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Resistance status of potato varieties to early blight under changing climate conditions in Polissia, Ukraine

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Article info

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Over the past decade, early blight caused by fungi of the genus Alternaria has remained the dominant potato disease in Ukraine. Its spread has been driven by climate change, particularly rising temperatures and moisture deficits during the growing season. To assess the resistance of potato varieties to early blight under abiotic stress conditions, 25 Ukrainian-bred potato varieties of different maturity groups were studied at the Polissia Research Department of the Institute for Potato Research, NAAS, during 2021–2024. The objective of the study was to determine the dynamics of early blight infection in potato varieties under changing climatic conditions in Polissia, Ukraine, to evaluate their resistance, and to identify varieties with high adaptability to the pathogen under varying moisture levels. The study employed field experiments, phytopathological assessment, and statistical data analysis. The studies conducted in 2021–2024 revealed a significant influence of hydrothermal conditions on disease development. Early-maturing varieties showed the highest levels of Alternaria spp. infection, with initial assessments ranging from 2.7 % to 19.5 %, increasing to 22.3–44.5 % by the third assessment. In medium-early varieties, infection ranged from 1.9%–12.2% at the first assessment stage and 17.0–37.3 % at the third. In medium-maturing varieties, the infection rates were 0.8–6.6 % and 11.5–31.7 %, respectively. The decrease in hydrothermal coefficient (HTC) from 0.87 to 0.32 resulted in increased pathogen infection levels in potato varieties, which was confirmed by negative correlation coefficients (r = –0.951...–0.999). The resistance level of the varieties also depended on moisture availability: under severe drought conditions (HTC < 0.50), early-maturing varieties exhibited the lowest resistance (4.0 points), medium-early varieties slightly higher (score 4.7 points), and medium-maturing varieties the highest among all groups (5.2 points). The scientific novelty of the study lies in establishing the relationship between early blight infection severity and hydrothermal conditions of the growing season as well as the maturity group. Moreover, the study identified varieties with consistently high resistance to Alternaria spp., including Radomysl, Tyras, Nahoroda, Avanhard, Opillia, Partner, Mezhyrichka 11, Bazaliia, Lietana, Serpanok, Alians, and Ivankivska rannia. The obtained results can be applied in breeding programs aimed at developing new potato varieties with enhanced resistance to early blight under climate change conditions.

Keywords: potato, variety, maturity group, early blight, resistance, infection level, moisture availability.

Статус стійкості сортів картоплі до альтернаріозу в умовах змінного клімату Полісся України

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Впродовж останнього десятиліття альтернаріоз, спричинений грибами роду *Alternaria*, залишається домінуючою хворобою картоплі в Україні. Його поширення зумовлене кліматичними змінами, а саме підвищенням температури та дефіцитом вологи в період вегетації культури. Для оцінки стійкості сортів картоплі до альтернаріозу в умовах абіотичного стресу, в Поліському дослідному відділенні ІК НААН протягом 2021–2024 рр. було вивчено 25 сортів картоплі різних груп стиглості української селекції. Метою досліджень було визначення динаміки ураження сортів картоплі альтернаріозом в умовах змінного клімату Полісся України, оцінку їх резистентності та виділення сортів з високою адаптивністю до збудника за різних рівнів вологозабезпечення. Використано методи польового дослідження, фітопатологічної оцінки та статистичної обробки даних. У ході досліджень, проведених в 2021–2024 рр., встановлено суттєвий вплив гідротермічних умов на розвиток хвороби. Ранньостиглі сорти демонстрували найвищий рівень ураженості *Alternaria* spp. вже на першому обліку 2,7–19,5 %, який збільшив до 22,3–44,5 % на третьому обліку. У середньоранніх сортах діапазон уражень становив відповідно 1,9–12,2 % при першому та 17–37,3 % при третьому обліку, а в середньостиглих 0,8–6,6 % та 11,5–31,7 %. Зниження гідротермічного коефіцієнта (ГТК) від 0,87 до 0,32 призвело до зростання рівня ураженості патогеном сортів картоплі, що підтверджено від'ємними кореляційними зв'язками (r = –0,951...–0,999). Рівень стійкості сортів також залежав від умов вологозабезпечення: за умов сильної посухи (ГТК < 0,50) ранньостиглі сорти демонстрували найнижчу стійкість (4 бала), середньоранні – дещо вищу (4,7 бала), середньостиглі – найвищу серед усіх груп стійкості (5,2 бала). Науковою новизною дослідження є встановлення залежності рівня ураження картоплі альтернаріозом від гідротермічних умов вегетаційного періоду та групи стиглості, а також виділення сортів з високою стабільною стійкістю до збудника *Alternaria* spp. (Радомисль, Тирас, Нагорода, Авангард, Опілля, Партнер, Межирічка 11, Базалія, Лєтана, Серпанок, Альянс та Іванківська рання). Отримані результати можуть бути використані в селекції для створення нових сортів із підвищеною стійкістю до альтернаріозу в умовах кліматичних змін.

Ключові слова: картопля, сорт, група стиглості, альтернаріоз, стійкість, рівень ураженості, вологозабезпеченість.

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Introduction

Global warming and the spread of plant pathogens cause annual losses of approximately 15 % of global crop yields, and this figure is expected to increase [1]. Fungi of the genus *Alternaria* spp. are cosmopolitan and widely distributed in natural environments and agrocenoses due to their ecological plasticity. They include saprophytic, endophytic, and phytopathogenic species capable of adapting to various environmental conditions [2]. Phytopathogenic representatives of this genus cause significant yield losses by infecting a wide range of agricultural crops, including potato [3]. Early blight affects both the above-ground parts and tubers of potato, which can lead to yield losses of up to 60 % [4]. The spread of the disease in potato is intensified by climate change, particularly rising temperatures and unstable moisture regimes [5]. According to research by Delgado-Baquerizo et al. [1], pathogenic fungi of the genus *Alternaria* spp. are more commonly found in tropical forests and arid regions, and their aggressiveness and prevalence increase under climate warming conditions. Early blight, caused by fungi of the genus *Alternaria* spp., is a polycyclic disease characterized by rapid pathogen accumulation under favorable conditions. This phytopathogen can infect plants across a wide range of climatic conditions and can cause significant crop damage without proper control [6, 7]. Considering global warming and the ability of *Alternaria* spp. fungi to adapt to high temperatures, increased aggressiveness of early blight is predicted in European countries and major potato-growing regions in the coming decades [8, 9]. The causal agents of early blight, namely *Alternaria solani* (early blight) and *Alternaria alternata* (brown spot), have long been considered major potato pathogens in growing regions across Europe [10–12], the United States [1, 14], China [15], Israel [16], South Africa [17], and Ukraine [18].

The limited number of potato varieties characterized by high resistance to early blight necessitates the use of fungicides in production as the primary means of controlling initial disease symptoms. However, recent studies indicate a gradual decline in fungicide effectiveness due to pathogen resistance development to major active ingredients [19, 20]. Given the growing role of potatoes in food security and the need to implement environmentally safe cultivation methods, the application of integrated plant protection strategies is an important aspect [21, 22]. The use of even partially resistant varieties combined with forecasting models based on meteorological parameters allow for reduced fungicide load requirements [4, 23]. The development of new approaches that consider evolutionary mechanisms of pathogen adaptation, as well as widespread implementation of non-mycotoxic control methods, is necessary to improve disease management system effectiveness [19, 21].

Thus, to minimize the risks of resistant *Alternaria* spp. strain spread and optimize fungicide protection, it is important to consider not only the quantity and frequency of treatments, but also the combination of plant genetic resistance with preventive and agrotechnical measures. In this context, the study on the resistance levels of modern potato varieties to early blight under the changing climate conditions of Ukraine's Polissia region becomes particularly relevant.

The aim of the study

To determine the dynamics of potato varieties' infection by early blight across different maturity groups under the changing climatic conditions of the Polissia zone of Ukraine; to assess the levels of resistance and identify varieties with stable resistance to the pathogen under varying moisture availability.

Tasks of the study:

1. To evaluate the dynamics of Alternaria infection in potato varieties of different maturity groups depending on the year, assessment stage, and hydrothermal conditions.
2. To characterize the influence of weather factors during the study years on the severity of Alternaria infection.
3. To identify variations in variety resistance to Alternaria depending on the level of moisture availability.
4. To select potato varieties with stable resistance to Alternaria, regardless of weather conditions.
5. To describe general trends in resistance of potato varieties of different maturity groups to Alternaria in relation to hydrothermal coefficient (HTC) levels during 2021–2024.

Materials and methods

The study was conducted under field conditions in the natural background of the Potato Breeding and Seed Production Laboratory of the Polissia Research Department of the Institute for Potato Research, NAAS, during 2021–2024.

The subject of the study were potato varieties bred by the Institute for Potato Research, the Polissia Research Department of the Institute for Potato Research, and PJSC Scientific and Production Association "Chernihiv Elite Potato" (Naukovo-Vyrobnyche obiednannia "Chernihivelitkartoplia"), representing different maturity groups: early – Tyras, Radomysl, Vzirets, Slavuta, medium-early – Levada, Partner, Mezhyrichka 11, Avanhard, Nahoroda, Opillia, Svitana, Fanatka, medium-maturing – Yavir, Lietana, Chervona ruta, Oleksandryt, Bazaliia, Ivankivska rannia, Alians, Charunka, Zhytnytsia, Myroslava, Rostavytsia, Sontsedar.

The experimental field soils are sod-podzolic sandy soils, typical of Central Polissia in Ukraine. They are characterized by low humus content (up to 0.8 %), acidic soil solution reaction (pH of salt extract 4.0–4.6), and low base saturation (less than 50 %). Soil granulometric composition: 93–96 % sandy fraction and 5–6.4 % clay fraction, resulting in a structureless soil mass and low water retention capacity (up to 21 %).

The assessment of the degree of potato variety infection with early blight during the vegetation period was conducted in field crop rotation, applying the generally accepted system of agrotechnical measures for the conditions of Ukraine's Polissia region according to scientific and practical recommendations of the Institute for Potato Research, NAAS [24]. For the objective

determination of plant infection levels during the budding–early tuber formation phase, fungicide treatments were not applied. Assessment of plant infection by the Alternaria pathogen was conducted three times during the vegetation period: the first assessment stage during the budding phase, subsequent ones at 7–10 day intervals. Disease symptom manifestation and dynamics of infection expansion on the leaf surface were recorded. Potato variety resistance was determined by the area of infected leaf surface using a 9-point scale according to the "Methodology for evaluating potato breeding materials for resistance to major pests and pathogens" (ed. S. O. Trybel and A. A. Bondarchuk, 2013) [25]: high resistance (9–8 points) – less than 5 % of leaf surface infected; resistant (7–6 points) – 5–25 %; moderate resistance (5–4 points) – 26–50 %; susceptible (3–2 points) – 51–75 %; low resistance (1 point) – over 75 % of infected surface.

The hydrothermal coefficient (HTC) was determined based on ten-day precipitation sums (mm) for the period with mean daily air temperatures above +10 °C and the sum of mean daily air temperatures above +10 °C. Initial meteorological data was obtained from the meteorological station of the Polissia Research Department of the Institute for Potato Research, NAAS. The mean HTC value for the period from planting to each assessment stage was determined by summing ten-day values and dividing by the number of ten-day periods: first assessment stage – for the period from the first ten-day period of May to the first ten-day period of July (7 ten-day periods); second assessment stage – from the first ten-day period of May to the second ten-day period of July (8 ten-day periods); third assessment stage – from the first ten-day period of May to the third ten-day period of July (9 ten-day periods). HTC values for the years of the study are presented in ***Table 1***.

Data processing was performed using statistical methods with the "Data Analysis" package in Microsoft Excel. Mean values, minimum and maximum values, coefficient of variation, correlation, and predictive values were calculated.

Table 1

Dynamics of hydrothermal coefficient (HTC) during assessment periods in 2021–2024

Decades	Years			
	2021	2022	2023	2024
May I	0.3	0.5	0.01	0.01
May II	1.1	0.3	0.01	0.01
May III	1.6	2.2	0.2	0.15
June I	1.7	0.3	0.8	0.7
June II	0.2	0.2	1.2	1.6
June III	0.5	2	0.7	0.01
July I	0.7	1.1	0.6	0.3
July II	0.7	2.9	0.15	0.01
July III	0.01	0.1	0.6	0.05

Results and discussion

Dynamics of Alternaria infection in potato varieties of different maturity groups depending on the year, assessment stage, and hydrothermal conditions. During the 2021–2024 seasons, the degree of *Alternaria* infection of above-ground mass (leaves) in potato varieties of different maturity groups was assessed across three evaluations. In the early variety group in 2021, Alternaria infection increased 9.3-fold from the first to the third assessment. In 2022, this value increased 5.6-fold, in 2023 – 8.2-fold, and in 2024 – only 2.3-fold, indicating different dynamics of Alternaria infection depending on weather conditions. It is important to note that in 2024, despite the smallest increase in infection percentage between assessments, all three assessments demonstrated high infection rates. The obtained results are consistent with data from Leiminger and Hausladen [26], who found that early-maturing potato varieties are more susceptible to *Alternaria*, and disease development intensity in them is significantly higher compared to medium- and late-maturing varieties. The coefficient of variation (V) during the years of the study ranged from 15 % to 84 %, indicating significant variability of infection within the group. The correlation between mean infection and HTC was negative and significant in 2021 and 2024 ($r = -0.982$ and $r = -0.999$), while in 2023 it was negative and moderate, confirming the substantial influence of hydrothermal conditions on the degree of phytopathogen infection: decreased HTC values led to increased *Alternaria* infection levels (***Table 2***).

Table 2

Percentage of above-ground mass infection in potato varieties by Alternaria depending on maturity group, year, and assessment, 2021–2024

Values	2021			2022			2023			2024		
	I	II	III	I	II	III	I	II	III	I	II	III
Early												
Mean	2.7	10.7	25	4	7.7	22.3	5.4	20.3	44.5	19.5	32.5	43.8
min	2.0	4.0	15	1	3.0	10.0	2.5	6.0	13.0	15.0	25.0	30.0
max	4.0	18.0	35	10	15.0	30.0	10.0	40.0	65.0	25.0	35.0	55.0
V	58	66	40	52	84	48	64	71	57	22	15	25
r		-0.982			0.238			-0.481			-0.999	
Medium-early												
Mean	1.9	11.7	23.8	2.3	6.7	19.7	1.9	6.6	17	12.2	19.2	37.3
min	1	6	15	0	3	12	1	4	9	0	5	34
max	3.5	20	33	5	15	30	5	10	25	25	30	45
V	54	49	36	84	65	33	85	37	42	88	58	12
r		-0.958			0.290			-0.411			-0.951	
Medium-maturing												
Mean	1.2	9.1	23	1.3	3.9	11.5	0.8	4.9	17.7	6.6	16.4	31.7
min	0.0	3.0	10	0.0	0.0	3.0	0.0	0.0	5.0	0.0	7.0	20.0
max	3.0	20.0	33	5.0	10.0	25.0	5.0	10.0	45.0	12.0	25.0	40.0
V	95	69	40	140	85	60	194	54	67	81	42	22
r		-0.981			0.292			-0.343			-0.982	

Notes: I – first assessment; II – second assessment; III – third assessment; V – coefficient of variation; r – correlation.

Medium-early varieties. The level of Alternaria infection among varieties of this maturity group increased 12.5-fold in 2021, 8.6-fold in 2022, 8.9-fold in 2023, and 3.1-fold in 2024. As with early varieties, the highest percentage of Alternaria infection was observed in 2024 across all assessments. High levels of variation (V from 12 % to 88 %) in individual years indicate different varieties' resistance to the phytopathogen. Research by Meno et al. [4] confirms that individual varieties in the medium-early group achieved high Alternaria infection severity rates. However, considering the periods of disease manifestation, infection intensity in them proved to be lower than in early-maturing varieties. The correlation between mean disease infection rate and HTC was negative and significant in 2021 and 2024 ($r = -0.982$ and $r = -0.999$), while in 2023 it was moderately negative.

Medium-maturing varieties. Medium-maturing varieties demonstrate the lowest disease infection values at the first assessment stage among other maturity groups during the years of the study, but the increase in disease infection percentage by the third assessment stage was significant: in 2021 – 19.2-fold, in 2022 – 8.9-fold, in 2023 – 22.1-fold, in 2024 – 4.8-fold. High levels of variation (V from 22 % to 194 %) confirm uneven disease infection within the group, which is supported by research results from Xue et al. [23], indicating the presence of individual varieties in the middle-late group with high susceptibility to Alternaria. The strongest negative correlation with HTC was observed in 2021 and 2024 ($r = -0.981$ and $r = -0.982$), while in 2023 the correlation was negative and moderate.

Analysis of the coefficient of variation by maturity groups indicates that the greatest variability in Alternaria infection among varieties was observed in the medium-maturing group (V up to 194 %). Meanwhile, in early-maturing and medium-early genotypes, this value did not exceed 84 % and 88 % respectively, indicating significant unevenness of disease infection among varieties.

The obtained results are consistent with research by other scientists, who indicate that infection of potato varieties by the Alternaria pathogen depends both on their level of genetic resistance to the pathogen and on weather conditions that influence disease development [11, 27].

Influence of temperature regime and precipitation on Alternaria development. Analysis of the influence of hydrothermal conditions on the dynamics of Alternaria infection in potato varieties, presented in ***Table 2***, revealed significant variability in infection degree depending on weather conditions and variety maturity groups. For an in-depth study of this relationship and the development of a predictive model, additional analysis was conducted. Considering that Alternaria development is closely related to temperature regime and precipitation amounts during critical periods, it was decided to focus on the influence of mean monthly temperatures and precipitation in June and July. To ensure data comparability and obtain more stable results, only those varieties that were studied throughout the entire 2021–2024 period were selected for further analysis. This allowed minimizing the influence of short-term factors and focusing on general trends. The results of this analysis are presented in ***Table 3***.

Table 3

Analysis of actual and predicted Alternaria infection in potato varieties considering weather factors in 2021–2024 seasons

Years	X1	X2	X4	X5	Yф	Yп	Yф–Yп
2021	20.6	25.1	20.3	15.7	11.5	12.35	-0.85
2022	21.3	20.3	19.1	25.3	10	9.87	0.13
2023	18.8	21.2	15.4	10.8	12.6	11.02	1.58
2024	20.4	24.2	15.5	4	24.3	23.96	0.34
R^2						0.971	

Notes: X1 – mean monthly temperature in June, °C; X2 – mean monthly temperature in July, °C; X4 – mean monthly precipitation in June, mm; X5 – mean monthly precipitation in July, mm; Yф – actual mean value of Alternaria infection degree, %; Yп – predicted mean value of infection degree, %; Yф – Yп – deviation between actual and predicted values; R^2 – model coefficient of determination.

According to the data in ***Table 3***, the highest level of predicted Alternaria infection in plants was observed in 2021 and 2024, which coincided with sharp temperature increases from June through July (by 4.5 °C in 2021 and by 3.8 °C in 2024) and significant decreases in precipitation from June through August (by 4.6 mm in 2021 and by 11.1 mm in 2024). Such conditions lead to rapid soil drying, plant weakening, and premature leaf senescence, which increases their susceptibility to Alternaria. In 2023, the predicted increase level was lower than in 2024, which can be explained by less pronounced temperature increase from June through July (+2.4°C) with simultaneous significant precipitation decrease (−4.6 mm). This confirms that sharp temperature increases combined with moisture deficit are key factors promoting intensive Alternaria development. In contrast, in 2022 the predicted infection level was the lowest (9.87 %), which was associated with a smaller difference between mean monthly temperatures in June and July (only +1 °C) and significant precipitation levels in July (25.3 mm), which even exceeded the June indicator (19.1 mm). Such temperature regime stability combined with adequate moisture levels contributed to reduced plant stress and, consequently, fewer Alternaria infections. Thus, the analysis confirms that sharp temperature increases in July combined with decreased precipitation levels create favourable conditions for Alternaria development, while stable temperatures and adequate moisture can significantly reduce infection risk.

As shown in the analysis of ***Table 3***, the developed model demonstrated high predictive accuracy, which is confirmed by the coefficient of determination ($R^2 = 0.971$). This indicates that the selected meteorological indicators almost fully explain the variation in the degree of Alternaria infection. Minor deviations between the actual and predicted values may be attributed to additional influencing factors such as microclimatic conditions [28, 29], soil type [30], varietal characteristics [11, 23], as well as the age structure of the leaf canopy [31] and morphological features of the tubers [27], among others.

Analysis of variability in varietal resistance by maturity group across assessment periods and years of the study. The dynamics of resistance expression in potato varieties of different maturity groups during 2021–2024 and across assessment periods are presented in ***Table 4***.

Early varieties. Among the early varieties' group, the

highest mean resistance value was recorded at the first assessment stage in 2021, which was conducted during the budding stage, indicating relative resistance at this stage of development. However, in 2024, this value decreased by 1.7 points. Radomysl variety demonstrated the highest resistance during this period. At the second assessment stage, the maximum mean resistance score was recorded in 2022, again with Radomysl as the leading variety. However, a decline of 2 points was observed in 2024, indicating increased Alternaria infection pressure. At the third assessment stage, the highest mean resistance score was noted in 2021, with Radomysl again showing the best performance. The lowest resistance values were recorded in 2023–2024, with Tyras being the leading variety in 2023 and Radomysl in 2024.

Table 4

Dynamics of resistance of potato varieties of different maturity groups to Alternaria during the 2021–2024 period

Varieties	2021			2022			2023			2024		
	I	II	III	I	II	III	I	II	III	I	II	III
Early												
Vsirets	8	8	5	7	7	5	7	6	2	6	5	3
Tyras	8	7	7	8	7	5	8	7	7	6	5	4
Radomysl	8	6	6	8	8	7	8	7	5	7	6	5
Slauta	-	-	-	-	-	-	7	4	2	6	5	4
Mean($\bar{X}$)	8	7	6	7.7	7.3	5.7	7.5	6	4	6.3	5.3	4
Medium-early												
Levada	8	6	5	7	6	5	-	-	-	-	-	-
Partner	8	7	5	8	7	6	8	7	6	6	5	5
Mezhyrichka 11	8	7	7	8	7	7	7	7	6	6	5	5
Avanhard	8	7	6	8	7	6	8	7	6	8	7	4
Nahoroda	8	7	6	9	8	6	8	8	7	-	-	-
Opillia	-	-	-	8	8	7	8	7	7	9	8	5
Svitana	-	-	-	-	-	-	8	7	6	6	5	4
Fanatka	-	-	-	-	-	-	8	7	7	8	7	5
Mean($\bar{X}$)	8	6.8	5.8	8	7.2	6.2	7.9	7.1	6.4	7.2	6.2	4.7
Medium-maturing												
Yavir	8	6	4	9	7	7	-	-	-	-	-	-
Lietana	8	7	5	8	8	7	8	7	7	7	6	5
Chervona ruta	8	7	6	9	8	8	-	-	-	-	-	-
Oleksandryt	8	7	7	-	-	-	7	7	6	-	-	-
Serpanok	8	7	6	8	8	4	8	7	6	7	7	6
Bazaliia	9	8	7	8	8	7	9	8	7	7	6	5
Ivankiv. rannia	9	8	5	7	7	6	8	8	5	7	5	4
Alians	8	7	5	8	7	7	9	7	4	9	7	5
Charunka	-	-	-	9	9	7	8	8	6	-	-	-
Zhytnytsia	-	-	-	-	-	-	9	9	7	7	6	6
Myroslava	-	-	-	-	-	-	9	7	7	7	6	5
Rostavytsia	-	-	-	-	-	-	9	7	6	9	7	6
Sontsedar	-	-	-	-	-	-	9	8	7	7	6	5
Mean($\bar{X}$)	8.3	7.1	5.6	8.3	7.8	6.6	8.5	7.6	6.2	7.4	6.2	5.2

Medium-early varieties. Unlike early varieties, this group demonstrated greater stability of resistance at the first assessment stage throughout 2021–2024. The highest mean resistance value was recorded in 2021 and 2022, while the decrease in 2024 was only 0.8 points. It is important to note that in 2022 Nahoroda variety, and in 2024 Opillia variety, showed no signs of above-ground mass infection by the pathogen. At the second assessment stage, the maximum mean resistance value was observed in 2022, where varieties Nahoroda and Opillia showed high resistance. The minimum mean resistance value was observed in 2024, but the decrease was only 1 point. During this period, Opillia variety demonstrated high resistance. At the third assessment stage, the maximum mean resistance value was recorded in 2023, where the highest points were obtained by varieties Nahoroda, Opillia, and Fanatka. The minimum resistance value was observed in 2024, with a decrease of 1.7 points. *Medium-maturing varieties*. Medium-maturing varieties demonstrated the highest mean resistance score at the first assessment stage throughout 2021–2024 compared to early and medium-early groups. Maximum resistance in this group was recorded in 2023, when varieties Bazaliia, Alians, Zhytnytsia, Myroslava, Rostavytsia, and Sontsedar showed no signs of leaf infection by Alternaria. The minimum mean resistance value was observed in 2024 (7.4 points), however varieties Alians and Rostavytsia demonstrated the highest points during this period. At the second assessment stage, the maximum mean resistance score was observed in 2022, where Charunka variety showed maximum resistance. The minimum resistance level was recorded in 2024, however varieties Serpanok, Alians, and Rostavytsia demonstrated high points. At the third assessment stage, the maximum mean resistance value was observed in 2022, where Chervona ruta variety showed high resistance. The minimum mean resistance score was observed in 2024, however varieties Serpanok, Zhytnytsia, and Rostavytsia demonstrated high points during this period.

Assessment of potato variety resistance to Alternaria depending on HTC. Analysis of the response of *early potato varieties* to moisture levels during 2021–2024 was established through analysis of Alternaria resistance dynamics (by mean score) in relation to changes in mean HTC values (averaged across three assessment stages) (***Fig. 1***). The most stable variety in terms

of resistance throughout the research years was Radomysl, which maintained a relatively high resistance level even in drought years. Tyras variety also demonstrated relative resistance, however under the most severe drought conditions in 2024, its resistance decreased by 2.3 points.

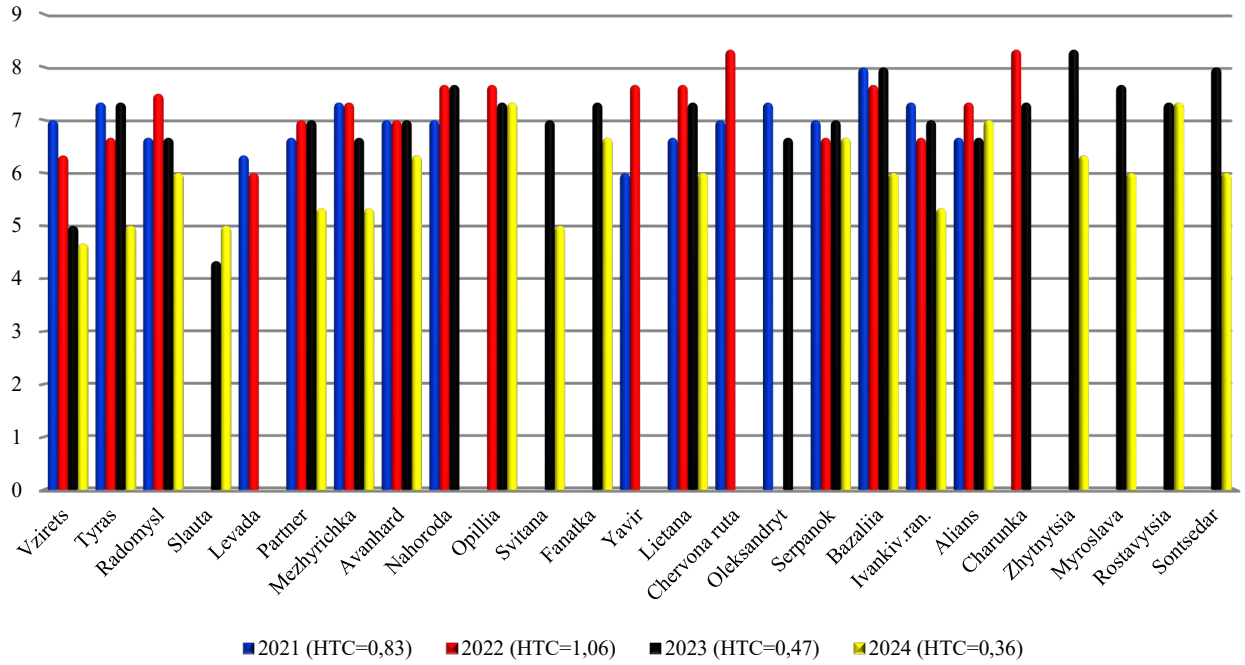

Fig. 1. Mean resistance score of potato varieties to Alternaria depending on variable moisture levels (HTC, mean of three assessment stages) in 2021–2024

The most pronounced decrease in mean resistance score under abiotic stress conditions was recorded in Vzirets variety, where the difference between values in the year with mild drought (2021) and the most drought period (2024) exceeded 2.3 points. Slauta, according to two-year data, demonstrates moderate resistance under drought conditions, which may indicate its increased sensitivity to moisture deficit. Analyzing the data, it can be concluded that among early potato varieties there is significant variability in drought response. Radomysl proved to be the most resistant, while varieties Vzirets and Slauta showed greater sensitivity to moisture deficit. Tyras variety demonstrates relative resistance, with score fluctuations depending on hydrothermal conditions. Overall, there is a trend toward decreased resistance levels in early-maturing varieties during years with low HTC, confirming the significant influence of drought on *Alternaria* manifestations.

Among the *medium-early potato* varieties, variability in resistance response to Alternaria under different hydrothermal conditions was also observed. Nahoroda variety exhibited the most stable mean resistance value during 2021–2024, consistently showing high resistance values regardless of HTC. Avanhard variety also showed high resistance overall; however, under conditions of severe drought (HTC = 0.36) in 2024, its mean resistance score decreased by 0.7 points. Varieties Mezhyrichka 11 and Partner remained stable in years with sufficient moisture (HTC > 1.0), but during drought periods (HTC < 0.5), their resistance values dropped by 2.0 and 1.7 points, respectively. Svitana variety was particularly sensitive to moisture deficit, showing a 2-point drop in resistance under extreme drought (HTC = 0.36). Fanatka variety demonstrated a similar tendency toward reduced resistance under abiotic stress; however, its score decreased by only 0.6 points. It is important to note that this variety maintained relatively high resistance even under moderate and severe drought conditions (HTC 0.47–0.36), remaining within the corresponding gradation. Based on the analysis of the data, it can be concluded that Nahrada variety is the most resistant to Alternaria among the medium-early varieties, regardless of hydrothermal conditions. Avanhard, Fanatka, and Opillia showed relative drought resistance, while Mezhyrichka 11, Partner, and Svitana appeared more sensitive to moisture deficit. *Medium-maturing varieties*. Among these, Bazaliia demonstrated the most stable resistance throughout the study period, maintaining a high resistance level regardless of hydrothermal conditions. A decline of 2 points was observed only under severe drought in 2024. Lietana, Serpanok, and Alians also exhibited relative resistance; however, under extreme drought in 2024, their resistance decreased by 1.7, 0.3, and 0.3 points, respectively. Yavir and Chervona ruta, evaluated in 2021 under mild drought conditions (HTC = 0.83), demonstrated relatively high resistance to Alternaria. In 2022 (HTC=1.06) under adequate moisture conditions, increased resistance of 1.7 and 1.3 points respectively, was observed. Specifically, Chervona ruta demonstrated the highest resistance in 2022 (8.3 points), indicating its high adaptability to adequate moisture conditions. However, their resistance was not evaluated under severe and very severe drought conditions (2023, 2024), which prevents conclusions regarding their resistance under such conditions. Oleksandryt, evaluated in 2021 (HTC=0.83) and 2023 (HTC=0.47), demonstrated high resistance to Alternaria under mild and severe drought conditions, respectively. A decrease in mean

resistance score of 0.6 points was observed from 2021 to 2023. However, its resistance was not evaluated under adequate moisture conditions (2022), which prevents conclusions regarding its resistance under such conditions. Varieties Ivankivska rannia, Zhytnytsia, Myroslava, Rostavytsia, and Sontsedar demonstrated high and relatively high resistance under severe and very severe drought conditions (2023, 2024), however their resistance was not evaluated under adequate moisture conditions (2022). Analyzing the data, it can be concluded that among medium-maturing potato varieties, there is significant variability in drought response. Bazaliia proved to be the most stable, while Ivankivska rannia, Lietana, Serpanok, and Alians showed greater sensitivity to moisture deficit. Yavir and Chervona ruta require further study under different moisture levels to assess their stability. Oleksandryt, Zhytnytsia, Myroslava, Rostavytsia, and Sontsedar require further study under adequate moisture conditions. Overall, there is a trend toward decreased resistance levels in medium-maturing varieties during years with low HTC, which may indicate significant drought influence on Alternaria manifestation.

Trends in potato variety resistance to Alternaria depending on moisture level (HTC). ***Table 5*** presents the average resistance score of potato varieties of different maturity groups based on three assessment stages in 2021–2024 in relation to the hydrothermal coefficient (HTC). The obtained data confirm the influence of moisture level on resistance to Alternaria. Specifically, in years with lower HTC (2023, 2024), a decrease in the average resistance score was observed in all maturity groups, particularly in the third assessment stage, indicating increased disease manifestation under moisture deficit conditions. In seasons more favorable for moisture (2021, 2022), varieties demonstrated higher resistance, which is confirmed by weaker dynamics of value decline between assessment stages.

Table 5

Dynamics of potato variety resistance of different maturity groups to Alternaria depending on moisture level (HTC) in 2021–2024

Maturity group	Year	I assessment		II assessment		III assessment		r
		HTC	$\bar{X}$	HTC	$\bar{X}$	HTC	$\bar{X}$	
Early			8.0		7.0		6.0	0.939
Medium-early	2021	0.87	8.0	0.85	6.8	0.76	5.8	0.919
Medium-maturing			8.3		7.1		5.6	0.959
Early			7.7		7.3		5.7	-0.236
Medium-early	2022	0.94	8.0	1.18	7.2	1.07	6.2	-0.486
Medium-maturing			8.3		7.8		6.6	-0.332
Early			7.5		6.0		4.0	0.528
Medium-early	2023	0.5	7.9	0.45	7.1	0.47	6.4	0.627
Medium-maturing			8.5		7.6		6.2	0.491
Early			6.3		5.3		4.0	0.990
Medium-early	2024	0.41	7.2	0.36	6.2	0.32	4.7	0.984
Medium-maturing			7.4		6.2		5.2	0.999

However, additional aspects of the moisture regime influence on Alternaria development should be considered. Research by Meno et al. (2019) [29] confirms that disease development is possible not only under sufficient moisture conditions, but also during prolonged interruptions of wet periods. Under field conditions, restoration of wet periods is possible during nighttime and early morning hours (due to dew formation), which should also be considered when assessing disease risks. Scientists Everts and Lacy [32], Vloutoglou and Kalogerakis [33], Van der Waals et al. [34] note that conidia of *Alternaria spp.* fungi, despite reduced humidity, can sporulate under the influence of short wet periods alternating with dry intervals throughout the day. This confirms the necessity of considering such periods as markers for fungicide application against Alternaria. Along with moisture level, temperature conditions have a significant impact on early Alternaria development. Research by Holley et al. [35] and Ganie et al. [36] confirms that alongside genotype, growing conditions seriously affect disease development, with temperature having the greatest impact rather than relative humidity or precipitation. This is consistent with our correlation analyses: correlation relationships between average resistance score and HTC are high and significant in 2021 and 2024, indicating a direct influence of hydrothermal conditions on variety resistance. In 2023, correlation coefficients were moderately positive, which may be attributed to specific weather conditions and varietal characteristics. In 2022, correlation was the weakest, which is likely related to other factors that influenced variety resistance during this period. These results emphasize the necessity for further research on the impact of short-term changes in humidity and temperature regime on Alternaria development under field conditions. This will allow for improved predictive models and the development of more effective approaches to breeding resistant potato varieties and plant protection systems.

Conclusions

The results of the studies conducted in 2021–2024 established a significant influence of hydrothermal conditions on the dynamics of potato variety infection by Alternaria under the changing climate conditions of the Polissia region of Ukraine.

1. Dynamics of potato variety infection by *Alternaria* spp. pathogen. Early-maturing varieties are characterized by the highest average level of phytopathogen infection already at the first assessment stage

(2.7–19.5 %), indicating their increased susceptibility to the disease. They demonstrate a smaller multiple increase in infection percentage by the third assessment stage, however, the overall infection level remains the highest (22.3–44.5 %) among other maturity groups. Medium-early varieties were characterized by a smaller proportion of potato genotype infection degree (1.9–12.2 % at the first assessment stage) and less decline in resistance by the third assessment stage (17–37.3 %) compared to early forms, indicating their relative tolerance to *Alternaria* spp. pathogen. Medium-maturing varieties showed the lowest infection level at the first assessment stage (0.8–6.6 %), however, they demonstrated a significant increase by the third assessment stage (11.5–31.7 %), which may indicate their tolerance at early development stages with subsequent active manifestation of disease symptoms. However, the overall infection level of medium-maturing varieties remains lower than in early-maturing ones, indicating their relatively higher resistance.

2. Impact of weather conditions on Alternaria development. It was established that during drought periods with reduced HTC values from 0.87 to 0.32, a significant increase in the level of potato variety infection by the phytopathogen is observed, which is confirmed by high negative correlations (r = –0.951...–0.999) and moderately negative correlations (r = –0.343... –0.488). In 2022, which was favorable for plant development (HTC > 1.0), the average infection level was lower, which is explained by less favourable conditions for pathogen development, and correlations were weak (r = 0.236–0.486).

3. Analysis of potato variety resistance level to Alternaria showed its variability depending on maturity group and hydrothermal conditions. At the first assessment stage, the highest resistance level (8.0–8.5 points) was observed in 2021–2023, with a gradual decline to 6.3–7.4 points in 2024 (HTC 0.87–0.41). At the second assessment stage, resistance decline was also observed under drought conditions (2023, 2024), however less pronounced than at the third assessment, with fluctuations from 7.0–7.8 points under favourable conditions (2021–2022) to 5.3–6.2 points under drought (2024). At the third assessment stage, significant resistance decline was noted in all groups: from 6.0–6.6 points under favourable conditions (2021–2023) to 4.0–5.2 points under severe drought (2024).

4. Identification of varieties with stable resistance. Early varieties: Radomysl, Tyras are resistant under sufficient moisture and moderate drought conditions, however, Tyras showed a decline in resistance to moderate level in the drought year. Medium-early varieties: Nahoroda, Avanhard, Opillia, Partner, Mezhyrichka 11 – demonstrate stable resistance, although under significant moisture deficit moderate decline in resistance is noted. Medium-maturing varieties: Bazaliia, Lietana, Serpanok, Alians, Ivankivska rannia – have high stable resistance, with insignificant decline in resistance even in drought years.

5. The general trend of potato variety resistance dependence to Alternaria on moisture level is confirmed by high correlations, especially in 2024 (r > 0.999…0.990), indicating the influence of HTC on the manifestation of potato variety resistance to Alternaria. Drought conditions (HTC < 0.50) promote enhanced Alternaria development, with early-maturing varieties demonstrating the lowest resistance level (4 points) to the phytopathogen. Medium-early varieties show intermediate values (4.7 points) in resistance between early and medium-maturing varieties (5.2 points). Medium-maturing varieties showed relatively greater stability in resistance, although they also demonstrated a decline in resistance at low HTC values.

Future research prospects are seen in expanding the temporal horizon of observations to study the dynamics of potato variety resistance to Alternaria under various climatic scenarios. Research on the impact of stress factor combinations, such as drought and high temperatures with uneven precipitation patterns, on the resistance of new promising hybrids and potato varieties is promising. Further research may be directed toward studying the influence of different agrotechnical approaches on the manifestation of potato variety resistance to Alternaria under the changing climate conditions of Central Polissya of Ukraine, which will allow for the development of adaptive potato cultivation strategies in this region.

Conflict of interest

The authors state that there is no conflict of interest.

References

1. Delgado-Baquerizo, M., Guerra, C. A., Cano-Díaz, C., Egidi, E., Wang, J.-T., Eisenhauer, N., Singh, B. K., & Maestre, F. T. (2020). The proportion of soil-borne pathogens increases with warming at the global scale. *Nature Climate Change*, 10 (6), 550–554. https://doi.org/10.1038/s41558-020-0759-3
2. Da Cruz Cabral, L., Rodríguez, A., Delgado, J., & Patriarca, A. (2019). Understanding the effect of postharvest tomato temperatures on two toxigenic *Alternaria* spp. strains: Growth, mycotoxins and cell-wall integrity-related gene expression. *Journal of the Science of Food and Agriculture*, 100 (1), 123–130. https://doi.org/10.1002/jsfa.9950
3. Schmey, T., Tominello-Ramirez, C. S., Brune, C., & Stam, R. (2024). Alternaria diseases on potato and tomato. *Molecular Plant Pathology*, 25(3), e13435. https://doi.org/10.1111/mpp.13435
4. Meno, L., Escuredo, O., Rodríguez-Flores, M. S., & Seijo, M. C. (2021). Looking for a sustainable potato crop: Field assessment of early blight management. *Agricultural and Forest Meteorology*, 308–309, 108617. https://doi.org/10.1016/j.agrformet.2021.108617
5. Escuredo, O., Seijo-Rodríguez, A., Meno, L., & Abellán, M. R. (2019). Seasonal dynamics of Alternaria during the potato growing cycle and the influence of weather on the early blight disease in North-West Spain. *American Journal of Potato Research*, 96 (4), 532–540. https://doi.org/10.1007/s12230-019-09739-2
6. Singh, V., Shrivastava, A., Jadon, S., Wahi, N., Singh, A., & Sharma, N. (2015). Alternaria diseases of vegetable crops and its management control to reduce the low production. *International Journal of Agriculture and Biology*, 7, 834–840.
7. Campos, H., & Ortiz, O. (Eds.). (2020). *The Potato Crop*. Springer International Publishing. https://doi.org/10.1007/978-3-030-28683-5
8. Kasprzyk, I., Rodinkova, V., Šaulienė, I., Rybníček, O., Thibaudon, M., Chłopek, K., Ščevková, J., Stach, A., Jędryczka, M., Skjøth, C. A., Kennedy, R., Magyar, D., Pálfi, X., Satchwell, J., & Myszkowska, D. (2015). Air pollution by allergenic spores of the genus Alternaria in the air of central and eastern Europe. *Environmental Science and Pollution Research*, 22, 9260–9274. https://doi.org/10.1007/s11356-014-4070-6

9. Skjøth, C. A., Damialis, A., Belmonte, J., De Linares, C., Fernández-Rodríguez, S., Grinn-Gofroń, A., Jędryczka, M., Kasprzyk, I., Magyar, D., Myszkowska, D., Oliver, G., Páldy, A., Pashley, C. H., Rasmussen, K., Satchwell, J., Thibaudon, M., Tormo-Molina, R., Vokou, D., Ziemianin, M., & Werner, M. (2016). Alternaria spores in the air across Europe: abundance, seasonality and relationships with climate, meteorology and local environment. *Aerobiologia*, 32 (1), 3–22. https://doi.org/10.1007/s10453-016-9426-6
10. Vandecasteele, M., Landschoot, S., Carretti, J., Verwaeren, J., Höfte, M., Audenaert, K., & Haesaert, G. (2018). Species prevalence and disease progression studies reveal seasonal fluctuations in the Alternaria population on potato. *Plant Pathology*, 67 (2), 327–336. https://doi.org/10.1111/ppa.12734
11. Abuley, I. K., Nielsen, B. J., & Labouriau, R. (2017). Resistance status of cultivated potatoes to early blight (*Alternaria solani*) in Denmark. *Plant Pathology*, 67 (2), 315–326. https://doi.org/10.1111/ppa.12744
12. Edin, E., Liljeroth, E., Andersson, B. (2019). Long term field sampling in Sweden reveal a shift in occurrence of cytochrome b genotype and amino acid substitution F129L in Alternaria solani, together with a high incidence of the G143A substitution in *Alternaria alternata*. *European Journal of Plant Pathology*, 155, 627–641. https://doi.org/10.1007/s10658-019-01798-9
13. Tymon, L. S., Cummings, T. F., & Johnson, D. A. (2016). Identification and aggressiveness of three *Alternaria* spp. on potato foliage in the US Northwest. *Plant Disease*, 100 (4), 797–801. https://doi.org/10.1094/PDIS-08-15-0942-RE
14. Ding, S., Meinholz, K., Cleveland, K., Jordan, S. A., & Gevens, A. J. (2018). Diversity and virulence of *Alternaria* spp. causing potato early blight and brown spot in Wisconsin. *Phytopathology*, 109 (4), 436–445. https://doi.org/10.1094/PHYTO-06-18-0181-R
15. Zheng, H. H., Zhao, J., Wang, T. Y., & Wu, X. H. (2016). Characterization of *Alternaria* species associated with potato foliar disease in China. *Plant Pathology*, 64 (3), 425–433. https://doi.org/10.1111/ppa.12274
16. Droby, S. (1984). Pathogenicity of Alternaria alternataon Potato in Israel. *Phytopathology*, 74 (5), 537. https://doi.org/10.1094/phyto-74-537
17. Dube, J. P., Truter, M., & van der Waals, J. E. (2014). First report of resistance to QoI fungicides in Alternaria alternata isolates from potato in South Africa. *Plant Disease*, 98 (10), 1431. https://doi.org/10.1094/PDIS-03-14-0225-PDN
18. Polozhenets, V. M., Nemeritska, L. V., Zhuravska, I. A., & Fedorchuk, S. V. (2014). Biolohichni osoblyvosti zbudnyka alternariozu plodiv ta obgruntuvannia zakhodiv zakhystu v umovakh Polissia Ukrainy. *Agropromyslove Vyrobnytstvo Polissia*, 7, 52–55. [in Ukrainian]
19. Einspanier, S., Susanto, T., Metz, N., Wolters, P. J., Vleeshouwers, V. G. A. A., Lankinen, Å., Liljeroth, E., Landschoot, S., Ivanović, Ž., Hückelhoven, R., Hausladen, H., & Stam, R. (2022). Whole-genome sequencing elucidates the species-wide diversity and evolution of fungicide resistance in the early blight pathogen Alternaria solani. *Evolutionary Applications*, 15 (10), 1605–1620. https://doi.org/10.1111/eva.13350
20. Odilbekov, F., Edin, E., Mostafanezhad, H., Coolman, H., Grenville-Briggs, L. J., & Liljeroth, E. (2019). Within-season changes in Alternaria solani populations in potato in response to fungicide application strategies. *European Journal of Plant Pathology*, 155, 953–965. https://doi.org/10.1007/s10658-019-01826-8
21. Meno, L., Abuley, I., Seijo, M. C., & Escuredo, O. (2024). Management Strategies for Early Blight in Potatoes: Assessment of the TOMCAST Model, Including the Aerobiological Risk Level and Critical Phenological Period. *Agriculture*, 14 (8), 1414. https://doi.org/10.3390/agriculture14081414
22. Devaux, A., Goffart, J. P., Kromann, P., Andrade-Piedra, J. L., Polar, V., Hareau, G., & Thiele, G. (2021). The potato of the future: Opportunities and challenges in sustainable agri-food systems. *Potato Research*, 64, 681–720. https://doi.org/10.1007/s11540-021-09501-4
23. Xue, W., Haynes, K. G., & Qu, X. (2019). Characterization of early blight resistance in potato cultivars. *Plant Disease*, 103 (2), 317–323. https://doi.org/10.1094/PDIS-05-18-0794-RE
24. Tekhnolohiia vyroshchuvannia kartopli. (n.d.). *Instytut kartopliarstva NAAN*. Retrieved from: https://ikar.in.ua/potato_intresting/technology/ [in Ukrainian]
25 Trybel, S. O., & Bondarchuk, A. A. (reds.) (2013). *Metodolohiia otsiniuvannia sortozrazkiv kartopli na stiikist proty osnovnykh shkidnykiv i zbudnykiv khvorob*. Kyiv: Ahrarna nauka [in Ukrainian]
26. Leiminger, J. H., & Hausladen, H. (2014). Untersuchungen zur Befallsentwicklung und Ertragswirkung der Dürrfleckenkrankheit (*Alternaria* spp.) in Kartoffelsorten unterschiedlicher Reifegruppe. *Gesunde Pflanzen*, 66, 29–36. https://doi.org/10.1007/s10343-014-0314-0
27. Duarte, H. S. S., Zambolim, L., Rodrigues, F. A., Paul, P. A., Pádua, J. G., Ribeiro Júnior, J. I., Júnior, A. F. N., & Rosado, A. W. C. (2014). Field resistance of potato cultivars to foliar early blight and its relationship with foliage maturity and tuber skin types. *Tropical Plant Pathology*, 39 (4), 294–306. https://doi.org/10.1590/S1982-56762014000400004
28. Wharton, P., & Wood, E. (2013). Early blight biology and control in potatoes. *University of Idaho, College of Agriculture and Life Sciences*, 1, 1–5. Retrieved from: https://objects.lib.uidaho.edu/uiext/uiext32089.pdf
29. Meno, L., Escuredo, O., Rodríguez-Flores, M. S., & Seijo, M. C. (2019). Interrupted wet period (IWP) to forecast the aerial alternaria in potato crops of a Limia (Spain). *Agronomy*, 9 (10), 585. https://doi.org/10.3390/agronomy9100585
30. Shtienberg, D. (2014). Alternaria diseases of potatoes: epidemiology and management under Israeli conditions. *Proceedings of the 14th EuroBlight Workshop, Limassol, Cyprus. Praktijkonderzoek Plant en Omgeving (PPO) Special Report 16*. (P. 169–180). Lelystad, Netherlands: Wageningen UR, Applied Plant Research
31. Dita Rodriguez, M. A., Brommonschenkel, S. H., Matsuoka, K., & Mizubuti, E. S. G. (2006). Components of resistance to early blight in four potato cultivars: effect of leaf position. *Journal of Phytopathology*, 154 (4), 230–235. https://doi.org/10.1111/j.1439-0434.2006.01089.x
32. Everts, K. L. (1990). The influence of dew duration, relative humidity, and leaf senescence on conidial formation and infection of onion by *Alternaria porri*. *Phytopathology*, 80 (11), 1203. https://doi.org/10.1094/phyto-80-1203
33. Vloutoglou, I., & Kalogerakis, S. N. (2000). Effects of inoculum concentration, wetness duration and plant age on development of early blight (Alternaria solani) and on shedding of leaves in tomato plants. *Plant Pathology*, 49 (3), 339–345. https://doi.org/10.1046/j.1365-3059.2000.00462.x
34. Van der Waals, J. E., Korsten, L., Aveling, T. A. S., & Denner, F. D. N. (2003). Influence of environmental factors on field concentrations of *Alternaria solani* conidia above a South African potato crop. *Phytoparasitica*, 31 (4), 353–364. https://doi.org/10.1007/bf02979806
35. Holley, J. D., Hall, R., & Hofstra, G. (2010). Effects of cultivar resistance, leaf wetness duration and temperature on rate of development of potato early blight. *Canadian Journal of Plant Science*, 65 (1), 179–184. https://doi.org/10.4141/cjps85-024
36. Ganie, S. A., Ghani, M. Y., Lone, A. H., Razvi, S. M., Mir, M. R., & Hakeem, K. (2015). Role of weather factors on early blight of potato under Kashmir Valley conditions. *Molecular Plant Breeding*, 6 (1), 1–5. https://doi.org/10.5376/mpb.2015.06.0004

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