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Dynamics of the content of nutrients in winter barley plants depending on the variety, sowing dates and plant growth regulators

Serhii Zaiets[*1], Lyudmila Onufran[1], Kateryna Fundirat[1], Serhii Yuzyuk[1], Lyudmila Kisil[2]

[1]Institute of Climate Smart Agriculture National Academy of Agrarian Sciences of Ukraine (NAAS)
67667, Mayatska road Str., 24, Khlibodarske village, Odesa region, Ukraine

[2]Kherson Regional Center for Hydrometeorology
73003, Perekopska Str., 17, Kherson, Ukraine

Abstract. The problem of increasing the production of winter barley grain on irrigated lands can be solved thanks to the improvement of the varietal composition, optimization of sowing dates and improvement of the nutrition system, in particular through the use of drugs with growth-regulating properties. Taking into account the important biological role of growth regulators in the plant nutrition system, the aim was to determine the influence of Gummifield Forte brix, MIR and PROLIS on the content of nitrogen, phosphorus and potassium in the main phases of plant development of different varieties of winter barley at optimal and late sowing dates. The research was conducted at the Institute of Irrigated Agriculture (now the Institute of Climate-Oriented Agriculture) of the National Academy of Sciences according to methodological recommendations for conducting field tests under irrigation conditions. In the above-ground mass of plants, straw and grain, the total content was determined: nitrogen – according to Kjeldahl, phosphorus – according to Murphy-Reilly, potassium – using a flame photometer. It was determined that on the irrigated lands of the South of Ukraine, the use of growth regulators Gumifield Forte brix, MIR and PROLIS had a significant effect on the accumulation of the main nutrients (especially nitrogen) by plants and winter barley grains. The highest content of basic nutrients in plants was at the early stages of development (spring tillering), after which their amount decreased until the end of the growing season of the crop. The maximum nitrogen content of 2.02% on dry matter on the Dev'iatyi val variety and 1.85% on the Academichnyi variety was provided by the use of Gummifield Forte Brix.Among the varieties, the Dev'iatyi val, on average, accumulated nitrogen in the grain for sowing on October 1 and 20 by 9.1 and 9.5 percentage points more than Akademichnyi, according to the plant growth regulator factor. Thanks to the treatment of winter barley seeds with plant growth regulators Gumifield Forte Brix and PROLIS and sowing the crop at the optimal time, it is possible to increase the nitrogen content in plants and grain by 6.0-15.1 and 9.3-22.5 percentage points, respectively, which will have a positive effect on grain formation and its quality. In further studies, it is necessary to optimize the application doses of mineral fertilizers using new multi-component growth regulators of winter barley plants under irrigation conditions in the South of Ukraine

Keywords: nitrogen, phosphorus and potassium content, biomass, sowing dates, multi-component preparations, irrigation

INTRODUCTION

The latest projections from the United Nations suggest that the world's population could grow to approximately 8.5 billion in 2030 and 9.7 billion in 2050, reach a peak of 10.4 billion people in the 2080s [1-3]. Considering that the population will increase by 1.7 billion people by 2050, and another 0.7 billion by 2080, there is a serious problem of providing them with food, a problem that will only worsen with time. Such an increase in the global population will occur under global climate change [4-6], from the adverse consequences of which vulnerable population groups will suffer the most [7; 8], which will require new methods of stabilizing and increasing the production of agricultural products. It is important to do this in an environmentally sound way

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by reviewing many existing approaches to agriculture, including plant nutrition, variety policies and sowing timing.

Barley is one of the most widespread grain crops in the world [9-11]. Its grain is widely used for fodder, food and technical purposes [12-14]. Considering the national economic importance of this crop, barley requires considerable attention and a careful technological approach.

In recent years, the areas of winter barley sowing have expanded significantly, both in the EU countries and in Ukraine. If at the beginning of the 21st century it was sown in Ukraine on an area of 300-500 thousand hectares, then in the last ten years – 0.9-1.5 million hectares [15; 16]. Mainly, its areas increase due to the decrease in spring barley crops. The main factors that give it an advantage over spring barley are high potential productivity, more efficient use of moisture and precipitation of the autumn-winter period, and early ripening [17], which allows growing agricultural crops in repeated crops under irrigation.

In recent years, the yield of winter barley in Ukraine has increased from 2.0 t/ha to 3.4 t/ha, or 1.7 times, but, unfortunately, it is two times lower than the indicator in the EU countries – 7.0 t/ha [18; 19]. That is, domestic agricultural producers are faced with the task of further increasing its yield.

Increasing and stabilizing the production of winter barley grain is possible only with clear and maximally effective implementation of all elements of growing technology. Among the most important and reliable factors for increasing the yield and quality of barley grain are the use of high-yielding varieties, their sowing at the optimal time and the use of biological growth regulators.

Varieties and hybrids of foreign selection can ensure the yield of winter barley at the level of 9-10 t/ha [20]. Currently, domestic breeders have also created new varieties of winter barley, the yield potential of which reaches 8-9 t/ha and more [21]. The use of these varieties can significantly increase the level of competitiveness of grain production of this valuable crop.

Global changes in climatic conditions that have occurred in recent decades require a certain correction in the technology of growing most agricultural crops, its adaptation to adverse abiotic factors. The first changes in the sowing dates of winter grain crops have already been made towards later dates [22-24].

It is known that the use of metabolites and phytohormones in crop production contributed to the development of the industry by stimulating growth processes and optimizing the ripening of agricultural crops [25-27], as well as influencing the formation of the root meristem [28; 29].

In the coming years, among the most priority directions is the increase in the production of high-quality grain, where plant growth regulators and microbiological preparations with growth-regulating properties can play an important role [30-32]. There are known types of biostimulants, including amino acids, humic substances, algae extracts, preparations based on microbes and others [33-35]. However, how plant growth regulators change the absorption of winter barley biomass of the main nutrients: nitrogen, phosphorus and potassium during irrigation has not been sufficiently studied.

Therefore, the purpose of the research was to determine the parameters of the accumulation of nutrients by plants in the main phases of the development of winter barley, depending on the varieties, sowing dates and multicomponent growth regulators in the conditions of irrigation in the south of Ukraine.

LITERATURE REVIEW

During an active physiological process, the plant absorbs nutrients, the content of which depends on both direct and indirect factors [36; 37]. It is believed that in order to obtain a higher yield, field crops must absorb a large amount of nutrients from the soil [38; 39]. However, the reaction of plants to nutritional conditions in different periods of vegetation is different, and the absorption of elements, due to the change in the nature and orientation of biochemical processes, is uneven.

According to the researches of V.V. Zerling, in the budding phase of plants, the optimal content of mineral nutrients in above-ground biomass should be 4.7-5.3% nitrogen, 0.55-0.65% phosphorus, and 4.2-4.2% potassium [40]. Due to the improvement of mineral nutrition, the content of these elements in the plant increases [41; 42].

A number of researchers also believe that the maximum amount of the main nutritional elements of the winter barley plant is accumulated at the beginning of spring tillering, and then their content gradually decreases and reaches the lowest values at the end of the growing season of the crop [43-45]. Having data on the actual content of nutrients at the beginning of spring bushing, it is possible to adjust the doses of fertilizers in the subsequent phases of plant development.

Among the main elements of plant nutrition necessary for the formation of grain yield, nitrogen occupies the most important place, since it plays a decisive role in almost all metabolic processes of plants, and its deficiency leads to a decrease in grain production [46; 47]. In almost all agricultural soils, including in Ukraine, nitrogen is at a minimum, or is a universal deficiency [48]. Therefore, when growing agricultural crops, nitrogen fertilizers should be used in the first place. On the dark chestnut soils of the south of Ukraine, under the condition of growing winter barley on irrigated lands, the optimal application rate should be N90 [49].

Scientists of the EU, USA and other countries of the world believe that, along with fertilizers and pesticides, plant growth regulators should occupy an important place in the technology of production of plant products. The use in the production of biological preparations improves the use of nutrients by plants, promotes the development of the root system and the resistance of the culture to adverse climatic conditions, as a result of which the condition of plants improves and their productivity increases [50-52]. Research conducted in EU countries [53; 54], Japan [55] and Ukraine [56] on grain crops, their influence on plant growth and development has also been documented. Therefore, the wide use in the production of growth regulators, which contain a balanced complex of phytoregulators, biologically active substances and microelements, is one of the possible factors in the regulation of plant growth processes and crop formation.

A number of researchers showed the mechanisms of the positive effect of phytohormones on cell division, the processes of photosynthesis and respiration, assimilation of nutrients by grain crops [57-59]. It was also established that the use of growth regulators contributes to the increase of nitrogen absorption by winter crops [60]. At the same time, the accumulation of nitrogen and phosphorus in plants was lower than in the later sowing period [61]. That is, due to late sowing dates, incorrectly formed sowing parameters have a negative effect on the growth and development of plants [62; 63], and therefore on the absorption of nutrients.

In addition, the background of plant nutrition is determined by varietal characteristics, since varieties react differently to the main elements of technology [64; 65].

That is, increasing the yield of agricultural crops with the use of growth regulators largely depends on sufficient provision of the nutritional background in combination with optimal sowing dates, as well as on the biological properties of the variety.

However, the influence of new multicomponent plant growth regulators on the accumulation of the main macronutrients during the growing season of winter barley, sown at different times on irrigated lands, has not been investigated before.

The relevance of conducting this research and summarizing the experimental material is due to the importance of the biological role of growth regulators and the limitation of scientific data on their influence on the content of nitrogen, phosphorus and potassium in plants of modern varieties of winter barley grown under irrigation conditions.

MATERIALS AND METHODS

To assess the potential ability of winter barley to accumulate nitrogen, phosphorus and potassium and spend them during the growing season of plants, the results of field and laboratory studies of the Department of Agricultural Technologies and the Laboratory of Analytical Research of the Institute of Irrigated Agriculture (now the Institute of Climate-Oriented Agriculture) of the National Academy of Sciences were used.

The research was carried out under irrigation conditions during 2016-2019 on a dark chestnut medium loamy slightly saline soil characterized by the following agrochemical and agrophysical parameters: humus content in the arable layer – 2.3%, density – 1.37 g/cm^3, moisture in humidity – 9.1%, the lowest moisture content – 20.3%; nitrates (according to Grandval-Liage) 7.9-24.2 mg/ha, mobile phosphorus (according to Machigin) – 53.8-83.9 mg/kg and exchangeable potassium (on a flame photometer) – 231-281 mg/kg of soil; the reaction of the soil solution is close to neutral, the pH of the salt extract is 7.1. Taking into account the low content of nitrogen in the soil and the high content of phosphorus and potassium, only ammonium nitrate in the dose of N45 was used for pre-sowing cultivation and in early spring, N45 was added.

The predecessor was soybeans harvested for grain. The technology of growing winter barley is generally accepted for the zone under irrigation conditions (except for the elements that were studied).

The experiment is three-factor: Factor A (barley varieties): Academichnyi and Dev'iatyi val, which have been included in the state register of plant varieties suitable for distribution in Ukraine since 2011 and 2014. Factor B (sowing dates): optimal (October 1) and late (October 20). Factor C (growth regulators): control (without treatment); Gumifield Forte Brix (seed treatment 0.8 l/t); MIR (seed treatment 6 g/t); PROLIS (seed treatment 5 g/t).

Features of the components and characteristics of the investigated plant growth regulators:

Gumifield Forte Brix, v.s. – highly effective, water-soluble, universal growth regulator, adaptogen and anti-stressor based on ammonium humate, the most active form of humate, contains 60 g/l of seaweed extract, which includes a complex of phytohormones and physiologically active substances, 135 g/l of humic acid salts, in h.: amino acids – 20 g/l, potassium (K2O) – 20 g/l and trace elements – 5 g/l, pH – 10-11 [66].

The drug MIR MARKA Z is a multi-purpose plant growth regulator created on the basis of synthetic compounds, contains heteroauxin – 10-20%, humic acids – 70-80% and a full range of trace elements useful for plants in chelated form: Fe – 0.6-0.8%, Mg – 3.6-5.3%, Mn – 0.7-2.6%, Zn – 1.1-5.0%, Mo – 0.2-1.0%, Cu – 0.6-0.8%, B – 0.5-1.2%) [67].

Plant growth regulator PROLIS TM – L-α proline heterocyclic amino acid (pyrrolidine-α-carboxylic acid), 995 g/kg, C5H9NO2, water-soluble powder, intended for biotic and abiotic stress reduction of plants, regulates the assimilation of macro- and microelements, and also stimulates immune system of plants [68].

Repeatability in experiments is three times. Variants were placed by the method of randomization. The sown area of the plots was 38.8, accounting – 28.6 m^2.

In the above-ground mass of plants, straw and grain, the total content was determined: nitrogen – according to Kjeldahl, phosphorus – according to Murphy-Reilly, potassium – using a flame photometer.

RESULTS AND DISCUSSION

The obtained data indicate that the treatment of winter barley seeds with multi-component plant growth regulators Gumifield Forte Brix, MIR and PROLIS increased the nitrogen content in plants. Thus, in the phase of spring bushing in the plants of the Akademichnyi variety after sowing on October 1 and 20 without the use of plant growth regulators, nitrogen was contained on average 3.14% and 3.17% on dry matter, respectively, and when they were applied it was significantly more – 3.34 -4.10% and 3.36-3.65% (Table 1).

Table 1. *Dynamics of nitrogen content in winter barley plants depending on the variety, sowing dates and plant growth regulators, % (average for 2017-2019)*

Variety	Sowing dates	Background of nutrition and plant growth regulators	Phases of plant development			
			Tillering	Launch into the tube	Earing	Full ripeness
		Nitrogen				
Akademichny	1 October	N_{90}	3.14	2.05	1.21	0.38
		N_{90} + Gumifield	3.34	1.88	1.16	0.39
		N_{90} + MIR	3.42	2.19	1.23	0.41
		N_{90} + PROLIS	4.10	1.73	1.49	0.38
	20 October	N_{90}	3.17	2.37	1.01	0.35
		N_{90} + Gumifield	3.43	2.29	1.19	0.36
		N_{90} + MIR	3.36	2.03	1.21	0.35
		N_{90} + PROLIS	3.65	2.50	1.44	0.33
Dev'iatyi val	1 October	tilleringN_{90}	4.11	2.57	1.47	0.43
		N_{90} + Gumifield	4.31	2.63	1.51	0.44
		N_{90} + MIR	4.15	2.65	1.45	0.45
		N_{90} + PROLIS	4,24	2.39	1.32	0.44
	20 October	N_{90}	3.82	2.57	1.32	0.35
		N_{90} + Gumifield	4.43	2.58	1.49	0.41
		N_{90} + MIR	4.05	2.72	1.42	0.47
		N_{90} + PROLIS	4.18	2.05	1.21	0.43

Source: *developed by the authors*

A similar pattern was also observed in the two-handed variety Dvyatiy val, but with a slightly higher nitrogen content in the plants. When sowing this variety on October 1 and 20 without the use of plant growth regulators, the nitrogen content was 4.11-3.82% on dry matter, respectively, and when they were applied – 4.15-4.31 and 4.05-4.43%, or by 0.04-0.20 and 0.23-0.61% more. At the same time, regardless of the timing of sowing, the Academichnyi variety provided the largest amount of this element in plants with the use of the PROLIS drug, and the Dev'iatyi val – Gummifield Forte Brix.

The data in Table 1 show that the most nitrogen in winter barley plants was contained in the tillering phase, after which its amount sharply decreased until the grain was fully ripe. Thus, during the period of tillering, the nitrogen content in plants was 3.14-4.43%, in the phase of emergence into the tube, its amount decreased to 1.73-2.72%, during earing – to 1.01-1.51%, and at full ripeness – up to 0.33-0.47%, which is due to its gradual consumption for growth processes and grain formation. The minimum nitrogen content in relation to the mass of dry matter was found in the phase of full ripeness of the grain, which is 88-91% less, compared to the tillering phase.

This can be explained by the anticipatory consumption of nitrogen by plants for the synthesis of organic matter in the second half of the growing season over the arrival of this nutrient through the root system.

It has been established that the process of phosphorus accumulation by winter barley plants also takes place more intensively at the beginning of spring bushing. Thus, in the indicated phase of development, the content of this element in plants of the Academichnyi variety, depending on the research options, ranged from 1.05 to 1.32%, and in the two-armed variety, Dev'iatyi val, 1.14 to 1.28% (Table 2).

Table 2. *Dynamics of phosphorus content in winter barley plants depending on the variety, sowing dates and plant growth regulators, % (average for 2017-2019)*

Variety	Sowing dates	Background of nutrition and plant growth regulators	Phases of plant development			
			Tillering	Launch into the tube	Earing	Full ripeness
		Phosphorus				
Akademichnyi	1 October	N_{90}	1.31	0.87	0.63	0.21
		N_{90} + Gumifield	1.31	0.92	0.55	0.17

Table 2, Continued

Variety	Sowing dates	Background of nutrition and plant growth regulators	Phases of plant development			
			Tillering	Launch into the tube	Earing	Full ripeness
Phosphorus						
Akademichnyi	1 October	N_{90} + MIR	1.32	0.85	0.58	0.17
		N_{90} + PROLIS	1.27	0.86	0.65	0.16
	20 October	N_{90}	1.09	0.81	0.57	0.18
		N_{90} + Gumifield	1.07	0.80	0.56	0.19
		N_{90} + MIR	1.05	0.75	0.57	0.17
		N_{90} + PROLIS	1.08	0.80	0.56	0.19
Dev'iatyi val	1 October	N_{90}	1.14	0.82	0.65	0.22
		N_{90} + Gumifield	1.25	0.80	0.62	0.21
		N_{90} + MIR	1.23	0.82	0.59	0.20
		N_{90} + PROLIS	1,27	0.87	0.60	0.23
	20 October	N_{90}	1,27	0.82	0.55	0.22
		N_{90} + Gumifield	1.28	0.83	0.57	0.21
		N_{90} + MIR	1.28	0.76	0.59	0.17
		N_{90} + PROLIS	1.18	0.79	0.56	0.22

Source: *developed by the authors*

If in plants of the Akademichnyi variety, a greater amount of phosphorus was accumulated during sowing on October 1, then in the two-handed variety Dev'iatyi val, no difference between the sowing dates was observed. Also, there were no changes in the phosphorus content in plants after seed treatment with growth regulators Gumifield Forte Brix, MIR and PROLIS, which is explained by its rather high content in the dark chestnut soil.

When the plants entered the tube, compared to the beginning of spring bushing, the phosphorus content decreased by 25-41 percentage points and ranged between 0.75-0.92%. The minimum amount of phosphorus in the vegetative organs of plants is noted when the grain is fully ripe (0.16-0.23%). There was no significant difference between the experimental variants in the accumulation of winter phosphorus by barley plants.

Therefore, it can be assumed that the largest part of phosphorus accumulates in plants at the early stages of organogenesis (spring tillering) and is sufficient to provide barley plants until the end of the growing season.

The maximum content of total potassium in winter barley plants of both varieties was also noted during spring tillering – 3.15-3.71% (Table 3).

Table 3. *Dynamics of potassium content in winter barley plants depending on the variety, sowing dates and plant growth regulators, % (average for 2017-2019)*

Variety	Sowing dates	Background of nutrition and plant growth regulators	Phases of plant development			
			Tillering	Launch into the tube	Earing	Full ripeness
Akademichnyi	1 October	N_{90}	3.48	2.98	1.93	1.62
		N_{90} + Gumifield	3.15	3.11	2.08	1.72
		N_{90} + MIR	3.50	3.20	1.92	1.66
		N_{90} + PROLIS	3.25	2.90	2.07	1.58
	20 October	N_{90}	3.37	3.30	2.10	1.51
		N_{90} + Gumifield	3.32	3.23	2.06	1.52
		N_{90} + MIR	3.42	2.95	1.79	1.46
		N_{90} + PROLIS	3.34	2.86	1.95	1.66
Dev'iatyi val	1 October	N_{90}	3.29	3.34	1.93	1.33
		N_{90} + Gumifield	3.26	3.08	2.04	1.43
		N_{90} + MIR	3.47	3.30	2.10	1.44
		N_{90} + PROLIS	3.55	3.31	2.07	1.44
	20 October	N_{90}	3.51	3.37	1.95	1.52
		N_{90} + Gumifield	3.71	3.32	2.05	1.60
		N_{90} + MIR	3.63	3.38	1.92	1.67
		N_{90} + PROLIS	3.33	3.01	2.10	1.56

Source: *developed by the authors*

Starting with spring bushing and before the plants emerge into the tube, the content of this element almost does not change. During the following periods, a gradual decrease in the amount of potassium in plants is noted: in the interphase period, "exiting the tube-earing" – up to 1.79-2.10%, and "earing – full grain maturity" – up to 1.33-1.72% depending on the options of the experiment.

It should be noted that there was no significant difference in the content of potassium in the plants in the experimental variants, due to its high content in the soil.

It was established that on the dark chestnut soil under irrigation, the highest content of nitrogen, phosphorus and potassium in plants was at the early stages of development (spring bushing), after which their amount decreased until the end of the growing season. These data indicate that in the early stages of winter barley vegetation, nitrogen, phosphorus and potassium accumulate in plants, creating a reserve of them, due to which later, in the process of reutilization, the vital activity of plants is ensured.

A.H. Musatov [69] pointed out that pointed out that thanks to the repeated use of plants, for some time, they ensure the growth of new tissues due to the internal reserves of nutrients formed earlier in the stems, if they do not come from the outside.

The obtained data on the content of nitrogen, phosphorus and potassium in the biomass of plants during the spring tillering of winter barley can serve as a basis for diagnosing and correcting the main macronutrient nutrition of the crop, as well as assessing the quality of agricultural products.

It was found that the growth and development of plants of the Academichnyi and Dev'iatyi val varieties was best when the content of nutrients in plants in the budding phase was: nitrogen 4.10-4.43%, phosphorus 1.23-1.32 and potassium 1.44-1.72% on dry matter.

There was no significant difference in the content of nutrients in plants and the dynamics of their content by development phase between the Academichnyiian and Dev'iatyi val varieties. Only in terms of nitrogen content, it was slightly higher in all phases of development on the Dev'iatyi val variety. On the other hand, according to the indicator of phosphorus and potassium in plants, the varieties are quite close.

Seed treatment with complex plant growth regulators and sowing dates affected the content of total nitrogen, phosphorus and potassium in winter barley grains. If during the cultivation of winter barley during irrigation, the content of potassium in the by-products (straw) significantly outweighed the values of nitrogen and phosphorus, then the grain contained the most nitrogen, then phosphorus, and the least - potassium.

The lower content of phosphorus and potassium in winter barley grains compared to nitrogen can be explained by the lack of application of these elements with fertilizers and their washing out from the arable layer of the soil due to vegetation irrigation.

The data shown in Figure 1 show that in winter barley of the Akademichnyi and Dev'iatyi Val varieties for sowing on October 1, the nitrogen content with the use of plant growth regulators exceeded the control options by 9.3-22.5 and 9.4-18.1 relative points depending on the drug.

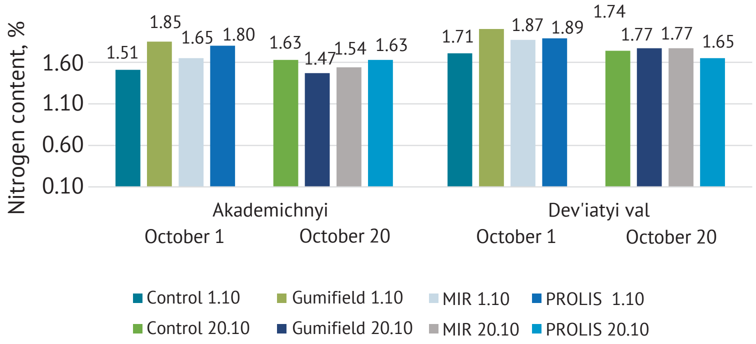

Figure 1. *Nitrogen content in winter barley grains depending on the variety, sowing dates and plant growth regulators, % on dry matter (average for 2016-2019)*

Source: *developed by the authors*

That is, during the specified sowing period, seed treatment with plant growth regulators of both varieties of winter barley had a positive effect on the nitrogen content in the grain. The use of Gumifield Forte Brix provided the maximum nitrogen content of 2.02% on dry matter in the Dev'iatyi val variety and 1.85% in the Academichnyi variety.

Another regularity was observed for sowing at a later date, on October 20. No advantages of using plant growth regulators over variants without them have been established on the Akademichnyi variety, and on the Dev'iatyi val variety – an excess of 3.5 relative points was provided only by the preparations Gumifield Forte Brix and MIR.

Among the "two-handed" varieties, the Dev'iatyi val, on average, accumulated nitrogen in the grain for sowing on October 1 and 20 by 9.1 and 9.5 relative points more than the typical winter Akademichnyi, according to the factor of plant growth regulators. This indicates that plants of the alternative dicot variety accumulated more nitrogen during the formation of more developed biomass.

Phosphorus content in winter barley grain compared to nitrogen had the opposite relationship, i.e. treatment of seeds with growth regulators did not lead to an increase in this nutrient, but on the contrary – in most cases to its decrease by 1.2-32.5 relative points (Fig. 2).

The largest difference between variants with plant growth regulators and without them in terms of the content of the specified nutrient in the grain was observed in the Academichnyi variety for sowing in the later period of October 20 and was 25.0-32.5 relative points. In the other studied options, varietal traits, sowing dates and biological preparations did not affect the accumulation of phosphorus.

The potassium content in the grain was also almost unaffected by varietal characteristics. Whereas during sowing on October 1, treatment of seeds with plant growth regulators in most cases led to its decrease by 2.2-6.8 percentage points (Fig. 3).

With the sowing of the Academichnyi grade in the later period of October 20 and thanks to the use of preparations, there was an increase in potassium content by 2.2-4.1 percentage points, while without them, on the contrary, a decrease by 8.2.

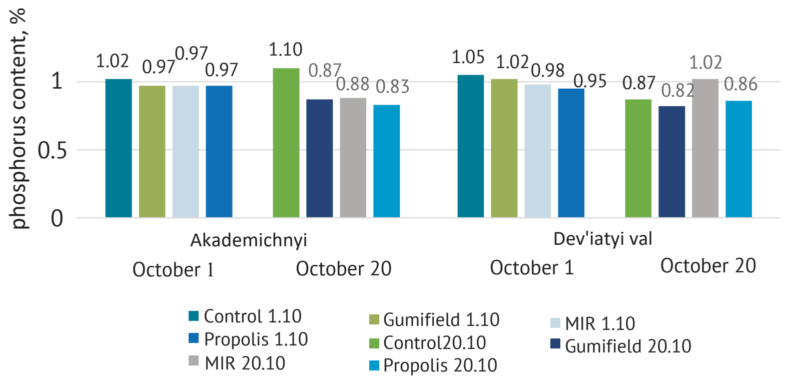

Figure 2. *Phosphorus content in winter barley grains depending on the variety, sowing dates and plant growth regulators, % on dry matter (average for 2016-2019)*

Source: *developed by the authors*

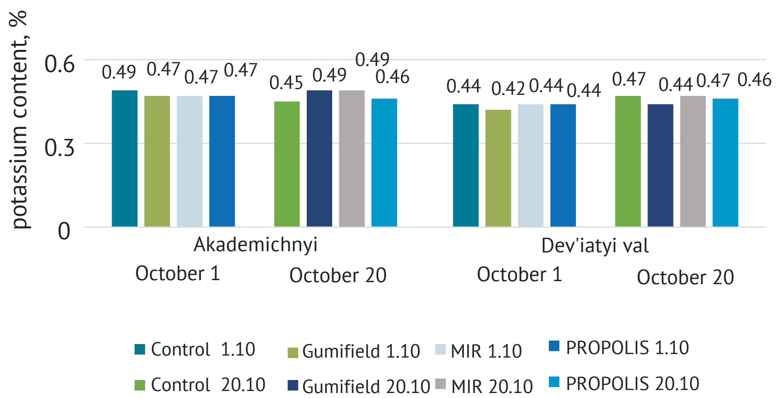

Figure 3. *Potassium content in winter barley grains depending on the variety, sowing dates and plant growth regulators, % on dry matter (average for 2016-2019)*

Source: *developed by the authors*

Sowing the two-handed variety Vyatiay val in the specified period, compared to October 1, with the application of growth regulators, increased the accumulation of potassium in the grain by 4.3-6.4, and also without them – by 6.4 percentage points. However, such differences in grain potassium accumulation between the investigated variants are not significant.

Experimental data show that the use of growth regulators improved, first of all, nitrogen nutrition of winter barley and almost did not affect the accumulation of phosphorus and potassium, both in plants and in grain. It was found that seed treatment with plant growth regulators can improve the accumulation of nutrients in winter barley after earing and increase the transition, mainly nitrogen, from vegetative organs to grain, thereby creating a favorable basis for crop formation.

Based on the results of research, we believe that the use of drugs with growth-regulatory properties for the cultivation of agricultural crops has a perspective, as it solves the problems of plant nutrition and environmental protection by reducing the use of mineral compounds.

CONCLUSIONS

The scientific novelty of this study is that, for the first time, experimental data were obtained on dark chestnut medium loamy soil under irrigation conditions in the south of Ukraine, which testifies to the significant influence of the multi-component plant growth regulators Gumifield Forte Brix, MIR and PROLIS on the variability of the content of the main nutrients in the biomass, and also in grain of various varieties of winter barley.

With a low content of nitrogen in the soil and increased phosphorus and potassium, against the background of the application of N90, the treatment of winter barley seeds with the indicated preparations, both at the optimal and late sowing times, increased the nitrogen content in plants and grain and practically did not affect the accumulation of phosphorus and potassium.

The two-handed variety Dev'iatyi val accumulated more nitrogen in all phases of plant development than the typical winter Akademichnyi, but they are quite close in terms of phosphorus and potassium content.

Regardless of the timing of sowing, the Academichnyi grade accumulated the largest amount of nitrogen in plants and grain with the use of PROLIS and Gumifield Forte Brix preparations, and the Dev'iatyi val – Gumifield Forte Brix.

The practical value of these studies lies in the fact that the use of multicomponent growth regulators in the treatment of winter barley seeds will contribute to the increase of nitrogen content in biomass, as one of the most important elements necessary for plant nutrition, their growth and development, and the formation of grain yield.

In the further scientific plans on the irrigated lands of the south of Ukraine, research should be provided to determine the optimal doses of mineral fertilizers for the use of new multicomponent plant growth regulators of winter barley.

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Динаміка вмісту елементів живлення в рослинах ячменю озимого залежно від сорту, строків сівби та регуляторів росту рослин

Сергій Олександрович Заєць[1], Людмила Іванівна Онуфран[1], Катерина Сергіївна Фундират[1], Сергій Миколайович Юзюк[1], Людмила Богданівна Кисіль[2]

[1]Інститут кліматично орієнтованого сільського господарства
Національної академії аграрних наук України (НААН)
67667, вул. Маяцька дорога, 24, сел. Хлібодарське, Одеська обл., Україна

[2]Херсонський обласний центр з гідрометеорології
73003, вул. Перекопська, 17, м. Херсон, Україна

Анотація. Проблему зі збільшення виробництва зерна ячменю озимого на зрошуваних землях можна вирішити завдяки покращенню сортового складу, оптимізації строків сівби та поліпшенню системи живлення, зокрема через застосування препаратів із росторегулюючими властивостями. Враховуючи важливу біологічну роль регуляторів росту в системі живлення рослин, ставилось за мету визначити вплив Гуміфілд Форте брікс, МИР і PROLIS на вміст азоту, фосфору й калію в основні фази розвитку рослин різних сортів ячменю озимого за оптимального та пізнього строків сівби. Дослідження проводилися в Інституті зрошуваного землеробства (нині Інститут кліматично орієнтованого сільського господарства) НААН за методичними рекомендаціями щодо проведення польових випробувань в умовах зрошення. У надземній масі рослин, соломі і зерні визначали вміст загальний: азоту – за К'єльдалем, фосфору – за Мерфі-Рейлі, калію – на полум'яному фотометрі. Визначено, що на зрошуваних землях Півдня України застосування регуляторів росту Гуміфілд Форте брікс, МИР і PROLIS істотно впливало на акумуляцію основних елементів живлення (особливо азоту) рослинами та зерном ячменю озимого. Найбільший вміст основних елементів живлення в рослинах був на ранніх етапах розвитку (весняне кущення), після чого їх кількість зменшувалась до кінця вегетації культури. Максимальний вміст азоту 2,02 % на суху речовину на сорті Дев'ятий вал та 1,85 % на сорті Академічний забезпечило використання препарату Гуміфілд Форте Брікс. Серед сортів Дев'ятий вал у середньому за фактором регулятора росту рослин акумулював азоту в зерні за сівби 1 і 20 жовтня на 9,1 та 9,5 відсоткових пункти більше, ніж Академічний. Завдяки обробці насіння ячменю озимого регуляторами росту рослин Гуміфілд Форте Брікс і PROLIS та сівби культури в оптимальні терміни можна підвищити вміст азоту в рослинах і зерні відповідно на 6,0-15,1 та 9,3-22,5 відсоткових пункти, що позитивно позначиться на формуванні зерна та його якості. У подальших дослідженнях необхідно оптимізувати дози внесення мінеральних добрив за використання нових багатокомпонентних регуляторів росту рослин ячменю озимого в умовах зрошення Півдня України

Ключові слова: вміст азоту, фосфору і калію, біомаса, терміни висіву, багатокомпонентні препарати, зрошення