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Spectral assessment of winter wheat varieties and breeding lines in the autumn period

Abstract. The introduction of modern methods of field assessment of winter wheat genotypes is an integral part of improving the quality of the breeding process. The creation, adaptation, and use of innovative screening technologies in breeding are becoming increasingly popular and allow the breeder to evaluate the original forms and newly created material more broadly and objectively. The autumn period is important for winter crops, when under favourable weather conditions (a gradual decrease in temperature) there is a slowdown in the growth rate of winter wheat, physiological and biochemical processes in the plant's body change, which contribute to its transition to a state of winter dormancy. The state of winter wheat crops (morpho-biometric indicators of plants) in the autumn period is largely decisive in the development of a sufficient level of winter hardiness, and therefore affects the further productivity of the crop. According to the results of the examination of morpho-biological and spectral analysis data, it was identified that before overwintering, the best condition for

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the first sowing period was distinguished by plants of winter wheat varieties: MIP Lada (NDVI=0.48), Erythrospermum 55023 line (NDVI=0.46), Lutescens 60049 (NDVI=0.46), varieties of MIP Vidznaka (NDVI=0.46) MIP IUvileina (NDVI=0.46), MIP Dniprianka (NDVI=0.46), and Lutescens 55198 line (MIP Darunok) (NDVI=0.47). In the standard Podolianka variety, the index value was at the level of 0.45. During the second sowing period, the following varieties were identified: MIP Assol (NDVI=0.32), Balada myronivs'ka (NDVI=0.32), Erythrospermum 55023 (NDVI=0.33), MIP Lada (NDVI=0.33), MIP IUvileina (NDVI=0.32), Lutescens 55198 (MIP Darunok) (NDVI=0.32), and Lutescens 60107 (NDVI=0.32). The NDVI index of the Podolianka variety was at the level of 0.32

Keywords: soft winter wheat, varieties, breeding samples, lines, autumn vegetation termination time, NDVI, morpho-physiological analysis, phenotyping

RELEVANCE

One of the factors in the intensification of agriculture in Ukraine is the use of remote sensing data. The introduction of modern methods for evaluating source material is becoming an integral part of accelerating the breeding process. It is necessary to analyse modern achievements in science and technology and learn how to use them to improve the research of new varieties and promising lines. Every day, the relevance of using UAVs (unmanned aerial vehicles) equipped with modern high-resolution cameras that can photograph plants in the visible and near-infrared spectra increases.

The development and implementation of field spectral analysis as one of the methods of plant phenotyping can increase the volume of breeding samples under study and simultaneously improve the quality of morphological analysis. The introduction of such diagnostic methods in the breeding process allows the breeder to comprehensively assess the state of development of each individual genotype in a relatively short period of time, and objectively assess their resistance against certain factors (drought resistance, frost and winter hardiness, resistance against phytopathogens). Digitisation of the obtained data becomes a replacement for outdated exclusively ocular records and eliminates the influence of the breeder's subjective assessment during accounting.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The genetic potential of modern winter wheat varieties, provided that favourable growing conditions are created, is able to provide a yield of 11.0-12.0 t/ha (Riznyk O.I. *et al*., 1994; Kovalyshyna H.M. *et al*., 2020). Therewith, modern varieties of winter wheat are characterised by increased requirements for growing conditions during the autumn growing season (Buhay S.M., 1965; Bulavka N.V. *et al*., 2018). In conditions of insufficient and unstable moisture, the study of the development of plants in the autumn growing season, when the resistance of winter crops to unfavourable conditions of the winter period and the size of the future crop are formed, especially when growing after non-paired predecessors, is important (Sayko V.F. *et al*., 2002; Pirych A.V. *et al*., 2018; Pirych A.V. *et al*., 2021).

Currently, methods of phenotyping winter wheat are the main ones in breeding this crop in leading breeding institutions of developed countries of the world. All spectral studies are conducted using the basic NDVI index, which is the basis for assessing biomass (Normalised Difference Vegetation Index. Rouse B.J. *et al*, 1973). Recent studies show a close correlation between NDVI obtained during winter wheat flowering and yield results (Duan T. *et al.*, 2017).

Given that the operation of collecting images using UAVs is less time-consuming, and due to the higher accuracy than the proximal sensing without the image previously used, it is expected that multispectral sensing based on aerial UAVs will increase the efficiency of high bandwidth phenotyping (Maimaitijiang M. *et al.*, 2017; Tattaris M. *et al.*, 2016).

Spectral assessment of winter wheat varieties, with parallel morpho-physiological analysis during the end of the autumn growing season, allows for fully assessing the state of autumn development of each individual genotype.

The purpose of the study is to conduct a spectral field and morpho-physiological assessment of winter wheat varieties and lines in the Forest-Steppe of Ukraine and assess the state of autumn development of the genotypes under study.

MATERIALS AND METHODS

The research was conducted during 2018-2020 in the crop rotation of the winter wheat breeding laboratory of the V.M. Remeslo Myronivka Institute of Wheat of the National Academy of Agrarian Sciences of Ukraine. Sowing was conducted after the soybeans in two terms: 2018 – September 25 and October 5; 2019 and 2020 – October 5 and 15.

Spectral evaluation of varieties and lines was performed using a Mavic zoom 2 UAV using a Parrot Sequoia multispectral camera. Pix4D-capture and Pix4Dmapper software were used to form the orthophoto plan. For the high-quality formation of the orthophoto plan, photofixing with a multispectral camera was conducted at a height of 30 m above the level of the object under study with an overlap of 80% of the images with a time interval of 2 seconds.

Morpho-biological analysis was conducted according to the method of F.M. Kuperman (Kuperman F.M., 1977), and according to the scientific paper of the Mironivka Institute of Wheat (Kolyuchuy V.T., 1977).

RESULTS AND DISCUSSION

The study was conducted during 2018-2020 in the crop rotation of the winter wheat breeding laboratory of the V.M. Remeslo Mironivka Institute of Wheat of the National Academy of Agrarian Sciences of Ukraine. Sowing was conducted after the predecessor of soybeans in two sowing periods: 2018 – September 25 and October 5; 2019 and 2020 – October 5 and 15. Contrasting weather conditions during the research period allowed for obtaining objective results. The autumn period of 2018 was excessively humid (GTC=1.76), and the temperature regime in September-October was very warm: the average air temperature was 16.6 and 10.6°C, respectively (the multi-year average – 14.2 and 8.3°C). In November, the average monthly temperature was 1.1°C below the climatic norm. The condition of the crops was assessed as good, the plants developed normally, which contributed to their successful overwintering. Weather conditions in the pre-sowing and sowing period of 2019 were quite dry: the amount of precipitation in August-October was 28.7 mm (the multi-year average value – 163.2 mm). Plants did not receive enough moisture for normal growth and development, and for rooting and forming a proper aboveground mass. The total amount of precipitation in August-September 2020/21 of the growing year reached only 10-20% of the norm. Weather conditions in October were quite favourable for the autumn development of winter wheat, rapid growth and development of plants were noted.

Seven new varieties and four breeding lines of winter wheat were used as the source material: MIP Assol, Balada myronivs'ka, Hratsiia myronivs'ka, Erythrospermum 55023 (Aurora myronivs'ka), MIP IUvileina, MIP Lada, MIP Dniprianka, Lutescens 55198 (MIP Darunok), Lutescens 37519 (MIP Vidznaka), Lutescens 60049, Lutescens 60107, and standard Podolianka variety.

The dates of morpho-biometric analysis of winter wheat plants and spectral survey of crops are 21.11.2018, 29.11.2019, and 10.11.2020. For three years of the studies, it was established that the value of biometric indicators of plants of varieties and breeding lines before wintering depended on the hydrothermal regime in the pre-sowing and sowing periods, during the autumn growing season: the amount of precipitation and uniformity of their distribution, moisture reserves in the soil, air temperature and its differences.

As a result of the conducted studies, it was identified that the height of plants after the end of the autumn growing season on average in the experiment was 10.24 cm (the first sowing period) and 8.11 cm (the second), the number of shoots per plant varied in the range of 3.35-3.10 pcs., respectively, the number of leaves – 7.34 and 3.59 pcs., the mass of one plant – 4.59 and 2.76 g, the vegetative mass after sampling and absolutely dry 25 plants – 14.35 and 6.22 g, 2.50 and 1.19 g, respectively. The greatest vegetative mass before the start of wintering was developed by winter wheat plants during the first sowing period in the 2018/19 growing year. Depending on the genotype and weather conditions, the plant height was in the range of 6.10 cm (Lutescens 60107) and 9.10 cm (Hratsiia myronivs'ka) in 2019/20 g.y.; 13.63 cm (Podolianka standard) and 21.28 cm (MIP Assol) in 2020/21 g.y.; 19.91 cm (Lutescens 55198) and 25.63 cm (MIP IUvileina) in 2018/19 g.y. In 2019/20 g.y. before wintering, plants of the first sowing period formed an insubstantial vegetative mass – 6.92 and 2.35 g (Lutescens 55198) and 3.65 and 6.92 g (Erythrospermum 55023). The lowest indicators of aboveground mass according to the experiment were identified in plants during the second sowing period of 2019/20, which negatively affected their resistance to adverse conditions of the cold period (low air temperatures in the absence of snow cover) (Table 1 and Table 2).

Table 1. Weighted average morpho-physiological and spectral characteristics of winter wheat varieties and lines for 1st sowing period (Myronivka Institute of Wheat, 2018-2020)

Variety, line	Number of stems, pcs.	Number of leaves, pcs.	Plant height, cm	Weight of 1 plant, g	Weight 25 plants, g	Weight of absolutely dry 25 plants, g	NDVI
MIP Assol	1.72	4.41	16.75	0.58	14.74	2.69	0.45
Balada myronivs'ka	1.94	5.24	15.63	0.70	17.14	2.89	0.44
Hratsiia myronivs'ka	1.63	4.06	15.87	0.55	14.62	2.68	0.45
Erythrospermum 55023	1.88	5.28	15.07	0.62	14.92	2.70	0.46
MIP IUvileina	1.30	3.85	16.38	0.54	12.98	2.37	0.46

Table 1, Continued

Variety, line	Number of stems, pcs.	Number of leaves, pcs.	Plant height, cm	Weight of 1 plant, g	Weight 25 plants, g	Weight of absolutely dry 25 plants, g	NDVI
MIP Lada	1.72	4.61	16.11	0.65	15.17	2.63	0.48
MIP Dniprianka	1.82	5.04	16.30	0.58	14.08	2.56	0.46
Lutescens 55198 (MIP Darunok)	1.95	5.17	16.97	0.65	16.75	3.03	0.47
Lutescens 37519 (MIP Vidznaka)	1.75	4.56	15.81	0.58	14.55	2.49	0.46
Lutescens 60049	1.87	4.96	13.32	0.53	12.94	2.37	0.46
Lutescens 60107	1.71	4.65	16.62	0.52	13.03	2.37	0.45
Podolianka St	**1.72**	**4.64**	**13.07**	**0.47**	**11.28**	**2.04**	**0.45**

Table 2. Weighted average morpho-physiological and spectral characteristics of winter wheat varieties and lines for 2nd sowing periods (Myronivka Institute of Wheat, 2018-2020)

Variety, line	Number of stems, pcs.	Number of leaves, pcs.	Plant height, cm	Weight of 1 plant, g	Mass 25 plants, g	Weight of absolutely dry 25 plants, g	NDVI
MIP Assol	1.04	2.32	11.46	0.23	5.77	1.06	0.32
Balada myronivs'ka	1.24	2.59	11.49	0.31	6.68	1.31	0.32
Hratsiia myronivs'ka	1.00	2.15	10.46	0.27	5.77	1.14	0.31
Erythrospermum 55023	1.08	2.41	10.62	0.28	5.86	1.12	0.33
MIP IUvileina	1.20	2.58	11.82	0.30	6.42	1.14	0.32
MIP Lada	1.07	2.43	11.37	0.29	6.42	1.31	0.33
MIP Dniprianka	1.24	2.84	11.37	0.31	6.80	1.28	0.30
Lutescens 55198 (MIP Darunok)	1.13	2.55	11.59	0.33	6.83	1.32	0.32
Lutescens 37519 (MIP Vidznaka)	1.00	2.21	11.71	0.31	6.39	1.29	0.31
Lutescens 60049	1.31	2.77	9.98	0.29	5.79	1.07	0.30
Lutescens 60107	1.39	3.04	11.21	0.30	6.00	1.14	0.32
Podolianka St	**1.23**	**2.55**	**10.93**	**0.26**	**5.87**	**1.15**	**0.32**

According to the results of the examination of morpho-biological and spectral analysis data, on average for three years, before overwintering, the best varieties of winter wheat during the first sowing period were: MIP Lada (NDVI=0.48), MIP IUvileina, MIP Dniprianka (NDVI=0.46), and the lines Erythrospermum 55023 (Aurora myronivs'ka), Lutescens 37519 (MIP Vidznaka), Lutescens 60049 (NDVI=0.46), and the Lutescensline 55198 (MIP Darunok) (NDVI=0.47). In the Podolianka standard variety, the index value was lower (NDVI=0.45). These varieties dominated the standard for several biometric indicators (Table 1).

During the second sowing period, the MIP Lada variety and the Erythrospermum 55023 (Aurora myronivs'ka) line were highlighted (NDVI=0.33). Varieties MIP Assol, Balada myronivs'ka, MIP IUvileina, and lines Lutescens 55198 (MIP Darunok) and Lutescens 60107 had index values at the level of the Podolianka standard variety (NDVI=0.32) (Table 2). In the future, the data of biometric indicators of winter wheat plants and spectral assessment during the resumption of spring vegetation and flowering will be analysed, followed by establishing their relationship with grain yield.

CONCLUSIONS

Based on the data obtained, the following conclusions can be drawn: before entering the winter, the best varieties and lines of winter wheat during the first sowing period were MIP Lada (NDVI = 0.48), MIP IUvileina, MIP Dniprianka (NDVI = 0.46), Erythrospermum 55023 (Aurora myronivs'ka), Lutescens 37519 (MIP Vidznaka), Lutescens 60049 (NDVI = 0.46), and line Lutescens 55198 (MIP Darunok) (NDVI = 0.47); on the second – MIP Lada and line Erythrospermum 55023 (Aurora myronivs'ka) (NDVI = 0.33), while for the variety of the Podolianka standard, the NDVI Index is determined at the level of 0.45 and 0.32, respectively.

These results will help to form methodological recommendations for spectral diagnostics of winter wheat.

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Спектральна оцінка сортів і селекційних ліній пшениці озимої в осінній період

Анотація. Впровадження сучасних методів польової оцінки генотипів озимої пшениці є невід'ємною частиною підвищення якості селекційного процесу. Створення, адаптація та використання інноваційних технологій скринінгу в селекції набувають все більшої популярності і дозволяють селекціонеру більш широко та об'єктивно оцінювати вихідні форми та новостворений матеріал. Для озимих культур важливим є осінній період, коли за сприятливих погодних умов (поступове зниження температури) відбувається уповільнення темпів росту озимої пшениці, змінюються фізіолого-біохімічні процеси в організмі рослини, які сприяють її переходу до стану зимового спокою. Стан посівів пшениці озимої (морфо-біометричні показники рослин) в осінній період значною мірою є визначальним у розвитку достатнього рівня зимостійкості, а отже, впливає на подальшу продуктивність культури. За результатами вивчення даних морфо-біологічного та спектрального аналізу встановлено, що перед перезимівлею найкращим станом для першого строку сівби вирізнялися рослини сортів пшениці озимої сорту Лада: МІП Лада (NDVI=0,48), лінії Erythrospermum 55023 (NDVI=0,46), Lutescens 60049 (NDVI=0,46), сортів МІП Відзнака (NDVI=0,46), МІП ІУвілейна (NDVI=0,46), МІП Дніпрянка (NDVI=0,46) та лінії Lutescens 55198 (МІП Дарунок) (NDVI=0,47). У стандартного сорту Подолянка значення індексу було на рівні 0,45. Під час другого строку сівби були виділені наступні сорти: МІП Ассоль (NDVI=0,32), Балада миронівська (NDVI=0,32), Еритроспермум 55023 (NDVI=0,33), МІП Лада (NDVI=0,33), МІП Іувілейна (NDVI=0,32), Лютесценс 55198 (МІП Дарунок) (NDVI=0,32) і Лютесценс 60107 (NDVI=0,32). У сорту Подолянка індекс NDVI був на рівні 0,32

Ключові слова: пшениця м'яка озима, сорти, селекційні зразки, лінії, час припинення осінньої вегетації, NDVI, морфо-фізіологічний аналіз, фенотипування