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Field Evaluation of Ukrainian Potato Varieties for Resistance to Fungal and Bacterial Pathogens in the Polissya Area of Ukraine

Ukrayna'nın Polissya Bölgesinde Ukrayna Patates Çeşitlerinin Arazide Fungal ve Bakteriyel Patojenlere Karşı Direnç Açısından Değerlendirilmesi

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ABSTRACT

This study aimed to assess the field resistance of Ukrainian potato varieties to fungal and bacterial pathogens under natural infectious conditions in the Polissya area of Ukraine. Field experiments were conducted during 2020-2022 to examine the manifestation and spread of fungal and bacterial diseases on 20 Ukrainian potato varieties across different maturity groups. Varieties were evaluated for resistance to Alternaria blight, *Rhizoctonia solani*, Common scab (***Streptomyces*** **spp.**), and Fusarium dry rot using predefined scales. The Ukrainian potato varieties Aria, Khortytsia, Kniahynia, Myroslava, Shchedryk, and Slovianka displayed field resistance to Alternaria blight. The varieties Charunka, Feia, Khortytsia, Okolytsia, and Shchedryk showed field resistance to *R. solani*. The varieties Aria, Okolytsia, Skarbnytsia, Strumok, and Slovianka were highly resistant to Common scab in field conditions, while Anika, Aria, Charunka, Kimmeria, Letana, Slovianka, Shchedryk, and Tyras exhibited field resistance to Fusarium dry rot. Twelve out of 20 potato varieties displayed field resistance to multiple pathogens with five of them (Aria, Charunka, Khortytsia, Slovianka, and Shchedryk) being resistant to the majority of pathogens under investigation. These varieties hold promise for integration into cropping systems with reduced fungicide usage. Additionally, these varieties can be recommended for inclusion in breeding programs as valuable sources of resistance to these fungal and bacterial pathogens. Future research should focus on elucidating the genetic basis of resistance in these varieties and further exploring the nature of inheritance of the observed resistance from the parental forms, that include the varieties Bellarosa, Beloruskyi 3, Bahriana, Slovianka, Oberih, Lyu, Meve, Kondor, Tyras and Barylchykha, and the hybrids 86.281c12, KE 78.50.53, 77.583/16, and P.88.12-11.

Keywords: Potato, resistance, *Alternaria solani*, *Alternaria alternata*, *Rhizoctonia solani*, *Streptomyces* spp., *Fusarium* spp.

ÖZ

Bu çalışma, Ukrayna'nın Polissya bölgesindeki doğal bulaşıcı koşullar altında Ukrayna patates çeşitlerinin fungal ve bakteriyel patojenlere karşı tarla direncini değerlendirmeyi amaçlamıştır. Farklı 20 Ukrayna patates çeşidinde fungal ve bakteri hastalıklarının ortaya çıkışını ve yayılmasını incelemek için 2020-2022 yılları arasında arazi denemeleri yapılmıştır. Çeşitler, önceden tanımlanmış skalalar kullanılarak Alternaria yanıklığı, *Rhizoctonia solani*, Adi uyuz (*Streptomyces* spp.) ve Fusarium kuru çürüklüğüne karşı direnç açısından değerlendirilmiştir. Ukrayna patates çeşitleri Aria, Khortytsia, Kniahynia, Myroslava, Shchedryk ve Slovianka çeşitleri Alternaria yanıklığına karşı; Charunka, Feia, Khortytsia, Okolytsia ve Shchedryk çeşitleri *R. solani*'ye karşı; Aria, Okolytsia, Skarbnytsia, Strumok ve Slovianka çeşitleri *Streptomyces* spp. ve Anika, Aria, Charunka, Kimmeria, Letana, Slovianka, Shchedryk ile Tyras, çeşitleri ise Fusarium kuru çürüklüğüne karşı arazi şartlarında direnç göstermişlerdir. 20 patates çeşidinden 12'si birden fazla patojene karşı çoklu direnç sergilemiş, bunlardan beşi (Aria, Charunka, Khortytsia, Slovianka ve Shchedryk) de araştırılan patojenlerin çoğuna karşı direnç sağlamıştır. Bu çeşitler, azaltılmış fungisit kullanımıyla ürün yetiştirme sistemlerine entegrasyon konusunda umut vaat etmektedir. Ek olarak bu çeşitler, fungal ve bakteriyel patojenlere karşı direnç kaynağı olarak ıslah programlarına dahil edilmek üzere önerilebilir. Gelecekteki araştırmalar, bu çeşitlerdeki direncin genetik temelini aydınlatmaya ve Bellarosa, Beloruskyi 3, Bahriana, Slovianka, Oberih, Lyu, Meve, Kondor, Tyras ve Barylchykha çeşitleri ile 86.281c12, KE 78.50.53, 77.583/16 ve P.88.12-11 melezlerini içeren ebeveyn formlardan sağlanan direncin kalıtımının doğasını araştırmaya odaklanmalıdır.

Anahtar Kelimeler: Patates, dayanıklılık, *Alternaria solani*, *Alternaria alternata*, *Rhizoctonia solani*, *Streptomyces* spp, *Fusarium* spp.

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Introduction

Many pests and pathogens can significantly affect potato cultivation in Ukraine, causing average annual yield losses of 20-25%. Total losses could be even higher because some of them can affect the crop not only during the growing season but also in the postharvest period and during storage of tubers (Cherednychenko et al., 2019; Kononuchenko & Molotskyi, 2003).

Late blight, caused by *Phytophthora infestans* (Mont.) de Bary, stands out as one of the most pervasive and devastating diseases, both on a global scale and within Ukraine. It is known to cause severe yield losses, particularly affecting early potato varieties, especially during epiphytotic years (Cherednychenko et al., 2008; Dong & Zhou, 2022; Flier & Turkensteen, 1999; Fry & Goodwin, 1997; Goodwin, 1997). Crop losses are higher in regions with emerging economies, primarily due to the unavailability of cost-effective chemical control strategies. As climatic conditions become more suitable for disease development, the consequences become even more severe, culminating in the total obliteration of yields (Rakotonindraina et al., 2012).

Alternaria blight, caused by *Alternaria solani* Sorauer and *Alternaria alternata* (Fr.) Keissler can also cause serious damage to the potato crop. A yield reduction of 30-35% may take place when over 40% of potato plants are affected in the field. Medium-ripe and medium-late maturing potato varieties are particularly susceptible to these pathogens (Andersen et al., 2018; Cherednychenko et al., 2016).

Rhizoctonia solani Kühn is another significant threat to potato seed production. The absence of resistant varieties may result in a mortality of approximately 50% of seedlings before emergence, with "white leg" symptoms appearing on nearly all plants during the growing season and sclerotia formation on the majority of tubers. Under favourable conditions, disease not only compromises seed material quality, but also causes substantial losses, potentially reaching 49% of the harvest (Zhang et al., 2021).

In Ukraine, the occurrence of late blight outbreaks exhibits substantial variability due to the multifaceted nature of factors influencing pathogen development, including weather conditions, agricultural practices, and potato varieties (Polozhenets, 1997). On the other hand, Rhizoctonia is documented annually at damage levels of 30-60% to sprouts, 25-70% to stolons, and 10-25% to roots, thereby significantly compromising the quality of planting material and overall tuber yields, where losses up to 40-60% were recorded (Cherednychenko et al., 2008).

In Polissya - the primary potato growing region of the country, potatoes are persistently affected by various diseases such as bacterial ring rot (*Clavibacter sepedonicus* (Spieckermann & Kotthoff; Li et al.), Common scab (*Streptomyces* spp.), powdery scab (cercozoan *Spongospora subterranea* (Wallroth) Lagerheim), potato wart disease (*Synchytrium endobioticum* (Schilbersky) Percival), late blight (*Phytophthora infestans* (Montagne) de Bary), early blight (*Alternaria* spp.), and Fusarium dry rot (*Fusarium* spp.). This persistence can be attributed to the optimal moisture and temperature conditions conducive to the development of these pathogens and cultivation practices of growers. Conversely, in the southern regions of Ukraine, characterized by elevated air and soil temperatures and a dearth of moisture during the plant's growing season, plant pathogens causing wilt diseases primarily prevail (Kononuchenko & Molotskyi, 2003).

Effective safeguarding crops against the diverse pathogens mentioned above can only be reached in an integrated approach. This approach involves the utilization of agrotechnical, chemical, biological, and economic methods, tailored to the specific soil and climatic conditions of the potato cultivation zone.

Presently, considerable emphasis within potato protection systems is directed towards the adoption of modern cultivation technologies and the utilization of new varieties featuring enhanced economic and qualitative characteristics. Nevertheless, chemical methods of combating pathogens remain important, although they often cause increased production costs, environmental pollution, and the emergence of pesticide resistance in harmful organisms (Andersen et al., 2018; Kononuchenko & Molotskyi, 2003; Lisovyi & Trybel, 1998).

In the Netherlands, a country with an annual potato production exceeding 7 million tons (including 1 million tons of seed potatoes), more than 50% of all pesticides employed for crops protection are dedicated to safeguarding potato against late blight. This safeguarding lead to annual losses of more than 100m euro on a harvest value of more than 700m euro (Haverkort et al., 2016). Notably, the measures implemented to combat late blight at global scale contribute to more than 10% of the overall CO_2 emissions associated with potato production (Haverkort & Hillier, 2011), and the combined expenses associated with yield loss and management worldwide range from of 3-10 billion USD annually (Dong & Zhou, 2022).

Given this scenario, significant efforts are directed towards the exploration of environmentally sustainable methods for pathogen control. These efforts span from the development of biological preparations as an alternative to chemical pesticides, adaptation of cultivation methods and fertilisation schemes, to the breeding of potato varieties with resistance against the most harmful pathogens, preferably in an integrated way (Ilchuk et al., 2021; Russell, 1982; Trybel et al., 2006).

To date, Ukrainian potato breeders have succeeded in generating numerous potato varieties characterized by (partial) field resistance to pests and diseases distributed in the country. Nevertheless, in practical cultivation, protective measures are typically formulated without taking resistance of these varieties into account (Ilchuk et al., 2021; Osypchuk, 2011; Podhaietskyi et al., 2018; Trybel et al., 2006). This, while it is widely acknowledged that favouring resistant varieties over those susceptible to pests and diseases can safeguard 15-20% of the yield and substantially enhances the overall efficacy of potato protection measures and reduction in pesticide usage (Lisovyi & Trybel, 1998; Osypchuk, 2011; Trybel et al., 2006).

Over the course of several decades, the Institute of Potato Research at the National Academy of Agrarian Sciences of Ukraine has undertaken a series of projects investigating the manifestation and development of fungal and bacterial diseases in potatoes, both under natural and artificially induced infection. The primary aim has been to enhance the potato breeding program, particularly with regards to resistance against Late blight, Alternaria blight, and Fusarium wilt (Andriychuk & Homyak, 2013; Cherednychenko et al., 2008; Cherednychenko et al., 2016; Cherednychenko et al., 2019; Koval et al., 1978; Koval et al., 1979; Koval et al., 1983; Podhaietskyi et al., 1994). Additionally, research has focused on improving resistance to Rhizoctonia and Common scab (*Streptomyces* spp.) (Polozhenets, 1997), as well as addressing issues related to Phytophthora and Fusarium dry rot (Podhaietskyi et al., 1994; Podhaietskyi et al., 2018). Throughout the research, several varieties were identified as valuable donors, providing essential traits for developing disease-resistant potato varieties.

This study aimed to extend the ongoing investigations into potato diseases dissemination, incidence and intensity on varieties from various maturity groups within the Ukrainian potato breeding programs. Additionally, the target was to evaluate the field resistance of these varieties to the predominant potato pathogens under the natural infectious conditions prevalent in the Polissya area of Ukraine during the 2020-2022 growing seasons.

Methods

The research was conducted at the Laboratory of Immunity and Plant Protection within the Breeding Department of the Institute of Potato Research, NAAS. The experimental site featured sod-podzolic sandy loam soil, characteristic of the Polissya area of Ukraine (village Nemeshaevo, Bucha district, Kyiv region, Ukraine) with humus content at 1.4%, easily hydrolysed nitrogen at 98, mobile phosphorus at 72, exchangeable potassium at 100 ml/kg, and calcium and magnesium at 4.4 and 0.5 mg equiv. per 100 g of soil, respectively. The meteorological data for 2020-2022 growing season is provided in Table 1. The presence of the pathogens studied (based on symptoms in the field expressed as incidence and intensity) during the growing seasons in the study years 2020-2022 is presented in Table 2.

The typical agricultural technology for potato cultivation in the Polissya area was applied during the study period, it comprises the following steps: 1) soil preparation involving disking and sowing of green manure (cover) crops or siderates such as oil radish, mustard or vetch-oat mixture; 2) successive stages of soil preparation and additional sowing of green manure crops (cultivation); 3) plowing the (green) mass of the green manure crops into the soil; 4) preparation of potato tubers for planting; 5) plowing; 6) pre-planting soil preparation (cultivating); 7) planting potatoes with localized application of mineral fertilizers, plant protection agents and growth regulators; 8) formation of high-volume ridges; 9) herbicide application before potato seedling emergence; 10) herbicide application on potato seedlings, combined with growth regulators, fungicides, and trace elements; 11) pest control measures against the Colorado potato beetle (*Leptinotarsa decemlineata* (Say)); 12) up to five fungicide treatments and foliar fertilization with complex water-soluble fertilizers at intervals of 7-10 days; 13) mowing potato crops; 14) further treatment of potato crops with contact fungicides; 16) harvesting of tubers; 17) post-harvest processing of potato tubers; and potato tuber storage at 2-4°C.

Twenty potato varieties were used in the study: A) *early maturity group*: Kimmeria, Shchedryk, Skarbnytsia, Slauta, and Tyras; B) mid-early maturity group: Aria, Fantazia, Strumok, and Zlahoda; C) medium-ripe maturity group: Anika, Charunka, Feia, Hurman, Ivankivska rannia, Kniahynia, Khortytsia, Letana, Myroslava, Okolytsia, and Slovianka (all originated from the Institute of Potato Research NAAS).

The field experiment was laid down in two variants: 1) a control variant subjected to three pesticide treatments, using the fungicide Acrobat 90/600 WG (active substances: dimethomorph 90 g/kg + mancozeb 600 g/kg; BASF, Germany) at a rate of 2 kg/ha and an insecticide for Colorado potato beetle control (Coragen 20, KC, chlorantraniliprole, 200 g/l; DuPont, USA) at a rate of 0.05-0.06 l/ha, and 2) an experimental variant without fungicide treatment, but maintaining the Colorado beetle insecticide treatment as mentioned above. Pesticide applications were made at budding phase, flowering phase and 10 days after that phase.

Plantings were done in two-row plots of 15 m^2 with 25 tubers per row. The experiment was laid down in randomized block design with three repeats.

Throughout the growing season, phenological observations were conducted, which included noting the features and start of key plant development phases and visually assessing crop conditions and disease symptoms. Records were also maintained for plant density (measured in thousands of plants per hectare) and yield (measured per plot and calculated as tons per hectare) (Bondarchuk & Koltunov, 2019).

Table 1

Meteorological data for the 2020-2022 growing seasons, 5 month period (Kyiv region, Ukraine)

	April			May			June			July			August		
	AT ^{0}C	ST ^{0}C	P mm	AT ^{0}C	ST ^{0}C	P mm	AT ^{0}C	ST ^{0}C	P mm	AT ^{0}C	ST ^{0}C	P mm	AT ^{0}C	ST ^{0}C	P mm
Season								2020							
I decade	7.5	2.7	14.0	11.1	10.5	28.1	18.9	21.7	15	21.4	19.2	13	23.2	19.5	0
II decade	8.4	5.6	15.0	14.6	14.3	36.9	20.8	22.2	13	21.2	20.8	20	24.1	23.0	7
III decade	10.2	7.9	12.0	20.5	20.6	45.0	22.7	24.0	12	20.6	18.0	42	22.8	20.1	0.3
Month average	8.7	5.4	82	15.4	15.1	110	20.8	22.6	40	21.1	19.3	70	23.4	20.9	7.3
10 years average	10		41	14.2		65	19.5		80	21.3		85	20.4		56
Deviation +/-	– 1.3		+ 41	+ 1.2		+45	+1.3		– 40	-0.2		– 15	+3.0		– 48.7
Season								2021							
I decade	8.9	3.7	12	10.4	10.5	15	17.8	21.0	13.6	20.8	25.3	16	23.2	20.8	6
II decade	9.7	5.9	17	14.5	14.3	13	20.7	22.5	12.4	21.2	24.7	21	24.1	25.0	5
III decade	10.9	8.7	13	17.5	20.6	9	22.5	23.6	11	22.6	19.1	40	22.9	23.5	10.2
Month average	8.5	6.1	83	14.5	15.1	37	20.3	22.4	37	21.5	23.0	77	23.4	23.1	21.2
10 years average	10		42	14.2		65	19.5		80	21.3		85	20.4		56
Deviation +/-	– 0.5		+ 41	+ 0.5		– 28	+0.8		– 43	+0.2		– 8	+3.0		– 34.8
Season								2022							
I decade	7.5	2.8	13	15.6	14.8	0	16.9	20.7	15	21.8	25.2	13	24.2	21.5	7
II decade	8.3	5.4	14	19.7	16.4	0	18.8	22.0	13	21.2	24.8	20	24.0	25.0	0
III decade	9.8	8.6	15	20.8	20.7	0	20.7	23.1	29	20.6	18.0	42	23.7	24.1	0.2
Month average	8.5	8.3	82	18.7	17.3	0	18.8	21.9	57	21.2	22.8	74	24.0	23.5	7.2
10 years average	10		42	14.2		65	19.5		80	21.3		85	20.4		56
Deviation +/-	– 1.5		+ 40	+4.5		– 65	+4.5		–23	–0.1		–11	+3.6		–48.8

* AT: Air temperature; ST: Soil temperature; P: Precipitation

During the vegetation season the incidence (the number of plant units that are (visibly) diseased, relative to the total number assessed) and severity (the area or volume of plant tissue that is (visibly) diseased, relative to the total plant tissue) of potato diseases were evaluated (Kumar et al., 2023; Trybel & Bondarchuk, 2013).

For assessment of disease severity, diseased leaves were categorized as per the scale:

Grade	Leaf area infected (%)
0	No disease symptoms
1	1-2.5
2	2.6-5
3	6-10
4	11-15
5	16-25
6	26-50
7	51-75
8	Total blight (death of all plants)

The incidence of Alternaria blight was noted from the first decade of June to the second decade of August three times. The indicator (R) for disease incidence was calculated using the formula 1:

$$R = (n/N) \times 100\% \quad (1),$$

where

R – disease incidence (%)

n – number of infected plants,

N- total number of plants examined.

The total disease severity was determined as a percentage by the formula 2:

$$\text{Disease severity} = (\sum ab/NK) \times 100\% \quad (2),$$

where

∑ summation,

a - number of leaves in each category

b - grade of disease severity

N – total number of leaves observed

K - Maximum numerical value/grade of disease severity

Table 2.

Severity and incidence of Alternaria *blight* (*A. solani*, *A. alternata*) *on potato varieties under cultivation conditions of the Polissya region in Ukraine, 2020-2022*

Potato variety	Severity, %						Incidence, %					
	I assessment		II assessment		III assessment		I assessment		II assessment		III assessment	
	Control	Experiment	Control	Experiment	Control	Experiment	Control	Experiment	Control	Experiment	Control	Experiment
Early maturity group												
Kimmeria	0	2.9*	2.0	7.6*	4.0	14.6*	0	7.5*	8.4	21.0*	12.0	34.0*
Skarbnytsia	0	3.7*	1.0	7.7*	3.5	14.7*	0	9.8*	8.0	30.0*	17.8	37.0*
Shchedryk	0	0.5*	0.5	3.2*	2.0	7.7*	0	2.5*	1.6	4.0*	5.6	14.0*
Slauta	0	2.1*	3.5	4.6	6.0	17.6*	0	4.9*	6.8	17.0*	10.4	26.0*
Tyras	0	3.7*	3.0	6.2*	9.5	15.6*	0	7.6*	8.8	22.0*	12.0	31.0*
Mid-early maturity group												
Aria	0	0.7*	0	3.0*	2.5	8.6*	0	2.0*	0	6.0*	8.0	14.0*
Zlahoda	0	4.7*	6.0	14.1*	11.5	20.9*	0	14.0*	13.7	41.0*	22.9	59.0*
Strumok	0	4.8*	2.9	11.5*	4.5	13.6*	0	12.0*	11.9	35.0*	16.7	48.5*
Fantazia	0	4.7*	2.7	10.7*	4.0	15.6*	0	10.5*	12.1	30.0*	15.7	41.5*
Medium-ripe maturity group												
Hurman	0	2.7*	2.3	9.1*	4.2	16.9*	0	6.8*	8.0	20.0*	14.4	36.5*
Slovianka	0	1.7*	1.8	7.2*	2.4	9.7*	0	4.9*	5.6	14.0*	8.0	30.0*
Anika	0	3.0*	1.4	5.5*	3.1	12.3*	0	7.1*	8.5	22.0*	15.4	38.5*
Okolytsia	0	8.1*	3.5	14.3*	4.7	18.7*	0	14.7*	14.2	44.0*	18.6	53.5*
Myroslava	0	2.3*	1.4	5.7*	4.6	10.0*	0	6.3*	7.6	19.0*	11.4	28.5*
Ivankivska rannia	0	2.5*	1.8	7.1*	3.1	12.6*	0	6.7*	8.0	20.0*	15.0	37.5*
Kniahynia	0	3.7*	2.1	8.3*	3.4	9.6*	0	9.7*	11.8	30.0*	15.4	35.5*
Charunka	0	3.3*	2.2	8.8*	3.2	13.0*	0	7.6*	9.2	23.0*	11.4	28.5*
Letana	0	2.0*	1.5	6.1*	3.0	12.1*	0	5.4*	6.4	16.0*	10.6	26.5*
Feia	0	1.7*	1.4	5.6*	3.8	15.4*	0	4.6*	5.5	14.0*	11.5	28.5*
Khortytsia	0	2.6*	1.6	6.5*	2.6	10.4*	0	4.1*	5.2	13.0*	9.8	24.5*

* the difference with the control is significant at $p \leq .05$

Table 3.
Varietal differences to potato tuber damage by fungal and bacterial pathogens, 2020-2022

No	Potato variety	Disease severity (percentage of potato tubers affected), %											
		Rhizoctonia solani				Common scab (*Streptomyces* spp.)				*Fusarium* dry rot (*Fusarium* spp.)			
		2020	2021	2022	Medium	2020	2021	2022	Medium	2020	2021	2022	Medium
Experimental group													
Early maturity group													
1.	Kimmeria	0	42.0*	24.0*	22.0	10.0*	13.0*	6.0*	9.7	8.0*	4.0*	17.0*	9.7
2.	Skarbnytsia	0	43.0*	24.0*	22.3	6.0*	5.0*	2.7*	4.6	16.0*	7.0*	17.8*	13.6
3.	Shchedryk	0	21.0*	9.0*	10.0	14.0*	23.0*	7.0*	14.7	6.0*	5.0*	12.0*	7.7
4.	Slauta	2.0*	49.0*	26.9*	26.0	6.0*	8.0*	4.4*	6.1	29.0*	10.0*	15.5*	18.2
5.	Tyras	0	42.0*	23.1*	21.7	24.0*	5.0*	2.8*	10.6	20.0*	3.0*	4.6*	9.2
Mid-early maturity group													
6.	Aria	4.0*	62.0*	2.2*	29.7	9.0*	9.0*	5.0*	7.7	19.0*	1.0*	1.5*	7.2
7.	Zlahoda	10.0*	21.0*	11.5*	14.2	7.0*	15.0*	8.2*	10.1	32.0*	19.0*	29.4*	26.8
8.	Strumok	8.0*	41.0*	22.5*	23.8	15.0*	7.0*	3.8*	8.6	21.0*	9.0*	14.0*	14.7
9.	Fantazia	3.0*	45.0*	24.7*	24.2	5.0*	19.0*	10.4*	11.5	17.0*	10.0*	15.0*	14.0
Medium-ripe maturity group													
10.	Hurman	0	49.0*	26.8*	25.3	11.0*	4.0*	2.0*	5.7	17.0*	10.0*	14.9*	14.0
11.	Slovianka	3.0*	56.0*	30.8*	29.9	4.0*	7.0*	3.8*	4.9	4.0*	5.0*	7.0*	5.3
12.	Anika	16.0*	55.0*	30.2*	33.7	1.0*	21.0*	12.0*	11.3	10.0*	8.0*	12.4*	10.1
13.	Okolytsia	0	20.0*	9.0*	9.7	6.0*	2.0*	1.2*	3.1	23.0*	8.0*	12.5*	14.5
14.	Myroslava	7.0*	42.0*	23.0*	24.0	17.0*	5.0*	2.8*	8.3	15.0*	9.0*	14.0*	12.7
15.	Ivankivska rannia	1.0*	57.0*	31.3*	29.8	22.0*	8.0*	4.5*	11.5	31.0*	5.0*	8.1*	14.7
16.	Kniahynia	2.0*	25.1*	14.5*	13.8	17.0*	4.0*	2.1*	7.7	12.1*	11.0*	13.2*	12.1
17.	Charunka	4.0*	26.0*	14.3*	14.8	7.0*	21.0*	11.8*	13.3	22.0*	4.0*	6.3*	10.8
18.	Letana	0	48.0*	26.4*	24.8	54.0*	21.0*	11.9*	29.0	15.0*	3.0*	4.6*	7.5
19.	Feia	4.0*	16.0*	10.0*	10.0	12.0*	7.0*	3.5*	7.5	15.0*	10.0*	16.0*	13.7
20.	Khortytsia	0	16.0*	8.8*	8.3	20.0*	12.0*	6.6*	12.9	23.0*	11.0*	17.1*	17.0
Control group													
Early maturity group													
1.	Kimmeria	0	8.4	4.8	4.4	2.0	2.6	1.2	4.3	1.5	0.8	3.4	1.9
2.	Skarbnytsia	0	8.6	4.4	4.3	1.2	1.0	1.4	1.2	3.2	1.4	3.5	2.7
3.	Shchedryk	0	4.2	1.5	1.9	2.8	1.6	1.3	1.6	1.2	1.0	2.4	1.5
4.	Slauta	0.5	9.8	5.0	5.1	1.1	1.6	0.8	1.2	5.8	2.0	3.1	3.6
5.	Tyras	0	8.2	4.2	4.1	4.6	1.0	0.6	2.1	4.0	0.6	0.9	1.8
Mid-early maturity group													
6.	Aria	1.0	8.5	0.5	3.3	2.1	2.2	1.2	1.8	4.7	0.2	0.4	1.8
7.	Zlahoda	2.5	5.0	2.9	3.5	1.7	3.7	2.0	2.5	8.0	4.5	7.3	6.6
8.	Strumok	2.0	10.0	5.6	5.9	3.5	1.5	1.0	2.0	5.2	2.5	3.5	3.7
9.	Fantazia	0.7	11.2	6.0	6.0	1.5	5.0	2.5	3.0	4.0	2.5	4.0	3.5
Medium-ripe maturity group													
10.	Hurman	0	9.8	5.5	5.1	2.2	1.0	0.5	1.2	3.4	2.0	1.0	2.1
11.	Slovianka	0.5	11.2	6.0	5.9	0.8	1.4	0.8	1.0	0.8	1.0	1.4	1.1
12.	Anika	3.2	11.0	6.0	6.7	1.0	4.2	2.4	2.5	2.0	1.6	2.5	2.0
13.	Okolytsia	0	4.0	1.8	1.9	2.0	0.5	0.2	0.9	4.6	1.6	2.5	2.9
14.	Myroslava	1.4	8.0	4.5	4.6	2.5	1.0	0.5	1.3	3.0	1.8	2.8	2.5
15.	Ivankivska rannia	0.2	11.4	6.3	6.0	3.5	1.6	1.0	2.0	6.2	1.0	1.6	2.9
16.	Kniahynia	0.4	9.0	4.9	4.8	3.0	0.8	0.4	1.4	5.6	3.0	4.6	4.4
17.	Charunka	0.8	5.0	2.9	2.9	1.5	4.0	3.0	2.6	4.4	0.8	1.3	2.2
18.	Letana	0	9.0	5.4	4.8	10.8	4.5	2.4	5.9	3.0	0.6	1.0	1.5
19.	Feia	1.0	3.0	2.0	2.0	2.0	1.4	0.7	1.4	3.0	2.0	3.2	2.7
20.	Khortytsia	0	3.2	1.8	1.7	4.0	2.4	1.3	2.6	4.6	2.2	3.4	3.4

* the difference with the control is significant at $p < 0.05$

Potato varieties were considered resistant to Alternaria blight, for which the disease incidence level should not exceed 30% of plants, while the level of disease severity had to be in the range of 3-10% (Trybel & Bondarchuk, 2013).

Varieties were considered resistant to Rhizoctonia (*R. solani*) for which 5 to 10% of the tubers were affected, for Common scab (*Streptomyces* spp.) – 5-20% of the tubers, and Fusarium dry rot (*Fusarium* spp.) – 5-10% of the tubers, respectively (Trybel & Bondarchuk, 2013).

The statistical processing of experimental data was conducted using disperse analysis (ANOVA) and software packages of Microsoft Office Excel 2010 and STATISTICA 10. The least significant difference (LSD) test was used to test for significant differences in multiple comparisons at the 0.05 significance level.

Results

It is known, that the incidence and severity of potato diseases can be influenced by weather conditions. Thus, a comprehensive analysis of the climatic factors during the research period was performed in objectively evaluating the growth and development of both potato plants and pathogens.

In the spring of 2020, the climatic conditions proved favourable for commencing field operations (Table 1). Soil preparation and potato planting took place between April 17 and April 19. The following month May was marked by higher temperatures (15.4°C as opposed to the long-term average of 14.2°C) and increased precipitation (exceeding the long-term average by 45 mm), which had a positive impact on the growth and development of potato seedlings. June, however, experienced a relatively drier period, with only half of the normal precipitation recorded. Nonetheless, early July brought rain, aiding plant development and facilitating the further formation of the crop following flowering.

The spring of 2021 witnessed favourable weather conditions for initiating field work, with soil preparation and potato planting conducted at the optimal period from April 5 to April 7, ensuring the speedy emergence of seedlings. May continued to feature elevated temperatures (14.5°C in contrast to the long-term average of 14.2°C) but was notably drier, with 28 mm less precipitation compared to the long-term average. This relatively dry condition had an initial adverse impact on the growth and development of potato plants. In June the dry spell continued, with only 37 mm of precipitation compared to the annual average of 80 mm. However, July brought more rainfall, mitigating the situation and creating more favourable growth conditions.

In 2022, during the start of field operations and the early stages of planting and the growth of early-ripening group plants, meteorological conditions had the most pronounced negative influence. In 2022, May and June experienced exceptionally high temperatures, surpassing the long-term averages by 4.5°C, and were marked by limited precipitation, with only 57 mm recorded compared to the long-term average of 80 mm. These conditions initially hindered the growth and development of potato plants. Nevertheless, July brought relief with 74 mm of rainfall (compared to the annual average of 85 mm), generally improving the conditions for plant growth and development. In 2022, the harvest yield was slightly higher when compared to 2020 (by 1.1-3.5 t/ha) and 2021 (by 1.4-3.8 t/ha), despite the earlier restraining meteorological conditions.

The relatively dry weather conditions during the 2020 - 2022 growing seasons significantly influenced the distribution of pathogens and the severity of potato diseases, particularly late blight (*Phytophthora infestans* (Mont.) de Bary) and Alternaria blight. These conditions, while unfavourable for late blight development, were rather optimal for the manifestation and harmfulness of Alternaria blight.

The initial signs of Alternaria blight on potato plants became evident during the formation of flower buds and at the onset of flowering. The disease exhibited a moderate progression during this phase, gradually extending its presence to encompass a larger portion of the plant. The disease severity levels were as follows: in the control, the range was from 2.0 to 11.5%, while in the experiment, it ranged from 7.7 to 20.9% at the third assessment. Furthermore, distinctions in lesion development were observed among potato varieties of different maturity groups. For early varieties, the severity of Alternaria disease ranged from 2.0 to 9.5% (control) and 7.7 to 17.6% (experiment), with the disease incidence from 5.6 to 17.8% (control) and 14.0-37.0% (experiment) of plants, respectively. Among mid-early varieties, the severity of Alternaria disease ranged from 2.5 to 11.5% (control) and from 8.6 to 20.9% (experiment), with the disease incidence of 8.0 and 22.9% (control) and 14.0-59.0% (experiment) of plants, respectively. In the medium-ripe variety group, the severity of Alternaria disease ranged from 2.4 to 4.7% (control) and 9.7 to 18.7% (experiment), with the disease incidence from 8.0 to 18.6% (control) and 24.5-53.5% (experiment) of plants, respectively. On average, over the course of three years of research, the following varieties demonstrated (partial) field resistance to Alternaria blight damage: Shchedryk among the early varieties (with disease severity at the end of the growing season at 7.7% and affecting 14.0% of the plants); Aria – among the mid-early varieties (with 8.6% of severity and 14.0% of incidence); and among the medium-ripe varieties, Kniahynia (9.6% and 35.5% respectively), Slovianka (9.7% and 30.0% respectively), Myroslava (10.0% and 28.5% respectively), and Khortytsia (10.4% and 24.5% respectively) (Table 2).

For Common scab development in 2020 – 2022, favourable conditions prevailed, as affirmed by the occurrence of the disease symptoms on the tubers of all studied varieties and significant disease severity observed on the majority of them. The manifestation of scab was facilitated by elevated temperatures and reduced precipitation levels during the latter part of the growth cycle of plants (Table 1). However, the year 2022 presented the least favourable conditions for this pathogen, resulting in a disease incidence on the majority of varieties that was 2-2.5 times lower than in the preceding years (Table 3).

In 2020, a decrease in the prevalence of *R. solani* was observed: the disease manifested only on a few studied varieties, with disease incidence generally remaining low (0-16%). The most conducive conditions for *R. solani* development were observed in 2021, notably characterized by low soil temperatures and early spring frosts with 16-62% disease incidence as a consequence.

Regarding Fusarium dry rot, a decline in disease incidence was in 2021 and 2022 compared to 2020, when up to 32% of the tubers were affected in the majority of the studied varieties (14 out of 20).

In the category of early potato varieties, observations of the development of pathogens showed that from 2020 to 2022 the extent of *R. solani* disease incidence on tubers ranged from 10.0 to 26.0% (1.9-5.1% in control); Common scab ranged from 4.6 to 14.7% (1.2-4.3% in control); and Fusarium dry rot ranged from 7.7 to 18.2% (1.5-3.6% in control). The Shchedryk variety displayed the highest field resistance to *R. solani*, with only 10.0% of affected tubers. Among the early varieties, the Skarbnytsia variety exhibited high field resistance to Common scab (4.6% affected tubers), while the other varieties were relatively resistant with disease incidence levels ranging from 6.1 to 14.7%. Notably, the Shchedryk variety also displayed field resistance to Fusarium dry rot (7.7%), with the Tyras (9.2%) and Kimmeria (9.7%) varieties showing adequate field resistance as well.

In the mid-early potato variety category, the percentage of tubers affected by *R. solani* ranged from 14.2 to 29.7%, indicating that none of the studied varieties displayed field resistance to the pathogen. Disease incidence for Common scab ranged from 7.7 to 11.5%, therefore, all varieties within this group demonstrated field resistance to the pathogen. Percentage of tubers affected by Fusarium dry rot ranged from 7.2 to 26.8%, where only the variety Aria demonstrated field resistance with the lowest degree of disease incidence (7.2%), while the other varieties were susceptible to the pathogen, with damage levels ranging from 14.0 to 26.8%.

Table 4.
Resistance and susceptibility rating of Ukrainian potato varieties to pathogens in the Polissya area of Ukraine, 2020-2022

No	Potato variety	Alternaria blight (*A. solani*, *A. alternata*)	*Rhizoctonia solani*	Common scab (*Streptomyces* spp.)	Fusarium dry rot (*Fusarium* spp.)
			Early maturity group		
1.	Kimmeria	S	S	R	R
2.	Skarbnytsia	S	S	HR	S
3.	Shchedryk	HR	R	R	HR
4.	Slauta	S	S	R	S
5.	Tyras	S	S	R	R
			Mid-early maturity group		
6.	Aria	HR	S	HR	R
7.	Zlahoda	S	R	R	S
8.	Strumok	S	S	HR	S
9.	Fantazia	S	S	R	S
			Medium-ripe maturity group		
10.	Hurman	S	S	R	S
11.	Slovianka	HR	S	HR	HR
12.	Anika	S	S	R	R
13.	Okolytsia	S	R	HR	S
14.	Myroslava	HR	S	R	S
15.	Ivankivska rannia	S	S	R	S
16.	Kniahynia	R	S	R	S
17.	Charunka	S	R	R	R
18.	Letana	S	S	S	HR
19.	Feia	S	R	R	S
20.	Khortytsia	R	HR	R	S

Note: HR - highly resistant, R - resistant, S - susceptible.

In the category of medium-ripe potato varieties, the percentage of tubers affected by *R. solani* ranged from 8.3 to 33.7%, by Common scab from 3.1 to 29.0%, and by Fusarium dry rot from 5.3 to 17.0%. Varieties Khortytsia, Okolytsia, and Feia exhibited a low level of *R. solani* disease incidence (8.3, 9.7 and 10.0% respectively) proving their field resistance to the pathogen. Varieties Okolytsia (3.1%) and Slovianka (4.9%) were highly resistant to Common scab, while the other varieties within this group, including Hurman, Feia, Kniahynia, and Myroslava, demonstrated relative field resistance to this pathogen. Slovianka (5.3%) and Letana (7.5%) were field resistant to Fusarium dry rot, while the majority of varieties within this group displayed an average field resistance to this pathogen (Table 3).

The data presented demonstrates, that several potato varieties exhibited field resistance to multiple diseases (Table 4). The varieties Kniahynia and Myroslava demonstrated resistance to the causative agents of two diseases: Alternaria blight and Common scab; varieties Anika, Kimmeria, and Tyras – to Common carb and Fusarium dry rot; varieties Feia and Okolytsia - to *R. solani* and Common scab.

The varieties Aria and Slovianka displayed relatively high field resistance to the causative agents of three diseases: Alternaria blight, Common scab, and Fusarium dry rot; whereas the variety Khortytsia exhibited resistance to the causative agents of Alternaria blight, *R. solani*, and Common scab and the variety Charunka – to *R. solani*, Common scab, and Fusarium dry rot. Within each ripening group, the presence and resulting resistance/susceptibility level to potato pathogens showed variations. While certain varieties exhibited resistance only to specific diseases, overall resistance was more pronounced in the early and mid-early groups, particularly in the variety Shchedryk, which demonstrated field resistance to all investigated pathogens.

Comparative analysis of the varieties showed that when there was no resistance to pathogens, potato yields were on average reduced with 16.7% during the study period. The highest yield losses were observed in the Slauta variety (17.0%) of the early maturity group, in the Zlahoda variety (16.6%) of the mid-early maturity group, and the Hurman (16.9%), and Okolytsia (18.0%) varieties of the medium-ripe group (Table 5).

Table 5.

Yield of Ukrainian potato variety in the Polissya area of Ukraine (2020-2022, t/ha)

		2020				2021				2022				average			
				difference to the control				difference to the control				difference to the control				difference to the control	
No	Potato variety	control	experiment	t/ha	%	control	experiment	t/ha	%	control	experiment	t/ha	t/ha	control	experiment	t/ha	%
								Early maturity group									
1.	Kimmeria	34.2	29.8*	4.4	12.9	32.5	28.1*	4.4	13.5	35.0	30.8*	4.2	12.0	33.9	29.6*	4.3	12.8
2.	Skarbnytsia	37.3	34.5*	2.8	12.0	30.9	27.0*	3.9	12.6	33.9	29.9*	4.0	11.7	34.0	29.9*	4.1	12.1
3.	Shchedryk	40.7	37.0*	3.7	9.1	38.7	35.0*	3.7	9.5	41.6	39.1*	2.5	8.4	40.3	36.7*	3.6	9.0
4.	Slauta	28.1	23.3*	4.8	17.2	29.4	24.1*	5.3	18.1	28.4	23.9*	4.5	15.7	28.6	23.7*	4.9	17.0
5.	Tyras	29.0	24.4*	4.6	16.7	25.9	21.4*	4.5	17.5	23.3	19.7*	3.6	15.4	26.1	21.8*	4.3	16.5
Average for the group														**32.6**	**28.2***	**4.4**	**13.5**
								Mid-early maturity group									
6.	Aria	37.7	34.9*	2.8	7.5	32.0	29.1*	2.9	9.0	35.5	33.0*	2.5	7.0	35.1	32.7*	2.7	7.8
7.	Zlahoda	25.4	21.2*	4.2	16.4	29.8	24.3*	5.5	18.5	26.3	22.4*	3.9	14.8	27.2	22.7*	4.5	16.6
8.	Strumok	29.2	24.7*	3.7	12.7	28.7	23.9*	4.8	16.6	25.4	22.4*	3.0	11.9	27.8	24.0*	3.8	13.7
9.	Fantazia	28.8	24.4*	3.4	11.8	30.1	25.6*	4.5	14.8	23.2	20.7*	2.5	10.7	27.4	24.0*	3.4	12.4
Average for the group														**29.4**	**25.7***	**3.7**	**12.6**
								Medium-ripe maturity group									
10.	Hurman	32.5	27.0*	5.5	16.9	23.7	19.4*	4.3	18.2	26.5	22.1*	4.1	15.5	27.6	22.9*	4.7	16.9
11.	Slovianka	37.4	34.4*	3.0	8.1	32.0	29.3*	2.7	8.6	43.4	40.2*	3.2	7.4	37.6	34.6*	3.0	8.0
12.	Anika	32.5	28.4*	4.1	12.7	21.7	18.8*	2.9	13.5	20.4	18.0*	2.4	11.7	24.9	21.8*	3.1	12.6
13.	Okolytsia	31.0	25.4*	5.6	18.1	27.0	21.8*	5.2	19.2	41.6	34.7*	6.9	16.6	33.2	27.2*	6.0	18.0
14.	Myroslava	35.8	32.8*	3.0	8.5	35.9	32.6*	3.3	9.1	54.6	50.3*	4.3	7.8	42.1	38.5*	3.6	8.5
15.	Ivankivska rannia	34.9	30.1*	4.8	13.7	31.9	27.1*	4.8	15.2	38.4	33.6*	4.8	12.6	35.1	30.3*	4.8	13.8
16.	Kniahynia	37.3	33.0*	4.3	11.6	37.7	32.8 *	4.9	12.9	49.5	44.2*	5.3	10.7	41.5	36.7*	4.8	11.7
17.	Charunka	29.1	25.4*	3.7	12.8	35.3	30.7*	4.6	13.1	33.3	29.4*	3.9	11.7	32.6	28.5*	4.1	12.5
18.	Letana	31.7	27.9*	3.8	12.0	28.0	24.4*	3.6	12.8	34.6	30.8*	3.8	11.0	31.4	27.7*	3.7	11.9
19.	Feia	32.4	27.5*	4.9	15.1	32.1	26.9*	5.2	16.3	36.1	31.1*	5.0	13.9	33.5	28.4*	5.1	15.1
20.	Khortytsia	27.1	24.6*	2.5	9.3	21.2	19.1*	2.1	9.8	23.4	21.4*	2.0	8.5	23.9	21.7*	2.2	9.2
Average for the group														**33.0**	**28.8***	**4.2**	**12.7**

* the difference with the control is significant at $p \leq .05$

Discussion

Ongoing research and studies on potato diseases and resistance at the Institute of Potato Research of NAAS date back to the 1970s and 1980s. Over the years, these efforts have resulted in the selection of potato varieties with significant (partial) field resistance to a range of pathogens, including Alternaria blight, Phytophthora, *R. solani*, Common scab, and Fusarium dry rot. These selected varieties have been important contributors to the development of other potato varieties, serving as donors of essential disease-resistant traits (Andriychuk & Homyak, 2013; Cherednychenko et al., 2008; Cherednychenko et al., 2016; Cherednychenko et al., 2019; Koval et al., 1978; Koval et al., 1979; Koval et al., 1983; Podhaietskyi et al., 1994; Polozhenets, 1997; Podhaietskyi et al., 2018).

The present investigation in the Polissya area of Ukraine showed that during 2020-2022 growing seasons Alternaria disease severity on the studied potato varieties was not exceeding 20.9% in the experiment group, while for *R. solani* it reached 29.9 %, for Common scab 29.0%, and for Fusarium dry rot 26.8%.

Our study highlights the importance of accounting for the specific disease resistance profiles of each potato variety when designing crop protection strategies. Varieties that exhibit a higher degree of susceptibility to wide range of potato pathogens, such as Fantazia, Hurman, Ivankivska rannia, Skarbnytsia, Letana, Slauta, Strumok and Zlahoda require meticulous (additional) protection measures, to mitigate crop losses and enhance overall quality.

To the contrary, varieties with field resistance to diseases, including Shchedryk (created with the involvement of multispecies hybrids 79/534/61 / 77.583/16), Aria (Delikat/Tyras), Slovianka (Kondor/KE78.50.53), Myroslava (Oberih/Bellarosa), Kniahynia (Slovianka/Bellarosa), and Khortytsia (UMO101696/Bellarosa), demonstrate noteworthy resistance to the key pathogens studied. This was in line with our previous studies, which took place under different weather conditions during the 2016-2017 seasons (Taktaev & Podberezko, 2020).

An analysis of the genealogy of these varieties suggests that the inheritance of resistance traits to specific diseases may be linked to the following varieties: Alternaria blight it is possibly derived from the varieties Amulet, Bellarosa, Bahriana and Slovianka; Rhizoctonia from Bahriana, Bellarosa, Delikat, and the hybrid KE 78.50.53; Common scab from Kondor, Bellarosa, and the hybrid 77.583/16; and Fusarium dry rot from Slovianka and the hybrid UMO 101696. The resistance exhibited by these varieties can significantly reduce the frequency of fungicide treatments during cultivation, thereby improving economic efficiency and promoting more ecological technology of potato production. These specific traits of the varieties should be thoughtfully considered when developing varietal technologies for their production.

The insights gained from these studies will continue to guide future research efforts, as such information on variety resistance is vital for the development of an effective potato protection system against harmful organisms. This knowledge contributes not only to the sustainability and efficiency of potato cultivation but also to the broader agricultural sector's efforts to address key challenges in crop disease management.

Conclusion and Recommendations

In conclusion, 12 out of 20 potato varieties developed within the Ukrainian selection program, including Anika, Aria, Charunka, Feia, Khortytsia, Kimmeria, Kniahynia, Myroslava, Okolytsia, Shchedryk, Slovianka, and Tyras displayed multiple (partial) field resistance to the pathogens causing Alternaria blight (*A. solani, A. alternata*), Rhizoctonia (*R. solani*), Common scab (*Streptomyces* spp.), and Fusarium dry rot (*Fusarium* spp.) These varieties stand out as promising candidates for inclusion in plant protection systems, offering the potential to significantly reduce the reliance on fungicide treatments, ultimately lowering production costs and increasing potato farming profitability.

Moreover, they present valuable resources in breeding programs for the development of new potato varieties with enhanced resistance.

While these findings shed light on the existence of resistance in these varieties, a profound study of the genetic basis of this resistance and the inheritance patterns from their parental forms is essential for a more comprehensive understanding. Such studies will not only strengthen our knowledge of resistance mechanisms but also contribute to the development of innovative and sustainable strategies for potato protection and breeding.

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