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INFLUENCE OF TEMPERATURE ON TUBER INFECTION BY PVY, PVM and PVS

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Seed-potato quality is closely related to tuber infection by viruses. Therefore it is necessary to analyse all factors influencing this infection and on this basis to draw conclusions on seed-potato production. Air temperature is a basic element of climate, and its means can be regarded as a complex climatic phenomenon [7, 12]. Sums of temperatures exceeding a certain threshold are the best index of air temperature, when its effect on gradations of vectors, and in this particular case — of aphids, is analysed. The fact that temperature sums are distinctly correlated with viral infection of potatoes can be explained by the effect of temperature on aphid gradations [5, 6]. Nevertheless, temperature influences the health of potatoes not only via its effect on vectors but also via direct action on host plants and virus multiplication. The effect of temperature on plant susceptibility as well as on multiplication and concentration of PVY has been reported by Nienhaus [9, 10], de Bokx [1, 2] and Close [3]. Data from the literature concerning PVM are scarce. Dziewońska [4] has found that at higher temperatures PVM could be detected earlier than at lower temperatures. However, there are no data on such an effect of temperature on tuber infection, which can depend on the influence of temperature on plant susceptibility, and in the first place on virus multiplication and penetration into tubers. Likewise, there is no information whether this effect is perceptible under natural conditions, and consequently whether it can be considered in the prognosis of seed-potato health. The aim of the present analysis was to elucidate this problem and to prepare the data for utilization in the prognosis of seed-potato health.

METHOD

In the present evaluation, for analysis of the effect of temperatures after inoculation on the percentage of infected tubers use was made of the results of studies published by Wisłocka [13-15], in which potatoes have been inoculated under field conditions with PVY, PVM and PVS. In the studies of Wisłocka, in separate 3-year experimental series the three above-mentioned viruses have been used for inoculation of potatoes with a spray-gun on three dates. Tubers have been collected on five dates (for PVY — on four dates). Experiments have been performed for the series with PVY, PVM and PVS on eight, three and four potato varieties, respectively. In the present analysis, in case of PVM the variety Pierwiosnek was ruled out, because it often exhibited tuber infection of 100%, this creating difficulties in the analysis of regression. However, the results obtained for this variety were given separately.

For statistical analysis we accepted the percentage of tuber infection, as found in these experiments, and transformed it according to the equation:

$$Y_v = \lg (p+1) \quad (\text{for PVM} \quad Y_M = \lg p) \qquad (1)$$

where: p — percentage of infected tubers.

Data of the local meteorological station were used for calculation of the mean daily air temperatures between 1-10 days (x_1) and between 11-20 days after inoculation (x_2), and in case of virus Y — also between 1-20 days after inoculation (x_3). Mean daily air temperatures after inoculation and virus infection in the successive years are presented in Table 1.

Table 1

Range of temperature variability and mean tuber infection in successive years

Virus	Year	Mean temperature (°C) after inoculation (PVY of 20 days, PVM and PVS of 10 days)	Mean percent of infected tubers	Range of temperature °C
PVY	1970	17.6	12.2	17.1—18.2
	1971	17.6	9.9	15.6—20.4
	1972	18.9	4.5	16.8—22.4
PVM	1973	16.7	41.5	13.3—20.7
	1974	14.8	27.2	14.3—15.3
	1975	17.9	63.0	14.3—20.9
PVS	1975	17.8	35.4	14.4—20.9
	1976	17.3	55.3	14.4—21.0
	1977	17.6	32.1	15.4—20.3

Analysis of simple and multiple regression of virus infection on temperature was carried out. The mean daily air temperatures after inoculation (x_1, x_2 and x_3) were accepted as independent variables.

Analysis of regression was at the first stage performed with elimination, from the total variability, of the effect of varieties, date of planting and date of harvest as well as of their. interations. The variability of years was salso eliminated. Thus, the analysis of regression was based on the variability of the interation between the experimental factors and years. At first it was determined which of the accepted independent variables (x_1, x_2, x_3) are best correlated with infection by the investigated viruses.

Moreover, the coefficient of determination was calculated for estimation of the participation of temperature in all environmental factors influencing the infection of tubers of the inoculated plants. Furthermore for PVM the analysis of regression was carried out for the different inoculation dates and different potato varieties, including variety Pierwiosnek.

RESULTS

INFECTION OF TUBERS BY PVY

Analysis of multiple regression demonstrated a significant correlation between PVY infection and temperatures x_1 and x_2 — the equation of regression is as follows:

$$Y_Y = -1.008 + 0.0386x_1 + 0.0714x_2 \text{ for } R = 0.363 \quad (a < 0.05) \qquad (2)$$

For simplification it can be assumed that the coefficients of regression do not differ, and then the equation of simple regression is obtained:

$$Y'_Y = -1.071 + 0.1130x_3 \qquad (3)$$

In this case the correlation coefficient decreased, but only very slightly, and amounted to:

$$r = 0.354 \quad (a < 0.05) \qquad (4)$$

Thus, it can be assumed that acceptation of the simplification according to equation [3] is admissible. For PVY, therefore, in the further analyses the mean daily air temperatures during 20 days after inoculation (x_3) were accepted.

The coeefficient of determination averaged about 12% and varied between 10-19%. Therefore, it can be stated that temperature exerts a significant effect on tuber infection of PVY-inoculated plants. For the accepted parameters, however, the observed effect of temperatures hardly exceeded the significance level, and under the experimental conditions used it accounted for no more than 10-20% of all environmental factors involved. In the analysis of regression on temperatures for each harvest date separately, it was found that the coefficients of regression and determination exhibit no downward tendency (Table 2 and Fig. 1). Thus, inhibition of virus penetration into the tubers by lower temperatures is not compensated in the later vegetation period.

INFECTION OF TUBERS BY PVM

In the analysis of multiple regression we obtained:

$$Y_M = 1.345 + 0.06619x_1 - 0.004475x_2 \text{ for } R = 0.563 \tag{5}$$

When single regression on x_1 was taken into account, regression on x_2 proved to be insignificant. Therefore, for analysis of PVM infection only the temperature of the first decade (x_1) was used:

$$Y'_M = 0.227 + 0.0845x_1 \text{ for } R = 0.549 \quad (\alpha \approx 0.05) \tag{6}$$

The coefficient of determination of temperatures averaged 30% and varied from about 50% (20-30 days after inoculation) to 20% (at tuber maturity).

According to Table 1, PVM infection is in the successive years related to temperatures, statistical analysis (Table 3) showed that after including of the variability of years into the analysed regression on temperatures, the effect of years was no more insignificant. It can be assumed that the differences in infection between years in the experiment may be attributed to the effect of temperatures. In this case we obtain the equation:

$$Y_M'' = 0.0153 + 0.0973x_1 \text{ for } R = 0.734 \quad (\alpha < 0.01) \tag{7}$$

Thus, after including of the variability of years into the analysed variability, the determination increased. More than 50% of variability ($d = 54\%$) caused by conditions of the natural environment can in this case be attributed to temperature during the first decade after inoculation (Table 2). During 3 decades after inoculation the coefficient of determination exceeded 60%. Therefore, it can be assumed that temperatures are the basic factor of the natural environment, influencing PVM

Table 2

Coefficients of regression (b) and determination (d) of virus infection on mean daily air temperature in dependence of harvest date

Virus	Temperatures taken for period	Coefficients	Values of coefficients						Degrees of freedom
			mean	for number of days from inoculation till harvest				after maturity	
				20	30	40	50		
PVY	20 days after inoculation	b	0.113	0.087	0.100	0.145	—	0.120	45
		d	12%*	10%*	12.5%*	19%**		11%*	
PVM	10 days after inoculation	b	0.097	0.130	0.099	0.099	0.093	0,065	11
		d	54%**	61%**	67%**	40%**	45%**	36%*	
PVS	10 days after inoculation	b	0.019	0,038	0.041	0,013	0.003	0.001	21
		d	3.3%	9.2%	7.4%	2.3%	0.1%	0.0%	

* Significant at $\alpha = 0.05$.
** Significant at $\alpha = 0.01$.

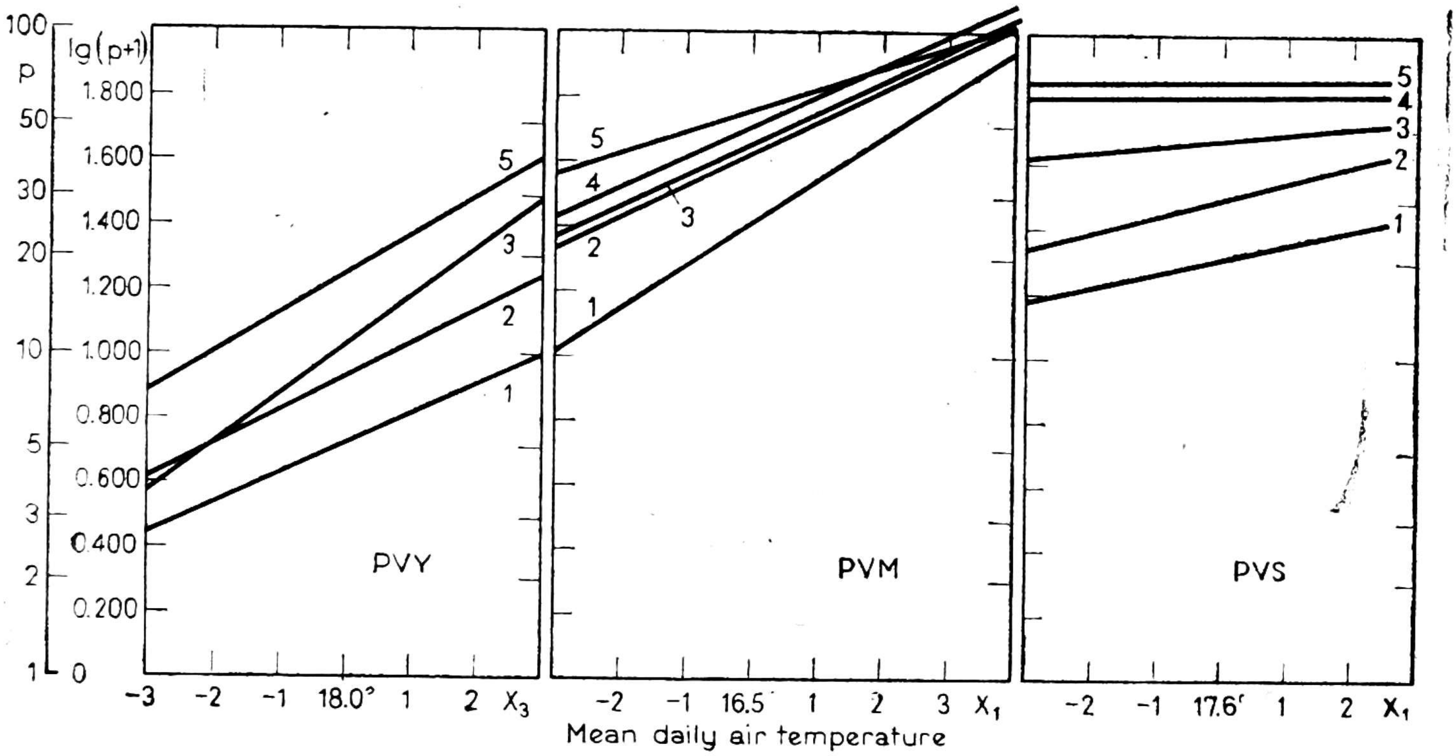

Fig. 1. Influence of air temperature on infection of potato tubers with PVY, PVS and PVM for different harvest dates;
x_1 — means for 10 days after inoculation, x_3 — means for 20 days after inoculation, P — percent of infected tubers, *1, 2, 3, 4* — harvest 20, 30, 40 and 50 days after inoculation, *5* — harvest at maturity

translocation into the tubers of plants inoculated with this virus. Analysis of regression on temperatures for the different dates of harvest (Fig. 1) indicates that the effect of post-inoculation temperatures on infection of tubers remains considerable till their maturity, though it perceptibly decreases. Later conditions cannot, therefore, fully compensate the effect of temperature in the first decade after inoculation. In the analysis of the effect of temperatures on the different potato cultivars and in case of different inoculation dates, the number of degrees of freedom was low (Fig. 2). Significant correlation was obtained for the most resistant cultivar Warta, as well as for the third date of inoculation (40 days after emergence). In case of more susceptible cultivar and earlier inoculation the effect was slighter and failed to be significant.

INFECTION OF TUBERS BY PVS

Analysis of regression did not demonstrate a significant effect of temperatures. The following equation was obtained:

$$Y_S = 1.272 + 0.0192x_1 \quad \text{for } R = 0.181 \quad (\alpha > 0.05) \tag{8}$$

Mean coefficient of determination is 3.3%, and attains 9% for harvest 20 days after inoculation. Thus, despite the lack of significance, on

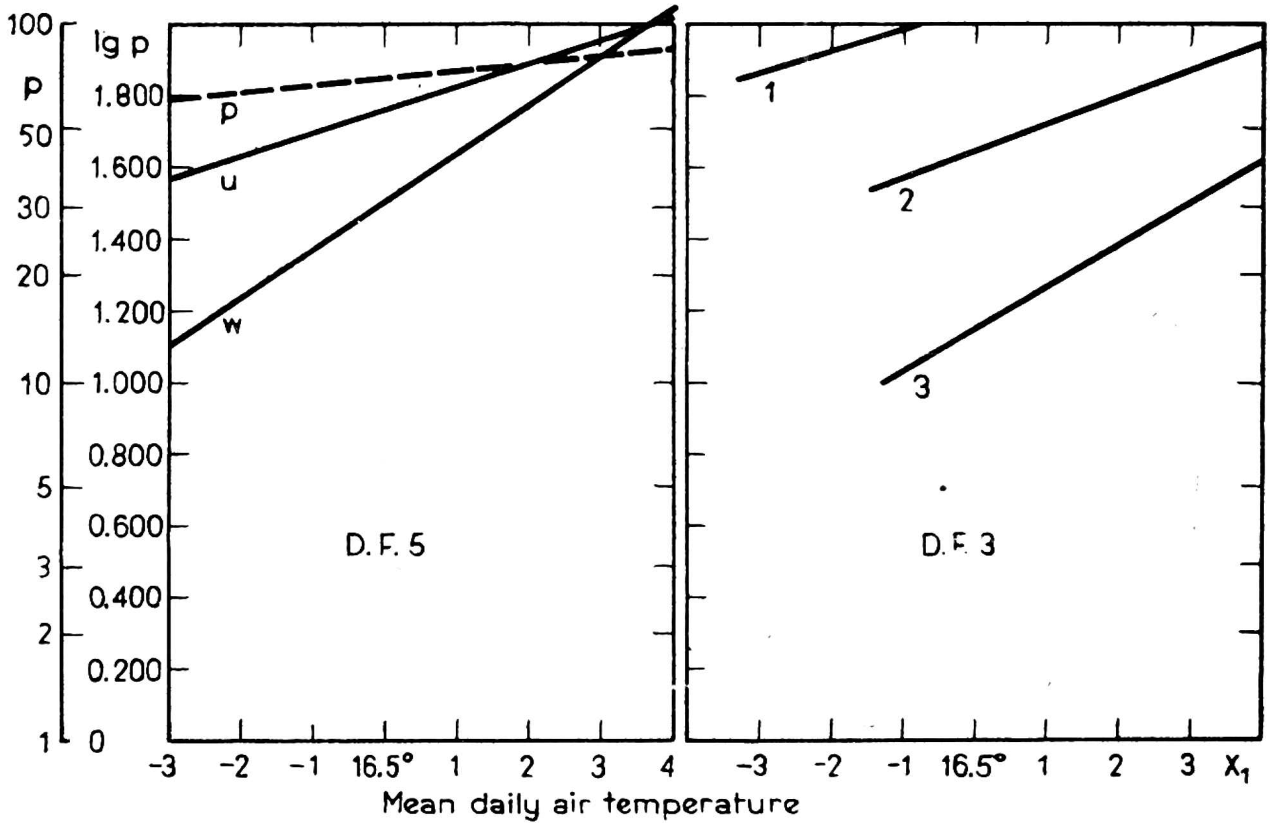

Fig. 2. Influence of air temperature on infection of potato tubers by PVM for different cultivars and various inoculation dates;
P — cv. Pierwiosnek (d = 19%), U — cv. Uran (d = 39%, $\alpha > 0.05$), W — cv. Warta (d = 59%, $\alpha < 0.05$),
***1* — inoculation 10 days after emergence (d = 41%), *2* — inoculation 25-30 days after emergence (d = 64%, $\alpha > 0.05$), *3* — inoculation 30-40 days after emergence (d = 87%, $\alpha < 0.05$), D. F. — degrees op freedom**

account of the logic trend of the results we consider their discussion to be appropriate. In any case the participation of temperatures in the environmental factors influencing tuber infection by PVS in plants inoculated with this virus is slight. Data from Table 1 indicate that the effect of years was not related to temperatures. As concerns the different dates of harvest (Table 2 and Fig. 1), correlation coefficients decreased with reterdation of harvest, and 50 days after inoculation there was not any more effect of temperatures on tuber infection. Therefore, it can be assumed that probably lower temperatures only decrease the rate of PVS translocation into tubers.

DISCUSSION

Statistical evaluation demonstrated a significant effect of temperatures after inoculation on the number of infected tubers. This effect was greatest with respect to translocation of PVM, but it was also distinctly significant with relation to PVY. Infection by PVY in a great measure determines the quality of seed-potatoes. Fig. 2 indicates that the effect of temperature is more important under less favourable conditions of virus spreading: more resistant varieties, later inoculation (Figs. 1 and 2). This phenomenon, observed for PVM, probably takes place also in case of PVY, though in the present evaluation its significance was not confirmed statistically.

Table 3

Analysis of variance of infection with PVM

Source of variation	Degrees of freedom		Sum of squares		Mean square	F - empirical
Total	89		18.05			
Cultivars (C)	1		1.21		1.213	4.59
Dates of inoculation (I)	2		7.52		3.767	14.26**
C×I	2		0.73		0.365	1.38
Years+Interaction of C and I with years	12		6.30		0.525	—
Regression to x_1		1		3.40	3.401	12.88**
Residual		11		2.90	0.264	
(Including years to the regression analysis)		(2)		(0.20)	0.100	<1
Date of harvest (H)	4		1.16		0.291	19.40**
Interactions C, I and H	20		0.40		0.020	1.33
Residual	48		0.72		0.015	

In the practice of seed production, virus transmission by aphids is usually late with respect to potato vegetation and is rather close to the time of harvest, especially if the haulm are destroyed. Air temperatures prevailing at this time can be of great importance, though this fact has not so far been appreciated.

The fact that the effect of temperature on translocation, and thus in practice on spread of PVM, is so strong can be one of the elements determining the geographic distribution of this virus. This effect, together with the occurrence of the most efficient vector of the virus — aphid *Aphis nasturtii* Kalt. [8], can be decisive of the greater endangering from PVM in the more continental climate of Central and East Europe, as compared with West Europe.

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ВЛИЯНИЕ ТЕМПЕРАТУР ВОЗДУХА ПОСЛЕ ИНОКУЛЯЦИИ НА ПОРАЖЕНИЕ КЛУБНЕЙ КАРТОФЕЛЯ НЕКОТОРЫМИ ВИРУСАМИ

Резюме

Констатировано существенное влияние температур в полевых условиях после искусственной инокуляции растений картофеля на количество пораженных клубней Y (PVY), M (PVM) и S (PVS) вирусами картофеля (положительная корреляция). Самое большое влияние наблюдалось при P M, при котором температура в течение 10 дней после заражения по действию превышала 50% всех факторов естественной среды, оказывающих влияние на это поражение. При PVM сильнейшее влияние температур наблюдалось при более устойчивых сортах и позднейшем заражении. Эффект этого влияния уменьшался спустя некоторое время после инокуляции, но оставался существенным до созревания клубней. Влияние температур на количество клубней, пораженных PVS, было значительно слабее, но удерживалось до окончания вегетации. При PVS наблюдалось только уменьшение быстроты проникновения вирусов к клубням при более низких температурах, но оно не достигло уровня статистической существенности.

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WPŁYW TEMPERATURY POWIETRZA PO INOKULACJI NA PORAŻENIE BULW ZIEMNIAKA NIEKTÓRYMI WIRUSAMI

Streszczenie

Stwierdzono istnienie wpływu temperatur w warunkach polowych po sztucznej inokulacji roślin ziemniaka na liczbę porażonych bulw wirusami Y (PVY), M (PVM) i S (PVS) ziemniaka (korelacja dodatnia). Największy wpływ zaobserwowano przy PVM, przy którym temperatura w ciągu 10 dni po zakażeniu przekraczała w oddziaływaniu 50% wszystkich czynników środowiska naturalnego wpływającego na to porażenie. Przy PVM silniejszy wpływ temperatur obserwowano przy odporniejszych odmianach i późniejszym zakażeniu. Efekt tego wpływu zmniejszał się z upływem czasu od inokulacji, ale pozostawał istotny do dojrzałości bulw. Wpływ temperatur na liczbę bulw porażonych PVY był znacznie słabszy, ale utrzymywał się do końca wegetacji. Przy PVS zaobserwowano jedynie zmniejszenie szybkości przenikania wirusów do bulw przy niższych temperaturach, ale nie osiągnęło ono poziomu statystycznej istotności.

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