Radchenko, M., Trotsenko, V., Butenko, A., Masyk, I., Bakumenko, O., Butenko, S., Dubovyk, O., Mikulina, M. (2023): Peculiarities of forming productivity and quality of soft spring wheat varieties. Agriculture and Forestry, 69 (4): 19-30. doi:10.17707/AgricultForest.69.4.02

DOI: 10.17707/AgricultForest.69.4.02

Mykola RADCHENKO*[1], Volodymyr TROTSENKO[1], Andrii BUTENKO[1], Ihor MASYK[1], Olha BAKUMENKO[1], Sergey BUTENKO[1], Olha DUBOVYK[1], Maryna MIKULINA[1]

PECULIARITIES OF FORMING PRODUCTIVITY AND QUALITY OF SOFT SPRING WHEAT VARIETIES

SUMMARY

Spring wheat becomes an important strategic grain crop in solving the problem of high–quality grain production. Therefore, main attention should be paid to selection of the most productive spring wheat varieties under certain conditions, as a variety is one of main means of increasing productivity of agricultural crops. The object of our research was varieties of soft spring wheat: Shirocco, Uliublena, Barvysta, Quintus. The best productivity indices of soft spring wheat were obtained when sowing variety Shirocco. This variety provided the largest plant weight –2.69 g, ear weight –1.51 g, and ear length –9.5 cm. The number of grains per ear was at the level of 25.0 pcs. with the mass of 1000 seeds –38.2 g. As a result of conducted research, it was found that yielding capacity of soft spring wheat averaged from 4.13 to 5.54 $t \cdot ha^{-1}$. The maximum grain yield on average during the research period was produced by variety Shirocco –5.54 $t \cdot ha^{-1}$. Varieties Uliublena, Barvysta, and Quintus provided grain yield at the level of 4.67, 4.13, and 4.81 $t \cdot ha^{-1}$, respectively. The highest amount of gluten, at the level of 32.5% with a protein content of 16.3%, was noted in the grain of soft spring wheat of variety Shirocco.

Keywords: variety, field germination, standing density, productivity, protein, gluten

INTRODUCTION

Grain industry is a source of stable development of agro-industrial complex. Despite the fact that soil and climatic conditions contribute to obtaining high yields, this industry does not meet export needs for high-quality grain. Spring wheat is becoming an important strategic grain crop in solving the problem of high-quality grain production (Yula, 2016).

[1]Mykola Radchenko (corresponding author: radchenkonikolay@ukr.net), Volodymyr Trotsenko, Andrii Butenko, Ihor Masyk, Olha Bakumenko, Sergey Butenko, Olha Dubovyk, Maryna Mikulina, Sumy National Agrarian University, 160 H. Kondratieva St., UA40021, Sumy, UKRAINE

Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.
Recieved:20/04/2023 *Accepted:11/10/2023*

However, the area sown under spring wheat has decreased to 80–170 thousand hectares in recent years. Considering great importance of this crop, scientists recommend expanding sowing area for spring wheat to 1 million ha. The main reason of spring wheat acreage decrease is its low yielding capacity (3–3.5 $t.ha^{-1}$), while foreign and domestic varieties included in the state register have a potential yielding capacity of 5–8 $t.ha^{-1}$ (Melnyk *et al.*, 2006; Usov and Manko, 2015).

Spring wheat is characterized by increased demands for growing conditions, and this requires development of highly adapted varietal technologies for its growing. According to the results of Vlasenko (2006), it was found that an important condition for this is further improvement of technologies for growing grain crops, in particular, spring soft wheat. However, only modern high-yielding varieties can cover cultivation costs. Therefore, main attention should be paid to selection of the most productive varieties of spring wheat under certain conditions, as a variety is one of main means for increasing productivity of agricultural crops.

Analysis of crop yielding capacities over the past 20 years shows that biological potential of varieties is realized at the level of 40–75% (Sokolov, 2011). The decisive importance in increasing the yield of cereal grain crops belongs to modern varieties that have a high level of productivity, are adapted to certain growing conditions, are characterized by resistance to adverse abiotic factors of environment and have high grain quality (Yula, 2010). The maximum realization of productivity potential of domestic spring wheat varieties should be based on morphophysiological analysis and the creation of highly productive agrophytocenoses taking into account soil and climatic conditions (Yula and Drozd, 2020).

Realization of genetic potential of grain productivity and quality of modern spring wheat varieties is an important reserve for the growth of grain production (Holik and Kabatsiura, 2012; Xhulaj *et al*., 2022). Among the varieties of different ecological and geographical origin, the maximum yield will be provided only by those genotypes which are well adapted to the conditions of one or another soil-climatic growing zone in terms of their ability to form productivity and adaptability and fully correspond to it by their parameters. Revealing genetic potential of modern soft spring wheat varieties, which are adapted to specific soil and climatic zones, gives prospects for grain production of this crop (Ishchenko, 2021).

The issues of technology formation for spring wheat cultivation were studied in research of many authors. The most important are presented in the studies of Borysonik (2001), Kumakova (1988), Pidruchna (2000), Hrynyk (2000), Konovalov (1999), Radchenko *et al.* (2021). Despite the fact that this issue has been studied to a certain extent, the components of improving technology for growing spring wheat aimed at the maximum realization of the varieties' potential under conditions of northeastern forest-steppe of Ukraine are not fully disclosed.

MATERIAL AND METHODS

Research on the influence of varietal characteristics on productivity of spring soft wheat varieties was carried out during 2020–2022 at educational and scientific productive complex of Sumy National Agrarian University. The research field is located in the Sumy district of the Sumy region, Ukraine, geolocation data 50°52.742 N latitude, 34°46.159E longitude, 137.7 m above sea level (50°52'46.6"N34°46'07.8"E Map date ©2023 Google). The experiments were conducted according to the methods described by Dospekhov (1985), Pidoprygora and Pisarenko (2003).

The following varieties of spring wheat were the object of research: Shirocco, Uliublena, Barvysta, Quintus. In the experiment, the predecessor was soybean. Sowing was carried out at the onset of soil physical maturity at a temperature of 6–8°C to a depth of 3-4 cm by the usual way with a width between rows of 15 cm and a sowing rate of 5.0 million similar seeds per 1 ha, with the help of planter Klen –1.5. For pre-sowing cultivation, mineral fertilizers were applied in the form of nitroamophoska 200 kg ha^{-1} of physical weight. Nitroamofoska is a complex nitrogen-phosphorus-potassium fertilizer. Mass fraction of nitrogen (N) 16%, phosphorus (P) 16%, potassium (K) 16%. The form of fertilizer is granular. Total area of the plot is 50 m^2, accounting area –30 m^2, repetition of the experiment -three times. Placement of plots is systematic.

During phenological observations, the growth and development phase of spring wheat was considered to begin with appearance of at least 10% of plants, and to be completed with appearance of 75% of plants.

Dynamics of above-ground mass growth was determined in the main phases of growth and development by selecting 25 plants in typical locations of the plots in two incompatible repetitions. The structure of the harvest was determined by the method of sampling sheaves from each accounting area. The area of leaf surface was determined by calculation method. Amount of gluten was determined according to STST 13586.1–68 Grain. Methods of determining the quantity and quality of wheat gluten. Amount of protein was determined according to STST 10846–91 "Grain and the products of its processing". Protein determination method. Statistical processing of experimental data was carried out according to Dospekhov (1985) using Microsoft Excel.

The soil of experimental field is a typical heavy loamy and medium-humus black soil, which is characterized by the following parameters: humus content in arable layer (according to I.V. Tiuryn) is 4.0%, reaction of the soil solution is close to neutral (pH 6.5), the content of easily hydrolyzed nitrogen (according to I.V. Tiuryn) 9.0 mg, movable phosphorus and exchangeable potassium (according to F. Chyrikov) 14 mg and 6.7 mg per 100 g of soil, respectively.

The average daily annual air temperature in 2020 was 10.2 °C, which is 2.8 °C higher than the long-term index of 7.4 °C. The maximum temperature – 35.0 °C was recorded in July in the third decade, and the minimum temperature - minus 14.0 °C in the first decade of February. Precipitation amount for the reporting year was 466 mm, which is 127 mm less than the long-term norm (593

mm).The average daily annual air temperature in 2021 was 9.4 °C, which is 2.0 °C higher than the long-term index of 7.4 °C. The maximum temperature – 35.0 °C was recorded in June in the third decade, and the minimum temperature - minus 24.0 °C in the second decade of January. Precipitation amount for the reporting year was 453 mm, which is 140 mm less than the long–term norm (593 mm).

The average daily annual air temperature in 2022 was 8.7 °C, which is 1.3 °C higher than the long-term index of 7.4 °C. The maximum temperature – 36.0 °C was recorded in June in the third decade, and the minimum temperature - minus 18.0 °C in the second decade of January. Precipitation amount for the reporting year was 604 mm, which is 11 mm more than the long-term norm (593 mm).

The most favorable year for yield formation was 2022. In 2019 and 2020 were observed dry conditions, which were characterized by low precipitations and extreme fluctuations in air temperature during vegetation period.

RESULTS AND DISCUSSION

Seed germination is primarily influenced by soil moisture and temperature, as well as agrotechnical measures (Shevnikov, 2012). After sowing qualities of seeds, in particular such index as laboratory germination, field germination of seeds is practically the first real factor in the formation of crop productivity (Nazarenko *et al.*, 2021). In field conditions, a complex of factors simultaneously contribute to its increase or decrease, but the main ones are temperature and soil moisture (Sviderko *et al*., 2004). In field conditions, many factors affect seed germination at once, the influence of most of which cannot be calculated in isolated laboratory conditions. And isolation of each of the factors does not allow to learn real picture of factors interaction influence on the formation of shootings (Verhunov, 2000; Guedioura *et al*., 2023). In the conditions of the educational and scientific production complex of Sumy National Agrarian University, it was found that spring wheat varieties had different field germination. Thus, the highest field germination was obtained for variety Shirocco –94.0%, somewhat lower indices were obtained for varieties Quintus –90.6%, Barvysta –90.0% and Uliublena –88.6%. The density of standing ranged from 443 to 470 units/m^2. The highest density was recorded for variety Shirocco –470 pcs/m^2, and the lowest – for variety Ulyubena –443.0 pcs/m^2 (Table 1).

Preservation of plants during vegetation period was in the range of 88.9–94.5%. The highest preservation of plants was obtained by variety Shirocco – 94.5% (444.0 pcs m^2), and the lowest - by variety Uliublena –88.9% (394 pcs m^2). For variety Quintus, this index was recorded at the level of 92.1% (417.0 pcs m^2), for variety Barvysta –91.1% (410 pcs m^2) (Table.1). The highest yield of spring wheat is formed at a density of 400–500 pics m^2, this density is provided at the sowing rate 5.0–5.5 million of similar seeds per hectare after the best predecessors, and after the worst ones -5.5–6.0 million of similar seeds per hectare (Demydov *et al*., 2017).

Table 1. Standing density of soft spring wheat depending on varietal characteristics (average for 2020–2022)

Variety	Field germination, %	Standing density, pcs m^2	Preservation of plants during vegetation period	
			pcs m^2	%
Shirocco	94.0	470.0	444.0	94.5
Uliublena	88.6	443.0	394.0	88.9
Barvysta	90.0	450.0	410.0	91.1
Quintus	90.6	453.0	417.0	92.1
LSD_{05}	1.5	5.16	5.33	1.61

According to the results of the research, the highest coefficient of productive tillering of spring wheat plants was obtained in the Shirocco variety – 1.30, and the number of productive shoots was 577 pcs m^2. Somewhat lower indices were obtained for varieties Uliublena –1.28 (508 pcs m^2), Quintus –1.18 (490.7 pcs m^2), Barvysta –1.11 (453.3 pcs m^2). (Table. 2). The yield of cereal breads is determined by the number of ear-bearing stalks per area unit and productivity of their ears. Special attention is required to the question of influence of controlled factors on the development of stem systems, since they play a significant role in the formation of plant productivity. Spring wheat has low productive bushiness (Demydov *et al*., 2017).

Table 2. Coefficient of productive bushing and number of productive stems depending on varietal characteristics (average for 2020–2022)

Variety	Coefficient of productive bushing	Number of productive stems, pcs m^2
Shirocco	1.30	577.0
Uliublena	1.28	508.0
Barvysta	1.11	453.3
Quintus	1.18	490.7
LSD_{05}	0.03	9.15

For optimal photosynthesis, the crop must have a certain leaf surface area (Radchenko *et al.,* 2022). However, it is necessary to distinguish leaf surface as a means of accumulating plastic substances for yield formation of grain, roots, and various fruits. During formation of grain yielding capacity, the excess leaf surface will not contribute to high yield of the crop, as part of leaves will be shaded by its upper circles (Zhemela and Shevnikov, 2013). According to the results of Lozinska and Fedoruk (2017), the index of leaf surface area of spring wheat changed significantly depending on variety assortment, and the largest leaf surface area was formed in the earing phase in the range of 33.4–34.1 thousand m^2ha^{-1}. In the studies of Sumy National Agrarian University, it was found that in the tillering phase of spring wheat, the leaf surface area was 4.0-6.0 thousand m^2ha^{-1}. The largest area was obtained by variety Shirocco –6.0 thousand m^2ha^{-1},

leaf surface area of the rest of varieties decreased to 5.7 thousand m^2ha^{-1} – variety Quintus, to 4.5 thousand m^2ha^{-1} – variety Uliublena and up to 4.0 thousand m^2ha^{-1} – variety Barvysta (LSD_{05}=0.38). Corresponding regularity was also observed in the phase of tube forming and earing. Thus, the leaf surface area of variety Shirocco was 38.4 thousand m^2ha^{-1}, variety Quintus –35.6 thousand m^2ha^{-1}, variety Uliublena –29.4 thousand m^2ha^{-1}, variety Barvysta –25.7 thousand. m^2ha^{-1} (LSD_{05}=2.71).

In the experiment, the maximum area of leaf surface was noted in the earing phase. When sowing variety Shirocco, leaf surface area was the largest and amounted to 43.2 thousand m^2ha^{-1}, which is 7.2% more than leaf surface area of variety Quintus (40.1 thousand m^2ha^{-1}), 19.4% more than variety Uliublena (34.8 thousand m^2ha^{-1}) and 27.1% more than variety Barvysta (31.5 thousand m^2ha^{-1}) (LSD_{05}=2.54) (Fig. 1).

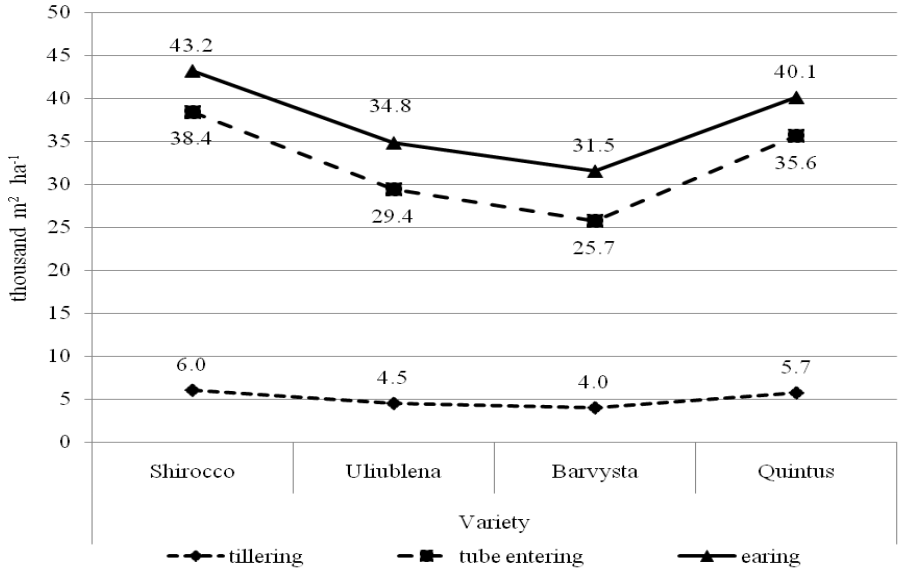

Figure 1. Leaf surface area of soft spring wheat by development phases depending on varietal characteristics (average for 2020–2022)

According to the results of research, the weight of a spring wheat plant varied between 2.05–2.69 g. The maximum weight of a plant was obtained for variety Shirocco –2.69 g. On average over the years of research, the plants of variety Shirocco had the largest ear weight –1.51 g. The lowest ear weight was obtained for variety Barvysta –1.25 g. For varieties Uliublena and Quintus, this index was 1.30 and 1.38 g., respectively (Table 3). The length of ear also varied depending on the variety. Thus, the length of ear for variety Shirocco is marked at the level of 9.5 cm, for variety Uliublena –8.0 cm, for variety Barvysta –7.8 cm, and for variety Quintus –8.8 cm (Table 3.). One of main components of plant

productivity determining yielding capacity of grain crops is plant weight, ear weight, ear length. The formation takes place during the period when plants are optimally provided with light, moisture, heat and other vital factors (Kalenska and Shutyy, 2015).

Table 3. Weight of plant and ear, length of the ear of soft spring wheat depending on varietal characteristics (average for 2020–2022)

Variety	Weight of plant, g	Weight of ear, g	Length of ear, cm
Shirocco	2.69	1.51	9.5
Uliublena	2.25	1.30	8.0
Barvysta	2.05	1.25	7.8
Quintus	2.36	1.38	8.8
LSD_{05}	0.11	0.07	0.46

The maximum index of grain weight from an ear of spring wheat was obtained from variety Quintus -0.98 g, which is 2.0% more than from variety Shirocco (0.96 g), 6.1% more than from variety Uliublena (0.92 g) and 7.1% more than from variety Barvysta (0.91 g) (Table 4). The most important feature in increasing productivity according to the results of Lukianenko (1990) is the mass of grain from an ear, which is an important element of crop structure and must be taken into account when developing a variety model.

As a result of conducted research, it was found that the biggest number of grains in the ear of a spring wheat plant had variety Quintus –31.2 pcs., and the smallest - variety Barvysta –24.0 pcs. Varieties Shirocco and Uliublena provided the number of grains at the level of 25.0 and 24.7 pcs., respectively (Table 4). Graininess of the ear is an index of productivity, which in its turn depends on the length of the ear, the number of ears in the ear. That is why, studying of this trait is an important component in spring wheat cultivation (Shelepov *et al.,* 2004; Lukhovyd, 2023).

Yielding capacity level is determined both by number of seeds per plant and by weight of 1000 seeds (Domaratskiy *et al.,* 2022). The weight of 1000 seeds is a varietal characteristic, but it depends on the influence of various factors (Hryhoriv *et al.,* 2022).

The research varieties formed different weight of 1000 seeds. The difference in this index between the varieties was in the range of 6.8 g. The maximum weight values of 1000 seeds were obtained in the variant with variety Shirocco –38.2 g. Somewhat smaller values of this index were obtained in the variants with variety Barvysta –37.9 g and Uliublena –37.2 g, and the lowest weight of 1000 seeds was recorded for variety Quintus –31.4 g (LSD_{05}= 1.58) (Table 4).

Table 4. Structural indices of a soft spring wheat plant depending on varietal characteristics (average for 2020–2022)

Variety	Weight of grain from an ear, g	Number of grains in an ear, pcs.	Weight of 1000 seeds, g
Shirocco	0.96	25.0	38.2
Uliublena	0.92	24.7	37.2
Barvysta	0.91	24.0	37.9
Quintus	0.98	31.2	31.4
LSD_{05}	0.04	2.57	1.58

As a result of conducted research, it was found that yielding capacity of soft spring wheat was on average from 4.13 to 5.54 t.ha^{-1} (LSD_{05}=0.21). The maximum grain yield on average during research period was produced by variety Shirocco -5.54 t.ha^{-1}. Varieties Uliublena, Barvysta and Quintus provided grain yield at the level of 4.67, 4.13 and 4.81 t.ha^{-1}, respectively (Fig. 2). Modern varieties of spring wheat have a high potential of yielding capacity, but the average yield in recent years under conditions of the forest-steppe of Ukraine was only 2.0–2.5 t.ha^{-1} (Polishuk and Antko, 2020). According to the results of research conducted by Ishchenko (2021), under conditions of unstable moisture, spring wheat produced a yield of 4.5 t.ha^{-1}, and the maximum yield of new varieties of soft spring wheat reached 5.85–6.20 t.ha^{-1}.

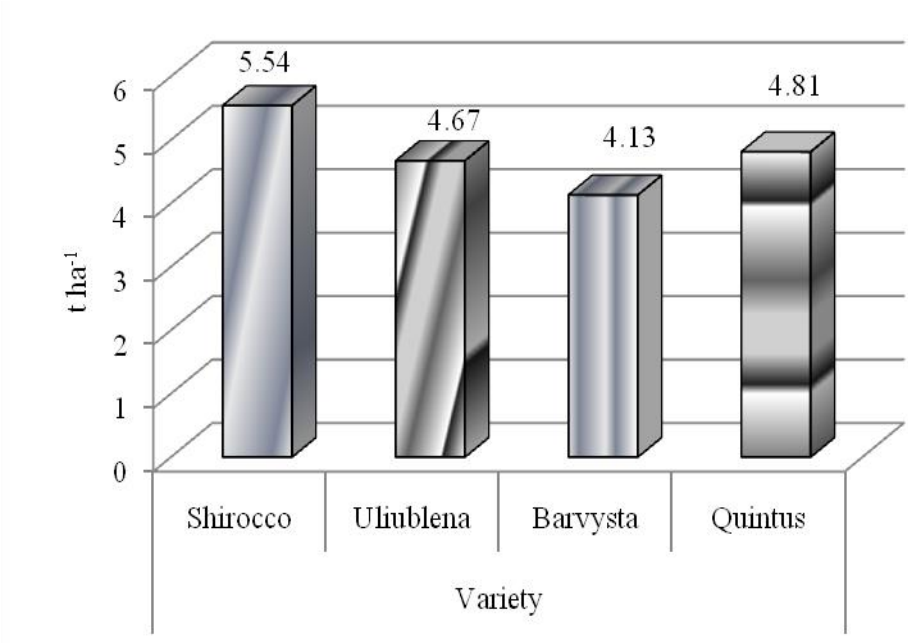

Figure 2. Yielding capacity of soft spring wheat grain depending on varietal characteristics (average for 2020–2022)

It has been experimentally confirmed that grain quality indices of modern varieties of spring wheat depend to a greater extent on varietal characteristics than on weather conditions. Cultivation improvement of new varieties of spring wheat, taking into account economic feasibility of grain production for this crop, is of particular importance (Lozinska and Chevstuk, 2019). Spring wheat grain has high baking and cereal qualities, contains more protein than winter wheat grain. Soft spring wheat grain has a protein content of 14–16% and a gluten content of 28–40% (Hospodarenko, 2001; Andriushchenko, 2002). In the studies conducted by Sumy National Agrarian University, the crude gluten content in the studied varieties ranged from 29.0 to 32.5% (LSD_{05}=0.71). The highest gluten content was obtained in the variant with variety Shirocco –32.5%, and the lowest - variety Barvysta –29.0%. Varieties Uliublena and Quintus showed gluten content at the level of 31.1 and 32.0%, respectively (Table 5).

Table 5. Quality of soft spring wheat grain depending on varietal characteristics (average for 2020–2022)

Variety	Gluten content, %	Protein content, %
Shirocco	32.5	16.3
Uliublena	31.1	15.0
Barvysta	29.0	14.8
Quintus	32.0	15.8
LSD_{05}	0.71	0.46

Protein content of variety Shirocco was 16.3%, variety Uliublena –15.0%, variety Barvysta –14.8%, and variety Quintus –15.8%. Thus, the highest protein content was obtained from variety Shirocco –16.3% (Table 5).

CONCLUSIONS

As a result of the research, it was found that the highest coefficient of productive tillering of spring wheat plants was obtained in the Shirocco variety – 1.30, and the number of productive shoots was 577 pcs m^2. In the experiment, the maximum leaf surface area was noted in the earing phase. When sowing the Shirocco variety, the leaf surface area was the largest and amounted to 43.2 thousand m^2ha^{-1}. On average, over the years of the study, the plants of the Shirocco variety had the highest ear weight –1.51 g, the lowest ear weight was obtained in the Barvysta variety 1.25 g. It was found that the largest number of grains in the ear of the spring wheat plant was in the Quintus variety –31.2 pcs., and the smallest for the Barvysta variety –24.0 pcs. For the Shirocco and Uliublena varieties, the number of grains was at the level of 25.0 and 24.7 pcs.

In the conditions of the natural and climatic zone of the Sumy region (north-eastern Forest-Steppe of Ukraine), it is proposed to grow the Shirocco variety to obtain a yield of spring wheat at the level of 5.54 $t.ha^{-1}$ with a gluten content of 32.5%, protein content of 16.3%.

REFERENCES

Andriushchenko, A. (2002). 4–5 million seeds per hectare is optimal. Proposal, 1: 40–41. [In Ukrainian]

Borysonik, Z. B. (2001). Bright ear crops. Kyiv: Harvest, 176 p. [In Ukrainian]

Demydov, O., Kavunets, V., Siroshtan, A., Hudzenko, V. & Khomenko, S. (2017). Spring wheat needs attention. Proposal, 1: 76–80. [In Ukrainian]

Domaratskiy Y., Bazaliy V., Dobrovol'skiy A., Pichura V. & Kozlova O. (2022). Influence of Eco-Safe Growth-Regulating Substances on the Phytosanitary State of Agrocenoses of Wheat Varieties of Various Types of Development in Non-Irrigated Conditions of the Steppe Zone. Journal of Ecological Engineering, 23(8), 299–308. doi.org/10.12911/22998993/150865

Dospekhov, B. A. (1985). Methods of field experience. Moscow: Kolos, 351 p. [In Russian]

Guedioura I., Rahmoune B., Khezzaren A., Dahoumane A. & Laouar N. (2023). Combined effect of soil practices and chemical treatments on weeds growth, soil features, and yield performance in field wheat crop under Mediterranean climate. Agronomy Research 21 (1), 62–77. doi.org/10.15159/AR.22.079

Hospodarenko, H. M. (2001). Features of fertilizing spring barley with clover seeding. Collection of scientific works of Umansky DAU, 51: 47–56. [In Ukrainian]

Hryhoriv, Y., Butenko, A., Kozak, M., Tatarynova, V., Bondarenko, O., Nozdrina, N., Stavytskyi, A. & Bordun, R. (2022). Structure components and yielding capacity of *Camelina sativa* in Ukraine. Agriculture and Forestry, 68 (3): 93–102. doi:10.17707/AgricultForest.68.3.07

Hrynyk, I. V. (2000). The influence of precursors and the fertilization system on the yield and quality of winter and spring wheat in the conditions of Polissia. Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine, Kyiv. (Candidates's thesis). [In Ukrainian]

Ishchenko, V. A. (2021). Comparative characteristics of productivity of spring wheat varieties in the Northern Steppe of Ukraine. Agrarian innovations, 7: 36–41. doi:10.32848/agrar.innov.2021.7.6

Kalenska, S. M. & Shutyy, O. I. (2015). The formation of structure indexes of durum spring wheat depending on type elements of technology cultivation. Bulletin of the Sumy National Agrarian University, 3 (29): 170–173. [In Ukrainian]

Konovalov, Yu. B. (1999). Formation of productivity of an ear of spring wheat and barley. Moscow: Kolos, 176 p. [In Russian]

Kumakova, V. A. (1988). Biological bases of spring wheat according to intensive technology. Moscow: Rosagropromizdat, 104 p. [In Russian]

Lozinska, T. P. & Chevstuk, A. V. (2019). Yield end quality of soft wheat varieties in the conditions of the experimental field Belotserkiv NAU. Scientific journal ΛΌΓΟΣ, 2: 73–75. [In Ukrainian]

Lozinska, T. P. & Fedoruk, Yu. V. (2017). Biological features of the formation of productivity of spring wheat in the conditions of the forest-steppe of Ukraine. Agriculture, 7(7): 3–8. [In Ukrainian]

Lukianenko, P. P. (1990). Selected writings. Moscow: Agropromizdat, 428 p. [In Russian]

Lykhovyd P. (2023). Choosing Important Traits for the Model of High-Yielding Winter Wheat Variety Based on the Results of Regional Ecological Varietal Testing. Journal of Ecological Engineering, 24(6), 8–12 doi.org/10.12911/22998993/162135

Melnyk, S. I., Sytnyk, V. P., Lazar, T. I., Voitov, I. M. & Kozatskyi, D. V. (2006). Recommendations for growing spring wheat in the forest-steppe of Ukraine. Kharkiv, 23 p. [In Ukrainian]

Nazarenko, M., Semenchenko, O., Izhboldin, O. & Hladkikh, Y. (2021): French winter wheat varieties under ukrainian north steppe condition. Agriculture and Forestry, 67 (2): 89–102. doi:10.17707/AgricultForest.67.2.07

Pidoprygora, V. S. & Pisarenko, P. V. (2003). Workshop on the basics of scientific research in agronomy. Poltava: Intergraphics, 138 p. [In Ukrainian]

Pidruchna, O. V. (2000). The influence of mineral fertilizers on the yield and grain quality of spring durum wheat under irrigation conditions in the south of Ukraine. National Agrarian University, Kyiv. (Candidates's thesis). [In Ukrainian]

Polishuk, M. I. & Antko, R. A. (2020). Improvement of technological approvals of spring wheat production in the conditions of the right-bank forest Ukraine. Agriculture and forestry, 17: 64–73. doi:10.37128/2707-5826-2020-2-6

Radchenko, M. V., Trotsenko, V. I., Butenko, A. O., Masyk, I. M., Hlupak, Z. I., Pshychenko, O. I., Terokhina, N. O., Rozhko, V. M. & Karpenko, O. Y. (2022). Adaptation of various maize hybrids when grown for biomass. Agronomy Research, 20(2): 404–413. doi:10.15159/AR.22.028

Radchenko, M. V., Trotsenko, V. I., Hlupak, Z. I., Zakharchenko, E. A., Osmachko, O. M., Moisiienko, V. V., Panchyshyn, V. Z., & Stotska, S. V. (2021). Influence of mineral fertilizers on yielding capacity and quality of soft spring wheat grain. Agronomy Research 19 (4): 1901–1913. doi:10.15159/AR.21.104

Shelepov, V. V., Malasai, V. M. & Penzev A. F. (2004). Morphology, biology, economic value of wheat. Mironovka, 524 p. [In Russian]

Shevnikov, D. M. (2012). The influence of mineral fertilizers on the nutrient regime of the soil during the cultivation of durum spring wheat. Bulletin of the Poltava State Agrarian Academy, 2: 203–206. [In Ukrainian]

Sokolov, V. M. (2011). Perspectives of breeding and seed production of grain crops. Scientific reasons for the intensification of grain production in Ukraine, 4: 26–34. [In Ukrainian]

Sviderko, M. S., Bolekhivskyi, V. P., Tymkiv, M. Yu. & Kubyshyn, S. Ya. (2004). Effectiveness of spring wheat cultivation technologies in the Western Forest Steppe. Kyiv: ECMO, 212 p. [In Ukrainian]

Usov, O. S. & Manko, K. M. (2015). Peculiarities of forming the yield of durum spring wheat depending on the predecessor and the main tillage. Collection of scientific papers of the Institute of Bioenergy Crops and Sugar Beet, 23: 70–75. [In Ukrainian]

Verhunov, I. M. (2000). Fundamentals of mathematical modeling for analysis and forecasting of agronomic processes. Kyiv: Noraprint, 146 p. [In Ukrainian]

Vlasenko, V. A. (2006). Assessment of adaptability of soft spring wheat varieties. Varietal research and protection of rights to plant varieties, 4: 93–103. [In Ukrainian]

Xhulaj, Bode, D. & Koto, R. (2022): Estimation of genetic variability of autochthonous wheat (*Triticum aestivum* L.) genotypes using multivariate analysis. Agriculture and Forestry, 68 (1): 131–143. doi:10.17707/AgricultForest.68.1.07

Yula, V. M. & Drozd, M. O. (2020). Productivity of soft spring wheat under adaptive cultivation technologies in the northern Forest Steppe. Collection of scientific papers of the National Scientific Center of the Institute of Agriculture of the Ukrainian Academies of Agrarian Sciences, 1–2: 98–109. [In Ukrainian]

Yula, V. M. (2010). Features of mineral nutrition of spring wheat depending on agrometeorological and agrotechnical factors. Collection of scientific papers of the National Scientific Center of the Institute of Agriculture of the Ukrainian Academies of Agrarian Sciences, 3: 216–227. [In Ukrainian]

Yula, V. M. (2016). The influence of elements of cultivation technology on grain quality of soft spring wheat of the Nedra variety. Collection of scientific works of the Institute of Agriculture of the National Academy of Agrarian Sciences, 3–4: 154–165. [In Ukrainian]

Zhemela, H. P. & Shevnikov, D. M. (2013). Photosynthetic productivity of durum spring wheat crops depending on mineral fertilizers and biological preparations. Bulletin of the Poltava State Agrarian Academy, 3: 36–40. [In Ukrainian]

Holik, O. V. & Kabatsiura, A. A. (2012). Characterization of the source material of spring wheat and spelled according to the ecological plasticity of productivity. Breeding and seed production, 101: 139–149. [In Ukrainian]