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Influence of Pre-Sowing Application of Mineral Fertilizers, Root and Foliar Nutrition on Productivity of Winter Triticale Plants

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ABSTRACT

The purpose of the research was to develop and scientifically substantiate the system of nutrition of winter triticale crops to optimize their production process and increase plant productivity in the Northern Steppe of Ukraine. The highest number of grains in the ear of the main and lateral stems of winter triticale was in the variants where foliar nutrition with a mixture of carbamide, magnesium sulfate and complex fertilizer Ferkrystal Summum during the 31st and 39th microphases and the variants where the third foliar nutrition during the 73-th microphase on the background of root application of ammonium nitrate at a dose of 150 kg/ha was conducted. In these variants, the number of grains in the ear on average over the years and variants for pre-sowing fertilization was 40.6 and 40.0 pieces, respectively, which is 11.2 and 11.5%, respectively, more than in the control. Carrying out three foliar nutrition with a mixture of carbamide, magnesium sulfate and complex fertilizer Fercrystal Summum on the background of root nutrition of ammonium nitrate during the 22nd microphase provided an increase in grain weight from the ear and lateral stems of winter triticale compared to the control (application of ammonium nitrate at the dose of 150 kg/ha on frozen thawed soil) by 0.24 and 0.23 g, respectively, or by 14.8 and 15.4%. The studied variants of pre-sowing application of mineral fertilizers significantly affected the parameters of productive plant stand (the number of plants and lateral productive stems), while nutrition provided significant changes in the parameters of grain productivity of winter triticale plants. On the basis of the researches, during winter triticale cultivation, the farms in the Northern Steppe of Ukraine are recommended to carry out pre-sowing application of ammophos ($N_{12}P_{52}$), to apply ammonium nitrate (N_{50}) for roots in the 22nd microphase in spring and carry out two foliar nutrition in the 31st and 39th microphases with a mixture of carbamide (N_{10}), hepatic magnesium sulfate (1.5 kg/ha) and complex water-soluble fertilizer Ferkrystal Summum.

Keywords: winter triticale, nutrition, plant productivity, pre-sowing fertilization, productive plant stand, complex fertilizers, growth stimulants.

INTRODUCTION

The most important indicator of food security, both at the regional and national levels, is the level of grain production. The key problem in the development of the agro-industrial complex of Ukraine is to increase yields and the gross grain harvest. Currently, the genetic potential of the cultivated varieties of cereals is realized only by 25–40% due to insufficient resistance of plants to stress factors [Zhuchenko, 2009].

Winter triticale has been recently gaining more and more attention because it outperforms other cereals in a number of such important indicators as yield and nutritional value of products. The prospects and value of triticale for the national economy is even greater due to the possibility of using it in several areas – food, forage and technical ones for the production of bioethanol [Bielski et al., 2019; Klikocka et al., 2019].

One of the most important agro-technical factors influencing grain yield is the nutrition system, primarily nitrogen [Dumbrava et al., 2016; Lestingi et al., 2010; Zecevic et al., 2010; Dekic et al., 2014]. By optimizing the rate of application of nitrogen fertilizers and the time of their implementation, one can significantly increase the level of realization of the genetic potential of grain productivity and improve its quality [Janusaukaite, 2013].

Retail application of nitrogen fertilizers provides significant increases in grain yield and significantly affects the protein content of grain. The effectiveness of the application of foliar nutrition of winter triticale plants with urea for the formation of the elements of productivity was confirmed by the research conducted at the Institute of Agriculture of the Carpathian region of NAAS. It was found out that the yield of triticale winter variety Garne in the Western Forest-Steppe, plant structure and grain quality increased due to foliar nutrition of plants with urea against the background of mineral fertilizers $N_{30}P_{30}K_{30}$ before sowing + + N_{30} during the tillering phase [Sviderko et al., 2010].

In terms of grain productivity and triticale grain quality, Janusaukaite D. [2013] considers 90 kg/ha to be the optimal nitrogen rate. Its increase to 120 kg/ha did not provide a significant increase in plant productivity and grain quality of winter triticale.

The researchers Bilitiuk A.P., Novytska N.V., Maksymiuk V.P. [2012] when choosing the forms of nitrogen fertilizers for winter triticale, preferred carbamide or urea-ammonia mixture, which in the same doses of nitrogen provide a better result compared to ammonium nitrate. The highest grain yield in the experiment was about 6.0 t/ha, it was formed against the background of the main application of $P_{60}K_{120}$ for the application of carbamide or urea-ammonia mixture in four steps: N_{30} before sowing and N_{30} during the III-rd, V-th and VII-th stages of organogenesis.

The scientists Nazranov H.M., Bzheumikhov V.S., Kalmykov A.M. [2011] believe that obtaining a winter triticale yield of more than 4.0 t/ha requires 101 kg/ha of nitrogen, 52 kg/ha of phosphorus and 30 kg/ha of potassium. They also note the low efficiency of autumn nitrogen application. Based on the study, the researchers recommend that all phosphorus and potassium be applied under pre-sowing cultivation, and nitrogen given three times – during the II-nd, IV-th and VIII-th stages of organogenesis at doses of 40, 30 and 31 kg/ha, respectively. In this variant, the grain yield of winter triticale averaged about 5.5 t/ha and was 0.8 t/ha higher than the variant where the rate of nitrogen, phosphorus and potassium was the same, but nitrogen was applied twice – for pre-sowing cultivation – 70 kg/ha and during the II-nd stage of organogenesis – 31 kg/ha.

A group of the researchers [Alyonin et al., 2020] note high efficiency of foliar nutrition of winter triticale crops with complex fertilizers with the addition of microelements in the chelated form in combination with growth regulators. Carrying out two foliar nutritions in the phase of tillering and earing with growth stimulant Poly-Feed in a single dose of 4 kg/ha on the background of root application of nitrogen fertilizers (60 kg/ha of the active substance) provided an increase in winter triticale grain yield by more than 20%. An increase in the content of amino acids in the grain was also noted. Besides, it was found out that the grain yield increased to a greater extent from foliar nutrition during the tillering phase. In particular, one-time foliar nutrition of winter triticale crops of Doctrine 110 variety in this phase with a complex fertilizer with the addition of microelements in chelated form – Master Special provided an increase in grain yield of 0.80 t/ha while in the earing phase – by 0.47 t/ha.

Studying different terms of application of one norm of nitrogen (120 kg/ha) under winter triticale Dumbrava M., Ion V., Epore L.I., Basa A.G., Ion N., Dusa E.M. [2016] found out that the largest increase was provided by three-times application of nitrogen – before sowing, in spring after the physical maturity of the soil and during tubing at the same dose – 40 kg/ha of the active substance. They also note that the second term of application is crucial – in early spring during the physical maturity of the soil, which coincides with the beginning of plant tillering. The yield of some varieties of winter triticale in the variant with the application of the full rate of nitrogen (120 kg/ha) in this period was actually on the same level with the yield in the variant of three-times application of nitrogen at a single dose of 40 kg/ha.

A similar view is held by Janusaukaite D. [2013] who notes that the best rate of nitrogen under spring triticale is 90 kg/ha, which should be given before sowing. Retail application before sowing (60 kg/ha) and during the tubing phase (30 kg/ha) did not provide a significant increase in grain yield compared to one-time application before sowing.

Production of high-quality plant products involves the development of measures to optimize mineral nutrition. In recent years, along with the use of traditional mineral fertilizers, there is a growing interest in complex water-soluble fertilizers with microelements in chelated form, as well as growth stimulants [Gaysin et al., 2010; Isaychev et al., 2012].

Deficiency of microelements in the soil reduces the effectiveness of mineral fertilizers, as important biochemical processes in plants are disrupted. Insufficient content of microelements leads to disruption of sugar metabolism, synthesis of protein compounds, reduces the resistance of plants to drought, disease, and exposure to low temperatures. The role of microelements increases notably at high air temperatures and lack of moisture in the soil, when the mobility of micronutrient salts and their availability to plants is low. In case of disturbance of root nutrition in this period, foliar nutrition is especially effective [Sheudzhen et al., 2010].

The use of chelated complex microfertilizers in the technology of growing cereals is one of the promising areas of providing plants with microelements and an effective measure to increase yields and product quality [Borodin, 2007; Kshnikatkina et al., 2014; Nikitin, 2017].

In the research of Kshnikatkina A.N., Kovalenko A.V. and Batkaeva O.R. [2009] grain yield of winter triticale of the varieties Doctrine 110 and Talva 100 after two foliar nutrition of crops with a mixture of complex water-soluble fertilizer Polly-Feed with biological preparation Baikal EM-1 during tillering and earing phases compared to the control variant increased by 43.2 and 32 6% respectively. In addition, the quality of grain improved significantly.

High efficiency of two foliar nutritions with complex fertilizers during the phases of tillering and complete earing of winter triticale crops is noted by Babaitseva T.A. and Sliusarenko V.V. [2020]. The application of complex water-soluble fertilizer Agree's Nitrogen Potassium in these phases, which in addition to a balanced amount of macro- and microelements also contains a complete set of amino acids, increased winter triticale grain yield of Izhevsk 2 and Zymogor by 6–24% and 2–11%, respectively.

In recent years, growth stimulators and regulators have been rapidly introduced into the world practice of agriculture [Calvo et al., 2014; Michalak et al., 2013]. This is a relatively new group of products that can significantly increase grain yield and quality, especially in unfavorable conditions for plant growth and development [Du Jardin, 2015; Radkowski et al., 2013, Colla et al., 2014].

Stimulators and growth regulators are especially important in the cases where the cultivation technology does not meet the genetic capabilities of the variety to ensure a sufficient degree of reliability and protection of the genotype from the adverse effects of the biotic and abiotic environmental factors, which allows realizing the full potential of plants. Their role is to activate physiological processes in the seed, and later in the plant, which has a positive effect on the yield and grain quality, ensuring maximum biological yield [Agyeyeva et al., 2015; Gaveliene et al., 2018; Colebrook et al., 2014].

Significant interest observed in recent years by the agricultural scientists and practitioners in growth stimulants stipulates their multifaceted effects on the plant body in certain phases of development and is associated, according to the research, with significant changes in metabolism, restructuring of metabolic systems, which relate to gene and hormonal levels and cellular energy exchange [Voloshchuk et al., 2015].

The modern market of agrochemicals is characterized by a wide range of different types of chemicals and biological products. In this regard, the study of the impact of fertilizers, growth stimulants, biological products, etc. on the growth and development of field crops, their yield and product quality is devoted to a significant number of works both in Ukraine [Sviderko et al., 2010; Bilitiuk et al., 2012; Agyeyeva et al., 2015; Voloshchuk et al., 2015] and abroad [Nikiforov et al., 2019; Kshnikatkina et al., 2017; Maksimov et al., 2018; Babajceva et al., 2020; Dyomina et al., 2019; Akgul et al., 2016; Bazzo et al., 2018; Chen et al., 2020].Therefore, there is a need for scientific justification for the use of microelement fertilizers and growth regulators in the technology of growing winter triticale.

The aim of the research was to develop and scientifically substantiate the system of nutrition of winter triticale crops to optimize the production process and increase the productivity of winter triticale plants in the Northern Steppe of Ukraine.

RESEARCH CONDITIONS AND METHODS

The research was conducted in 2018–2020 according to the generally accepted method [Moiseichenko et al., 1994] on the areas of PE named after Shevchenko of Velykyi Burluk district of Kharkiv region. The soil of the research area is typical, medium humus chernozem. The thickness of the humus layer is 40–50 cm. The arable soil layer (0–20 cm) contains 3.7% of humus. The content of easily hydrolyzed nitrogen is 8.7 mg/100g of soil; phosphorus and potassium (according to Chirikov's method) – 107–120 and 125–135 mg/kg, respectively. The reaction of the soil solution is neutral (pH = 6.4–6.7).

A two-factor field experiment was performed by the method of split plots in four replications. Three variants of pre-sowing application of mineral fertilizers were studied (factor A): 1 – $N_{32}P_{32}K_{32}$ (200 kg/ha of nitroammophoska); 2 – $N_{12}P_{52}$ (100 kg/ha of ammophos); 3 – N_7P_{31} (60 kg/ha of ammophos). The second-order plots were seven nutrition variants (factor B) (Table 1). The area of the sown area of the experiment is 150 m^2; the accounting one – 100 m^2.

Nutrition was performed with different variants of a mixture of urea at a dose of 10 kg/ha ($N_{5.4}$), hepatic magnesium sulfate at a dose of 1.0 kg/ha and complex water-soluble fertilizer Ferkrystal Summum ($N_{15}P_{15}K_{15}$) at a dose of 1.5 kg/ha. This innovative fertilizer, in addition to nitrogen, phosphorus and potassium, contains a number of microelements (B, Zn, Cu, Mn, Mo, Fe) balanced for cereals. They are chelated by potassium lignosulfonate and EDTA. It also contains a growth stimulant based on plant amino acids derived from the extract of bacteria Ascophyllum nodosum. Besides, this fertilizer also contains phytohormones and oligosaccharides.

The research was carried out on the highly productive, drought-resistant variety of winter triticale Shalanda created at the Plant Production Institute named after V.Ya. Yuriev of NAAS. It was included in the State Register of Plant Varieties of Ukraine in 2014 and recommended for cultivation of the Forest-Steppe of Ukraine.

The agricultural techniques in the experiment, with the exception of the studied elements, were generally accepted for the research area. Winter triticale was sown in the third decade of September with a sowing rate of 4.0 million pcs/ha. The predecessors in the experiment were sugar beets under which $N_{60}P_{60}K_{60}$ was added.

The research area is characterized by unstable humidity conditions. In different years, the amount of precipitation during the growing season of plants deviates significantly from the climatic norm. The most favorable weather conditions for winter triticale plants developed in 2019.

In April, May and the first two decades of June 2018, precipitation was three times less than

Table 1. Scheme of the studied nutrition variants (factor B)

<table>
<tr><th rowspan="2">Variant</th><th colspan="5">Phases of nutrition according to the international BBCH scale</th></tr>
<tr><th>Nutrition on frozen thawed soil</th><th>22</th><th>31</th><th>39</th><th>73</th></tr>
<tr><td>1</td><td>(150 kg/ha NH_4NO_3)</td><td>–</td><td>–</td><td>–</td><td>–</td></tr>
<tr><td>2</td><td>–</td><td rowspan="6">(150 kg/ha NH_4NO_3)</td><td>–</td><td>–</td><td>–</td></tr>
<tr><td>3</td><td>–</td><td>N_c (10 kg/ha) + + $MgSO_4$ (1.0 kg/ha)</td><td>–</td><td>–</td></tr>
<tr><td>4</td><td>–</td><td>N_c (10 kg/ha) + + $MgSO_4$ (1.0 kg/ha) + + FS* (1.5 kg/ha)</td><td>–</td><td>–</td></tr>
<tr><td>5</td><td>–</td><td>N_c (10 kg/ha) + + $MgSO_4$ (1.0 kg/ha)</td><td>N_c (10 kg/ha) + + $MgSO_4$ (1.0 kg/ha)</td><td>–</td></tr>
<tr><td>6</td><td>–</td><td>N_c (10 kg/ha) + + $MgSO_4$ (1.0 kg/ha) + + FS* (1.5 kg/ha)</td><td>N_c (10 kg/ha) + + $MgSO_4$ (1,0 kg/ha) + + FS* (1.5 kg/ha)</td><td>–</td></tr>
<tr><td>7</td><td>–</td><td>N_c (10 kg/ha) + + $MgSO_4$ (1.0 kg/ha) + + FS* (1.5 kg/ha)</td><td>N_c (10 kg/ha) + + $MgSO_4$ (1.0 kg/ha) + + FS* (1.5 kg/ha)</td><td>N_c (10 kg/ha) + + $MgSO_4$ (1.0 kg/ha) + + FS* (1.5 kg/ha)</td></tr>
</table>

Note: FS – complex water-soluble fertilizer Ferkrystal Summum.

normal. Only at the end of June a significant amount of precipitation (over 35 mm) fell. Drought was accompanied by high temperatures. In particular, on some days of the first decade of June, the daytime temperature exceeded 34 °C, which in combination with the lack of precipitation significantly complicated the growth processes of winter triticale plants.

The amount of precipitation during the spring-summer vegetation of winter triticale plants in 2019 and 2020 was virtually the same, but in 2019 precipitation was more evenly distributed and that year's moisture conditions for winter triticale plants were much better. Only in the period from the 10-th to 30-th of June there was a slight deficit of precipitation, but it did not actually harm the plants because in the previous months there was enough rain.

In 2020, the amount of precipitation in the spring and summer period of triticale plants development was the highest, but they were distributed very unevenly, and plants experienced a lack of moisture in critical periods of development. In particular, in March and April the amount of precipitation was three times less than the climatic norm against the background of the deficit of precipitation in winter. During a downpour in late May (about 70 mm per day) hail fell, which, however, lasted no more than a minute and had no critical consequences. Low temperatures during the second and third decades of May, combined with heavy rainfall, slowed the growth and development of winter triticale plants. Drought and high daytime temperatures in June led to lower grain yields due to shrinkage.

The variability of the temperature indicators, different amounts of precipitation during the vegetation of plants and their uneven distribution during the spring-summer vegetation throughout the research years significantly affected the processes of plant growth and development, and hence grain yield. At the same time, such weather conditions are already the norm for the Northern Steppe of Ukraine. In general, the variety of weather conditions in the years of the research, made it possible to more objectively determine the impact of the studied factors on the grain productivity of winter triticale plants.

RESULTS AND DISCUSSION

In the conducted researches the productivity of winter triticale plants changed significantly only under the influence of the studied nutrition variants. No significant effect of pre-sowing application of mineral fertilizers on the studied elements of plant productivity has been established. There was only a statistically unproven tendency to increase the elements of plant productivity on the variants of pre-sowing application of ammophos at a dose of $N_{12}P_{52}$.

The largest number of grains in the ear of the main and lateral stems was formed in the variant where foliar nutrition was carried out with a mixture of carbamide, magnesium sulfate and water-soluble complex fertilizer Ferkrystal Summum during the 31-st and 39-th microphases according to the international BBCH scale and the variant where, in addition, the third nutrition was carried out during the 73-rd microphase against the background of root application of ammonium nitrate at a dose of 150 kg/ha. In these variants, the number of grains in the ear on average by years and the variants of pre-sowing application of mineral fertilizers was 40.6 and 40.0 pieces respectively, which is 11.2 and 11.5% more than in the control (Table 2).

Replacement of early spring application of ammonium nitrate by pre-sowing application at the same dose (150 kg/ha) was more effective from the point of view of ear graininess of the stems of the main and lateral systems. Due to this, the number of grains in the ear of the main stem increased by 2.7%, the lateral one – by 2.0%. However, according to the statistical analysis, no significant difference between these variants has been proven.

The tendency to increase the number of grains in the ear of the main and lateral system of winter triticale stems when replacing the application of ammonium nitrate on the frozen thawed soil by its radical application later – during the 22nd microphase according to the international BBCH scale is quite natural, because the formation of the ear and its graininess occurs in the period from the 30th to the 39th microphase, so nitrogen introduced at the root is mostly used for the formation of ears, spikelets and their graininess, while nitrogen introduced from the frozen thawed soil is partially lost due to leaching and denitrification. In some years, there may be zero efficiency of nutrition on the frozen thawed soil, which can be caused by prolonged frosty spring, when nitrogen evaporates from the field surface, or vice versa, at low prolonged positive temperatures can leach into the lower soil layers and not actually used by plants.

The greatest impact on increasing the grain size of the ear of both stem systems was provided

Table 2. Ear graininess of the main and lateral system of winter triticale stems, depending on different variants for pre-sowing application of mineral fertilizers, root and foliar nutrition, pcs. (Average for 2018–2020)

Nutrition variants (factor B)	Variants for pre-sowing application of complex fertilizers (factor A)			Average
	$N_{32}P_{32}K_{32}$ (*st*)	$N_{12}P_{52}$	N_7P_{31}	
Average number of grains in the ear of the main stem				
1*	36.5[a**]	36.7[a]	36.3[a]	36.5[a]
2	37.8[a]	37.6[a]	37.2[a]	37.5[a]
3	38.7[b]	38.8[b]	38.2[a]	38.6[b]
4	39.2[b]	39.4[b]	38.9[b]	39.2[b]
5	39.8[b]	40.3[b]	39.2[b]	39.8[b]
6	40.5[c]	40.8[c]	40.4[c]	40.6[c]
7	40.6[c]	40.9[c]	40.5[c]	40.7[c]
Average	39.0[a]	39.2[a]	38.7[a]	39.0
$LSD_{05\ (main\ effect\ of\ factor\ A)}$ – 1.4 pcs.; $LSD_{05\ (main\ effect\ of\ factor\ B)}$ – 1.7 pcs.; $LSD_{05\ (partial\ comparisons\ of\ factor\ A)}$ – 1.9 pcs.; $LSD_{05\ (partial\ comparisons\ of\ factor\ B)}$ – 2.2 pcs.				
Average number of grains in the ear of the stem of the first order				
1	34.3[a]	34.8[a]	34.2[a]	34.4[a]
2	35.3[a]	35.1[a]	34.9[a]	35.1[a]
3	36.5[b]	36.4[a]	36.3[b]	36.4[b]
4	37.0[b]	37.1[b]	36.9[b]	37.0[b]
5	37.4[b]	37.7[b]	36.9[b]	37.3[b]
6	38.5[c]	38.5[c]	38.1[c]	38.4[c]
7	38.3[c]	38.8[c]	38.4[c]	38.5[c]
Average	36.8[a]	36.9[a]	36.5[a]	36.7
$LSD_{05\ (main\ effect\ of\ factor\ A)}$ – 1.1 pcs.; $LSD_{05\ (main\ effect\ of\ factor\ B)}$ – 1.4 pcs.; $LSD_{05\ (partial\ comparisons\ of\ factor\ A)}$ – 1.6 pcs.; $LSD_{05\ (partial\ comparisons\ of\ factor\ B)}$ – 1.7 pcs.				

Note: * – the content of nutrition variants is presented in Table 1, ** – belonging of the indicators to statistically identical rank groups according to Duncan's criterion. In the statistical calculations, the years were taken as replication.

by the first foliar nutrition of plants during the 31-st microphase according to the international BBCH scale, because exactly during this period ear differentiation takes place. Foliar nutrition in this phase with a mixture of urea, hepatic magnesium sulfate and complex water-soluble fertilizer Ferkrystal Summum, against the background of root application of ammonium nitrate in the 22-nd microphase, provided an increase in the number of grains in the ear of the main stem compared to the control variant by 2.7 pcs. (7.3%), and in the ear of the lateral stem – by 2.6 pcs. (7.6%).

Carrying out the second foliar nutrition in the 39-th microphase with the same mixture of preparations further increased the number of grains in the ear of the main stem by 1.4 pcs. (3.6%), lateral stem – 1.4 pcs. (3.8%). This can be attributed to the increased graininess of individual spikelets, as during this microphase the spikelets differentiate, i.e., flowers are laid in the spikelets.

Addition to the working solution of urea and magnesium sulfate of complex water-soluble fertilizer Fercrystal Summum during nutrition in the 31-st and 39-th microphases significantly increased the ear grain size of both systems of winter triticale stems compared to the variant where only a mixture of urea and sulfur was applied. This indicates the importance of proper plant nutrition in the phase of laying the reproductive organs. That is, providing plants with a balanced set of macro-, meso- and microelements in this period is an effective way to increase the number of grains in the ear.

The influence of the studied variants of foliar nutrition, as well as pre-sowing application of mineral fertilizers on the variability of the weight of 1000 grains of the main and lateral stems has not been statistically proven. At the same time, there was a tendency to increase the weight of 1000 grains in the variants for foliar nutrition under the 39-th and 73-rd microphases (Table 3).

Foliar nutrition with urea and magnesium sulfate during the 31-st microphase did not show a tendency to increase the weight of 1000 grains

Table 3. Weight of 1000 grains from the ear of the main and lateral system of winter triticale stems with different variants for pre-sowing application of complex fertilizers, root and foliar nutrition, g. (Average for 2018–2020)

Nutrition variants (factor *B*)	Variants for pre-sowing application of complex fertilizers (factor *A*)			Average
	$N_{32}P_{32}K_{32}$ (st)	$N_{12}P_{52}$	N_7P_{31}	
Average weight of 1000 grains from the ear of the main stem				
1*	44.5^{a}	44.5^{a}	44.4^{a}	44.5^{a}
2	44.5^{a}	44.6^{a}	44.5^{a}	44.5^{a}
3	44.6^{a}	44.7^{a}	44.4^{a}	44.6^{a}
4	44.7^{a}	44.8^{a}	44.7^{a}	44.7^{a}
5	45.2^{a}	45.1^{a}	45.2^{a}	45.2^{a}
6	45.3^{a}	45.5^{a}	45.4^{a}	45.4^{a}
7	45.5^{a}	45.7^{a}	45.8^{a}	45.7^{a}
Average	44.9^{a}	45.0^{a}	44.9^{a}	44.9
$LSD_{05\ (\text{main effect of factor } A)}$ – 1.7 pcs.; $LSD_{05\ (\text{main effect of factor } B)}$ – 1.5 pcs.; $LSD_{05\ (\text{partial comparisons of factor } A)}$ – 2.1 pcs.; $LSD_{05\ (\text{partial comparisons of factor } B)}$ – 1.8 pcs.				
Average weight of 1000 grains from the ear of the stem of the first order				
1	43.2^{a}	43.1^{a}	43.2^{a}	43.2^{a}
2	43.6^{a}	43.2^{a}	43.3^{a}	43.4^{a}
3	43.5^{a}	43.3^{a}	43.3^{a}	43.4^{a}
4	43.6^{a}	43.7^{a}	43.4^{a}	43.6^{a}
5	44.1^{a}	44.0^{a}	43.7^{a}	43.9^{a}
6	44.6^{a}	44.5^{a}	44.1^{a}	44.4^{a}
7	44.5^{a}	44.8^{a}	44.4^{a}	44.6^{a}
Average	43.9^{a}	43.8^{a}	43.6^{a}	43.8^{a}
$LSD_{05\ (\text{main effect of the factor } A)}$ – 1.3 pcs.; $HIP_{05\ (\text{main effect of the factor } B)}$ – 1.8 pcs.; $LSD_{05\ (\text{partial comparisons of the factor } A)}$ – 1.6 pcs.; $HIP_{05\ (\text{partial comparisons of the factor } B)}$ – 2.3 pcs.				

Note: * – the content of nutrition variants is presented in Table 1, ** – belonging of the indicators to statistically identical rank groups according to Duncan's criterion. In the statistical calculations, the years were taken as replication.

from the ear of the main and lateral stems. In particular, as in the variant without nutrition, it was 44.5 and 43.4 g, respectively.

The largest weight of 1000 grains from the ear of the main and lateral stems on average in the variants for pre-sowing fertilization – 45.7 and 44.6 g, respectively, was in the variant of three-time foliar nutrition. It increased by 1.2 g (2.7%) and 1.4 g (3.2%), respectively compared with the control variant. As nutrition contributed both to the formation of more grains in the ear of the main and lateral stems, and provided the production of grain with a greater weight of 1000, their impact on the weight of grain from the ear was even greater.

Carrying out three-time nutrition against the background of root application of ammonium nitrate during the 22-nd microphase increased the weight of grain from the ear of the main and lateral stems of triticale compared to the control (application of ammonium nitrate at a dose of 150 kg/ha on the frozen thawed soil) by 0.24 and 0.23 g, respectively, or 14.8 and 15.4% (Table 4).

At the same time, the weight of grain from the ear of the main stem on the variants with three-time foliar nutrition did not differ statistically from the variant where two-time nutrition was performed. Besides, the addition of urea and magnesium sulfate of complex fertilizer Ferkrystal Summum also did not provide a significant increase of the indicator. According to the statistical analysis, they belonged to one homogeneous group. In the context of the studied variants for pre-sowing application of mineral fertilizers, a similar trend was observed.

A slightly different effect of the studied variants of foliar nutrition was observed on the change of grain weight indicators from the ear of the lateral stem. Carrying out the third nutrition during the 73-rd microphase also did not provide a significant increase in the weight of grain from the ear of the lateral stem, but a significant increase was proved by adding to the tank mixture of complex fertilizer Ferkrystal Summum during the second nutrition.

Table 4. Weight of grain from the ear of the main and lateral system of winter triticale stems, depending on different variants for pre-sowing application of complex fertilizers, root and foliar nutrition, g. (Average for 2018–2020)

Nutrition variants (factor B)	Variants for pre-sowing application of complex fertilizers (factor A)			Average
	$N_{32}P_{32}K_{32}$ (st)	$N_{12}P_{52}$	N_7P_{31}	
Weight of grain from the ear of the main stem				
1*	1.63^{a}	1.63^{a}	1.61^{a}	1.62^{a}
2	1.68^{a}	1.68^{a}	1.66^{a}	1.67^{a}
3	1.73^{a}	1.74^{a}	1.70^{a}	1.72^{b}
4	1.75^{a}	1.77^{b}	1.74^{a}	1.75^{b}
5	1.80^{b}	1.82^{b}	1.77^{b}	1.80^{c}
6	1.84^{b}	1.86^{b}	1.83^{b}	1.84^{c}
7	1.85^{b}	1.87^{b}	1.85^{b}	1.86^{c}
Average	1.75^{a}	1.77^{a}	1.74^{a}	1.75
$LSD_{05\ (main\ effect\ of\ factor\ A)}$ – 0.06 pcs.; $LSD_{05\ (main\ effect\ of\ factor\ B)}$ – 0.07 pcs.; $LSD_{05\ (partial\ comparisons\ of\ factor\ A)}$ – 0.10 pcs.; $LSD_{05\ (partial\ comparisons\ of\ factor\ B)}$ – 0.13 pcs.				
Weight of grain from the ear of the lateral stem				
1	1.48^{a}	1.50^{a}	1.48^{a}	1.49^{a}
2	1.54^{a}	1.52^{a}	1.51^{a}	1.52^{a}
3	1.56^{a}	1.58^{a}	1.57^{a}	1.57^{b}
4	1.61^{b}	1.62^{b}	1.60^{b}	1.61^{c}
5	1.65^{b}	1.66^{b}	1.61^{b}	1.63^{c}
6	1.72^{c}	1.72^{c}	1.68^{c}	1.71^{d}
7	1.71^{c}	1.74^{c}	1.71^{c}	1.72^{d}
Average	1.61^{a}	1.62^{a}	1.59^{a}	1.61
$LSD_{05\ (main\ effect\ of\ factor\ A)}$ – 0.04 pcs.; $LSD_{05\ (main\ effect\ of\ factor\ B)}$ – 0.05 pcs.; $LSD_{05\ (partial\ comparisons\ of\ factor\ A)}$ – 0.07 pcs.; $LSD_{05\ (partial\ comparisons\ of\ factor\ B)}$ – 0.09 pcs.				

Note: * – The content of nutrition variants is presented in Table 1, ** – belonging of the indicators to statistically identical rank groups according to Duncan's criterion. In the statistical calculations, the years were taken as replication.

A certain interaction of the studied factors on the variability of grain weight from the ear of the main and lateral stem, by analogy with the previously analyzed indicators has not been established. The influence of nutrition on the grain productivity of the ear of the main and lateral stems on the background of different variants for pre-sowing fertilization was virtually the same.

The level of grain productivity of crops is determined on the one hand by the average productivity of plants (weight of grain from the ear of the main and lateral stem system), on the other – the number of plants per unit of the sown area. Therefore, along with the assessment of the impact of any element of cultivation technology on the productivity of an individual plant, it is necessary to assess its impact on the parameters of plant stand.

In contrast to the indicators of individual productivity of plants, their number per unit area was characterized by significant variation depending on the studied variants for pre-sowing application of mineral fertilizers. Thus, the number of plants before harvest was the largest in the variants for pre-sowing application of ammophos at the rate of $N_{12}P_{52}$. In this variant, it averaged 277 pcs/m^2 in terms of years and nutrition variants, which is 13 pcs/m^2 more than in the control variant (Table 5).

The main reason for the higher density of winter triticale plants in this variant is the higher dose of phosphorus due to which the plants were better hardened to the winter period. Significantly more nitrogen was applied to the control, the action of which, in contrast to phosphorus, was aimed at forming a larger vegetative weight. Under certain circumstances, such as late sowing, nitrogen application at a dose of 30 kg/ha, etc. has a positive effect on overwintering plants, but in our case, sowing dates were optimal, plants had enough time to harden, so the task of increasing the vegetative weight of plants faster did not arise. Based on this, the dose of nitrogen N_{32} is not unreasonably high, because in this case a greater vegetative weight was formed, which was one of the reasons for the preservation of fewer plants before spring

Table 5. Number of plants and lateral productive stems of winter triticale with different variants of pre-sowing fertilization, root and foliar nutrition, pcs./m^2 (average for 2018–2020)

Nutrition variants (factor B)	Variants for pre-sowing application of complex fertilizers (factor A)			Average
	$N_{32}P_{32}K_{32}$ (st)	$N_{12}P_{52}$	N_7P_{31}	
Number of plants				
1*	263^a	272^a	264^a	266^a
2	263^a	274^a	264^a	267^a
3	264^a	274^a	267^a	268^a
4	265^a	280^a	265^a	270^a
5	263^a	278^a	266^a	269^a
6	266^a	281^a	266^a	271^a
7	265^a	280^a	264^a	270^a
Average	264^a	277^b	265^a	269
$LSD_{05\ (main\ effect\ of\ factor\ A)}$ – 11 pcs.; $LSD_{05\ (main\ effect\ of\ factor\ B)}$ – 13 pcs.; $LSD_{05\ (partial\ comparisons\ of\ factor\ A)}$ – 14 pcs.; $LSD_{05\ (partial\ comparisons\ of\ factor\ B)}$ – 17 pcs.				
Number of lateral productive stems				
1	73^a	81^a	72^a	75^a
2	78a	87^a	76^a	80^b
3	79^a	90^b	81^b	83^b
4	86^b	96^b	84^b	89^c
5	86^b	96^b	84^b	89^c
6	87^b	98^c	88^c	91^d
7	87^b	97^c	88^c	91^d
Average	82^a	92^a	82^a	85
$LSD_{05\ (main\ effect\ of\ factor\ A)}$ – 4 pcs.; $LSD_{05\ (main\ effect\ of\ factor\ B)}$ – 4 pcs.; $LSD_{05\ (partial\ comparisons\ of\ factor\ A)}$ – 6 pcs.; $LSD_{05\ (partial\ comparisons\ of\ factor\ B)}$ – 7 pcs.				

Note: * – The content of nutrition variants is presented in Table 1, ** – belonging of the indicators to statistically identical rank groups according to Duncan's criterion. In the statistical calculations, the years were taken as replication

vegetation compared to the variant of pre-sowing application of $N_{12}P_{52}$.

Due to the greater number of plants per unit area, the number of lateral productive stems was also higher in the variants for pre-sowing application of ammophos at a dose of 100 kg/ha ($N_{12}P_{52}$). On average, by years and nutrition variants the number of lateral productive stems made up 92 pcs./m^2, which was 10 pcs./m^2 more comparing to the control variant.

There was no significant effect of the studied variants of root and foliar nutrition on the variability of the number of winter triticale plants. At the same time, there was a tendency to maintain a larger number of them under the condition of foliar nutrition during the 31-st and 39-th microphases.

Factor B variants had a significantly greater influence on the number of lateral productive stems of winter triticale. In particular, on average, according to the years and studied variants of pre-sowing application of mineral fertilizers, the number of lateral productive stems on the variant of three-time foliar nutrition (variant №7) was 91 pcs./m^2, which is 16 pcs./m^2 or 21.0 % more compared to the control variant.

There was virtually no difference in the number of plants between the variants of two-time and three-time foliar nutrition, as well as the variant of one-time foliar nutrition during which the plants were fed with a mixture of carbamide, magnesium sulfate and complex water-soluble fertilizer Fercrystal Summum. Based on this, the later the nutrition is applied, the less is its impact on the parameters of productive plant stand.

This is logical, because the plants have already been formed before tubing, so nutrition can only provide the best conditions for the formation of more productive stems, and at the beginning of tubing. After the plants have passed the 31–35-th microphases of BBCH, foliar nutrition no longer actually affects the formation of more productive stems, except when anti-stress and stimulant preparations are added to the working mixture.

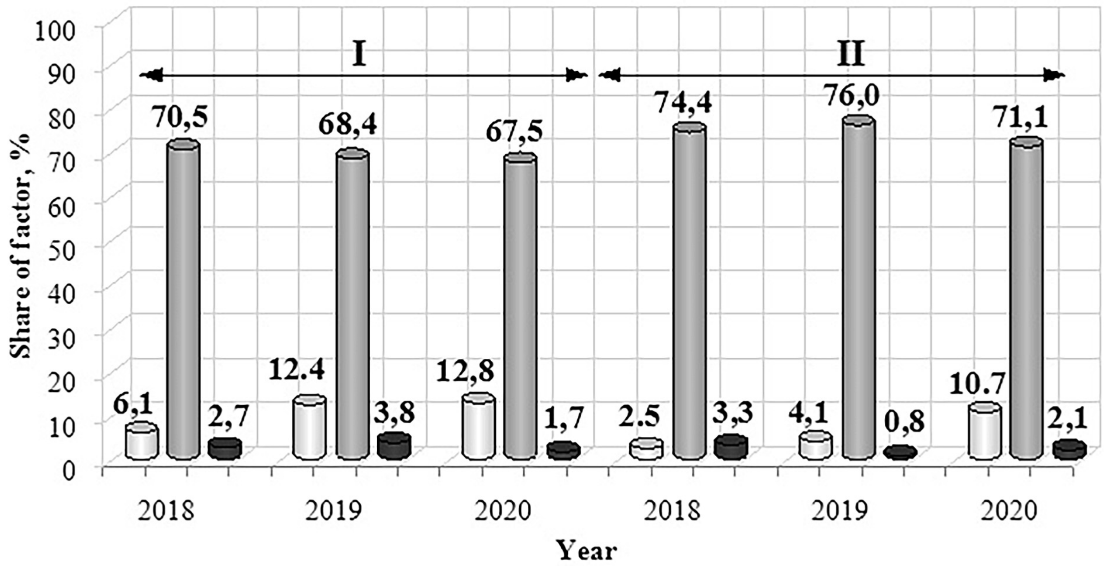

Figure 1. The shares of the studied factors and their interaction in the change in the number of grains in the ear of the main (I) and lateral (II) stems of winter triticale plants, %

Analyzing the influence of the studied factors as the sources of variability of the indicators of individual productivity of winter triticale plants, it is worth noting a much higher role of the studied nutrition variants. In particular, the share of this factor in the variability of the number of grains in the ear of the main stem in 2018, 2019 and 2020 made up 70.5, 68.4 and 67.5%, respectively, while the share of the studied variants for pre-sowing mineral fertilizers was only 6.1%, 12.4 and 12.8%, respectively (Fig. 1). The shares of factor A, as well as the interaction of the studied factors, in the variability of the number of grains from the ear of the main and lateral stem of winter triticale in all years have not been statistically proven.

The influence of nutrition as the sources of variability in the number of grains from the spikelets of lateral stems of triticale was even higher: 74.4 – in 2018, 76.0 – in 2019 and 71.1% in 2020. The share of the studied variants of pre-sowing fertilization, as well as the interaction of these factors in all years was insignificant.

A similar trend was observed in the analysis of the shares of the influence of the studied factors on the variability of grain weight from the ear of the main and lateral stems of winter triticale. In particular, the share of the influence of the

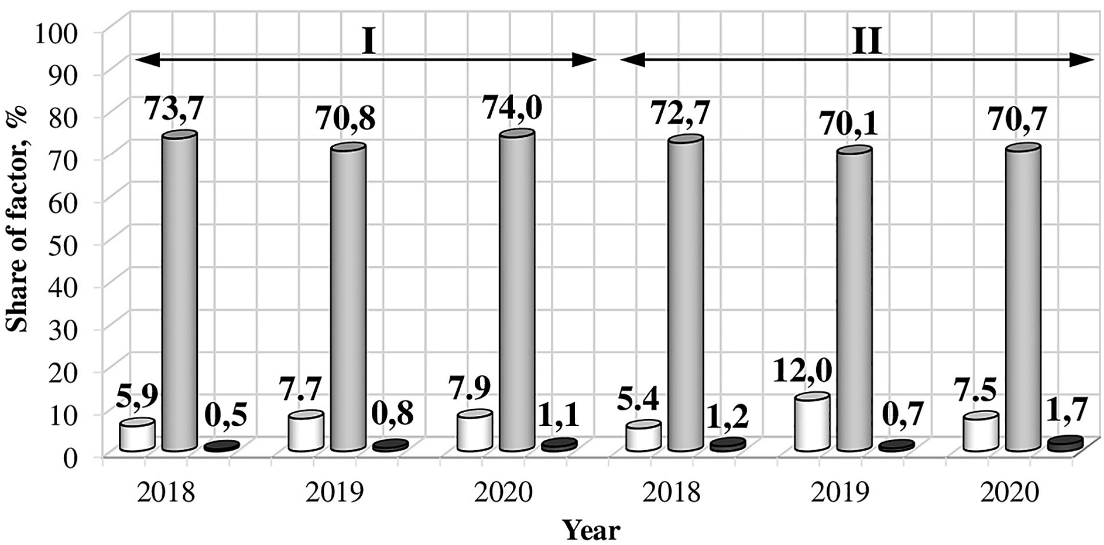

Figure 2. The share of the studied factors and their interaction in the change of grain weight from the ear of the main (I) and lateral (II) stems of winter triticale plants, %

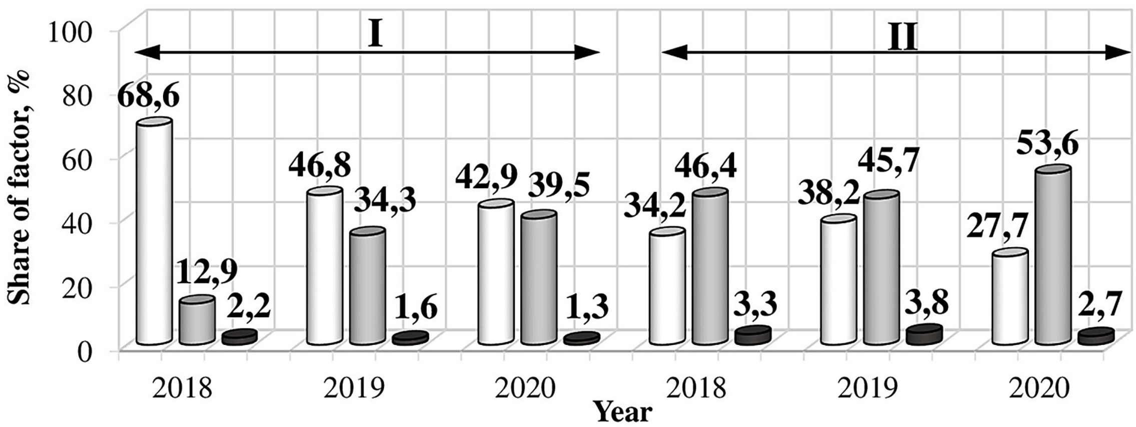

Figure 3. The share of the studied factors and their interaction in the variability of the number of plants (I) and lateral productive stems (II) of winter triticale, %

studied fertilization variants as a source of variability of grain weight from the ear of the main stem in 2018, 2019 and 2020 was 73.7%, 70.8 and 74.0%, respectively, and the weight of grain from the ear of the lateral stem was 72.7%, 70.1 and 70.7% (Fig. 2). The shares of the influence of the studied variants of pre-sowing application of mineral fertilizers as well as the interaction of the studied factors have not been statistically proven.

The variability of the number of plants per unit area, on the contrary, largely depended on the influence of the studied variants for pre-sowing application of mineral fertilizers. In particular, the share of this factor in the variability of the number of plants in 2018, 2019 and 2020 was 68.6%, 46.8 and 42.9%, respectively (Fig. 3). The share of the studied nutrition variants in the variability of the number of plants in all years was smaller but significant – 12.9, 34.3 and 39.5%, respectively.

The variability in the number of the lateral productive stems was also largely due to the influence of factor *B*. In 2018, 2019 and 2020, it was 46.4%, 45.7 and 53.6%, respectively. The shares of the interaction of the studied factors in the variability of the number of plants and lateral productive stems of winter triticale in all years were not significant.

Correlation relationships of varying strengths were observed between the studied plant productivity parameters, some of which required analysis. Thus, the number and weight of grain from

Table 6. Coefficients of correlation between productivity indicators, biological productivity and duration of separate phases of development of winter triticale

Indicator	NP	NLPS	GEMS	GELS	W_{1000} EMS	W_{1000} ELS	WGMS	WGLS	BY	DT	DMR
NP											
NLPS	0.92										
GEMS	0.51	0.62									
GELS	0.68	0.57	0.88								
W_{1000} EMS	0.43	0.62	0.94	0.90							
W_{1000} ELS	0.53	0.68	0.82	0.92	0.96						
WGMS	0.61	0.86	0.93	0.89	0.74	0.61					
WGLS	0.27	0.75	0.79	0.82	0.72	0.84	0.93				
BY	0.45	0.95	0.72	0.81	0.55	0.62	0.92	0.94			
DT	0.14	0.27	0.35	0.31	0.29	0.20	0.27	0.32	0.31		
DMR	0.22	0.29	0.42	0.39	0.32	0.22	0.31	0.34	0.36	0.44	

Note: NP – number of plants; NLPS – number of lateral productive stems; GEMS – grains from the ear of the main stem; GELS – grains from an ear of the lateral stem; W1000 EMS – weight of 1000 grains from the ear of the main stem; W1000 ELS – weight of 1000 grains from the ear of the lateral stem; WGMS – weight of grain from the ear of the main stem; WGLS – weight of grain from the ear of the lateral stem; BY – biological grain yield; DT – duration of the tillering phase; DMR – duration of the phase of milk ripeness.

the ear of the main stem had an average direct relationship with the number of plants per unit area – $r = 0.51$ and $r = 0.61$ (Table 6), although logically, between these indicators a direct relationship can exist only at certain intervals, and then it is transformed into parabolic, because with increasing plant density, the productivity of the ear should decrease.

This result is due to the studied factors, namely the variants of foliar nutrition. With the improvement of nutrition of winter triticale crops, a larger number of plants was preserved at the time of harvest, as well as a larger number and weight of grains in the ear of both stem systems was formed. This is the reason for the positive relationship between the number and weight of grains in the ear of the main stem and the number of plants.

The number of grains in the ear of the main and lateral stem system, as well as the weight of grain from the ear of the lateral stem system had a medium direct relationship with the duration of the phase of tillering and milk ripeness of the grain. That is, with the prolongation of these phases of growth and development, grain productivity of plants increases. This is natural, because one of the positive aspects of the influence of nutrition is the “stretching” of the development phases, due to which the conditions for the formation of a stronger basal zone are better during the tillering phase, and during milk ripeness there is more time to fill the grain.

CONCLUSIONS

The largest number and weight of grains in the ear of the main and lateral stems of winter triticale for an average of three years is 40.8 and 38.5 pieces and 1.86 and 1.72 g, respectively, was formed in the variant of two-time foliar nutrition – in the 31-st and 39-th microphases on the international scale BBCH with the mixture of carbamide (N_{10}), hepatic magnesium sulfate (1.0 kg/ha) and complex fertilizer Ferkrystal Summum (1.5 kg/ha) against the background of pre-sowing application of ammophos ($N_{12}P_{52}$) and root application of ammonium nitrate (150 kg/ha) during the 22-nd microphase. Carrying out the third nutrition during the 73-rd micro-phase from the point of view of grain productivity of plants was not effective.

The studied variants of pre-sowing application of mineral fertilizers significantly affected the parameters of productive plant stand, while nutrition provided significant changes in the parameters of grain productivity of winter triticale plants.

On the basis of the research, the farms in the Northern Steppe of Ukraine are recommended to carry out pre-sowing application of ammophos ($N_{12}P_{52}$), to apply ammonium nitrate (N_{50}) for roots in the 22-nd microphase in spring and to carry out two-time root nutrition with a mixture of carbamide (N_{10}), magnesium sulfate (1.5 kg/ha) and complex water-soluble fertilizer Ferkrystal Summum in the 31-st and 39-th microphases during winter triticale cultivation.

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