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YIELD AND GRAIN QUALITY OF SOFT WINTER WHEAT DEPENDING ON THE FERTILIZATION IN THE NORTHERN STEPPE OF UKRAINE

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Abstract

The results of the long-term researches on determination of the influence of mineral fertilizers on the soft winter wheat yield and grain quality after black fallow and after spring barley in the conditions of Northern Steppe of Ukraine are presented. According to the research in 2012-2014 it is established that application of spring-summer nitrogenous top-dressing at sowing after black fallow provided (according to the quality indicators set regulated by the current national standard for wheat DSTU 3768: 2019) formation of grain of the second class of quality at winter wheat varieties Lytanivka, Zamozhnist, Antonivka and Rozkishna and for the most part the first class - at variety Sonechko by the yielding capacity within 6.19-6.60; 6.25-6.74; 5.60-6.08; 5.89-6.37 and 5.38-5.71 t/ha respectively. The expediency of double top dressing of winter wheat sowings after spring barley is scientifically proved: ammonium nitrate in dose N_{30} early in the spring on frozen-melted soil and in the end of tillering stage of plants, that provided the obtainment of yielding capacity of 4.70-5.28 t/ha with grain quality of the second and third class in the favorable moisture years. Studies conducted in 2016-2018 found that the highest yields in varieties Kokhanka, Missiya Odeska and in Pylypivka grown after black fallow were formed by plant feeding with ammonium nitrate locally in the late tillering phase, dose of 60 kg/ha, active substance. In this feeding mode increase in yield compared with the control (without feeding) was, depending on variety, 0.58-0.64 t/ha. The highest yield (7.23 t/ha) was formed by Pylypivka variety. When growing winter wheat after spring barley, the increase in grain yield, compared with the control (without feeding) in variety Kokhanka, on average for three years depending on feeding option, was 0.48-1.20 t/ha; in Missiya Odeska - 0.36-1.15; and in Pylypivka - 0.51-1.16 t/ha. The highest increase in yield was provided by the application of nitrogen fertilizer (a dose of 60 kg/ha) on frozen-melted soil and in two terms: spreading N_{60} on frozen-melted soil and local application of N_{30} at the end of tillering. The Kokhanka variety yield under these feeding mode was 5.31 and 5.46 t/ha, respectively, Missiya Odeska - 4.78 and 5.03 t/ha, and Pylypivka - 5,47 and 5.62 t/ha. The highest grain yield (5.62 t/ha) was formed by winter wheat variety Pylypivka with application of ammonium nitrate N_{60} on frozen-melted soil and local application of N_{30} at the end of tillering. Experimental data analysis and generalization showed that application of nitrogen fertilizers in spring-summer growing season after both predecessors, as a rule, facilitated improved grain quality, namely: grain nature, vitreousity, protein and crude gluten content, flour sedimentation.

Key words*: winter wheat, variety, mineral fertilizers, predecesor, yield, grain quality.*

INTRODUCTION

Stable demand for food in the world opens up prospects for expanding the market for Ukrainian agricultural products. Among other crops, the leading place belongs to winter wheat, the main food crop. In recent years, quantitative indicators of the yield for soft winter wheat (*Triticum aestivum* L.) fully cover domestic demand for food wheat and allow to increase its exports, which contributes to strengthening the country's economy (Kernasiuk, 2020; Procopenko, 2019).

Among the most important factors influencing the formation of winter wheat yield and quality are the weather conditions during the growing season, variety, predecessor and crops fertilizer.

Modern varieties should be characterized by adaptability to growing conditions, resistance to environmental stressors, especially in the area of insufficient and unstable moisture - conditions of Ukraine's Steppe Zone (Netis, 2008; Remeslo & Saiko, 1981; Sobolev, 1979). Winter wheat is a crop demanding to nutritional conditions.

From this point of view, it is desirable to sow after the best predecessors, with sufficient essential nutrients reserves necessary for optimal plants growth and development, nitrogenous substances accumulation in the vegetative mass; all this is a guarantee of good yields of high quality grain (Likhochvor, 2016; Maathus & Diatloff, 2013; Romheld & Kirkby, 2010; Solodushko, 2016). To form 1 ton of winter wheat, grain the following is required: 25-35 kg of nitrogen, 11-13 kg of phosphorus, 20-27 kg of potassium, as well as a number of other elements such as calcium, magnesium, sulfur and others. As yield increase, so does the nutrients removal from the soil by wheat plants (Karasiuk et al., 1995).

However, regardless of the planned harvest, available varieties, predecessors and the effective soil fertility level, the use of mineral fertilizers on standard black soil has its own peculiarities. Phosphorus and potassium fertilizers in full ($P_{45-60}K_{30-45}$) are applied with the main tillage or with the pre-sowing cultivation. After non-fallow predecessors, where the mobile nitrogen compounds content is bordering low and medium supply (7-13 mg/kg) there is a need to apply nitrogen fertilizers in the pre-sowing period in doses 45-60 kg/ha of acting substance. However, the final calculation of the fertilizers amount is adjusted according to the soil diagnostics results (Buka, 2000; Cherenkov et al., 2021).

Based on the previous studies analysis, it is proved that the nitrogen nutrition optimization for winter wheat growing season has a significant impact on the formation of yield and grain quality of this crop. Early spring fertilization is particularly appropriate for weakened crops (especially the ones not fertilized in the autumn). Such fertilization promotes plant regeneration after winter, enhances tillering and the new shoots formation (Vaguseviciene et al., 2012). Grain quality is improved by application of later feedings - at the end of the tillering phase, in the earing phase and at the milk ripeness beginning. In the context of the introduction of new high-yielding winter wheat varieties against the background of climate change, studies of the fertilizers impact on yield and grain quality for these varieties after various predecessors continue to remain relevant (Zhemela & Musatov, 1989).

MATERIALS AND METHODS

The research experimental part was conducted on the research farm "Dnipro" (State Enterprise "Institute of Grain Crops of NAAS of Ukraine") located in the central part of Ukraine's Northern Steppe. The experimental fields soil cover is represented by ordinary low-humus full-profile black soil. The soil mechanical composition is medium loamy. The zone climate is temperate-continental with insufficient and unstable moisture. Field experiments were performed after black fallow and after spring barley. For pre-sowing cultivation after black fallow the background fertilizer was applied in doses $N_{0-30}P_{60}K_{30}$, and after the stubble predecessor - $N_{60}P_{60}K_{30}$. Wheat seeds were sown with a CH-16 seeder with a row spacing - 15 cm, seed wrapping depth - 5-6 cm. Harvesting was carried out separately on different plots by "Sampo - 500" combine.

Experiments were laid down by the successive plots method, in a systematic way. The accounting plot area was 30-35 m^2, the repetition of experiments - three times. In different years, were studied the grain yield and quality dependence on nitrogen fertilization for soft winter wheat varieties Lytanivka, Zamozhnist, Antonivka, Sonechko, Rozkishna, Kokhanka, Missyia Odeska and Pylypivka. According to variety testing results the varieties Zamozhnist and Kokhanka are classified as valuable in terms of grain quality, other varieties are classified as strong. Grain quality indicators were determined according to the methodology provided by current national regulations. The distribution of winter wheat grain into classes was carried out in accordance with Ukraine's grain standard DSTU 3768: 2019.

RESULTS AND DISCUSSIONS

Agro-meteorological conditions during the research years were different and significantly affected the winter wheat plants growth and development, and thus the formation of yield and grain quality. The vegetation period of 2011/12 was extremely dry. The precipitation amount for the year, starting from August 2011 and ending in July 2012, was lower by 122.9

мм compared to the average long-term data. The autumn period of 2011 was very unfavorable for moisture, the lack of precipitation was about 75%. It should be noted that under such conditions more damage was seen in crops after non-fallow predecessors, while after fallow crops were in satisfactory condition. In experiments after spring barley at autumn vegetation end crops were liquefied and heterogeneous, the plants were in the 3rd leaf appearance phase and the tillering beginning. December warm spells weakened the plants hardening before winter process, and very cold and dry weather, which settled in late January and lasted until the end of the second decade of February, also worsened the winter crops condition. During the spring-summer vegetation of plants, abnormally hot, with a lack of precipitation weather was observed in the period from April 24 to June, which led to delayed grain filling, premature ripening and reduced yields. In subsequent years, the weather conditions were more favorable for winter wheat growth, development and yield formation.

Comparing the winter wheat yield in different weather conditions, it can be noted that on average for varieties Lytanivka, Zamozhnist, Antonivka, Sonechko and Rozkishna depending on the experiment variant with growing after black fallow this indicator value in 2012 was 3.87-4.27 t/ha, in 2013 - 6.67-7.40, and in 2014 - 6.77-7.23 t/ha. After spring barley the yield varied in 2012 between 2.24 and 2.39 t/ha, in 2013 and 2014 it was significantly higher and varied from 4.16 to 4.70 and from 4.73 to 5.28 t/ha, respectively.

In all years after black fallow and in favorable for moisture 2013 and 2014 after spring barley there were increases in yields when nitrogen feedings were applied. The highest values were established after fallow in the experiment option where at the spring tillering phase end ammonium nitrate was applied locally: dose N_{60}; and after spring barley - for two step application of this fertilizer:N_{30} on two dates: on permafrost soil and locally. In 2012, nitrogen feedings after the stubble predecessor was ineffective and in most experiment variants did not increase yields. On average, in 2012-2014, winter wheat cultivation after black fallow for varieties Lytanivka, Zamozhnist, Antonivka, Sonechko and Rozkishna in the variants with feedings formed the yield in the range of 6.10-6.60; 6.25-6.74; 5.60-6.08; 5.89-6.37 and 5.38-5.71 t/ha, respectively.

In the growing season 2011/12 in dry weather conditions, low yields of winter wheat were noted. But studied varieties both after black fallow and after spring barley, formed high-protein grain, which according to current national regulations (DSTU 3768: 2019) corresponded mainly to the first class quality (protein content in grain more than 14%, crude gluten - more than 28%). In 2013 after black fallow, on average in all experiment variants the protein content in grain, depending on the variety, was 12.7-14.0%, gluten - 23.4-27.6% (the second class), in 2014, respectively, 11.2-13.4 and 23.7- 27.7% (the second and third class). After spring barley, in 2013 the amount of protein in grain was 11.0-12.4%, and gluten - 19.0-23.0% (the third class), in 2014, respectively, 11.6-13.4 and 24.0-30.3% (the second and third classes).

The grain protein content of winter wheat varieties depended on nitrogen feedings. On average, in 2012-2014, in the experiment variants where such feedings were applied, the highest protein and crude gluten content in wheat grain after black fallow was in variety Sonechko (14.0-14.5 and 27.5-30.2% respectively), while in the control group these indicators were 13.4 and 27.2%, respectively. In other varieties, after nitrogen feedings the protein content varied between 12.8 and 13.9%, gluten - 25.4-27.3%; in the control group - between 12.3-12.8% and 24.4-24.9%, respectively. The highest indicators of protein and gluten content in winter wheat grain of different varieties were formed with two-step nitrogen feedings of crops: at the tillering phase end the with ammonium nitrate (a dose of 30 kg/ha of acting substance), and urea in the earing phase (Table 1). According to the set of quality indicators in variety Sonechko with different fertilizer options, excluding feedings with urea-ammonia mixture (UAN-32), the first class quality grain was formed, in other varieties - the second class quality grain.

Table 1. The grain protein and gluten content in winter wheat varieties depending on the nitrogen feedings after black fallow, 2012-2014

Nitrogen fertilizer	Grain protein content, %					Grain gluten content, %				
	1*	2	3	4	5	1	2	3	4	5
No feeding - control (background $P_{60}K_{30}$)	12.4	12.7	12.8	13.4	12.3	24.4	24.4	24.8	27.2	24.9
N_{30} at the end of plants tillering, ammonium nitrate	13.0	13.4	13.4	14.1	12.9	25.8	25.7	26.0	28.5	26.4
N_{30} at the end of plants tillering, UAN-32	13.0	13.3	13.2	14,0	12.9	25.8	25.4	25.7	27.5	26.5
N_{30} in the earing phase foliar, urea	12.8	13.3	13.3	14.0	13.0	25.6	26.0	25.5	28.4	26.5
N_{60} at the end of plants tillering, ammonium nitrate	13.0	13.6	13.5	14.4	13.2	26.6	26.2	26.1	29.9	26.7
N_{30} at the end of plants tillering, ammonium nitrate + N_{30} in the earing phase foliar, urea	13.3	13.9	13.6	14.5	13.5	26.8	26.3	27.0	30.2	27.3
**1 - Lytanivka; 2 - Zamozhnist; 3 - Antonivka; 4 - Sonechko; 5 - Rozkishna*										

After spring barley, like after black fallow, the highest amount of protein and crude gluten in wheat grain, on average for three years of research, was in the variety Sonechko. With different nitrogen feedings, in the grain of this variety the protein content was in the range of 13.1-14.3%, gluten - 26.3-30.1% (in the control, respectively 13.3 and 26.7%). In other varieties with spring-summer fertilization of crops these indicators varied between 11.8-13.7 and 23.3-26.5% respectively. In the control group, grain protein content depending on the varieties, was 11.9-12.7%, and crude gluten - 23.6-24.6%. The best grain quality was obtained with two-step nitrate feeding of winter wheat varieties: ammonium nitrate (dose 30 kg/ha of acting substance) in early spring on frozen-thawed soil and at the tillering phase end; ammonium nitrate (dose 30 kg/ha of acting substance) at the tillering phase end and urea N_{30} in the earing phase (Table 2).

According to the set of quality indicators in variety Sonechko with above variants of nitrogen feedings the first class grain was formed. With different variants of feedings - the second class grain was formed.

Table 2. The grain protein and gluten content in winter wheat varieties depending on the nitrogen feedings after spring barley, 2012-2014

Nitrogen fertilizer	Grain protein content, %					Grain gluten content, %				
	1*	2	3	4	5	1	2	3	4	5
No feeding - control (background $N_{60}P_{60}K_{30}$)	12.0	12.7	12.5	13.3	11.9	24.1	24.6	24.1	26.7	23.6
N_{30} at the end of plants tillering, ammonium nitrate	12.4	13.0	12.9	13.6	12.2	25.8	24.9	25.7	28.3	23.9
N_{30} at the end of plants tillering, UAN-32	12.2	12.6	12.4	13.1	11.8	24.0	24,0	23.7	26.3	23.3
N_{60} at the end of plants tillering, ammonium nitrate	12.3	13.2	13.0	13.4	12.4	25.9	25.3	26.0	28.2	24.8
N_{30} in early spring on frozen-thawed soil + N_{30} at the end of plants tillering, ammonium nitrate	13.3	13.4	13.7	14.0	12.4	27.6	27.3	26.5	29.0	25.7
N_{30} at the end of plants tillering, ammonium nitrate + N_{30} in the earing phase foliar, urea	12.5	13.1	12.9	14.3	12.7	25.7	26.5	26.1	30.1	26.1
**1 - Lytanivka; 2 - Zamozhnist; 3 - Antonivka; 4 - Sonechko; 5 - Rozkishna*										

According to 2016-2018 research results with winter wheat varieties Kokhanka, Missiya Odeska and Pylypivka, it was found that after black fallow among the nitrogen feedings options the higher yield was obtained with applying ammonium nitrate locally (a dose - N_{60} at the end of spring tillering). This feeding option provided an increase in grain yield 0.58-0.64 t/ha depending on the variety. We would like to note the tendency to increased yields with foliar feedings with urea in the plants earing phase. However, significant difference compared to the control group (only pre-sowing application of complete fertilizer $N_{30}P_{60}K_{30}$) was noted with combination of urea and "Falcon" fungicide in dispencing container. Among the studied varieties higher yield in all experiment variants was formed by variety Pylypivka with the highest indicator (7.23 t/ha) in the variant with N_{60} application locally (Table 3.).

Table 3. Influence of nitrogen feedings on yield, grain protein and gluten content for different varieties of winter wheat after black fallow, 2016-2018

Nitrogen fertilizer	Yield, t/ha			Grain protein content, %			Grain gluten content, %		
	1*	2	3	1	2	3	1	2	3
No feeding – control (background $N_{30}P_{60}K_{30}$)	6.43	6.30	6.59	11.8	11.9	12.0	20.8	19.9	21.2
N_{30} at the end of plants tillering, ammonium nitrate	6.78	6.64	6.98	12.0	12.1	12.5	21.4	20.6	23.0
N_{60} at the end of plants tillering, ammonium nitrate	7.01	6.91	7.23	12.3	12.3	12.7	22.0	22.0	23.5
N_{30} in the earing phase foliar, urea	6.54	6.42	6.72	12.6	12.4	12.7	22.7	22.0	24.1
Mixture of urea (N_{30}) + fungicide Falcon (600 ml/ha) in the earing phase foliar	6.68	6.51	6.84	12.9	12.3	12.4	23.8	21.9	22.4
**1 - Kokhanka; 2 - Missiya Odeska; 3 - Pylypivka*									

As for the winter wheat grain quality it should be noted that the nitrogen fertilizers use in the spring-summer growing season after black fallow, as a rule, helped to increase the grain protein and crude gluten content. For varieties Kokhanka and Missiya Odeska, the best options were those where winter wheat crops had feedings with ammonium nitrate at the tillering phase end (dose 60 kg/ha of acting substance) and foliar feedings with urea (simultaneously with fungicide). In winter wheat variety Pylypivka for protein compounds accumulation the most effective were feedings at the tillering phase end locally (N_{30-60}) and foliar N_{30} in the earing phase.

In winter wheat cultivation after spring barley (against the background of $N_{60}P_{60}K_{30}$) nitrogen feedings at different times and with different doses (ammonium nitrate was always used) had a positive effect on the grain yield.

The yield increase compared to the control in variety Kokhanka was 0.48-1.20 t/ha, Missiya Odeska - 0.36-1.15 t/ha, and in variety Pylypivka - 0.51-1.16 t/ha.

The most effective was N_{60} application in early spring on frozen-thawed soil, as well as its combination with subsequent feeding with N_{30} locally at the tillering end. With such feeding options Kokhanka variety yield was 5.31 and 5.46 t/ha respectively, for Missiya Odeska - 4.78 and 5.03 t/ha, for Pylypivka - 5.47 and 5.62 t/ha (Table 4.).

It was established that the higher grain protein and gluten content in winter wheat varieties after spring barley was formed, as a rule, in cases where the total nitrogen dose for crops feeding was 60-90 kg/ha.

The largest amount of grain protein compounds was with two-step plants feeding: N_{60} in early spring on frozen-thawed soil and N_{30} locally at the tillering phase end. Depending on the variety with such fertilizing system the grain protein content varied between 11.7-12.5%, and crude gluten - 19.0-23.1%; the highest rates were in the varieties Pylypivka and Kokhanka, and lower - in variety Missiya Odeska.

It should be noted that during the research years nitrogen feedings of winter wheat crops after both predecessors helped to increase not only the grain protein and gluten content, but in most cases it improved such indicators as grain nature and vitreousity, flour sedimentation rate.

Table 4. Influence of nitrogen feedings on yield, grain protein and gluten content for different varieties of winter wheat after spring barley, 2016-2018

Nitrogen fertilizer	Yield, t/ha			Grain protein content, %			Grain gluten content, %		
	1*	2	3	1	2	3	1	2	3
No feeding - control (background $N_{60}P_{60}K_{30}$)	4.26	3.88	4.46	11.4	11.4	11.4	19.3	16.3	18.3
N_{30} in early spring on frozen-thawed soil	4.91	4.45	5.08	11.4	11.4	11.4	19.3	16.9	19.4
N_{60} in early spring on frozen-thawed soil	5.31	4.78	5.47	11,8	11,8	11,8	21.0	18.0	21.5
N_{30} at the end of plants tillering	4.74	4.24	4.97	11.6	11.6	11.6	21.0	17.2	20.4
N_{30} in early spring on frozen-thawed soil + N_{30} at the end of plants tillering	5.16	4.60	5.32	12.0	12.0	12.0	22.5	19.2	21.7
N_{60} at the end of plants tillering	5.08	4.54	5.25	11.9	11.9	11.9	22.7	18.9	22.0
N_{60} in early spring on frozen-thawed soil + N_{30} at the end of plants tillering	5.46	5.03	5.62	12.3	12.3	12.3	22.9	19.0	23.1
**1 - Kokhanka; 2 - Missiya Odeska; 3 - Pylypivka*									

CONCLUSIONS

During the research, a significant decrease in winter wheat yield was revealed. It was a result of abnormally adverse weather during the growing season 2011-2012.The average grain yield by variety depending on experiment option after black fallow amounted to 3.87-4.27 t/ha, after spring barley - 2.24-2.39 t/ha. In other years with more favorable weather the above indicators values after fallow, as a rule, exceeded 6-7 t/ha, and after the stubble predecessor - 4-5 t/ha. The grain protein and crude gluten content in the arid year 2012 was the highest among the research years and amounted at least 14 and 28%, respectively, which was at the first class quality level. In other years these quality indicators were formed at significantly lower levels.

Winter wheat crops spring-summer feedings with nitrogen fertilizers were more effective in favorable years for moisture. After black fallow (against $N_{0-30}P_{60}K_{30}$) the highest yield increases were observed in the variant where ammonium nitrate was applied locally at spring tillering phase end - dose N_{60}. After spring barley (against $N_{60}P_{60}K_{30}$) - with two-step feedings: N_{30-60} on frozen-thawed soil and N_{30} locally at the tillering end. Winter wheat crops nitrogen feedings after both predecessors helped to improve grain quality indicators such as protein and gluten content, grain nature, vitreousity and flour sedimentation rate.

Higher yields in 2012-2014 were formed by winter wheat varieties Zamozhnist, Lytanivka and Rozkishna, grain quality - Sonechko variety; in 2016-2018, the most productive variety was Pylypivka, the best grain quality was in varieties Kokhanka and Pylypivka.

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