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Effect of fertilizers and soil cultivation on productivity of cultures of crop rotation

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The purpose to determine effect of different systems of basic soil cultivation and methods of fertilizing on productivity of crops of field rotation. **Methods.** Field, statistical (statistical analysis of results of probes), comparative-calculation (determination of power efficiency of growing crops in crop rotation). They carried out experiments according to conventional techniques in farming agriculture. Weather conditions during probes on the average appeared typical for Kiev area, however they differed on rainfall and sum of active temperatures above 10°C in some months and years, and as a result productivity of crops varied. **Results.** Probes have shown that use of organic-mineral fertilizer system has not essentially lowered productivity of winter wheat in comparison with mineral one. Essential lowering was observed at organic fertilizer system: in a link with Lucerne — on 32%, soya bean — 31.3, corn for silage — on 33.3% in comparison with use of mineral system. The highest productivity of winter wheat was on the background of moldboard-subsoil cultivation. Favorable soil conditions for yield of root crops were created at mineral fertilizer system. Application differential and moldboard-subsoil cultivation promoted essential growth of productivity of sugar beet. Productivity of sunflower was essentially above at use of mineral fertilizer system. At application of organic-mineral system productivity was diminished by 6%. Productivity at differential and moldboard-subsoil cultivations essentially did not differ (a variance was 2.6 t/hectare). **Conclusions.** By results of probes it is established that the best alternative for basic soil cultivation in crop rotation had appeared moldboard-subsoil one. Its use secured increased productivity of beet sugar, winter wheat after soya bean and corn for silage as compared to control. Application of shallow cultivation led to lowering of productivity of cultures of crop rotation. Use of organic-mineral fertilizer system essentially did not reduce productivity of cultures of crop rotation in comparison with mineral system.

Key words: *typical chernozem, soil cultivation, fertilizers, yield ability, productivity.*
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Analysis of recent studies and publications. Among all the agrocenosis parameters, bioefficiency is the most variable and integral indicator of crops growing in crop rotation, in which the plants' genetic potential, soil fertility, weather conditions and agricultural efficiency are accumulated. Its increase has remained the main priority of agricultural production. In spite of significant progress in the world economy's agrarian sector, the issue of further increase in crop high-yields is becoming highly relevant due to certain causes [3-9].

The impact of soil tillage methods on crop yields is determined by the complex combination of regulated and unregulated factors, among which the most important ones are the weather, the biological features of crops and their placement in crop rotation, soil physical properties, conditions of plant nutrition, soil physical and chemical regime, weeds growing in soil and crops.

Soil and subsoil soil tillage are used for field crop growing. There is no consensus on the superiority of one of them among scholars and practitioners [8, 11].

The purpose of the research is to determine the impact of different systems of primary soil tillage and fertilizer systems on yields in field crop rotation.

Materials and methods of the study. The experimental part of the work was carried out on the experimental field of the Scientific and Educational Innovative Center of Agrotechnologies PLC «Agrofirma Kolos» (2011 – 2017) of the Skvyra district (Kyiv region) in the stationary experiment, based on a 10-field crop rotation, expanded in time and space. Soil of the experimental field is typical chernozem. Humus content in the cultivated layer 4.6 – 4.8% (according to Tiurin), lightlyhydrogenated nitrogen (Cornfield) – 14.4 mg/100 g of soil, mobile phosphorus (Chirikov) – 15.2 mg/100 g of soil, exchangeable potassium – 15.2 mg/100 g of soil (Chirikov). The soil volume in the equilibrium state is 1.24 g/cm^3, hydrolytic acidity – 1.14 mg ek/100 g soil, saline pH – 6.4.

Scheme of the rotating crops in field crop rotation was the following: alfalfa, alfalfa, winter wheat, sugar beet, barley, soybean, winter wheat, silage corn, winter wheat, and sunflower. In this crop rotation, three levels of fertilizer per hectare of crop rotation were used: the mineral system – compost 4.5 tons + $N_{80}P_{96}K_{108}$; organic-mineral – compost 4.5 t + $N_{40}P_{48}K_{54}$ + 3.5 t by-products and green manure mass and organic – compost 4.5 t + 3.0 t by-products and green manure mass. The following fertilizers have been used in the experiment: compost, ammonium nitrate, superphosphate granulated and potassium chloride.

The second factor studied was the system of the primary soil tillage: 1) differentiated tillage (control) recommended in the Forest-Steppe and involves five-stage plowing according to crop rotation, two surface

cultivations for winter wheat after soybeans and silage corn and chisel cultivation for barley; 2) soil/subsoil tillage covers two-stage plowing for sugar beet and sunflower in crop rotation, for the rest of the crops without crop cultivation; 3) subsoil tillage for all crops in crop rotation. Area of plots was 240 m^2; there was four-time repetition of test variants.

Energy efficiency has been determined according to O. V. Medvedovskyi's methods [4].

The findings of the study. According to our research, the fertilizer system has had a significant impact on the yield of the first-year use alfalfa. The highest yield during the research years was due to the mineral system, and the least – without fertilizers use, (52% less than the mineral system). Application of organic fertilizer system on the basis of compost 4.5 t/ha of rotating area increased the yield of the first-year use alfalfa by 2.5 t/ha, which is 23% more than in the control stage without fertilizers (Table).

The interaction of the fertilizer system with the primary soil tillage was manifested in the following phenomena. According to soil/subsoil tillage the yield was 13.7 t/ha, the lowest yield, namely 11.7 t/ha with the shallow soil tillage application. During the years of research, the yield of alfalfa in the first year of use has not significantly differed. The highest yield of alfalfa was obtained at the level of 17 t/ha of green mass in 2017.

The yield of alfalfa in the second year of use in two mowing stages was higher than in the first one. The yield with the mineral fertilizer system application was 20.7 t/ha, which is 42% more than in control stage, without fertilizers. The organic-mineral fertilizer system led to insignificant decrease in alfalfa yield compared to the mineral fertilizer system. In another variant, where the yield formation was influenced by the organic fertilizers use, 4.5 t/ha of compost per hectare of the rotating area, the increase in green mass yield was 3.3 t/ha higher than without fertilizers application.

The yield of alfalfa of the second year of use was 17.3 t/ha according to the differentiated soil tillage – 17.6 t/ha, according to soil/subsoil tillage – 17.9 t/ha, and 14.9 t/ha – using shallow tillage.

The yield of winter wheat during the years of research has been moderate and fluctuated within the range of 3.3 – 6.8 t/ha. Due to the organic-mineral fertilizer system, the yield of winter wheat in three fields of crop rotation has not differed significantly from control. Significant decline in the yield of winter wheat was observed in the organic fertilizer system – in the field with alfalfa at 32%, soybean – 31.3% and 33.3% of silage corn compared to the mineral system. In the organic-mineral fertilizer system, the yield of winter wheat has significantly differed from the mineral system. So the yield of winter wheat after alfalfa in the organic-mineral system led to a decrease of 0.2 t/ha (HIP_{05} = 0.18 t/ha), after soybean – 0.4 t/ha (HIP_{05} = 0.25 t/ha), after corn for silage – 0.4 t/ha (HIP_{05} = 0.27 t/ha) in comparison with the mineral fertilizer system.

Among the cultivating variants, the highest yield was due to the soil/subsoil tillage application. The use of shallow tillage led to a significant decrease in winter wheat yield compared to control.

The yield of sugar beet during crop rotation has varied slightly. Thus, the yield of sugar beet in the average was 32–63 t/ha. Insufficient water supply in August and September 2015 negatively affected root formation and, consequently, low yields of all experiment variants. It has been established that the most favorable soil conditions for the yield of root crops were formed due to the mineral fertilizer system. On average, during the years of research, the yield of root crops in terms of the organic-mineral fertilizers use was 4.6% lower than the mineral system, and organic – by 37.5%.

The use of differentiated and soil/subsoil tillage contributed to a significant increase in the yield of sugar beet. The use of shallow tollage contributed to a significant decrease in the yield of sugar beet compared to control by 14.2%.

The application of the organic-mineral fertilizer system has not led to a significant reduction in the yield of barley compared to the mineral fertilizer system.

The organic fertilizer system yielded the mineral one to 53.2%. This is due to the poor nutrient soil regime, since the use of organic fertilizers only in the organic system leads to a negative nutrients balance in soil.

The yield of barley during the years of research has been the same for differentiated (control) and soil/subsoil tillage in crop rotation (3.7 t/ha), and the application of shallow tillage reduced the yield by 10.8%.

The highest yield of soybean during the years of research has been noted in the use soil/subsoil tillage due to the mineral fertilizer system of 3.4 t/ha, organic-mineral –3.2 t/ha, organic – 1.8 t/ha. The shallow soil tillage led to a significant decline in yields. Soybean yield over the years has not significantly fluctuated.

Corn is a crop of high potential for the formation of green mass harvest in the conditions of Forest-Steppe.

The yield of silage crop on average due to crop rotation was within the range of 30 – 62 t/ha with significant variations in experimental variants.

The application of the organic-mineral and organic fertilizer systems has led to a significant decrease in the yield of silage corn, respectively, by 6.4 and 37%, in comparison with the mineral fertilizer system.

Among the soil tillage, it has been observed that the shallow tillage formed lower yield by 11.7% compared to the variant, where the soil tillage was used in the system of primary soil cultivation in crop rotation.

According to the research results the fertilizer systems have had significant impact on the sunflower yield. The most favorable conditions were formed in the variant with the mineral fertilizer system. The average yield was 3.3 t/ha. The yield decreased by 6% in the organic-mineral fertilizer system. Significantly lower, by

39% compared to the control, was the sunflower yield by means of the organic fertilizer system. The variants of differentiated and soil/subsoil tillage have not differed significantly, which amounted to 2.6 t/ha.

According to the ecologization on chernozem, the typical yield of the main crops does not undergo significant changes in comparison with the mineral fertilizer system.

On average, due to crop rotation the yields were, t/ha: alfalfa – 12.9, alfalfa – 16.6, winter wheat – 5.0, sugar beet – 49, spring barley – 3.5, soybean – 2.4, winter wheat – 5.1, corn for silage – 48.6, winter wheat – 4.8, sunflower – 2.4.

Change in crop yields depending on fertilizers and primary tillage systems (2011 – 2017)

crop	Fertilizer system				HIP_{05}	Primary tillage			HIP_{05}
	no fertilizers (control)	± % to control				differentiated (control)	± % to control		
		organic	organic-mineral	mineral			soil/ subsoil	shallow	
Alfalfa	8,1	+3,2	+101	+107	8,4	13,6	+0,7	-14,7	9,4
Alfalfa	11,2	+29	+78	+84	7,0	17,6	+1,73	-13,8	10,1
Winter whet	3,3	+39	+100	+106	3,2	5,4	-7,4	-14,8	3,6
Sugar beet	32	+24	+90	+99	3,5	51	+5,9	-14,5	6,4
Barley	2,2	+31,8	+100	+113	6,8	3,7	0,0	-10,8	10,3
Soybean	1,3	+38	+146	+161	7,0	2,5	0,0	-8	8,7
Winter wheat	3,0	+53	+110	+120	3,1	5,1	+1,9	-1,9	4,9
Corn for silage	35	+12	+66	+76	2,7	51	-0,4	-10,9	3,2
Winter wheat	2,8	+50	+111	+125	4,2	4,8	+2,1	-2,1	5,6
Sunflower	1,4	+43	+121	+136	8,7	2,6	0,0	-19	11,2

There was a significant difference between the variant without fertilizers and the organic-mineral fertilizer system for all crops in crop rotation.

The analysis of impact of the fertilizer systems on crop yields in crop rotation indicates that there is no significant difference between the organic-mineral and the mineral fertilizer systems for alfalfa growing of the first and second year of use and sunflower.

There was a significant difference between the organic-mineral and the mineral fertilizer system for winter wheat growing after all precursors, sugar beet, barley, soybean, silage corn.

The application of the organic fertilizer system has significantly reduced the crop yields in crop rotation compared to the organic-mineral and the mineral fertilizer system.

The crop yields depend on many factors combination, such as the conditions of plant nutrition, fertilization, biological features of crops [7].

The assessment indicator of different soil tillage systems, as well as other agricultural measures, is the quantity and quality of agricultural crops yield, which reflects the effect on the plant of all cultivation conditions, which also may change by means of soil tillage [2].

The positive effect of subsoil, minimum and soil tillage on the productivity of agricultural crops has been studied in many scientific institutions. At the same time, minimum soil cultivation does not only decrease crop yields, but in some cases even increases with the overall reduction of energy costs for cultivation [1, 10].

Issues related to the minimization of energy costs on agricultural production are becoming very relevant in modern agriculture.

The most promising technologies include those in which the energy consumption of production is reduced, and the energy efficiency factor, on the contrary, is increased.

The calculation of energy efficiency showed that the organic-mineral fertilizer system application, the energy intensity of crops growing was 176.6 GJ/ha, or 16.9% more than using the mineral fertilizer system. Due to the organic fertilizer system application energy costs was 121.4 GJ/ha, or 31% less than using the organic-mineral fertilizer system.

It has been established that the highest coefficient of energy efficiency was observed without the use of fertilizers – 7.3. In the organic-mineral fertilizer system, the energy efficiency coefficient of 6.9 per 13.1% exceeded the mineral system. Less energy-saving was the mineral fertilizer system.

Soil/subsoil tillage (K_{ee} – 7.0) and differentiated tillage (K_{ee} – 6.8) was the most energy-efficient variants, and the shallow tillage (K_{ee} – 6.5) was less energy-efficient due to the lower crop yields in crop rotation.

The energy coefficient reached the maximum values in the variants with the least energy consumption (without fertilizers), indicating energy savings for crops growing in crop rotation in these experimental variants.

The application of high doses of mineral fertilizers in the mineral fertilizer system provided for an increase in the absolute values of the energy output, but caused an increase in its costs for the product formation and a reduction in energy efficiency.

Conclusions

Crop yields of ten-field crop rotation have depended on the systems of primary soil tillage and fertilizers. According to the research outcomes, it has been found that the best variant of the primary soil tillage in crop rotation was soil/subsoil tillage, in which sugar beet, winter wheat after soybeans and silage corn responded by yields increasing in comparison with control. The use of shallow soil tillage led to a decrease in crop yields of crop rotation.

The organic-mineral fertilizer system application has not significantly reduced the crop yields in crop rotation compared to the mineral fertilizer system use.

In terms of energy consumption efficiency the most rational variant has been with no fertilizers (Kee = 7.3) compared to the use of mineral fertilizers (Kee = 6.1).

Among the primary soil tillage systems in crop rotation, soil/subsoil tillage and differentiated tillage has proved to be the most energy-efficient variant, and the shallow tillage – the less energy-efficient.

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