

Formation of Productivity in Durum Spring Wheat depending on the Variety

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Article Details: Received: 2024-12-24 | Accepted: 2025-03-13 | Available online: 2026-03-31

<https://doi.org/10.15414/afz.2026.29.01.47-55>

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An effective means of increasing the total harvest and improving the quality of durum spring wheat grain is the introduction of modern varieties. The aim of the study was to investigate the impact of varietal characteristics on the growth and development processes, yield formation, and grain quality of durum spring wheat. The study of varieties for productivity and quality indicators of durum spring wheat was conducted according to the following scheme: Nashchadok, Demira, Ksantiya, MIP Raiduzhna, MIP Magdalena, and Diana. The dynamics of aboveground biomass growth were determined at key stages of growth and development by sampling 25 plants in a typical plot with two incompatible replications. The yield structure was assessed by collecting sample sheaves from each accounting plot. Protein content was determined using a SapNIR 2750 infrared analyzer according to DSTU (State Standard of Ukraine) 4117:2007 "Grain and grain products." The highest percentage of preserved plants was observed in the Demira variety – 86.4% (376.4 plants/m²). On average, over the years of the study, the highest yield was obtained from the Demira variety, amounting to 4.42 t/ha, which exceeded the yield of MIP Magdalena by 0.28 t/ha, Diana by 0.7 t/ha, Ksantiya by 0.82 t/ha, MIP Raiduzhna by 0.89 t/ha, and Nashchadok by 1.0 t/ha. Consequently, the lowest yield was recorded for the Nashchadok variety – 3.42 t/ha. The protein content in durum spring wheat grain ranged from 12.0% to 13.1%. The highest protein content was noted in the Demira variety (13.1%), while the lowest was observed in Nashchadok (12.0%).

Keywords: variety, germination, productivity, yield, protein

1 Introduction

Ukraine is one of the main suppliers of grain to the global market, and grain production is one of the key sectors of the agro-industrial complex, significantly influencing the formation of food and feed reserves as well as the economy as a whole. Increasing grain production is a primary direction of modern agriculture and a guarantee of the state's food security. It is worth noting the growing global demand for products made from durum wheat grain, which is included in the group of healthy, balanced, and nutritious products. In terms of its significance as a food product, durum wheat ranks second after soft wheat in many countries worldwide, with global production reaching 30–35 million tons (Mefleh et al., 2019).

Cultivation of spring wheat is economically justified as it primarily eliminates the need for importing food grain. The quality of wheat grain, as well as other agro-industrial products, is determined by a combination of its beneficial properties that meet specific consumer needs and are achieved through systematic regulation of consumer attributes and characteristics of the product, with assessment at each stage of design, production, storage, transportation, and processing (Velimirović et al., 2023).

Durum wheat is a type of wheat used for commercial purposes and consumed as a food product in the human diet (Saini et al., 2022). It is also the sole source of raw material for the production of premium-quality pasta characterized by high strength, amber-yellow color, low

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digestibility, minimal substance loss during cooking, pleasant taste, and nutritional value (Hospodarenko et al., 2022). Durum wheat ranks second in the world after soft wheat in terms of cultivation areas, accounting for about 10% of the global wheat sowing area. The largest areas of durum wheat cultivation are concentrated in Portugal, Spain, and Italy, where it is grown for the production of high-quality pasta (Semiani et al., 2016), as a high flour yield is possible only due to its dense, hard, vitreous, and large endosperm. For comparison, while 4 million tons of durum wheat are grown in Italy, Ukraine produces only 30,000 tons (Zhemela et al., 2020), as the domestic production of pasta usually relies on soft wheat varieties, which reduces their cost (Chaika & Barabolia, 2022).

An effective means of increasing the gross harvest of wheat grain and improving its quality is the introduction of new varieties and intensive resource-saving cultivation technologies. At the same time, the production of spring wheat grain remains low and unstable due to insufficient consideration of the biological characteristics of varieties and the agro-climatic potential of the cultivation region (Barabolia & Latysh, 2024).

Analysis of crop yield levels over the past 20 years indicates that the biological potential of varieties is realized at a level of 40–75% (Macholdt & Honermeier, 2017). Modern varieties, characterized by high productivity, adaptation to specific growing conditions, resistance to unfavorable abiotic environmental factors, and high grain quality, play a crucial role in increasing the yield of cereal crops. The maximum realization of the productivity potential of domestic spring wheat varieties should be based on morphophysiological analysis and the creation of highly productive agrocenoses, taking into account soil and climatic conditions.

One of the main factors stabilizing grain production is modern domestic varieties with high yield potential. Realizing the genetic potential for productivity and grain quality in modern spring wheat varieties is a significant reserve for increasing grain production. Among varieties of various ecological and geographical origins, only those genotypes that are well adapted to the conditions of a specific soil-climatic zone in terms of productivity formation and adaptability will ensure maximum yield. The productivity of spring wheat depends on the complex influence of abiotic and anthropogenic factors. Unlocking the genetic potential of modern durum spring wheat varieties adapted to specific soil-climatic zones provides promising opportunities for grain production of this crop (Kharchenko et al., 2019).

In this context, it is advisable to increase the share of durum wheat cultivation, which can be processed domestically, generating profits to support and expand

current agricultural operations. Currently, there is a growing demand among domestic agricultural producers for durum spring wheat seeds, as its profitability is significantly higher than that of soft wheat varieties (Yarchuk et al., 2019).

Additionally, to ensure the stability of high-quality durum spring wheat grain production in agricultural enterprises, it is recommended to cultivate at least 2–3 varieties with slightly different plant responses to growing conditions.

2 Material and Methods

The research on the varietal characteristics of spring durum wheat (*Triticum durum*) was conducted at the experimental field of Sumy National Agrarian University. The experimental field is located in the Sumy district of the Sumy region, Ukraine, geolocation data 50° 52.742 N latitude, 34° 46.159 E longitude, 137.7 m above sea level (50° 52' 46.6" N 34° 46' 07.8" E Map date ©2023 Google). The experiments were carried out during the years 2022–2024.

The study of the varieties for productivity and quality indicators of spring durum wheat was performed according to the following scheme: Nashchadok, Demira, Ksantiya, MIP Raiduzhna, MIP Magdalyna, Diana. The seeding rate for the tested varieties was 5.0 million seeds per hectare. The cultivation technology of spring durum wheat was generally accepted for the Forest-Steppe zone of Ukraine, except for the specific research objectives. The preceding crop in the study was soybean. Sowing was performed using a Klen-1.5 seeder at soil temperatures of 6–8 °C. The row sowing method was used with a row spacing of 15 cm and a seed depth of 3–4 cm. During sowing, mineral fertilizers were applied at a rate of $N_{30}P_{30}K_{30}$. Nitroammophoska, a complex mineral fertilizer containing nitrogen, phosphorus, and potassium (NPK), was used. The proportions of nitrogen, phosphorus, and potassium were equal at 16 ±1% each. The total active ingredient content was 48% of the total mass. The experimental plots were arranged systematically, one after another. Each plot had an area of 45 m², with a record-keeping area of 30 m².

Phenological observations of plant growth and development, as well as accounting for spring durum wheat, were conducted using state methodologies (Pidoprygora & Pisarenko, 2003; Rozhkov et al., 2016). The dynamics of aboveground biomass accumulation were determined at key growth and development stages by sampling 25 plants in a typical plot with two non-contiguous repetitions, and the yield structure was assessed by sampling test sheaves from each accounting plot.

Protein content was determined using a SupNIR 2750 infrared analyzer in accordance with DSTU 4117:2007 "Grain and its processed products" (DSTU 4117:2007, 2017).

Mathematical processing of the primary data and their reliability assessment were performed using Microsoft Excel (Yeshchenko et al., 2014). Descriptive statistics were made at Statistica 10.0 (StatSoft Inc., Tulsa, USA). The least significant difference (LSD) for durum spring wheat yield between varieties was calculated using a standard statistical approach based on the ANOVA model.

The soil of the experimental plots was typical deep medium-loamy black soil, characterized by the following indicators: humus content ranging from 4.1 to 4.3% (by I.V. Tyurin), salt pH in the range of 6.2–6.5. The average content of nutrients was as follows: nitrogen (by Kornfield) – 128.5 mg/kg of soil; phosphorus and potassium (by Chirikov) – 211.6 and 81.1 mg/kg of soil, respectively.

The total precipitation during the growing season of spring durum wheat in 2022 was 370 mm, which is 133 mm higher than the long-term average (237 mm). The monthly distribution of precipitation was as follows: April – 107 mm, May – 26 mm, June – 155 mm, July – 82 mm.

The total precipitation during the growing season of 2023 was 222 mm, which is 15 mm lower than the long-term average (237 mm). The monthly distribution of precipitation was: April – 54 mm, May – 17 mm, June – 71 mm, July – 80 mm.

The total precipitation during the growing season of 2024 was 150 mm, which is 87 mm lower than the long-term average (237 mm). The monthly distribution of precipitation was: April – 48 mm, May – 34 mm, June – 51 mm, July – 17 mm.

The average daily temperature during the growing season of spring durum wheat in 2022 was 16.0 °C, which is 0.2 °C higher than the long-term average (15.8 °C). The monthly distribution of average daily temperatures was: April – 8.3 °C, May – 13.3 °C, June – 21.0 °C, July – 21.3 °C.

In 2023, the average daily temperature was 16.6 °C, which is 0.8 °C higher than the long-term average (15.8 °C). The monthly distribution was: April – 9.8 °C, May – 15.5 °C, June – 19.3 °C, July – 21.6 °C.

In 2024, the average daily temperature was 19.2 °C, which is 3.4 °C higher than the long-term average (15.8 °C). The monthly distribution was: April – 12.9 °C, May – 16.0 °C, June – 22.4 °C, July – 25.4 °C.

Overall, the most favorable years for crop yield formation were 2022 and 2023. Dry conditions prevailed in 2024,

characterized by low precipitation and extreme deviations in air temperature during the vegetation period.

3 Results and Discussion

The number of plants per unit area contributing to yield formation largely depends on field germination. Field germination of seeds is the number of seedlings that emerge under field conditions, expressed as a percentage of the amount of viable seeds sown. It is known that field germination is always lower than laboratory germination; thus, plant density depends not only on the seeding rate but also on field germination. During the growing season, the number of emerged plants decreases under the influence of various factors (Trotsenko et al., 2023; Peter Kovár et al., 2024). After seed quality indicators, such as laboratory germination, field germination is essentially the first real factor influencing crop productivity. Under field conditions, a complex of factors simultaneously acts, which may either increase or decrease field germination (Radchenko et al., 2024).

It is worth noting that field germination rates within 84–86% for early spring cereal crops are generally sufficient, as wheat compensates for a low plant density per unit area through tillering (Soares et al., 2020).

Based on our research, it was established that field germination of durum spring wheat varied depending on varietal characteristics, ranging from 83.5% to 87.1% ($LSD_{05} = 1.14$) (Yeshchenko et al., 2014). The highest field germination rate was recorded for the Demira variety at 87.1%, while the lowest was for the Nashchadok variety at 83.5%. For the Ksantiya variety, field germination was 84.6%; for the MIP Raiduzhna variety – 84.1%; for the MIP Magdalena variety – 86.4%; and for the Diana variety – 85.2% (Table 1).

Plant density is one of the key indicators significantly determining the yield of agricultural crops, including wheat. In turn, it depends on seed field germination and plant survival rates (Gasanova et al., 2012).

Thus, in our studies, the plant density varied across the experimental variants and ranged from 417.5 plants/m² to 435.5 plants/m² ($LSD_{05} = 2.96$) (Yeshchenko et al., 2014). The highest plant density was noted in the variant with the Demira variety and amounted to 435.5 plants/m². Slightly lower plant density was observed in the variants with the MIP Magdalena variety – 432.0 plants/m², the Diana variety – 426.0 plants/m², the Ksantiya variety – 423.0 plants/m², the MIP Raiduzhna variety – 420.5 plants/m², and the lowest plant density was noted in the sowing of the Nashchadok variety – 417.5 plants/m² (Table 1).

Another equally important indicator is plant survival during the vegetation period. It shows the ratio of plants preserved until harvest to the number of viable seeds sown. The formation of spring wheat yield is influenced by moisture, tillering intensity, lighting, damage by harmful organisms, etc. Researchers indicate that by the harvest period, only 50–60% of plants from sown seeds in spring cereals are preserved (Lozinska, 2015).

The plant survival rate during the vegetation period ranged from 80.5% to 86.4% ($LSD_{05} = 1.52$) (Yeshchenko et al., 2014). The highest percentage of preserved plants was noted in the sowing of the Demira variety – 86.4% (376.4 plants/m²), while the lowest survival rate was noted in the Nashchadok variety – 80.5% (336.0 plants/m²). In the sowing of Ksantiya, the plant survival rate during the vegetation period was 81.6% (345.2 plants/m²), in MIP Raiduzhna – 81.0% (340.6 plants/m²), in MIP Magdalena – 84.7% (366.0 plants/m²), and in Diana – 81.9% (348.9 plants/m²) (Table 1).

Spring wheat possesses the beneficial property of tillering. Tillering depends on varietal characteristics, climatic factors, soil nutrients, etc. Research indicates that yield levels depend on the number of productive stems per unit area. Studies show that the tillering coefficient of wheat varies from 1.5 to 10 or more shoots. However, there is currently no consensus on the extent to which its

variation affects the mass of the agocenosis, its structure, and productivity (Rroco & Menge, 2000).

The productive tillering coefficient in our experiments ranged from 1.07 to 1.15 ($LSD_{05} = 0.02$) (Yeshchenko et al., 2014). The maximum productive tillering coefficient was obtained with the sowing of the Demira variety – 1.15, while the lowest value was obtained with the Nashchadok variety – 1.07 (Table 2).

Scientific studies indicate (Lozinska, 2015) that an increase in the number of productive stems in cereal crops contributes to increased yield; however, the optimal number varies depending on the variety. Optimal planting density is understood as such a number of productive stems where stem closure in the stand is achieved (without mutual shading), high photosynthesis productivity is ensured, the feeding area is effectively used, and high yield is obtained. Scientists have determined the optimal density of productive spring wheat stems to be 550–600 plants/m².

According to research results, the highest number of productive stems was obtained with the Demira variety – 432.9 plants/m². The lowest number of productive stems was obtained with the Nashchadok variety – 359.5 plants/m². In the investigated varieties Ksantiya, MIP Raiduzhna, MIP Magdalena, and Diana, the number of productive stems amounted to 383.2,

Table 1 Plant density of hard spring wheat depending on varietal characteristics (average for 2022–2024)

Variety	Field germination (%)	Plant density (plants/m ²)	Plant survival during the vegetation period	
			plants/m ²	%
Nashchadok	83.5	417.5	336.0	80.5
Demira	87.1	435.5	376.4	86.4
Ksantiya	84.6	423.0	345.2	81.6
MIP Raiduzhna	84.1	420.5	340.6	81.0
MIP Magdalena	86.4	432.0	366.0	84.7
Diana	85.2	426.0	348.9	81.9
LSD_{05}	1.14	2.96	2.74	1.52

Table 2 Coefficient of productive tillering and the number of productive stems depending on varietal characteristics of durum spring wheat (average for 2022–2024)

Variety	Coefficient of productive tillering	Number of productive stems (pcs/m ²)
Nashchadok	1.07	359.5
Demira	1.15	432.9
Ksantiya	1.11	383.2
MIP Raiduzhna	1.09	371.3
MIP Magdalena	1.13	413.6
Diana	1.11	387.3
LSD_{05}	0.02	3.87

371.3, 413.6, and 387.3 plants/m², respectively (LSD₀₅ = 3.87) (Yeshchenko et al., 2014). (Table 2).

It is known that the yield of agricultural crops depends on the efficiency of photosynthesis in crops. Chlorophyll plays an important role in photosynthesis, serving as the main biochemical source of plant nutrition, with its products being used for yield formation. Insufficiently rapid leaf growth reduces chlorophyll accumulation, thereby decreasing grain yield. The leaf area and its chlorophyll content are influenced by cultivation technology, making it necessary to create crops with optimal leaf area. Both insufficient and overly developed leaf areas reduce solar energy utilization efficiency (Koliuchyi et al., 2007).

The conducted studies showed that the accumulation of leaf surface area during the initial vegetation period

occurred slowly. During the tillering phase, the leaf surface area ranged from 3.8 to 5.8 thousand m²/ha (LSD₀₅ = 0.17) (Yeshchenko et al., 2014). The highest leaf surface area was recorded for the Demira variety at 5.8 thousand m²/ha. Slightly lower values were obtained for the MIP Magdalena variety at 5.4 thousand m²/ha, Diana at 5.1 thousand m²/ha, Ksantiya at 4.8 thousand m²/ha, MIP Raiduzhna at 4.3 thousand m²/ha, and the lowest for Nashchadok at 3.8 thousand m²/ha.

During the stem elongation phase, the intensity of leaf surface area growth increased, ranging from 27.3 to 37.6 thousand m²/ha (LSD₀₅ = 2.86) (Yeshchenko et al., 2014). The highest leaf surface area was again recorded for the Demira variety at 37.6 thousand m²/ha, while the lowest was for Nashchadok at 27.3 thousand m²/ha (Figure. 1).

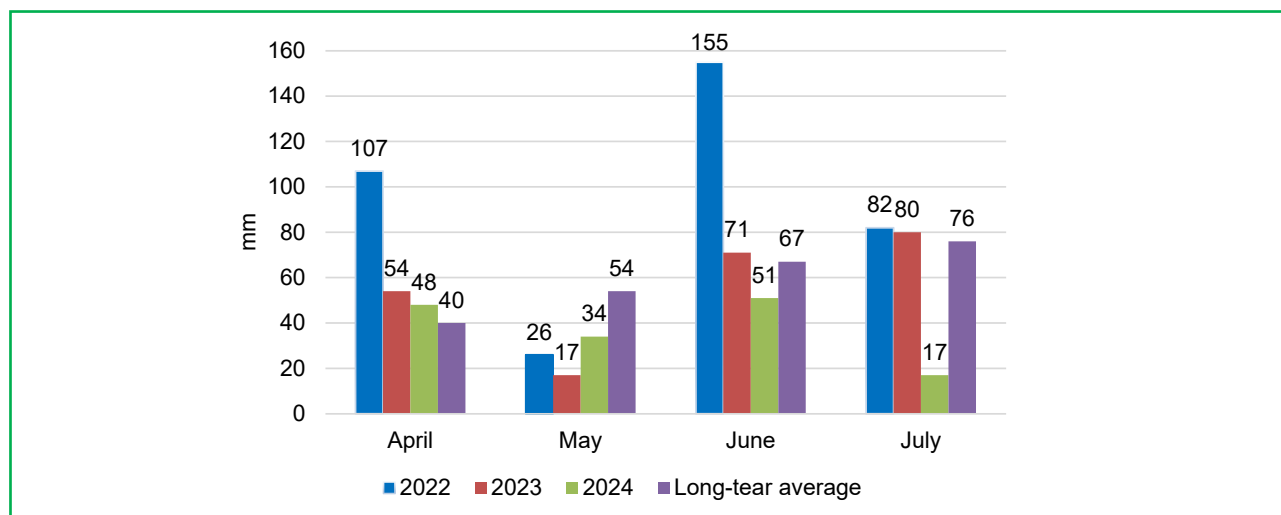


Figure 1 Amount of Atmospheric Precipitation During the Growing Season of 2022–2024

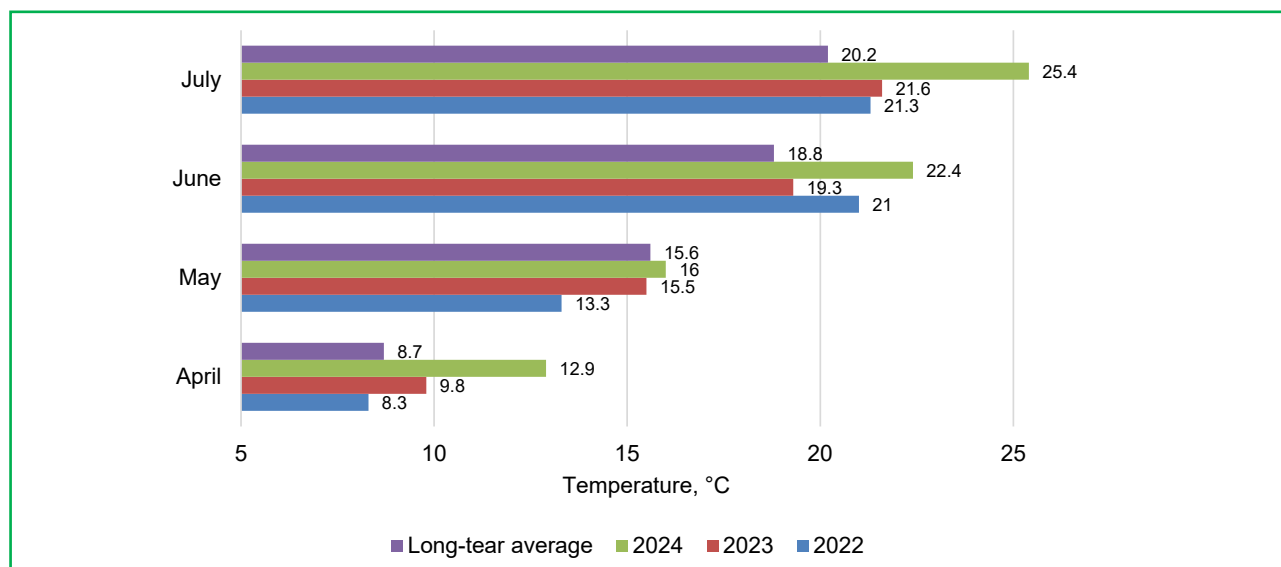


Figure 2 Dynamics of the Average Daily Air Temperature During the Growing Season of 2022–2024

The maximum leaf surface area was achieved during the heading phase. The highest value was obtained for the Demira variety at 42.8 thousand m²/ha. Slightly lower values were observed for the MIP Magdalena variety at 39.7 thousand m²/ha, Diana at 38.2 thousand m²/ha, Ksantiya at 36.4 thousand m²/ha, MIP Raiduzhna at 34.5 thousand m²/ha, and the lowest for Nashchadok at 32.6 thousand m²/ha (LSD₀₅ = 2.93) (Yeshchenko et al., 2014) (Figure. 1).

The study of yield structure enables a more comprehensive identification of the potential of individual agricultural crop varieties and allows for more precise monitoring of yield formation mechanisms under different growing conditions (Hryhoriv et al., 2022).

An important criterion for evaluating cereal crops is their grain productivity, which includes the following elements: ear weight, ear length, the number of grains per ear, ear grain weight, and the weight of 1,000 grains. The analysis of yield structure with a focus on physiological parameters of plants is particularly effective, as 90–95% of yield structure element realization depends on the photosynthetic activity of plants in the agroecosystem. The formation of yield structure elements in wheat begins at the early stages of organogenesis, when vegetative and generative spheres are established, tillering stems are determined, and the root system's development, plant architecture, and habitus are defined (Harasim et al., 2016).

As a result of the conducted research, it was established that the highest plant weight of durum spring wheat was formed by the Demira variety – 2.95 g, while the lowest was observed in the Nashchadok variety – 2.24 g (LSD₀₅ = 0.18). The spike weight varied across

the experimental options from 1.45 to 1.84 g (LSD₀₅ = 0.096). (Yeshchenko et al., 2014). The maximum spike weight was recorded in the Demira variety – 1.84 g, followed by the MIP Magdalena variety – 1.76 g, Diana – 1.68 g, Ksantiya – 1.63 g, MIP Raiduzhna – 1.51 g, and Nashchadok – 1.45 g (Table 3).

The length of the spike in durum wheat is largely determined by its genotype but is also influenced by growing conditions. The spike length is most significantly affected by varietal traits. Some varieties have compact spikes with spikelets located close together, while others have loose spikes with larger gaps between spikelets. Varieties with loose spikes generally have longer spikes, but this does not necessarily mean that shorter compact spikes have lower productivity. Wheat spikes can vary in length: short (up to 8 cm), medium (8–10 cm), and long (over 10 cm) (Shelepov et al., 2007).

According to the results of the study, significant differences in spike length were observed among the varieties. The longest spike was recorded in the Demira variety at 7.1 cm, which was 0.3 cm longer than the MIP Magdalena variety (6.8 cm), 0.5 cm longer than the Diana variety (6.6 cm), 0.7 cm longer than the Ksantiya variety (6.4 cm), 1.1 cm longer than the MIP Raiduzhna variety (6.0 cm), and 1.3 cm longer than the Nashchadok variety (5.8 cm) (LSD₀₅ = 0.19) (Yeshchenko et al., 2014) (Table 3).

When assessing productivity, it is recommended to consider such critical elements as the grain weight per spike and the number of grains per spike. The number of grains per spike is genetically determined but can vary depending on a higher number of fertile florets and relatively fewer spikelets or vice versa – fewer fertile florets with more spikelets. The most critical characteristic

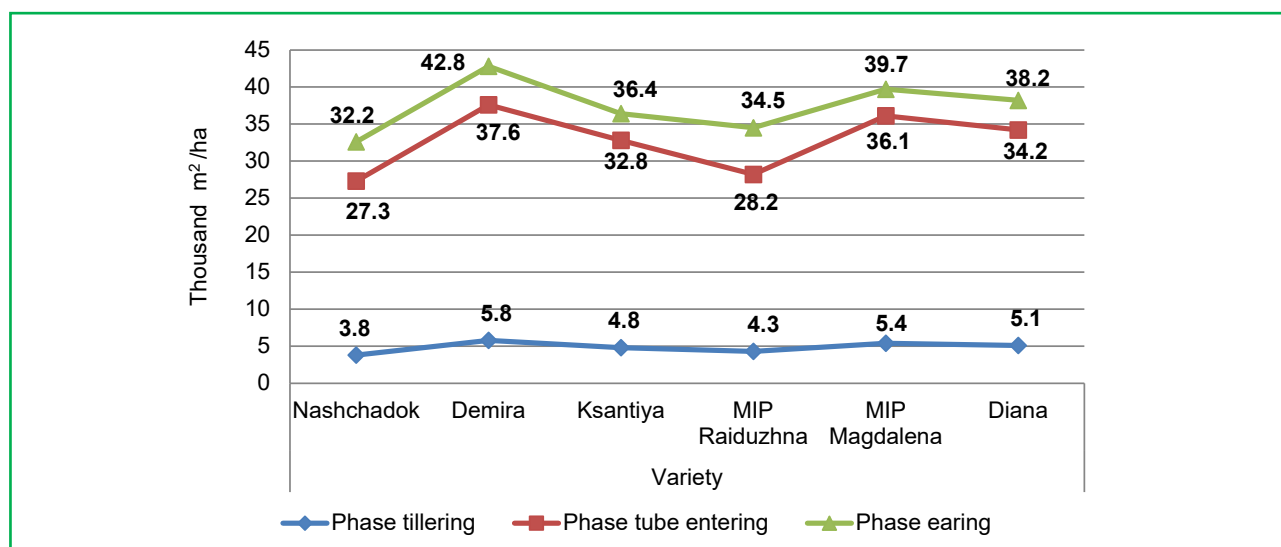


Figure 3 Leaf surface area of durum spring wheat by development phases depending on varietal characteristics (average for 2022–2024)

Table 3 Weight of plants and spikes, spike length of durum spring wheat depending on varietal characteristics (average for 2022–2024)

Variety	Plant weight (g)	Spike weight (g)	Spike length (cm)
Nashchadok	2.24	1.45	5.8
Demira	2.95	1.84	7.1
Ksantiya	2.57	1.63	6.4
MIP Raiduzhna	2.36	1.51	6.0
MIP Magdalyna	2.81	1.76	6.8
Diana	2.63	1.68	6.6
LSD ₀₅	0.18	0.096	0.19

in the productivity structure of the plant is the grain weight per spike, which must be considered when developing a variety model (Radchenko et al., 2023).

Analysis of the data showed that the grain weight per spike in durum spring wheat ranged from 0.94 g to 1.02 g (LSD₀₅ = 0.023) (Yeshchenko et al., 2014). The maximum grain weight per spike was recorded in the Diana variety – 1.02 g. Other varieties showed slightly lower grain weights per spike: MIP Magdalyna – 1.01 g, Ksantiya – 0.96 g, Diana – 0.96 g, MIP Raiduzhna – 0.95 g, and the lowest in the Nashchadok variety – 0.94 g (Table 4).

The increase in yield of varieties is due to the increase in grain weight per spike, which depends on the number of grains and their fullness (Radchenko et al., 2023). Depending on the variety, the number of grains per spike ranged from 23.4 in the variety Nashchadok to 25.0 in the variety Demira (LSD₀₅ = 0.55) (Yeshchenko et al., 2014). For other studied varieties, namely MIP Magdalena, Diana, Ksantiya, and MIP Raiduizhna, the number of grains per spike was recorded at 24.6, 23.7, 23.6, and 23.5, respectively. Thus, the highest number of grains per spike was obtained for the variety Demira – 25.0 (Table 4).

The development of seedlings and the growth intensity of young plants depend on the nutrient mass in the endosperm of wheat grain. Moreover, flour quality is directly dependent on grain size. The degree of grain

fullness and size is indicated by the weight of 1,000 grains. The weight of 1,000 grains is an important element of the crop structure that characterizes grain size and fullness. The weight of 1,000 grains is a variable trait.

Over the years of research, it was found that the weight of 1000 grains, depending on the variety, ranged from 40.2 to 40.8 g (LSD₀₅ = 0.35) (Yeshchenko et al., 2014). The highest weight of 1000 grains was recorded for the variety Demira – 40.8 g, which is higher compared to the variety MIP Magdalena by 0.1 g (40.7 g), the variety Ksantiya by 0.2 g (40.6 g), the variety Diana by 0.3 g (40.5 g), the variety MIP Raiduizhna by 0.4 g (40.4 g), and the variety Nashchadok by 0.6 g (40.2 g) (Table 4).

Spring wheat is usually less productive (by 10–15%) than winter wheat, which can be compensated by growing modern varieties (Zecevic et al., 2014). following regional agronomic practices, including sowing, fertilization, plant protection, and harvesting (Barabolia & Doronin, 2023).

On average, over the years of research, the highest yield was obtained for the variety Demira, amounting to 4.42 t/ha, which is higher compared to the variety MIP Magdalena by 0.28 t/ha (4.14 t/ha), the variety Diana by 0.7 t/ha (3.72 t/ha), the variety Ksantiya by 0.82 t/ha (3.68 t/ha), the variety MIP Raiduizhna by 0.89 t/ha (3.53 t/ha), and the variety Nashchadok by 1.0 t/ha (3.42 t/ha) (LSD₀₅ = 0.065). The strength of the factor's influence was

Table 4 Structural indicators of spring durum wheat plants depending on varietal characteristics (average for 2022–2024)

Variety	Grain weight per spike (g)	Number of grains per spike	Weight of 1000 grains (g)
Nashchadok	0.94	23.4	40.2
Demira	1.02	25.0	40.8
Ksantiya	0.96	23.6	40.6
MIP Raiduizhna	0.95	23.5	40.4
MIP Magdalena	1.01	24.6	40.7
Diana	0.96	23.7	40.5
LSD ₀₅	0.023	0.55	0.35

Table 5 Yield and quality of spring durum wheat grain depending on varietal characteristics (average for 2022–2024)

Variety	Yield (t/ha)	Protein (%)
Nashchadok	3.42	12.0
Demira	4.42	13.1
Ksantiya	3.68	12.4
MIP Raiduizhna	3.53	12.2
MIP Magdalena	4.14	12.9
Diana	3.72	12.7
LSD ₀₅	0.065	0.40

$\eta = 87.5\%$. (Yeshchenko et al., 2014). Thus, the lowest yield was recorded for the variety Nashchadok – 3.42 t/ha (Table 5).

Agroecological conditions of cultivation influence both the yield and the biochemical composition of the spring wheat crop. The protein content, as part of the grain's biochemical composition, varies greatly depending on growing conditions, ranging from 8.0% to 20.0% or more (Gülhan Baytekin Karaoğlu et al., 2024).

The protein content in the grain of durum spring wheat varied from 12.0% to 13.1% (LSD₀₅ = 0.40). The strength of the factor's influence was $\eta = 81.0\%$. (Yeshchenko et al., 2014). The highest protein content was observed in the Demira variety at 13.1%, while the lowest was observed in the Nashchadok variety at 12.0%. The protein content in the MIP Magdalena variety was 12.9%, in the Diana variety – 12.7%, in the Ksantiya variety – 12.4%, and in the MIP Raiduizhna variety – 12.2% (DSTU 4117:2007, 2017) (Table 5).

4 Conclusions

The highest plant density was recorded in the Demira variety, amounting to 435.5 plants/m². Plant retention during the growing season ranged from 80.5% to 86.4%. The highest percentage of retained plants was noted in the Demira variety – 86.4% (376.4 plants/m²), while the lowest was in the Nashchadok variety – 80.5% (336.0 plants/m²). The maximum grain weight per spike was recorded in the Diana variety – 1.02 g. The other studied varieties showed slightly lower grain weight per spike, specifically, 1.01 g in the MIP Magdalena variety, 0.96 g in the Ksantiya variety, 0.96 g in the Diana variety, 0.95 g in the MIP Raiduizhna variety, and the lowest weight was observed in the Nashchadok variety – 0.94 g.

On average, over the years of the study, the highest yield was obtained in the Demira variety, amounting to 4.42 t/ha, which was higher compared to the MIP Magdalena variety by 0.28 t/ha (4.14 t/ha), the Diana variety by 0.7 t/ha (3.72 t/ha), the Ksantiya variety by 0.82 t/ha (3.68 t/ha), the MIP Raiduizhna variety by 0.89 t/ha (3.53 t/ha), and

the Nashchadok variety by 1.0 t/ha (3.42 t/ha). Thus, the lowest yield was noted in the Nashchadok variety – 3.42 t/ha. The protein content in the grain of durum spring wheat varied from 12.0% to 13.1%. The highest protein content was observed in the Demira variety at 13.1%, while the lowest was observed in the Nashchadok variety at 12.0%. The protein content in the MIP Magdalena variety was 12.9%, in the Diana variety – 12.7%, in the Ksantiya variety – 12.4%, and in the MIP Raiduizhna variety – 12.2%.

Conflict of Interest

The authors declare that they have no competing interests.

Author Contributions

Mykola Radchenko conceived and designed the study. Andrii Butenko, Maryna Mikulina and Natalia Kandyba performed the data collection and statistical analyses. Oleg Kolisnyk, Liudmyla Yakovets and Vasyl Filon conducted the literature review and contributed to manuscript drafting. Mykola Radchenko, Valentina Rozhko and Olena Karpenko contributed to the interpretation of the results. Mykola Radchenko took the lead in writing the manuscript. All authors provided critical feedback and contributed to refining the research, analysis, and manuscript.

AI and AI-Assisted Technologies Use Declaration

No generative AI tools/AI-assisted technologies were used during the preparation of the manuscript.

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