AGROGENE EVOLUTION OF CHERNOZEMS TYPICAL AGROCHEMICAL PARAMETERS

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The main factors of agrogenic evolution of chernozems typical example are revealed on research results in long-term stationary experiments of Slobozhansk Experimental Field and Myronivka Institute of Wheat named after V.M. Remeslo. The direction of change of agrochemical properties of chernozems after newly-ploughed virgin soil or long-term fallow land under the influence of prolonged use of mineral and organic fertilizers is showed.

Key words: *chernozem, virgin land, fallow land, mineral fertilizers, humus fund, nutrient regime.*

Introduction. Development of Soil Science in Ukraine, in particular its Kharkov school is closely linked to an eminent scientist, theorist and practitioner of Agricultural Soil Science Alexei Nikanorovich Sokolowsky and his disciples and followers A.M. Grinchenko, N.K. Krupsky, G.S. Green', A.M. Mozhejko and others. The main direction of Agricultural Soil Science, as understood A.N. Sokolovsky, is to approximate the research results as close as possible to the needs of practical farming. Therefore, simultaneously with the development of this new field of soil science as colloidal soil science, problems of alkaline soils reclamation, colloid-chemical technology of soil properties changes, as well as issues of soil fertility have been extensively studied (A.M. Grinchenko, N.K. Krupsky, G.Ya. Chesnyak, etc.) [1, 2].

Studies of soil fertility led to the investigation of human evolution of soils, including problems of dehumification, decalcification, nutrient regime change against the background of the intensification of agriculture, especially large-scale chemicals application in agriculture in the 80-90s the twentieth century. As a result the theory of cultural soil-forming process has been formulated as one of that new factor. Compilation of data of long-term stationary experiments in former Myronivka Experiment Station, Kharkov Agricultural Institute, NSC "Institute of Soil Science and Agrochemistry Research" conducted primarily on chernozems typical of Forest Steppe of Ukraine, as well as long-term experiments of the former regional experimental stations and comparative studies of soil in preserved virgin sanctuaries (Michaylovskaya virgin soil etc.) with their analogs in agricultural use provided an opportunity to establish the basic laws of evolution of humus content and nutrient status [3-5].

Research Methods. The main long-term experiment is installed in 1969 on the long-term fallow land site (roughly from 1935-1940). The plot is presented by a chernozem typical heavy-loamy with the following indices of soil fertility before the experiment (1969): total humus content 4,8-5,0 %, nitrogen 0,22 %, phosphorus 0,12 %, potassium 2,15 %. Detailed experimental design is published [6].

Soil samples were taken after each rotation cycle. The last term of sampling was in 2008.

Besides that experiment, the results of the analysis of samples taken at long term experiment (since 1912) of Myronivka Institute of Wheat after 18 rotations of five-

field crop rotation on variants with three fertilizer systems: mineral, organic and organo-mineral are used in the investigation.

Discussion of investigation results. Evolution of chernozems' humus profile after newly-plowing of virgin soil or long-term fallow land due to the change of a certain type of steppe vegetation from a closed cycle of organic matter and nutrients, to open one, resulted in a disorder of formed relations of humification and mineralization processes.

Under the influence of agricultural use the biological activity of soils increases, microorganisms enhancing mineralization predominate in microbial cenosis, under their influence labile humus content increases. Processes of intensified mineralization of chernozems' humus fund are not limited by arable layer. Increasing of mobility of organic substances in agrophytocenosis resulted in their partial displacement to subsurface horizon, therefore, in the first 12-15 years after plowing of virgin soil and fallow land there are some signs of stabilization or even a slight increase in its reserves in the subsurface layer on the background of a humus content sharp decrease in the topsoil (Table 1).

1. Dynamics of humus content and humus reserves in chernozem typical heavy-loamy after fallow land plowing on different agrochemical backgrounds (Slobozhansk Experimental Field)

Experiment variant	Layer, cm	Before the experiment		After VI rotation of crop rotation	
		1	2	1	2
Fallow land	0-30	5,0	214	-	-
	30-60	3,9	112	-	-
	0-60	-	326	-	-
Control (yearly plowing without fertilizers)	0-30	-	-	3,9	129
	30-60	-	-	3,3	103
	0-60	-	-	-	232
Manure, 140 t/ha over period of three rotations (background)	0-30	-	-	4,2	156
	30-60	-	-	3,6	117
	0-60	-	-	-	273
Background + 2N2P2K	0-30	-	-	4,5	161
	30-60	-	-	3,4	115
	0-60	-	-	-	276

Note. 1 – humus content, %; 2 – humus reserves, t/ha;
2N2P2K –average annual double dose of mineral fertilizers is 240 kg AD/ha

Intensive mineralization of humus in the plow layer (up to 20 % of the original content) occurs in the first 12-15 years of agricultural use, and then quasi-equilibrium state of humus fund has been settling, the last is further characterized by minor changes in the humus content and reserves.

The main factors determining the dynamics of humus content in arable soils are organic and mineral fertilizers. While organic fertilizers act as a direct source of organic matter income to the soil, and also increase the amount of above-ground and root residues by the crop nutrition improving and enhancement of agro-physical soil properties. Maximum effect in stabilizing and maintaining the level of humus content is achieved for example on the chernozem typical of Steppe zone by applying a double dose of fertilizer for crops in crop rotation on the background of application average dose manure 10-12 tons per hectare.

It should be noted that even in the variants of long experiments in which only organic fertilizers systematically was applied, there is only a slowdown of humus mineralization intensity in comparison with the control, but it levels in the virgin soils and fallow lands is not achieved (Table 2).

The application of higher doses of fertilizers without simultaneous manure using enhances the processes of humus mineralization and increases its mobility.

New plowing of virgin lands or long-term fallow chernozem and its' agricultural using significantly alters the most of humus state indices: the ratio Cgk:Cfk is widening, mobility of humus is increasing and humus is depleting by nitrogen. Thus, the losses of humus in chernozem soils after virgin o fallow lands new plowing resulted in increased mineralization intensity, as well as change the processes of humus formation, humus accumulation and redistribution of organic matter in the soil profile.

2. Humus profile formation of chernozem typicalsandy-loam under the influence of different fertilizer systems (Myronivka Institute of Wheat, data for 90 years)

Variant	Layer, cm	Humus content, %	
		total	labile (Yegorov technique)
Fallow land	0-20	4,7	0,16
	20-40	3,7	0,12
	40-60	3,3	0,07
Plowing without fertilizers (control)	0-20	3,6	0,14
	20-40	3,3	0,06
	40-60	2,4	0,03
Organic fertilizer system	0-20	4,0	0,15
	20-40	3,5	0,08
	40-60	2,6	0,04
Mineral fertilizer system	0-20	3,9	0,22
	20-40	3,3	0,08
	40-60	3,0	0,04
Organic and mineral fertilizer system	0-20	3,9	0,38
	20-40	3,6	0,15
	40-60	2,9	0,04

Physico-chemical properties of chernozems (pH_{KCl}, hydrolytic acidity, amount and composition of exchangeable cations, the depth of the carbonate horizon) are significantly affected by application of moderate doses of fertilizers for a long time or higher doses ones.

Intensification of agriculture resulted in the radical changes of the chernozems topsoil, which is transformed into a new separate horizon, having no analogues in natural soils by the indices. Against the background of biological processes activation the intensive mineralization of organic matter in the topsoil occurs, which causes decreasing of total content of nitrogen and phosphorus - the most important elements of nutrition (Fig. 1). However, mineral nitrogen content increases by the whole of profile on control variant after the fallow land new plowing (comparatively to fallow) even then the nitrogen balance in six crop rotation was negative. It should be noted the nitrogen fertilizers influence on the soil nitrogen mobilization resource, which facilitates to further accumulation of so-called "extra-nitrogen" [7].

Mineral forms of nitrogen (mainly nitrates) forming in the process of organic matter mineralization transports in the soil profile with down flow of precipitation moisture out of the soil profile, i.e. environmental problems become aggravated.

Phosphorus in soils, in contrast to the biogeochemistry of nitrogen, hydrogen, oxygen and sulfur, is the result of biogenic processes only that consist in its biological accumulation due to the transfer from parent rock in the humus profile, and its content in the soil depends on two factors: the phosphorus content in the parent rock and its redistribution in the profile due to biological and soil-forming processes, as well as changes associated with agrogenic exposure [8]. Phosphate mode specific for each type of soil forms under influence of many factors, which is characterized by a certain ratio of mineral and organic phosphates and their fractions.

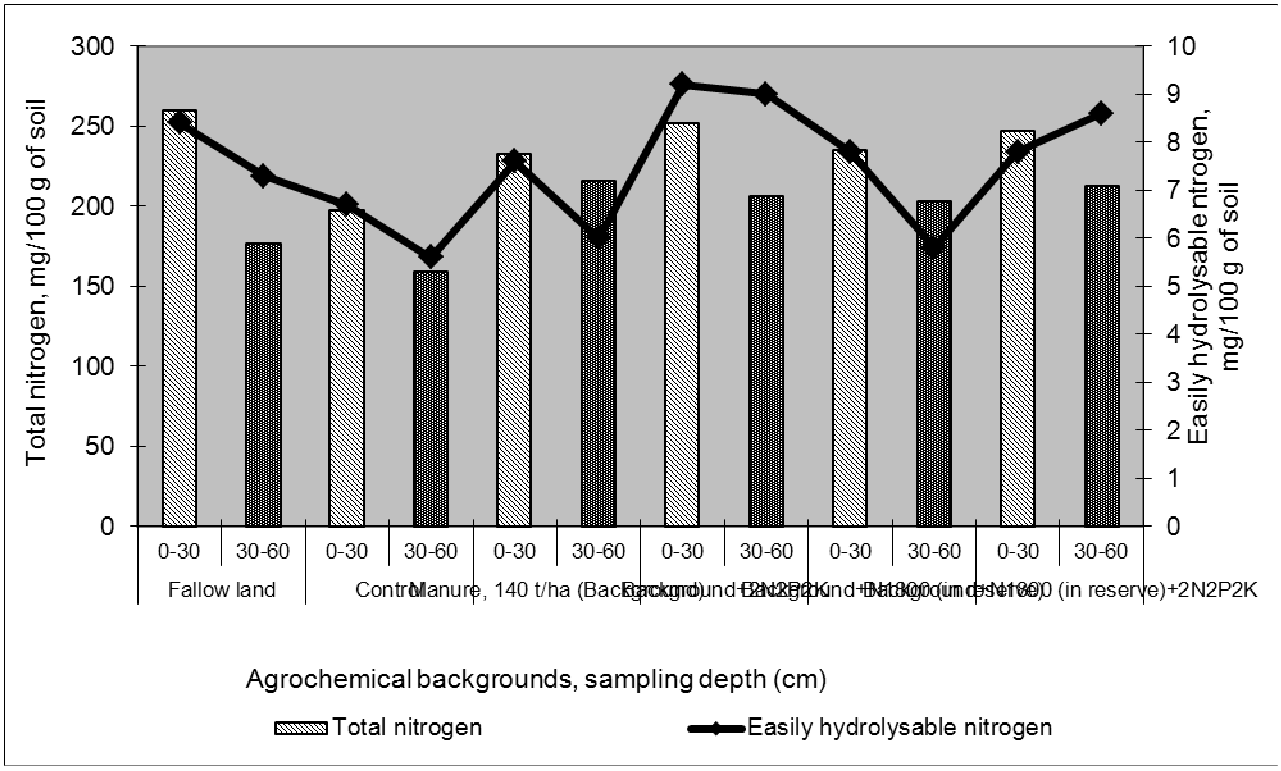


Fig. 1. Influence of agrochemical background on the nitrogen content in chernozem typical

Number of elements included in the cycle significantly change after plowing of virgin soil or fallow land. There is tendency to reduction of total phosphorus in the topsoil when balance of phosphorus in the control variant is negative (Table 3) [9]. A regular increase of this index extending to a depth of 40-60 cm for 18 rotations of five-field crop rotation determined on fertilized backgrounds with its positive balance. Organogenic cultivated phosphate profile is forming which main distinctive features are increasing of mobile phosphates content and the most available to plants phosphates fractions (Table 4).

3. Influence of regular fertilizers application on phosphorus total content in chernozem typical sandy-loam for 18 rotations of five-field crop rotation

Layer, cm	Phosphorus content in variants of experiment, mg P_2O_5/100 g of soil				
	virgin soil	Without fertilizers (control)	Organic fertilizer system	Mineral fertilizer system	Organic and mineral fertilizer system
0-20	134	129	162	167	174
20-40	128	138	159	156	161
40-60	142	140	158	153	156
60-80	133	134	131	135	149
80-100	118	123	123	117	130

It was determined that residual reserves of phosphate fertilizers accumulated in the soil are available for plant nutrition, and most importantly are crystallized very slowly (for decades). On these soils (with residual reserves of phosphorus) the efficiency of nitrogen fertilizers application increases and, conversely, additional yield from phosphorus fertilizers decreases. Processes of the residual phosphates accumulation in soils are determined in long-term stationary experiments, as well as arise from of the generalization of the results of large-scale agrochemical research in all soil-climatic zones of Ukraine.

4. Aftereffect of fertilizers on the phosphate fund structure of chernozem typical heavy-loamy

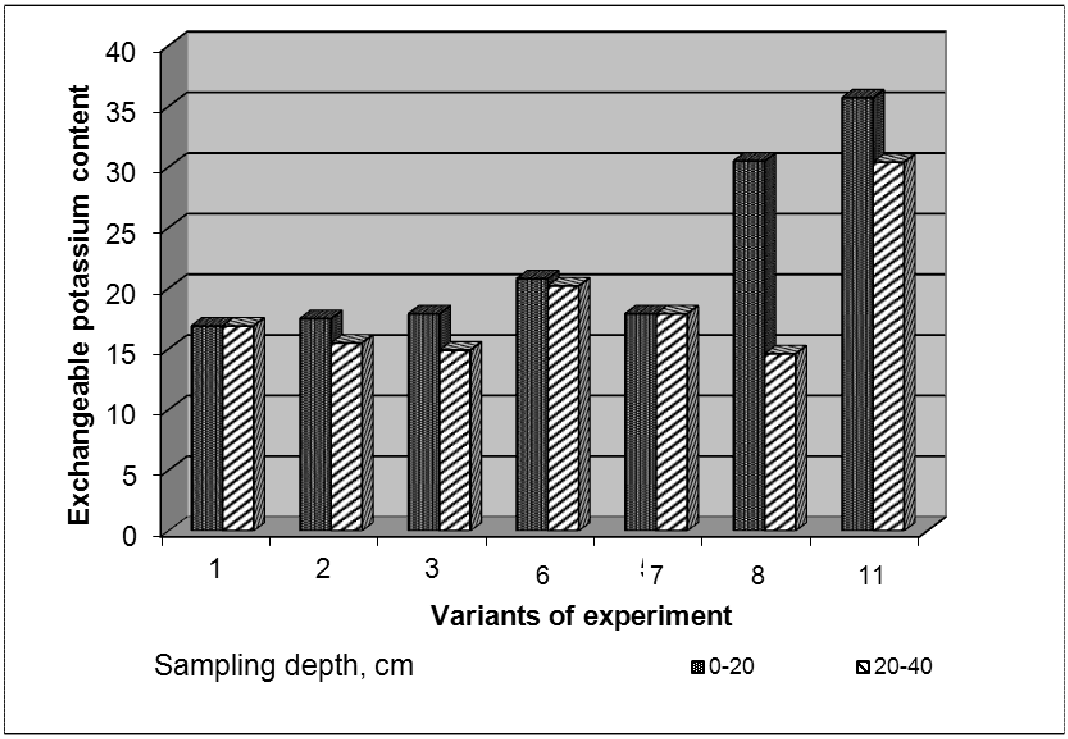
Layer, cm	P_2O_5 content, mg/100 g of soil			Sum of active phosphates	Rate of mobility P_2O_5, mg/l
	total	organic	mobile (by Chirikov)		
Fallow land, more than 75 years					
0-20	125,0	62,2	5,0	35,1	0,06
20-40	113,4	60,0	4,7	26,2	0,03
40-60	107,7	49,1	carbonates	24,4	0,03
60-80	103,9	undefined	carbonates	-	0,03
80-100	99,8	undefined	carbonates	-	0,04
Control (plowing without fertilizers, 30 years)					
0-20	112,0	38,8	4,7	23,7	0,04
20-40	105,0	37,5	4,6	22,7	0,03
40-60	96,3	33,1	carbonates	24,8	0,03
60-80	92,3	32,2	carbonates	-	0,04
80-100	90,6	29,1	carbonates	-	0,03
Manure, 140 t/ha (background)					
0-20	117,1	45,5	5,4	27,5	0,04
20-40	109,3	40,6	5,3	24,0	0,03
40-60	108,4	40,6	carbonates	25,2	0,02
60-80	99,0	undefined	carbonates	-	0,02
80-100	98,8	undefined	carbonates	-	0,02
Background + P_{1800} (in reserve)					
0-20	148,2	55,1	11,7	46,9	0,3
20-40	129,3	54,5	10,7	39,9	0,2
40-60	114,2	48,1	carbonates	27,4	0,05
60-80	106,2	undefined	carbonates	-	0,05
80-100	103,5	undefined	carbonates	-	0,04
Background + P_{1800} + 2N2P2K					
0-20	159,4	undefined	17,3	72,5	0,7
20-40	134,6	undefined	13,6	54,4	0,2
40-60	115,9	undefined	carbonates	32,4	0,2
60-80	101,2	undefined	carbonates	-	0,1
80-100	94,3	undefined	carbonates	-	0,04

Potassium content and its forms in the soil depend on the clay minerals nature and granulometric composition. In the Forest-Steppe and Steppe soil-climatic zones of Ukraine the soils with loamy and clay granulometric composition with a high total potassium content are dominated (1,9 to 2,2 %). Therefore, beliefs about the low efficiency of potassium are prevailed in practice of fertilizers application. Currently, however, due to the sharp change in the structure of sown areas (mainly due to the increase in the share of sunflower) potassium problem acquires a new shape.

Studies suggest that the above-mentioned changes of acid regime, composition of exchangeable cations, a profound restructuring of the mineralogical composition under the influence of fertilizers affect on potassium fund of chernozem.

Plowing of long-term fallow lands causes significant changes in the potassium fund structure, especially it is reflected in the content of mobile forms of potassium, which is decreasing comparably with fallow lands is observed on unfertilized backgrounds (in 1,5 times).

On agrochemical backgrounds with the application of high doses of mineral fertilizers in reserve the substantial changes in the content and ratio of the main forms of potassium in the 25th year of their after-effect is not determined. This indicates that the residual forms of potassium fertilizers have entered in the structure of secondary potassium-containing minerals that are characteristic to chernozem soils. A substantial increase in the content of exchangeable forms of potassium (in 1,8-2,1 times) as a result of systematic application of fertilizers (Fig. 2) was ascertained. However, the accumulated exchangeable potassium have gradually transformed from reducing the content of the soluble fraction to increasing its slightly soluble forms.



Variants of experiment: 1 – Fallow land; 2 – Absolute control; 3 – Manure, 140 kg/ha (background); 6 – Background+ K1800 (in reserve); 7 – Background+$(NPK)_{1800}$ (in reserve); 8 – Background +$(NPK)_{1800}$+$N_1P_1K_1$; 11 – Background+$N_2P_2K_2$ (regularly)

Fig. 2. Changes of exchangeable potassium content in chernozem typical for six rotations of six-field crop rotation, mg/100 g of soil (Slobozhansk Experimental Field)

Conclusions. So significant changes of potential fertility took place under the influence of agriculture intensification in typical chernozems after new plowing of virgin soils and fallow lands that human agricultural activities were considered to be the modern soil formation factor, which is named the cultural soil-forming process. However, generalize data suggest that at this stage of the evolution of agrochemical parameters of arable chernozems typical does not go beyond the parameters characteristic for chernozem soil.

The results showed that long-term agricultural use of chernozems typical after plowing of virgin soil or long-term fallow lands resulted in significant changes in the agrochemical properties of soil and formation its agrogenic profile. Activization of organic matter mineralization processes led to a decrease in humus content, the loss of which over 10-12 years after fallow land plowing in the topsoil reached 20 % compared to the untilled plot.

Chernozems typical in agrocenosis compared to virgin analogs are characterized by changes in phosphate, nitrogen and potassium funds. Particular attention should be paid to the formation of cultivated phosphate fund with the different structure of all fractions of phosphorus in the soil and the presence of long effect, due to its positive balance in previous years.

References

1. Гринченко А.М. Окультуривание почв – основа повышения природно-экономического плодородия. – Харьков, 1984. – 80 с. *(A.M.Grinchenko. Cultivation of the soil is the basis of increasing of natural and economic fertility) (Rus.).*

2. *Гринченко А.М.* Динамика элементов плодородия мощного чернозема в зависимости от длительного сельскохозяйственного использования и внесения удобрений / А.М. *Гринченко, Г.Я. Чесняк, О.А. Чесняк* // Почвоведение. – 1969. – № 5. – С. 27–35. (*A.M.Grinchenko, G.Ya.Chesnyak, O.A.Chesnyak. Dynamics of fertility elements of thick chernozem depending on long-term agricultural using and fertilizers application) (Rus.).*

3. *Носко Б.С.* Минеральные удобрения в системе факторов антропогенной эволюции черноземов / Б.С.Носко // Почвоведение. – 1996. – № 12. – С. 1508–1516. (*B.S. Nosko. Mineral fertilizers in the system of factors of chernozems human evolution) (Rus.).*

4. *Носко Б.С.,* Вплив різних факторів та типів ґрунтових процесів на формування фосфатного фонду ґрунтів / Б.С.Носко, В.І. Бабинін, Є.Ю. Гладкіх, Л.М. Бурлакова // Вісник аграрної науки. – 2010. – № 7. – С. 17–22. (*B.S. Nosko, V.I. Babynin, Ye.Yu. Gladkih, L.M. Burlakova. Influence of different factors and types of soil processes on the formation of soil phosphate fund) (Ukr.).*

5. *Носко Б.С.* Закономерности формирования агрогенного профиля черноземов типичных лесостепи Украины после распашки целины и многолетней залежи / Б.С.Носко // Почвоведение. – 2013. – № 3. – С. 359-371 (*B.S. Nosko. Laws of agrogene profile formation of chernozems typical of Ukraine Steppe after the new plowing of virgin soils and long-term fallows) (Rus.).*

6. *Носко Б.С.* К вопросу об использовании искусственных агрохимических фонов при изучении эффективности удобрений / Б.С.Носко // Агрохимия. 1975. – №6. – С. 76–82 (*B.S. Nosko.* On the use of artificial agrochemical backgrounds in the study of fertilizer efficiency*) (Rus.).*

7. *Семенов В.М.* Образование “экстра-азота” в удобренных почвах и его роль в питании растений / В.М. Семенов // Агрохимия. – 1999. – № 8. – С. 5–12. *(V.M. Senmenov. Formation of "extra-nitrogen" in the fertilized soils and its role in plant nutrition) (Rus.).*

8. *Ковда В.А.* Биогеохимия почвенного покрова. – М.: Наука, 1985. – 260 с. (V.A.Kovda. Soil biogeochemistry*) (Rus.).*

9. *Носко Б.С.* Влияние длительного применения минеральных и органических удобрений на фосфатный фонд чернозема типичного легкосуглинистого / Б.С. Носко, А.И. Шевченко, В.И. Бабынин, Л.Н. Бурлакова // Агрохимия. – 2008. – N 9. – С. 23-28 . (*B.S. Nosko, V.I. Babynin, A.I. Shevchenko, L.M. Burlakova.* Influence of long-term application of mineral and organic fertilizers on phosphate fund of chernozem typical sandy-loamy*) (Rus.).*

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