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PRODUCTIVITY OF THE FOREST-STEPPE TYPICAL CROP ROTATIONS DEPENDING ON THE INTENSITY OF THE AGROCHEMICAL LOAD

Presented the results of productivity research in typical crop rotation in Right Bank Forest-Steppe of Ukraine according to the different systems of fertilizing and chemical melioration within 21 years. Identified the need of re-liming and application of by-products as an organic fertilizer and confirmed a close relationship between the effective level of fertility and agrochemical load on gray forest soil.
Keywords: *gray forest soil, effective fertility, crop rotation, liming, fertilization, productivity of arable land*

Introduction. Rational use of ground resources and soil fertility problem remains one of the most relevant in modern agriculture, because in recent years the number of chemical and organic fertilizers does not comply with the laws of agriculture, which resulted in negative balance of all elements (deficit in the average amount of NPK is 100-120 kg/ha per year) [1]. Chemical amelioration of acidic and saline soils almost not performed. The long decline in agricultural production and a marked decrease in fertility of basic soil types makes us look for new ways for the efficient use of natural soil fertility potential [2].

Numerous studies of soil scientists processed technological aspects of expanded reproduction and preservation of soil fertility based on established optimal parameters of the material composition, functional properties and modes of each type of soil, in which realized fertility potential in the yield of crops [3, 4, 5]. However, the level of the biological potential of soil fertility parameters of acid-base regime and demands of the modern market economy affect the formation of the corresponding specialization of agriculture, simplification of crop rotations and changes in the structure of sown areas, which are mostly not appropriate to maintain soil fertility at a consistently high level [6].

According to long-term research in stationary experiments of NSC “Institute of Agriculture NAAS” and production experience, the yield of crops mainly depends on the power of the agrochemical agriculture, which share is 41%. Next in importance are weather 27%, 14% varietal characteristics, the system of protection is 12% and other factors of farming systems - 6% [7]. Should be noted that according to the laws of agriculture, all factors are equal, their effectiveness largely depends on the complex use, but agrochemical block, no doubt, remain a major factor influencing the effective soil fertility in field agro ecosystems.

The purpose of research. Improvement of rational use of natural soil fertility potential from the perspective of solving the optimizing problem in their physical and chemical properties and stable productivity providing through the agrocenoses optimization of agrochemical effects in soil.

Materials and Methods. Research based on stationary experiment of agropedology department in research station “Chabany” NSC "Institute of Agriculture NAAS" in three fields of 7-field crop rotation during 1992-2012 years. In the experiment studied different doses and forms of lime, organic fertilizers and their combination on the properties of gray forest soil and crop rotation productivity. Experiment has 19 variants with quadruple repeatability. The area of the cultivated plots is 60 m2 (10×6) in accounting - 24 m2 (6×4). Studies were conducted in 7-field grain cultivated crop rotation with this set and the alternation of crops in time: vicia-oat mix; winter wheat; sugar beets; barley overseeding with clover; clover; winter wheat; corn for silage.

The system of fertilizing included two levels of organic and three levels of mineral fertilizers. Organic fertilizers were made under sugar beet and corn for silage (only in the first

rotation) at a dose of 35 and 52 t/ha, what means 10 and 15 t/ha per hectare of crop rotation area. Mineral fertilizers for the single dose made at the rate of: vicia-oat mix – $N_{30}P_{45}K_{45}$; under winter wheat – $N_{60}P_{60}K_{60}$; under sugar beet – $N_{75}P_{75}K_{95}$; under spring barley – $N_{45}P_{45}K_{45}$; under corn for silage – $N_{90}P_{90}K_{90}$; Red clover grown without fertilizers.

Lime (limestone and dolomite) was contributed in year of growing vicia-oat mix (spring 1992) in forms and doses according to the scheme of the experiment and output hydrolytic acidity of the soil in each variant which was studied - 1.0 and 1.5 doses by hydrolytic acidity. In the first rotation 1/7 dose of lime contributed annually for each culture of crop rotation and 2.5 kg $CaCO_3$ per 1 kg of nitrogen fertilizers for additional acidity neutralization of physiologically acid fertilizers. Since 2006 (the beginning of the third rotation of crop rotation) experiment was reconstructed. Conducted another liming with defecate and introduced three variants with application of saponite, manure and green manure substituted with by-products.

Besides, in 2006, introduced rotation with the alternation of crops: soybeans - spring wheat - corn for silage - barley + clover - clover for green fodder (2nd Escarpment for green manure) - winter wheat - millet. The dose of mineral fertilizers was: winter and spring wheat - $N_{60}P_{30}K_{60}$, soybeans – $N_{30}P_{30}K_{45}$, spring barley – $N_{60}P_{30}K_{45}$, corn for silage – $N_{90}P_{45}K_{90}$, millet – $N_{60}P_{30}K_{60}$, red clover is grown without fertilizers. Phosphate and potash fertilizers introduced with autumn plowing, nitrogen fertilizers with Pre-tillage and plant nutrition.

Results of accounting processed by analysis of variance. Determination of the main yield and by-products was determined annually for each of plots, the weight of grains counted in yield from 1 hectare based on pollution. Harvesting of cereals and legumes performed by direct harvesting, roots were collected manually, corn for silage and clover for green fodder counted manually with the following field mopping with forage harvester machines.

Research results. Yield of crops is an integral indicator of effective soil fertility because its level is determined as a complex combination of soil, biological and weather factors. It established that on its level has a significant impact not only soil moisture or mobile forms of nutrients, but also the reaction of soil solution that limits the obtaining high quality and yields because most crops for their growth and development require a weakly acid or neutral reaction.

The obtained results indicate that improvements in physical, chemical and agrochemical parameters of soil fertility under the influence of liming, including chemical melioration contributed to increasing productivity of crop rotation links (Tables 1 and 2). Performance analysis of crop rotation cultures in the I-st and II-nd rotations gives reason to believe that the use of limestone ameliorant $CaMg(CO_3)_2$ (dolomite) turned out better than normal lime. Increase in yield from ameliorative influence of dolomite as in the first years after the introduction (first rotation, 1992-2000) and the next (second rotation, 1999-2007) were respectively 0.43 and 0.69 t/ha grain units, which exceeded the increase in the version with limestone flour by 0.2 and 0.12 t/ha.

Supportive liming (var. 9) in the first rotation provided the increase in the level of variation which used full dose of lime by hydrolytic acidity (var. 7). But in the second rotation liming dose of 1/7 Hg yield increment annually fell by almost half compared to the entering of traditional full dose $CaCO_3$. Adding small amounts of calcium carbonate (var. 10), designed to neutralize physiologically acid of mineral fertilizers (2.5 kg per 1 kg of N fertilizer) almost did not change the parameters of soil fertility. However, it should be noted that small increments from lime, at 0.13 t/ha in the first rotation and 0.19 t/ha of grain units in the second received in the following way of chemical amelioration of gray forest soils, show a positive effect even in this amounts of Ca^{2+} in metabolic reactions.

Application of organic-mineral fertilization system with high doses of mineral fertilizers on the background by liming full dose Hg provided the highest level of performance in the first (4,92-4,98 t/ha of grain units) and second (4,90-4,95 t/ha grain units) rotations of 7-field rotation. Adding of high doses of mineral fertilizers (var. 19) without manure on the liming background provide a similar growth in the first rotation. However, in the second rotation was deteriorating of physical and chemical soil properties in this variant (var. 19), leading to a decrease in yield and overall performance of crop rotation (4.76 t/ha of grain units).

Method of making lime at different depths (var. 11) was significantly higher than the efficiency of traditionally (for plowing) introduced lime (var 7). Increase in yield was higher in the first rotation by 0.13 t/ha of grain units compared with major soil cultivation and was the same in the second rotation, which confirms the prospects of its application.

Table 1

Productivity of grain cultivated crop rotation according to the system of fertilization and liming

Variant	Productivity of crop rotation cultures, t/ha of grain units					
	I rotation 1992-2000	growth of yield		II rotation 1999-2007	growth of yield	
		liming	total of the factors		liming	total of the factors
1. Without fertilizer	3,17	-	-	2,53	-	-
2. $CaCO_3$ (1,0Hg)	3,60	0,43	-	2,84	0,31	-
3. NPK	4,14	-	0,97	3,73	-	1,20
4.NPK+$CaCO_3$ (1,0Hg)	4,29	0,15	1,12	4,01	0,28	1,48
5. Manure +$CaCO_3$ (1,0Hg)	3,95	-	0,78	3,71	-	1,18
6. Manure + NPK – Background	4,46	-	1,29	4,00	-	1,47
7. Background + $CaCO_3$ (1,0Hg)	4,69	0,23	1,52	4,57	0,57	2,04
8. Background + $CaMg(CO_3)_2$ (1,0Hg)	4,89	0,43	1,72	4,69	0,69	2,16
9. Background + $CaCO_3$ (1/7Hg) annually	4,72	0,26	1,55	4,35	0,35	1,82
10. Background +$CaCO_3$ 2,5kg*1kg N	4,59	0,13	1,42	4,19	0,19	1,66
11. Background + $CaCO_3$ (1,0Hg) layer by layer	4,82	0,36	1,65	4,56	0,56	2,03
12. Manure + 1,5NPK + $CaCO_3$ (1,0Hg)	4,79	-	1,62	4,68	-	2,15
13. Manure + 2NPK +$CaCO_3$ (1,0Hg)	4,92	-	1,75	4,95	-	2,42
14. Manure + 1,5NPK +$CaCO_3$ (1,5Hg)	4,69	-	1,52	4,96	-	2,43
15. Manure + 1,5NPK + $CaCO_3$ (1,0Hg) + By-products	4,98	-	1,81	4,90	-	2,37
16. By-products	3,46	-	0,29	2,75	-	0,22
17. 1,5 Manure + 1,5NPK+ $CaCO_3$ (1,0Hg)	4,73	-	1,56	4,76	-	2,23
18. 1.5NPK+ $CaCO_3$ (1,0Hg)	4,81	-	1,64	4,52	-	1,99
19. 2NPK + $CaCO_3$ (1,0Hg)	4,93	-	1,76	4,76	-	2,23

Analyzing the overall performance of cultures under intensive agrochemical effects in soil (variant 14), accordingly to making one and half dose of lime, found the highest level of performance in the second crop rotation - 4.96 t/ha of grain units and accordingly the highest increase from the total of factors that was 2.43 t/ha.

Therefore, the use of fertilizers in combination with liming increases their effectiveness not only in the early years of implementation, but also in after 8-14 years, it most clearly seen under increased amounts of lime. However, reducing the overall level of productivity in the experiment at the end of the second rotation connected in some way with the fading ameliorative effect of lime.

Therefore, the yield of crops typical for forest-steppe zone crop rotation on the lime background increases in the 1st and gradually decreases in the 2nd rotation of 7-field crop rotation, which is associated with deterioration of physical and chemical properties of the soil. Studies indicate the correctness of our conclusions about the need for full dose re-liming (1,0 Hg $CaCO_3$) at least every

10 years, which will ensure the maintenance of the reaction of soil solution at an optimal level, thereby ensuring obtaining of significant increases of crop yields.

Repeated chemical amelioration (Table 2) provided the increase in output in the third rotation from the use of full dose $CaCO_3$ (1,0 Hg) in the defecate form (var. 2) at 0.47 t/ha of grain units relative to the control variant. Entering of defecate ($CaCO_3$ 1,0Hg) in combination with mineral fertilizers (var. 4) provide performance level of crop rotation at the level of 3.75 t/ha of grain units, 56% higher than version without fertilizer and 16% - variant of mineral fertilizers. Simultaneous use of defecate ($CaCO_3$ 1,0Hg), by-products and mineral fertilizers (var. 7) increased productivity by 73%. Application of defecate neutralize soil acidity, also caused by physiologically acidic fertilizers, creates favorable for crops reaction of environment in which they use better soil nutrients and fertilizers, contributing to higher productivity. Therefore, the efficiency of mineral fertilizers application on the background of liming significantly increased.

Table 2

Performance of variable crop rotation according to the system of fertilization and repeated chemical amelioration

Variant	Productivity of crop rotation cultures, t/ha of grain units		
	III rotation 2006-2012	growth of yield	
		chemical amelioration	total of the factors
1. Without fertilizer	2,41	-	-
2. $CaCO_3$ (1,0Hg)	2,88	0,47	-
3. NPK	3,22	-	0,81
4.NPK+$CaCO_3$ (1,0Hg)	3,75	-	1,34
5. Manure +$CaCO_3$ (1,0Hg)	3,06	-	0,65
6. Manure + NPK – Background	3,63	-	1,22
7. Background + $CaCO_3$ (1,0Hg)	4,17	0,54	1,76
8. Background + $CaMg(CO_3)_2$ (1,0Hg)	4,20	0,57	1,79
9. Background + $CaCO_3$ (1/7Hg) annually	3,93	0,30	1,52
10. Background +$CaCO_3$ 2,5kg*1kg N	4,55	0,92	2,14
11. Background + $CaCO_3$ (1,0Hg) layer by layer	4,29	0,66	1,88
12. Manure + 1,5NPK + $CaCO_3$ (1,0Hg)	4,54	-	2,13
13. Manure + 2NPK +$CaCO_3$ (1,0Hg)	4,81	-	2,40
14. Manure + 1,5NPK +$CaCO_3$ (1,5Hg)	4,76	-	2,35
15. Manure + 1,5NPK + $CaCO_3$ (1,0Hg) + By-products	4,37	-	1,96
16. By-products	2,70	-	0,29
17. 1,5 Manure + 1,5NPK+ $CaCO_3$ (1,0Hg)	4,47	-	2,06
18. 1.5NPK+ $CaCO_3$ (1,0Hg)	4,34	-	1,93
19. 2NPK + $CaCO_3$ (1,0Hg)	4,67	-	2,26

The increase in crop productivity depended on the level of fertilizer, lime doses and its compatible introduction with saponite and by-products. Higher dose $CaCO_3$ operates more efficiently compared to smaller (by a similar system of fertilization, var. 10, 11), due to the high sensitivity of crops to liming and accelerated achievement of optimal response of soil solution, as well as improvement of other properties of the soil. Application one and half dose of $CaCO_3$ by Hg in conjunction with one and half dose of mineral fertilizers $N_{77}P_{42}K_{77}$ and by-products (var. 14) ensured the average yield of crops at the level of 4.76 t/ha of grain units. Which is 9% higher than the option of a single dose $CaCO_3$ by Hg (var. 18), which did not make by-products and 97% higher than the control variant.

Concomitant usage of doses $CaCO_3$ 0,75 by Hg combined with saponite (1.5 t/ha) on the background of mineral fertilizers and by-products provide the overall performance of crops at the level of 4.55 t/ha of grain units, which is 25% above the background option (var. 6) and 88 % of control. Received sufficiently high agronomic effect of the composition due to both ameliorative effects on soil and simultaneous improvement of its nutritional profile.

Thus, re-liming of gray forest soils with periodically flushing water regime is a necessary measure to increase their effective fertility. Considering that the best indicators of physical and chemical properties of gray forest soils provide significant increases of yields, we can state the obvious need for periodic chemical amelioration of acid gray forest soils, which will reduce the shortage of agricultural products because of failure to conduct the event again after 10-12 years.

In general, the use of different technologies of liming in grain cultivated and variable crop rotations on acidic gray forest soil (three rotation of 7-field crop rotation) provides a significant performance increase of 1 ha of arable land, which is in intensive cultivation on the level of 0,15-0,92 tons of grain units.

Table 3 presents summary, average productivity of 1 ha of gray forest soils studied during 21 years, depending on the intensity of agrochemical block of farming. For analysis were taken variations of chemical amelioration which essentially unchanged during a specified period, and fertilization system that contained minor changes witch cannot significantly affect the conclusions.

Table 3

Performance of gray forest soil depending on the intensity of agrochemical exposure (average of 1992-2012 years)

Variant	1 ha of crop rotation area performance				The gain from agrochemical factor, %
	I rotation 1992-2000.	II rotation, 1999-2007	III rotation, 2006-2012	average	
1. Without fertilizer	3,17	2,53	2,41	2,70	-
2. $CaCO_3$ (1,0Hg)	3,60	2,84	2,88	3,10	15
3. NPK	4,14	3,73	3,22	3,70	37
4.NPK+$CaCO_3$ (1,0Hg)	4,29	4,01	3,75	3,92	45
5. Manure +$CaCO_3$ (1,0Hg)	3,95	3,71	3,06	3,57	32
6. Manure + NPK – Background	4,46	4,00	3,63	4,03	49
7. Background + $CaCO_3$ (1,0Hg)	4,69	4,57	4,17	4,48	66
8. Background + $CaMg(CO_3)_2$ (1,0Hg)	4,89	4,69	4,20	4,59	70
12. Manure + 1,5NPK + $CaCO_3$ (1,0Hg)	4,79	4,68	4,54	4,67	73
13. Manure + 2NPK +$CaCO_3$ (1,0Hg)	4,92	4,95	4,81	4,89	81
14. Manure + 1,5NPK +$CaCO_3$ (1,5Hg)	4,69	4,96	4,76	4,80	78
16. By-products + (green manure III rotation)	3,46	2,75	2,70	2,97	10
18. 1.5NPK+ $CaCO_3$ (1,0Hg)	4,81	4,52	4,34	4,56	69
19. 2NPK + $CaCO_3$ (1,0Hg)	4,93	4,76	4,67	4,79	77

Note. *Green manure and by-products in the third rotation replaced manure*

Thus, the variants without mineral fertilization and liming (var. 1 and 16) showed significant decrease in agrocenosis performance on a background of significant deterioration of soil fertility basic indicator. Adding the entire non-tradable crop in arable layer of gray forest soils can increase productivity of 1 ha only by 10%. Periodic introducing only of calcium carbonate increases the productivity of arable land by 15%, and the combination of chemical amelioration with entering of

organic fertilizers (var. 5) together with the improvement of nutrient and acid-base regimes providing gains at the level of 0.87 t/ha of grain units.

Conclusions. It was established that under the same weather conditions and the use of the main components of agriculture - crop rotation, tillage, crop protection products, varieties, role of agrochemical factor on gray forest soils increases to 77-81%, confirming the critical role of this factor in ensuring the agrocenosis performance growth and reproduction of potential and increasing of soil effective fertility.

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Анотація

Ткаченко М.А., Літвінов Д.В.

Продуктивність типових сівозмін лісостепу залежно від інтенсивності агрохімічного навантаження

Висвітлено результати досліджень по вивченню продуктивності типових сівозмін Правобережного Лісостепу України залежно від різних систем удобрення та хімічної меліорації протягом 21 року. Встановлено необхідність повторного вапнування і застосування побічної продукції у якості органічного добрива та підтверджено тісний взаємозв'язок між ефективною родючістю та рівнем агрохімічного навантаження на сірий лісовий ґрунт.

***Ключові слова**: сірий лісовий ґрунт, ефективна родючість, сівозміна, вапнування, добрива, продуктивність ріллі*

Аннотация

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Продуктивность типичных севооборотов Лесостепи в зависимости от интенсивности агрохимической нагрузки

Представлены результаты исследований по изучению продуктивности типичных севооборотов Правобережной Лесостепи Украины в зависимости от различных систем удобрения и химической мелиорации в течении 21 года. Установлена необходимость повторного известкования и применения побочной продукции в качестве органического удобрения и подтверждена тесная взаимосвязь между эффективным плодородием и уровнем агрохимического нагрузки на серую лесную почву.

***Ключевые слова**: серая лесная почва, эффективное плодородие, севооборот, известкование, удобрения, продуктивность пашни*