 5.*Soil bulk density in g/cm^3 – maize,* ***a)*** *"3-5 leaf" and* ***b)*** *"tasseling" phase, 2018*

At the Haplic Vertisols at the end of the growing season, the measured values for this parameter were above the equilibrium density of 1.2-1.3 g/cm^{-3}. After plowing at a depth of 15-18 cm, the soil in the 10-30 cm layer is more compacted, with a volume density of 1.56 g/cm^{-3} at a depth of 20-30 cm. The bulk density of the plots having a disking of 10-12 cm is higher than in the case of plowed variants - the difference is most significant in the layer 10-20 cm – 0.16 g/cm^{-3}.Due to the significant moisture deficit, the bulk density has high values for the entire investigated profile up to 40 cm.

In the second year, in the “3-5 leaf” phase of maize, values for the parameter, which are in the range optimal for the development of the root mass of the plants, were reported. An exception to this tendency is the values reported for the 30-40 cm layer for plowed variants.

For the 10-20 cm layer, the parameter values are with 0.04 g/cm^{-3} and 0.08 g/cm^{-3} higher on the plowed plots compared to those with a deeper loosening. Although the humidity at the time of determination is about 70% of the MFMC, the values for the bulk mass in the 20-40 cm layer reach the upper limit of the optimum values (fig. 5,a).

At the Haplic Vertisols at the end of the vegetation season, values for this parameter were measured above the equilibrium density of 1,2-1,3 g/cm^{-3}. After plowing at a depth of 25-28 cm, the soil in the 10-30 cm layer is more compacted, with a volume density of 1,60 g/cm^{-3} at a depth of 20-30 cm (fig. 5,b). The differences in the values for the bulk density of the plots with loosening of 32-35 cm compared to the variants with plowing in this layer are statistically proved. Due to the significant moisture deficit, the bulk density has high values for the entire investigated profile up to 40 cm.



a) **b)**

Fig. 6. *Soil bulk density in g/cm^3 – wheat and triticale, a) “breeding” and “class formation” phase*

In the third year, the lowest values were reported in the 0-40 cm layer in the plowed and fertilized $T_1O_1P_1$ variant in the wheat breeding phase, with differences of 0,06 g/cm^{-3} and 0,07 g/cm^{-3} for the 20-40 cm layer, and respectively are statistically proven (fig. 6,b).For the 0-30 cm tillage layer, the parameter values are up to the limits of the optimum density for this soil difference.

When considering the parameter in the grading phase, with the exception of the plowing and fertilizing variant $T_1O_1P_1$, a significant increase in the volume density was found in all 20-40 cm layers, the highest value being expressed in the $T_1O_2P_1$ variant - from 1,52 g / cm^{-3} to 1,55 g/cm^{-3}. The difference in bulk density between plowed variants must be noted. In the fertilized variant, the average difference for the studied profile 0-40 cm is 0.06 g/cm^{-3}, which is probably due to the density of the sowing and the more powerful root mass of the plants after the applied fertilization.

In the waxy maturity phase, due to the lack of moisture, the soil thickens strongly. In the 10-40 cm layer, the bulk density has values that limit the functions of the root system of wheat plants. The strongest compaction in the 10-20 cm layer in the disking and fertilizer $T_0O_2P_2$ variant is 1.73 g/cm^{-3} (fig. 6,b).

This fact, the presence of moisture only in the layer under the subsoil, confirms the established conclusion that there is a process of considerable compaction, despite the high plasticity of the clay soil aggregates.

Total porosity of Haplic Vertisols

In the first year until the wheat “tillering” phase and the occurrence of oat rotation, as a result of the good moisture content, the total porosity in the surface layer is 54.34% and 51.55%, respectively, for the area under first and second crop rotation. Then the values decrease in profile depth and in the layer 30-40 cm it is 47.79% and 43.18%. In the “waxy maturity” phase of wheat, the total soil porosity decreases by 3-5%, more significantly in the surface layers.

As a result of the good humidification in the winter-spring period, in 2018, in the phase “3-5 leaf” of maize, there is an increase in the overall porosity of the profile depth for the Vertisols compared to the “waxy maturity” phase in wheat in the 2017 (Table 2). In the O_1 system, the percentage increase is from 8.08 to 10.70%, which is most significant for the layer 0 - 10 cm (as a result of the applied treatment and winter water supply) and 30 - 40 cm (as a result of good humidity in winter). The most significant increase in the total porosity of the layer 10 - 20 cm (14.80%) is with the highest importance for the cultivation of O_2 (Table 2, b).

By reducing the water content of the soil in the “tasseling” phase, the bulk density increases, which leads to a decrease in porosity. In the O_1 tillage system, the reduction for the layer 0 - 10 cm is the lowest - only 0.12% to 3.48% for the layer 20 - 30 cm. In the O_2 system with plowing, the porosity reduction is the greatest in the 0-10 cm layer - by 5.97% and up to 1.49% for the deepest soil layer. With the increase of the moisture deficit up to the “waxy maturity” phase, the percentage of pores in soil decreased, more tangibly in the layer of 30-40 cm, which shows that the effect of the extension is lost (Table 2, c). Kercheva and Dilkova (2005) calculated the so-called "Reference" values of the bulk density that a soil would have with an optimal, critical and limiting content of drainage-aeration pores.

In the production year 2018/2019, the tendency to decrease the porosity in profile depth for both tillage systems is maintained for the Vertisols (Table 3). During the “germination” phase, a significant decrease in the overall porosity of the 10 - 40 cm layer is observed relative to the 0 - 10 cm soil layer. In the O_1 tillage system for wheat and deep loosening in the precursor, the porosity was statistically proven to be higher than in the O_2 layer 10 - 40 cm, increasing from 2.61% for 10 - 20 cm to 2.74% for 30 - 40 cm. probably the parameter values are influenced by the effect of the basic maize processing.

Table 2. *Total porosity of Haplic Vertisols in %, maize 2018*

Variance source	Sum of sq.m.	Sum of sq.m.%	Amount of light	Average area	F-ref.	Level of importance
Depth (D)	167.165		3	55.722	23.390	.000***
Tilth (O)	28.755		1	28.755	12.071	.001***
Crop rotation (S)	566.684		1	566.684	237.879	.000***
D*O	4.417		3	1.472	.618	.608 -
D*S	20.234		3	6.745	2.831	.054 -
O*S	.007		1	.007	.003	.957 -
D*O*S	2.000		3	.667	.280	.840 -
Mistake	76.232		32	2.382		
General amount	865.493		47			

a)

Depth (cm)	Tilth	Crop rot.*	General perc. (%)
0 – 10	1	1	52,239
		2	47,925
	2	1	51,368
		2	46,038
10 – 20	1	1	50,995
		2	43,522
	2	1	50,373
		2	42,516
20 – 30	1	1	49,751
		2	41,509
	2	1	48,259
		2	40,000
30 – 40	1	1	49,751
		2	42,390
	2	1	46,642
		2	40,503

LSD 5% =2.929
LSD 1% =3.937
LSD 0,1%=5.208

b)

Depth (cm)	Tilth	Crop rot.*	Gen.perc. (%)
0 - 10	1	1	50.114
		2	44.403
	2	1	45.398
		2	43.396
10 - 20	1	1	48.134
		2	44.252
	2	1	46.517
		2	42.874
20 - 30	1	1	46.269
		2	42.258
	2	1	44.776
		2	38.868
30 - 40	1	1	46.891
		2	41.258
	2	1	45.149
		2	39.497

LSD 5% =2.567
LSD 1% =3.450
LSD 0,1%=4.564

c)

By the time of the “spindle making” phase (Table 3, a,b), the porosity decreases throughout the study profile, with the decrease being most sensitive in the 0 - 10 cm layer:

7.59% for O_1 and 9.08% for O_2 treatment and respectively 3.48% and 2.98% for the 30-40 cm layer.

Table 3. *Total porosity of Haplic Vertisols in %, wheat and triticale 2019*

Variance source	Sum of sq.m.	Sum of sq.m.%	Amount of light	Average area	F-ref.	Level of importance
Depth (D)	196.394		3	65.465	40.313	.000***
Tilth (O)	55.666		1	55.666	34.279	.000***
Crop rotation (S)	411.139		1	411.139	253.178	.000***
D*O	9.827		3	3.276	2.017	.131 -
D*S	20.140		3	6.713	4.134	.014 *
O*S	5.481		1	5.481	3.375	.075 -
D*O*S	18.334		3	6.111	3.763	.020 *
Mistake	51.965		32	1.624		
General amount	768.946		47			

a)

Depth (cm)	Tilth	Crop rot.*	General perc. (%)
0 - 10	1	1	50.995
		2	47.403
	2	1	47.637
		2	46.541
10 - 20	1	1	48,134
		2	43.629
	2	1	45.274
		2	40.616
20 - 30	1	1	47.388
		2	43.503
	2	1	44.527
		2	40.610
30 - 40	1	1	45.517
		2	42.384
	2	1	44.279
		2	42.239

LSD 5% =2.188
LSD 1% =2.848
LSD 0.1% =3.767

b)

Depth (cm)	Tilth	Crop rot.*	Gen.perc. (%)
0 - 10	1	1	41.542
		2	41.132
	2	1	45.522
		2	41.887
10 - 20	1	1	42.542
		2	40.126
	2	1	35.572
		2	38.239
20 - 30	1	1	41.667
		2	39.855
	2	1	38.930
		2	34.340
30 - 40	1	1	39.925
		2	37.610
	2	1	38.433
		2	36.723

LSD 5% =4.268
LSD 1% =5.737
LSD 0.1% =7.590

c)

Due to the lack of soil moisture and strong soil compaction in the "waxy maturity" phase, the porosity is significantly reduced, with differences between 17.04 % and 11.19 %

for the O_1 and O_2 variants in the 0 - 10 cm and 10.08% and 8.03% for depth 30 - 40 cm. In the "waxy maturity" phase, the porosity leveling in the depth 0 - 30 cm (from 41.54 to 41.67%) is observed in the O_1 tillage system, while in the O_2 treatment it is the lowest in the 10 - 20 cm layer - only 35.57% (Table 3, c).

From the analysis of variance, it was found that, in the spring, differences were demonstrated depending on the depth of the layer, the type of cultivation applied, and between the two crop rotations. At the end of the vegetation season, the differences in layers, less than the structural condition of the soil of the two test areas - first and second crop rotations - are well proven, while differences in cultivation variants are unproven.

Influence of the studied factors on soil nutrition.

Table 4. *Agrochemical analysis of Haplic Vertisols – wheat and oats, 2017*

By №	Variants	Depth of layer cm	pH		$NH_{4+}NO_3$	P_2O_5	K_2O	Humus
			H_2O	KCl	mg/kg	mg/100 g		%
First crop rotation–wheat								
1	$T_0O_1P_1$	0-30	6.4	5.6	13.8	0.9	23.5	3.39
2	$T_0O_1P_1$	30-60	6.2	5.4	13.2	0.7	15.4	3.04
3	$T_1O_1P_1$	0-30	6.5	5.6	22.5	1.8	26.2	3.86
4	$T_1O_1P_1$	30-60	6.9	6.1	20.7	1.1	18.7	2.95
5	$T_1O_1P_2$	0-30	5.7	4.9	21.9	5.8	24.5	3.93
6	$T_1O_1P_2$	30-60	6.4	5.6	12.1	1.2	17.4	3.11
7	$T_0O_2P_2$	0-30	5.7	5.0	17.3	3.0	26.4	3.54
8	$T_0O_2P_2$	30-60	6.3	5.5	14.9	1.1	19.7	3.47
9	$T_1O_2P_1$	0-30	5.7	4.8	14.4	5.4	21.2	3.98
10	$T_1O_2P_1$	30-60	6.1	5.4	27.6	0.7	20.0	3.34
11	$T_2O_2P_2$	0-30	6.3	5.5	21.3	7.3	33.5	4.07
12	$T_2O_2P_2$	30-60	7.2	6.6	23.0	0.5	19.7	3.16
Second crop rotation–oats								
13	$T_0O_1P_1$	0-30	6.1	5.1	13.8	1.0	27.3	3.78
14	$T_0O_1P_1$	30-60	6.5	5.6	12.7	0.6	21.4	3.17
15	$T_1O_1P_1$	0-30	6.1	5.2	19.0	3.5	28.2	3.81
16	$T_1O_1P_1$	30-60	6.6	5.7	13.8	1.0	22.6	2.94
17	$T_1O_1P_2$	0-30	5.7	4.8	28.8	4.5	40.7	4.08
18	$T_2O_1P_2$	30-60	6.1	5.4	21.3	0.5	19.1	3.35
19	$T_0O_2P_2$	0-30	5.4	4.8	13.0	7.0	30.0	3.87
20	$T_0O_2P_2$	30-60	6.1	5.3	13.2	1.5	21.8	3.27
21	$T_1O_2P_1$	0-30	5.4	4.8	21.9	7.5	28.7	3.83
22	$T_1O_2P_1$	30-60	6.4	5.5	19.0	1.4	21.8	2.73
23	$T_1O_2P_2$	0-30	5.4	4.8	24.8	6.7	26.4	3.78
24	$T_1O_2P_2$	30-60	6.1	5.3	19.0	3.1	19.6	3.54

The impact of the tillage system on soil fertility is assessed by changes in nutrient content and their accessibility to plants.

Agrochemical analysis of soil samples taken during the vegetation season showed that the content of mobile forms of nitrogen was satisfactory to good in the tested area. There was a tendency for a slight increase in the content of absorbable forms of phosphorus, from low level in the beginning of the experiment, in variants with fertilization it was 2.4-7.3 mg/100 g, in the range of unsatisfactory for the layer 0-30 cm (table 4).

Table 5. *Agrochemical analysis of Haplic Vertisols – maize, 2018*

By №	Variants	Depth of layer cm	pH		$NH_{4+}NO_3$	P_2O_5	K_2O	Humus
			H_2O	KCl	mg/kg	mg/100 g		%
First crop rotation - maize								
1	$T_0O_1P_2$	0-30	6.2	5.5	21.9	0.4	23.1	3.15
2	$T_0O_1P_2$	30-60	6.6	5.8	18.0	0.2	19.6	3.37
3	$T_1O_1P_1$	0-30	6.1	5.4	38.6	2.0	27.4	3.55
4	$T_1O_1P_1$	30-60	6.6	5.8	27.1	0.3	21.3	2.99
5	$T_1O_1P_2$	0-30	5.4	4.9	30.5	3.1	27.0	4.07
6	$T_1O_1P_2$	30-60	6.6	5.4	28.2	1.0	20.5	3.74
7	$T_0O_2P_2$	0-30	6.3	5.6	23.6	0.2	22.9	3.04
8	$T_0O_2P_2$	30-60	6.5	5.8	14.9	0.5	22.8	2.72
9	$T_1O_2P_1$	0-30	6.1	5.2	36.1	1.5	32.9	3.73
10	$T_1O_2P_1$	30-60	6.6	5.8	26.5	0.2	23.5	3.28
11	$T_1O_2P_2$	0-30	6.1	5.2	29.4	1.3	30.8	3.79
12	$T_1O_2P_2$	30-60	6.3	5.6	22.5	0.2	23.7	3.35
Second crop rotation - maize								
13	$T_0O_1P_1$	0-30	6.2	5.6	23.2	1.5	23.7	3.14
14	$T_0O_1P_1$	30-60	6.2	5.6	20.2	0.2	20.4	2.70
15	$T_1O_1P_1$	0-30	6.1	5.1	25.9	2.1	26.9	3.61
16	$T_1O_1P_1$	30-60	6.1	5.3	24.8	0.2	22.9	3.36
17	$T_1O_1P_2$	0-30	6.1	5.1	28.2	4.6	33.6	4.16
18	$T_2O_1P_2$	30-60	6.1	5.3	27.1	0.9	24.2	3.72
19	$T_0O_2P_1$	0-30	6.2	5.6	20.2	0.2	27.7	4.06
20	$T_0O_2P_1$	30-60	6.7	6.0	15.2	0.2	24.0	3.13
21	$T_1O_2P_1$	0-30	6.3	5.6	23.6	3.2	24.7	3.57
22	$T_1O_2P_1$	30-60	6.4	5.8	27.6	0.4	21.4	2.83
23	$T_1O_2P_2$	0-30	6.1	5.2	28.8	3.5	28.5	4.02
24	$T_1O_2P_2$	30-60	6.1	5.3	26.5	0.3	21.5	3.85

Phosphorus is only 0.2 to 1.7 mg / 100 g of soil in the 30-60 cm bed. This low stock is explained by the fact that low fertilization rates are applied annually in order to maintain the ecological equilibrium in the soil and also to the exports with the relatively high yields of the cultivated crops. This finding is also confirmed by the reduction in the content of digestible forms of potassium, although to a lesser extent. For potassium, the reduction in content is more pronounced for the 30-60 cm layer. It is also noteworthy that during the period of using the area in Bojurishte for experimental purposes - over 25 years, the humus content decreased on average by about 0,3%.

There was a tendency for a slight increase in the content of available fraction of phosphorus, from slightly early in the experiment to 2.0-4.6 mg/100 g soil in the fertilizer variants, in the range of unsatisfactory for the layer 0-30 cm. In the 30-60 cm base layer, phosphorus is only 0.2 to 1.0 mg/100 g soil (trace state). For potassium, the reduction in content is more visible for the 30-60 cm layer, where the content is 20.5-24.2 mg/100 g of soil. It is also noteworthy that for the period of use of the area for experimental purposes, there is no significant difference in the availability of digestible forms of potassium between fertilized and non-fertilized variants.

Table 6. *Agrochemical analysis of Haplic Vertisols – wheat and triticale 2019*

By№	Variants	Depth of layer cm	pH		$NH_{4+}NO_3$	P_2O_5	K_2O	Humus
			H_2O	KCl	mg/kg	mg/100 g		%
First crop rotation – wheat								
1	$T_0O_1P_1$	0-30	6.3	5.5	12.1	0.4	25.5	3.98
2	$T_0O_1P_1$	30-60	6.5	5.6	7.9	0.2	18.4	3.76
3	$T_1O_1P_1$	0-30	6.1	5.2	15.3	5.4	23.7	3.83
4	$T_1O_1P_1$	30-60	6.2	5.4	11.5	0.7	21.5	3.37
5	$T_1O_1P_2$	0-30	6.0	4.9	14.4	2.3	24.8	3.88
6	$T_1O_1P_2$	30-60	5.9	5.1	10.3	1.5	27.7	4.23
7	$T_0O_2P_2$	0-30	6.4	5.5	12.7	0.2	30.6	3.48
8	$T_0O_2P_2$	30-60	6.5	5.7	10.2	0.2	27.7	3.44
9	$T_1O_2P_1$	0-30	5.8	4.9	15.6	8.5	22.3	3.53
10	$T_1O_2P_1$	30-60	6.2	5.7	11.5	0.2	21.1	3.45
11	$T_1O_2P_2$	0-30	5.9	4.9	17.3	4.0	27.5	3.73
12	$T_1O_2P_2$	30-60	6.6	5.6	11.5	0.5	23.7	3.13
Second crop rotation – triticale								
13	$T_0O_1P_1$	0-30	6.1	5.2	12.8	0.2	26.0	4.01
14	$T_0O_1P_1$	30-60	6.3	5.5	6.9	0.2	19.9	3.79
15	$T_1O_1P_1$	0-30	6.0	5.1	20.2	3.6	23.8	3.95
16	$T_1O_1P_1$	30-60	6.0	5.3	16.1	0.5	19.3	3.65
17	$T_1O_1P_2$	0-30	6.0	4.9	18.4	2.8	29.4	3.76
18	$T_1O_1P_2$	30-60	6.2	5.2	19.0	0.2	25.2	4.26
19	$T_0O_2P_2$	0-30	6.2	5.6	14.4	0.2	30.5	4.11
20	$T_0O_2P_2$	30-60	6.7	6.1	11.0	0.2	23.4	3.87
21	$T_1O_2P_1$	0-30	5.9	4.9	15.6	2.1	27.7	3.51
22	$T_1O_2P_1$	30-60	6.1	5.2	12.7	0.2	26.0	4.09
23	$T_1O_2P_2$	0-30	5.8	5.2	16.7	2.8	36.1	3.64
24	$T_1O_2P_2$	30-60	6.3	5.4	12.7	0.2	25.1	3.44

In the third year was established that the content of digestible forms of nitrogen was satisfactory. Compared to the data from the previous year, nitrogen was lower in all the variants tested. This indicates that much of the available nitrogen was exported with production. This assumption is confirmed by the observance of the highest values for total absorbed nitrogen for the 0-30 cm layer in the $T_1O_2P_2$ and $T_1O_2P_1$ in wheat crops – 17.3 mg/kg and 15.6 mg/kg soil respectively (table 6). In non-fertilized variants, the content of this macronutrient is slightly lower. The content of nitrogen in the 0-30 cm layer is naturally higher, with the largest difference between the two layers being found in the $T_0O_2P_2$ variant – 5.8 mg/kg soil.

In the second crop rotation of triticale cultivation, the results of agrochemical analysis are similar. A slightly higher content of assimilated nitrogen was found compared to the one in the tested area with wheat. In view of the lower grain yields obtained from the triticale, this difference in the established quantities is real.

The highest nitrogen content was reported in the $T_1O_1P_1$ variant – 20.2 mg/kg soil, for the 0-30 cm layer. For the 30-60 cm base layer, the amount of nitrogen is highest for the $T_1O_1P_2$ variant – 19.0 mg/kg soil. On the tested site with triticale, the differences in the assimilated nitrogen content between fertilized and non-fertilized variants are more pronounced.

The content of mobile forms of phosphorus is low, with traces in the subsoil 30-60 cm layer. Although the tested area is regularly fertilized with phosphorus, its amount does not increase. In the wheat area, phosphorus reaches 8.5 mg/100 g in the $T_1O_2P_1$ variant and is even lower in the other fertilized variants. In the non-fertilized variants, phosphorus is practically absent. These findings lead to the assumption that a significant portion of the phosphorus imported into the fertilizer goes into inimitable form. At the triticale tested area, the absorbed phosphorus content is even lower, although the fertilization rate is similar to that of wheat.

The content of absorbed potassium in the Vertisols is good. In the first crop rotation in wheat variants for the 0-30 cm layer, it ranges from 22.3 mg/100 g of soil ($T_1O_2P_1$ var.) to 30.6 mg/100 g of lime ($T_0O_2P_2$). Potassium is 3-4 mg/100 g less in the 30-60 cm layer. With this macronutrient, the fertilization effect is not detected, it is probably supported by the introduction of plant residues.

For triticale variants, potassium has a higher content in the 0-30 cm layer – 23.8 to 36.1 mg/100 g of soil, respectively. In the variant with the highest potassium content - $T_1O_2P_2$, the difference in the reported amount between the two test layers was the largest – 11.0 mg/100 g.

Conclusion

The study showed that soil moisture was a major limiting factor for crop development. The soil moisture content is influenced by the type of soil tillage, although the density of the weeds is also less affected by the parameter.

The bulk density of the Haplic Vertisols is inversely correlated with the soil moisture content. In the case of deep loosening of maize, its values are reduced compared to those with plowing. Lower values were found for the parameter after plowing as a pre-sowing treatment for wheat, compared to the variants with disking.

In the case of strong moisture deficiency, the bulk density values rise to the limit for the functioning of the plant root system.

The applied fertilization mainly affects the content of nitrate and ammonium nitrogen, the phosphorus forms remain with low values, it is clearly necessary to raise the norm and with a methodical approach it is necessary to achieve a sustainable level of absorbed phosphates. The content of the absorbed potassium is still satisfactory, and based on the data from the analysis, its reduction and export with the produced products are smaller.

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