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FORMATION OF STRUCTURAL-AGGREGATE COMPOSITION AND WATER-PHYSICAL PROPERTIES OF GRAY FOREST SOIL DEPENDING ON MINERAL FERTILIZERS AND LONG-TERM EFFECT OF LIME

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Abstract. *The article presents the research data of structural-aggregate composition, water-physical constants and density of compilation gray forest coarse-dust–light-loam soil for the systematic use of mineral fertilizers and long-term action (8 th - 10 th year) of chemical melioration. The influence of the long action of a single dose of lime on hydrolytic acidity on the transformation parameters of soil properties was established. The presented results of the use* $CaCO^3$ *(1,0 Нг), testify to an increase in the quantities of agronomically valuable part of the soil in 3.5 %. At the same time, the volume of adsorbed water by the soil increased and keeping it in the capillary and general space.*

The shown influence of the systematic use of physiologically acidic mineral fertilizers on the agrophysical and water-physical properties of gray forest soil. Adding $N_{50}P_{30}K_{55}$ *led to increased content of dust fraction of soil and reduce its filtration capacity, which is bad for the soil properties.*

The use of a single and a double dose of mineral fertilizers intensified the peptization of soil aggregates. Due to this, increased the amount of finely-dispersed parts, which is sedimented and accumulated in the lower layers of the soil. As a result, the filtration ability of the soil and absorbing its properties deteriorated, and the density of the composition during vegetation increased.

Keywords: *structural aggregate composition, density of compaction, capillary moisture capacity, total moisture capacity, water-permeability*

The periodically flushing type of water regime, which is genetically formed on acidic gray forest soil, leads to deterioration of its properties due to the physical accumulation and sedimentation of small particles of dust in the soil pores.

Silting the soil pores leads to changes in such parameters of its physical structure, as the density of compaction, total porosity, the ratio of capillary porosity to non-capillary [5].

As result of this, changing the parameters of water and soil physical constants, that is total moisture (TM), the smallest and capillary (CM), indicators of the moisture gap of capillary bond, stable fading, maximum hygroscopicity. The listed indicators reflect both the quantitative degree of soil moisture and qualitative characteristics of water concerning its mobility and access to plants: readily accessible, accessible, inaccessible, unproductive and inaccessible [7].

An important property of the soil is permeability - the ability to absorb and skip water of atmospheric precipitation. The level of permeability depends on the mechanical composition, structure, content of organic matter, water resistance of soil aggregates and their compaction, moisture and the composition of exchange-absorbed cations of the soil complex [12].

Absorption by soil is determined by the presence in the arable layer of water-resistant aggregates larger than 1 mm in size, which have a high intergranular porosity. The water-permeability of the soil directly depends on the content of humus and calcium, since these components contribute to the formation of water-resistant aggregates. Single-valence cations cause dispersion of soil colloids, destroy its structure of aggregates and reduce water-permeability [2].

At the same time, the deterioration agro-physical indicators of the soil separately, and the water-physical constants, appear less to a degree compared to agrochemical indicators. In addition, the arrival of calcium carbonate in the soil, due to liming, in our opinion, can significantly affect its agro-physical, physical and water-physical properties [10]. Changes in physical indicator of soil due to chemical melioration may be due to changes in the processes of structure formation due to the saturation of the soil complex with calcium ions, and the assistance of accumulation of sodium ions, magnesium, iron, etc. [9]. However, the deterioration of the soil structural-aggregate state of North-Western Precarpathians occurs due to the reduction content of agronomically valuable aggregates to 35-45 %, and water-resistant to 20-30 % [6].

The soil structure is considered as the physical structure of the soil substance, conditioned of its size, shape, quantitative ratio, the nature of the relationship and the location of elementary soil parts, also aggregates that are composed of them [13]. The physical state of the soil is practically completely determined by the state of the soil structure. The soil structure should be understood as the dimensional discrete distribution of soil phase components: solid, liquid and gaseous, which in turn determines the structure of pore space of the soil [1].

Analysis of literary sources, recently published, testifies of less interest in agronomic physics to the soil of light granulometric composition [11]. Such soils are characterized by low intensity of processes associated with the phenomena on the surface of components of disperse systems, the absence of the ability to form an agronomically valuable structure [4, 3].

The purpose of the research was to determine the impact of the prolonged use of mineral fertilizers and liming on the indicators of the agrophysical and water-physical properties of gray forest soil.

Research methodology. The research were conducted during 2013-2015 years at the NSC "Institute of Agriculture of NAAS" in a stationary experiment of the Department Pedology, founded in 1992 and held in 3 fields of seven cultures crop rotation, in the soybean - spring wheat - buckwheat. The capillary and total moisture content were determined by the method saturation of cylinders (500 cm^3) with undisturbed structure, soil permeability in the field - Nesteryova (PVN-00), soil density - by the method of the cutting ring N.A. Kachinskiy DSTU ISO 11272-2001, structural and aggregate composition – sieve by method in the modification of N.I. Savvinov in accordance with DSTU 4744: 2007. The liming of the soil was carried out at the end of the 2^{nd} crop rotation (2005).

Results of the research and their discussion. The using of gray forest soil in agricultural production, without the applying of any fertilizer, led to degradation processes. Reducing the percentage content of finely-dispersed of the soil and the content of nutrients, especially calcium and magnesium cations, occurs as a result sedimentation of soil cleaners and accumulation in soil pores and capillaries of aggregates, which which causes the transformation of agrophysical and water-physical properties of the soil. The structural-aggregate composition of the soil in the variant without fertilizers was characterized primarily by high content percentage of microaggregate part (<0.25 mm) and was 25.3-26.0 %. It should be noted that the higher percent content of macro aggregates also in this variant is fixed in a fraction of 5.0-3.0 mm (Table 1). Due to the destruction structure of the arable layer, for the tillage, the density of compaction decreases. Although, the subsequent process of shrinkage during the period of vegetation compacted soil at the expense of its shredded structure. The average density of soil compaction for the year was 1.4 g/cm^3. The coefficient of structurality in the variant of non-fertilizers during the research period was the smallest among other variants and fluctuated within 1.02-1.05. However, indicators of water-physical properties fluctuated within of 27,5-30,1 % of TM and 22,2-24,3 % of CM.

Mineral fertilizers used in the fertilizer system, for the purpose in order to plants with easily accessible nutrient elements, had a physiologically sour nature. Getting into the soil physiologically acidic types of mineral fertilizers increase the content of hydrogen ions in the soil solution, which increases the acidity of the soil [8]. Besides, the ion bond is weakening, which is followed by decreasing the coefficient of water-resistance of the aggregates and increasing the structure's crumbling for less of their abolition. That is, the peptization process intensifies and as a consequence increases amount not involved in aggregation finely-dispersed part of the soil. Accordingly, there is a transformation of the agrophysical and water-physical properties of gray forest soils. The coefficient of structurality in the variant where the used full doses of mineral fertilizers ranged from 1,03 to 1,06. Thus, there was observed the highest percentage of aggregates under soybean and wheat crops in the fraction <0.25 mm (Table 1).

The density of gray forest soil compaction for the systematic use of a single dose of mineral fertilizers was at the level of the value a variant non-fertilizers and during the research period was at 1.42 g/cm^3. It should be noted that the initial stages of plant growth and development, the used of mineral fertilizers contributed to a decrease the density of soil compaction of 0.01-0.04 g/cm^3, and at the end of vegetation, the indicator was equal to the value of the variant non-fertilizers. Besides, the absorption and holding capacity of the soil was at the level of 21.9-24.2 % of CM, and 27.5-30.8 % of the TM. Although, the data on the permeability of gray forest soils in variant 3 were the smallest and the average annual value of it was 1.9 % smaller relative to the non-fertilizer variant. In our opinion, this is caused by the accumulation of finely-dispersed in the capillaries of the soil as a result of their colmatation. At the same time, the content of capillary moisture in the gray left soil decreased for the 2nd and 3rd years of the study, which was lower than in the non-fertilized variant (Table 2). Sedimentation and accumulation of finely-dispersed particles in the lower layers of the soil, caused by a much denser compaction, which reduced the pore volume and filtration capacity of the soil.

1. Structural-aggregate composition of the arable layer (0-20 cm) of gray forest soil for the influence of mineral fertilizers and the long-lasting effect of lime.

Variant	Content fractions of macro-aggregates,% in diameter, mm										Separation is less than 0.25 mm	The sum of macro aggregates is more than 10,0 mm and the separation are less than 0,25 mm	Coefficient of Structural Cstr.
	more than 10.0	10,0-7,0	7,0-5,0	5,0-3,0	3,0-2,0	2,0-1,0	1,0-0,5	0,5-0,25	more than 0.25	from 10.0 to 0.25			
8th year of lime activity (Soybean, 2013)													
1. Without fertilizer (control)	23,8	4,53	3,41	13,7	6,72	7,50	7,86	6,93	74,4	50,6	25,6	49,4	1,03
2. $CaCO_3$ (1.0 Hr)	26,7	6,72	4,71	11,2	9,58	5,24	9,59	7,05	80,8	54,1	19,2	45,9	1,18
3. NPK	23,2	5,58	4,13	12,1	8,61	6,05	7,67	6,91	74,2	51,0	25,8	49,0	1,04
4. NPK + $CaCO_3$ (1.0 Hr)	24,6	7,43	5,00	12,7	9,89	5,68	8,04	7,44	80,9	56,2	19,1	43,8	1,28
19. 2NPK + $CaCO_3$ (1,0 Hг)	29,2	6,60	6,46	12,0	9,25	6,82	7,59	6,67	84,5	55,4	15,5	44,6	1,24
9th year of lime activity (Wheat spring, 2014)													
1. Without fertilizer (control)	23,6	4,54	3,59	13,7	6,81	7,64	7,94	6,97	74,7	51,2	25,3	48,8	1,05
2. $CaCO_3$ (1.0 Hr)	26,5	6,78	4,86	11,3	9,62	5,32	9,58	7,06	81,0	54,5	19,0	45,5	1,20
3. NPK	22,9	5,69	4,26	12,1	8,61	6,10	7,70	7,01	74,4	51,5	25,6	48,5	1,06
4. NPK + $CaCO_3$ (1.0 Hr)	24,5	7,44	5,03	12,7	9,94	5,75	8,10	7,41	80,9	56,4	19,1	43,6	1,29
19. 2NPK + $CaCO_3$ (1,0 Hг)	29,0	6,61	6,47	11,9	9,25	6,88	7,64	6,73	84,5	55,5	15,5	44,5	1,25
10th year of lime activity (Buckwheat, 2015)													
1. Without fertilizer (control)	23,6	4,45	3,32	13,7	6,64	7,45	7,83	7,05	74,0	50,4	26,0	49,6	1,02
2. $CaCO_3$ (1.0 Hr)	26,6	6,70	4,82	11,2	9,56	5,24	9,59	7,05	80,8	54,2	19,2	45,8	1,18
3. NPK	23,3	5,53	4,09	12,0	8,57	5,98	7,63	6,91	74,1	50,7	25,9	49,3	1,03
4. NPK + $CaCO_3$ (1.0 Hr)	24,6	7,41	5,03	12,7	9,87	5,75	8,02	7,42	80,8	56,2	19,2	43,8	1,28
19. 2NPK + $CaCO_3$ (1,0 Hг)	29,3	6,56	6,41	11,9	9,23	6,77	7,55	6,60	84,3	55,1	15,7	44,9	1,22

The obtained indicators of agrophysical, water-physical and physical-chemical properties of gray forest soil (var. 2) testify to the saturation of the absorbing complex with cations of alkaline earth metals is important for the aggregation of structural separately. At the same time, the coefficient of structurality was higher than in the variant of non-fertilized and fluctuated within 1.18-1.20. The application of a single dose of lime by hydrolytic acidity contributed to a uniform increase in the percentage content of an agronomically valuable (10-0,25 mm) part of the soil (Table 1). The aggregation of soil particles in the variant where $CaCO_3$ (1.0 Hr) was introduced, uniformly in all fractions at the expense of separately smaller than 0.25 mm. The content of soil aggregate <0.25 mm for the reclamation, during the research period was less than 6.5 % for the non-fertilizer variant.

2. Water-physical properties of gray forest soil for the use of mineral fertilizers and the long aftereffect of lime

Variant	Density, g/cm3			Capillary moisture,%			Total moisture,%			Water permeability, mm/min		
	1	2	3	1	2	3	1	2	3	1	2	3
1. Without fertilizers (control)	1,43	1,41	1,43	22,5	24,3	22,2	27,7	30,1	27,5	10,6	10,3	10,3
2. $CaCO_3$ (1.0 Hr)	1,36	1,36	1,38	26,9	28,8	25,8	30,6	31,8	30,3	11,1	10,8	10,8
3. NPK	1,40	1,42	1,43	23,3	24,2	21,9	28,3	30,8	27,5	10,4	10,1	10,1
4. NPK – $CaCO_3$ (1.0 Hr)	1,37	1,38	1,38	27,6	29,8	27,1	31,7	33,1	31,3	12,2	11,9	11,9
19. 2NPK + $CaCO_3$ (1,0 Hr)	1,37	1,37	1,39	27,3	30,3	26,5	27,6	30,6	27,2	11,6	11,3	11,3

1. - 8th year of lime activity, 2. - 9th year of lime activity, 3. - 10th year of lime activity

Together with the transformation of the structural and aggregate state of gray forest soil, changes also occurred in the indicators of water-physical properties. The content of capillary moisture for the use of lime fluctuated within 25,8-28,8 %, which is respectively higher than in the soil of variant without fertilizer of 3.6-4.5 %. The maximum amount of moisture (TM) adsorbed by gray forest soils in the variant where the $CaCO_3$ in a single dose was calculated from hydrolytic acidity, in the range of 30.3-31.8 %. Changes in water-physical indicators occurred due to the prolonged action of re-liming due to the strengthening process of aggregation of gray forest soils. At the same time, the permeability of the soil in the variant where the applied meliorant was higher than the non-fertilized ones at 4.72-4.85 mm/min (Table 2), which increased as a result of soil moisture absorption and a decrease in its filtration.

Adding of complete doses of lime with mineral fertilizers has increased the positive effect on the formation of the structural-aggregate state of gray forest soil. The content of agronomically valuable aggregates in the variant where used single doses of mineral fertilizers and lime by hydrolytic acidity exceeded the value of the variant without fertilizers by 5.53 %. It should be noted that the combined application of mineral fertilizers, together with lime, the amount of agronomically valuable aggregates (10-0.25 mm) was at the level of the variant where full dose of lime by hydrolytic acidity was used. The coefficient of structurality over the years of the research study was within the range of 1.28-1.29. Moreover, the rate of filtration of water through gray forest soil for the combination of $CaCO_3$ (1.0 Hr) and mineral fertilizers increased to 12.0 mm/min, which exceeded the soil permeability value of the variant where $CaCO_3$ (1.0 Hr) was used on average by 1.1 mm/min. At the same time, the density of soil compaction was higher on average by 0.01 g/cm^3. Based on the above, it can be concluded that the combination of mineral fertilizers with chemical melioration improved the structural-aggregate state of gray forest soil and its adsorption capacity.

As result of the colmatation of silt and fine dust down the profile, there was a partial melting of pores between the aggregate space. As a result, the volume of capillary space on the ground of the variant with single doses of mineral fertilizers used together with lime (var. 4) were higher than those in the variant where used only mineral fertilizers (var. 2), which is traced in increasing the percentage content capillary moisture at 4.3-5.6 %. At that, the ability of the soil to contain the maximum amount of water (TM), by the greater volume of capillaries, fluctuated within 31.3-33.1 %.

A double dose of mineral fertilizers, applied on gray forest soil, together with lime in a full dose with hydrolytic acidity (var. 19), increased the acidification of soil solution. The increase in the amount of hydrogen ion caused in the transformation the structure of absorbing complex at the expense of displacement cations of alkaline earth metals. However, there were changes in the indicators of agrophysical, water-physical properties.

The structural aggregate composition of gray forest soil for the use of a double dose of mineral fertilizers and the total dose of lime had a smaller amount of agronomically valuable aggregates by 0.93 % relative to the one where single doses of lime and mineral fertilizers were used. At the same time, the content of the dust fraction was the smallest, testifying about better aggregation of the soil separately this variant. The coefficient of structural varies within the range of 1.22-1.25. Analyzing the results obtained, which are presented in Table 1, we can conclude that the use of elevated doses of mineral fertilizers (var. 19) on gray forest soil causes aggregation of a large fraction (>10 mm), but as is known, large aggregates (more than 10 mm) are not resistant to the effects of destructive factors, such as water and mechanical cultivation. During the vegetation, for the destruction of lumpy structural elements are singled out smaller aggregates and a dusty part of the soil (separated by less than 0.25 mm), which remain within the aggregate space. Accordingly, water-physical properties deteriorate, in particular, the absorption capacity of the soil decreases. The permeability at the same time was less by 5.0 % relative to the indicators in the case where single doses of lime and mineral fertilizers (var. 4) were used, fluctuating within 11.3-11.6 mm/min. Besides, lower values of soil adsorption capacity were also recorded. The moisture content absorbed by the capillaries of gray forest soil during the years of research varied within the range of 26.5-30.3 % and the value of total moisture content at that was at 27.2-30.6 %.

Conclusion. As a result of the use of the full dose of lime on the gray forest coarse-dust–light-loam soil, changes occurred in the organization of aggregates of the structural state. The adsorption capacity of the soil and water content in the capillary and total pore space of the soil has improved and the density indicator has decreased.

Application of $N_{50}P_{30}K_{55}$ on acidic gray forest soil causes the development of peptizing soil aggregates, and at the expense of periodically flush type of water regime, the colmatation of the finely dispersed part of the soil increases and accumulation in the lower horizons. As a result, indicators of agrophysical and water-physical properties of the soil deteriorate.

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ФОРМУВАННЯ СТРУКТУРНО-АГРЕГАТНОГО СКЛАДУ ТА ВОДНО-ФІЗИЧНИХ ВЛАСТИВОСТЕЙ СІРОГО ЛІСОВОГО ҐРУНТУ ЗАЛЕЖНО ВІД МІНЕРАЛЬНИХ ДОБРИВ І ТРИВАЛОЇ ДІЇ ВАПНА

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Анотація. *У статті представлені дані досліджень структурно-агрегатного складу, водно-фізичних констант та щільності складення сірого лісового крупнопилувато-легкосуглинкового ґрунту за систематичного використання мінеральних добрив та тривалої дії (8-й – 10-й рік) хімічної меліорації. Встановлено вплив тривалої дії одинарної дози вапна за гідролітичною кислотністю на трансформацію показників властивостей ґрунту. Представлені результати використання* $CaCO_3$ *(1,0 Нг), свідчать про збільшення кількості агрономічно цінної частини ґрунту на 3,5%. Разом з цим, збільшився об'єм адсорбованої води ґрунтом та утримання її в капілярному та загальному просторі.*

Показано вплив систематичного використання фізіологічно кислих мінеральних добрив на агрофізичні та водно-фізичні властивості сірого лісового ґрунту. Внесення $N_{50}P_{30}K_{55}$ *зумовило підвищення вмісту пилуватої фракції ґрунту та зниження його фільтраційної здатності, що є негативним для властивостей ґрунту.*

Застосування як одинарної так і подвійної дози мінеральних добрив посилило пептизацію ґрунтових агрегатів. За рахунок цього, збільшилася кількість дрібнодисперсної частини, що седиментується та акумулюється в нижніх шарах грунту. В результаті погіршилася фільтраційна здатність ґрунту та адсорбуючі його властивості а щільність складення впродовж вегетації підвищувалася.

Ключові слова: *структурно агрегатний склад, щільність складення, капілярна вологоємність, повна вологоємність, водопроникність.*

ФОРМИРОВАНИЕ СТРУКТУРНО-АГРЕГАТНОГО СОСТАВА И ВОДНО-ФИЗИЧЕСКИХ СВОЙСТВ СЕРОЙ ЛЕСНОЙ ПОЧВЫ В ЗАВИСИМОСТИ ОТ МИНЕРАЛЬНЫХ УДОБРЕНИЙ И ДЛИТЕЛЬНОГО ДЕЙСТВИЯ ИЗВЕСТИ

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Анотация. *В статье представлены данные исследований структурно-агрегатного состава, водно-физических констант и плотности сложения серой лесной крупнопилевато-легкосуглинистой почвы за систематического использования минеральных удобрений и длительного действия (8-й - 10-й год)* *химической мелиорации. Установлено влияние длительного действия одиночной дозы извести по гидролитической кислотности на трансформацию показателей свойств почвы. Представлены результаты использования $CaCO_3$ (1,0 Нг), свидетельствуют об увеличении количества агрономически ценных почвеных частиц на 3,5 %. Вместе с тем, увеличился объем адсорбированной воды почвой и содержание его в капиллярном и общем пространстве.*

Показано влияние систематического использования физиологически кислых минеральных удобрений на агрофизические и водно-физические свойства серой лесной почвы. Внесение $N_{50}P_{30}K_{55}$ обусловило повышение содержания пылеватой фракции почвы и снижение его фильтрационной способности, что является негативным для свойств почвы.

Применение одиночной и двойной дозы минеральных удобрений усилило пептизацию почвеных агрегатов. За счет этого увеличилось количество мелкодисперсных частиц, которие седиментируются и аккумулируются в нижних слоях почвы. В результате ухудшилась фильтрационная способность почвы и адсорбирующие его свойства а плотность сложения в течение вегетации повышалась.

***Ключевые слова:** структурно-агрегатный состав, плотность сложения, капилярная влагоемкость, полная влагоемкость, водопроницаемость*