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ESTIMATION OF POTENTIAL ABILITY OF PODZOLIZED BLACK SOIL TO AGGREGATION UNDER THE CONDITIONS OF LONG-TERM USAGE OF FERTILIZERS IN FIELD CROP ROTATION

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The influence of fertilizer systems on podzolized black soil ability on aggregation during a long-term stationary experiment is determined. With increasing rates of mineral fertilizers the soil aggregation processes become worse and it shows a positive effect of organic and organic-mineral fertilizing systems of crops on forming its structure.

Powerful peculiar factor of soil fertility is macro- and microstructure, which determines the level of all its agro-physical properties: solidity of compilation, peculiarities of soil water regime, gas exchange processes, soil air composition and also living conditions of soil biota. In addition, macro- and microstructure are closely connected with nutrient regime, which defines the level of soil fertility and productivity of the agricultural crops. The structural soil consistence depends on the fertilizer system in crop rotation. Positive role of organic fertilizers in the formation of agronomically valuable structure is practically assured. There are some contradictions speaking about mineral fertilizers especially physiologically acidic. I. Hodunov and others [1], D.I. Nazarova and others [2] L.I. Martynovych [3] consider that mineral fertilizers even with higher rates do not significantly affect the structural soil consistence. According to the data of M.V. Hnivenko [4], M.I. Horkun [5] structural and aggregate consistence of the soil deteriorates with the increasing of fertilizers rates.

The aim of our study was to determine the potential ability of podzolized black soil to aggregation during long-term usage of mineral, organic and organic-mineral fertilizer systems in field crop rotation.

Methodology of the Research. The researches were conducted during a long-term stationary experiment (since 1964) of the Department of Chemistry and Soil Science of Uman National University of Horticulture on podzolized heavy-loamy black soil. The basis of the experiment is 10-course field crop rotation, deployed in time and space with mineral, organic and organic-mineral fertilizer systems. Fertilizers are applied in single, double and triple saturation levels of rotation with plant food elements. A single rate of mineral fertilizers is $N_{45}P_{45}K_{45}$, organic – 9 t/ha of manure and organic-mineral system as for single rate – 4.5 t/ha of manure + $N_{22}P_{34}K_{18}$.

Experiments were carried out at the field crop rotation link: pea after maize for grain – winter wheat – silage for corn. Fertilizers were applied under pea at the rate of variants in mineral system $N_{10}P_{10}K_{10}$, $N_{30}P_{30}K_{30}$ and $N_{60}P_{60}K_{60}$; for winter wheat – $N_{45}P_{45}K_{45}$, $N_{90}P_{90}K_{90}$ and $N_{135}P_{135}K_{135}$, and for silage corn – $N_{50}P_{50}K_{50}$, $N_{100}P_{100}K_{100}$

and $N_{200}P_{200}K_{200}$; organic fertilizers were applied under sugar beet which was a forecrop before pea and under silage corn using 40, 45, 60 t/ha. According to organic-mineral system such mineral fertilizer was applied under pea as $P_{10}K_{10}$, under winter wheat – $N_{22,5}P_{22,5}K_{22,5}$, under silage corn – $N_{22,5}P_{50}$, manure was used in the amount of 15 t/ha for the same crops as in organic systems. Soil samples for analysis were selected among sowing crops which were planted 45 years ago at the beginning of the experiment.

Although there are different points of view about fertilizers participation in the soil aggregation, we performed comparative analysis and calculations by different methods for greater reliability of the research results. In particular, soil dispersion was determined due to the method of N.A. Kachynskyy [6], coefficient of structuring was calculated with the help of Faheler [7] method, field aggregator level by Beiver and Roades [7] method, coefficient of micro aggregation by V.N.Dymo [8] method, grain-size index by A.F. Vadyunyna [7] method.

The results of the research. Based on our data of grain-size and micro-aggregative distribution of podzolized black soil, on the terms proposed by different researchers we conducted a comprehensive assessment of the effects of long-term usage of different systems and fertilization levels in crop rotation on the level of soil structure formation and its ability to aggregate.

A way to assess the potential soil ability to aggregation proposed by N.A. Kachynskyy became the most frequently used. It is based on the supposition that the microstructure is formed entirely by the smallest fraction – silt, the particles of <0.001 mm, so the nature of the aggregation processes is estimated only by characteristics of particles consistency of a given size. The index which was received with this method is a factor of dispersion. We can judge about the substantiality of micro aggregates and soil structure as a whole using this index. The higher is the level of the index, the less strong is the microstructure, and thus its potential ability to aggregate is also low.

Usage of mineral fertilizer system and growing crops in rotation with no fertilizer promoted increasing of dispersion rate in soil layer of 0-30 cm (Table 1).

Organic and organic-mineral fertilizer systems with different levels of fertilizers saturation provided a lower level of dispersion factor compared to the methods with no fertilizers and with mineral fertilizer system. Thus, organic fertilizers contribute stability forming of disperse system and, consequently, better micro-aggregation.

Regardless of fertilizing system the highest dispersion factor is in the top soil of 10 – cm that indicates a lower potential ability of microstructure to aggregate. It gradually decreases with the depth and reaches minimum in the subsoil layer of 30-40 cm.

Inverted value of soil dispersion is its structural factor determined by Faheler method. Its value increases along with the size of micro-aggregates water resistance and describes potential ability of soil to structuring.

It was found in the result of the calculations that the long-term usage of mineral fertilizers in crop rotation and cultivation without these fertilizers causes reduction of structuring factor compared with the options where organic fertilizers were used (Table 2).

1. Dispersion coefficient of podzolized black soil during a long-term usage of fertilizers in crop rotation, %

Research variant	Soil layer, cm			
	0–10	10–20	20–30	30–40
Without fertilizer	21,04	20,71	19,90	9,99
$N_{45}P_{45}K_{45}$	24,42	24,37	23,30	12,27
$N_{135}P_{135}K_{135}$	34,19	46,84	40,82	16,11
Manure 9 t	18,49	13,58	17,33	11,76
Manure 18 t	8,66	7,04	7,11	6,55
Manure 4,5 t + $N_{22}P_{34}K_{18}$	20,31	21,06	26,33	21,20
Manure 13,5 t+ $N_{67}P_{102}K_{54}$	12,21	10,70	12,35	8,19
HIP_{05}	*2,4*	*2,8*	*1,6*	*1,0*

Increasing the level of fertilizers saturation to the level of $N_{135}P_{135}K_{135}$ causes reduction of this index in 1,1-1,4 times in the soil layer of 0-30 cm. Negative effect of a long-term usage of high doses of fertilizers in the subsoil is hardly evident, structuring factor depending on the saturation fertilizer level was within 87,73-83,89%. The above data indicate reduction of the stability of the microstructure during a long-term usage of mineral fertilizer system and crops cultivation without any fertilizer.

2. Coefficient of podzolized black soil structuring during a long-term usage of fertilizers in crop rotation, %

Research variant	Soil layer, cm			
	0–10	10–20	20–30	30–40
Without fertilizer	50,37	47,47	59,18	66,37
$N_{45}P_{45}K_{45}$	51,03	50,74	51,81	62,30
$N_{135}P_{135}K_{135}$	47,55	40,53	33,45	62,88
Manure 9 t	59,07	62,07	61,72	65,19
Manure 18 t	66,93	68,77	68,24	65,90
Manure 4,5 t + $N_{22}P_{34}K_{18}$	53,76	54,93	56,31	60,47
Manure 13,5 t +$N_{67}P_{102}K_{54}$	64,12	66,76	67,89	70,52
HIP_{05}	*3,9*	*3,8*	*3,6*	*4,6*

A long-term usage of organic fertilizer system in crop rotation promotes soil forming with high potential ability to aggregation. Thus, during the saturation of crop rotation area with organic fertilizers of 9 t/ha structuring in the ploughing layer was higher than in non-fertilized variants and with applied mineral fertilization system in accordance 1,03-1,1 and 1,1-1,5 times. Increasing the level of organic fertilizers usage in crop rotation to 18 t/ha contributed to the growth of potential ability of

podzolized black soil to aggregation. Thus, the index in the ploughing layer of 0-30 cm higher in 1,2-1,7 times than the variants with mineral system and options where fertilizers were not applied – in 1,2 times.

The positive effect of organic fertilizers on the ability of the studied soil to aggregation is shown in their combined application with mineral fertilizers. However, the level of this index in these variants is somewhat lower compared with organic fertilizer system, especially speaking about the variant with 4,5 tons of manure + $N_{22}P_{34}K_{18}$, where results in the layer of 0-30 cm are at non-fertilized level and variants with mineral fertilizer system. Increasing of fertilizer saturation in rotation according to this system to the level of 13,5 tons of manure + $N_{67}P_{102}K_{54}$ provided increasing of structuring value to the levels of organic fertilizer system.

Aggregation level offered by Beiver and Roades foresees the assessment of the potential ability of the soil to aggregate due to the ratio of actual water-resistant micro-aggregates larger than 0,05 mm, without grain size elements of the same size to the total number of micro-aggregates of > 0,05 mm in size. With this indicator you can judge about the quantitative characterization of the microstructure and its water resistance, the ability to aggregate increases with the water resistance growth.

Data from Table 3 show that the fertilization of agricultural crops in the rotation significantly affects the degree of soil aggregation and the nature of the effect on this rate of fertilization, were observed similar tendencies as in the above mentioned parameters.

According to some authors an objective absolute indicator of assessment of soil microstructure could serve a micro-aggregation coefficient offered by V.M. Dimo. Evaluation of microstructure after this method takes into consideration the absolute amount of content and water-resistant aggregates from 0,01 to 0,25 mm in size.

Analyzing the data in Table 4, it should be noted that the growth of micro-aggregation coefficient in variants with organic and organic-mineral fertilizer systems indicates the crucial role of organic fertilizers as ameliorant in forming of optimal agro-physical soil properties and processes of micro-aggregation particular.

3. Degree of aggregation of podzolized black soil during a long-term fertilizer application

Research variant	Soil layer, cm			
	0–10	10–20	20–30	30–40
Without fertilizer	49,39	57,02	77,85	82,35
$N_{45}P_{45}K_{45}$	47,84	55,58	76,41	83,77
$N_{135}P_{135}K_{135}$	42,14	50,93	73,30	82,16
Manure 9 t	55,86	68,17	82,83	89,44
Manure 18 t	84,87	93,50	94,88	96,64
Manure 4,5 t + $N_{22}P_{34}K_{18}$	52,23	62,58	70,92	83,51
Manure 13,5 t+ $N_{67}P_{102}K_{54}$	73,82	80,23	87,28	98,10
HIP_{05}	*4,4*	*5,1*	*5,9*	*6,3*

4. Micro-aggregation coefficient of podzolized black soil during a long-term usage of fertilizers in crop rotation

Research variant	Soil layer, cm			
	0–10	10–20	20–30	30–40
Without fertilizer	49,39	57,02	77,85	82,35
$N_{45}P_{45}K_{45}$	47,84	55,58	76,41	83,77
$N_{135}P_{135}K_{135}$	42,14	50,93	73,30	82,16
Manure 9 t	55,86	68,17	82,83	89,44
Manure 18 t	84,87	93,50	94,88	96,64
Manure 4,5 t + $N_{22}P_{34}K_{18}$	52,23	62,58	70,92	83,51
Manure 13,5 t+ $N_{67}P_{102}K_{54}$	73,82	80,23	87,28	98,10
HIP_{05}	*4,4*	*5,1*	*5,9*	*6,3*

The positive effect of manure in maintaining the potential ability of the soil to the formation of microstructure is also confirmed by the increasing level of grain-size index of structuring, calculated by the method of A.F. Vadyunyna who offered the formula for calculating this index as a result of a grain-size analysis. Thus mechanical elements can be divided into active, which have cementing properties and can be involved in coagulation and passive elements implicated in structure formation. So grain-size structuring index for black soil is determined by the ratio of the sum of interest amount of silt and fine dust to medium and large dust. Using only fertilizer in rotation as at a low level – $N_{45}P_{45}K_{45}$, and at a high level – $N_{135}P_{135}K_{135}$ and also crop cultivation with no fertilizers show reduction of this index in the top soil layers of 0-10 and 10-20 cm respectively in 1,3 -1,6 and 1,3-1,4 times in comparison with the corresponding figures for organic and organic-mineral systems (Table 5).

5. Grain-size index of podzolized black soil structuring during a long-term usage of fertilizers in crop rotation, %

Research variant	Soil layer, cm			
	0–10	10–20	20–30	30–40
Without fertilizer	49,39	57,02	77,85	82,35
$N_{45}P_{45}K_{45}$	47,84	55,58	76,41	83,77
$N_{135}P_{135}K_{135}$	42,14	50,93	73,30	82,16
Manure 9 t	55,86	68,17	82,83	89,44
Manure 18 т	84,87	93,50	94,88	96,64
Manure 4,5 t + $N_{22}P_{34}K_{18}$	52,23	62,58	70,92	83,51
Manure 13,5 t+ $N_{67}P_{102}K_{54}$	73,82	80,23	87,28	98,10
$HIP_{0,5}$	4,4	5,1	5,9	6,3

Organic fertilizers in a rate of 18t/ha of crop rotation area increase grain-size structuring index in 1,7 times against the variant without any fertilizers and twice against mineral system in a rate of $N_{135}P_{135}K_{135}$.

Against the background of organic-mineral systems the positive effect on structural condition of the soil significantly increases which was determined by this method at their maximum rate of 13.5 t/ha of manure $N_{67}P_{102}K_{54}$. The influence of fertilization on grain-size structuring index moving into the subsurface layer is somewhat reduced but it still remains significant at the variants with the highest rates of fertilizers and on the depth of 30 – 40 cm.

Conclusion. Determination with different methods of the potential ability of podzolized black soil to aggregation during a long-term usage of fertilizers in crop rotation makes it possible to generalize the findings.

Mineral fertilizers in comparison with non-fertilized variant reduce the structuring coefficient of the soil, micro-aggregation coefficient and grain-size structuring index. Aggregation degree as index using mineral fertilizers even three times, remains within insignificant difference.

Applying of organic fertilizers improves soil aggregation. Moreover, with increasing the rates of these fertilizers their positive effect on structural consistence of the soil increases substantially.

Combination of organic and mineral fertilizers for their positive effects on aggregation of podzolized black soil is almost equal to the organic fertilizer systems.

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Оценка потенциальной способности чернозема оподзоленного к агрегации при длительном применении удобрений в полевом севообороте

В полевом долгосрочном (с 1964 г) стационарном опыте кафедры агрохимии и почвоведение Уманского НУС изучалось различными методами влияние минеральных, органических и органо-минеральных систем удобрения на формирование микроструктуры чернозема оподзоленного. Удобрения вносились на трех уровнях: одинарная норма минеральных удобрений – $N_{45}P_{45}K_{45,}$ органических – 4,5 т/га навоза и органо-минеральная – навоза 4,5 т/га +$N_{22}P_{34}K_{18}$. Исследование проводилось в звене полевого севооборота: горох– пшеница озимая — кукуруза на силос с внесением под горох в минеральной системе $N_{10}P_{10}K_{10}$, $N_{30}P_{30}K_{30}$, $N_{60}P_{60}K_{60}$; под пшеницу озимую соответственно $N_{45}P_{45}K_{45}$, $N_{90}P_{90}K_{90}$, $N_{200}P_{200}$ K_{200}, навоз вносили подпредшественник гороха сахарную свеклу и под кукурузу на силос соответственно 40, 45 и 60 т/га.

Минеральные удобрения снижают коэффициенты структурности и агрегации, а также гранулометрический показатель структурности почвы, а степень агрегатности даже при тройной норме минеральных туков остается в пределах несущественной разницы.

Органические удобрения способствуют существенному улучшению агрегатности почвы. Органо-минеральные системы удобрения, особенно при тройном их сочетании, по своему положительному влиянию на агрегацию чернозема оподзоленного не уступают органическим системам.

***Ключевые слова**: системы удобрения,чорнозем оподзоленный, агрегация, коэффициент микроагрегации, коэффициент дисперсности, степень агрегации.*

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Evaluation of potential capacity of podzolized black soil to aggregation in durable application of fertilizers in field rotation

In the long-term (since 1964) permanent field experiment of the Department of Agrochemistry and Soil Science of Uman National University of Horticulture the influence of mineral, organic and organo-mineral fertilizer systems on the formation of microstructure of the podzolized black soil has been researched with the help of different methods. The fertilizers were applied on three levels: single rate of mineral fertilizers — $N_{45}P_{45}K_{45}$, organic — 4,5t/ha of manure and organo-mineral-of manure 4,5t/ha + $N_{22}P_{34}K_{18}$. The research was carried out in the field rotation link: peas - winter wheat - silage maize with the application of mineral system $N_{10}P_{10}K_{10}$, $N_{30}P_{30}K_{30}$, $N_{60}P_{60}K_{60}$ under peas; under winter wheat respectively $N_{45}P_{45}K_{45}$, $N_{90}P_{90}K_{90}$, $N_{200}P_{200}K_{200}$, manure was applied under sugar beets which were peas predecessor and under silage maize respectively 40,45 and 60 t/ha.

Mineral fertilizers reduce the coefficients of soil pedality and micro-aggregation as well as the granulometric index of soil pedality but the aggregation level even at the triple rate of solid mineral fertilizers remains within the non-significant difference.

Organic fertilizers facilitate the essential improvement of soil aggregation.

Organic-mineral fertilizer systems, especially in their triple combination, are not worse than organic systems in terms of their positive effect on the black soil aggregation.

***Key words**: fertilizer systems, podzolized black soil, aggregation, micro-aggregation coefficient, dispersion coefficient, aggregation degree.*