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# INFLUENCE OF SEEDING RATE ON THE PRODUCTIVITY AND QUALITY OF SOFT SPRING WHEAT GRAIN (*TRITICUM AESTIVUM* L.)

## SUMMARY

The grain industry in Ukraine is the most important component of the agro-industrial complex. At the same time, spring wheat grain production remains low and unstable due to insufficient efficiency of cultivation technology. The purpose of the research was to establish optimal seeding rates for soft spring wheat (*Triticum aestivum* L.) seeds of the Shirocco variety. The study of the influence of the seeding rate on the productivity and quality indicators of soft spring wheat was carried out according to the scheme: 3.5 million pcs $ha^{-1}$, 4.0 million pcs $ha^{-1}$, 4.5 million pcs $ha^{-1}$, 5.0 million pcs $ha^{-1}$; 5.5 million pcs $ha^{-1}$; 6.0 million pcs $ha^{-1}$. As a result of the research, it was found that the highest density of standing was obtained on the variant with a seeding rate of 6.0 million pcs $ha^{-1}$ – 522 pcs $m^2$ with plant preservation during the growing season of 86.8% (453.1 pcs $m^2$). The maximum yield was observed on the variant with a seeding rate of 6.0 million pcs $ha^{-1}$ – 5.63 t $ha^{-1}$. At a seeding rate of 3.5, 4.0, 4.5, 5.0, 5.5 pcs $m^2$ the yield was 4.07, 4.58, 4.76, 5.00, 5.30 t $ha^{-1}$, respectively. According to the results of the research, it was studied that at a seeding rate of 6.0 million pcs $ha^{-1}$, the highest yield of spring wheat grain was obtained – 5.63 t $ha^{-1}$, and the maximum quality indicators of gluten and protein content at a seeding rate of 5.5 million pcs $ha^{-1}$ – 25.5, 13.82%, respectively.

**Keywords**: seeding rate, standing density, productivity, yield, protein, gluten.

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## INTRODUCTION

The grain industry in Ukraine is the most important component of the agro-industrial complex. Grain is the basis for food production, raw materials for many industries, fodder for animals and is an integral part of the country's food security. Grain is also the main exchange-traded food commodity (Halenko, 2017). Wheat occupies a prominent place among grain crops around the world and is the main food product for about 35% of the world's population and provides about 20% of humanity's energy needs (Demydov *et al.,* 2017a; Velimirović *et al.,* 2023). Today, on the territory of our country, the question arises of solving the scientific and technical problem of improving the regulatory provision of grain quality and harmonizing it with international standards (Khomenko *et al.,* 2018). Significant success in social and cultural development is achieved only by those countries that are able to ensure the highest quality of their products. Therefore, the grain industry of Ukraine is faced with the task of ensuring a stable growth of grain production and the achievement of certain quality characteristics, which should satisfy both all the needs of the country in the domestic market and provide an opportunity to be competitive in the foreign market (Kaflevska and Kozyar, 2013).

Spring wheat is a valuable grain crop and is not inferior in quality to winter wheat, and the emergence of new varieties of strong wheat makes it possible to obtain a higher grain quality than that of winter wheat varieties under the same soil and climatic growing conditions (Yula, 2016; Yarchuk *et al.,* 2019; Litvinov *et al.,* 2020).

Grain, which is obtained from soft varieties of spring wheat, is used to make bread, confectionery, cereals and pasta. In Ukraine, it is sown on an area of only 160–190 thousand hectares. Such a slight distribution of spring wheat is explained by the fact that it is significantly inferior in terms of grain yield of winter wheat (Zinchenko, 2016).

But in recent years, there has been an upward trend in spring wheat crops. From the status of insurance, it is gradually turning into one of the main crops, the cultivation of which is aimed at the production of high-quality grain to improve baking properties (Tanchyk *et al.*, 2019; Nazarenko *et al.*, 2023).

During the sowing process, it is imperative to recognize that augmented seeding rates do not confer a proportional increase in the yield of spring wheat. Conversely, elevated seeding rates engender heightened grain consumption, elevate susceptibility to lodging, pests, and diseases. Conversely, inadequate seeding rates contribute to delayed tillering and uneven ripening of the crop, as substantiated by the findings of Karpenko *et al.* (2020). To a large extent, the seeding rate of wheat depends on the biological characteristics of the variety. Varieties that are characterized by high bushiness and plant height, unstable to lodging, provide maximum grain yield at reduced seeding rates, and low-growing and semi-dwarf varieties – at increased ones. Therefore, for undersized and semi-dwarf varieties, it is recommended to increase the seeding rate by 0.5–1.0 million pcs $ha^{-1}$, compared to tall varieties. However, even varieties with a low stem at an increased seeding rate (more than 6 million pcs $ha^{-1}$) suffer from a deterioration in illumination in crops, an increase in nutrient and water consumption, and a higher incidence of plant diseases, resulting in a decrease in yield (Kochmarsky *et al.,* 2014).

There are recommendations for the use of thicker crops on weedy lands. The augmentation of seeding rates from 3 to 5 million grains per hectare resulted in a notable reduction in weed infestation, exhibiting a decrease ranging from 1.2 to 1.5 times. The seeding rate of spring wheat is higher than that of winter wheat, since it does not have an autumn tillering period, as a result of which it has a lower tillering coefficient (about 1.3). Under current conditions, it is recommended to sow wheat after the worst predecessors of 5.5–6.0, and after the best 5.0–5.5 million germinating grains per hectare (Hansueli and Rainer, 2015).

The purpose of the study was to determine the influence of the seeding rate on the processes of growth and development, the formation of yield and grain quality of spring wheat (*Triticum aestivum* L.).

## MATERIAL AND METHODS

The study of the seeding rate of soft spring wheat was carried out in the conditions of a field stationary experiment on the territory of the educational and scientific production center of Sumy National Agrarian University. The experimental field is located in the Sumy district of the Sumy region, Ukraine, geolocation data 50°52.742N latitude, 34°46.159E longitude, 137.7 m above sea level (50°52'46.6"N 34°46'07.8"E Map date ©2023 Google). The study was conducted during 2021–2023.

The study of the impact of seeding rates on the productivity and quality indicators of soft spring wheat was carried out according to the scheme: 3.5 million pcs $ha^{-1}$, 4.0 million pcs $ha^{-1}$, 4.5 million pcs $ha^{-1}$, 5.0 million pcs $ha^{-1}$; 5.5 million pcs $ha^{-1}$; 6.0 million pcs $ha^{-1}$. The object of the study was a variety of soft spring wheat Shirocco. The technology of spring wheat cultivation is generally accepted for the conditions of the Forest-Steppe zone of Ukraine, except for the questions posed to the study. The studies were carried out after the predecessor soybean. Sowing of spring wheat was carried out with a seeder Maple – 1.5, at a soil temperature of 6–8 °C. The method of sowing is ordinary continuous, the depth of seed incorporation is 3–4 cm. During cultivation, fertilizer was applied at a dose of $N_{32}P_{32}K_{32}$ as a background fertilizer. Nitrogen-phosor-potassium complex mineral fertilizer was applied. Mass fraction: total nitrogen – 16 ± 1%, toaliy in terms of $K_2O$ – 16% ± 1%, total phosphates – 16 ± 1%. The plots were systematically arranged one after the other, the area of 1 plot was 50 $m^2$ and the computing area was 30 $m^2$.

The dynamics of ground mass growth was determined at the main stages of growth and development by selecting 25 plants in a typical plot with two incompatible repetitions, and the yield structure by selecting test sheaves from each accounting plot (Pidoprygora and Pisarenko, 2003).

The amount of gluten was determined by manual washing in water according to STST 13586.1–68 Grain (СТСТ 13586.1–68). Methods for determining the quantity and quality of wheat gluten. The amount of protein was determined according to STST 10846–91 (СТСТ 10846–91) "Grain and products of its processing". Protein determination method.

Mathematical and statistical processing of experimental data and determination of the reliability of the results obtained was carried out according to Dospekhov (1985) using Microsoft Excel.

The soil of the test site is a typical thick heavy loamy and medium-humus chernozem, which is characterized by the following indicators: the content of humus in the arable layer (according to I.V. Tyurin) is 4.0%, the reaction of the soil solution is close to neutral (pH 6.5), the content of easily hydrolyzed nitrogen (according to I.V. Tyurin) is 9.0 mg, mobile phosphorus and exchangeable potassium (according to F. Chirikov) is 14 mg and 6.7 mg per 100 g of soil, respectively.

The average daily annual air temperature in 2021 was 9.4 °C, which is 2.0 °C higher than the long-term indicator of 7.4 °C. Its absolute maximum of 35.0 °C was recorded in June in the third decade, and the minimum was minus 24.0 °C in the second decade of January. The amount of precipitation for the reporting 2020–2021 agricultural year was 453 mm, which is 140 mm less than the long-term indicator (593 mm). Precipitation was distributed by periods of the year in the following order: autumn 2020 – 75 mm (54% of the long-term indicator of 139 mm); winter 2020–2021 – 90 mm (74% of the long-term indicator of 122 mm); spring 2021 – 119 mm (90% of the long-term indicator of 132 mm); summer 2020 – 169 mm (85% of the long-term indicator of 200 mm).

The average daily annual air temperature in 2022 was 8.7 °C, which is 1.3 °C higher than the long-term indicator of 7.4 °C. Its absolute maximum of 36 °C was recorded in June in the third decade, and its minimum in January in the second decade minus 18.0 °C. The amount of precipitation for the reporting 2021–2022 agricultural year was 604 mm, which is 11 mm more than the long-term indicator (593 mm). Precipitation was distributed by periods of the year in the following order: autumn 2021 – 96 mm (69% of the long-term indicator of 139 mm); winter 2021–2022 – 103 mm (84% of the long-term indicator of 122 mm); spring 2022 – 144 mm (109% of the long-term indicator of 132 mm); summer 2022 – 261 mm (130% of the long-term indicator of 200 mm).

The average daily annual air temperature in 2023 was 9.0 °C, which is 1.6 °C more than the long-term indicator of 7.4 °C. Its absolute maximum of 36 °C was recorded in August in the first decade, and its minimum in January in the first decade was minus 19 °C. The amount of precipitation for the reporting 2022–2023 agricultural year was 634 mm, which is 41 mm more than the long-term indicator (593 mm). Precipitation was distributed by periods of the year in the following order: autumn 2022 – 176 mm (127% of the long-term indicator of 139 mm); winter 2022–2023 – 102 mm (84% of the long-term 122 mm); spring

2023 – 83 mm (63% of the long-term figure of 132 mm); summer 2023 – 273 mm (136% of the long-term indicator of 200 mm).

In general, 2022 and 2023 were the most favorable for the formation of crop yields. Dry conditions developed in 2021, which was characterized by low rainfall and extreme deviation in air temperature during the growing season.

## RESULTS AND DISCUSSION

It is well known that pre-sowing preparation of grain seeds is an important condition in increasing the yield of grain crops. By sowing seeds with high varietal and sowing qualities, it is possible to obtain a yield increase of more than 30%. Due to the increase in the germination rate of seeds, their quality also improves. It has been proven that field germination, productivity and quality are closely interrelated (Alimov and Shelestov, 1995; Sviderko *et al.*, 2004). In the studies of Sumy National Agrarian University, it was found that the field germination of spring wheat ranged from 87.0 to 89.8% ($LSD_{05}$ (Least Significant Difference) = 0.56). The maximum indicators of field germination were noted on the variant with a seeding rate of 3.5 million pcs $ha^{-1}$ and amounted to 89.8%, slightly lower indicators were observed at a seeding rate of 4.0 million pcs $ha^{-1}$ – 89.4%, 4.5 million pcs $ha^{-1}$ – 88.7%, 5.0 million pcs $ha^{-1}$ – 88.0%, 5.5 million pcs $ha^{-1}$ – 87.2%, 6.0 million pcs $ha^{-1}$ – 87.0%. The standing density ranged from 314.3 pcs $m^2$ to 522.0 pcs $m^2$ ($LSD_{05}$ = 9.45). The highest density of spring wheat was obtained at a maximum seeding rate of 6.0 million pcs $ha^{-1}$ and amounted to 522.0 pcs $m^2$, a decrease in the seeding rate led to a decrease in the density of standing. Thus, the lowest density of spring wheat was obtained on the variant of 3.5 million pcs $ha^{-1}$ and amounted to 314.3 pcs $m^2$ (Table 1).

Table 1. Stand density of soft spring wheat depending on the seeding rate (average for 2021–2023)

| Seeding rate, million pcs $ha^{-1}$ | Field germination, % | Standing density, pcs $m^2$ | Plant safety during the growing season | |
|---|---|---|---|---|
| | | | pcs $m^2$ | % |
| 3.5 | 89.8 | 314.3 | 283.5 | 90.2 |
| 4.0 | 89.4 | 357.6 | 321.8 | 90.0 |
| 4.5 | 88.7 | 399.2 | 357.2 | 89.5 |
| 5.0 | 88.0 | 440.0 | 389.0 | 88.4 |
| 5.5 | 87.2 | 479.6 | 418.7 | 87.3 |
| 6.0 | 87.0 | 522.0 | 453.1 | 86.8 |
| $LSD_{05}$ | 0.56 | 9.45 | 10.0 | 0.36 |

The preservation of plants during the growing season ranged from 86.8 to 90.2% ($LSD_{05}$ = 0.36). The maximum preservation of plants was recorded on the variant with a seeding rate of 3.5 million pcs $ha^{-1}$ – 90.2% (283.5 pcs $m^{2}$), and the lowest preservation was obtained using a seeding rate of 6.0 million pcs $ha^{-1}$ –

86.8% (453.1 pcs $m^2$). For sowing spring wheat with a seeding rate of 4.0 million pcs $ha^{-1}$ plant safety was 90.0% (321.8 pcs $m^2$), 4.5 million pcs $ha^{-1}$ – 89.5% (357.2 pcs $m^2$), 5.0 million pcs $ha^{-1}$ – 88.4% (389.0 pcs $m^2$), 5.5 million pcs $ha^{-1}$ – 87.3% (418.7 pcs $m^2$) (Table 1).

A decrease in crop productivity is caused by a deviation of the seeding rate from the optimum. Competition between plants increases with unreasonably high seeding rates, as a result of which the productivity of individual plants and sowing as a whole decrease. An increase in the seeding rate leads, as a rule, to a decrease in the coefficient of total tillering, the mass of dry matter in the plant and the number of nodal roots. The ability to bush in wheat, as well as in other cereals, is determined by both the method of sowing and the seeding rate and is related to the area of nutrition: the number of productive stems decreases with a decrease in the area of nutrition and vice versa (Cherenkov *et al.*, 2009). According to the results of the research, the indicator of the coefficient of productive tillering in the conditions of Sumy National Agrarian University ranged from 1.23 to 1.33 ($LSD_{05}$ = 0.56). Thus, the highest coefficient of productive tillering was obtained at a seeding rate of 3.5 million pcs $ha^{-1}$ and was 1.33, and the lowest at the seeding rate was 6.0 million pcs $ha^{-1}$ – 1.23 (Table 2).

A fairly important indicator in which soft wheat forms the highest yield is the density of productive stems: 400–500 plants per 1 $m^2$. Such plant density requires a mild seeding rate for wheat after the best and worst predecessors: 5.0–5.5 and 5.5–6.5 million pcs $ha^{-1}$ respectively (Demydov *et al.*, 2017b). In the conditions of the educational and scientific production center of Sumy National Agrarian University, it was noted that the number of productive stems was the highest in the variant with a seeding rate of 6.0 million pcs $ha^{-1}$ – 557.3 pcs $m^2$. The smallest number of productive stems was observed at a seeding rate of 3.5 million pcs $ha^{-1}$ – 377,1 pcs $m^2$. At a seeding rate of 4.0 million pcs $ha^{-1}$ of productive stems amounted to 427.8 million pcs $ha^{-1}$, 4.5 million pcs $ha^{-1}$ – 453.6 pcs $m^2$, 5.0 million pcs $ha^{-1}$ – 486.3 pcs $m^2$, 5.5 million pcs $ha^{-1}$ – 519.2 pcs $m^2$ (Table 2).

Table 2. Productive tillering coefficient and number of productive stems depending on the seeding rate (average for 2021–2023)

| Seeding rate, million pcs $ha^{-1}$ | Productive tillering coefficient | Number of productive stems, pcs $m^2$ |
|---|---|---|
| 3.5 | 1.33 | 377.1 |
| 4.0 | 1.32 | 427.8 |
| 4.5 | 1.27 | 453.6 |
| 5.0 | 1.25 | 486.3 |
| 5.5 | 1.24 | 519.2 |
| 6.0 | 1.23 | 557.3 |
| $LSD_{05}$ | 0.03 | 9.13 |

One of the main factors in the yield of grain crops is the weight of the plant, the weight of the ear and the length of the ear. Formation takes place during the period when plants are best provided with light, moisture, heat and other vital factors (Kalenska and Shutyy, 2015). In the conditions of the educational and scientific production center of Sumy National Agrarian University, the weight of the spring wheat plant depended on the seeding rate and ranged from 2.27 g to 2.96 g ($LSD_{05}$ = 0.58). The highest weight of the plant was obtained at a seeding rate of spring wheat of 3.5 million pcs $ha^{-1}$ – 2.96 g, and ear weight – 1.80 g. The lowest weight indicators were obtained at the seeding rate of 6.0 million pcs $ha^{-1}$ – 2.27 and 1.42 g, respectively. At the seeding rate of 4.0 million pcs $ha^{-1}$ – 2.88, 1.73 g, 4.5 million pcs $ha^{-1}$ – 2.78, 1.70, 5.0 million pcs $ha^{-1}$ – 2.64, 1.62 g, 5.5 million pcs $ha^{-1}$ – 2.45, 1.51 g, respectively (Table 3).

The length of an ear of wheat is largely determined by the genotype, but it also depends on the growing conditions. The ear of wheat plants can be of different lengths: short – up to 8 cm, medium – 8–10, long – more than 10 cm. Under unfavorable conditions for the development of the growth cone, in particular, the lack of nutrients and moisture in the soil, strong thickening of plants, lack of light, spikelet tubercles in the upper part of the growth cone underdeveloped and dry out. This leads to a sharp reduction in the size of the ear. In addition, some of the spikelet’s die off in the process of growth and development. In addition to varietal characteristics and meteorological conditions, the size of the ear is also influenced by certain elements of the technology, in particular the seeding rate, with the help of which it is important to delay the time of laying the apical spikelet in the ear (Shelepov et al., 2007). According to the results of research conducted in the conditions of Sumy National Agrarian University, the length of the ear changed due to the seeding rate. Thus, the highest ear length was noted in the variant for spring wheat with a seeding rate of 3.5 million pcs $ha^{-1}$ and was 9.2 cm, the shortest ear length was observed at a seeding rate of 6.0 million pcs $ha^{-1}$ – 7.8 cm (Table 3).

Table 3. Weight of the plant and ear, ear length of soft spring wheat depending on the seeding rate (average for 2021–2023)

| Seeding rate, million pcs $ha^{-1}$ | Plant weight, g | Ear weight, g | Spike length, cm |
|---|---|---|---|
| 3.5 | 2.96 | 1.80 | 9.2 |
| 4.0 | 2.88 | 1.73 | 9.0 |
| 4.5 | 2.78 | 1.70 | 8.7 |
| 5.0 | 2.64 | 1.62 | 8.4 |
| 5.5 | 2.45 | 1.51 | 8.0 |
| 6.0 | 2.27 | 1.42 | 7.8 |
| $LSD_{05}$ | 0.58 | 0.04 | 0.28 |

The grain weight of an ear is a sign of structures such as length, the number of ears and grains in an ear, the weight of 1000 grains and is due to many genes with different types of interactions. In practice, the mass of the grain of the ear has always been given one of the central places. Ear selection is the main principle of work of many breeders (Shakalii, 2017). The maximum weight of grain per ear in the experiments of Sumy National Agrarian University varied in the range of 1.01–1.08 g ($LSD_{05}$ = 0.02). The highest weight of grain per ear was obtained at a seeding rate of 3.5 million pcs $ha^{-1}$ and amounted to 1.08 g, slightly lower indicators were observed at the seeding rate of 4.0 million pcs $ha^{-1}$ – 1.07 g, 4.5 million pcs $ha^{-1}$ – 1.05 g, 5.0 million pcs $ha^{-1}$ – 1.03 g, 5.5 million pcs $ha^{-1}$ – 1.02 g and 6.0 million pcs $ha^{-1}$ – 1.01 g (Table 4).

The grain content of the ear and the total tilleriness are inversely dependent on each other, since a large number of nutrients are spent on the creation of the vegetative mass, and by the time of ear formation, their content in the most bushed plants becomes insufficient for the full formation of the crop. The number of grains per ear increases with a decrease in the seeding rate to 3.0–4.0 million pcs $ha^{-1}$ (Lykhochvor, 2004). According to Yula and Oliinyk (2013), Macholdt and Honermeier (2017), high productivity of winter wheat crops can be achieved only if there is an optimal ratio between the components of productivity, which are laid down at the early stages of plant development and formed during the growing season. In the studies carried out by Sumy National Agrarian University, it was found that the maximum number of grains was obtained on the variant with a seeding rate of 3.5 million pcs $ha^{-1}$ – 28.2 pcs. An increase in the seeding rate led to a decrease in the number of grains in ears of corn. Thus, the smallest amount of grains was obtained on a warrant with a seeding rate of 6.0 million pcs $ha^{-1}$ – 27.2 pcs. At seeding rates of 4.0, 4.5, 5.0, 5.5 million the number of grains $ha^{-1}$ was 28.0, 27.8, 27.5, 27.4 pcs., respectively (Table 4).

Table 4. Structural indicators of the spring bread wheat plant depending on the seeding rate (average for 2021–2023)

| Seeding rate, million pcs $ha^{-1}$ | Grain weight per ear, g | Number of grains per ear, pcs. | Weight of 1000 seeds, g |
|---|---|---|---|
| 3.5 | 1.08 | 28.2 | 38.3 |
| 4.0 | 1.07 | 28.0 | 38.2 |
| 4.5 | 1.05 | 27.8 | 37.8 |
| 5.0 | 1.03 | 27.5 | 37.5 |
| 5.5 | 1.02 | 27.4 | 37.2 |
| 6.0 | 1.01 | 27.2 | 37.1 |
| $LSD_{05}$ | 0.02 | 0.16 | 0.15 |

From a breeding point of view, the weight of 1000 grains are of great importance, which is a reliable indicator in the selection for yield (Shakalii, 2020). The weight of 1000 grains depend on both environmental factors and the seeding rate, as a result of which it can vary widely (Chetveryk *et al.*, 2021). According to the results of research in the conditions of the educational and scientific production center of Sumy National Agrarian University, the weight of 1000 grains ranged from 37.1 to 38.3 g ($LSD_{05}$ = 0.15). Thus, the highest weight of 1000 grains were noted in the variant with a seeding rate of 3.5 million pcs $ha^{-1}$ – 38.3. An increase in the seeding rate led to a decrease in the weight of 1000 grains and the smallest weight was observed at a seeding rate of 6.0 million pcs $ha^{-1}$ – 37.1 g (Table 4).

Dry conditions in recent years have led to low yields of spring wheat, which did not exceed 3.52 t $ha^{-1}$. Modern varieties of spring wheat of foreign and domestic selection, included in the State Register of Plant Varieties of Ukraine, have a high yield potential and can provide a yield of 5–8 t $ha^{-1}$ in production conditions (Lozinska and Fedoruk, 2017; Radchenko *et al.*, 2023). As a result of the research conducted by Sumy National Agrarian University, it was found that the yield according to the experiment options ranged on average from 4.07 t $ha^{-1}$ to 5.63 t $ha^{-1}$ ($LSD_{05}$ = 0.12). The maximum yield of spring wheat was obtained at a seeding rate of 6.0 million pcs $ha^{-1}$ and amounted to 5.63 t $ha^{-1}$. A decrease in the seeding rate affected the decrease in grain yield. So, at a seeding rate of 5.5 million pcs $ha^{-1}$, the yield was 5.30 t $ha^{-1}$, 5.0 million pcs $ha^{-1}$ – 5.00 t $ha^{-1}$, 4.5 million pcs $ha^{-1}$ – 4.76 t $ha^{-1}$, 4.0 million pcs $ha^{-1}$ – 4.58 t $ha^{-1}$ and at a seeding rate of 3.5 million pcs $ha^{-1}$ – 4.07 t $ha^{-1}$ (Table 5).

The crude gluten content in wheat grain ranges from 5 to 36%. The gluten content of wheat grains and the physical properties that characterize their quality can vary significantly (Hasanova, 2017). In the conditions of the educational and scientific production center of Sumy National Agrarian University, it was found that the gluten content depended on the seeding rate. Thus, the maximum amount of gluten was noted on the variant with a seeding rate of 5.5 million pcs $ha^{-1}$ and amounted to 25.20%, and the smallest amount of gluten was obtained with a seeding rate of 6.0 million pcs $ha^{-1}$ – 23.64%. Reduction of seeding rate from 5.0 to 3.5 million pcs $ha^{-1}$ led to a decrease in the amount of gluten. Thus, it is noted that at a seeding rate of 5.0 million pcs $ha^{-1}$ – gluten content was 24.81%, 4.5 million pcs $ha^{-1}$ – 24.32%, 4.0 million pcs $ha^{-1}$ – 24.05% and 3.5 million pcs $ha^{-1}$ – 23.85% (Table 5).

Table 5. Yield and grain quality of soft spring wheat depending on the seeding rate (average for 2021–2023)

| Seeding rate, million pcs $ha^{-1}$ | Yield, t $ha^{-1}$ | Gluten content, % | Protein content, % |
|---|---|---|---|
| 3.5 | 4.07 | 23.85 | 13.10 |
| 4.0 | 4.58 | 24.05 | 13.17 |
| 4.5 | 4.76 | 24.32 | 13.41 |
| 5.0 | 5.00 | 24.81 | 13.56 |
| 5.5 | 5.30 | 25.20 | 13.82 |
| 6.0 | 5.63 | 23.64 | 12.64 |
| $LSD_{05}$ | 0.12 | 0.20 | 0.13 |

In addition to yield, an important characteristic is to obtain a consistently high protein content in wheat grain, without reducing the yield level (Bilousova, 2019; Radchenko *et al.*, 2021).

If the grain contains less than 9% protein, then it is not worth talking about the satisfactory quality of flour from such a crop. The minimum protein content in bread wheat grain should be 12% to ensure satisfactory quality (Bozhko and Burdeynaya, 2010; Cherno, 2015). In the studies conducted by Sumy National University, the protein content in the grain of bread spring wheat was at the level of 12.64–13.82% ($LSD_{05}$ = 0.13).

At a seeding rate of 3.5 million pcs $ha^{-1}$ the protein content was 13.10%, 4.0 million pcs $ha^{-1}$ – 13.17%, 4.5 million pcs $ha^{-1}$ – 13.41%, 5.0 million pcs $ha^{-1}$ – 13.56%, 5.5 million pcs $ha^{-1}$ – 13.82%, 6.0 million pcs $ha^{-1}$ – 12.64%. According to the results of the research, the highest protein content was obtained at a seeding rate of 5.5 million pcs $ha^{-1}$ – 13.82% (Table 5).

## CONCLUSIONS

According to the results of the research, it was found that the highest density of spring wheat plants was obtained on the variant with a seeding rate of 6.0 million pcs $ha^{-1}$ – 522 pcs/$m^2$. In the experiment, it was found that the maximum preservation of plants during the growing season was 6.0 million pcs $ha^{-1}$ and amounted to 86.8% (453.1 pcs $m^2$). The number of productive stems was the highest in the variant with a seeding rate of 6.0 million pcs $ha^{-1}$ – 557.3 pcs $m^2$, and the smallest number of productive stems was noted at a seeding rate of 3.5 million pcs $ha^{-1}$ – 377.1 pcs $m^2$.

It is noted that the maximum yield of spring wheat was obtained at a seeding rate of 6.0 million pcs $ha^{-1}$ – 5.63 t $ha^{-1}$. A decrease in the seeding rate affected the decrease in grain yield. So, at a seeding rate of 5.5 million the yield was 5.30 t $ha^{-1}$, 5.0 million pcs $ha^{-1}$ – 5.00 t $ha^{-1}$, 4.5 million pcs $ha^{-1}$ – 4.76 t $ha^{-1}$, 4.0 million pcs $ha^{-1}$ – 4.58 t $ha^{-1}$ and at a seeding rate of 3.5 million pcs $ha^{-1}$ – 4.07 t $ha^{-1}$. On average, over the years of research, the maximum amount of gluten was observed in the variant with a seeding rate of 5.5 million pcs $ha^{-1}$ and amounted to 25.20%. According to the results of the research, the highest protein content was obtained at a seeding rate of 5.5 million pcs $ha^{-1}$ – 13.82%.

In the soil and climatic conditions of the Sumy region (north-eastern Forest-Steppe of Ukraine), in order to obtain a yield of soft spring wheat at the level of 5.63 t $ha^{-1}$, it is proposed to sow with a seeding rate of 6.0 million pcs $ha^{-1}$, and to obtain the largest amount of gluten in the grain 25.20% with a protein content of 13.82%, reduce the seeding rate to 5.5 million pcs $ha^{-1}$.

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