С. І. Бурикіна[1]
Кандидат с. –г. наук
А.І. Кривенко[1]
Доктор с.-г. наук
[1]Одеська державна сільськогосподарська дослідна станція ІВПіМ НААН України
Г. Капустіна[2]
Кандидат с. –г. наук
[2]Одеська філія ДУ «Інститут охорони ґрунтів України»
В. В. Гамаюнова[3]
Доктор с.-г. наук, професор
[3]Миколаївський національний аграрний університет

EFFICIENCY OF WINTER WHEAT FERTILIZATION SYSTEMS IN THE STEPPE ZONE OF SOUTHERN UKRAINE

(Эффективность систем удобрения озимой пшеницы в степной зоне юга украины)

Introduction

Agriculture in Ukraine accounts for up to 25 % of the country's national income and its products account for up to 15 % of total exports, with the majority of both production and export accounted for by winter wheat grain. According to experts, the export potential of Ukraine can be almost doubled by optimizing the growing area and increasing the yield (Fedulova, 2011; Serdyuk, 2012)

In the last decade, the sown area of wheat in Ukraine has stabilized at the level of 6.3-6.8 million hectares, of which 52.8% of the total area is sown in the Steppe zone, including in the Odessa region – 17.5% , Mykolaiv-12.1% and Kherson-13.1% [Kiev,2020]. A powerful factor in increasing productivity is the application of mineral fertilizers, the norms and ratios of which are established experimentally for the soil and climatic zones of Ukraine (Poperelya, Chervonis, Litvinenko, Sokolov, 2008)

In Germany, when systematizing long-term data [(1979 -2016) of stationary experiment with different doses of nitrogen fertilizers [Heil, Lehner, Schmidhalter, 2020], it was shown that different levels of nitrogen fertilizers change the response of plants to drought: reducing the amount of nitrogen fertilizers by 20-30% reduces the sensitivity to the absence of precipitation. Scientists of Kharkiv National University conducted an analysis of winter wheat yield over a 37-year period ([Kobchenko, Kobchenko, Rezunenko, 2014), which showed a high degree of correlation (r = 0.67-0.85) between the effectiveness of fertilizers, weather conditions and crop productivity.

Thus, the research of scientists has shown that the variability of weather and climatic conditions is the cause of significant variability in the yield of grain crops and the payback of fertilizers. In statistical studies to determine the degree of influence of climate factors on the productivity of grain crops, the results of temporary field experiments were mainly used, and large samples were based on official data in general for regions, regions or countries. At the same time, studies based on the results of long-term stationary experiments can be of high theoretical importance for crop production in certain soil and climatic zones and economically strategic, since it will allow predicting the volume of gross grain production.

Material and Methods

To determine the effectiveness of fertilizers on winter wheat crops in the weather conditions of the Black Sea steppe, we systematized the data of the field stationary experiment for two rotations of the grain of the fallow crop rotation (2007-2020). During these years the fertilizer systems for the variants of the experiment did not change, the wheat variety was sown . Knopa, the alternation of crops in the crop rotations was constant. Winter wheat was sown according to the following predecessors: black fallow, sideral fallow, wheat after sideral fallow and winter rapeseed.

Soil southern chernozem low-humus heavy-loamy on loess. Fertilizer options are given in the presentation of the results.

Agronomic efficiency was calculated as the amount of additional grain yield per unit of applied fertilizers (Instructions…, 1987). To characterize the economic efficiency, we determined the net income per 1 dollar of the costs associated with the use of fertilizers. At the same time, the cost of the crop increase obtained from fertilizers and the costs of their acquisition and application were taken into account. The actual volume of work performed was taken into account on the basis of technological maps at prices at the end of 2020 (Statistics …,2020; Mazorenko, Mazneva, 2006; Monitoring of prices…,2020). If necessary, we used the official data of the State Statistics Committee (Agriculture of Ukraine, 2020; Agricultural sales, 2020).

The energy assessment of fertilizer systems was carried out through the energy efficiency coefficient (C_{ee}), that is, the ratio of the amount of renewable energy accumulated in the increase in yield to the total cost of anthropogenic energy for the formation of this increase (Medvedovsky, Ivanenko,1988; Ushkarenko, Laser, Ostapenko, Boyko, 1997).

As an indicator of aridity, the hydrothermal coefficient of G. T. Selyaninov (HTC) was used, which is the ratio between the amount of precipitation for the period when the air temperature was above 100C and the sum of active temperatures for the same period, reduced by 10 times. Climate scientists have established the following criteria for characterizing drought: HTC <0.4 - very severe drought; from 0.4 to 0.5-severe drought; from 0.5 to 0.6-average drought; HTC from 0.7 to 0.9-mild drought; from 1.0 to 1.5-fairly wet, HTC > 1.5-excessively wet (Kulbida, Barabash, 2009).

The results were processed statistically using the Microsoft Excel software package for personal computers. The arithmetic mean and standard error were determined. The significance of the differences between the control and experimental variants was evaluated according to the Student's criterion and the lightest significant difference (LSD) was considered significant differences, where $P < 0.05$ (Dospekhov,1971; Ushkarenko, Nikishenko, Goloborodko, Kokovikhin,2008).

. Precipitation mode analysis during 2007-2020 are presented in Table 1. The average amount of precipitation for the agricultural year was 443.3 mm. The number of cases when this indicator is out of range ($m_{average}$ $+\sigma$) is equal to the number of cases located in the range ($m_{average}$- σ), which, with almost no asymmetry (-0.16), indicates a uniform distribution of data relative to the average, the coefficient of variability is 28.3%.

Table 1:- **Characteristics of the precipitation regime during the research period**

Indicator	Precipitation,mm				The number of days with precipitation							
					in total				less than 5 mm, % of the total Indicator			
	1	2	3	4	1	2	3	4	1	2	3	4
Average	443,3	145,9	128,7	95,8	52,5	18,4	11,5	16,6	47,3	43,5	45,1	55,6
Standard error	33,5	20,5	18,4	11,3	4,3	2,1	1,0	2,0	4,2	6,4	6,6	5,9
Standard deviation	125,4	76,7	68,9	42,2	15,9	7,8	3,8	7,5	15,6	24,0	24,6	22,2
Kurtosis	-0,76	-1,37	0,59	-0,26	-0,99	1,1	-0,06	5,0	0,53	-0,52	0,96	0,39
Asymmetry	-0,16	0,46	0,5	0,37	0,32	1,17	0,73	1,65	0,59	0,71	0,64	0,14
Minimum value	232,5	56,0	12,4	32,7	30	9	6	5	21,1	13,4	3	11,1
Maximum value	616,1	262,8	280	180	82	37	19	38	81,7	90	100	94,4
Coefficient of variation	28,3	52,6	55,3	44,1	30,3	42,5	33,2	45,5	33,0	55,1	54,6	39,9

1- . 1 - agricultural year; 2 - the period of spring-summer vegetation before harvesting; 3-autumn; 4-winter.

Results and Discussion

The calculations carried out for each of the predecessors showed that at different levels of yield, in the increments according to the norms of fertilizers, the pattern was not determined by the predecessor, but only by weather conditions, doses and the ratio of nutrients in the fertilizer systems. Therefore, we considered it appropriate in the future to operate with data averaged over the predecessors. Table 2 shows the average yield of wheat by fertilizer options over the years of the study.

In the non-fertilized variant, the winter wheat grain yield averaged 3.32 t / he over 14 years, the difference with the fertilization systems ranged from +1.00 t / he to + 2.24 t / he, which was mathematically reliable since $LSD_{0.95}$ = 0.64 t / he. The variability of the yield over the years was great: from 44.4% to 26.7%, but the most dependent on the conditions of the year was the option without fertilization (44.4%) and the option where only phosphorus - potassium fertilizers were applied during all the years of research (36.6%). The degree of variation in the yield of winter wheat also depended on the rate of

Table 2: - **Winter wheat yield by fertilizer system options, t / he (2007-2020)**

Variant	Years														average
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
control	3,58	5,53	4,18	4,19	3,37	3,40	4,20	2,95	2,10	5,55	2,77	1,39	2,17	1,13	3,32
$P_{60}K_{60}$	4,36	6,91	5,90	5,29	4,71	3,85	510	3,60	3,60	5,94	3,75	2,41	2,70	2,36	4,32
N_{60}	4,64	7,13	5,23	5,25	4,92	4,40	5,25	3,65	2,53	5,79	3,50	3,06	3,37	2,20	4,35
$N_{60}P_{60}$	4,31	7,19	5,75	5,69	5,25	4,49	5,64	3,66	3,19	6,21	4,03	3,02	2,89	1,85	4,51
$N_{60}K_{60}$	4,68	6,36	5,77	5,59	5,25	4,76	5,58	3,67	3,08	6,06	3,98	2,26	3,22	2,40	4,48
$N_{60}P_{30}K_{30}$	4,53	7,19	5,47	5,58	5,46	4,36	5,25	3,99	3,04	6,64	3,88	2,95	3,35	2,44	4,58
$N_{60}P_{60}K_{60}$	4,24	7,41	5,65	5,98	5,43	5,10	5,76	3,86	3,41	6,71	4,38	3,53	3,39	2,11	4,78
N_{120}	4,41	7,22	5,92	6,10	6,21	5,03	5,83	3,96	3,70	7,13	4,55	3,78	4,11	2,27	5,02
$N_{120}P_{30}K_{30}$	4,35	7,15	5,73	6,05	5,88	4,67	5,91	4,22	3,56	7,36	5,32	3,61	3,92	2,70	5,03
$N_{120}P_{30}K_{60}$	4,39	7,15	5,71	6,49	6,05	4,80	5,90	4,02	3,58	7,10	5,83	3,64	3,84	2,71	5,09
$N_{120}P_{60}K_{30}$	4,70	7,33	5,98	6,87	6,11	4,89	5,90	3,94	3,60	7,40	6,17	4,04	4,02	2,97	5,28
$N_{120}P_{60}K_{60}$	4,36	7,41	5,85	6,64	6,06	5,19	5,89	4,09	3,74	7,52	5,90	3,84	4,24	2,18	5,21
N_{180}	3,63	6,87	5,53	6,60	6,26	5,77	6,03	4,34	4,05	7,99	5,37	4,60	3,68	2,92	5,26
$N_{180}P_{60}$	4,48	7,08	5,67	6,56	6,07	5,66	5,76	4,06	3,56	6,98	4,49	4,02	4,08	2,87	5,10
$N_{180}K_{60}$	4,08	6,94	6,25	6,17	6,00	5,38	5,77	4,09	3,56	7,58	4,71	4,15	4,09	3,05	5,13
$N_{180}P_{30}K_{30}$	4,42	7,36	6,21	6,67	6,42	4,45	6,29	4,02	3,94	7,83	6,18	4,45	3,87	2,92	5,36
$N_{180}P_{60}K_{60}$	4,00	7,69	5,99	7,23	6,54	5,82	6,37	4,15	4,10	8,38	6,32	4,26	4,09	2,96	5,56
$LSD_{0,95}$															0,64

nitrogen fertilizer. Thus, in the fertilizer block, where the nitrogen dose was 60 kg / ha, the average coefficient of variation was 32.3% with a variation from 30.4 to 33.8%; with N120 - 29,0% (28,5-29,4%); with N180 - 27.9% with an interval from 26.7% to 29.0%. Thus, there is a tendency to reduce the dependence of the yield level on the growing conditions when applying fertilizers in general, and there is a small, but still present, decrease in the coefficient of variation with an increase in the dose of mineral fertilizers.

The average yield of winter wheat for fertilizer options ranged from 7.15 t/he (2007) to 2.56 t/he (2020).

Table 3: Structure of yield years for the period 2007-2020. According to the data of stationary field experience.

Таблица 3: - **Структура урожайности лет за период 2007-2020 гг. По данным стационарного полевого опыта.**

Yield, t/he		Years	Number of years		Average yield on the option without fertilizers
average	range of fluctuations		in total	% of the total number of years	
7,10	7,04-7,15	2008, 2016	2	14,3	5,54
5,88	5,76-6,17	2009, 2010, 2011, 2013	4	28,6	3,99
4,72	4,35-4,91	2007, 2012, 2017	3	21,4	3,25
3,69	3,52-3,96	2014, 2015, 2018, 2019	4	28,6	2,15
2,56	-	2020	1	7,1	1,13
in total			14	100	-

* the average amount of NPK = 180 kg/ha for the fertilizer variants with the ratio (1.9:0.6:0.6), if 1= 60 kg / he

Among the 14 years, we identified years with similar yield levels, which are presented in Table 3. During the study period, only two years (14.3%) were marked by a high level of yield (7.00 t/he) and one year the grain yield was the lowest – 2.56 t/he. A relatively high agronomic efficiency was observed at the average yield level for the fertilizer variants (5.88 t/he) and amounted to 10.5 kg of grain per 1 kg of d.v. NPK, the lowest was at the level of 2.56 t / ha - 7.9 kg/kg (or 24.8% less). With an average grain yield on the fertilized variants of 7.10 t / ha, 4.72 and 3.69 t/ha, the agronomic efficiency was 8.7; 8.2 and 8.6 kg / kg, that is, it differed slightly from each other (within a 5 percent error), and from the maximum was, respectively, 82.9%, 78.1% and 81.9%. The average agronomic efficiency of fertilizers for 2007-2020 is shown in Table 4, and the individual elements of nutrition in Fig. 1 (payback of mineral nitrogen) and Fig. 2 (payback of phosphorus and potassium).

From the data in Table 4, it can be seen that the payback of a unit of winter wheat growth depends on both the rate of application of mineral fertilizer and the ratio of nutrients in it. If we consider blocks of fertilizers with different doses of nitrogen application, the following trends are observed: - the agronomic efficiency of a complete mineral fertilizer is higher, and at half the rate of PK (10.5 kg / kg - $N_{60}P30K_{30}$), higher

Table 4 - **Agronomic efficiency of fertilizer systems depending on the application dose and the ratio of nutrients**

Fertilizer System	Sum N P K	N : P : K 1= 60 kg/he	kg of grain growth per 1 kg of mineral fertilizers
$P_{60}K_{60}$	120	0 : 1 : 1	8,3
$N_{60}P_{60}$	120	1 : 1 : 0	9,9
$N_{60}K_{60}$	120	1 : 0 : 1	9,7
$N_{60}P_{30}K_{30}$	120	1 : 0,5 : 0,5	10,5
$N_{60}P_{60}K_{60}$	180	1 : 1 : 1	8,1
$N_{120}P_{30}K_{30}$	180	2 : 0,5 : 0,5	9,5
$N_{120}P_{30}K_{60}$	210	2 : 0.5 : 1	9,8
$N_{120}P_{60}K_{30}$	210	2 : 1 : 0.5	9,3
$N_{120}P_{60}K_{60}$	240	2 : 1 : 1	7,9
$N_{180}P_{60}$	240	3 : 1 : 0	7,4
$N_{180}K_{60}$	240	3 : 0 : 1	7,5
$N_{180}P_{30}K_{30}$	240	3 : 0,5 : 0,5	8,5
$N_{180}P_{60}K_{60}$	300	3 : 1 : 1	7,5

than when applying phosphorus-potassium (8.3 kg / kg), nitrogen-phosphorus (9.9 - $N_{60}P_{60}$) and nitrogen - potassium fertilizers (9.7 - $N_{60}K_{60}$). With an increase in the nitrogen rate, the payback of a unit of the active substance NPK at the same rate of PK decreases (at $N_{180}P_{30}K_{30}$-81.0% of $N_{60}P_{30}K_{30}$, at $N_{120}P_{30}K_{30}$-90.5%, with the introduction of $N_{180}P_{60}K_{60}$, the decrease is 7.4% against the dose of $N_{60}P_{60}K_{60}$, and at N_{120} against the same background PK-2.5%.

According to of Shevchenko M. S., Shevchenko S. M. and Polenok A.V., increasing the dose of fertilizers for winter wheat from $N_{60}P_{30}$ to $N_{80}P_{40}$ even under irrigation conditions on chestnut soils of the Kherson region was impractical, since the increase was at the level of 0.06-0.12 t / ha and did not justify itself economically (Shevchenko, Shevchenko, Polenok, 2019). According to the standards of the FAO, the optimal payback is 10 kg of grain per 1 kg of NPK (FAO).

The average recoupment of mineral nitrogen over 14 years of observations naturally decreases with an increase in the application dose from 60 kg / ha to 180 kg / ha (Fig. 1), and at the same dose - the agronomic efficiency of pure nitrogen is higher than

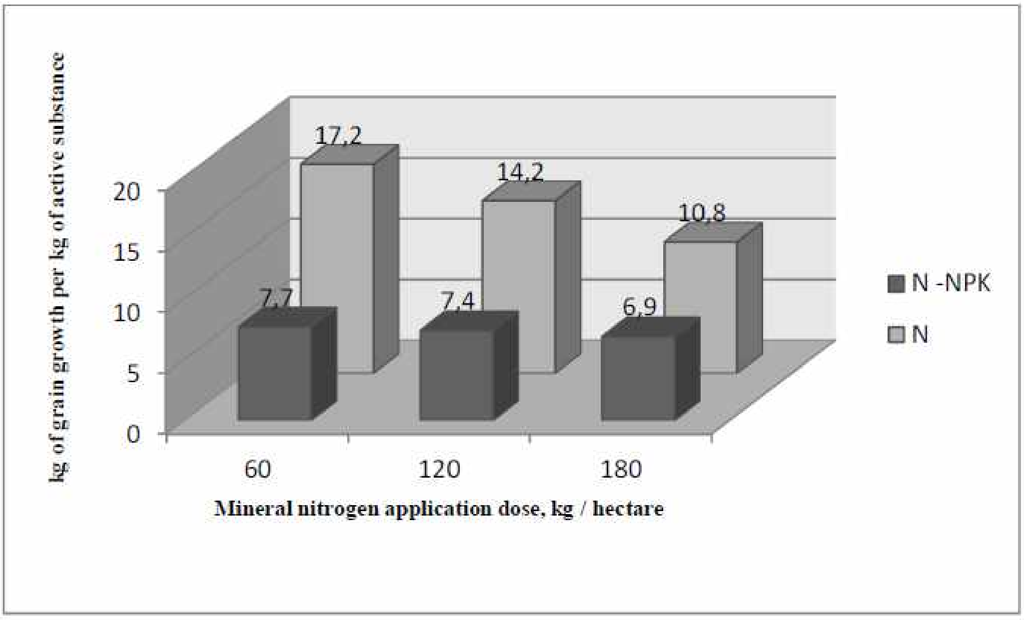

Fig.: 1**: Agronomic efficiency of mineral nitrogen with separate application and as part of a complete mineral fertilizer (average for 2007-2020)**

nitrogen in the composition of a complete mineral fertilizer: 2.2 times, 1.9 times and 1.6 times, respectively, the norms of 60,120 and 180 kg/ha. The average efficiency of phosphorus and potassium over a 14-year period (Fig. 2) at the rate of their application of 60 kg / ha was directly dependent on the dose of mineral nitrogen (r = 0.98) and with a nitrogen dose of 60 kg/he was 5.0 - 4.5 kg / kg, and at 180 kg/he-7.2-7.7 kg / ha.

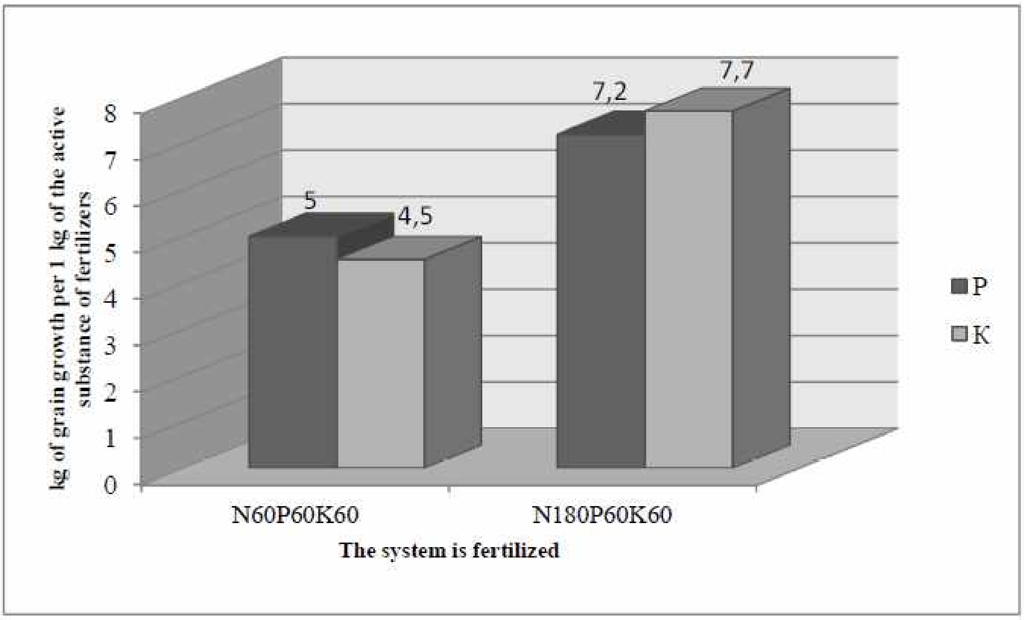

Fig. 2: **Agronomic efficiency of phosphorus and potassium at different nitrogen doses (average for 2007-2020)**

Assessment of the energy efficiency of winter wheat cultivation according to different predecessors (Table. 5) showed that the total energy costs differed little in all variants and ranged from 18.45 GJ/ha (the precursor of winter rapeseed) up to 20.67 GJ / ha (the precursor is black fallow). The difference is mainly due to the cost of transporting different volumes of grain from the combine and for their primary processing (cleaning of weed impurities). In addition, when growing winter wheat in re-sowing after sideral fallow, there were additional costs for protective equipment (ground beetle), this option also had the smallest energy return (Cee = 2.86).

The maximum coefficient of energy efficiency was observed when growing winter wheat on black fallow (4.69) and it was almost the same when it was placed on the sideral fallow, where winter vetch was used for sideration (4.68). The recoupment of energy in the cultivation of winter wheat after cruciferous crops occupies an average position, regardless of whether a representative of this genus is used for sideration (mustard, Cee = 3.78) or as an independent crop, such as winter rapeseed (Cee-3.89).

Table 5: - **Energy assessment of winter wheat cultivation technology depending on the predecessor (2007-2020)**

Indicator	The precursor of				
	fallow			winter rapeseed	winter wheat
	black	sideral			
		vetch winter	mustard		
Average yield by fertilizer systems, t / ha	**5,89**	**5,52**	**3,98**	**4,36**	**3,32**
Energy yield with yield, GJ / ha	**96,90**	**90,81**	**65,48**	**71,73**	**54,62**
Total energy consumption, GJ / ha	**20,67**	**19,38**	**17,32**	**18,45**	**19,10**
Energy Efficiency Coefficient (Cee)	**4,69**	**4,68**	**3,78**	**3,89**	**2,86**

The energy and economic efficiency of fertilizer systems was determined by the amount of increase in the yield of winter wheat, which they provided. Table 6 shows the efficiency parameters generalized by the blocks of mineral nitrogen application doses. If fertilizer systems with an energy efficiency coefficient ≥ 2.0 are considered resource-

Table 6: **- Economic and energy efficiency of fertilizers at different doses of mineral nitrogen, taking into account the precursors**

Yield growth, t / ha	Average Cee values for fertilizer system blocks											
	N_{60}	N_{120}	N_{180}	N_{60}	N_{120}	N_{180}	N_{60}	N_{120}	N_{180}	N_{60}	N_{120}	N_{180}
	fallow black			fallow sideral			winter rapeseed			winter wheat		
3,5-4,0	-	4,45	3,82	-	5,45	4,10	-	5,37	4,04	-	-	-
3,0-3,5	-	4,08	-	-	4,32	3,39	-	4,74	3,57	-	-	-
2,5-3,0	-	3,82	3,13	6,76	3,85	2,90	7,10	4,12	2,90	-	-	-
2,0-2,5	6,93	3,22	2,62	5,88	3,15	2,35	6,13	3,43	2,32	5,50	3,20	2,32
1,5-2,0	4,45	2,36	2,20	4,95	2,92	1,82	4,92	2,87	1,80	4,50	2,45	1,82
1,0-1,5	3,69	1,76	1,75	3,49	2,15	1,40	3,53	2,12	1,52	3,80	2,11	1,35
0,5-1,0	-	1,45	1,50	2,28	1,77	0,65	2,47	1,51	0,81	2,90	1,58	0,8
≤0,5	1,76	-	-	1,05	0,71	0,27	1,33	-	-	1,63	-	-
Average yield on the option without fertilizers, t / ha												
4,50				3,91			3,11			1,84		
Net profit, USD/USD												
Yield growth, t/ ha	N_{60}	N_{120}	N_{180}	N_{60}	N_{120}	N_{180}	N_{60}	N_{120}	N_{180}	N_{60}	N_{120}	N_{180}
	fallow black			fallow sideral			winter rapeseed			winter wheat		
3,5-4,0	-	2,36	2,04	-	2,41	2,47	-	3,21	2,43	-	-	-
3,0-3,5	-	2,20	-	-	2,34	1,95	-	2,36	1,38	-	-	-
2,5-3,0	-	1,61	1,30	3,0	1,54	1,45	2,69	1,89	1,14	-	-	-
2,0-2,5	1,74	0,93	1,15	2,0	1,62	1,34	2,92	1,19	0,80	1,41	0,92	0,97
1,5-2,0	0,78	0,78	0,51	1,20	0,93	0,83	2,10	0,52	0,47	0,87	0,39	0,40
1,0-1,5	0,69	0,30	0,14	0,80	0,66	0,46	1,36	0,36	-0,19	1,01	0,10	0,11
0,5-1,0	-	-0,16	-0,23	-0,43	-0,24	-0,28	0,55	-0,08	-0,34	0,26	-0,16	-0,44
≤0,5	0,18	-	-0,68	-0,63	-0,70	-0,78	0,18	-	-	-0,20	-	-

saving (Methods..., 2000), then the use of N60 at different ratios of batteries for all predecessors has a Cee from 2.47 to 6.93; at the same time, it is economically justified provided that it provides crop gains from 1.0 t / ha to 2.5 t / ha and with a net profit of 69 cents to $ 2.92 per dollar of costs. The probability of obtaining such increases reaches 75-

80% when growing wheat for sideral fallow and winter rapeseed and 67.9-51.6% - for black fallow and winter wheat, which went after sideration; for the first two predecessors, fertilizer systems with N60 can provide a maximum yield increase of 2.5-3.0 t / ha, but the frequency of such cases is low (10.7-7.5%).

Fertilizer systems with N120 and N180 in 40% of cases, when placing winter wheat crops in pairs and winter rapeseed, give an increase in its grain yield from 2.5 t / ha to 3.5 t /ha and a net profit from 0.8 to 3.21$/$. If winter wheat is grown in repeated sowings on sideral fallow, then according to fertilizer systems with N120-180, the yield increase is 1.0-2.5 t / ha in 83.7-95% of cases, but the net profit is 0.92-0.97 USD/USD. it is noted only at the upper limit of the increase (2.0-2.5 t / ha), which happens in three cases out of ten, and the yield increase of less than 2.0 t/ha provides in this case only from 10 to 40 cents per dollar of costs. Almost all fertilizer systems and on a good predecessor are unprofitable, if the increase in the yield of wheat grain when using them does not exceed 1.0 t/ha.

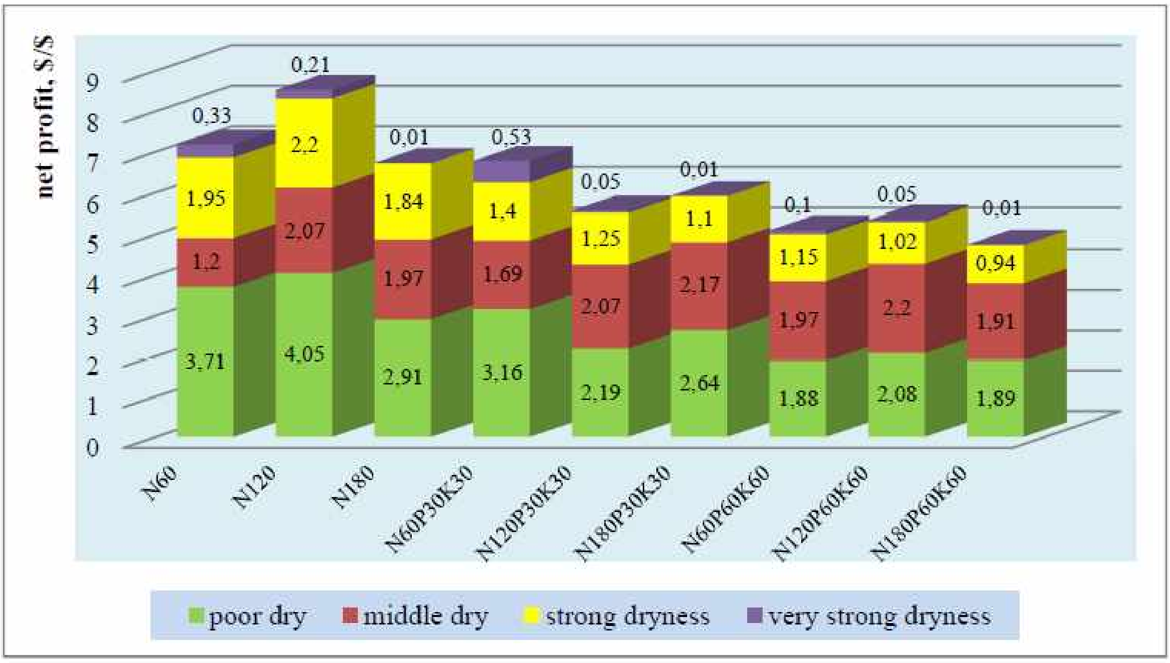

Fig. 3: - **Payback of 1 $, invested in mineral fertilizers, $ of net profit with a dry of varying degrees in May and April**

The economic efficiency of fertilizer systems also depended on the hydrothermal conditions of the spring vegetation of winter wheat (Fig. 3): the higher the degree of aridity, that is, the lower the hydrothermal coefficient, the lower the profit received from the use of fertilizers.

It should also be noted that when using fertilizer systems with the inclusion of $N_{120-180}$, the quality of winter wheat grain was very high and exceeded the requirements of the regulatory document for the first class: the concentration of protein ranged from 14.5 to 17.5%, and gluten-from 28 to 40%. But this had little effect on economic efficiency, since the price difference between the third and first class did not exceed $ 7-11, and the protein content above 14% was not taken into account at all, while the cost of fertilizers is constantly growing [20,21]. Thus, without changing the price policy of the state, the use of high rates of fertilizers will be economically impractical with increases of less than 1.0 t / ha. With fertilizer systems with N_{60}, the grain quality did not exceed the requirements of the regulatory document for the third class, sometimes, in a particularly dry period of filling, it corresponded to the second.

When choosing a fertilizer system, you should take into account the initial state of fertility and the subsequent effect of fertilizers on the parameters of soil fertility. With a low level of fertility, increased fertilizer rates provide an economically profitable increase in the productivity of winter wheat crops (from + 2.0 t / ha), a net profit of more than $ 1.0 per dollar of costs and a return on energy costs of more than 2 times.

Table 7: **Weighted average parameters of the effectiveness of mineral fertilizer systems on winter wheat crops**

Fertilizer system	**Efficiency**		
	increase, t / ha	**energy, Cee**	**economic, USD/USD**
$N_{60}P_{30-60}K_{30-60}$	**1,52**	**3,63**	**0,98**
$N_{120}P_{30-60}K_{30-60}$	**2,04**	**2,41**	**0,79**
$N_{180}P_{30-60}K_{30-60}$	**2,22**	**2,09**	**0,69**

The weighted average parameters of the efficiency of fertilizer systems for growing winter wheat are shown in Table 7, from which it is obvious that with an increase in the nitrogen dose from 60 kg/ha to 180 kg/ha against the background of P30-60K30-60, crop gains increase from 1.52 t / ha to 2.22 t/ha, but the energy efficiency coefficient decreases, although it remains within the limits that characterize the fertilizer system as resource-saving, and net profit also decreases by $ 1. costs from $ 0.98 to $ 0.69

Conclusions

Thus, the analysis of the results of the 14-year period of winter wheat cultivation showed:

- the agronomic efficiency of the complete mineral fertilizer is higher (10.5 kg / kg - N60P30K30) for the application of phosphorus-potassium (8.3 kg / kg - P60K60), nitrogen - phosphorus (9.9 - N60P60) and nitrogen-potassium fertilizers (9.7-N60K60);

- with an increase in the rate of application of mineral nitrogen, the payback of a unit of active substance NPK with the same rate of RC decreases: against the background of P30K30-from 9.5 % to 19.0%, against the background of P60K60 – from 2.5 % to 7.4%;

- the payback of mineral nitrogen naturally decreases with an increase in the application dose from 60 kg / ha to 180 kg / ha, and at the same rate, the agronomic efficiency of pure nitrogen is higher than nitrogen in the composition of a complete mineral fertilizer: 2.2 times, 1.9 times and 1.6 times, respectively, the norms of 60,120 and 180 kg / ha;

- the efficiency of phosphorus and potassium at the rate of their application of 60 kg / ha is directly dependent on the dose of mineral nitrogen ($r = 0.98$) and with N60 was 5.0-4.5 kg / kg, and with N180-7.2 -7.7 kg / ha ;

- when applying N60, the energy efficiency coefficient ranges from 2.48 to 3.70, depending on the precursor; the use of this nitrogen dose in combination with phosphorus-potassium fertilizers increases the energy payback from 8.1% to 27.0%; a similar trend is observed when using N120 and N180, but the absolute values of the energy efficiency coefficients range from 2.41-3.26, and 1.82-2.56, respectively;

- when growing winter wheat using sideral fallow and winter rapeseed, fertilizer systems with nitrogen norms N120-180 in 40% of cases give winter wheat grain yield increases from 2.5 t / ha to 3.5 t / ha and net profit from 0.8 to 3.21 $/$;

- in repeated sowings of winter wheat on the sideral pair, the net profit of 0.92-0.97 $/$ is noted only at the upper limit of the increase (2.0-2.5 t / ha), which happens in three cases out of ten, in all other cases it is less than 40 cents per dollar.;

- with the current price policy, almost all systems of fertilizing winter wheat, even when it is grown according to a good predecessor, are unprofitable if the increase in grain yield is less than one ton per hectare;

- weighted average indicators of fertilizer efficiency on winter wheat crops are as follows: N60P30-60K30-60-yield increase of 1.52 t / ha; energy efficiency coefficient of 3.63; net profit of 0.98 $/$; N120P30-60K30-60-yield increase of 2.04 t / ha; energy efficiency coefficient of 2.41; net profit of 0.79 $/$; N180P30-60K30-60-yield increase of 2.22 t /ha; energy efficiency coefficient of 2.09; net profit of 0.69$/$.

References

1. Agriculture of Ukraine. Statistical collection. (2020) Kiev: **76-124**.
2. Agricultural sales price indices in 2020. URL: ukrstat.gov.ua.

3. Company "Marker Group" online service of monitoring prices in the market of agricultural resources of Ukraine (2020). URL: http://map.markergroup.info

4.Dospekhov B.A. (1971) Field experiment planning and statistical processing of its data. M .: Kolos.:**207.**

5.Fedulova I. V. (2011) Expert import potential of the agro-industrial complex of Ukraine. Expectations and challenges for the food sector in terms of EU enlargement. Warsaw.: **68-84**.

6.Food and Agricultural Organization-Food and Agriculture Organization of the United Nations. FAO: URL: http://faostat fao.org/site/.

7.Foreign economic activity of Ukraine.URL: http: ukrstat.gov.ua. Website of the State Statistics Committee of Ukraine.

8.Heil K., Lehner A., Schmidhalter Urs. (2020) Development of Wheat Yields in a Long-Term Experiment in an Area with Pleistocene Loess. *Climate*. **8: 100-116.** Doi: 10.3390/cli8090100.

9. Instructions and standards for determining the economic and energy efficiency of fertilization. (1987) Moscow: AgroNIITEIPP: **44.**

10. Kobchenko Yu. F., Kobchenko O. Yu, Rezunenko O. A. (2014) Influence of weather factors on the formation of grain crops in the Kharkiv region. *Bulletin of Kharkiv National University. No. 1098. Series "geology – geography – ecology"*. **40: 86-91.**

11.Kulbida M.I., Barabash M.B.(2009) Climate of Ukraine: in the past ... and the future?: monograph. Moscow: Stal Publ.: **85-98**.

12. Mazorenko D.I., Mazneva G. Ye. (2006) Technological maps and costs of growing crops with different resources. Kharkiv: KhNTUSG. : **725**.

13. Medvedovsky OK, Ivanenko P.I. (1988) Energy analysis of intensive technologies in agricultural production. K.: Yield: **205.**

14.Melnyk A.V., Bychenko K.V. (2013) State and prospects of grains cultivation in the World and Ukraine. *Bulletin of Sumy National Agrarian University*. **11 (26):131-134**.

15. Methods of bioenergy assessment of agricultural systems and agricultural technologies (2000). Kiev.: **48.**

16. Monitoring of prices of mineral fertilizers, official site of the State Institution "Institute of Soil Protection of Ukraine" (2020) URL: http://www.iogu.gov.ua/monitoring/

17.Poperelya F., Chervonis M., Litvinenko M., Sokolov V.(2008) Strategy of growing and using Ukrainian wheat in market conditions. Offer.URL: https://propozitsiya.com/ua/strategiya-viroshchuvannya-i-vikoristannya-ukrayinskoyi-pshenici-v-rinkovih-umovah

18.Serdyuk T. Yu. (2012) General characteristics of foreign economic activity in Ukraine. Businessinform.2:90-93.

19. Statistics of the US dollar exchange rate (2020). URL: https://net.dn.ua/money/stat.php.

20. Ushkarenko V.O., Laser P.N., Ostapenko A.I., Boyko I.O.(1997) Methods for assessing the bioenergy efficiency of crop production technologies. Kherson.: 21.

21. Ushkarenko V.O., Nikishenko V.L., Goloborodko S.P., Kokovikhin S.V.(2008) Dispersion and correlation analysis of the results of field experiments: [textbook]. Kherson: Aylant:372.

Abstract

Обобщены результаты длительного стационарного опыта по изучению эффективности различных систем минеральных удобрений при выращивании пшеницы озимой в полевом севообороте.
Определены средневзвешенные показатели эффективности удобрений на посевах озимой пшеницы : $N_{60}P_{30\text{-}60}K_{30\text{-}60}$ - прирост урожая 1,52 т/га; коэффициент энергетической эффективности 3,63; чистая прибыль 0,98 $/$; $N_{120}P_{30\text{-}60}K_{30\text{-}60}$ -

прирост урожая 2,04 т/га; коэффициент энергетической эффективности 2,41; чистая прибыль 0,79 $/$; $N_{180}P_{30-60}K_{30-60}$ - прирост урожая 2,22 т/га; коэффициент энергетической эффективности 2,09; чистая прибыль 0,69 $/$.