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Potato varieties resistance study to wart *Synchytrium endobioticum* (Schilbersky) Percival and late blight *Phytophthora infenstans* (Mont) de Bary

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Abstract. The results of research on the selection of potato varieties and breeding material from Institute for potato study NAAS and Institute of Agriculture of Carpathian Region NAAS are presented in this paper.
There were selected 12 potato varieties of Ukrainian breeding with high resistance level: 'Aria', 'Glazurna', 'Knyagynya', 'Zheran', 'Zhytnytsia', 'Podolyanka', 'Skarbnytsia', 'Slavyanka', 'Chervona Ruta', 'Fantasy', 'Schedryk' and 'Chortytsia' (1.2–2.4 points (R1) and 2 varieties ('Dyvo' and 'Povin' - 3.4 and 3.0 points (R2)) by the research results for potato assessment to wart in 2020–2021 by the results of field and laboratory studies for determining Ukrainian breeding potato varieties resistance to wart *Synchytrium endobioticum* (Schilb) Perc. There were chosen 6 varieties with relatively high resistance degree to late blight *Phytophthora infenstans* (Mont) de Bary (7.2–8.5 points): 'Aria', 'Dyvo', 'Zhytnytsia', 'Knyagynia', 'Podolyanka' and 'Slavyanka' by the choice. The evaluation results allow to put them into the State Register of plant varieties suitable for dissemination in Ukraine. These potato varieties recommend for implementation in potato disease sources and usage as a parent form for crossing as sources of potato resistance to wart and late blight.

Key words: choice, donor, late blight, resistance, *Solanum tuberosum* L., wart.

INTRODUCTION

Potatoes are one of the most valuable and important agricultural crops with various uses. It has been growing in many countries worldwide. It is ranked fourth after rice, wheat, and maize by growing area. The gross potato harvest in Ukraine (nearly 330 m tones) and the sown area (more than 18 m ha) confirm the importance of crops in global problem of food providing (Zelya, 2009). Potato is a second bread for Ukraine. It

takes special place for today during the war in country, when many lands damaged and blown up.

The potato wart causative agent *Synchytrium endobioticum* (Schilb.) Perc. belongs to the kingdom simple fungi and intercellular obligate parasites. It is narrow and specializes in nature. *Synchytrium endobioticum* (Schilb.) Perc. infects plants of the family *Solanaceae*. Among these are potato, tomato, bittersweet nightshade, black nightshade, and physallis. The causative agent may be saved in soil in the form of winter and summer zoosporangium to 46 years old, as per J. Przetackiewicz data (Przetakiewicz, 2014).

Potato warts were first identified in 1888 in Austrian-Hungary (Kirally et al., 1970). It was determined in England in 1898 (Bojnansky, 1984). Some sources were identified in Scotland, Wales, and Ireland in 1902 (Zelya et al., 2018). Warts appeared in the USA in 1918 (Kirally et al., 1970). Potato warts were recorded in 1914 in Norway and in 1915 in Sweden (Bojnansky, 1984). The sources were determined in Poland in 2008 (Zelya et al., 2018), they were determined in Turkey in 2009 (Çakir & Demirci, 2017). Potato wart sources have been recorded in 38 countries worldwide (Europe, Africa, North America, and South America) (Van de Vossenberg et al., 2022).

Potato wart has variety specialization towards to basic plant-host-potato.

There were determined 40 different potato wart fungi pathotypes as per data EPPO (European and Mediterranean Plant Protection Organization). The new pathotypes differs from pathotype appearing in Germany, Czech Republic, Slovakia, Poland, Turkey, Greece, Peru, Canada, India, Italy (Obidiegwu et al., 2014; Novikova et al., 2021). The causative agent belongs to List of regulated pests A2) (EPPO Standard, 2004).

Potato wart spread in 5 regions on area 2315.26 ha in Ukraine (Zelia et al., 2020).

Aggressive causative agents of potato warts were recorded in the mountain-Carpathian zone of Ukraine in 1961. They infected potato varieties that were resistant to the common pathotype. New potato wart causative agent pathotypes appear in sources with a high density of potato monoculture, full absence of phytosanitary terms, growing variety mixes with different resistance to warts, favorable climatic and soil conditions for disease development, and not following quarantine rules (Zelia et al., 2020). There are 5 pathotypes of potato wart causative agent: D1-dalem (common) pathotype and 4 aggressive: 11-Mizhirrya; 13-Rachiv; 18-Yasynnia and 22-Bystrets (Zelia et al., 2020).

Late blight is the second most dangerous disease affecting potatoes. Late blight is a potentially dangerous potato disease. This destroys the assimilating plant surface during tuber formation. This causes a serious decrease in yield and tuber decay during storage.

Serious changes in disease development and adaptation of causative agents to external terms have recently been observed. The pathogen virulence spectrum and aggressiveness increased. Races of *Phytophthora infenstans* have been identified based on their ability to circumvent the protection afforded by specific R genes (Black, 1951; Mastenbroek, 1952). Thus, yield loss also increased. The appearance of new *Phytophthora infenstans* population isolates A1, A2 types of compatibility and sex processes with oospore formation may come to be saved in soil for many years (Razukas et al., 2008). This caused the phytosanitary state of potato sown (Valskyte et al., 2003; Holiachuk & Kosylovych, 2018) and chemical plant protection became difficult through the appearance of phytophthora-resistant forms to fungicides.

There are different methods for dealing with warts, late blights, and other potato diseases. Among these are agrotechnical, chemical, and biological. Much attention has been paid to the development of biological ways to combat plant diseases. They are alternatives to chemical means of protection, which has a negative impact on the ecology of agrophytocenosis. Improving the production of the most resistant potato varieties is the most profitable, ecologically friendly, and effective method for controlling potato disease (Zelya et al., 2018).

Ukrainian science-research plant quarantine station IPP NAAS conducted work with the choice of new potato varieties and hybrids on resistance to common and aggressive pathotypes of wart-causative agents determined in Ukraine areas over 84 years.

The joining of field trials for potato resistance-determining diseases with the most exact methods of laboratory diagnostics allows the division of varieties and hybrids based on the degree of resistance (Zelya, 2009).

The breeding evaluation and choice of resistant potato varieties for disease conduct enriching zoned assortment of new potato varieties.

The new potato varieties put into production in sources of disease-causative agents spread favors the potato production increase and improves the phytosanitary state of households.

The purpose research is evaluation and choice of potato varieties of Ukrainian breeding, resistant to wart and late blight for implementation in potato disease sources and usage as a parent form for crossing.

MATERIALS AND METHODS

There were 14 potato varieties of Ukrainian breeding: ‘Aria’, ‘Dyvo’, ‘Zheran’, ‘Zhytnytsia’, ‘Podolyanka’, ‘Povin’, ‘Santarka’, ‘Skarbnytsia’, ‘Slavyanka’, ‘Solocha’, ‘Chervona Ruta’, ‘Fantasy’, ‘Schedryk’, ‘Chortytsia’ for resistance study to potato wart causative agent and late blight. The Institute for Potato Study National Academy of Agrarian Sciences of Ukraine and the Institute of Agriculture Carpathean Region National Academy of Agrarian Sciences of Ukraine began potato breeding in 1932 and 1945, respectively. The variety ‘Poliska rozheva’ used for positive control and for negative ‘Glazurna’ for wart sensitivity. Registration of potato varieties conducted in Ukraine during 1999–2021 (State register of plant varieties suitable for dissemination in Ukraine, 2022). The variety ‘Nezabudka’ used for positive control and ‘Glazurna’ was used as a negative control for late blight sensitivity. The experiments were conducted in the laboratory conditions of laboratory of quarantine pests and diseases in the Ukrainian Science Research Plant Quarantine Station Institute of Plant Protection National Academy of Agrarian Sciences of Ukraine (v. Boiany Chernivtsi district Chernivtsi region) and field trials (settlement Berehomet. Vyzhnytsia district, Chernivtsi region).

The methodological requirements for the evaluation and choice of potato breeding material resistant to warts developed by specialists UkrSRPQSIPP NAAS, harmonized with EU requirements, as per the protocol for *Synchytrium endobioticum* (Schilb) Perc. 7/28 used during potato resistance testing to wart (EPPO Standard, 2004; EPPO Standard, 2017).

Two methods used for laboratory diagnostics:

a) Method potato infecting by potato samples by winter zoosporangia *Synchytrium endobioticum (Schilb) Perc*. soil/pearlite (1:1). The potato varieties were prepared for

inoculation in special containers using winter zoospores in the laboratory. They put into specially prepared pearlite (with granule dimension 1.25–4.0 mm, company 'Agrowinn', 'Vinnytsia'). Perlite was used as a favorable medium for tuber growth. The studied varieties were infected in substrate soil/perlite, with infectious loadings of the winter zoosporangia wart causative agent together with winter zoosporangia *Synchytrium endobioticum* (Schilb) Perc. 40–50 zoosporangium /1 g substrate for resistance potato testing to wart and control varieties: positive control varieties infected by potato wart causative agent ('Poliska rozheva') and negative control varieties not infected by any causative agent ('Glazurna'). Containers leaved in climatic chamber for 75 days at 60–80% of humidity, lighting 1,600 lx 12/12 at temperature 17–18 °C. They watered every three days. The reaction of the pathogen in the potato samples was determined over 75 d. The plants dig out of the container, and every potato sample analyzed, as well as with the control varieties.

b) Method potato infecting by summer zoosporangia *Synchytrium endobioticum* (Schilb) Perc. The paper ring was fixed around the stem part of the tuber by heating mixed paraffin and Vaseline (1:1). Distilled water was placed into the ring by adding fresh warts, which consisted of summer zoospores of the causative agent. The samples were incubated in a climatic chamber at 11 °C for infection stimulation. The paper rings put off after from potato tubers for 24 hours and continued incubation at temperature 17–18 °C, humidity 80% for 20 d without lighting. The reaction of the pathogen in the potato samples was determined after a specified period. The potato sprout-infected cuttings were analyzed under a microscope (15×10) mark BioLight 300 (DELTA optical, Poland).

The degree of resistance to wart defined on a per 5 points scale: 1 – high resistance, early necrosis, soruses absence (R1); 2 – resistant, late necrosis, simple soruses (R1); 3 – weak resistant, very late necrosis, to five soruses (R2); 4 – weakly resistant, dense soruses formation with potato sprouts (S1); 5 – strongly susceptible, dense soruses, wart node (S2) (Zelya et al., 2018).

The generally approved techniques by Kirally are used for laboratory terms for infesting potato varieties by causative agent inoculums *Phytophthora infenstans* (Mont) de Bary (Kirally et al., 1970). This technique was modified by the Institute for Potato Study, National Academy of Agrarian Sciences, with the addition (Cherednychenko et al., 2021). Field trials were conducted as per previously described techniques (Razukas et al., 2008).

The infected degree defined using 9 point scale: 9 – very high resistance (symptoms of infected absent); 7 – relatively high resistance (infected tissue takes from 10% to 25% surface and tubers cut); 5 – mid resistance (infected from 25% to 50%); 3 – low resistance (infected from 50% to 75%); 1 – very low resistance (infected more than 75%). (Methodological recommendations for potato studies conducted 2002) (Cherednychenko et al., 2021).

The testing of potato variety resistance was conducted on two different scales of evaluation of resistance degree. The scale for potato testing resistance to wart is 5 points scale and for resistance to late blight (*Phytophthora infenstans* (Mont) de Bary.) is 9 points scale.

There were favorable conditions for the field trails, potato development during the growing period, for example, the air temperature was in the range of 10.1–21.2 °C in

2020 and 10.4–22.6 °C in 2021, and the amount of precipitation was 402 mm in 2020 and 373 mm in 2021 (Table 1).

Table 1. Weather indexes during the growing period (2020–2021 years)

Years	Month	Average temperature (°C)			Precipitation (mm)		
		Rate	Factically	Deviation	Rate	Factically	% from rate
2020	April	9.2	10.1	+ 0.9	47	19	39
2021		9.9	10.4	- 2.5	44	32	73
2020	May	14.9	12.9	- 2.0	76	131	176
2021		15.1	14.2	- 0.9	75	84	112
2020	June	18.0	19.4	- 0.9	75	84	112
2021		18.8	19.4	+ 0.6	93	83	89
2020	July	19.8	20.3	+ 0.5	96	85	89
2021		20.5	22.6	+ 2.1	93	78	84
2020	August	19.1	21.3	+ 2.2	75	27	36
2021		19.9	19.5	- 0.4	66	96	144

Statistics of Tables 3 and 4 show means and their standard deviations (x ± SD). The reliability of differences between samplings was assessed by the dispersion analysis with further evaluation of the least significant difference (*LSD*) using the Statistica 5 software package.

RESULTS AND DISCUSSION

Description of Ukrainian potato varieties

The Table 2 are presented the main potato characters used for potato cultivars description.

Table 2. Pedigree information of Ukrainian potato cultivars

Varieties	Registration in Ukraine	Maturity	Parentage
1.‘Aria’	2014	Mid-Early	‘Delikat’ × ‘Tiras’
2. ‘Dyvo’	2014	Early	‘Izora’ × (‘Ausonia’ × ‘Lugovska’)
3. ‘Zhytnytsia’	2020	Early	‘Zdabitok’ × ‘Santarka’
4. ‘Zheran’	2006	Early	‘Dobrochin’ × ‘Post 86’
5. Knyagynia’	2019	Medium	‘Slavyanka’ × ‘BellaRossa’
6. ‘Podolyanka’	2006	Early	‘Ausonia’ × 88.1439-38
7. ‘Povin’	2000	Early	76.198/175 × 70.533-38
8. ‘Slavyanka’	1999	Medium	KE 78.5053 x‘Kondor’
9. ‘Skarbnytsia’	2008	Very late	77.583/16 × ‘Liu’
10. ‘Solocha’	2019	Late	‘Umo101117’ × ‘Tiras’
11. ‘Chervona ruta’	2005	Mid-late	‘Agria’ × 87.127/15
12. ‘Fantasy’	2001	Mid-Early	79.534/61 × ‘Beloruska 3’
13. ‘Schedryk’	2011	Early	85.2391s12 × ‘Bagryana’
14. ‘Chortytsia’	2020	Very late	‘Umo 101117’ × ‘Santarka’
‘Poliska rozheva’	1989	Mid-late	‘Nemichaevska iuvileyna’ × ‘Perlina’
‘Glazurna’	2010	Early	‘Gorlitsa’ × ‘Dobrochin’
‘Nezabudka’	2022	Early	‘Vityazi’ × ‘Nemichaevska iuvileyna’

Potato variety 'Aria' received from crossing parents forms 'Delikat' × 'Tiras'. It is mid-early table variety. It has pink tubers of round-oval shape. The flowers are red-violet The flesh is cream. The starch content is 15.5%. It is resistant against potato wart (1.2 points), relatively resistant against late blight (8.2 points). The variety put into the State Register in 2014 after state testing on resistance to specified diseases. The growing areas are: Polissya, Foreststeppe Ukraine. Yield - is to 36 t ha^{-1}.

Potato variety 'Dyvo' received from crossing parent's forms 'Izora' × ('Ausonia' × 'Lugovska'). It is early and table variety. The tubers are white and oval. The flowers are white colour. The starch content is 13–14%. The weak wart resistance degree consisted of 3.0 points; and to late blight was 8.1 points, respectively. The recommended areas are Western Foreststeppe. Yield - is to 38.0 t ha^{-1}.

Potato variety 'Zhytnytsia' received from crossing parent's forms 'Zdabitok' × 'Santarka'. It is early table variety. Tubers are oval. The flesh is white. The starch content is 14.4–15.9%. It has resistance to common patotype (D1) of potato wart. The wart resistance degree consisted of 1.4 points; and to late blight was 8.0 points. The variety put into the State Register in 2020. The recommended areas are: Polissya, Foreststeppe. Yield - is to 48 t ha^{-1}.

Potato variety 'Zheran' received from crossing parent's forms 'Dobrochin' × 'Post 86'. It is first early and table variety. Tubers are oblong and oval form. They are pink colour. The crown of flowers is reddish purple. The starch content is 14–15%. It has resistance to wart (2.2 points); relatively high resistance to late blight (7.2 points). It registered in 2006. The recommended areas for growing: Polissya, Foreststeppe, Steppe. Yield - is to 40 t ha^{-1}.

Potato variety 'Knyagynia' received from crossing parent's forms 'Slavianka' × 'Bellarosa'. It is medium table variety. It has light- pink tubers. The flesh is yellow colour. The flowers are red-violet. The starch content is 14–15%. It is resistant to common pathotype (D1) of potato wart (1.6 points). It has a high resistance against late blight (8.3 points). It registered in 2019. The recommended areas for growing: Polissya, Foreststeppe, Steppe. Yield - is to 52 t ha^{-1}.

Potato variety 'Podolyanka' received from crossing parent's forms 'Ausonia' × 88.1439s6. It is early table variety. Tubers are oval yellow. The flesh is yellow-light. The starch content is 15%. It has resistance to wart (1.4 points); high resistance to late blight (8.5 points). It registered in 2006. The recommended areas for growing are: Polissya, Foreststeppe. Yield - is to 37 t ha^{-1}.

Potato variety 'Povin' received from crossing parent's forms 76.198/175× 79.533-38. It is early potato table variety. Tubers are round and red colour. The flowers are red - violet. The starch content is 15–16%. It has weak resistance to wart (3.0 points); relatively high resistance to late blight (7.5 points). It registered in 2000. The recommended areas for growing are: Woodlands, Forest-steppe, Steppe. Yield - is to 42 t ha^{-1}.

Potato variety 'Slovyanka' received from crossing parent's forms KE 78.5053 × 'Kondor'. This variety is medium and table. Potato tubers are long-oval. The tubers are red violet. The skin is red and smooth. Leaves are big light green. This variety has a high yielding. The strarch content is 12–13%. The cultivar is resistant to wart (2.0 points), resistant to late blight (8.3 points). The variety put into the State Register in 1999. The recommended areas for growing are: Polissya, Foreststeppe. Yield - is to 50 t ha^{-1}.

Potato variety 'Skarbnytsia' received from crossing parent's forms 77.583/16 × 'Liu'. It is very late table. Tubers are oval and yellow colour. The flesh is cream and light-yellow colour. The crown of flowers is reddish purple. The starch content is 12.6–13.0%. It has resistance to wart (1.8 points), relatively high resistance to late blight (7.5 points). It registered in 2006. The recommended areas for growing: Woodlands, Forest-steppe, Steppe. Yield - is to 33.0 t ha^{-1}.

Potato variety 'Solocha' received from crossing parent's forms 'Umo 101117' × 'Tiras'. It is late variety. Tubers are dark-violet colour and round form. The flesh is dark-violet colour. The flowers are white. The starch content is 19.2%. The cultivar is resistant to wart (1.2 points), low resistant to late blight (3.4 points). The variety put into the State Register in 2019. The recommended areas for growing are Woodlands, Foreststeppe. Yield - is to 44 t ha^{-1}.

Potato variety 'Chervona ruta' received from crossing parents forms 'Agria' × 87.127/15. It is mid-late variety. Tubers are short-oval. The flesh is white. The flowers are red-violet. The starch content is 19–20%. The cultivar is resistant to wart (1.8 points), resistant to late blight (7.4 points). The variety put into the State Register in 2005. The recommended areas for growing are: Woodlands, Forest-Steppe. Yield - is to 39 t ha^{-1}.

Potato variety 'Fantasy'. Received from crossing parent's forms 79.534/61 × 'Beloruska 3'. It is mid-early variety. Tubers are red ova and cream colour. The flesh is white. The flowers are red-violet. The starch content is 18-19%. It has resistance to wart (2.4 points) and relatively high resistant to late blight (7.6 points). It registered in 2001. The recommended areas for growing are: Woodlands, Forest-steppe, Steppe. Yield - is to 45 t ha^{-1}.

Potato variety 'Schedryk' received from crossing parent's forms 85.2391s12 × 'Bagryana'. It is early and table variety. Tubers are round and yellow colour. The flesh is white. The flowers are white. The starch content is 13–14%. It is resistant to potato wart (1.2 points), relatively resistant to late blight (7.4 points). It registered in 2011. The recommended areas for growing: Woodlands, Foreststeppe, Step. Yield - is to 48 t ha^{-1}.

Potato varieties 'Chortytsia' received from crossing parent's forms 'Umo101117' × 'Santarka'. It is very-late and table variety. The tubers are red and prolonged form. The flesh is red colour. The flowers are white. The starch content is 19%. It is resistant to potato wart (1.4 points), late blight (7.6 points). The variety put into the State Register in 2020. The recommended areas for growing are: Woodlands, Foreststeppe. Yield - is to 40 t ha^{-1}.

Potato variety 'Poliska rozheva' (positive control of potato warts). It received from crossing parent's forms 'Nemichaevska iuvileyna' × 'Perlina'. This is a mid-late and table variety. The tubers were red and oval. The flesh is white. The flowers are red violet. The starch content is 17–18%. It is resistant to late blight, less resistant to common scab, black rot, and ring rot, and is resistant to warts. The recommended area for growth is woodlands. The variety does not put into the State Register. Yield - is to 38 t ha^{-1}.

Potato variety 'Glazurna' (negative control to potato wart and late blight) received from crossing parent's forms 'Gorlitsa' × 'Dobrochin'. It is early and table variety. The tubers are red and oval. The crown of flowers is reddish purple. The starch content is 15.7%. It has a high nutritious quality. It has resistance to potato wart (1.2 point), late blight (8.2 point). The variety put into the State Register in 2010. The recommended areas are: Woodlands, Step. Yield - is to 36 t ha^{-1}.

Potato variety 'Nezabudka' (positive control to late blight). It received from crossing parent's forms 'Vityazi' × 'Nemichaevska iuvileyna'. It is early and table variety. The rubbers are short - oval and hite colour. The flesh is cream. The flowers are white. The starch content is 13.3–15.3%. It has resistance for potato wart, is susceptible to late blight. There is no in State Register in January, 2022. Yield - is to 30 t ha^{-1}.

Evaluation and choice of potato varieties of Ukrainian breeding of wart causative agent *Synchytrium endobioticum*

By the study's results, the following 14 varieties of Ukrainian breeding 'Aria', 'Dyvo', 'Zheran', 'Zhytnytsia', 'Podolyanka', 'Poivn', 'Santarka', 'Skarbnytsia', 'Slavyanka', 'Solocha', 'Chervona Ruta', 'Fantasy', 'Schedryk', 'Chortytsia' among testing varieties for evaluation and choice of potato varieties resistant to common pathotype (D1) causative agent during 2020–2021 (Table 3).

Table 3. The evaluation results and choice of potato breeding material resistant to common pathotype of potato wart (2020–2021 years)

Nr.	Varieties	Research results on resistance to common pathotype						Resistance group (M ± m)
		Laboratory			Field			
		Total number of plants tested	Number of plants infected	Infection rate (%)	Total number of plants tested	Number of plants infected	Infection rate (%)	
1.	'Aria'	10	0	0	30	0	0	1.2 ± 0.03 (R1)
2.	'Dyvo'	10	0	0	30	0	0	3.4 ± 0.06 (R2)
3.	'Zhytnytsia'	10	0	0	30	0	0	1.4 ± 0.03 (R1)
4.	'Zheran'	10	0	0	30	0	0	2.2 ± 0.03 (R1)
5.	'Knyagynia'	10	0	0	30	0	0	1.6 ± 0.06 (R1)
6.	'Podolyanka'	10	0	0	30	0	0	1.4 ± 0.03 (R1)
7.	'Povin'	10	0	0	30	0	0	3.0 ± 0.03 (R2)
8.	'Slavyanka'	10	0	0	30	0	0	2.0 ± 0.03 (R1)
9.	'Skarbnytsia'	10	0	0	30	0	0	1.8 ± 0.06 (R1)
10.	'Solocha'	10	0	0	30	24	80	1.2 ± 0.03 (R1)
11.	'Chervona ruta'	10	0	0	30	0	0	1.8 ± 0.03 (R1)
12.	'Fantasy'	10	0	0	30	0	0	2.4 ± 0.03 (R1)
13.	'Schedryk'	10	0	0	30	24	80	1.2 ± 0.06 (R1)
14.	'Chortytsia'	10	0	0	30	0	0	1.4 ± 0.03 (R1)
	'Poliska rozheva' (positive control)	10	10	100	30	30	100	5.0 ± 0.03 (S2)
	'Glazurna' (negative control)	10	0	0	30	0	0	1.2 ± 0.03(R1)

The resistance degree to wart consisted of 1 point for the following potato varieties 'Aria', 'Knyagynia', 'Zhytnytsia', 'Podolyanka', 'Skarbnytsia', 'Chervona Ruta', 'Schedryk' and 'Chortytsia' (high resistant, early necrosis, soruses absence (R1) (Table 3). The resistance degree was on the level 2 points (resistant, late necrosis, simple soruses (R1) for potato varieties 'Zheran', 'Slavyanka' and 'Fantasy'. The potato varieties 'Dyvo' and 'Povin' showed a moderate reaction to pathogen infected (3 - weak resistant, very late necrosis, to five soruses (R2). Two varieties ('Solocha' and

'Schedryk') of potatoes are in the R1 resistance group. The results of field studies showed that the infection rate is 80%. The laboratory tests conducted in this way on all 14 potato samples (100%), So they showed resistance to common pathotype D1 potato wart S*ynchytrium endobioticum* (Schilb) Perc.

The infection rate of the susceptible control variety 'Poliska rozheva' range from 80–100%. The degree of infected consisted of five points (strongly susceptible, dense soruses, wart node (S2). Summer zoosporangia wart-causing agents were observed under a microscope at the top of the infected sprouts. The negative control (resistant variety - 'Glazurna') was consisted of 0%. The resistance degree consisted of 1 point (high resistance, early necrosis, sorus absence (R1)). There were no causative agents of potato warts determined in field conditions for any variety, except for the positive control (highly resistant to potato wart 'Poliska rozheva'). The warts were determined (Fig. 1).

Figure 1. Potato variety 'Poliska rozheva' infected by potato wart causative agent *Synchytrium endobioticum* (Schilb) Perc.

Assessment and choice of potato varieties of Ukrainian breeding resistant to late blight *Phytophthora infenstans* (Mont) de Bary

There were chosen 6 potato varieties ('Aria', 'Zhytnytsia', 'Knyagynia', 'Podolyanka' and 'Slavyanka'- breeding of Institute for Potato Study National Academy of Agrarian Sciences of Ukraine; 'Dyvo' - breeding of Institute of Agriculture of Carpathean Region National Academy of Agrarian Sciences of Ukraine with high resistance to late blight (8 points - high resistance (surface infected, necrosis takes to 10% of surface and tuber's cut) among 14 potato varieties of Ukrainian breeding by the results of laboratory testing studies conducting. The following varieties: 'Zheran', 'Povin', 'Skarbnytsia', 'Chervona Ruta', 'Fantasy', 'Schedryk' and 'Chortitsia', which consisted of 42.8% from total number. They were infected at 7 points (relatively high resistance (infected tissue takes from 10% to 25% surface and tubers cut).

The variety 'Solocha' showed the lowe resistance. This consists of three points. More than 50% of leaves surfaces and potato tubers were removed (Table 4).

We obtained the same results in the field trials. The field experiments conducted on the area of Ukrainian Science- Research Plant Quarantine Station IPP NAAS in village Boyany Chernivtsi district, Chernivtsi region. Potato varieties 'Aria', 'Zhytnytsia', 'Knyagynia', 'Podolyanka, Slavyanka' Dyvo' showed the high field resistance to disease causative agent (in the scope 8 points). The following varieties: 'Zheran', 'Povin', 'Skarbnytsia', 'Chervona Ruta', 'Fantasy', 'Schedryk' and 'Chortitsia' showed the resistance on 7 point (relatively high resistance in field conditions). The average point consisted of 8–7 points on resistance to late blight. These potato varieties may serve as parent forms for crossing and receiving resistant descendants. They were infected at 25% of leaves surface and tubers. The variety 'Nezabudka' (for positive control) wasinfected

to 80% of leaves surface (1 point) and infected tubers (Fig. 2), The potato variety ‘Glazurna’ (for negative control) had the late blight infected degree on the level 5%.

Table 4. Assessment results and choice of potato breeding material resistant to late blight *Phytophthora infenstans* (Mont) de Bary (2020–2021 years)

Nr.	Varieties	Research results on resistance to common pathotype					
		Laboratory			Field		
		Total number of plants tested	Infection rate (%)	Point (M ± m)	Total number of plants tested	Infection rate (%)	Point (M ± m)
1.	‘Aria’	5	10	8.1 ± 0.06	10	10	8.2 ± 0.06
2.	‘Dyvo’	5	5	8.2 ± 0.06	10	10	8.1 ± 0.04
3.	‘Zhytnytsia’	5	5	8.1 ± 0.04	10	10	8.0 ± 0.03
4.	‘Zheran’	5	15	7.0 ± 0.06	10	25	7.2 ± 0.06
5.	‘Knyagynia’	5	10	8.2 ± 0.06	10	10	8.3 ± 0.03
6.	‘Podolyanka’	5	10	8.4 ± 0.04	10	10	8.5 ± 0.06
7.	‘Povin’	5	15	7.4 ± 0.06	10	15	7.5 ± 0.04
8.	‘Slavyanka’	5	10	8.2 ± 0.05	10	10	8.3 ± 0.03
9.	‘Skarbnytsia’	5	15	8.0 ± 0.06	10	15	7.5 ± 0.06
10.	‘Solocha’	5	50	6.0 ± 0.03	10	60	3.4 ± 0.06
11.	‘Chervona ruta’	5	25	7.3 ± 0.06	10	25	7.4 ± 0.03
12.	‘Fantasy’	5	25	7.4 ± 0.03	10	25	7.6 ± 0.06
13.	‘Schedryk’	5	25	7.2 ± 0.06	10	25	7.4 ± 0.06
14.	‘Chortytsia’	5	25	7.5 ± 0.06	10	25	7.6 ± 0.04
	‘Nezabudka’ (pozitive control)	5	80	1.7 ± 0.06	10	80	1.8 ± 0.06
	‘Glazurna’ (negative control)	5	5	8.1 ± 0.06	10	5	8.2 ± 0.03

It is necessary to conduct control inspection every five years on resistance to diseases as per ‘Statement potato testing order on resistance to wart’ (1996) on potato varieties with high yield and tasting qualities included in in State Register of plant varieties suitable for dissemination in Ukraine early (in 2000–2015). The reaction on potato wart infection did not change on the following potato varieties: ‘Aria’, ‘Dyvo’, ‘Zheran’, ‘Glazurna’, ‘Zheran’, ‘Podolyanka’, ‘Povin’, ‘Slovyanka’, ‘Skabnytsya’ and ‘Chervona Ruta’ (Zelya, 2018). Some of them were resistant to late blight. There were chosen 5 potato varieties among the new: ‘Zhytnytsya’, ‘Knyagynia’, ‘Solocha’, ‘Schedryk’ and ‘Chortytsia’.

Figure 2. Potato variety ‘Nezabudka’ infected by late blight *Phytophthora infenstans* (Mont) de Bary.

Potato varieties showed the negative reaction on pathogen infected recommends improving in disease sources and to use in breeding for crossing and to receive the resistant descendants.

The present potato varieties recommend breeders of Ukrainian research institutions in the form of parents' forms for crossing and implementing disease sources. This decreases the infectious load of the present pathogens in the soil and improves the phytosanitary state of agricultural plots.

CONCLUSIONS

The evaluation of potato breeding material using laboratory and field methods allows the determination of potato varieties that are most resistant to diseases of potato wart *Synchytrium endobioticum* (Schilb) Perc. with resistance points 1–2 and late blight *Phytophthora infenstans* (Mont) de Bary with resistance points 7–8.

There were selected 12 potato varieties of Ukrainian breeding with high resistance level: 'Aria', 'Glazurna', 'Knyagynya', 'Zheran', 'Zhytnytsia', 'Podolyanka', 'Skarbnytsia', 'Slavyanka', 'Chervona Ruta', 'Fantasy', 'Schedryk' and 'Chortytsia' (1.2–2.4 points (R1) and 2 varieties ('Dyvo' and 'Povin' - 3.4 and 3.0 points (R2)) by the research results for potato assessment to wart in 2020–2021 by the results of field and laboratory studies for determining Ukrainian breeding potato varieties resistance to wart *Synchytrium endobioticum* (Schilb) Perc. There were chosen 6 varieties with relatively high resistance degree to late blight *Phytophthora infenstans* (Mont) de Bary (7.2–8.5 points): 'Aria', 'Dyvo', 'Zhytnytsia', 'Knyagynia', 'Podolyanka' and 'Slavyanka' by the choice. The evaluation results allow to put them into the State Register of plant varieties suitable for dissemination in Ukraine.

The present potato varieties recommend breeders of Ukrainian research institutions in the form of parents forms for crossing and implementing disease sources. This decreases the infectious load of the present pathogens in the soil and improves the phytosanitary state of agricultural plots.

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REFERENCES

Black, W. 1951. XVII. Inheritance of resistance to blight (*Phytopthora infestans*) in potatoes: inter-relationships of genes and strains. Proceedings of the royal society of Edinburgh. *Section B. Biology* **64**(3), 312–352. https://doi.org/10.1017/S0080455X00009905

Bojnansky, V. 1984. Potato wart pathotypes in Europe from an ecological point of view. *Bulletin OEPP/EPPO Bulletin* **14**(2), 141–146. https://doi.org/10.1111/j.1365-2338.1984.tb01861.x

Çakir, E. & Demirci, F. 2017. A new pathotype of *Synchytrium endobioticum* in Turkey: Pathotype 2. *Bitki koruma bulteni* **57**(4), 415–422. https://doi.org/10.16955/bitkorb.340441

Cherednychenko, L., Furdyha, M., Sobran, V. & Suchkova, V. 2021. Assessment of resistance against late bligth of potato on leaves of newly created and original selection material of potato. *Bulletin of Agricultural Science* **99**(6), 24–33. https://doi.org/10.31073/agrovisnyk202106-03

EPPO Standard PM 7/28/. 2004. 1 *Synchytrium endobioticum*. *Bulletin OEPP/EPPO Bulletin* **34**(2), 213–218. https://doi.org/10.1111/j.1365-2338.2004.00722.x

EPPO Standard PM 7/28/2. 2017. *Synchytrium endobioticum*. Bulletin *OEPP/EPPO Bulletin* **47**(3), 420–440. https://doi.org/10.1111/epp.12441

Holiachuk, Yu. & Kosylovych, H. 2018. Genetic structure of populations of causal agent of late blight of potato in Western Forest-Steppe of Ukraine Journal of Lviv National Agrarian University. *Agronomy* **22**(1), 217–222.

Kirally, Z., Klement, Z., Solymosy, F. & Voros, J. 1970. Methods in plant pathology (with special reference to breeding for disease resistance). Academiai Kiado, Budapest, 509 pp.

Mastenbroek, C. 1952. Over de differentiatie van *Phytophthora infestans* (Mont.) de Bary en de vererving van de resistentie van *Solanum demissum* Lindl. Wageningen University. Promotor(en): J.C. Dorst; A.J.P. Oort. - Amsterdam : Kinsbergen, Dissertation – 121 pp.

Novikova, L.Yu., Chalaya, N.A., Sitnikov, M.N., Gorlova, L.M., Kiru, S.D. & Rogozina, E.V. 2021. Dynamics of tuber weight in early potato varieties in the contrasting weather conditions of the Northwestern Russia. *Agronomy Research* **19**(1), 185–198. https://doi.org/10.15159/ar.20.241

Obidiegwu, J.E., Flath, K. & Gebhardt, C. 2014. Managing potato wart: a review of present research status and future perspective. *Theoretical and applied genetics* **27**(4), 763–780. https://doi.org/10.1007/s00122-014-2268-0

Przetakiewicz, J. 2014. First report of *Synchytrium endobioticum* (potato wart disease) pathotype 18 (T1) in Poland. *Plant Disease* **98**(5), 688–688. https://doi.org/10.1094/PDIS-06-13-0646-PDN

Razukas, A., Jundulas, J. & Asakaviciute, R. 2008. Potato cultivars susceptibility to potato late blight (*Phytophthora infestans*). *Applied ecology and environmental research* **6**(1), 95–106. https://doi.org/10.15666/aeer/0601_095106

Valskyte, A., Tamosiunas, K., Gosovskiene, J. & Cesevicius, G. 2003. Monitoring of early attacks of late blight in Lithuania. *Agronomy Research* **1**, 105–111.

Van de Vossenberg, B.T.L.H., Prodhomme, C., Vossen, J.H & Van der Lee, T.AJ. 2022. *Synchytrium endobioticum*, the potato wart disease pathogen. *Molecular Plant Pathology* **23**(4), 461–474. https://doi.org/10.1111/mpp.13183

Zelia, A., Hunchak, V., Melnyk, A., Andriichuk, T., Popesku, H. & Zadorskyi, E. 2020. The phytosanitary term of old sources potato wart *Synchytrium endobioticum* (Schilb.) Perc. in Ukraine. *Quarantine and Plant Protection* (4–6), 9–15 (in Ukrainian with English summary). https://doi.org/10.36495/2312-0614.2020.4-6.9-15

Zelya, A.G., Zelya, G.V., Oliynyk, T.M., Pylypenko, L.A., Solomyiciuk, M.P., Kordulean, R.O., Skoreyko, A.M., Bunduc, Yu.M. & Ghunchak, V.M. 2018. Screening of potato varieties for multiple resistance to *Synchytrium endobioticum* in Western region of Ukraine. *Agricultural Science and Practice* **3**, 3–11. https://doi.org/10.15407/agrisp5.03.003

Zelya, A.G. 2009. Selection of new potato test-assortment for identification of potato wart *Synchtrium endobioticum* (Schilb.) Perc. *Bulletin OEPP/EPPO Bulletin* **39**(1), 71 pp.