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The Role of Winter Wheat Plant Height in the Formation of Grain Yield Depending on Varietal Characteristics and Weather Conditions

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Abstract. Winter wheat is one of the main food crops that ensures the national food security of Ukraine with general production and high-quality grain. The area of winter wheat sowing ranks first in Ukraine, and the production of high-quality grain is of particular relevance. In the technology of its cultivation, the selection of varieties is a decisive factor in increasing yield and improving the quality of grain. The purpose of this study was to determine the influence of weather conditions and variety characteristics during the year on plant height, lodging resistance, and yield of winter wheat. This paper presents data on the results of the research of 20 varieties of soft winter wheat in the conditions of the Research-to-Practice Centre of the Mykolaiv National Agrarian University from 2017 to 2022. During the study, generally accepted methods were used: system approach, system analysis, analysis and synthesis, field and statistical method. The study also analysed the influence of variety characteristics and weather conditions in the years under study on the yield of soft winter wheat. It was established that the optimal plant height of winter wheat varieties ranged within 94.9-100.7 cm, at which the highest grain yield is formed, from 7.09 t/ha in the Staleva variety to 7.73 t/ha in the Duma Odeska variety. An increase in the height of the winter wheat varieties under study by 4.0-6.4% led to a decrease in yield from 4.5 to 20.9%. It was established that the awned varieties of soft winter wheat formed a higher grain yield, compared to the thornless forms, which had a higher plant height and less lodging resistance. The conducted studies confirmed that, on average, the resistance to lodging was higher in the thornless forms of winter wheat plants, which is 0.4 points higher than in the awned ones. The higher average grain yield of soft winter wheat was formed by varieties of spiny forms, which is 5.8% more than that of awned varieties. The obtained results will contribute to the wide application of the varieties of soft winter wheat under study for this soil and climate zone, which will further contribute to the increase in yield and gross grain harvests

Keywords: soft winter wheat, lodging resistance, awned and awnless forms, air temperature, precipitation amount

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INTRODUCTION

Food production is one of the strategic industries of any country in the world. In modern economic conditions, the importance of the agricultural sector in the economy is growing, since the sale of agricultural products benefits the competitiveness of Ukraine, i.e., its gross domestic product. An essential part of agricultural production is the production of food crops. For a long time, Ukraine has been among the world's top ten in terms of grain production per capita.

The yield of winter wheat varieties is affected by weather conditions during the growing years of the crop and agricultural techniques. Thus, Žofajová *et al.* (2017) and Berdnikova & Kucherak (2021) found that genotype, year, and location substantially affect yield and yield components. Nazarenko *et al.* (2020) and Demydov *et al.* (2021) compared winter wheat varieties of Ukrainian and French selection, according to the results of which 6 highly productive varieties were bred (Dyvo, Metelytsia (first group), Vekha (second), Fihura, Manella, Matrix (third)). Some varieties were bred in a separate year without a predominance of the standard on average: varieties Laval, Dijon, Polisianka, Zorepad Bilotserkivskyi, Bodychek in the conditions of the 2016-2017 growing year; Nasnahy in the conditions of 2018-2019. The Pamiati Hirka variety showed a higher yield under conditions of two years of vegetation, without an advantage per the standard regarding three-year results.

Research by Bazalii *et al.* (2019) and Gamayunova *et al.* (2022) proved that in the conditions of southern Ukraine, it is necessary to grow plastic varieties of wheat with increased yield stability (Khersonska awnless, Khersonska 99, Znakhidka Odeska, Askaniiska, Klarysa), if strict stress limits are expected in the environmental conditions. Based on the results of research by L. Wu & H. Zhatova (2022), wheat varieties with high-performance parameters were selected. These are such varieties as Okhtyrchanka Yuvileina, Svitanok Myronivskyi, Melodiia Odeska, Kubok, Zorepad, Ovidii, Shchedra Nyva, Oktava Odeska, and Slaven. In the studies of Markovska *et al.* (2018), Gavrilyuk (2016) the Konka winter wheat variety produced a seed yield of 3.59 t/ha, which is 8.2% more than Khersonska 99.

Djaman *et al.* (2018) and Harkness *et al.* (2020) established that grain yield depended on the variety of winter wheat, decreased over the years and ranged within 1.84-7.09 t/ha. TAM107 received the largest grain yield. M.M. Korkhova (2019) conducted a comparative analysis of varieties of soft winter wheat and spelt, which indicated that, on average, in 2016-2018, a higher height of plants (130.7 cm) was formed in the awnless variety Zoria Ukrainy compared to the awned ones under study, which is 6.7% more than the Yevropa variety, 25.9% more than the Vidrada variety, 32.9% more than the Shestopalivka variety, and 33.7% more than the Zysk variety However, the higher yield (5.53-6.27) was formed by the awned varieties of wheat – Zysk, Shestopalivka, Vidrada, and Yevropa, which is 29.8-38.1% more than the awnless variety Zoria Ukrainy.

Bondarenko & Nazarenko (2022), Panfilova (2021) claim that high-yielding genotypes form yield due to added spikes, have higher lodging resistance due to lower plant height and grain mass in the spike, respectively, and spend fewer nutrients on stem formation. Zhupina *et al.* (2022) found that the growth of plant height of hybrid populations of winter wheat leads to a decrease in grain yield. Thus, there is no consensus among scientists regarding the effect of plant height on lodging resistance and the formation of grain yield of soft winter wheat varieties of distinct morphological characteristics, since the research was conducted in years with different weather conditions. Furthermore, with the advent of new varieties in production, this issue requires more research.

The purpose of this paper was to establish varietal characteristics and the influence of weather conditions during the year on resistance to lodging and yield of winter wheat, as well as on plant height.

MATERIALS AND METHODS

Experimental research was conducted for five years (2017-2022) in the conditions of the Educational Research-to-Practice Centre of the Mykolaiv National Agrarian University (ERPC MNAU), which belongs to the Southern Steppe zone of Ukraine. The experiment included 20 variants (winter wheat varieties), which were placed in the experimental field of the ERPC MNAU according to the method of complete randomization in threefold repetition. The area of the sowing plot was 70 m^2, and the accounting plot was 35 m^2. The agricultural technique of conducting the experiments was generally accepted for the existing zonal recommendations for the conditions of the Southern Steppe zone of Ukraine. Winter wheat was sown in the first decade of October, with a seeding rate of 4.5 million pcs./ha.

The soil of the experimental field is a typical southern chernozem, residual slightly saline heavy loam in the loess, humus content (0-30 cm) – 3.1-3.3%, soil solution is neutral (pH 6.8-7.2). On average, the arable layer contains 15-25 mobile forms of nitrates, 41-46 mobile phosphorus and 389-425 mg/kg exchangeable potassium.

The material for research was 20 varieties of soft winter wheat, the owners of which are leading scientific institutions of Ukraine and the near abroad: Ozerna, Staleva (Private Agricultural Breeding and Research Enterprise "Bor"); Kvitka Poliv, Lehenda Bilotserkivska (Bila Tserkva Research and Breeding Station of the Institute of Bioenergy Crops and Sugar Beet of the National Academy of Agrarian Sciences of Ukraine); Mudrist Odeska, Duma Odeska (Breeding and Genetics Institute – National Centre for Seed Science and Varietal Research); Koshova, Maria (Institute of Irrigated

Agriculture, NAASU); Zdobna, Dyvo (V. Ya. Yuriev Institute of Plant Breeding of the NAASU); MIP Assol, MIP Valencia (V. M. Remeslo Myroniv Institute of Wheat of the NAASU); Pamiati Hirka, Kraievyd (Institute of Agriculture, NAASU); Katarina, Centurion (Viterra SEED – Germany); Felix, PONTUKUS, Faustus, Glaucus ("Shtrube Ukraine GmbH" LLC), which are registered in the State Register of Plant Varieties Suitable for Distribution in Ukraine in 2013-2019 (State Register of Plant Varieties..., 2022). Varieties of soft winter wheat were characterized by morphological features, namely by height, presence of awns or teeth, and maturity group (Table 1).

***Table 1**. Morpho-biological characteristics of soft winter wheat varieties*

No. seq.	Varieties	Plant: by height (stem and spike)	Spike: awns or teeth of the lower flower scales	Ripeness group
1	Ozerna	short-stemmed	awns present	mid-early
2	Staleva	short-stemmed	awns present	mid-early
3	Kvitka Poliv	medium-grown	teeth present	mid-early
4	Lehenda Bilotserkivska	medium-grown	teeth present	mid-season
5	Mudrist Odeska	short-stemmed	awns present	mid-early
6	Duma Odeska	short-stemmed	awns present	short-season
7	Koshova	short-stemmed	awns present	short-season
8	Maria	short-stemmed	awns present	short-season
9	Zdobna	short-stemmed	awns present	mid-early
10	Dyvo	short-stemmed	awns present	mid-early
11	MIP Assol	medium-grown	teeth present	mid-season
12	MIP Valencia	semi-dwarfs	awns present	mid-season
13	Pamiati Hirka	short-stemmed	awns present	mid-season
14	Kraievyd	short-stemmed	awns present	mid-season
15	Katarina	semi-dwarfs	teeth present	short-season
16	Centurion	semi-dwarfs	awns present	mid-early
17	Felix	semi-dwarfs	teeth present	short-season
18	PONTICUS	semi-dwarfs	teeth present	short-season
19	Faustus	semi-dwarfs	teeth present	short-season
20	Glaucus	semi-dwarfs	teeth present	mid-season

***Source:** compiled by the authors*

The analysis of agroclimatic conditions uses data from the Pessl Instruments weather station (iMETOS), manufactured in Austria, which not only provides highly accurate local meteorological data, but also provides 6-day weather forecasts. Weather stations are equipped with sensors that determine the following indicators: amount of precipitation, air and soil temperature, air, soil, and leaf humidity level, wind speed, etc. The height of winter wheat plants was determined before harvesting on 100 plants permanently set aside for this purpose, using a measuring ruler evenly placed on the accounting area of each plot. The stems were measured from the surface of the soil to the top of the plant. The last indicator is the average height of plants on the plot.

Lodging resistance of soft winter wheat plants was evaluated from the beginning of this phenomenon to harvesting every 5-10 days (these observations could reveal the properties of individual crops returning to their previous vertical position) on a ten-point scale. Yield was accounted continuously from the entire accounting area. Soft winter wheat was harvested by a SAMPO-500 combine harvester. After threshing, the thresher of the grain harvester was turned off at each plot, and the harvested grain was weighed and adjusted to the standard humidity (14%) and purity (100%). The research results, obtained in the form of analytical digital materials, are processed statistically and mathematically according using the methods of dispersion and variation analyses with Microsoft Excel and Agrostat computer software.

The years of research differed substantially in weather conditions. Thus, 2017/2018 and 2021/2022 agricultural years were moderately wet, during the growing season 338.5 and 331.6 mm of precipitation fell, respectively, while in 2019/2020 – 161.2 mm; 2018/2019 – 547.6 mm, and 2020/2021 – 603.7 mm. 2018/2019 and 2020/2021 were the most favourable in terms of weather conditions, and 2019/2020 was the least favourable. Such contrasting conditions allowed

the authors to investigate the influence of weather conditions on plant height, lodging resistance, and grain yield of soft winter wheat.

RESULTS AND DISCUSSION

Plant height is a genetically inherited trait that characterizes the ecological plasticity of genotypes in various soil and climatic conditions and depends on weather conditions. Plant resistance to lodging and grain yield depends on the height and anatomical properties of the wheat stem.

M.M. Gavrilyuk (2019) conventionally divides winter wheat varieties by height into five types: dwarfs – under 60 cm; semi-dwarfs – 60-85 cm, which include MIP Valencia, Katarina, Centurion, Felix, PONTICUS, Faustus, and Glaucus; short-stemmed – 85-105 cm (Ozerna, Staleva¸ Mudrist Odeska, Duma Odeska, Koshova, Maria, Zdobna, Dyvo, Pamiati Hirka, Kraievyd); medium-sized – 105-120 cm (Kvitka Poliv, Lehenda Bilotserkivska, MIP Assol), and tall – over 120 cm. Most of the varieties included in the State Register (2022) belong to the short-stemmed type, but the share of semi-dwarf varieties has decreased. Most of the varieties of soft winter wheat under study are classified as short-stemmed and semi-dwarf, and only three are classified as medium-sized.

The formation of plant height was substantially influenced by weather conditions during the years of research. It was found that the greater precipitation, the taller the winter wheat plants. Thus, in years with a large amount of precipitation of 574.6 mm (2018/2019) and 603.7 mm (2020/2021), the plant height of the varieties of soft winter wheat under study was formed at 70.6-118.2 and 73.5-125.5 cm, respectively (Fig. 1).

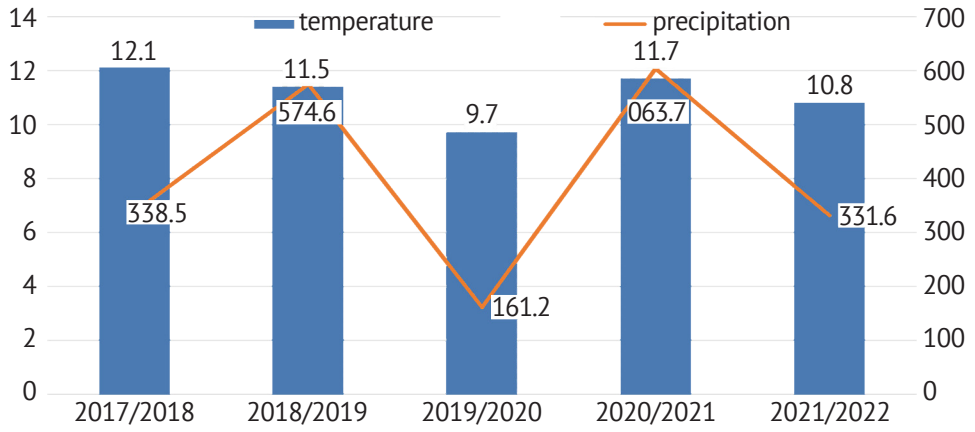

***Figure 1**. Average air temperature and precipitation (2017/2018–2021/2022)*
***Source:** compiled by the authors*

On average, by varieties, the lower height of winter wheat plants (82.9 and 82.5 cm) was formed in 2017/2018 and 2021/2022 with precipitation of 338.5 mm and 331.6 mm, respectively. It was found that winter wheat plants of the varieties under study were formed lower in height (55.4-94.3 cm) in 2019/2020, when only 161.2 mm of precipitation fell, and the average annual air temperature was 9.7°C. Over five years of research (2018-2022), the taller height of winter wheat plants was formed by the varieties Kvitka Poliv (107.4 cm) and Lehenda Bilotserkivska (106.5 cm), which is 6.2–40.2% taller the other varieties under study. The lowest plant height on average for 2018-2022 was formed by the varieties Katarina (64.2 cm) and Felix (69.2 cm) (Table 2).

***Table 2**. Height of soft winter wheat plants depending on varietal characteristics and weather conditions, cm*

No. seq.	Varieties	Years					Average for 2018-2022
		2018	2019	2020	2021	2022	
1	Ozerna	83.3	99.0	79.0	105.3	86.3	90.6
2	Staleva	81.8	94.9	73.7	101.0	80.6	86.4
3	Kvitka Poliv	100.4	118.2	91.0	125.5	101.7	107.4
4	Lehenda Bilotserkivska	101.7	115.2	94.3	122.5	98.7	106.5
5	Mudrist Odeska	91.2	108.2	88.8	114.0	91.2	98.7
6	Duma Odeska	85.9	100.7	75.3	106.0	86.6	90.9

Table 2, Continued

No. seq.	Varieties	Years					Average for 2018-2022
		2018	2019	2020	2021	2022	
7	Koshova	84.7	100.5	80.0	106.0	85.3	91.3
8	Maria	84.5	102.2	83.0	106.7	85.4	88.8
9	Zdobna	86.2	101.2	76.7	106.5	84.1	90.9
10	Dyvo	81.8	94.7	72.8	99.7	78.3	85.5
11	MIP Assol	96.4	113.3	77.9	120.5	95.2	100.7
12	MIP Valencia	77.8	94.6	73.9	98.5	77.8	84.5
13	Pamiati Hirka	89.9	105.9	83.1	113.8	88.8	96.3
14	Kraievyd	87.4	103.8	80.9	109.3	86.5	93.6
15	Katarina	61.0	70.6	55.4	73.5	60.3	64.2
16	Centurion	76.1	89.8	68.6	94.0	75.0	80.7
17	Felix	66.5	76.0	59.5	79.2	64.7	69.2
18	PONTICUS	77.2	90.7	68.5	96.5	77.4	82.1
19	Faustus	73.2	85.0	68.0	91.5	72.3	78.0
20	Glaucus	71.6	83.7	66.3	87.3	72.8	76.3
Average by variety		82.9	97.4	75.8	102.	82.5	84.6
$LSD_{0.05}$ (cm), partial differences		1.38	2.87	2.88	2.91	3.51	0.74

Source: *compiled by the authors*

Thus, the highest plant height on average for soft winter wheat varieties (102.7 cm) was formed in 2021, which is 19.3% more than in 2018, 5.2% more than in 2019, 26 .2% more than in 2020, and 19.7% more than in 2022. Based on the results of variance analysis, it was found that the smallest significant difference in factor A (Varieties) was 1.38 cm (2018), 2.87 cm (2019), 2.88 cm (2020), 2.91 cm (2021) and 3.51 cm (2022). Over the years of research, it was established that winter wheat varieties Ozerna, Staleva, Katarina, Centurion, Felix, Ponticus, Faustus, Glaucus had a very high resistance to lodging – 9 points, varieties Maria, Dyvo, Kvitka Poliv, MIP Assol, MIP Valencia, Pamiati Hirka, Kraievyd, Centurion – high resistance (8.0-8.6 points), Mudrist Odeska variety – medium resistance (7.8 points), and the varieties Lehenda Bilotserkivska, Duma Odeska, Koshova, Zdobna – below average (6.2-6.6 points) (Fig. 2).

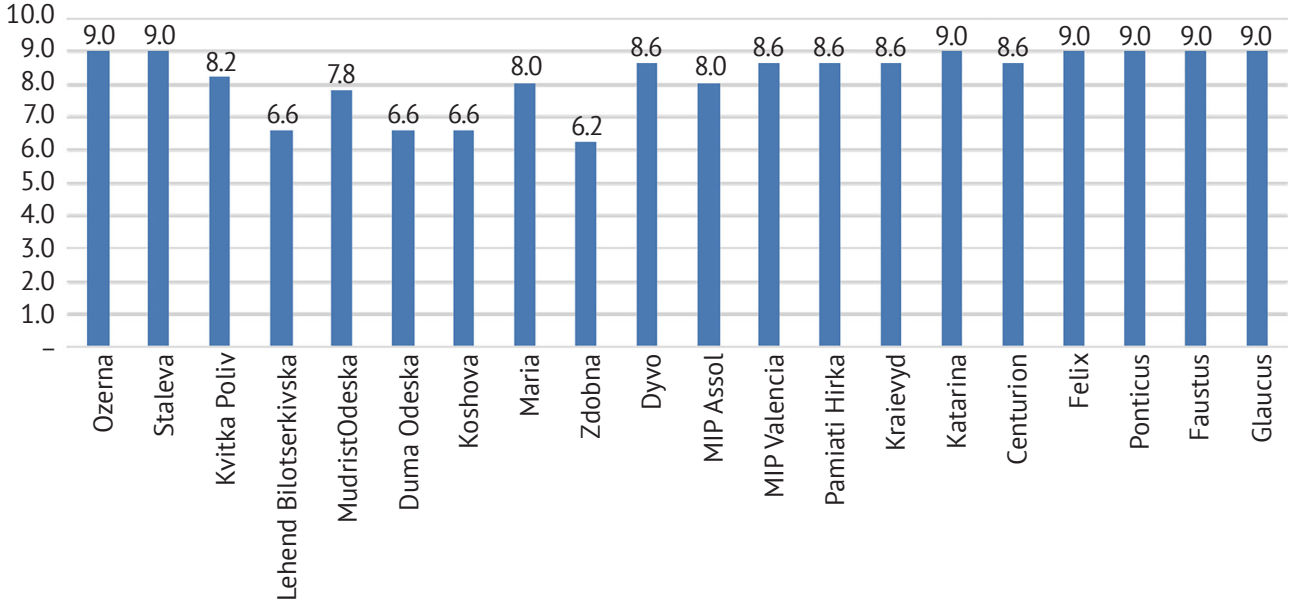

Figure 2*. Resistance to lodging of soft winter wheat plants depending on the variety (average for 2018-2022), points*
Source: *compiled by the authors*

Previous studies by M. Korkhova & V. Mykolaichuk (2022) established that the yield of winter wheat varieties is substantially influenced by weather conditions in the years of research, namely the amount of precipitation and air temperature. According to the research results, the highest grain yield (6.88 t/ha) on average for varieties was formed by winter wheat plants in 2019, which is 20.1% more than in 2018, 31.0% more than in 2020, 8.7% more than in 2021, and 21.8% more than in 2022 (Table 3).

***Table 3**. Yield of soft winter wheat grain depending on varietal characteristics and the year of research, t/ha*

No. seq.	Varieties	Years					Average for 2018-2022
		2018	2019	2020	2021	2022	
1	Ozerna	5.34	7.52	5.57	6.53	5.87	6.17
2	Staleva	5.07	7.09	5.34	6.43	5.07	5.80
3	Kvitka Poliv	5.22	7.60	5.09	6.01	5.77	5.94
4	Lehenda Bilotserkivska	4.72	6.15	4.56	6.23	5.73	5.48
5	Mudrist Odeska	6.07	7.61	4.97	6.21	5.12	6.00
6	Duma Odeska	5.42	7.73	5.18	6.41	6.47	6.24
7	Koshova	6.11	7.52	5.08	6.34	4.95	6.00
8	Maria	6.25	7.21	4.91	6.02	5.02	5.88
9	Zdobna	5.81	7.18	4.76	6.19	5.97	5.98
10	Dyvo	5.50	6.84	4.71	6.08	5.11	5.65
11	MIP Assol	5.41	6.50	4.08	6.21	4.53	5.35
12	MIP Valencia	5.56	6.57	4.50	6.02	4.55	5.44
13	Pamiati Hirka	5.61	6.69	5.20	6.87	5.44	5.96
14	Kraievyd	5.50	6.59	5.08	6.48	6.00	5.93
15	Katarina	5.14	6.34	3.12	6.37	5.73	5.34
16	Centurion	5.37	6.48	4.87	6.02	5.39	5.63
17	Felix	5.67	6.70	4.01	6.12	4.59	5.42
18	PONTICUS	5.77	6.75	4.13	6.42	4.63	5.54
19	Faustus	5.12	6.24	4.29	6.26	5.75	5.53
20	Glaucus	5.34	6.37	4.92	6.41	5.97	5.80
Average yield by variety		5.50	6.88	4.75	6.28	5.38	5.76
$LSD_{0,05}$ (t/ha), partial differences		0.22	0.25	0.20	0.24	0.26	0.07

***Source:** compiled by the authors*

Thus, in 2020, the lowest grain yield was obtained – 4.75 t/ha on average for varieties. On average, over five years of research, a higher yield (6.24 t/ha) was obtained in the Duma Odeska variety, which is 1.1-14.4% more than in other varieties under study. The lowest average grain yield was formed by the Katarina variety – 5.34 t/ha. In 2018, the best result in terms of yield was shown by the Maria variety (6.25 t/ha), in 2019 – by the Duma Odeska variety (7.73 t/ha), in 2020 – by the Ozerna variety (5.57 t/ha), in 2021 – Pamiati Hirka (6.87 t/ha), and in 2022 – the Duma Odeska variety (6.47 t/ha). The lowest grain yield in the same years was formed by the following varieties: Lehenda Bilotserkivska (4.72 t/ha and 6.15 t/ha) in 2018 and 2019, Katarina (3.12 t/ha) in 2020, Kvitka Poliv (6.01 t/ha) in 2021 and MIP Assol (4.53 t/ha) in 2022.

However, for each variety, there is an optimal plant height, at which it forms a higher grain yield. The present study confirms this. Thus, the highest grain yield (7.52 t/ha) was obtained in the Ozerna variety when the plant height was 99.0 cm, while the lowest yield was 5.34 t/ha (2018) with a plant height of 83.3 cm. For the Staleva variety, the optimal height of the plants, at which the crop is formed at the level of 7.09 t/ha, is 94.9 cm. A further increase in plant height to 101 cm (2021) led to a 9.3% decrease in yield. The varieties of winter wheat Kvitka Poliv, Lehenda Bilotserkivska and MIP Assol, which according to the height group are medium-sized, formed a higher grain yield (7.60, 6.23, and 6.50 t/ha, respectively), for plant heights of 113.3-122.5 cm (Fig. 3).

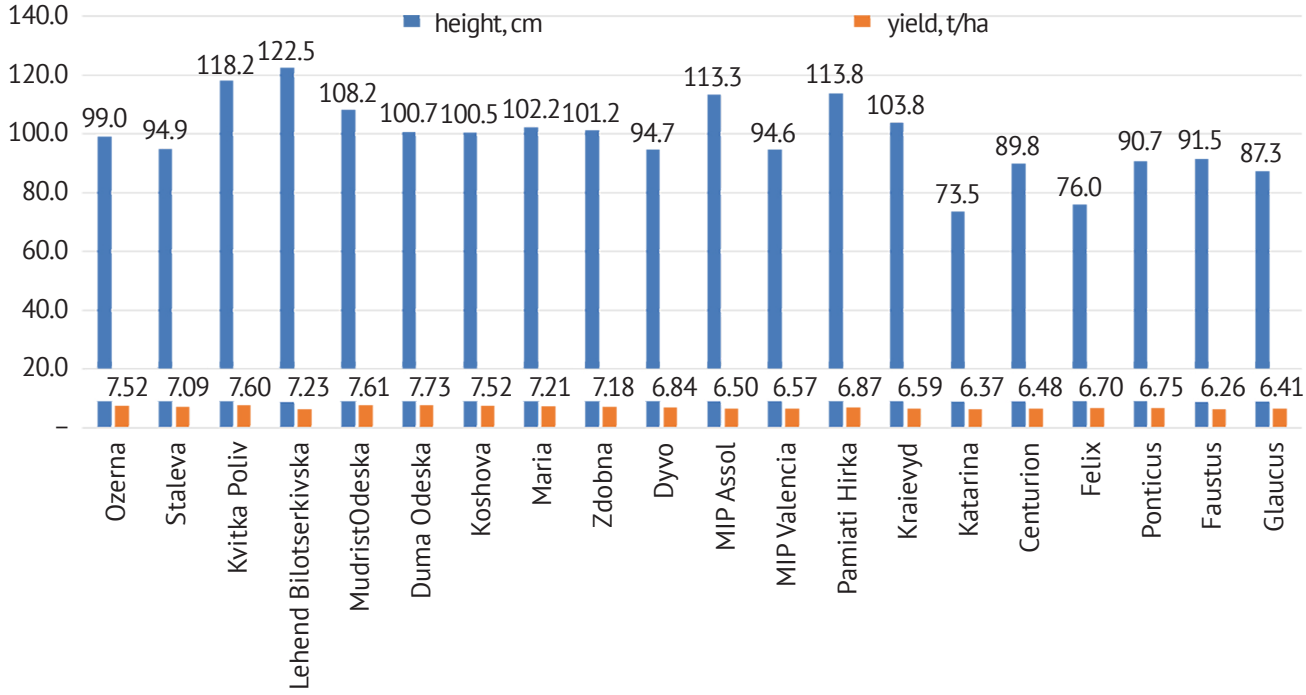

***Figure 3**. Optimum height and yield parameters of soft winter wheat varieties(average for 2018–2021), cm*
***Source:** compiled by the authors*

Optimum plant height parameters of wheat varieties of the short-stemmed winter group (Ozerna, Staleva, Mudrist Odeska, Duma Odeska, Koshova, Maria, Zdobna, Dyvo, Pamiati Hirka, Kraievyd), for which the grain yield was formed at 6.59-7.73 t/ha (2019 and 2021) were from 94.9 to 103.8 cm. Semi-dwarf varieties – Katarina, Felix, Ponticus, Faustus, MIP Valencia, Centurion, Glaucus – in 2021 produced a higher grain yield (6.37-6.75 t/ha) at plant heights of 73.5-94.6 cm.

An increase in the height of plants of the winter wheat varieties Mudrist Odeska, Duma Odeska, Koshova, Maria, Zdobna, Dyvo, MIP Assol, MIP Valencia, Kraievyd, Centurion, Felix, Ponticus by 4.0-6.4% led to a decrease in the yield level from 4.5 (MIP Assol) to 20.9% (Kvitka Poliv). Many years of research by W.P. Bruening (2019) found that awned varieties of soft winter wheat formed a higher grain yield, compared to awnless forms, which had greater plant height and lesser lodging resistance. The present study partially confirms. Thus, the average plant height of the winter wheat varieties of awned forms was 89.9 cm, while in awnless ones – 85.6 cm, which is 4.4 cm less (Table 4).

***Table 4**. Winter wheat grain yield depending on the morphological characteristics of the variety (average for 2018-2022), t/ha*

Indicators	Varieties	
	Awned	Awnless
Average plant height, cm	89.9	85.6
Average lodging resistance, score	8.0	8.4
Yield, t/ha	5.89	5.55

***Source:** compiled by the authors*

The average lodging resistance by varieties was higher in awnless forms and amounted to 8.4 points, which is 0.4 points higher than in spinous forms of winter wheat plants. It was found that among the winter wheat varieties under study, awned forms formed a higher grain yield (5.89 t/ha), which exceeded the yield of awnless forms by 5.8%. Among the varieties of winter wheat under study, which were conditionally divided into three groups according to the group of maturity, the higher grain yield (5.88 t/ha) was formed by mid-early varieties (Ozerna, Staleva, Kvitka Poliv, Mudrist Odeska, Zdobna, Dyvo, Centurion), and the smallest – 5.66 t/ha – by short-season varieties (Duma Odeska, Koshova, Maria, Katarina, Pontikus, Faustus, Felix (Table 5).

***Table 5**. Grain yield of winter wheat depending on the maturity group of the variety (average for 2018-2022), t/ha*

Indicators	Varieties		
	Short-season	Mid-early	Mid-season
Average plant height, cm	80.7	91.5	93.0
Average lodging resistance, score	8.2	8.2	8.2
Yield, t/ha	5.71	5.88	5.66

***Source:** compiled by the authors*

Thus, it can be assumed that awned short-season forms have greater resistance to drought, which is an essential indicator for the Southern Steppe zone of Ukraine, where studies were conducted. Li *et al.* (2022), Lollato *et al.* (2019) state that lodging resistance is highly dependent on the plant height of each variety. Therefore, the authors believe that this should be considered when choosing a variety for different soil and climatic conditions, predecessors, soil fertility. The present study does not support this statement. Thus, the medium-growing varieties Kvitka Poliv and MIP Assol, on average, over the years of research, had a high lodging resistance (8.0-8.2 points), while the short-stemmed ones (Zdobna, Koshova, and Duma Odeska) had an average resistance (6.2 points) and below average (6.0 points).

Research by Vlasenko *et al.* (2018) and Lavrinenko *et al.* (2020) conducted with 50 varieties of winter wheat found that the shorter the growing season of the genotype, the shorter the plants, which is also confirmed by the present study. It was found that among the 20 varieties under study, the highest plant height (76.3-106.5 cm) was formed by medium-ripening varieties Lehenda Bilotserkivska, MIP Assol, MIP Valencia, Pamiati Hirka, Kraievyd, Glaucus, and the smallest (64.2–91.3 cm) – Duma Odeska, Koshova, Maria, Katarina, Ponticus, Faustus, and Felix.

Wang *et al.* (2022), Visioli *et al.* (2018) claim that as the height of winter wheat plants decreases, their productivity increases. Yes. Zaika (2021), F. Spolidorio (2019) prove that short-stemmed winter wheat has various sources of mechanisms affecting the redistribution of plastic substances from the vegetative to the generative part, so even tall varieties with high stem strength can exceed short-stemmed ones in terms of yield. This is confirmed by the present research.

Thus, on average, over the years of research (2018-2022), the yield of the medium-grown winter wheat variety Kvitka Poliv was 5.94 t/ha, which is 0.31-0.60 t/ha more than that of the semi-dwarf varieties Katarina, Centurion, Felix, Faustus, and Ponticus.

CONCLUSIONS

According to the results of five-year research (2018-2022) in the conditions of the Southern Steppe of Ukraine with varieties of soft winter wheat with distinct morphological characteristics, it was found that in the wet 2021, the height of plants of the short-stemmed varieties Mudrist Odeska (114.0 cm); Duma Odeska (106.0 cm); Maria (106.7 cm); Zdobna (106.5 cm); Pamiati Hirka (113.8 cm) and Kraievyd (109.3 cm) were formed as medium-growing, while the varieties Kvitka Poliv and Lehenda Bilotserkivska, which belong to the group of medium-growing ones, formed a height of 125.5 and 122.5 cm, i.e., as in tall-growing. In the dry year of 2020, the semi-dwarf varieties Katarina (55.4 cm) and Felix (59.5 cm) formed the height of plants as dwarfs, and the short-stemmed ones – Ozerna (79.0 cm); Staleva (73.7 cm); Duma Odeska (75.3 cm); Koshova (80.0 cm); Maria (83.0 cm); Zdobna (77.6 cm); Dyvo (72.8 cm) – as semi-dwarves. The soft winter wheat variety MIP Assol, which in terms of height belongs to the medium-growing group, in 2020 formed the height of plants at the level of semi-dwarf plants – 77.9 cm.

The short-stemmed and semi-dwarf varieties Ozerna, Staleva, Katarina, Felix, Ponticus, Faustus, and Glaucus were very resistant to lodging (9 points), and the least resistant (6.2-6.6 points) were the medium-growing (Lehenda Bilotserkivska) and short-stemmed varieties (Duma Odeska, Koshova, Zdobna). The optimal height of winter wheat plants (94.9-100.7 cm) was established, at which a higher grain yield is formed at 7.09 t/ha in the Staleva variety to 7.73 t/ha in the Duma Odeska variety, which belong to groups of short-stemmed plants.

Thus, it was found that, on average, over five years of research (2018-2022), among the 20 varieties of winter wheat under study, spiny forms (Ozerna, Staleva, Mudrist Odeska, Duma Odeska, Koshova, Maria, Zdobna, Dyvo, MIP Valencia, Pamiati Hirka, Kraievyd, Centurion) formed a 4.8% higher plant height and a 5.8% higher grain yield than awnless – Kvitka Poliova, Lehenda Bilotserkivska, MIP Assol, Katarina, Felix, Ponticus, Faustus, and Glaucus. Mid-season varieties (Ozerna, Staleva, Kvitka Poliv, Mudrist Odeska, Zdobna, Dyvo, and Centurion) produced 2.9% more grain yield than short-season ones (Duma Odesa, Koshova, Maria, Katarina, Ponticus, Faustus, and Felix) and 3.7% more than mid-season ones (Lehenda Bilotserkivska, MIP Assol, MIP Valencia, Pamiati Hirka, Kraievyd, and Glaucus). In the future, it is planned to analyse the influence of weather conditions on the duration of the main interphase

periods, the coefficient of productive tillering, the number of internodes, their length, and the weight of grain from 1 ear, which will give a more complete characterization of the winter wheat varieties under study.

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Роль висоти рослин пшениці озимої у формуванні врожайності зерна залежно від сортових особливостей та погодних умов

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Анотація. Пшениця озима є однією з основних продовольчих культур, що забезпечує національну продовольчу безпеку України загальним виробництвом та високоякісним зерном. Площа посіву пшениці озимої займає перше місце в Україні, а виробництво зерна високої якості має актуальне значення. У технології його вирощування вирішальним фактором підвищення врожайності та покращення якості зерна є добір сортів. Метою роботи було визначити вплив погодних умов та особливостей сорту протягом року на висоту рослин, стійкість до вилягання та врожайність пшениці озимої. У статті наведено дані про результати дослідження 20 сортів пшениці м'якої озимої в умовах Навчально-практичного центру Миколаївського НАУ з 2017 по 2022 роки. У ході дослідження використовувалися загальноприйняті методи: системного підходу, системного аналізу, аналіз та синтез, польовий та статистичний метод. Проаналізовано вплив особливостей сорту та погодних умов у досліджувані роки на врожайність пшениці м'якої озимої. Встановлено, що оптимальна висота рослин сортів пшениці озимої коливалась від 94,9 до 100,7 см, за якої формується найвищий врожай зерна на рівні від 7,09 т/га у сорту Сталева до 7,73 т/га у сорту Дума одеська. Збільшення висоти рослин досліджуваних сортів пшениці озимої на 4,0-6,4% призводило до зниження рівня врожайності від 4,5 до 20,9%. Встановлено, що остисті сорти пшениці м'якої озимої формували більшу врожайність зерна, порівняно з безостими формами, які мали більшу висоту рослин та меншу стійкість до вилягання. Проведеними дослідженнями підтверджено, що у середньому по сортам стійкість до вилягання була вища саме у безостих форм рослин пшениці озимої, що на 0,4 бали вище, ніж у остистих. Більшу середню урожайність зерна пшениці м'якої озимої сформовано сортами остистих форм, що на 5,8% більше, ніж у остистих. Отримані наукові результати досліджень сприятимуть широкому застосуванню досліджуваних сортів пшениці м'якої озимої для даної ґрунтово-кліматичної зони, що в подальшому сприятиме підвищенню врожайності та валових зборів зерна

Ключові слова: пшениця м'яка озима, стійкість до вилягання, остисті та безості форми, температура повітря, сума опадів