Changes in the agrochemical status of Haplic Vertisols depending on the agro-technical measures

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Abstract

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

The aim of the study is to identify the changes in the 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, a field trials, based on the block method in the Sofia Region on a Haplic Vertisols were carried out.

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, AGROCHEMICAL PROPERTIES

Introduction

The problems of agriculture in the separated regions are different, they are specific, especially and according to Stoinev [1], they can be solved only through the implementation of complexes of activities united in a comprehensive ecological farming system.

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 [2] 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 [3, 4, 5, 6, 7].

The aim of the study is to identify the changes in the 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 experience, based on the block method – standard (on the long plots) in the Bozhurishte trial base of ISSAPP "N. Poushkarov", Sofia Region, was executed.

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

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 (in kg/ha of active substance).

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.

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:

- mobile forms: nitrogen - by the method of Bremner and Kiney; phosphorus - by the method of P. Ivanov; potassium by the method of P. Ivanov;

- reaction of soil solution (pH) - potentiometrically in water (H_2O) and potassium chloride (KCl);

- carbonates - by the method of Scheibler;

- content of organic matter in soil - according to Tyurin;

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.

Scheme 1. Crop rotation and fertilization

Years / Crop rotation	2016-2017	2017-2018	2018-2019
First rotation	Wheat $N_0/N_{140}P_{100}K_{60}$	Maize $N_0/N_{160}P_{100}$	Wheat $N_0/N_{140}P_{100}K_{60}$
Second rotation	Oats $N_0/N_{140}P_{100}K_{60}$	Maize $N_0/N_{160}P_{100}$	Triticale $N_0/N_{140}P_{100}K_{60}$

Scheme 2. Soil tillage systems in crop rotation

Crop	Year	Soil tillage systems	
		O_1	O_2
Wheat/ Oats	2016-2017	Plowing 18-20 cm	Discing 10-12cm
Maize	2017-2018	Loosening 35-40cm	Plowing 28-30 cm
Wheat/ Triticale	2018-2019	Plowing 15-18cm	Discing 10-12 cm

Table 1. Agrochemical properties of Haplic Vertisols

Horizon and depth in cm	pH		Total N %	C: N	$CaCO_3$	saturation with bases (V%)	Humus cont. %
	H_2O	KCL					
Ap 0-26	6,20	5,30	0,134	11,7	0,0	95,9	2,75
A′ 26-40	7,10	5,40	0,117	12,8	0,0	94,4	2,55
A″ 40-56	7,10	5,60	0,110	13,2	0,0	96,9	2,51
A‴ 56-85	7,10	5,90	0,093	12,0	0,0	95,7	2,13
$B_к$ 85-100	7,60	6,90	0,036	14,0	4,35	99,2	0,87
$B_{ск}$ 100-140	8,10	7,20	0,040	11,6	6,87	100,0	0,80
$C_к$ 140-170	8,20	7,10	0,037	12,1	4,70	-	0,91

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.

The investigations were carried out at the Bozhurishte experimental base of ISSAPP "N. Pushkarov "on Haplic Vertisols with a powerful (about 1 m), slightly clay humus horizon. A 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.

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.

Results and discussion

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, ie. in the range of unsatisfactory for the layer 0-30 cm (table 2).

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%.

The agrochemical analysis of the soil samples taken at the end of the maize growing season shows that, in the tested area, the content of mobile nitrogen forms is satisfactory to good. In the 0-30 cm layer for fertilized variants, the content of digestible forms is 29,4-38,6 mg /kg soil in the first crop rotation and 23,6-28,8 mg/kg soil in the second (table 3). The differences between fertilized and non-fertilized variants are more visible in the first crop rotation - from 8,6 to 16,7 mg/kg soil for the 0-30 cm layer and 9,1-10,2 mg/kg respectively for the 30-60 cm layer . There is no tendency to influence based on the soil tillage options. However, in the first crop rotation in the 30-60 cm layer, a higher content of absorbed nitrogen was reported in plowed variants than in loosening ones. In Vertisols, despite annual fertilization with phosphorus, the stock is poor.

There was a tendency for a slight increase in the content of absorbable forms of phosphorus, from slightly early in the experiment to 2,0-4,6 mg/100 g soil in the fertilizer variants, ie. 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.

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 4). 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 Haplic 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.

Table 2. 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

Table 3. 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

Table 4. Agrochemical analysis of Haplic Vertisols – wheat and triticale 2019

By№	Variants	Depth of layer	pH		$NH_{4+}NO_3$	P_2O_5	K_2O	Humus
		cm	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

Conclusion

The study showed that, 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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