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FORMATION TECHNOLOGICAL PROPERTIES OF WINTER WHEAT GRAIN WITH INTRODUCTION OF DIFFERENT DOSES AND TERMS OF NITROGENIC NUTRITION ELEMENTS

The influence of nitrogen fertilization on the formation of technological properties of grain of modern varieties of soft winter wheat was established – with increasing intensity of cultivation technology the protein content increased by 10–15%, gluten to 27.9%, the volume yield of bread increased by 25.8%. The optimal doses and terms of nitrogen fertilization of winter soft wheat were specified in order to optimize nitrogen nutrition of plants and grain formation with the improved technological properties: N70N30N70 – combination of early spring N70 with foliar fertilization at the stage of stem elongation N30 and N70 at the beginning of wheat earing and N100N70N70 – combination of early spring N100 with foliar fertilization in the phase of stem elongation N70 and N70 at the beginning of wheat earing.
The varieties of winter soft wheat were evaluated for their ability to form high-quality grain that meets the requirements of bakery production. The positive effect of nitrogen fertilization on all the varieties studied was established by trial baking, the best results were obtained in the variety Lira Odeska.
Key words: *grain, winter wheat, properties, protein, gluten, quality of bread.*

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ФОРМУВАННЯ ТЕХНОЛОГІЧНИХ ВЛАСТИВОСТЕЙ ЗЕРНА ПШЕНИЦІ ОЗИМОЇ ЗА ВНЕСЕННЯ РІЗНИХ ДОЗ ТА ТЕРМІНІВ ЕЛЕМЕНТІВ АЗОТНОГО ЖИВЛЕННЯ

Встановлено вплив азотного підживлення на формування технологічних властивостей зерна сучасних сортів пшениці озимої м'якої – зі збільшенням рівня інтенсивності технології обробітку вміст білка збільшувався на 10–15%, клейковини до 27,9 %, об'ємний вихід хліба зростав на 25,8 %. Уточнено оптимальні дози та терміни проведення азотного підживлення пшениці озимої м'якої з метою оптимізації азотного живлення рослин та формування зерна з покращеними технологічними властивостями: N70N30N70 – поєднання ранньовесняного N70 з позакореневим підживленням у фазі виходу в трубку N30 та N70 на початку колосіння пшениці та N100N70N70 – поєднання ранньовесняного N100 з позакореневим підживленням у фазі виходу в трубку N70 та N70 на початку колосіння пшениці.
Проведено оцінку сортів пшениці озимої м'якої за їх здатністю формувати високоякісне зерно, що відповідає вимогам хлібопекарського виробництва. Шляхом пробної випічки встановлено позитивний вплив азотного підживлення за усіма сортами, що досліджували, найкращі результати отримано у сорту Ліра Одеська.
Ключові слова: *зерно, пшениця озима, властивості, білок, клейковина, якість хліба.*

Problem statement. Wheat is the main source of food grain. However, the current level of grain production does not fully meet the needs of the processing industry. Therefore, one of the important tasks of modern crop production is to increase the yield of cultivated wheat varieties. Along with increasing wheat yields, the problem of improving grain quality is acute.

In order to fulfill the high productivity potential, inherent in the new generation of wheat varieties, as well as to obtain high-quality food grain, it is necessary to ensure optimal plant nutrition conditions.

Through the use of nitrogen fertilizers, conditions are created for the full implementation of the potential yield of cultivated varieties and grain production with high protein content and improved technological properties. With the emergence of new varieties of winter wheat, resistant to lodging and affection, it is important to study their response to high levels of nitrogen nutrition and the possibility of forming in these conditions high quality grain that meets the requirements of bakery production.

Previous research. In order to fulfill high productivity potential inherent in the new generation of winter wheat varieties, as well as to obtain high-quality grain suitable for food purposes, it is necessary to ensure optimal plant nutrition conditions. Through the use of nitrogen fertilizers, conditions for the full implementation of the potential yield of cultivated varieties and improving technological properties of grain are created. With a high yield, the level of protein accumulation in the grain is defined by the presence of nitrogen in the soil in a form accessible to the plant, especially during the initial grain formation [1–3].

The use of fertilizers in optimal doses has a significant

Table 1

The amount of gluten from the grain of winter wheat depending on the level of nitrogen nutrition, 2021, %

Variant of the experiment	Variety			On average of the experiment
	Zhytnytsia Odeska	Lira Odeska	Oranta Odeska	
N_0 (control)	15,1	16.2	16.3	15.9
N_{70} – physical maturity of the soil	18.7	18.8	18.3	18.6
N_{70} – before earing	23.6	23.3	23.1	23.3
$N_{70+30+70}$	24.0	25.7	24.7	24.8
$N_{100+70+70}$	25.6	27.9	26.2	26.6
On average of the variety	21.4	22.4	21.7	21.8
			LSD_{05} %	2.0

Table 2

Quality of gluten from grain of winter wheat varieties depending on the level of nitrogen nutrition, 2021, FDM units

Variant of the experiment	Variety			On average of the experiment
	Zhytnytsia Odeska	Lira Odeska	Oranta Odeska	
N_0 (control)	60 (I. good)	68 (I. good)	65 (I. good)	64 (I. good)
N_{70} – physical maturity of the soil	64 (I. good)	75 (I. good)	70 (I. good)	70 (I. good)
N_{70} – before earing	89 (II. satisfac.)	83 (II. satisfac.)	85 (II. satisfac.)	88 (II. satisfac.)
$N_{70+30+70}$	84 (II. satisfac.)	85 (II. satisfac.)	93 (II. satisfac.)	87 (II. satisfac.)
$N_{100+70+70}$	85 (II. satisfac.)	84 (II. satisfac.)	96 (II. satisfac.)	88 (II. satisfac.)
On average of the variety		79 (II. satisfac.)	82 (II. satisfac.)	79 (II. satisfac.)
			LSD_{05} %	5.0

effect not only on increasing the yield of winter wheat, but also on improving grain quality [4–7]. However, a number of scientists [8–10] point out that with high doses of nitrogen, along with an increase in protein content, a decrease in yield can be observed. Excess nitrogen contributes to the lodging and development of diseases and, consequently, grain quality reduction.

There are contradictory data in the literature on the influence on the yield and quality of winter wheat grain of different methods and terms of nitrogen application. A number of researchers note the inexpediency of dividing nitrogen dose into parts and believe that a guaranteed increase in yield can be obtained only under autumn application [11], but explain this primarily by the economic disadvantages of dividing the total dose of basic fertilizer and nutrition.

A large number of scientists [12, 13] recommend applying fertilizers in small quantities, i.e., in a few, from 2 to 5 doses. Other scientists [14, 15] report a good effect obtained from the use of nitrogen in the autumn, but not the full dose, and only a part of it. Numerous studies conducted in Ukraine and abroad show that in the initial stages of their development, winter crops need a moderate nitrogen nutrition. The application of high doses of nitrogen in the autumn under seeding leads to growing of winter crops, poor preparation for overwintering (insufficient accumulation of insoluble carbohydrates, poor northwarding) and, as a consequence, significant plant death in spring [13, 15].

The method of nitrogen fertilization is of a particular importance, as nitrogen nutrition should be optimal during all stages of morphogenesis. At the stages of stem elongation and earing nitrogen fertilizers are usually applied in the form of root, and at the beginning of grain filling – in the form of foliar application, which has a positive effect on grain quality, namely significantly increases protein and crude gluten in grains [16, 17].

The aim of the study is to establish the influence of the level and term of nitrogen nutrition application on the technological properties of grain of winter wheat varieties.

Research methodology. The research to study the influence of nitrogen fertilizers on yield formation and technological properties was performed in the research field of farming enterprise "Zlagoda" of Haisyn district, Vinnytsia region and in the research laboratory of the Department of Grain Technology and Grain Processing of Uman National University of Horticulture in 2021. The object of the study was three varieties of soft winter wheat: Zhytnytsia Odeska, Lira Odeska, Oranta Odeska.

For the full implementation of the genetic potential of varieties on the background of pre-sowing application of complex fertilizers, wheat plants were fertilized with ammonium nitrate. Five variants of fertilizer application (ammonium nitrate) were used in the study. In the first variant, nitrogen fertilization was not carried out (control N_0). In the second variant, nitrogen was applied at a dose of 70 kg/ha at the time of physical maturity of the soil (early spring nitrogen fertilization) – N_{70}, in the third variant – the same dose of nitrogen in the form of root fertilization before wheat earing – N_{70}. In the fourth variant, against the background of early spring nitrogen fertilization at the onset of physical maturity of the soil (N_{70}), root nitrogen fertilization was carried out at a dose of 30 kg/ha at the stage of stem elongation and 70 kg/ha at the beginning of wheat earing – $N_{70}N_{30}N_{70}$. In the fifth variant, against the background of early spring nitrogen fertilization (N_{100}), root fertilization with nitrogen at a dose of 70 kg/ha was carried out at the stage of stem elongation and the beginning of earing wheat – $N_{100}N_{70}N_{70}$.

Table 3

Protein content from grain of winter wheat varieties depending on the level of nitrogen nutrition, 2021, %

Variant of the experiment	Variety			On average of the experiment
	Zhytnytsia Odeska	Lira Odeska	Oranta Odeska	
N_0 (control)	9.4	10.3	10.1	9.9
N_{70} – physical maturity of the soil	11.1	11.4	11.1	11.2
N_{70} – before earing	13.3	13.2	13.1	13.2
$N_{70+30+70}$	13.8	13.9	14.5	14.1
$N_{100+70+70}$	14.3	14.9	14.3	14.5
On average of the variety		12.4	12.8	12.6
			LSD_{05} %	0.5

Table 4

Volume yield of bread from grain of winter wheat varieties depending on the level of nitrogen nutrition, 2021, cm³

Variant of the experiment	Variety			On average of the experiment
	Zhytnytsia Odeska	Lira Odeska	Oranta Odeska	
N_0 (control)	812	893	860	855
N_{70} – physical maturity of the soil	824	996	737	852
N_{70} – before earing	883	1105	917	968
$N_{70+30+70}$	862	1092	839	931
$N_{100+70+70}$	874	1124	976	991
On average of the variety		851	1042	866
			LSD_{05} %	19

To grade the quality of winter wheat grain obtained in each variant, the following indicators were determined: protein content (GOST 10846–91 (Kjeldahl method)), quantity and quality of fibrin (GOST 13586.1–68), volume yield of bread and the total baking evaluation (in points).

Statistical processing of research results was performed by t analysis-of-variance method (Dospiekhov, 1985) using computer programs Statistika, Microsoft Ecxel.

Results of the study. The main indicator that characterizes the technological properties of wheat grain is the content of gluten and its rheological properties. Gluten is a complex protein–carbohydrate–lipid complex, which consists of 80–85% protein and is an important indicator of the quality of grain and wheat flour. The quantity and quality of gluten in general are determining indicators of the quality of grain and flour. Proof of this is the fact that these indicators in the state standards for wheat and flour were and remain the main in determining the class of grain or variety of flour. In DSTU 3768–2019, the content and quality group of gluten also determine the grade of wheat grain, but at the same time the protein content is normalized and it is emphasized that preference is given to the protein content when assigning grain to one or another class.

On average, in our studies, the values of this indicator varied from 15.1 to 27.9% depending on the genetic characteristics of varieties and the application of nitrogen fertilizers (Table 1).

In terms of gluten content in the grain in the control variant, the studied varieties did not differ significantly (15.1–16.3% - corresponding to the level of weak wheat), but the lowest value was observed in the variety Zhytnytsia Odeska. A more intensive increase in the amount of gluten, depending on the variant of experiment, occurred in the grain of winter wheat Lira Odeska.

Carrying out early spring nutrition (variant 2) increased gluten content compared to the control variant by an average of 2.7%. However. this is not enough to move to a higher quality group. A single nitrogen fertilization (variant 3) carried out before wheat earing significantly increased gluten content of all varieties by an average of 7.4%. but the yield in this variant was lower compared to variant 2. The average increase in gluten content compared to variant 2 was 4.7%. In variant 3. the grain of all varieties met the requirements of satisfactory filler (23.1–23.6%).

During the three nitrogen fertilizations (variant 4), along with the increase in yield, there was an increase in the accumulation of gluten in the grain by an average of 1.5% compared to variant 2 and 8.9% compared to the control. A further increase in the dose of nitrogen fertilizations (variant 5), although not significantly increased the grain yield, but increased gluten content by another 1.8%. The most valuable in terms of quality was wheat grain grown in experimental variants 4 and 5.

The rheological properties of washed-out gluten are represented by a complex of physicochemical properties: elasticity, tensile strength, gas holding capacity – they are valuable fundamental pillars that form the mechanical basis of the dough, and later, the structure of the bread crumb.

The results obtained to determine the quality of gluten are presented in table 2. On a relatively low nitrogen background (N_0 and N_{70} in early spring) good rheological properties of gluten were observed in the variety Zhytnytsia Odeska, weaker gluten – in the variety Lira Odeska.

In the variant with later nitrogen fertilization (variant 3) and in the combination of early spring and late fertilizations (variants 4 and 5), in which the amount of gluten in the grain increased, there was a weakening of gluten and transition from the first (I) quality group to the second (II) (increase in FDM). Particularly noticeable weakening of gluten in these cases occurred in the variety Oranta Odeska.

Protein is an important part of the diet of both humans and animals, plays an important role in metabolism. Determining the content of protein in grain and seeds is primarily necessary for pricing: when selling agricultural

Table 5

General bakery evaluation of winter wheat varieties depending on the level of nitrogen nutrition, 2021, point

Variant of the experiment	Variety			On average of the experiment
	Zhytnytsia Odeska	Lira Odeska	Oranta Odeska	
N_0 (control)	3.3	3.4	3.0	3.2
N_{70} – physical maturity of the soil	3.0	3.5	3.4	3.3
N_{70} – before earing	3.2	4.2	3.4	3.6
$N_{70+30+70}$	3.6	4.2	3.5	3.8
$N_{100+70+70}$	3.7	4.4	4.2	4.1
On average of the variety	3.4	3.9	3.5	3.6

products DSTU regulates the minimum level of this indicator, and supply contracts may set requirements for the supply of products with a specific high-quality indicator.

Protein is an important nutrient in cereal grains and processed products. The protein content can vary from 5 to 26% in different types of cereals. Also, depending on the sample, amino acid composition of the protein, which directly affects its nutritional value, will also be different.

The protein content is very important, in particular, for wheat, because in commercial relations it affects the grain class, and in production it is an indicator of flour-milling and baking properties of wheat.

Our research found that with increasing the level of intensity of processing technology, protein content increased from 10% (control) to 14.6% in the 5th variant (Table 3).

On a low nitrogen background (control) the variety Zhytnytsia Odeska had a lower ability to accumulate proteins. Variety Lira Odeska responded to increased nitrogen nutrition better than others, i.e., protein content in grain increased with increasing doses of nitrogen nutrition. Thus, in variant 4, the increase in protein content compared to the control was by 4.4% in the variety Zhytnytsia Odeska and 3.6 and 4.2% – in the varieties Lira Odeska and Oranta Odeska, respectively. The largest accumulation of protein in the grain occurred in variant 5, regardless of the variety and was in the range of 4.2–4.9%. The content of protein in the grain during the three nitrogen fertilizations increased by 4.3–5.1%.

To forecast the quality of bakery products, it is not enough to know the quality indicators of the flour specified in the regulations for it. Indicators characterizing its baking properties, which are characterized by a set of indicators that are due to its biochemical composition, as well as the dispersion of particles, are important.

Baking properties determine the behavior of flour in the technological process, they shape the quality of bread and depend on the state of carbohydrate-amylase, protein-proteinase, lipid-lipolytic complexes, as well as the content of compounds that cause darkening of flour in bread making. Among the latter, the amino acids tyrosine and phenylalanine and the enzyme polyphenol oxidase are the most important.

Baking properties of flour are due to a combination of the following indicators: the ability to form a dough with certain structural and mechanical properties and a certain degree of their change during fermentation – by the strength of flour; gas-forming ability, i.e. the ability to ensure the release of a certain amount of carbon dioxide for a certain time of fermentation of the dough; the color of the flour and its ability to darken in the process of bread making; autolytic ability, i.e. the ability to break down high molecular weight components under the action of their own flour enzymes and the accumulation of water-soluble substances; the size of the flour particles; water absorption capacity.

Evaluating baking properties of grain, it was found that variety Lira Odeska differed in all cases of the experiment by the indicator of volumetric yield of bread (Table 4).

The lowest volume of bread for all the varieties studied was observed in the control variant. Early spring nitrogen fertilization significantly increased the volume yield of bread in the variety Lira Odeska (by 11.5% compared to the control), while the variety Oranta Odeska volume yield decreased by 14.3% and amounted to 737 cm^3, and in the variety Zhytnytsia Odeska the studied indicator did not increase significantly (824 cm^3).

Carrying out nitrogen fertilization (N_{70}) before earing (variant 3) helped to increase the volume yield of bread for all varieties of winter wheat, which were studied in the range of 6.6–23.7%, with the highest value observed in the variety Lira Odeska (1105 cm^3).

The combination of early spring with later nitrogen fertilization in variant 4, along with the increase in the yield of winter wheat, also increased the volume yield of bread compared to variant 2 by 38-102 cm^3, but compared to variant 3, on the contrary, the volume yield of bread decreased by 13–78 cm^3. In addition, it should be noted that a significant decrease and increase in the value of the volume of bread yield occurred in the variety Oranta Odeska, which can probably be explained by the peculiarity of this variety.

A significant increase in the volume yield of bread was observed in variant 5, compared to the control indicator it increased by 7.6–25.8% depending on the variety. The highest volume yield of bread was observed in the variety Lira Odeska – 1124 cm^3, which increased compared to the control by 25.8%.

The complex characteristic of baking properties of flour is received by carrying out trial baking. According to the standard for trial baking, the dough is prepared by straight dough method. The quality of baked bread is determined 4 hours after baking. The correct shape of bread, shape stability (ratio of height to diameter), crust color (pale, golden-yellow, light brown, brown, dark brown), crust surface condition: smooth, uneven, (with swelling, bumpy, with cracks or oven breaks) are evaluated.

The color of crumb (white, light-gray. dark) is evaluated. Attention is paid to the uniformity of crumb color. Porosity of the crumb, uniformity or unevenness of the pores, their size (small, medium, large), the wall thickness of the pores (thick- or thin-walled) is evaluated. The elasticity of the crumb is determined by pressing it with fingers, it is characterized as good, medium or bad. Attention is paid to the stickiness of the crumb. Taste, aroma and crunch are also evaluated. The best bread according to the set of baking indicators was noted in the variety Lira Odeska according to all variants of the experiment (Table 5).

Oranta Odeska variety had low indicators of bread quality in variants without nitrogen fertilization (control), but in the variant with a high level of nitrogen nutrition (variant 5), according to the general baking evaluation, it was close to Lira Odeska variety.

There was a positive effect of grain nitrogen fertilization on the baking properties carried out before wheat earing (variant 3) in the variety Zhytnytsia Odeska (3.2 points), and a significant effect in the variety Lira Odeska (4.2

points), while in the variety Oranta Odeska baking evaluation remained unchanged. The combination of early spring and late nitrogen fertilization (variant 4) also had a positive effect on improving general baking evaluation, especially in the variety Zhytnytsia Odeska, while in the variety Lira Odeska the value was stable.

Conclusions. It was found that the amount of gluten varied from 15.1 to 27.9% depending on the genetic characteristics of varieties and the application of nitrogen fertilizers. With increasing gluten in the grain, there was a weakening and transition from the first (I) quality group to the second (II), and this was especially noticeable in the variety Oranta Odeska.

Increase in the level of intensity of processing technology contributed to the increase of protein content from 10% (control) to 14.6% in the 5th variant. Zhytnytsia Odeska variety had the lowest ability to accumulate proteins.

Early spring nitrogen fertilization reduced the volume yield of bread by 14.3% in Oranta Odeska variety, however, the application of fertilizers before earing and in other variants of the experiment increased the volume yield of bread by 7–26% depending on the variety. The highest volume yield of bread was observed in the variety Lira Odeska – 1124 cm^3.

Bread of the variety Lira Odeska was noted as the best bread according to the set of baking indicators in all variants of the experiment; in the variant with a high level of nitrogen nutrition (variant 5) according to general baking estimate the variety Oranta Odeska was close.

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