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CROP CAPACITY OF WINTER WHEAT ON PODZOLIZED CHERNOZEM IN THE RIGHT-BANK FOREST-STEPPE DEPENDING ON VARIOUS TYPES AND SYSTEMS OF FERTILIZING AND THEIR PAYBACK

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The results of the study of winter wheat crop capacity and the payback of the applied fertilizer in the conditions of full and partial compensation of estimated moving of main nutrients from the soil.

The increase of grain production and its quality improvement remains a major problem for agricultural production in Ukraine, which can be solved only through the rational usage of land resources by implementing scientifically based system of arable farming into every farm enterprises, by means of improving of soil fertility and applying of intensive technology of crops cultivation [1].

Concerning the sowing areas the winter wheat takes the first place among the main food crops in Ukraine (more than 50% of grain sown area). It is the essential food crop, providing more than a half of grain production. Compared to the spring crops it is characterized by higher yield indices, grain is rich in gluten, protein and other valuable nutrients. Therefore, it is widely used for food production purposes, especially in the bakery and confectionery industry, as well as for the production of groats, macaroni, noodles and other products [2,3].

Now both in the world and in Ukraine there is a tendency to reduce the costs of growing crops, particularly of winter wheat. In this regard, it is necessary to optimize the agro-technical methods of the crop cultivation. [4] It is known, that fertilizer is one of the most effective and fast-acting factors to increase the yield capacity of crops and of winter wheat as well.

Research Methodology. Field research was carried out during the years 2011-2012 in a temporary experiment of the Department of Agro chemistry and Soil Science of Uman NUH. Experiment scheme included partial and full compensation of estimated exhaustion of main nutrients by yield (fig. 1).

Winter wheat was seeded in grain-tilled crop rotation with such rotation of crops: winter wheat, corn, spring barley and soybean. The research field area was100 m^2, the control field area – 80 m^2. The experiment was carried out simultaneously in four fields in 2011, including three-time options repeat.

The soil of the research area is heavy-loamy podzolized chernozem on loess. Humus content in the soil of the experimental plots according to DSTU4289: 2004 is increased, the reaction of soil solution is near to neutral, hydrolytic acidity (GOST 26212-91) – 1,9-2,6 resin/kg of soil, the content of actuated compositions of phosphorus and potassium (according to DSTU4115–2002) – is higher than average, alkaline and hydrolyzed nitrogen compounds content (using the Kornfild method) is low.

1. Experiment scheme

Saturation with fertilizers per 1 ha of crop rotation area (an experiment option)	crop rotation			
	Winter wheat	Corn for grain	Spring barley	Soybean
Without fertilizer (control)	–	–	–	–
N_{55}	N_{75}	N_{80}	N_{35}	N_{30}
N_{110}	N_{150}	N_{160}	N_{70}	N_{60}
$P_{60}K_{80}$	$P_{60}K_{80}$	$P_{60}K_{110}$	$P_{60}K_{70}$	$P_{60}K_{60}$
$N_{110}K_{80}$	$N_{150}K_{80}$	$N_{160}K_{110}$	$N_{70}K_{70}$	$N_{60}K_{60}$
$N_{110}P_{60}$	$N_{150}P_{60}$	$N_{160}P_{60}$	$N_{70}P_{60}$	$N_{60}P_{60}$
$N_{55}P_{30}K_{40}$	$N_{75}P_{30}K_{40}$	$N_{80}P_{30}K_{55}$	$N_{35}P_{30}K_{35}$	$N_{30}P_{30}K_{30}$
$N_{110}P_{60}K_{80}$	$N_{150}P_{60}K_{80}$	$N_{160}P_{60}K_{110}$	$N_{70}P_{60}K_{70}$	$N_{60}P_{60}K_{60}$
$N_{110}P_{30}K_{40}$	$N_{150}P_{30}K_{40}$	$N_{160}P_{30}K_{55}$	$N_{70}P_{30}K_{35}$	$N_{60}P_{30}K_{30}$
$N_{110}P_{60}K_{40}$	$N_{150}P_{60}K_{40}$	$N_{160}P_{60}K_{55}$	$N_{70}P_{60}K_{35}$	$N_{60}P_{60}K_{30}$
$N_{110}P_{30}K_{80}$	$N_{150}P_{30}K_{80}$	$N_{160}P_{30}K_{110}$	$N_{70}P_{30}K_{70}$	$N_{60}P_{30}K_{60}$

All calculations and observations were carried out according to generally accepted methods. Harvesting of winter wheat was carried out by applying direct combine harvesting method, separately in each plot [5].

Fertilizers were applied as ammonium nitrate, superphosphate granules and potassium chloride.

Research Results. As a result of the conducted conducted research, it was found out that applying fertilizers in the norm of $N_{150}P_{60}K_{80}$ enabled to get the highest yield, which was in 2011 – 7.28 t/ha (fig. 2). This ensured a yield capacity growth by 3.81 t/ha or 109% compared to the control fertilizer-free with the yield capacity respectively 3.47 t/ha.

In 2011 the closest to the best option was the yield of wheat due to application of half-norm of potassium and full-norm of nitrogen and phosphorus ($N_{150}P_{60}K_{40}$). The productivity growth relative to the control was 3.65 t/ha or 105% in this option. Half-norm compensation of phosphorus removal with full-norms of nitrogen and potassium ($N_{150}P_{30}K_{80}$) provided, though inessential, but relatively less within both options, yield capacity increase – 3.42 t/ha or 99%. Basing on this, it can be concluded that phosphorus is more important for winter wheat yield formation than potassium. Evidence of this is the comparison of the options $N_{150}K_{80}$ and $N_{150}P_{60}$. Their yields is 6.52 and 6.74 t/ha respectively, the difference between the options is 0.22 t/ha.

However, the wheat yield is affected by applying of nitrogen fertilizers. Comparing the crop capacity of winter wheat within the option including the application of N_{75}, N_{150} and $P_{60}K_{80}$, it can be concluded that the applying of half-norm of nitrogen separately is not compatible only with the second option of simultaneous

full-norm applying of phosphorus and potassium together (5.14 vs. 4.36 t/ha), but it dominates significantly. Applying of full-norm of nitrogen (N_{150}) provided the yield of 6.32 t/ha and a significant advantage over both neighbouring options.

2. Crop capacity of winter wheat and payback of fertilizers depending on the types and norms of their application in 2011

Experiment option	Crop capacity, t/ha	Increase in productivity		Payback for 1 kg of fertilizer ($N+P_2O_5+K_2O$), kg of grain
		t/ha	%	
Without fertilizer (control)	3,47	–	–	–
N_{75}	5,14	1,67	48	22,3
N_{150}	6,32	2,85	82	19,0
$P_{60}K_{80}$	4,36	0,89	25	6,4
$N_{150}K_{80}$	6,52	3,05	88	13,9
$N_{150}P_{60}$	6,74	3,27	94	15,6
$N_{75}P_{30}K_{40}$	5,67	2,20	63	15,2
$N_{150}P_{60}K_{80}$	7,28	3,81	110	13,1
$N_{150}P_{30}K_{40}$	6,83	3,36	97	15,3
$N_{150}P_{60}K_{40}$	7,12	3,65	105	14,6
$N_{150}P_{30}K_{80}$	6,89	3,42	99	13,2
HIP_{05}	*0,57*	–		

The comparison of the options N_{75} and $N_{75}P_{30}K_{40}$ shows a smaller effect of phosphorus and potassium on the crop capacity of winter wheat. Their crop capacity was 5.14 and 5.67t/ha respectively. So, the application of lower than a half-norm of nitrogen half-norms of phosphorus and potassium provided the yield growth to 0.53 t/ha, which wass only 10%, whereas the increase after the further application of N_{75} (comparison of the options $N_{75}P_{30}K_{40}$ and $N_{150}P_{30}K_{40}$) provided a significant increase in productivity – to 1.16 t/ha or 21%.

The comparison of the all options to the control in 2011 indicates their significant advantage (or even of the option $P_{60}K_{80}$, which was characterized by the worst indices).

In general, in 2011considering the index of crop capacity on the level of better option (with full compensation of the estimated remove of the main nutrition constituents with yield ($N_{150}P_{60}K_{80}$)) there were options with the complex application of a half-norm of phosphorus and potassium combining it with full-norm application of nitrogen and also compatible application of only full-norms of nitrogen and phosphorus. Other options were characterized as significantly worse in comparison with the best option in the experiment.

It is known that the evaluation of the fertilizing system of both in crop rotation and individual crops is carried out not only in accordance with the level of yield growth. Among the important indicators there are preservation and all possible increase of soil fertility, environmental protection, and payback of costs for fertilizer application. To calculate the last index it is important to know the payback of a crop increase of unit of active substance of applied fertilizers.

The payback of the fertilizer application is determined by the division of the yield increase on the quantity of applied fertilizers. Therefore, the greater is the yield increase at a less usage of fertilizer, the higher is their payback from the harvest. In 2011 the highest payback was made from applying of nitrogen. Option N_{75} has provided the highest indices of payback – 22.3 kg/kg. Application of full-norm of compensation for nitrogen removing by yield (N_{150}) was the closest to the best option and it provided a payback at a level of 19.0 kg/kg.

The option, characterized by the highest obtained yield indices ($N_{150}P_{60}K_{80}$), in terms of return of applied fertilizers was not the best, because of a large number of applied fertilizers. The indices were 13.1 kg/kg. At the level of this option there were also the indices of the option $N_{150}P_{30}K_{80}$ -13,2 kg/ha. The reason for this, we believe, is a low payback rate from fertilizers applied, the rate of which in both cases was 80 kg/ha. Similar to these indicators there was also another option, which included a full-norm of potassium application – $N_{150}K_{80}$. Thus, the payback was 13.9 kg/kg in 2011. Comparing to the above-described, advantage of this option is due to the high payback of the application of nitrogen fertilizers.

The combination of potassium with phosphorus applied in full norms ($P_{60}K_{80}$) in 2011 gave the worst results in terms of payback from the obtained yield (6.4 kg/kg). The reason for this, in our opinion, is the application of potassium, but not phosphorus as a combination of full norms of nitrogen and phosphorus ($N_{150}P_{60}$) provided a significantly higher return (15.6 kg/kg) compared with the option of a combination of nitrogen and potassium ($N_{150}K_{80}$), which provided a payback at 13.9 kg/kg. The evidence of a greater importance of phosphorus than potassium is also in a comparison of the last two options, where for a full compensation of nitrogen removing, a full norm of phosphorus and a half-norm of potassium ($N_{150}P_{60}K_{40}$) was applied, and then vice versa ($N_{150}P_{30}K_{80}$). Thus payback decreased from 14.6 to 13.2 kg/kg.

In 2012, similar to the last year, the control option was characterized by the lowest yield of winter wheat, where no fertilizers were applied and it was 2.59 t/ha (fig. 3). The worst among the researched options was the option with application of full-norm of phosphorus with no potassium oxide (3.65 t/ha). The option of applying a half-norm of nitrogen separately, dominated insignificantly over it (N_{75}). Thus the yield was 3.76 t/ha.

A substantial increase to the full application norm of nitrogen fertilizer for winter wheat resulted in further essential increase. Full compensation of nitrogen removing by the crop provided a crop capacity of 4.51 t/ha. The grain gathering increased only by one centner per hectare at a full compensation of removing and application of potassium (up to 4.62 t/ha). The application of full-norm of nitrogen and phosphorus provided yield at a level og 5.81 t/ha, consequently, on the level of the best options of the experiment in 2012.

3. Crop capacity of winter wheat and payback of fertilizers depending on the types and norms of their application in 2012

Experiment option	Crop capacity, t/ha	Increase in productivity		Payback for 1 kg of fertilizer ($N+P_2O_5+K_2O$), kg of grain
		t/ha	%	
Without fertilizer (control)	2,59	–	–	–
N_{75}	3,76	1,17	45	15,6
N_{150}	4,51	1,92	74	12,8
$P_{60}K_{80}$	3,65	1,06	41	7,5
$N_{150}K_{80}$	4,62	2,03	78	9,2
$N_{150}P_{60}$	5,81	3,22	124	15,3
$N_{75}P_{30}K_{40}$	4,77	2,18	84	15,0
$N_{150}P_{60}K_{80}$	6,36	3,77	145	13,0
$N_{150}P_{30}K_{40}$	5,78	3,19	123	14,5
$N_{150}P_{60}K_{40}$	6,05	3,46	134	13,8
$N_{150}P_{30}K_{80}$	6,04	3,45	133	13,3
HIP_{05}	*0,31*	–		

At the level of the option with the application of a full-norm of nitrogen fertilizer there was also an option of applying a half of the calculated remove of basic nutrient compounds by the crop ($N_{75}P_{30}K_{40}$). In this option the yield was 4.77 t/ha, which prevailed the indices of the control option up to 2.18 t/ha or 84%.

The highest grain yield of winter wheat was 6.36 t/ha or 145% in the option of full compensation of the removing by crop ($N_{150}P_{60}K_{80}$) from that of the control variant. There was the yield obtained in the option of full nitrogen and phosphorus compensation with potassium half compensation norm (6.05 t/ha) within the fault of the research regarding the above mentioned option. Almost the same crop capacity was estimated with the option $N_{150}P_{30}K_{80}$ (6.04 t/ha). The advantage of these options over the control was 134 and 133% respectively.

The payback from the applied fertilizers was the lowest at applying $P_{60}K_{80}$ and in 2012 it was 7.5 kg/kg. The nearest to this index there were the indices of applying full norms of nitrogen and potassium ($N_{150}K_{80}$), the payback of which was 9.2 kg/kg. Similar to the last year, the highest payback was obtained of 75 kg/ha of nitrogen (15.6 kg/kg), but the full norm of nitrogen was not the best option and its payback was only 12.8 kg/kg. Instead, one of the best option was a half-norm compensation of all the nutrients ($N_{75}P_{30}K_{40}$), the payback of which was 15.0 kg/kg. We cannot estimate the importance of a balanced application of all the nutrients in extreme conditions of the year 2012 because of the option of full-norm application of nitrogen and phosphorus ($N_{150}P_{60}$), the payback of which was 15.3 kg/kg. However, the

payback of the option of application of a half-norm of phosphorus and potassium with a full-norm application of nitrogen ($N_{150}P_{30}K_{40}$) was higher than the payback of the last two options ($N_{150}P_{60}K_{40}$ and $N_{150}P_{30}K_{80}$), indicating a greater importance in the formation of winter wheat crop capacity more with the application of nitrogen than with phosphorus and potassium. The payback of these options was 14.5, 13.8 and 13.3 kg/kg respectively. The comparison of the last two options also indicates a higher importance of phosphorus compared to potassium in the formation of wheat yield.

The comparison of two years of research shows that the weather conditions influenced significantly the growth of winter wheat plants and, as a result, its yield in the experiment. In particular, the yield was 3.47 and 2.59 t/ha on the control plots in 2011 and 2012 respectively. The highest yield indices differed significantly and were respectively 7.28 and 6.36 t/ha. A greater variability by year both in 2011 and 2012 above mentioned options showed because of separate application of nitrogen N_{75} and N_{150}. The yield was respectively 5.14, 6.32 and 3.76, 4.51 t/ha. A separate application of nitrogen leads to a sharper decrease of the crop capacity in an unfavourable year comparing to full compensation of removing or with no applied fertilizer.

In general, the correlation between the crop capacities is stable within the options of each year except for the last two options. It should also be noted that the yield of winter wheat of the option in the experiment of 2012 was also affected by the preceding fertilization applied for soybeans.

Conclusions. The crop capacity of winter wheat on podzolized chernozem of the Right-Bank Forest-Steppe depends significantly on the level of applied fertilizer while its growing and how well the estimated removing by the crop is compensated, so high its indices will be. First of all, it is necessary to compensate the removing of nitrogen with lack of funds of domestic economy, then phosphorus, and after all – potassium. The payback of the applied fertilizers was the highest at the least applying of nitrogen fertilizer.

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В статье Г.М. Господаренка, Н.Б. Ещенко в результате проведенных исследований установлено, что урожайность озимой пшеницы на черноземе оподзоленном Правобережной Лесостепи существенно зависит от уровня применения удобрений при ее выращивании.

Наивысшая урожайность была при внесении $N_{150}P_{60}K_{80}$ и составила в среднем за два года 6,8 т/га. Наименьшее снижение урожайности зафиксировано при внесении половинной нормы калия на фоне полных норм азота и фосфора. Высокая урожайность сформирована также при внесении только полных норм азота и фосфора без калия вообще.

По показателю окупаемости в оба года, лучшими оказались варианты с половинной нормой азота (N_{75}) каждый килограмм которых окупился в среднем за два года 18,9 кг зерна. Ближайший к этому показателю была окупаемость удобрений в варианте совместного применения азота и фосфора.

Самая низкая урожайность и окупаемость удобрений была при совместном применении полных норм фосфора и калия ($P_{60}K_{80}$) и составила в среднем за два года исследований соответственно 4,0 т/га и 6,8 кг/кг.

Следовательно, при выращивании озимой пшеницы нужно в первую очередь обеспечить потребность в азоте, затем в фосфоре и в последнюю очередь калии.

Ключевые слова: *пшеница озимая, минеральные удобрения, урожайность, окупаемость.*

In the article of G.M. Gospodarenko, N.B. Eshchenko as a result of the research was found that the yield of winter wheat on the Right-Bank Forest-Steppe chernozem podzolized significantly depends on the level of fertilizer application during its cultivation.

The highest yield was after applying $N_{150}P_{60}K_{80}$ and averaged over two years 6.8 t/ha. The smallest decrease of yield observed after adding half-norm of potassium against the background of full norms of nitrogen and phosphorus. High yields are also formed when adding a full norms of nitrogen and phosphorus without potassium at all.

In terms of payback in two years the best options were with a half-norm nitrogen (N_{75}), each kilogram are paid off in two years, 18.9 kg/kg. Nearest to these indicators was payback of fertilizers in the variant of combined application of nitrogen and phosphorus.

The lowest yield and payback of fertilizer was compatible with the full application of phosphorus and potassium ($P_{60}K_{80}$) is averaged over two years 4.0 t/ha and 6.8 kg/ha.

So, when growing winter wheat, first should be provided the need in nitrogen, phosphorus, and at least potassium.

Key words: *winter wheat, mineral fertilizer, yield, payback.*