Розділ 4

СЕЛЕКЦІЯ І НАСІННИЦТВО

UDC 633.21:631.526.3 (4) (477.83/86)

THE RESULTS OF BREEDING THE SELECTION-VALUABLE POTATO HYBRIDS BY THE METHOD OF STEPWISE INTERVARIETAL HYBRIDIZATION

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https://doi.org/10.31734/agronomy2023.27.121

Zaviriukha P. The results of breeding the selection-valuable potato hybrids by the method of stepwise intervarietal hybridization

To implement programs of applied potato breeding at Lviv NEU, when creating the initial breeding **material**, the staged intervarietal crossings were carried out. Its idea was to combine a complex of valuable economic traits that were inherent in the original parental forms into one genotype.

As a result of the stepwise intervarietal hybridization in Lviv NEU, several new hybrid forms of potatoes of different origins and maturing periods were created. The original parental forms for hybridization used potato varieties of Ukrainian selection, namely Borodianska Rozheva, Vodohrai, Hibrydna 14, Volia, Zakhidna, Zov, Lishchyna, Lvivianka, Oksamyt, Povin, Svitanok Kyivskyi, and foreign varieties, such as Nevska, Suzorye, Aminca, Sante, hybrid SVP.

The task of the research was to give a comprehensive assessment of promising intervarietal hybrids of potatoes according to their valuable economic and biological characteristics so that the best forms could be recommended as candidates for new varieties.

The research was conducted during 2020–2022. 9 new potato hybrids of different maturity groups were used for the studies. Each of the hybrids and the corresponding standard varieties of potatoes were planted on land plots with a plant feeding area of 70×35 cm, which amounted to 40.8 thousand plants per 1 ha. The experimental sites were placed in triplicate, using a systematic method. The registered area of the site was 25 m^2. Potato varieties of domestic selection were used as standards, in particular, Vodohrai variety – for the mid-early group, Volia variety – for mid-ripening, and Zakhidna – for mid-late.

It is established that the stepwise intervarietal hybridization allows combining potentially high productivity (1000 g/bush and higher), intensive crop formation with increased starch content in tubers (16–18 %), and high resistance to late blight (at the level of 7–8 points).

Basing on the conducted research of the comprehensive evaluation of the economic and biological characteristics of new intervarietal hybrids of potatoes, the mid-early hybrid 02/10-40 (Borodianska rozheva × Suzorye), the mid-ripening 11/4-1 (Zakhidna × Vodohrai) and the mid-late hybrid 16/17-1 [(Zakhidna × Sante) × (Volia × Lishchyna)] were marked as they significantly prevailed in the complex of economic and valuable characteristics of the corresponding standard varieties. It is proposed to continue further selection work with them according to the accepted schemes and potato selection, intensively multiply, and prepare to pass to the State variety tests as candidates for new varieties of the crop.

Key words: potato, selection, step hybridization, intervarietal hybrids, selection, selection-valuable traits.

Завірюха П. Результати виведення селекційно-цінних гібридів картоплі методом ступінчастої міжсортової гібридизації

З метою реалізації програм з прикладної селекції картоплі у Львівському НУП під час створення вихідного селекційного матеріалу проводять ступінчасті міжсортові схрещування, ідеологія яких полягає у поєднанні в одному генотипі комплексу цінних господарських ознак, які притаманні вихідним батьківським формам.

У результаті міжсортової ступінчастої гібридизації у ЛНУП створено низку нових гібридних форм картоплі різного походження та строків дозрівання. Вихідними батьківськими формами для гібридизації слугували сорти картоплі української селекції: Бородянська рожева, Водограй, Гібридна 14, Воля, Західна, Зов, Ліщина, Львів'янка, Оксамит, Повінь, Світанок київський та іноземні сорти: Nevska, Suzorye, Aminca, Sante, hybrid SVP.

Завдання досліджень полягало в тому, щоб дати комплексну оцінку перспективним міжсортовим гібридам картоплі за цінними господарсько-біологічними ознаками, щоб найкращі форми рекомендувати як кандидати у нові сорти.

Дослідження проводили протягом 2020–2022 рр. Для досліджень використовували дев'ять нових гібридів картоплі різних груп стиглості. Кожен із гібридів та відповідних стандартних сортів картоплі висаджували на ділянках із площею живлення рослин 70×35 см, що становило 40,8 тис. рослин на 1 га. Експериментальні ділянки були розміщені у трьох повтореннях, із використанням систематичного методу. Облікова площа ділянки – 25 $м^2$. Стандартами слугували сорти картоплі вітчизняної селекції: для середньоранньої групи – Водограй, середньостиглої – Воля, та середньопізніх – Західна.

Встановлено, що ступінчаста міжсортова гібридизація дозволяє поєднати потенційно високу продуктивність (1000 г/кущ і вище), інтенсивне формування врожаю з підвищеним умістом крохмалю в бульбах (16–18 %) і високу стійкість до фітофторозу (на рівні 7–8 балів).

На основі проведених досліджень з комплексної оцінки господарських і біологічних ознак нових міжсортових гібридів картоплі виділено й відібрано середньоранній гібрид 02/10-40 (Бородянська рожева × Сузор'є), середньостиглий 11/4-1 (Західна × Водограй) і середньопізній 16/17-1[(Західна × Sante) × (Воля × Ліщина)], які істотно переважають за комплексом господарсько-цінних ознак відповідні сорти-стандарти. Зауважено доцільність продовжити з ними подальшу селекційну роботу відповідно до прийнятої схеми селекції картоплі, інтенсивно розмножувати й готувати для передачі у Державне сортовипробування як кандидатів у нові сорти цієї культури.

Ключові слова: картопля, селекція, ступінчаста гібридизація, міжсортові гібриди, відбір, селекційно-цінні ознаки.

Problem setting. In solving the problem of providing food to mankind, a special place is given to potato, which currently ranks fourth among food crops in the world after corn, wheat, and rice, and will continue to be the crop of the future. The food use of potatoes is confirmed statistically. Thus, according to the data of the International Food Organization FAO, about 60 % of the crop grown in the world is used just for people food, about 15 % – for animal feed, about 5 % – for cattle feed, and 11 % – as planting material for reproduction of a new crop [19; 20].

Therefore, increasing potato production remains an urgent task for both scientists and practitioners. It is well known that, in addition to the technological, organizational, and logistical aspects of increasing the yield of potatoes, its selection remains one of the most effective directions to intensify potato growing from both an economic and ecological point of view, as emphasized by the well-known potato breeders M. D. Honcharov [1], A. A. Osypchuk [12; 13], P. D. Zaviriukha [3], etc. In this regard, the creation and introduction of new high-quality potato varieties with high adaptive potential, resistant to biotic and abiotic factors into production is always an urgent and priority task of breeding institutions and their breeding programs [18].

Analysis of recent research and publications. Potato breeding is one of the important sections of agricultural science. The creation and introduction of new high-yielding varieties into production play an important role in increasing the gross production of potatoes, improving quality and reducing its cost [18]. At the same time, those varieties that are well adapted to specific soil and climatic conditions for their cultivation can fully realize their potential [5; 8; 9].

Modern commodity producers of potatoes of various forms of ownership, individual farms, farmers demand such varieties of "second bread", which are characterized by a complex of economically valuable features, namely high yield, good consumer qualities, resistance to fungal, viral, bacterial diseases and nematodes, mechanical damage, adverse conditions cultivation [12].

In Ukraine, large potato harvest shortages occur as a result of late blight, viral, and other diseases, the quality of potatoes is significantly impaired by common scab, stem nematode, etc. Therefore, an important requirement and direction of selection is the creation of varieties that are resistant to the causative agents of these diseases. The current direction of selection is the creation of varieties resistant to diseases that occur during storage and with good winter dormancy [2; 4; 16].

An extremely urgent task of modern potato breeding is also to combine resistance against diseases and pests with the main economic and valuable traits in new varieties. It is possible to solve these tasks thanks to purposeful selection, which is based on the use of a variety of source materials, knowledge of the genetic nature of parental pairs involved in hybridization, the use of effective evaluation methods, and the selection of desired genotypes [5; 14].

At the current stage, domestic and foreign scientists have developed effective methods of potato selection for various characteristics and models of new varieties of this crop [1; 3; 5; 21].

Undoubtedly, the success of potato selection, like other crops, ultimately depends on the availability, successful selection, and quality of the raw material. Parental pairs for hybridization must have a high combinatorial capacity and be a donor of many traits for their effective use in breeding [6; 7].

Varieties with high overall combining ability, as carriers of valuable additive gene complexes, are the best starting material for obtaining combinations with high genetic and breeding value. They are more likely to identify and select hybrid offspring with genetically fixed high yield and resistance to diseases, especially to the late blight pathogen [17].

Meanwhile, despite the well-known successes of domestic potato breeding, the creation of new varieties of this crop with a complex of valuable economic and biological traits, including resistance to the most harmful organisms, remains an urgent task.

Setting objectives. To implement programs of applied potato breeding to create the initial selection material, the Lviv NEU conducts stepwise intervarietal crossings, the idea of which is to combine a complex of valuable economic traits that are inherent in the original parental forms into one genotype [6; 11].

As a result of intervarietal stepwise hybridization, several new hybrid forms of potatoes of different origins and maturity dates were created, which at the final stage underwent thorough selection work.

Therefore, the task of the research was to provide a comprehensive assessment of promising intervarietal hybrids of potatoes according to their valuable economic and biological characteristic, and their disease resistance, so that the best forms could be recommended as candidates for new varieties.

Research material and methodology. When creating new hybrids that were the subject of our research, the following potato varieties of Ukrainian selection were used as the original parental forms: Borodianska Rozheva, Vodohrai, Volia, Hibrydna14, Zakhidna, Zov, Lishchyna, Lvivianka, Povin, Svitanok Kyivskyi and foreign varieties – Nevska, Suzorye, Aminca, Sante, hybrid SVP.

The research was conducted during 2020–2022. The research field of the Department of Genetics, Breeding and Plant Protection is represented by dark gray podzolic light loamy soil. The depth of the plowed layer was 0–30 cm. The content of humus in the plowed layer ranged from 2.33 to 2.78 %, the pH of the salt extract was 5.8; the content of mobile forms of easily hydrolyzed nitrogen (according to Kornfield) – 88–96 mg/kg, mobile phosphorus (according to Maslova) – 46–57 mg/kg and exchangeable potassium (according to Maslova) – 111–127 mg/kg of air-dry soil. Annually, the predecessor of potatoes in selective crop rotation was winter wheat.

9 new potato hybrids of mid-early, mid-ripe, and mid-late ripeness groups were used for the research. Each of the hybrids and the corresponding standard varieties of potatoes were planted in a competitive and dynamic variety test on four-row plots of 30 tubers in a row with a plant feeding area of 70×35 cm, which amounted to 40.8 thousand plants per 1 ha. Experimental sites were placed in triplicate, using a systematic method. Potato varieties of domestic selection were used as standards: Vodohrai – for the mid-early group, Volia – for mid-ripening, and Zakhidna – for mid-late.

The final accounting of the harvest was carried out by the continuous weight method with the determination of the average productivity of one plant, followed by conversion to the yield of tubers from 1 ha. The starch content in the tubers was determined by their specific weight in water. The research results were processed statistically using the dispersion method [15].

Agricultural technology on the experimental field is typical, and generally accepted for growing potatoes in the Western forest-steppe zone, except the use of pesticides for treatments against late blight, to objectively conduct field phytopathological assessments of the resistance of the above-ground mass of plants (tops) to the specified disease. At the same time, three field trips were held annually to evaluate damage late blight according to the international 9-point scale [10]. In particular, 9 points – there is no damage to the aerial part of the plants (top); 8 – isolated spots of plant damage; 7 – damage to the leaf surface of plants by 5–15 %; 6 – 16–25 % damage; 5 – 26–40 % damage; 4 – 41–50 % damage; 3 – 51–70 % damage; 2 – damage by 71–80 % and 1 point – damage to the leaf surface of plants by 81–100 %.

Research results. Productivity is the most important indicator of each variety, including potato varieties. It is determined primarily by the genetic characteristics of the variety, and its productivity potential. Undoubtedly, it changes greatly under the influence of growing conditions, that is, technology.

To ensure a high level of final productivity, especially in the coniferous season value has selection such varieties potatoes, which would be in a specific region and soil and climatic conditions were characterized plasticity, high productivity and sufficient stability.

As a result of the research, it is established that the final productivity of the studied potato hybrids was significantly influenced by the features of the meteorological conditions during the growing season and the genotypic features of a specific hybrid. Thus, the average yield of potatoes, according to the experiment in 2020, was 1012 g/bush, while in 2021 it was 875 g/bush, or 15.7 % less (Table 1).

When determining the average productivity of the intervarietal hybrids of potatoes for 2020–2022 and the subsequent conversion to their yield per hectare, it was established that in the medium-early group, the advantage of the new hybrid 02/10-40 (Borodianska Rozheva × Suzorye) above the standard reached 84 c/ha with a yield of 428 c/ha (Table 1).

In the medium-ripe group, the highest yield of tubers among other intervarietal hybrids was shown by the new hybrid 11/4-1 (Zakhidna × Vodohrai), in which it was quite high and reached 518 c/ha, which is 134 c/ha or 34.8 % more from the productivity of the Volia standard variety (346 c/ha).

In the medium-late group, the intervarietal hybrid 16/17-1 [(Zakhidna × Sante) × (Volia × Lishchyna)] was the best in terms of tuber yield – an average of 463 c/ha, which is 117 c/ha (33.8 %) more than the indicator of the Zakhidna standard – 346 c/ha.

Thus, in the process of selecting the original parent forms and carrying out a series of stepwise intervarietal crossings, it is possible to create hybrid offspring of potatoes of different maturity groups, which can be high-quality initial material when breeding this crop for high productivity.

One of the particularly valuable components of potato tubers is the natural carbohydrate starch, which not only determines the nutritional value of the tubers, but is also the main raw material for many branches of the processing industry. Even the latest use of potato starch for the production of household bags with biodegradable within a year makes this compound not just unique, but the world's savior from environmental pollution with terrible plastic.

Table 1

Final productivity parameters of the intervarietal hybrids of potato of different maturity groups, 2020–2022

Name of the variety, crossing	Selective number	Productivity, g/bush				Harves, c/ha	To *St*	
		2020	2021	2022	sir.		c/ha	%
Mid-early hybrids								
Vodohrai	*St*	865	777	891	845	344	-	-
Svitanok Kyivskyi × (Zakhidna × Povin)	16/1-12	961	851	1068	960	392	+48	13.9
Zakhidna × (Zov × Nevska)	14/9-30	972	805	1052	943	385	+41	11.9
Borodianska rozheva × Suzorye	02/10-40	998	902	1247	1049	428	+84	24.4
Medium-ripe hybrids								
Volia	*St*	1003	824	996	941	384	-	-
Zakhidna × Vodohrai	11/4-1	1364	1097	1346	1269	518	+134	34.8
(Zakhidna × Aminca) × (Volia × Lishchyna)	14/16-2	1207	1031	1341	1193	487	+103	26.8
(Zakhidna × Sante) × (Volia × Lishchyna)	15/5-19	998	856	993	949	387	+3	0.7
Mid-late hybrids								
Zakhidna	*St*	745	733	1066	848	346	-	-
[(Hybrid 14 × Lvivianka) × hybrid SVP)] × Zakhidna	11/3-2	994	872	1089	985	402	+56	16.1
Zakhidna × (Borod. Rozheva × Oksamyt)	11/15-12	958	824	1101	961	392	+46	13.3
(Zakhidna × Sante) × (Volia × Lishchyna)	16/17-1	1082	930	1390	1134	463	+117	33.8
Average for the year		***012***	***75***	***138***	***008***	-	-	
LSD_{05}, g/bush		3	7	9		-	-	

Taking into account all the bias in the use of starch, when conducting potato selection, attention is also paid to the creation of high-starch varieties, or varieties with an increased starch content. Therefore, in 2020–2022, the studied intervarietal hybrids of potatoes were evaluated the starchiness of their tubers (Table 2).

Table 2

Starch content in tubers of intervarietal hybrids of potatoes of maturity groups, 2020–2022

Name of the variety, crossing	Selective number	Starch content, %				To *St*
		2020	2021	2022	sir	
Mid-early hybrids						
Vodohrai	*St*	15.4	13.8	13.2	14.1	-
Svitanok Kyivskyi × (Zakhidna × Povin)	16/1-12	15.4	14.2	14.8	14.8	+0.7
Zakhidna × (Zov × Nevska)	14/9-30	17.5	16.3	17.0	16.9	+2.8
Borodianska rozheva × Suzorye	02/10-40	18.0	17.2	17.4	17.5	+3.4
Medium-ripe hybrids						
Volia	*St*	14.9	13.1	14.1	14.0	-
Zakhidna × Vodohrai	11/4-1	16.4	15.2	15.9	15.8	+1.8
(Zakhidna × Aminca) × (Volia × Lishchyna)	14/16-2	17.9	16.7	17.2	17.3	+3.3
(Zakhidna × Sante) × (Volia × Lishchyna)	15/5-19	17.6	16.2	17.0	16.9	+2.9
Mid-late hybrids						
Zakhidna	*St*	15.4	14.4	15.4	15.1	-
[(Hybrid 14 × Lvivianka) × hybrid SVP)] × Zakhidna	11/3-2	17.9	16.5	17.3	17.2	+2.1
Zakhidna × (Borodianska Rozheva × Oksamyt)	11/15-12	14.9	14.1	14.8	14.6	-0.5
(Zakhidna × Sante) × (Volia × Lishchyna)	16/17-1	18.2	16.8	17.6	17.5	+2.4
Average for the year		***16.7***	***15.3***	***15.9***	-	-
LSD_{05}, %		0.43	0.35	0.38	-	-

The data in the Table 2 show that in the medium-early group, it is necessary to highlight the intervarietal hybrid 02/10-40 (Borodianska rozheva × Suzorye) – on average, during the three years of the research, the starch content in the tubers was 17.5 % against 14.1 % in the Vodohrai standard, or was higher by 3.4 %.

Except for hybrid 11/4-1 (Zakhidna × Vodohrai), other hybrid forms of the medium-ripening group significantly exceeded the Volia standard (14.0 %) in terms of the absolute value of starch content in tubers. This is especially true for the intervarietal hybrid 14/16-2 [(Zakhidna × Aminca) × (Volia × Lishchyna)] – 17.9 % in 2020 and 17.2 % in 2022 respectively, 14.9 and 14.1 % in the Volia standard.

In the mid-late group, the researchers selected two hybrid forms that may be promising ones in potato selection for the starchiness of the tubers. In particular, they include the hybrid 11/3-2 [(Hybridna 14 × Lvivianka) × hybrid SVP)] × Zakhidna], the average starch content in the tubers of which was 17.2 % and the hybrid 16/17-1 [(Zakhidna × Sante) × (Volia × Lishchyna)] – 17.5 % when the value of this indicator in the standard variety Zakhidna is 15.1 % in 2020–2022.

Thus, the given data indicate that among the newly created assortment of potatoes at the Lviv NEU using stepwise intervarietal hybridization, there are promising forms that are characterized by an increased content of starch in the tubers and are high-quality raw material for selection work for their economic and valuable trait.

The zone of the western forest-steppe is characterized by mass distribution and aggressiveness of one of the most dangerous diseases of potatoes, i.e. late blight. The use of expensive chemicals to protect potato plants from late blight significantly increases the total cost and cost of grown products. At the same time, the level of its environmental safety decreases. Based on this, the cultivation of such varieties, which are marked by a high level of genetically determined immunity against this disease, is important in the system of protecting potatoes from late blight.

The obtained research data show that some of the new intervarietal potato hybrids are successfully combined into one genotype high productivity, increased starch content in tubers with increased and high resistance of the tops against late blight (at the level of 7–8 points on the international 9-point scale). The results of the phytopathological assessment of the studied potato hybrids against late blight are shown in the Table 3.

Table 3

The degree of resistance of the new intervarietal hybrids of potatoes against late blight on the natural infection background of Wester Forest-Steppe, 2020–2022

Name of the variety, crossing	Selective number	Years	Damage top late blight, %			Durability against Phytophthora, points		
			1 pt.	2 pts.	3 pts.	1 pt.	2 pts.	3 pts.
Mid-early hybrids								
Vodohrai	*St*	2020	s.s.*	20	40	8	6	5
		2021	s.s.	25	45	8	6	4
		2022	5	20	35	7	6	5
Svitanok Kyivskyi × (Zakhidna × Povin)	16/1-12	2020	0	10	25	9	7	6
		2021	0	10	30	9	7	5
		2022	s.s.	10	20	8	7	6
Zakhidna × (Zov × Nevska)	14/9-30	2020	s.s.	15	30	8	7	5
		2021	0	10	30	9	7	5
		2022	s.s.	15	25	8	7	6
Borodianska rozheva × Suzorye	02/10-40	2020	0	s.s.	15	9	8	7
		2021	0	s.s.	15	9	8	7
		2022	s.s.	10	20	8	7	6
Medium-ripe hybrids								
Volia	*St*	2020	s.s.	15	40	8	7	5
		2021	10	20	45	7	6	4
		2022	10	20	40	7	6	5
Zakhidna × Vodohrai	11/4-1	2020	0	10	15	9	8	7
		2021	0	10	20	9	8	6
		2022	s.s.	10	20	8	7	6

Continuation of Tabl3

(Zakhidna × Aminca) × (Volia × Lishchyna)	14/16-2	2020	0	0	20	9	9	6
		2021	0	0	20	9	9	6
		2022	0	s.s.	25	9	8	6
(Zakhidna × Sante) × (Volia × Lishchyna)	15/5-19	2020	0	s.s.	10	9	8	7
		2021	s.s.	s.s.	10	8	8	7
		2022	s.s.	5	10	8	7	7
Mid-late hybrids								
Zakhidna	*St*	2020	10	35	50	7	6	4
		2021	15	40	50	7	5	4
		2022	10	20	35	7	6	5
[(Hybrid 14 ×Lvivianka) × hybrid SVP)] × Zakhidna	11/3-2	2020	s.s.	s.s.	15	8	8	7
		2021	s.s.	s.s.	15	8	8	7
		2022	s.s.	10	20	8	7	6
Zakhidna × (Borodians-ka Rozheva × Oksamyt)	11/15-12	2020	0	s.s.	10	9	8	7
		2021	s.s.	s.s.	10	8	8	7
		2022	s.s.	10	15	8	7	7
(Zakhidna × Sante) × (Volia × Lishchyna)	16/17-1	2020	10	10	20	7	7	6
		2021	15	15	2 5	7	7	6
		2022	10	15	20	7	7	6

Note: s.s.* – single phytophthora spots on plant leaves potatoes.

According to field phytopathological evaluations conducted in 2020 and 2021, 2022 hybrid 02/10-40 (Borodianska rozheva × Suzorye) stood out in the group of mid-early forms with high resistance to late blight at the level of 9-7 points. Among the studied medium-ripening forms, hybrids 11/4-1 (Zakhidna × Vodohrai) – 9-7 points 15/5-19 [(Zakhidna × Sante) × (Volia x Lishchyna)] – also 9-7 points on the international 9-point scale.

In the selection of potatoes for phytofluoride resistance, such mid-late hybrids as 11/3-2 [(Hibrydna 14 × Lvivyanka) x hybrid SVP)] × Zakhidna] and 11/15-12 [Zakhidna × (Borodianska rozheva × Oksamyt)] are promising. The hybrid 16/17-1 [(Zachidona × Sante) × (Volia × Lishchyna)] of the same maturity group also exceeded the standard for resistance to late blight.

According to phytopathological assessments, late blight caused more damage to plants in 2021, which was explained by excessive precipitation during the growing season contributing to the spread and greater aggressiveness of this harmful phytopathogen.

Thus**,** researchers of Lviv NEU have bred new promising potato hybrids, which are characterized by a complex of selectively valuable traits, including immunity to the most harmful disease, i.e. late blight, which allows limiting the use of chemical pesticides and thus obtaining ecologically safe products.

Conclusions and proposals for practical selection

1. The intervarietal hybridization of potatoes allowed creating a genotype of newly created hybrids with potentially high productivity (1000 g/bush and higher), intensive crop formation with increased starch content in tubers (16–18 %), and high resistance to late blight (at the level of 7–8 points on the international 9-point scale).

2. With the selected promising hybrids 02/10-40, 11/4-1, 16/17-1, it is proposed to carry out further selection work by the accepted scheme of the potato selection process, intensively multiply them, and prepare them for transfer to the State Variety Trial as candidates for new varieties.

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Стаття надійшла 29.08.2023