ЗЕМЛЕРОБСТВО І РОСЛИННИЦТВО

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O. P. VOLOSHCHUK, doctor of agricultural sciences
M. S. ZAPISOTSKA, postgraduate
Institute of Agriculture of Carpathian Region of NAAS
Hrushevskoho street, 5, v. Obroshyne, Lviv district, Lviv region,
81115, e-mail: olexandravoloschuk53@gmail.com

INFLUENCE OF MINERAL FERTILIZERS ON GRAIN PRODUCTIVITY OF SOFT WINTER WHEAT PLANTS IN WESTERN FOREST-STEPPE OF UKRAINE

The application of fertilizers for soft winter wheat in conditions of Western region is not always accompanied by a significant return, since the main limiting factors for obtaining high yields are the low content of humus and mobile forms of nutrients, increased acidity and leaching regime. Under such conditions, the level of productivity of gray forestal surface-gleyed soils does not exceed 1.3–1.5 t/ha of grain units. Therefore, for the formation of grain and seeds of high sowing quality, it is necessary to fully supply plants with all nutrients in a certain ratio.

The article presents the research results for 2019–2021 in improving the nutritional system of soft winter wheat plants due to the application rates of various types of mineral fertilizers by stages of organogenesis. The obtained experimental data have confirmed that the optimal supply of plants with mineral fertilizers contributes to the formation of a more powerful root system and aboveground mass, which ensures a better use of nutrients from the soil and fertilizers. In such conditions, plants develop faster, tolerate the influence of negative environmental factors more easily and are more resistant to diseases. It was found that at higher rates of the main application of mineral fertilizers $N_{30}P_{70}K_{120}S_{21}$ and $N_{30}P_{90}K_{160}S_{28}$, the percentage of plants' overwintering was 95.0–95.9 %. The leaf surface area of soft winter wheat varieties in the VIII stage of organogenesis was the highest – 58.9 thous. m^2 at the application rate of $N_{220}P_{90}K_{160}S_{28}$. With the use of mineral fertilizers, the plants showed higher resistance to diseases, so the percentage of powdery mildew damage was lower by 8.1 %, dark brown spot – 3.8, leaves' septoriosis – 8.6, spike's septoriosis and fusariosis – 0.6–1.1 %.

The grain yield of soft winter wheat varieties was formed both under the influence of weather factors and the rates of mineral fertilizers' application. In 2019, this indicator varied from 3.52 t/ha (control) to 7.43 t/ha ($N_{280}P_{110}K_{200}S_{35}$), in 2020, respectively, 2.61–6.07 t/ha, and in 2021 – 2.82–6.51 t/ha. Compared to the control (without fertilizers) by the application rate of mineral fertilizers $N_{168}P_{66}K_{120}S_{21}$ the varieties formed a significantly higher grain yield – 1.66 t/ha, by $N_{224}P_{88}K_{160}S_{28}$ – 2.75 t/ha and by $N_{280}P_{110}K_{200}S_{35}$ – 3.69 t/ha.

Key words: soft winter wheat, variety, rate of mineral fertilizers, plants' overwintering, leaf surface area, disease resistance, grain yield.

Волощук О. П., Запісоцька М. С.
Інститут сільського господарства Карпатського регіону НААН

Вплив мінеральних добрив на зернову продуктивність рослин пшениці м'якої озимої в Західному Лісостепу України

Внесення добрив під пшеницю м'яку озиму в умовах Західного регіону не завжди супроводжується значною віддачею, оскільки основними лімітуючими чинниками отримання високих урожаїв залишаються низький вміст гумусу та рухомих форм поживних речовин, підвищена кислотність та промивний режим. За таких умов рівень продуктивності сірих лісових поверхнево оглеєних ґрунтів не перевищує 1,3–1,5 т/га зернових одиниць. Тому для формування зерна і насіння високих посівних якостей потрібне повне забезпечення рослин усіма елементами живлення в певному співвідношенні.

Подано результати досліджень за 2019–2021 рр. з удосконалення системи живлення рослин пшениці м'якої озимої за рахунок норм внесення різних видів мінеральних добрив в етапах органогенезу. Одержані експериментальні дані підтвердили, що оптимальне забезпечення рослин мінеральними добривами сприяє формуванню більш потужної кореневої системи та надземної маси, а це забезпечує краще використання елементів живлення з ґрунту та добрив. За таких умов рослини швидше розвиваються, легше переносять вплив негативних чинників зовнішнього середовища та більш стійкі до захворювань. Встановлено, що за вищих норм основного внесення мінеральних добрив $N_{30}P_{70}K_{120}S_{21}$ і $N_{30}P_{90}K_{160}S_{28}$ відсоток перезимівлі рослин становив 95,0–95,9 %. Площа листкової поверхні сортів пшениці м'якої озимої в VIII етапі органогенезу була найвищою – 58,9 тис. м^2 за норми $N_{220}P_{90}K_{160}S_{28}$ з поетапним внесенням азоту. Із застосуванням мінеральних добрив рослини проявляли вищу стійкість до хвороб, тому відсоток ураження борошнистою росою був нижчим на 8,1 %, темно-бурою плямистістю – 3,8, септоріозом листя – 8,6, сепроріозом і фузаріозом колоса – 0,6–1,1 %.

Урожайність зерна сортів пшениці м'якої озимої формувалася як під впливом погодних факторів, так і норм внесення мінеральних добрив. У 2019 р. цей показник варіював від 3,52 т/га (контроль) до 7,43 т/га ($N_{280}P_{110}K_{200}S_{35}$), у 2020 р. – відповідно 2,61–6,07 т/га, а в 2021 р. – 2,82–6,51 т/га. Порівняно з контролем (без добрив) за норми внесення мінеральних добрив $N_{168}P_{66}K_{120}S_{21}$ сорти сформували достовірно вищу врожайність зерна на 1,66 т/га, за $N_{224}P_{88}K_{160}S_{28}$ – на 2,75 і $N_{280}P_{110}K_{200}S_{35}$ – на 3,69 т/га.

Ключові слова: пшениця м'яка озима, сорт, норма мінеральних добрив, перезимівля рослин, площа листкової поверхні, стійкість до хвороб, урожайність зерна.

Introduction. Rational or scientifically sound use of mineral fertilizers remains an effective factor in guaranteed and efficient production of agricultural products in various forms of management. According to the FAO, by the proper application of mineral fertilizers you can get 30-40% increase in yield [6, 9, 25, 28].

In developed countries with a high level of mineral fertilizers, the yield of leading cereals is 3–6 times higher than in developing countries [3].

Soils with good physical and agrochemical properties, rich in easily accessible forms of nutrients, are necessary for the manifestation of high potential of winter wheat. Among all the nutrients necessary for plant growth and development, the main role belongs to nitrogen, phosphorus and potassium, each of which performs a special physiological function in plant nutrition and can not be replaced by others [13, 29, 21, 27].

The manufacturability of the variety and its ability to withstand adverse growing conditions without loss of genetic potential is due to various factors, among which the feeding system occupies a special place [10, 11, 15, 22].

A large number of studied agricultural measures, other than those involved in traditional cultivation technology, indicate that there are still unexhausted reserves in increasing the gross grain harvest of soft winter wheat. Often weather conditions are unfavorable, so there is a need for targeted selection of agricultural techniques that would not reduce the natural adaptive properties of plants and from provision of plants with mineral nutrients throughout the growing season depends yield and quality of products [1, 2, 7, 14, 18, 26, 30].

Intensive varieties are characterized by higher requirements for nutritional conditions and only with a full and balanced supply of nutrients can fully realize their genetic potential [5].

Studies of recent years, as well as the practice of growing winter wheat by intensive technology have shown that to obtain the maximum yield of high quality grain, at high doses of fertilizers requires a predominance of nitrogen: 1.5 : 1 : 1. The need for high doses of nitrogen is due to high removal of nitrogen from the soil, which exceeds 3–4 times the removal of phosphorus [4, 12, 17, 23].

According to the Myronivka Institute of Wheat named after V. M. Remeslo NAAS, the best ratio of nutrients N : P : K is 1.5 : 1 : 1. The same ratio is recommended for the regions of Western Ukraine [8].

The aim of our research was to identify the reaction of soft winter wheat varieties on the level of plants' mineral nutrition in order to form a yield of 5-6 t/ha of high sowing qualities seed.

Materials and methods. Field experiments were carried out in the crop rotation of Department of Seed Production and Seed Science of the Institute of Agriculture of the Carpathian Region of NAAS during 2019-2021.

The object of research were varieties included in the Register of Plant Varieties suitable for distribution in Ukraine in 2018–2019, in particular: Trudivnytsia myronivska (control), MWI Vyshyvanka (Myronivskyi Wheat Institute named after V. M. Remeslo NAAS); Hraciia bilotserkivska, Kvitka poliv (Bila Tserkva SSES of Institute of bioenergetic crops and sugar beets NAAS); Vodohray, Spivanka poliska (National Research Center "Institute of Agriculture of NAAS of Ukraine").

The total area of research site – 60 m^2, accounting area – 50 m^2. Placement of options – systematic, repetition – triple.

The soil of the experimental plots is gray forestal surface-gleyed, light-loamy, characterized by the following indicators: humus content (according to Tyurin) – 1.7%, amount of absorbed bases – 13.7 mg-eq per 100 g of soil, alkaline-hydrolyzed nitrogen (according to Cornfield) – 89.6 mg/kg of soil, mobile phosphorus and exchangeable potassium (according to Kirsanov) – 69.5 and 68.0 mg/kg of soil respectively. According to the gradation, such soil has a very low supply of nitrogen, medium – phosphorus and low – potassium. The reaction of the soil solution (pH_{salt} 5.4) – weakly acidic.

Agricultural techniques for growing winter wheat varieties are generally accepted for cultivation in this area. The predecessor is winter rape. The sowing period is 25.09–01.10. The sowing rate is 5.5 million germinated seeds/ha. Seed treatment – disinfectant vitavax 200 FF, 34 % v.s.k. (3.0 l/t). Protection of plants from weeds and diseases – herbicides: roundup, 48% (4.0 l/ha); granstar, 75% v.r. (0.025 g/ha); fungicide: falcon, k.e. (0.6 l/ha).

The scheme of the experiment included: 1 – control (without fertilizers), 2 – $N_{168}P_{66}K_{120}S_{21}$, 3 – $N_{224}P_{88}K_{160}S_{28}$, 4 – $N_{280}P_{110}K_{200}S_{35}$. Mineral fertilizers were applied in various forms, in particular: in all variants of the experiment we used a complex nitrogen-phosphorus-potassium fertilizer – nitroammophoska $NPK_{8-19-29}$(3S).

1st variant of experiment $N_{90}P_{50}K_{90}S_{19}$ – nitroammophoska $NPK_{8-19-29}$(3S) (265 kg/ha) by cultivation; VVSN 20–22 (permafrost soil) – ammonium sulfate (50 kg/ha); VVSN 30–32 (entering the tube phase) – ammonium nitrate (90 kg/ha); VVSN 37–49 (earing phase) – ammonium nitrate (80 kg/ha).

2nd variant of experiment $N_{90}P_{50}K_{90}S_{19}$ – nitroammophoska $NPK_{8-19-29}$ (3S) (370 kg/ha) by cultivation; VVSN 20–22 (permafrost soil) – ammonium sulfate (50 kg/ha) + ammonium nitrate (150 kg/ha); VVSN 30-32 (entering the tube phase) – ammonium nitrate (130 kg/ha); VVSN 37–49 (earing phase) – ammonium nitrate (93 kg/ha);

3rd variant of experiment $N_{90}P_{50}K_{90}S_{19}$ nitroammophoska $NPK_{8-19-29}$ (3S) (450 kg/ha) by cultivation; VVSN 20–22 (permafrost soil) – ammonium sulfate (60 kg/ha) + ammonium nitrate (190 kg/ha); VVSN 30–32 (entering the tube phase) – ammonium nitrate (160 kg/ha); VVSN 37–49 (earing phase) – ammonium nitrate (150 kg/ha).

The research was conducted according to generally accepted methods: Omeliuta V. P., Grygorovych I. V., Chaban V. S. etc., 1986 [16]; Peterson N. V., Chernomyrdina T. O., Kuryliak E. K., 1993 [19]; Fursova G. K., Fursov D. I., Sergeeva V. V., 2004 [24]; Ushkarenko V. O. et al., 2013 [20].

Results and discussion. The winter period of 2018–2019 was marked by some variety. In January precipitation was 153%, and in February the air temperature was plus 1.8 °C (up to long-term averages of 40 mm and -3.7 °C). Overwintering of plant varieties depended on their development at the time of cessation of autumn vegetation, which was influenced by the level of nutrition in the studied variants of the experiment. Under the influence of sufficient supply of plants with mineral nutrition, winter hardiness of varieties increased. This contributed to the ability of plants to withstand prolonged exposure to subzero temperatures in a state of cessation of growth and deep dormancy, and as a result the plants became adapted to the cold (hardening). Freezing of plants was not observed, the percentage of overwintering was high and in the control was 91.7%. The best development of plants on variants with the application of mineral fertilizers contributed to the growth of this indicator by 3.1–6.1%.

The winter period of 2019–2020 was abnormally warm. In December, the air temperature was 2.7 °C with a long-term average of 1.8 °C, in January – 0.7 °C (minus 4.6 °C), and in February minus 2.5 °C (-3.7 °C). The amount of precipitation compared to long-term average was respectively 104 %, 71 and 162 %. Such favorable weather conditions and good plant development ensured a high percentage of overwintering plants.

In the variety Trudivnytsia myronivska, the percentage of overwintering of plants varied from 91.1% on control without fertilizers to 94.6 % on the norms of mineral fertilizers $N_{220}P_{90}K_{160}S_{28}$. The same trend was observed in MWI Vyshyvanka – 91.6–94.3 %, Hraciia bilotserkivska – 92.0–95.1, Kvitka poliv – 93.1–95.9, Vodohray – 92.7–96.0, Spivanka poliska – 93.4–96.2 %. If we analyze the impact of mineral fertilizers on overwintering of plants, then in the control (without fertilizers) it was the lowest – 92.3 %, at the level of mineral nutrition $N_{90}P_{50}K_{90}S_{19}$ increased by 1.3%. The increase in fertilizer application rates led to an increase in this indicator by 2.3–3.1 %.

Warm winter in 2020–2021 and high adaptive properties of varieties also contributed to good overwintering of plants. The obtained data confirm that the percentage of mineral fertilizers was 2.6–4.2% higher than the control. The increase in the application rates of phosphorus-potassium fertilizers and sulfur led to an increase in this indicator by 1.2–1.6 %.

During the research years (2019–2021) the average percentage of overwintering plants of winter wheat varieties under control (without fertilizers) was 91.5% (Table 1).

1. Average percentage of overwintering of soft winter wheat plants depending on the variety and application rates of mineral fertilizers (2019–2021), %

Mineral fertilizer rate, d.r./ha	Year			Average	± to control	
	2019	2020	2021			
Control (without fertilizers)	91,7	92,3	90,4	91,5	-	
$N_{30}P_{50}K_{90}S_{19}$	94,8	93,6	93,0	93,8	2,3	-
$N_{30}P_{70}K_{120}S_{21}$	96,3	94,6	94,2	95,0	3,5	1,2
$N_{30}P_{90}K_{160}S_{28}$	97,8	95,4	94,6	95,9	4,4	2,1
$LSD_{0,05}$	1,0	0,9	0,5			

With the application of mineral fertilizers in the norm $N_{30}P_{50}K_{90}S_{19}$ increased to 93.8% or 2.3 %. The best level of nutrition at higher application rates $N_{30}P_{70}K_{120}S_{21}$ and $N_{30}P_{90}K_{160}S_{28}$ provided a higher wintering rate of 95.0–95.9 %.

Establishing the leaf surface area of winter wheat varieties under the influence of mineral fertilizers, we found that over the years of research in the VIII stage of organogenesis, this figure was the highest. At the control the average leaf surface area of varieties was 52.4 thousand m^2/ha, with the introduction of $N_{90}P_{50}K_{90}S_{19}$ increased by 1.8 thousand m^2/ha and the highest (58.9 thousand m^2) was by the $N_{220}P_{90}K_{160}S_{28}$.

A set of agricultural measures aimed at stabilizing plant nutrition conditions can significantly limit the adverse effects of diseases on crops, as the Western Forest-Steppe zone is specific. In the weather conditions of 2019–2021 vegetation periods the average percentage of winter wheat plant damage by powdery mildew ranged from 21.3 in control to 13.2 % by the norm of mineral fertilizers $_{0}P_{90}K_{160}S_{28}$ (Table 2). At $LSD_{0,05}$ = 0.6 %, the development of dark brown leaf spot was observed the highest in the control (without fertilizers) and within the error between the levels of mineral nutrition of plants.

2. Resistance of soft winter wheat plants' varieties to diseases depending on the norms of mineral fertilizers application (2019–2021), %

Rate of mineral fertilizers, d.r./ha	Leaves (VVSN 39)			Ear (VVSN 69)	
	powdery mildew (*Erysiphe graminis (DC)*)	dark brown leaf spot (*Fusarium Link.*)	leaves' septoriosis (*Septoria tritici Desm.*)	septoriosis (*Septoria nodorum Berk.*)	fusarium wilt (*Fusarium Link.*)
Control (without fertilizers)	21,3	8,9	20,6	3,9	1,9
$N_{90}P_{50}K_{90}S_{19}$	15,4	5,7	16,3	2,2	1,3
$N_{168}P_{70}K_{120}S_{21}$	14,7	5,5	12,9	2,1	1,0
$N_{220}P_{90}K_{160}S_{28}$	13,2	5,1	12,0	2,0	0,8
$LSD_{0,05}$	2,6	0,6	2,5	1,0	0,5

The largest lesion of leaves' septoriosis was in control – 20.6 %. With the application of mineral fertilizers in the norm $N_{168}P_{70}K_{120}S_{21}$ plants were more resistant to this disease, so the percentage of damage was lower by 7.7 % compared to control and 4.3 % lower than by the norm $N_{90}P_{50}K_{90}S_{19}$, and equivalent to higher – $N_{220}P_{90}K_{160}S_{28}$. According to the development of ear diseases, there is a general pattern – compared to the control, the percentage of them decreased by all rates of mineral fertilizers. With the increase in the rates of mineral fertilizers, the indicators of plant and ear structure increased (Table 3).

3. Indicators of plant structure and ears of soft winter wheat varieties depending on the norms of mineral fertilizers application (2019–2021)

Rate of mineral fertilizers, d.r./ha	Height of plants, cm	Number of shoots, pcs	Ear length, cm	Number of spikelets in the ear, pcs	Number of grains in the spikelet, pcs	Weight of grain from the plant, g	Mass of 1000 grains, g
Control (without fertilizers)	89,3±1,12	2,8±0,43	7,32±0,07	14,6±0,17	30,0±0,58	1,76±0,76	41,7±0,78
$N_{90}P_{50}K_{90}S_{19}$	91,4±2,06	3,3±0,64	8,76±0,13	17,5±0,24	44,0±0,61	2,21±0,98	45,9±0,89
$N_{168}P_{70}K_{120}S_{21}$	93,5±2,83	3,7±0,75	9,84±0,16	19,7±0,26	51,0±0,69	2,39±1,12	46,4±0,92
$N_{220}P_{90}K_{160}S_{28}$	96,7±3,12	3,91±0,96	10,1±0,20	20,2±0,37	57,0±0,77	2,54±1,38	47,3±0,98
LSD_{05}	1,0	0,3	0,05	0,04	0,02	0,14	0,10

Thus, the height of plants under control (without fertilizers) was 89.3 cm, and according to the norms of fertilizers $N_{220}P_{90}K_{160}S_{28}$ was higher by 7.4 cm. The number of stems on the plant also increased from 2.8 to 3.9 pieces. The same trend was observed for the length of the ear (2.78 cm), the number of ears in the ear (5.5 pieces) and grains in the ear (27 pieces). The best nutrition background of winter wheat varieties contributed to the increase in grain weight of the plant and a higher weight of 1000 seeds.

Weather conditions of the vegetation period of 2019 contributed to the grain productivity of varieties within 3.52 (control) – 7.43 t/ha (rate of mineral fertilizers $N_{220}P_{90}K_{160}S_{28}$). Compared with the control, the significant increase in yield was 0.96–3.91 t/ha ($LSD_{0.05}$ = 0.55 t/ha). In 2020 the lowest grain yield was provided by the control option (without the application of mineral fertilizers) – 2.61 t/ha, ie due to the natural fertility of the soil. By the application rates of $N_{90}P_{50}K_{90}S_{19}$, the highest increase to the control was obtained by 2.23 t/ha and the highest according to the norms of $N_{220}P_{90}K_{160}S_{28}$ – 3.46 t/ha.

Grain yield in 2021 varied from 2.32 in the control to 6.04 t/ha in the variant of mineral fertilizers $N_{220}P_{90}K_{160}S_{28}$. For $LSD_{0.05}$ = 0.42 t/ha, significant yield increases of 1.79–3.72 t/ha compared to control were provided by all norms of mineral fertilizers. Compared with the norm of mineral fertilizers $N_{90}P_{50}K_{90}S_{19}$, the increase in yield increased by 1.10 t/ha by the norm $N_{168}P_{70}K_{120}S_{21}$ and 1.93 t/ha by $N_{220}P_{90}K_{160}S_{28}$.

During three years of research, the general pattern of increasing the yield of soft winter wheat varieties under the influence of mineral fertilizers was maintained. In the control (without fertilizers) the average grain yield was 2.82 t/ha (Table 4).

4. Average grain yield of soft winter wheat varieties depending on the rates of mineral fertilizers (2019–2021)

Rate of mineral fertilizers, d.r./ha	Year			Average	± to control	
	2019	2020	2021			
Control (without fertilizers)	3,52	2,61	2,32	2,82	-	
$N_{90}P_{50}K_{90}S_{19}$	4,48	4,84	4,11	4,48	1,66	-
$N_{168}P_{70}K_{120}S_{21}$	5,81	5,61	5,47	5,57	2,75	1,09
$N_{220}P_{90}K_{160}S_{28}$	7,43	6,07	6,04	6,51	3,69	2,03
$LSD_{0,05}$	0,50	0,36	0,42			

In the variant with the introduction of a lower rate of mineral fertilizers, the varieties formed a higher yield compared to the control by

1.66 t/ha. Significantly higher growth was provided by $N_{168}P_{70}K_{120}S_{21}$ and $N_{220}P_{90}K_{160}S_{28}$, respectively 2.75 and 3.69 t/ha.

Conclusions

1. On the background of mineral nutrition of plants of soft winter wheat varieties, their best growth and development was observed in the autumn period, which provided a 3.1–6.1% higher overwintering compared to the control (without fertilizers).

2. With the application of mineral fertilizers the varieties formed a larger leaf area by 1.8–6.5 thousand m^2/ha.

3. With optimal nutrition plant varieties were more resistant to disease, the percentage of lesions decreased, in particular, powdery mildew by: 8.1%, dark brown spot – 3.8, leaf septoriosis – 8.6, ear septoriosis and fusarium – 0,6–1.1 %.

4. Application rate $N_{90}P_{50}K_{90}S_{19}$ (nitroammophoska $NPK_{8-19-29}$ (3S) - 450 kg/ha by cultivation; VVSN 20–22 (permafrost soil) ammonium sulfate – 60 kg/ha + ammonium nitrate – 190 kg/ha; VVSN 30–32 (phase of plants entering the tube) ammonium nitrate – 160 kg/ha; VVSN 37–49 (earing phase) ammonium nitrate – 150 kg/ha) provided a significant increase in grain yield – 3.69 t/ha.

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