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Review
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ANALYSIS OF INITIAL BREEDING MATERIAL BASED ON KEY ECONOMICALLY VALUABLE TRAITS

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The article presents results from analysing a nursery of initial breeding material (hybridisation nursery) to identify and incorporate the most suitable cultivated potato varieties and interspecific hybrids created from phylogenetically distant species into breeding work to develop new potato varieties adapted to the soil and climate conditions of the Western Forest-Steppe region of Ukraine. The main research methods used were field trials, analytical techniques, and statistical analysis. The results showed that interspecific hybrids are characterised by many tubers per plant (11.3–27.0), with relatively high average tuber weight (74–89 g). These hybrids exhibit traits of cultivated varieties in terms of high productivity per plant, average tuber mass, and marketability of tubers (up to 95.0 %). The interspecific hybrids are characterised by high tuber marketability, increased starch content, and high resistance of vegetative mass to late blight (7.3–8.8 points on a 9-point scale). Analysis of the interspecific hybrids as one of the groups incorporated into the breeding work allows the conclusion that developing varieties with high yields combined with late blight resistance and valuable economic traits is possible. Ukrainian and foreign potato varieties in the initial breeding material nursery, such as Slava, Legenda, Duzha, Svalyavska, Shchedryk, Myroslava, Chervona Ruta, Krynytsa, and Pryhozha, are recommended for incorporation into the hybridisation process to create new breeding material.

Keywords: potato, variety, interspecific hybrid, yield, resistance, late blight.

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Аналіз розсадника вихідного матеріалу картоплі, як етапу селекційної роботи

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Наведено результати досліджень проведення аналізу розсадника вихідного матеріалу (розсадника гібридизації) задля встановлення і залучення в селекційну роботу найбільш придатних культурних сортів картоплі та міжвидових гібридів, що створені на основі філогенетично віддалених видів для створення нових сортів картоплі стосовно ґрунтово-кліматичних умов Західного Лісостепу України. Основні методи досліджень – польовий, аналітичний та статистичний. Результатами досліджень встановлено, що для міжвидових гібридів є характерними такі показники, як велика кількістю бульб під кущем (11,3–27,0 шт.), достатньо висока їх масою (74–89 г). Цим гібридам притаманні ознаки культурних сортів за високої продуктивності одного куща, середньої маси та товарність бульб (до 95,0 %). Міжвидові гібриди характеризуються високою товарністю бульб, підвищеним вмістом крохмалю та проявом високої стійкості вегетативної маси проти фітофторозу (7,3–8,8 балів). Проведення аналізу міжвидових гібридів, як однієї з груп, що залучено в селекційну роботу, дозволяє зробити висновок щодо можливості створення сортів з високою урожайністю в поєднанні зі стійкістю проти фітофторозу та господарсько-цінними показниками. Сорти, що знаходяться у розсаднику вихідного матеріалу української та закордонної селекції: Слава, Легенда, Дужа, Свалявська, Щедрик, Мирослава, Червона рута та Криниця, Пригожа рекомендовано до залучення в гібридизаційний процес щодо створення нового селекційного матеріалу.

Ключові слова: картопля, сорт, гібрид, урожайність, стійкість, хвороба.

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Introduction. Currently, the most relevant task of potato breeding is the combination of varieties of essential economically valuable traits with resistance to diseases and pests [12].

The solution to this task lies in targeted breeding, based on the knowledge of the genetic nature of parental pairs using various source materials and effective methods of evaluation and selection of the desired genotypes [31].

Analysis of recent research and publications. The correlation variability of traits in living organisms has long interested breeders.

Correlation (from Latin *correlatio* – relative) is a relationship between individual parts and traits of an organism, which manifests in that a change in one trait leads to a correlative change in another [18].

The potato breeding scheme includes the following nurseries:

– Collection nursery, where domestic, foreign, and local varieties, wild and cultivated species, and interspecific hybrids, used as parental forms in practical breeding or in creating new source material, are studied:

– Parental form nursery – varieties selected by a set of traits in the collection nursery are grown;

– First selection (seedlings and single-tuber) – single-tuber or the so-called "first tuber generation" are studied;

– Second selection (first or second tuber generation). Material selected in the previous year based on the clonal principle is grown and

studied from seedlings (first tuber generation), from single-tubers (second tuber generation);

– Third selection (second or third tuber generation). Selection numbers are studied on two-row plots of 40–140 bushes each;

– Main testing – a comparison with standard varieties of material selected last year in the third selection nursery;

– Competitive-ecological testing – the study of selection numbers selected last year from the main testing nursery;

– Culling is carried out over 2–3 years in different soil and climatic zones compared to standard varieties determined for these zones. For the first year of testing, seed material of selection numbers is distributed by the originator from selection reproduction, and for standards – elite or super-elite of the exact origin.

In the second and third years of competitive-ecological testing, local reproduction seed material (overlaying) is used at each location.

– Production testing.

In particular, the selection material is tested for resistance to diseases and pests in experiments conducted on infectious and provoking backgrounds. In laboratory conditions, selection material is evaluated for biochemical and taste qualities. Based on field and laboratory assessments, selection material is selected, and the best genotypes are passed to state variety testing. The collection nursery studies domestic, foreign, and local varieties, wild and cultivated species, and interspecific hybrids used as parental forms in practical breeding or creating new source material [19].

Many researchers note that in many organisms, traits are intertwined. In such cases, determining one trait allows predicting the presence of another [20].

The significance of trait interrelation aids in selecting needed forms and accelerates the breeding process. In practical work, an association can be used in two ways – depending on the relationship and its type. In the first case, attention is paid to the value of the correlation coefficient and its signs before concluding the practical value of such a dependency. An example is all instances of well-defined linear correlation that have been used in breeding work for a long time. In the second case, the coefficient value and even its sign play no substantial role, and the type of relation is either direct or curvilinear [30].

In many cases, the productivity of agricultural plants is conditioned by numerous quantitative traits, which result from the interaction of the plants' hereditary characteristics with a complex of external environmental conditions. Other quantitative or qualitative traits can influence the size of a quantitative trait. For example, the anatomical structure of tissue and sugar content in the cellular sap of plants can affect their winter hardiness. Hence, considering quantitative traits, including plant yield, one can also speak of their qualitative characteristics [1, 32].

For instance, the precocity of seedlings at a young age can be determined by the number of days from planting to flowering, as tuberization in potato plants is often associated with flowering and yield – at early digging [11, 17, 22, 26].

According to consolidated observations of many researchers, a very simple and, at the same time, very reliable way is determining the precocity of potatoes in both first-year seedlings and tuber reproductions [36].

Additionally, the precocity of first-year seedlings in tuber reproductions can be determined by certain morphological traits that change with plant age [23, 35].

Potatoes plants' precocity is associated with traits like rapid development of leaf dissection, maximum dissection in the early tier, and a few monopodia tiers. Conversely, late-maturing potato forms are characterised by slow development of leaf dissection, high placement of leaves with maximum dissection, and a large number of monopodia tiers.

The correlation discovered by many scientists between different potato traits is of practical interest. It can be used in breeding work, especially the positive correlation between starch content in first-year seedling tubers and their tuber propagation, indicating the possibility of selecting high-starch forms from first-year seedlings [28, 33, 37].

However, insufficiently studied in potato

culture are the issues of correlation variability in hybrid populations obtained from crossing new potato varieties, particularly those created through interspecific hybridisation, the nature of inheritance of economic and biological traits in such hybrid populations, and other knowledge that could help combine necessary traits in one variety and develop new valuable varieties of this crop [6].

Alongside this, it's considered expedient to continue studying the correlation between different traits, which could promote a more effective selection of potato seedlings and a better evaluation of them in breeding work. It's evident that correlation is not constant and varies in different populations, so it should be used considering the characteristics of each population [24].

Potato varieties have significant genetic diversity, both old and modern, domestic and foreign, and they are used in breeding as genetic sources or donors for traits like high yield, precocity, resistance to viral diseases, good taste qualities, and others.

Local varieties and varieties created on a multispecies basis gain significant importance as source material. Scientists note their endurance in adverse growing conditions and high adaptability in various soil-climatic zones.

It's believed that interspecific hybridisation for increasing yield and starchiness is promising when these indicators are combined in the first generations. This is possible using predominantly large-tuber *S. leptostigma* and high-yielding *S. molinae* species. The simplest way to create such varieties is hybridisation with cultivated species without negative traits of wild species, namely *S. andigenum* and *S. curtilobum*.

As parental forms in breeding for these indicators, the following species were used: *S. andigenum, S. demissum, S. semidemissum, S. curtilobum, S. leptostigma, S. commersonii, S. chacoense, S. gibberulosum*, and varieties Smachna, Mavka, Karpatian, Zarevo, Belarusian Starchy, Bekra, Svitannia Kyivska, Belarusian 3, Leander, Pokra, Perlina, Garnet, Poliska pink and hybrids 77.583/16, 1509c/55, /692c/68, 498c/66, 1-35c/61, 1–53c/61, and others. For breeding use for resistance against late blight, promising samples of *S. andigenum, S. bulbocastanum, S. berthaultii, S. brachycarpum* species, and several other less common phylogenetically distant species are considered [5, 7, 10, 39, 40].

Regarding yield in combination with potato starchiness, it is established that each variety or hybrid gives a variation series of forms during self-pollination. In most of these, the characteristics of the original form are retained, and the hybrid progeny determines the average index of both parental forms. Other genotypes deviate both towards increased traits and their reduction. Therefore, in breeding for these traits, the main focus is on selecting genotypes in high-starchy classes [9, 2–4, 8, 9, 21, 34].

Materials and methods. Breeding trials in 2023 were conducted in the fields of a 4-field crop rotation at the Department of Crop Breeding of the Institute of Potato Research of NAAS, located in Obroshyne, Lviv district, Lviv region. The precursor to the potato crops were winter grains with post-harvest sowing of cover crops.

The under study are grey forest soils, superficially gleyed, coarse-loamy to light-loamy on loess-like deposits. They are heterogeneous in terms of mechanical composition profile, significantly affecting their moisture regime. The upper horizons have higher moisture content compared to the lower ones. For this reason, the soils undergo excessive moisture and gleying during rainy seasons or years with a high amount of precipitation. In dry years, they are sufficiently provided with productive moisture. Moreover, the groundwater significantly influences gleying, with the depth ranging between 1.5–1.8 meters.

According to conducted agrochemical analyses, the soils under investigation are poor in humus (1.58–1.67 %), have an acidic soil solution reaction (pH 4.80–5.17), a sum of absorbed bases of 6.20–7.22, and hydrolytic acidity of 2.87–3.29 mg-eq per 100 g of soil.

The studies were conducted according to commonly accepted methods in potato cultivation. The assessment of potato samples

for resistance to late blight was assessed in field conditions on a natural infection background by visual observations of plant disease (three times per vegetation period) from the time of disease onset, using a 9-point SEV scale [13–16, 25].

Interspecific hybrids, created based on phylogenetically distant species, were obtained from the coordinating institution – the Institute of Potato Research of NAAS, to expand the hybridisation nursery and conduct breeding work.

Results and discussion. The correct and justified selection of the initial parental forms for hybridisation largely determines the quality of the breeding process. Hereditary traits are considered the basis for effective progeny during the creation of hybrids. The role of parental forms in creating a hybrid is that they carry specific potential for the newly created form, which combines their traits.

The complexity lies in the fact that each of the individual traits or properties of the parents is not directly transferred to the created progeny. In the hybrid, the properties of the parental forms are combined according to different hereditary traits. They can change in each hybrid [38].

For successful pair selection, it's necessary to thoroughly study all traits and biological properties of the planned crossing components, their history, and breeding value, and consider the conditions of interest to the breeder, under which traits and properties form best. Only then can one choose a suitable parental pair [27, 29].

The research was conducted according to the complete breeding process scheme. A sign nursery was formed from the initial potato material of various origins, and its complex evaluation was carried out according to the leading indicators: productivity, economically valuable and qualitative indicators, and resistance to late blight (visually) of the available material.

Late blight (*Phytophthora infestans (mont.) De bary*) is caused by fungus and is one of the most damaging diseases of the crop. It causes the loss of vegetative mass (leaves) of potato plants during the growing period and, during storage, causes tubers to rot.

The harmfulness of the disease can lead to the death of 50–60 % of plants and, in years of epidemics, even more significant losses. We analysed all available breeding material for resistance to this disease, considering the research area's high susceptibility to late blight outbreaks, which are observed almost annually.

The source material created by involving phylogenetically distant species in the hybridisation process is biologically and morphologically similar to cultivated varieties. However, these hybrids lag behind varieties concerning the average mass of marketable tubers, affecting the productivity of one bush. They also stand out in stolon length, stem number, and much more extended vegetation periods, corresponding to late-ripening potato varieties.

Interspecific hybrids are characterised by these indicators: a large number of tubers under the bush (11.3–27.0 units) and a sufficiently high mass (74–89 g). These hybrids have traits of cultivated varieties with high productivity per bush, moderate tuber mass, and marketability (up to 95.0 %).

Incorporating these genes into hybridisation has practical significance for potato breeding, as interspecific hybrids are characterised by high tuber marketability, increased starch content, and high vegetative mass resistance to late blight (7.3–8.8 points).

Analysing interspecific hybrids as one group involved in the breeding process allows the conclusion of the possibility of creating varieties with high yield combined with late blight resistance and economically valuable characteristics.

Characteristics of interspecific hybrids created based on phylogenetically distant species and potato varieties by primary indicators are presented in Table 1.

It should be noted that in terms of the number of tubers per bush and their marketability, varieties from different original institutions and foreign varieties: Mavka, Duża, Svalyavska, Myroslava, Sluch, Pamir, Alouette, Vytok stood out.

1. Evaluation results of varieties and hybrids from the source breeding material nursery

Variety Name, Hybrid Number and Origin	Number of Tubers, units/bush	Average Tuber Weight, g	Tuber Marketability, %	Yield, t/ha	Resistance to Late Blight, points (9-point scale SEV)
1	2	3	4	5	6
Hybrids created based on phylogenetically distant species					
88.1450 c.2 *((S. acaule* × *S. bulbocastanum)* × *(S. phureja* × *S. andigenum))* × Aurelija	19,0	77	84,0	28,6	8,0
90.841 c.2 *((S. acaule* × *S. bulbocastanum)* × *(S. phureja, S. demissum* × *S. andigenum*)) × ((Poliyska Rozheva × Lviv'ianka) × (Gidra × Gitte))	11,3	78	76,4	22,3	8,8
91.765/15 *((S. acaule* × *S. bulbocastanum)* × *(S. phureja* × *S. demissum*)) × (Marko × Volovetska)	16,1	74	83,7	26,5	7,9
89.721 c.23 *((S. demissum* × *S. bulbocastanum)* × *S. andigenum*)) × Belaruska 3	18,8	89	95,0	25,3	7,3
90.674/12 *((S. acaule* × *S. bulbocastanum)* × *(S. phureja* × *S. demissum*)) × (Marko × Volovetska)	22,2	79	71,8	23,7	8,0
86.563 c.4 ((*S. acaule* × *S. bulbocastanum*) × *S. phureja*) × (*S. demissum* × *S. andigenum*))	27,0	81	76,9	31,9	8,0
Carpathian Agriculture Research Institute NAS varieties					
Mavka	7,2	89	80,0	21,6	7,9
Slava	6,7	77	78,0	35,4	7,8
Vira	7,8	78	79,0	30,9	7,3
Vira	6,6	74	80,0	28,0	8,0
Legenda	8,0	89	79,8	38,0	8,1
Varieties of the Lviv National University of Nature Management					
Zahidna	8,1	78	77,0	25,6	8,0
Student	5,6	77	79,4	26,5	7,8
Duza	7,1	80	90,0	31,0	7,7
Varieties of the Institute of Agrarian Resources and Regional Development NAS					
Svalyavska	7,8	80	75,4	27,0	8,2
Perechynska	7,6	63	78,9	25,3	8,7
Institute of Potato Research NAS varieties					
Chervona Ruta	7,4	81	80,9	33,0	8,8
Myroslava	6,5	89	89,0	37,9	7,9
Sluch	6,9	80	87,6	32,9	7,9
Shchedryk	8,0	90	91,0	41,0	7,5
Foreign varieties					
Nevska	7,8	76	78,0	19,3	5,8

1	2	3	4	5	6
Typhoon	6,9	67	75,5	16,2	5,9
Pamir	9,1	78	78,2	17,6	6,1
Alouette	8,9	81	80,1	15,6	6,3
Krynytsia	14,5	83	84,1	28,7	6,9
Pryhozha	12,4	87	76,6	29,9	6,8
Vytok	16,9	88	90,1	30,4	8,0

Special attention deserves Ukrainian varieties – Legend, Perechynska, Shchedryk, and Chervona Ruta. Although they belong to different maturity groups, they show high resistance to late blight (7.5–8.8 points) combined with high yield (33.0–41.0 t/ha) in the conditions of the Western Forest-Steppe.

High resistance to late blight along with high yield was exhibited by varieties – Slava, Duża, Svalyavska, Chervona Ruta, Shchedryk, Alouette, Krynytsia – from different original institutions.

The analysis of the obtained data regarding the economic indicators of the varieties indicates their recommended involvement in the breeding process as donors of listed traits regarding the soil and climatic conditions of the Western Forest-Steppe of Ukraine.

Conclusions

1. Interspecific hybrids are characterised by a large number of tubers per bush (11.3–27.0 units) and a sufficiently high tuber mass (74–89 g). These hybrids possess traits of cultivated varieties with high productivity per bush, moderate tuber mass, and marketability (up to 95.0 %).

2. Incorporating these genes into hybridisation has practical significance for potato breeding, as interspecific hybrids are characterised by high tuber marketability, increased starch content, and high vegetative mass resistance to late blight (7.3–8.8 points). Analysing interspecific hybrids as one of the groups involved in the breeding process allows the conclusion of the possibility of creating varieties with high yield combined with late blight resistance and economically valuable characteristics.

3. High resistance to late blight along with high yield was exhibited by varieties such as Knyahynia, Myroslava, Legend, Oksamyt-99, Krynytsia, Pryhozha, Vytok, Alouette, Zakhidna, Svalyavska, among others.

4. Varieties present in the nursery of source material from both Ukrainian and foreign selections: Slava, Legend, Duża, Svalyavska, Shchedryk, Myroslava, Chervona Ruta, Krynytsia, Pryhozha are recommended for involvement in the hybridisation process to create new breeding material.

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