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Agrochemical characteristics of Haplic Chernozems in conventional and transition to organic farming

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Abstract

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The research was carried out in 4-field crop rotation in the experimental field (Haplic Chernozems) of Dobrudzha Agricultural Institute – General Toshevo. The study covers the period 2018-2020. Agrochemical analyzes characterize two systems of agricultural farming - transition to organic farming (TOF) and conventional one (CF).

The nutrition regime in conventional part of the trail was differentiated by using mineral fertilization with variable nitrogen norms - from 0 to 180 kg N/ha against background fertilization with 60 kg P_2O_5/ha and 60 kg K_2O/ha.

After nearly four years period of transition to organic farming statistically significant differences in soil pH values were found between organic and conventional systems. The transition to organic farming keeps the level of the soil reaction close to neutral without a significant difference between its values in layers 0-20 cm and 20-40 cm. Annual application of nitrogen fertilizaion, especially with 180 kg N/ha lead to the lowest value of this indicator in the depth to 40 cm.

The forms of mineral nitrogen and their total amount are reliably influenced by the meteorological conditions during the years of research. It has been found that over 60% of mineral nitrogen is in nitrate form. In all variants of conventional farming there is a clear reduction of mineral nitrogen in the underlying layer, while in the transition to organic farming its content is maintained at the level of the surface layer.

Over the years, the variation in the values of available phosphorus at the studied depths is from 2.31 mg P_2O_5/100 g soil to 17.76 mg P_2O_5/100 g soil depending on the type of variant. As commented above, these changes are statistically significant and the scattering of the trait is large.

In the conventional farming system, the annual nitrogen fertilization with increasing norms against the background of PK leads to enrichment of the upper part of the root layer with available phosphorus.

At this stage, no statistically significant differences were found in the content of exchanged potassium in the transition to organic farming and the variants of conventional production with lower fertilizer norms. In the variant with annually nitrogen fertilization ($N_{180}P_{60}K_{60}$) there is a tendency to enrich the two soil layers not only with available phosphorus, but also with cation-exchanged potassium.

A statistically significant negative correlation was found between the soil reaction and the sum of forms of mineral nitrogen and available phosphorus. The correlations are positive. Almost all correlations of cation exchange potassium with other indicators are statistically insignificant.

Despite the relatively short period of transition to organic farming, changes in the content of available for plants forms of nitrogen, phosphorus and potassium have been found. This transition period has had a particularly favorable effect on soil acidity.

Key words: Transition to organic farming, Conventional farming, Agrochemical characteristics, Haplic Chernozems

Introduction

The development of mankind from ancient times to the present day is inextricably linked with the ability of man to grow agricultural products and expand his knowledge of the world around him. Historically, of the several main types of agriculture, intensive farming is currently the most common. It is characterized by increasing investments of industrial chemicals in the soil, the development of new production technologies or individual technological units. Excessive use of synthetic agents (pesticides, mineral fertilizers, growth regulators) has become more and more noticeable environmental pollution. This leads to a significant increase in health problems and nature rehabilitation measures. Recently, the inexpediency of excessive chemicalization has been increasingly recognized worldwide. It is particularly worrying that 1/3 of the pollution falls on agriculture (Atanasova and Maneva, 2013).

Zinati (2002) pointed out that the organic farming system, substitutes cultural and biological inputs for synthetically made fertilizers and chemicals for crop nutrition and pest management. During the transition from conventional to organic farming, growers may face pest control difficulties and lower yields when conventional practices are abandoned. As a result of a number of studies, the author found that implementation of crop and pest management practices depends on geographical location, climate, available onsite resources and history of the land. During transition, growers rely on cultural mechanisms and on organic and natural enemies to suppress pest populations. All agrotechnical practices (crop rotation, cultivation, cover crops, mulches, crop diversification, resistant varieties, insect traps...) also enrich the soil biota and increase crop yields before produce is certified organically grown. A healthy soil is one of the fundamental goals of organic farming. Early organic farming advocates such as Sir Albert Howard and J.I. Rodale made a connection between healthy soils, healthy plants, and healthy people (Granatstein, 2003).

In recent times organic farming keeps attractingthe interest of producers and consumers alike, aimingat the creation of a sustainable production system, with a capacity to sustain and protect nature and the landscape, as well as to minimize environmental damage induced by existing agriculturalpractices, which by their high chemical approach disruptedand harmed ecosystems, thereby degrading food-supplying natural resources (Pacini et al., 2003; Lund and Algers, 2003).

Farming practices affect the amount of and type of crops produced and thereby the amount of residues added to the soil (Johnston et al., 2009). Comparing agriculture land with corresponding natural land, the latter will contain more SOM. The underlying reason is that plant residues are removed in agricultural system and a portion of organic matter produced is not returned to the soil.

The report, which represents the USDA's first systemaric look at organic farming since chemical farming became dominant in the 1940's, does not suggest that a sweeping conversion of farmers to organic methods is either likely or desirable. But it suggests that many farmers can, and perhaps should, adopt organic farmer practices, combining them with conventional practices if necessary or desired (Carter, 1980)

Since the beginning of the last century, mankind has injected increasing amounts of reactive nitrogen into the environment, intentionally as fertilizer and unintentionally as a by-product of combusting fossil fuels. As a result nitrogen cycle is being altered causing possible grave impacts on biodiversity, global warming, water quality, human health, and even the rate of population growth in several parts of the world (Singh at al., 2008). According to authors the current status of reactive nitrogen which consists of all biologically, chemically and radiatively active nitrogen compounds in terrestrial, coastal and atmospheric realms and development of technologies to minimize nitrogen impacts on the environment needs to be addressed in the right perspective. The development of policy to control unwanted reactive N release in the environment is difficult because much of the reactive N release is related to food and energy production and reactive N species can be transported great distances in the atmosphere and in aquatic systems.

Presently, organic farming is implemented in all member-states to a larger or smaller extent. The European Union acknowledges the significance of organic farming as a realistic proposal in the context of a new agricultural production model and in a constantly changing and competitive environment (Oxouzi and Bagiatis, 2012).

The aim of this work was to assess soil properties in tested variants of conventional and transition to organic farming. The quality criterion was the possibility of implementing general and specific objectives of organic farming. In this paper the following criteria were selected as the assessment parameters: pH (H_2O & KCl), available nitrogen mineral forms and available forms of phosphorus and potassium.

Material and methods

The research was carried out in 4-field crop rotation in the experimental field (Haplic Chernozems) of Dobrudzha Agricultural Institute – General Toshevo. The study covers the period 2018-2020. Agrochemical analyzes characterize two systems of agricultural production systems - transition to organic farming (TOF) and conventional one (CF).

The nutrition regime in conventional part of the trail was differentiated by using mineral fertilization with variable nitrogen norms depending on the previous crop. After spring pea, 30, 60 and 90 kg N/ha were used, and after the rest of the previous crops – 60, 120 and 180 kg N/ha. With the exception of the control variant ($N_0P_0K_0$ – CF-T_0), which represented the natural fertility of the slightly leached Chernozem soil. All fertilizer variants were against background fertilization with 60 kg P_2O_5/ha and 60 kg K_2O/ha. The part of transition to organic farming starts at the end of 2016.

After the wheat harvest in each of the research years at the end of July soil samples were taken from the layers 0-20 and 20-40 cm.

The soil samples are air-dried and prepared according to the requirements of each specific analyse:

- Soil pH was determined in water and salt suspension of 1 n KCl. (Palaveev, Totev, 1979).
- The sum of the mineral nitrogen forms in soil, was determined by extraction with 1% K_2SO_4 (mg/1000 g soil). The identification of NO_3-N in the filtrate was done using the disulfophenol method; and ammonium nitrate was determined by the phenol method (Agro-chemical methods for soil investigation, 1975).

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- Available phosphorus and the exchangeable potassium were determined by AL-method (by the modification of Ivanov, 1984). Phosphorus available to plants (mg P_2O_5/100 g soil) was determined colorimetrically, and in the same solution - the amount of exchangeable potassium (mg K_2O/100 g soil) through flame photometry.

The data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using MSTATC software programs. The resultant data were statistically processed using variance analysis, F test and LSD (Least Significant Difference) test, which are commonly utilized in the multi-criterial statistical analysis. The SPSS version 16.0 statistical package was used. The significance of the treatments' effect was considered at 0.05 probability level (Gomez and Gomez, 1984). After performing the analysis of variance, we compared the means for each treatmen, using the Waller-Duncan's Multiple Range Test. Finally, Pearson correlation coefficients ("R coefficients") were computed and tested for significance.

Results and discussion

Our results from the multifactor analysis of variances of the pH and the forms of nitrogen, phosphorus and potassium available to plants for the study period show significant dynamics in reliability depending on the studied factors and soil layers (Table 1). In the surface layer 0-20 cm the strength of the influence of the factor *Year* is statistically significant at the values of NH_4-N and available to plants phosphorus and potassium. The studied *Variants* in the conventional agricultural production, as well as the variant in transition to biologically reliable, but with different force influence the values of the studied indicators with the exception of NO_3-N. In the surface layer, the interaction between the factors has a statistically significant effect only on the values of digestible phosphorus.

In the underlying layer, the meteorological features during the years of study statistically significantly and with different strength affect the values of the tested agrochemical parameters with the exception of those of NO_3-N. In the deeper soil layer, a significant difference between the studied variants was found at pH-H_2O and the digestible forms of phosphorus and potassium. It was also found that in this soil layer the mutual influence between the tested factors is statistically insignificant.

Comparing the results for scattering the values of the different agrochemical indicators, we find that their coefficient of variation is characterized by the lowest degree of scattering of the values of the soil reaction (pH-H_2O, pH-KCl). This fact is an indication of an extremely homogeneous sample (Table 2).

The results obtained for the content of cation-exchanged potassium at a depth of 0-40 cm are distinguished by a relatively homogeneous sample. For all other studied indicators, the scattering of the trait is large and the sample is defined as highly heterogeneous.

Table 1. Analysis of the variances of the Agrochemical soil characteristics by soil layers (values of parameter *p*) (Tests of Between-Subjects Effects)

Source	Dependent Variable	df	Type III Sum of Squares 0-20 cm	Type III Sum of Squares 20-40 cm	Mean Square 0-20 cm	Mean Square 20-40 cm	F 0-20 cm	F 20-40 cm	Sig. 0-20 cm	Sig. 20-40 cm
Years (1)	pH - Water	2	0,006	0,301	0,003	0,150	0,175	5,704	,841^{NS}	0,008
	pH - KCl	2	0,041	0,243	0,021	0,122	1,838	5,177	,177^{NS}	0,012
	NO_3 - N	2	12,543	13,760	6,272	6,880	0,444	1,148	,645^{NS}	0,331^{NS}
	NH_4 - N	2	110,714	88,206	55,357	44,103	125,624	52,707	0,000	0,000
	SUM Min. N	2	191,101	150,195	95,551	75,098	5,866	8,885	0,007	0,001
	Available P_2O_5	2	83,706	42,510	41,853	21,255	15,430	5,591	0,000	0,009
	Exengeable K_2O	2	115,050	377,111	57,525	188,555	15,264	98,447	0,000	0,000
Variants (2)	pH - Water	4	0,716	0,481	0,179	0,120	10,424	4,557	0,000	0,005
	pH - KCl	4	0,350	0,326	0,087	0,081	7,758	3,466	0,000	0,019^{NS}
	NO_3 - N	4	186,593	58,328	46,648	14,582	3,305	2,432	,023^{NS}	0,069^{NS}
	NH_4 - N	4	10,677	10,226	2,669	2,556	6,057	3,055	0,001	0,032^{NS}
	SUM Min. N	4	282,808	105,857	70,702	26,464	4,340	3,131	0,007	0,029^{NS}
	Available P_2O_5	4	408,289	128,677	102,072	32,169	37,631	8,462	0,000	0,000
	Exengeable K_2O	4	77,471	57,841	19,368	14,460	5,139	7,550	0,003	0,000
1 x 2	pH - Water	8	0,138	0,102	,017	0,013	1,003	0,484	0,454^{NS}	0,858^{NS}
	pH - KCl	8	0,101	0,111	,013	0,014	1,117	0,592	0,380^{NS}	0,776^{NS}
	NO_3 - N	8	103,023	74,054	12,878	9,257	0,912	1,544	0,520^{NS}	0,184^{NS}
	NH_4 - N	8	4,337	3,392	0,542	0,424	1,230	0,507	0,316^{NS}	0,842^{NS}
	SUM Min. N	8	139,772	71,783	17,472	8,973	1,073	1,062	0,408^{NS}	0,415^{NS}
	Available P_2O_5	8	97,186	42,070	12,148	5,259	4,479	1,383	0,001	0,244^{NS}
	Exengeable K_2O	8	58,915	38,699	7,364	4,837	1,954	2,526	0,088^{NS}	0,031^{NS}

Table 2. Statistical parameters and degree of variation of the studied agrochemical parameters average for the period 2018-2020, (Descriptive Statistics N=45)

Indices	Minimum 0-20 cm	Minimum 20-40 cm	Maximum 0-20 cm	Maximum 20-40 cm	Mean 0-20 cm	Mean 20-40 cm	Std. Deviation 0-20 cm	Std. Deviation 20-40 cm	CV% 0-20 cm	CV% 20-40 cm
pH - Water	5,78	5,88	6,59	6,88	6,1709	6,3284	0,17672	0,19513	2,86	3,08
pH - KCl	4,65	4,69	5,25	5,51	4,9047	5,0433	0,13737	0,17748	2,80	3,52
NO_3 - N	3,74	3,30	22,33	17,22	8,0571	6,7251	4,06080	2,72196	50,40	40,47
NH_4 - N	2,34	2,09	8,57	8,48	4,9982	4,3713	1,77705	1,69844	35,55	38,85
SUM - Min. N	7,47	7,03	30,90	25,70	13,0549	11,0964	5,00538	3,63507	38,34	32,76
Available P_2O_5	2,33	1,56	20,96	14,92	8,0982	4,7653	3,90383	2,72742	48,21	57,24
Exengeable K_2O	18,06	17,20	28,00	28,00	23,0349	21,6964	2,87820	3,47429	12,49	16,01

Soil pH is an important parameter affecting biological, chemical and physical properties. Soil pH determines plant nutrient availability, mobility of pollutants and microorganisms' activity. Aggregate structure in clay soils is affected by soil pH conditions through dispersion and stabilization of soil particles (Tellie, 2013).

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Changes in soil pH can have implications for nutrient availability. The preferred range of soil pH(w) for plant growth is 6 (slightly acid) to 8 (slightly or mildly alkaline), with nutrient availability optimised in the range 6–7 (Rayment and Lyons, 2011). In our experiment the changes of the soil reaction in conventional wheat production by years show that with increasing the norm of nitrogen the values of the indicator show a tendency to decrease, ie. to acidification. This fact applies to both studied soil layers in the upper part of the humus-accumulation horizon. The highest and respectively close to the natural state of this indicator are the established values in the transition to organic production (Table 3).

Table. 3. Changes in the values of the soil reaction depending on the variants in the experiment by years of research

	Soil depth	pH **H_2O**			pH **KCl**		
	cm	***2018***	***2019***	***2020***	***2018***	***2019***	***2020***
BIO-part	0 -20	6,43	6,32	6,35	5,12	5,08	4,96
	20 -40	6,35	6,70	6,42	5,04	5,34	5,08
T0	0 -20	6,20	6,30	6,16	4,95	4,95	4,81
	20 -40	6,26	6,44	6,26	5,02	5,12	4,88
T1	0 -20	6,10	6,13	6,25	4,87	4,93	4,97
	20 -40	6,23	6,42	6,31	4,97	5,16	5,10
T2	0 -20	6,10	6,19	6,11	4,79	4,95	4,84
	20 -40	6,33	6,45	6,26	5,06	5,15	5,03
T3	0 -20	5,96	5,91	6,06	4,74	4,82	4,79
	20 -40	6,10	6,20	6,19	4,86	4,96	4,88

The meteorological conditions during the research years do not have a significant influence on the values of the soil reaction in the surface layer 0-20 cm (Table 4). In the underlying layer, a statistically significant influence in the direction of a slight increase in the values of the indicator was found in 2019.

Table 4. Changes in the values of the soil reaction by years of research (N=15)

Years	pH - H_2O		pH - KCl	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm
2018	6,16 a	6,25 a	4,89 a	4,99 a
2019	6,17 a	6,44 b	4,95 a	5,15 b
2020	6,19 a	6,29 a	4,87 a	4,99 a

Problems associated with soil acidity are aluminum toxicity and low phosphorus- and molybdenum availability. Soil acidification is a process occurring naturally in soils, however, through intensified agriculture acidification accelerates (Troeh and Thompson, 2005). Soil pH is often hypothesized to be a major factor regulating organic matter turnover and inorganic nitrogen production in agricultural soils (Kemmitt at al., 2006).

Average for the study period in the upper soil layer a well-defined differentiation in the values of the indicator was established depending on the type of the studied variants (Table 5).

Table 5. Changes in the values of the soil reaction according to variants of kind of farming (N=9)

Variants	pH - H_2O		pH - KCl	
	0-20	20-40	0-20	20-40
Bio	6,37 c	6,49 c	5,05 c	5,15 b
T_0	6,22 b	6,32 ab	4,90 b	5,01 ab
T_1	6,16 b	6,32 ab	4,92 b	5,08 b
T_2	6,13 b	6,35 bc	4,86 ab	5,08 b
T_3	5,98 a	6,17 a	4,78 a	4,90 a

During the transition to organic production, higher values of the soil reaction were found, approaching as much as possible to slightly acidic/neutral. In the variants of conventional production it was found that in the control and variants with low rates of nitrogen fertilization the values of the soil reaction significantly decreased, and in the variant with annual application of 180 kg N/ha the lowest value of this indicator was reached.

On average for the study period and at a depth of up to 40 cm there is a clear tendency for soil acidification in the variants of conventional agricultural farming (Figure 1).

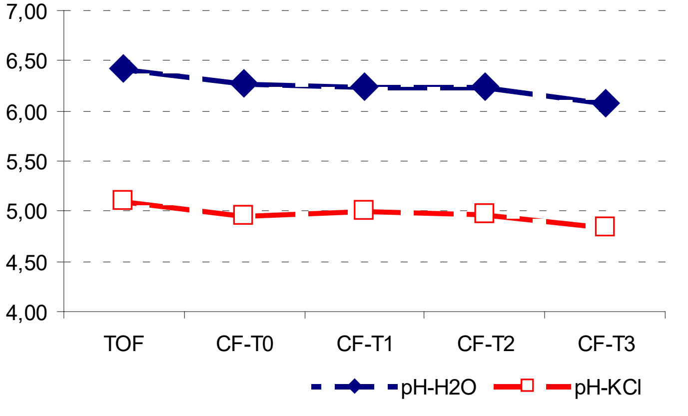

Figure 1. Dynamics in the values of the soil reaction in the layer 0-40 cm depending on the tested variants in transition to organic farming (TOF) and fertilizer variants in conventional farming (CF)

In the research of Nankova et al. (2005) was found that long-term agricultural

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use of slightly leached Chernozems combined with the application of high fertilizer norms, especially unbalances ones, have a negative environmental effect. Soil acidification has been found with annual application of $N_{180}P_0K_0$. The same is expressed in the reduction of the pH values (H_2O) from 1.08 ($N_0P_0K_0$) to 1.3 units compared to the virgin state under grass vegetation. Increasing levels of nitrogen fertilization increase the hydrolytic acidity of the soil, especially in the surface layer, and lead to decrease in the degree of saturation with bases.

Ammonium is the major form of N available to plants under conditions that are unfavorable for the nitrification process (e.g. poor aeration and/or soil acidity). Ammonium cannot accumulate in cell to any great extent without damage to the plant and it is normally converted to amino acids or amides in the root and translocated to the tops in these organic forms (Haynes, 1986).

The predominant form of N available to plants is NO_3^- since under most soil conditions NH_4^+ - N is rapidly nitrified to NO_3^- - N. The utilization of NO_3^- by higher plants involves several processes, including uptake, storage, translocation, reduction and incorporation of N into organic forms. Some species reduce considerable quantities of NO_3^- in their roots where as others translocate most of it to the leaves where it is reduced (Guerrero et al., 1981). The obtained values for the content of the sum of the forms of mineral nitrogen and their variation in the surface layer by years of research is statistically significant (Figure 2).

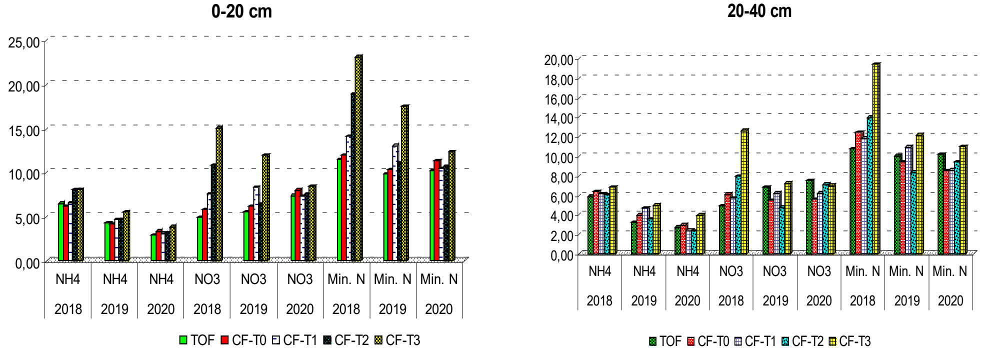

Figure 2. Forms of mineral nitrogen in the transition to organic farming and variants of conventional farming, mg N/1000 g soil

This fact also applies to the dynamics of NH_4 values, while variations in nitrate nitrogen have not been demonstrated. As a result of the mathematical analysis it was found that the studied options: the transition to organic farming and those from conventional, have a greater impact on the values of forms of mineral nitrogen in the soil (46.08%) compared to the years of study (31,14%).

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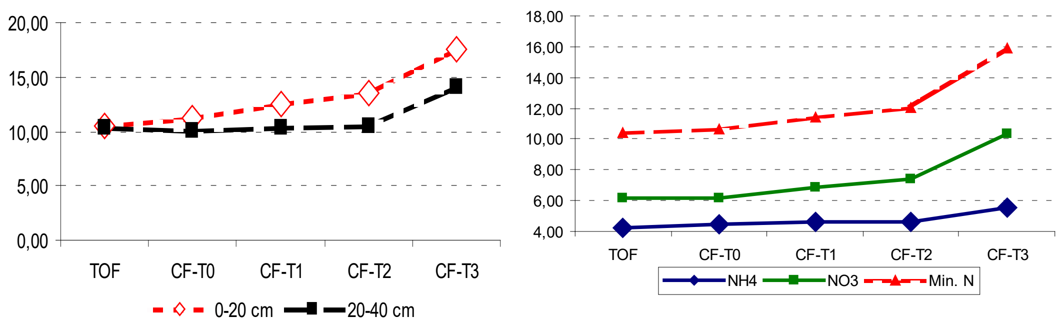
In the deeper layer we find a slight decrease in the values of the forms of mineral nitrogen compared to the layer 0-20 cm. For NO_3-N for this relatively short study period, which characterizes the transition to organic production, the strength of the influence of the two factors, as well as their interaction is unreliable. The meteorological conditions of the years of research increase the strength of the influence of this factor on the values of NH_4-N (88.06%) in the deeper layer. In this layer, it was also found that the *Variant* factor has a statistically insignificant effect on the sum of forms of mineral nitrogen. At the end of the vegetation, on average for three years the total amount of mineral nitrogen in the soil is low and for the layer 0-40 cm varies from 10.38-15.88 mg N/1000 g, (Figure 3). It has been found that over 60% of mineral nitrogen is in nitrate form. In all variants of conventional farming system there is a clear reduction of mineral nitrogen in the underlying layer, while in the transition to organic farming its content is maintained at the level of the surface layer.



By soil layers Average for 0-40 cm layer

Figure 3. Dynamics in the values of mineral nitrogen by layers and on average for the investigated period at a depth of 0-40 cm depending on the tested variants

Over the last 150 years, agricultural activities have strongly altered the global P cycle, mainly by exploiting lithospheric reserves of P ore for application as mineral fertilizer in industrialized agricultural systems (Elser and Bennett, 2013). Phosphorus accumulated in agricultural soils has become an important reserve of P, which has been denoted as P legacy (Sharpley et al., 2013, Haygarth et al., 2014). Significant P legacies can be found in industrialized countries with a long history of high input agriculture based on access to P fertilizers at low cost (Cordell et al., 2009, Mogollron et al., 2018). However, only a small fraction of the P accumulated in soils is actually available for plant nutrition, because P can be strongly bounded to soil particles.

Research on the state of available and total phosphorus in the chernozem soils of Dobrudzha is associated with the long-term application of various agrotechnical practices in scientific experiments and mass agricultural lands in conventional production (Yankov et al., 2004; Yankov and Nankova, 2009; Nankova and Yankov, 2013[a], 2013[b]). These studies include changes in phosphorus concentration along the depth of the profile as well as depending on the size of the soil aggregates (Nankova, 2012; Nankova et al., 2014). In the present study, focused not only on the changes in conventional agricultural production, the changes in the transition to organic farming in 4-field crop rotation were also studied. For the period from 2017-2020 we have established dynamics in the changes of the content of digestible phosphorus depending on the studied variants in the experiment (Table 6).

Table 6. Changes in the content of digestible phosphorus by years of research depending on the options in conventional production and in the transition to organic farming

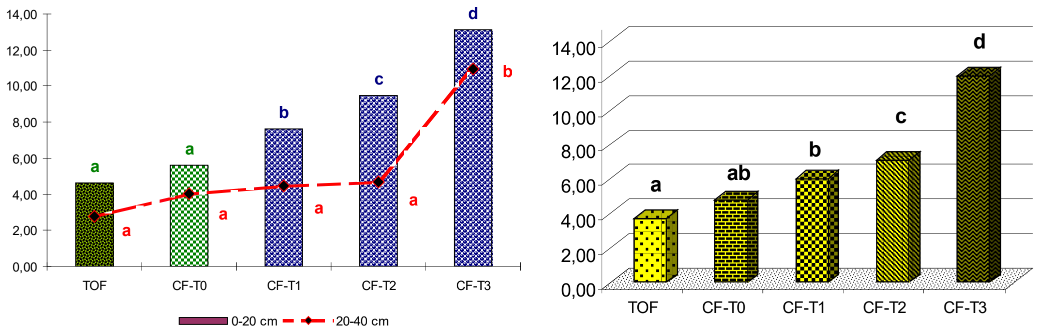
Variants	**Soil depth cm**	Investigated years		
		2018	2019	2020
TOF	0 -20	4,64	4,82	4,51
	20 -40	3,01	2,31	3,02
CF-T0	0 -20	6,12	4,35	6,34
	20 -40	4,53	2,15	5,40
CF-T1	0 -20	10,35	7,20	5,30
	20 -40	6,03	3,99	3,37
CF-T2	0 -20	10,61	7,83	10,07
	20 -40	4,87	3,53	5,61
CF-T3	0 -20	17,76	8,77	12,79
	20 -40	11,09	5,67	16,04

Over the years, the variation in the values of available phosphorus at the studied depths is from 2.31 mg P_2O_5/100 g soil to 17.76 mg P_2O_5/100 g soil depending on the type of variant. As commented above, these changes are statistically significant and the scattering of the trait is large. After the 2018 harvest, both soil layers have a higher content of available phosphorus compared to 2019 and 2020 (Table 7).

Table 7. Influence of meteorological conditions of the years of research on the average content of available phosphorus, mg P_2O_5/100 g soil

Years	Soil depth, cm	
	0-20	20-40
2018	9,90 b	5,91 b
2019	6,60 a	3,53 a
2020	7,80 a	4,86 ab

In both studied soil layers, the variant in transition to organic farming and the control variant of conventional one are characterized by the lowest concentrations of available phosphorus, and the differences between them are statistically insignificant (Figure 4).



By layers Average for depth 0-40 cm

Figure 4. Influence of the tested variants on the available phosphorus content on average for the study period at the studied depths, mg P_2O_5/100 g soil

The Rupp et al. (2018) investigation clearly demonstrated the need for long-term studies evaluating the relation between plant available P in soil and P concentration in leachates to predict the P leaching potential from agriculturally managed soils. farmers should be supported to change their fertilization strategy and to reduce external inputs of P fertilizers to get the top soil P in balance. According to the author farmers should be supported to change their fertilization strategy and to reduce external inputs of P fertilizers to get the top soil P in balance.

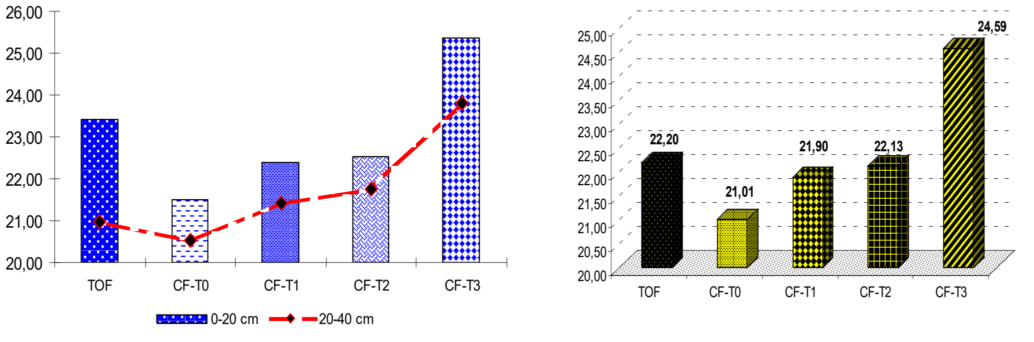
On average, for all variants in the experiment, statistically significant differences were found in the concentration of cation-exchanged potassium by years of study (Table 8). For both studied soil layers with the highest content in the concentration of this indicator is 2019. In the surface layer the concentration of potassium in 2018 and 2020 is insignificant differences, while for the layer 20-40 the differentiation by years is very well expressed.

Table 8. Influence of meteorological conditions of the years of research on the average content of cationexchangeable potassium, mg K_2O/100 g soil

Years	Depth, cm	
	0-20	20-40
2018	21,27 a	18,06 a
2019	25,14 b	25,14 c
2020	22,69 a	21,89 b

As it is known potassium (K) is an essential nutrient for plant growth, but it generally receives less attention than nitrogen (N) and phosphorus (P) in many crop production systems. For some nutrients such as K and P, there are not many differences between management of conventional and organic production, except for some of the allowable nutrient sources. Organic regulations require growers to rely on the use of untreated products for supplying K, where conventional producers have a wider range of materials available to maintain soil fertility and meet crop nutrient demands (Mikkelsen, 2007). At the end of the study, the author points out, that if a need for supplemental K exists, organic producers generally should first consider locally available K resources and supplement with mineral sources.

In our study in the conventional production in the variant with nitrogen fertilization ($N_{180}P_{60}K_{60}$) there is a tendency to enrich the two soil layers not only with available phosphorus, but also with cation-exchanged potassium (Figure 5).



By layers Average for depth 0-40 cm

Figure 5. Influence of the tested variants on the cation-exchanged potassium content on average for the study period at the studied depths, mg K_2O/100 g soil

At the end of the nearly 4-year period from the beginning of the transition to organic farming, it is obvious that in this variant (TOF) the concentration of available potassium is higher than in the control of conventional production, as well as the low and moderate rate of nitrogen fertilization. The differences found, however, are statistically insignificant. Only with systematic intensive nitrogen fertilization does the root layer up to a depth of 40 cm have a significantly higher concentration of exchanged potassium compared to other variants.

Numerous studies were conducted with the changes in soil fertility in long-term agrotechnical experiments as well as with characterization of virgin slightly leached Chernozems (Nankova and Kalinov, 1992; Nankova et al., 2005; Nankova et al., 2010; Nankova et al., 2012; Nankova, 2012; Shishkov et al., 2019; Nankova and Filcheva, 2020). In most of them it was found that a characteristic feature of the slightly leached chernozems of Dobrudzha is their good and very good supply of available potassium.

Studies by a large team from Poland in the area of 55 organic farms located in Warminsko-Mazurskie province show that the content of available phosphorus and mineral nitrogen was very low or low in most of the studied soils, which can lead to disturbance of homeostasis of agroecosystems. Potassium content in these soils was high (Niemiec at al., 2020).

A statistically significant negative correlation was found between the soil reaction and the sum of forms of mineral nitrogen and available phosphorus (Table 9). The values of the correlation coefficients of the studied indicators are differentiated by depth. The total amount of mineral nitrogen is in significantly stronger positive correlations with the content of NO_3-N compared to that of the ammonium form. The same correlates significantly with the soil reaction, as the value of the correlation decreases slightly in depth.

Table 9. Correlation dependences between the tested agrochemical indicators by depth of research

Indices	pH- H_2O	pH - KCl	NO_3 - N	NH_4 - N	Sum Min N	Available P_2O_5	Exengeable K_2O
0-20 cm							
pH- H_2O	1						
pH - KCl	0,851(**)	1					
NO_3 - N	-0,676(**)	-0,510(**)	1				
NH_4 - N	-0,294	-0,172	0,374(*)	1			
Sum Min N	-0,652(**)	-0,474(**)	0,944(**)	0,659(**)	1		
Available P_2O_5	-0,641(**)	-0,627(**)	0,489(**)	0,462(**)	0,561(**)	1	
Exengeable K_2O	-0,078	0,174	0,094	-0,124	0,032	0,084	1
20-40 cm							
pH- H_2O	1						
pH - KCl	0,919(**)	1					
NO_3 - N	-0,368(*)	-0,269	1				
NH_4 - N	-0,476(**)	-0,422(**)	0,316(*)	1			
Sum Min N	-0,498(**)	-0,399(**)	0,896(**)	0,704(**)	1		
Available P_2O_5	-0,763(**)	-0,762(**)	0,527(**)	0,504(**)	0,630(**)	1	
Exengeable K_2O	0,163	0,172	-0,043	-0,349(*)	-0,196	-0,071	1

There is a clear negative correlation between the soil reaction and the content of available phosphorus. This tendency is even more pronounced in the layer of 20-40 cm. The correlation between the content of available phosphorus and the forms of mineral nitrogen, as well as their sum, is positive and statistically significant. This trend is also stronger in the underlying layer. No significant correlations were found between the soil reaction and the potassium digestible content of the plants in both

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soil layers studied. With the exception of its correlation with ammonium nitrogen in layer 20-40 cm, all other studied correlations of potassium are statistically insignificant.

Conclusions

After nearly four years period of transition to organic farming statistically significant differences in soil pH values were found between organic and conventional systems. The transition to organic farming keeps the level of the soil reaction close to neutral without a significant difference between its values in layers 0-20 cm and 20-40 cm. Annual application of nitrogen fertilizaion, especially with 180 kg N/ha lead to the lowest value of this indicator in the depth to 40 cm.

The forms of mineral nitrogen and their total amount are reliably influenced by the meteorological conditions during the years of research. It has been found that over 60% of mineral nitrogen is in nitrate form. In all variants of conventional farming there is a clear reduction of mineral nitrogen in the underlying layer, while in the transition to organic farming its content is maintained at the level of the surface layer.

Over the years, the variation in the values of available phosphorus at the studied depths is from 2.31 mg P_2O_5/100 g soil to 17.76 mg P_2O_5/100 g soil depending on the type of variant. As commented above, these changes are statistically significant and the scattering of the trait is large.

In the conventional farming system, the annual nitrogen fertilization with increasing norms against the background of PK leads to enrichment of the upper part of the root layer with available phosphorus.

At this stage, no statistically significant differences were found in the content of exchanged potassium in the transition to organic farming and the variants of conventional production with lower fertilizer norms. In the variant with annually nitrogen fertilization ($N_{180}P_{60}K_{60}$) there is a tendency to enrich the two soil layers not only with available phosphorus, but also with cation-exchanged potassium.

A statistically significant negative correlation was found between the soil reaction and the sum of forms of mineral nitrogen and available phosphorus. The correlations are positive. Almost all correlations of cation exchange potassium with other indicators are statistically insignificant.

Despite the relatively short period of transition to organic farming, changes in the content of available for plants forms of nitrogen, phosphorus and potassium have been found. This transition period has had a particularly favorable effect on soil acidity.

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