Scientific Papers. Series A. Agronomy, Vol. LXVII, No. 2, 2024
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

# FORMATION OF YIELD AND BIOCHEMICAL PARAMETERS OF WINTER WHEAT GRAIN DEPENDING ON AGRONOMIC PRACTICES OF CULTIVATION

**Iryna HASANOVA[1], Yanina ASTAKHOVA[1], Nataliia NOZDRINA[2], Mykola SOLODUSHKO[1], Oleksandr PEDASH[1], Olena DRUMOVA[1], Natalia ZAVALYPICH[1]**

[1]State Enterprise Institute of Grain Crops of National Academy of Agrarian Sciences of Ukraine, 14 Volodymyr Vernadskyi Street, 49009, Dnipro, Ukraine
[2]Dnipro State Agrarian and Economic University, 25 Serhii Yefremov Street, 49000, Dnipro, Ukraine

Corresponding author email: gasanovai434@gmail.com

***Abstract***

*In the Northern Steppe of Ukraine, a significant effect of weather conditions, predecessors, fertilisation and sowing dates on the formation of yield and biochemical parameters of winter wheat grain was established. It was found that the cultivation of winter wheat on black fallow and after spring barley resulted in higher yields at the optimal sowing date (20-25 September) compared to early (5-10 September) and late (5-10 October) sowing dates. Pre-sowing application of complete mineral fertiliser and nitrogen feeding led to an improvement in both yield and grain quality of winter wheat. Moreover, more significant increases in winter wheat yield were recorded after the non-fallow predecessor. The durum winter wheat of Burshtyn variety produced a lower yield compared to the soft wheat varieties, but it exceeded these varieties in terms of protein content. The sedimentation values of durum wheat flour were very low (in the range of 12-20 ml), which indicates the specificity of its uses. At the same time, the sedimentation values of flour of soft wheat varieties used for baking purposes varied between 35-50 ml, depending on the agronomic practices of cultivation.*

**Key words:** *biochemical parameters of grain, fertilisation, predecessor, sowing date, winter wheat, yield.*

## INTRODUCTION

Wheat is the main food crop for many countries around the world. Increasing the grain yield and quality is a priority for humanity in the modern world (Shelepov et al., 2004; Golomsha & Dziadykevich, 2017). Soft wheat (*Triticum aestivum* L.) grain is used for flour production and bread baking, while durum wheat (*Triticum durum* Desf.) grain is used for making groats and pasta (Hlynka et al., 1964). In Ukraine, according to the current DSTU 3768-2019, soft wheat grain is graded into four classes depending on its quality characteristics, and durum wheat grain into five classes. Grain with low quality characteristics is used for fodder and for alcohol production.

The main grain quality indicators regulated by the standard include moisture content, grain volume weight, vitreousness, protein content, crude gluten content, falling number and others. At the request of the customer, such important indicators as flour strength and sedimentation value are also determined (Kirpa et al., 2019). Higher quality wheat grain has a higher nutritional value and is therefore in greater demand among customers.

The biochemical quality indicators of wheat grain, which characterise its nutritional value, include the content of protein, carbohydrates, fats, enzymes, vitamins and other compounds. Protein is one of the essential components of wheat grain. Amino acids are the main structural elements of proteins, and wheat grain contains 20 amino acids. Eight essential amino acids are especially significant because they are not synthesised in the human body (Sisakian & Markosian, 1959).

The protein content in grain of winter wheat, which cultivation prevails over spring wheat in Ukraine, rages from 7-8% to 19-20%. The average protein content in grain of this crop is about 10-14% (Cherenkov et al., 2021). Winter wheat grain of modern high-yielding varieties has lower protein content than of the extensive varieties that were common in the past

(Nikolaev, 1991). Grain with the highest protein content is usually produced in the south-eastern regions of the country (Netis, 2011).

As mentioned earlier, high-quality soft winter wheat grain is primarily used in the flour production. The properties of flour determine the volume of bakery products, their appearance, colour, porosity and elasticity of the breadcrumb, and other indicators. Direct methods for assessing grain and flour quality and the rheological properties of dough include determining the gluten content and quality in grain and flour, flour strength with an alveograph, water absorption capacity of flour, stability and mixing tolerance index with a farinograph, etc. However, the most objective assessment of flour can be obtained by means of laboratory or trial baking of bread (Strelnikova, 1971).

At the same time, there are methods for indirectly assessing the baking properties of wheat flour, which are distinguished by their expressiveness and high productivity, in contrast to cumbersome and time-consuming direct methods. The main requirement for these methods is their maximum correlation with the assessment by an alveograph, mixograph, farinograph, depending on the nature of the measurements. Among these methods, the sedimentation method is widespread. The method is based on mixing a small amount of flour with weak solutions of organic acids. After settling for five minutes, the volume of sediment formed by the swelling of gluten and starch is measured. A higher volume of sediment means better quality wheat (Zeleny, 1962). According to these studies, the sedimentation value of flour is an indicator of gluten quality, but other scientists have found a strong correlation between the sedimentation value and the protein content (Gospodarenko et al., 2020).

The formation of yield, as well as physical and biochemical parameters of grain quality depends on a number of factors that affect winter wheat during its growth and development. These include hydrothermal conditions during the growing season, and such components of agricultural technology as variety, predecessor, fertilisation, sowing date and other (Zhemela & Musatov, 1989; Cherenkov et al., 2015).

As we know, winter wheat is one of the crops that requires a significant amount of nutrients for harvest formation and responds well to mineral fertilisation, especially nitrogen fertilisers (Marchuk, 2009; Chirita et al., 2023). At the same time, an excessive dosage of nitrogen fertilisers does not ensure further increase in yield and grain quality of winter wheat (Stefanova-Dobreva, 2022). Some researchers estimate that the increase in yield dependent on nitrogen by 50-55%, and the increase in protein content in grain by 70% (Gospodarenko et al., 2020), and the effect of nitrogen prevail over weather conditions and other factors. However, the impact of different factors on grain yield and quality may vary from year to year (Netis, 2011).

Experimental results reveal that the increase in yield from fertilisers in dry growing conditions is 25-30% lower than in years with favourable moisture conditions. In such years, phosphorus fertilisers have a positive effect, while high doses of nitrogen fertilisers have a negative effect on plant development (Krut & Tararyka, 2000; Netis, 2008).

It is known that one of the critical steps in growing winter wheat is the optimal sowing date. Sowing dates have a major effect on the winter wheat growth and development, overwintering of plants, yield and grain quality. Sowing dates differ for various soil and climatic zones and should be adjusted considering the particularities of the weather conditions of the year, predecessors, soil moisture content, etc. It has been established that a shift in sowing dates from the optimal ones, both towards early and late sowing, leads to a sharp decrease in yield (Cherenkov et al., 2015). In wet, warm and long autumns, winter wheat provides the highest yields when sown later than the average long-term dates, and in years with less favourable autumn conditions - at earlier dates (Netis, 2011).

There are different points of view on the effect of sowing date on the grain quality of winter wheat. According to the opinion of numerous scientists, the lowest protein content is formed at early sowing dates. Sowing at optimal and late dates, when plants develop a smaller vegetative mass, increases the protein content in winter wheat grain (Korkhova, 2014; Partal et al., 2023). According to other researchers,

such dependencies were not observed in all cases (Solodushko et al., 2016).
Given the considerable experimental data obtained in different soil and climatic zones, the integrated effect of weather conditions and main agricultural practices on the formation of grain yield and biochemical parameters of modern soft winter wheat varieties compared to durum wheat varieties under cultivation in the Northern Steppe of Ukraine has not been sufficiently studied.

## MATERIALS AND METHODS

The field trials with winter wheat were laid out on black fallow and after spring barley fields at the State Enterprise Institute of Grain Crops of the National Academy of Agrarian Sciences of Ukraine. The soil of the experimental plots is low humus full-profile ordinary chernozem. The mechanical composition of the soil is medium loamy. The nitrification capacity of the topsoil is 17-20 mg per 1 kg of absolutely dry soil. The climate of the zone is temperate continental with insufficient and unstable moisture content.
The most widespread winter wheat varieties in the region were selected for the research. Sowing and fertilisation of wheat crops was carried out by the experimental design in accordance with generally accepted methods (Tsikov & Pikush, 1983; Dospekhov, 1985). Sowing was carried out using a mounted seeder CH-16. Complete fertiliser $N_{0-30}P_{60}K_{30}$ was introduced into the pre-sowing cultivation on black fallow, and $N_{60}P_{60}K_{30}$ was applied after the stubble predecessor. Nitrogen feedings were carried out on frozen-thawed soil in the spring and locally at the end of the tillering stage of plants, using ammonium nitrate fertiliser. A Sampo-500 combine harvester was used to harvest the wheat, and the grain yield was recalculated for 14 % moisture content. Obligatory sampling of grain from different experimental variants was carried out during the research to determine its quality indicators. The protein content in the grain was determined by infrared spectroscopy using a NEOTEC 4256 device. For calibration of the device, the values of total nitrogen obtained by the Kjeldahl method were used (DSTU ISO 20483:2016). The sedimentation value was evaluated by the micromethod in a 2% acetic acid solution using a 3.2 g flour sample and a 100 ml calibrated cylinder (Pumpyansky, 1971; Sozinov et al., 1977).

## RESULTS AND DISCUSSIONS

Weather conditions during the growing season of winter grain crops have a significant impact on the plant growth, development in autumn, their overwintering, root system development and growth of aboveground mass in spring, formation of generative organs, yield and grain quality. During the research, significant variations were observed in such indicators as air temperature and precipitation at different stages of plant development. The last 15 years of research have been characterised by mostly satisfactory and favourable weather conditions for winter wheat. However, the 2011/12 growing season should be singled out, when a combination of unfavourable meteorological factors had a negative impact on plant productivity. The dry autumn growing season, occasional sharp temperature drops in winter and acute moisture deficit during critical stages of plant development in spring resulted in low wheat productivity, especially after the fallow predecessors.
After the stubble predecessor, the average yield of winter wheat for the studied soft winter wheat varieties in 2012 was 2.30 t/ha, while in the more favourable years (2013 and 2014) the values of this indicator were 4.45 and 5.05 t/ha, respectively. On black fallow, the yield in 2012 was also lower (4.08 t/ha) compared to 2013 and 2014, when it was 7.03 and 7.05 t/ha, respectively. Despite the low yields in 2012, the protein content in grain was the highest compared to other years of research. Thus, the protein content of winter wheat after spring barley was 14.9% and 14.6% on black fallow. After the stubble predecessor, these indicators correlated with the indicators of flour sedimentation. At the same time, no such correlation was observed for black fallow (Table 1).
In the relatively favourable 2017-2019 years for winter wheat, a significant advantage of the black fallow over the stubble predecessor for this crop in yield formation was also revealed.
Depending on the variety, sowing date and fertilisation option, the wheat yield on black

fallow varied from 4.36 to 7.16 t/ha, and after spring barley, this indicator varied from 2.55 to 6.05 t/ha (Table 2). It should be noted that after both predecessors, the yield of soft winter wheat varieties Lastivka odeska and Holubka odeska was higher than that of Burshtyn variety of durum wheat. At the sowing date of 20-25 September, the yields of the varieties were higher compared to the early sowing date (5-10 September) and the late sowing date (5-10 October). At the same time, the Holubka odeska variety was more plastic in terms of sowing dates than the varieties Lastivka odeska and Burshtyn.

Table 1. Winter wheat yield and biochemical parameters depending on the predecessor under various weather conditions of the seasons under study

| Predecessor | Years of study | Yield,t/ha | Protein content, % | Sedimentation value, ml |
|---|---|---|---|---|
| Black fallow (background $P_{60}K_{30}$) | 2012 | 4.08 | 14.6 | 59.2 |
| | 2013 | 7.03 | 13.2 | 63.4 |
| | 2014 | 7.05 | 12.3 | 64.6 |
| Spring barley (background $N_{60}P_{60}K_{30}$) | 2012 | 2.30 | 14.9 | 58.4 |
| | 2013 | 4.45 | 11.8 | 47.8 |
| | 2014 | 5.05 | 12.1 | 49.4 |

Table 2. The effect of sowing time and fertilization on the winter wheat yield, t/ha, 2017-2019

| Variety | Sowing time | Fertilizer option | | |
|---|---|---|---|---|
| | | without fertilizer (control lot) | pre-sowing application of complete fertilizer | fertilizing system* |
| Predecessor – black fallow ($N_{30}P_{60}K_{30}$) | | | | |
| Lastivka Odeska (soft wheat) | 5-10 September | 5.34 | 5.86 (+0,52) | 6.13 (+0,27) |
| | 20-25 September | 6.04 | 6.85 (+0,81) | 7.10 (+0,25) |
| | 5-10 October | 5.23 | 5.79 (+0,56) | 6.08 (+0,29) |
| Holubka Odeska (soft wheat) | 5-10 September | 6.14 | 6.69 (+0,55) | 7.04 (+0,35) |
| | 20-25 September | 6.18 | 6.76 (+0,58) | 7.16 (+0,40) |
| | 5-10 October | 6.01 | 6.52 (+0,51) | 6.89 (+0,37) |
| Burshtyn (durum wheat) | 5-10 September | 4.87 | 5.44 (+0,57) | 5.97 (+0,53) |
| | 20-25 September | 5.22 | 5.85 (+0,63) | 6.40 (+0,55) |
| | 5-10 October | 4.36 | 4.98 (+0,62) | 5.49 (+0,51) |
| Predecessor – spring barley ($N_{60}P_{60}K_{30}$) | | | | |
| Lastivka Odeska (soft wheat) | 5-10 September | 3.27 | 4.35 (+1,08) | 5.47 (+1,12) |
| | 20-25 September | 3.39 | 4.77 (+1,38) | 5.75 (+0,98) |
| | 5-10 October | 3.13 | 4.46 (+1,33) | 5.60 (+1,14) |
| Holubka Odeska (soft wheat) | 5-10 September | 3.74 | 5.05 (+1,31) | 5.91 (+0,86) |
| | 20-25 September | 3.82 | 5.26 (+1,44) | 6.05 (+0,79) |
| | 5-10 October | 3.44 | 4.81 (+1,37) | 5.67 (+0,86) |
| Burshtyn (durum wheat) | 5-10 September | 2.76 | 4.13 (+1,37) | 4.99 (+0,86) |
| | 20-25 September | 3.11 | 4.63 (+1,52) | 5.53 (+0,90) |
| | 5-10 October | 2.55 | 3.94 (+1,39) | 4.73 (+0,79) |

Notes: *On the background of pre-sowing fertilizer on black fallow - $N_{30}$ at the end of plants tillering locally; after spring barley - $N_{30}$ was applied on frozen-thawed soil + $N_{30}$ locally. Ammonium nitrate was used for nitrogen feeding.

The analysis of all sowing dates showed that the lower yield of winter wheat was formed on the unfertilised background, pre-sowing application of complete fertiliser $N_{30}P_{60}K_{30}$ on black fallow contributed to an increase in yield compared to the control by 0.51-0.81 t/ha, and after the stubble predecessor, the application of $N_{60}P_{60}K_{30}$ before sowing led to an increase in grain yield by 1.08-1.52 t/ha. Further feeding winter wheat on black fallow at the end of tillering stage with a local application of $N_{30}$ contributed to a further increase in yield by 0.25-0.55 t/ha, and after barley spring, feeding with $N_{30}$ in two steps (on frozen-thawed soil and locally) resulted in an additional increase in yield, which varied within 0.79-1.14 t/ha.

The application of mineral fertilisers had a positive effect on the protein content of winter wheat grain. The highest values after both predecessors were formed against the background of pre-sowing fertilisation followed by nitrogen feedings. The protein content of durum wheat grain was generally higher in comparison with soft wheat (Figures 1 and 2).

In the cultivation on black fallow, the protein content in the grain of Burshtyn variety varied from 12.9 to 14.6% depending on the sowing date and fertilisation, in Lastivka odeska variety - 12.0 to 13.6%, and in Holubka odeska variety it was the lowest and varied from 11.0 to 12.6%. After the stubble predecessor, the protein content in durum wheat varied within 11.9-14.5%, in soft wheat varieties Lastivka odeska and Holubka odeska - 11.5-13.4% and 10.7-12.4%, respectively.

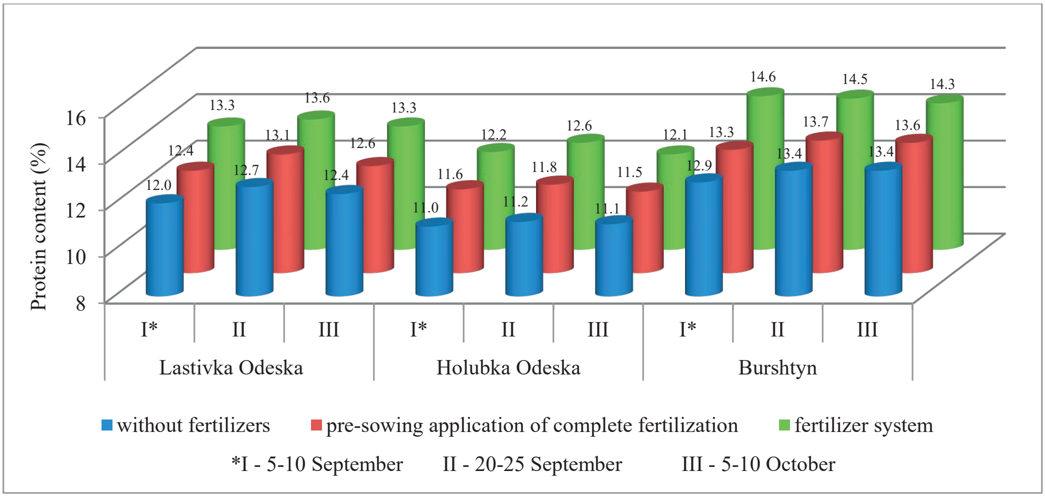


Figure 1. The effect of sowing time and fertilization on the protein content of winter wheat grain after black fallow, 2017-2019

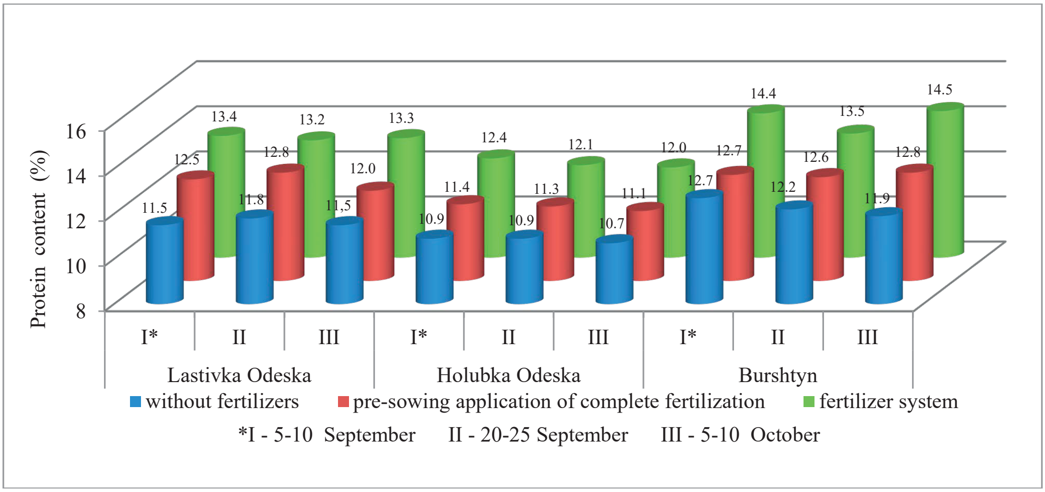


Figure 2. The effect of sowing time and fertilization on the protein content of winter wheat grain after barley spring, 2017-2019

The sedimentation value of flour in all varietie was the highest at the late sowing date (5-10 October), and the lowest at the early sowing date (5-10 September). However, the value of this indicator was significantly higher in the soft wheat varieties compared to the durum wheat variety and, depending on the experimental variant, amounted to 37-50 ml for black fallow, and 35-45 ml after spring barley. The sedimentation value of flour in the durum wheat of Burshtyn variety varied between 12 and 20 ml depending on the predecessor, fertilisation and sowing date (Figures 3 and 4). These data once again confirm the different purposes of different wheat types. Soft wheat flour should be used for bread baking, because it is characterised by higher flour sedimentation, which is closely related to the flour strength and rheological properties of the dough.

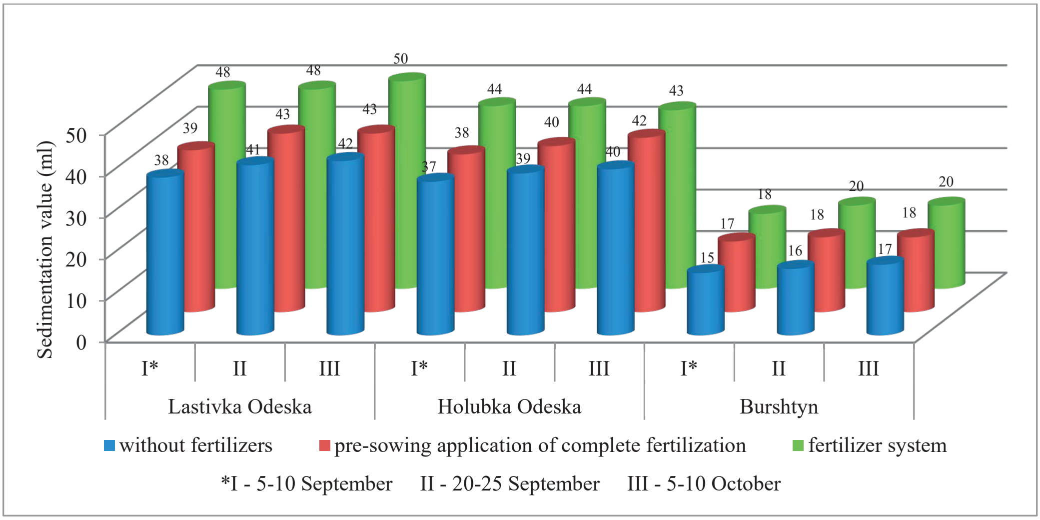


Figure 3. The effect of sowing time and fertilization on the sedimentation value of winter wheat flour after black fallow, 2017-2019

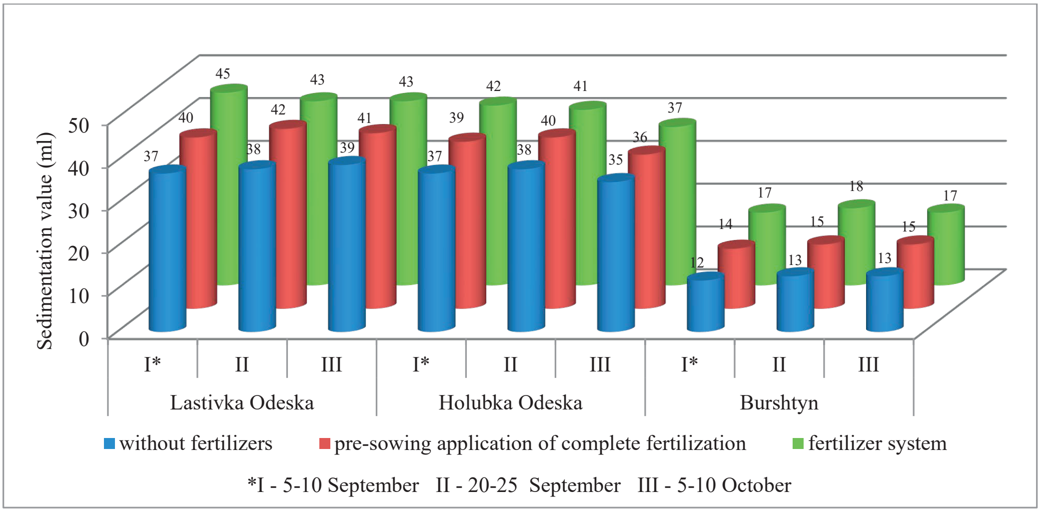


Figure 4. The effect of sowing time and fertilization on the sedimentation value of winter wheat flour after barley spring, 2017-2019

## CONCLUSIONS

Based on the studies conducted in the Northern Steppe of Ukraine, the peculiarities of the effect of weather conditions, predecessors, sowing dates and mineral fertilisation of crops on the formation of yield, protein content in grain and flour sedimentation of different varieties of winter wheat were revealed. It was found that higher yield was recorded during the cultivation of winter wheat on black fallow compared to the stubble predecessor, at the optimal sowing date (20-25 September), and with the fertilisation system, which includes nitrogen feeding against the background of pre-sowing application of complete fertiliser. Higher increases in yield as a result of fertilisation were observed when winter wheat was grown after spring barley. In the case of shifting the sowing date from the optimal one towards early or late sowing, the lowest decrease in yield was observed in the soft wheat of Holubka odeska variety compared to the varieties Lastivka odeska and Burshtyn.

The biochemical properties of grain depended mostly on the type of winter wheat (soft or durum) and fertilisation of crops. In the durum wheat of Burshtyn variety, the protein content in the grain under different experimental variants was mostly higher than in the soft wheat varieties (Lastivka odeska and Holubka odeska). At the same time, the sedimentation value of flour, which is closely related to baking properties, was significantly lower and ranged from 12-20 ml, depending on the technology components. For soft wheat varieties, the values of this indicator varied between 35-50 ml.

## ACKNOWLEDGMENTS

The work was carried out as part of the scientific research on 2016-2020 “To develop the theoretical basis of grain quality regulation systems of ear crops to meet the needs of the food industry of Ukraine” (state registration number 0116U001245), with financial support of the National Academy of Agrarian Sciences of Ukraine.

## REFERENCES

Cherenkov, A. V., Nesteretc, V. H., Solodushko, M. M. et. al. (2015). A winter wheat in the zone of Steppe, climatic changes and technologies of growing: *monograph.* Dnipropetrovsk: Nova ideolohiia.

Cherenkov, A.V., Solodushko, M.M., Yaroshenko, S.S. et. al. (2021). Features of growing winter wheat in the Steppe of Ukrain: *Monograph.* Kyiv: Agrarna nauka.

Chirita, S., Rusu, T., Urda, C., Chetan, F., Racz, I. (2023). Winter wheat yield and quality depending on chemical fertilization, different treatments and tillage systems. *AgroLife Scientific Journal,* Vol. 12, No. 1. 34–39.

Dospekhov, B.A. (1985). Methods of field experiments (with the basics of statistical processing of research results). M.: Agropromizdat.

DSTU 3768-2019 “Wheat. Specification” (2019). Kyiv, 15 p.

DSTU ISO 20483:2016 (ISO 20483:2013, IDT) Cereals and pulses. Determination of the nitrogen content and calculation of the crude protein content Kjeldahl metod (2017). Kyiv, 11 p.

Golomsha, N. E., Dziadykevich, O. Ya. (2017). Competitive advantages of grain industry products on the world market. *Ekonomika APK,* 11. 61–65.

Gospodarenko, G. M, Cherno, O. D, Liubych, V. V., Ryabovol, Y. S., Kryzhanivsky, V. G. (2020). Yield and baking properties of winter wheat grain at different doses and terms of nitrogen fertilizer application. *Bulletin of Poltava State Agrarian Academy,* 3. 22–31. doi:10.31210/visnyk2020.03.02

Hlynka, I. et. al. (1964). Wheat chemistry and technology (I. Hlynka, Ed.). American Association of Cereal Chemists, St. Paul, Minnesota.

Kirpa, M. Ya., Lupitko, O. I., Morhun, O. V. (2019). The new standard for wheat grain: features of development and application. *Grain Crops.* 3, 2. 233–239.

Korkhova, M. M. (2014). Yield and grain quality of winter wheat grown in the conditions of the Southern Steppe of Ukraine. *Varietal research and protection of rights to plant varieties,* 4. 82–86.

Krut, V. M., Tararyka, O. H. (2000). Agriculture in conditions of insufficient moisture (scientific and practical conclusions). Kyiv: Agrarna nauka.

Netis, I. T. (2008). Droughts and their impact on winter wheat crops: *monograph.* Kherson: Ailant.

Netis, I. T. (2011). Winter wheat in Ukraine: *monograph.* Kherson: Oldi-plus.

Nikolaev, E. V. (1991). Reserves for increasing grain production of strong and valuable wheat. K.: Urozhay.

Marchuk, I. (2009). Modern fertilizers are worth the harvest. *Propozyciya* [Proposition]*,* 4. 42–45.

Partal, E., Oltenacu, C. V., Paraschivu, M., Cotuna, O., Contescu, E. L. (2023). Wheat yield and quality under the influence of sowing date, plant density and variety in south of Romania. *Scientific Papers. Series A. Agronomy,* Vol. LXVI, No. 2. 339–345.

Pumpyansky, A. Ya. (1971). Technological properties of soft wheat. L.: Kolos.

Shelepov, V. V., Malasai, V. M., Penzev, A. F. (2004). Morphology, biology, economic value of wheat.

Sisakian, N. M., Markosian, L. S. (1959). Amino acid composition of wheat grain proteins. *Biochemistry.* 24, 6. 1094–1103.

Solodushko, M. M., Hasanova, I. I., Pryadko Yu. M., Nosenko Yu. M. (2016). Yield and grain quality of winter wheat and triticale depending on predecessors and sowing dates. *Byuleten Institutu Silskogo Gospodarstva Stepovoi Zoni NAAN Ukrainy.* Dnipropetrovsk, 11. 35–39.

Sozinov, A. A., Blokhin, N. I., Vasilenko, I. I. et. al. (1977). Guidelines for assessing grain quality. M.

Stefanova-Dobreva, S., Muhova, A., Bonchev, B. (2022). Nitrogen and phosphorus fertilizers affecting the quality and quantity of the durum wheat. *Scientific Papers. Series A. Agronomy,* Vol. LXV, No. 1. 533–539.

Strelnikova, M. M. (1971). Improving the quality of wheat grain. Kyiv: Urozhay.

Tsikov, V. S., Pikush, G. R. (1983). Methodological recommendations for conducting field experiments with grains, legumes and forage crops. Dnepropetrovsk.

Zeleny, L. (1962). Wheat sedimentation test. *Cereal Science Today,* 7, 7. 226–230.

Zhemela, H. P., Musatov, A. H. (1989). Agrotecnical basics of grain quality improvement. Kyiv: Urozhay.