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THE OCCURRENCE OF MAJOR POTATO VIRUSES IN POLAND

*Michał Kostiw**

Plant Breeding and Acclimatization Institute – National Research Institute
Department of Potato Protection and Seed Science in Bonin
76-009 Bonin, Poland

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Abstract: The research was carried out in field conditions in Bonin in the north of Poland, in 1996–2009, and additionally in Bonin, Przechlewo (also in the north of Poland) and Stare Olesno located in the southern part of Poland, in 2008 and 2009. The outcome showed that *Potato virus Y* posed the most serious threat to potatoes. The share of progeny tubers infected by this pathogen was 32.5% (mean of 1996–2009) and was considerably higher in comparison to PVM (18.2%) and PVS (22.1%), and in particular to PLRV (15.3%). The additional research carried out in the years 2008 and 2009 in three places: Bonin, Przechlewo (located in the north of Poland) and Stare Olesno (south of Poland) included three potato cultivars of low resistance to PLRV. The results also showed a very low pressure of this virus in both years and in all places of the research. In Przechlewo, PLRV was not detected at all in progeny tubers. While in Stare Olesno and particularly in Bonin, the percentage of PLRV-infected tubers was very small. The average for years and the average for localities amounted to 2.1 and 0.3%, respectively. Whereas the share of tubers infected by PVY, PVM and PVS was considerably higher and ranged from 11.8% to 59.8% depending on the cultivar, year and place. The progeny tubers infected by PVY and PVM were mostly detected in the very early term of exposure(from the 21st of May to the 1st of June). Whereas PVS posed the most serious threat in a somewhat later term i.e. during the exposure of plants which lasted from the 1st of June to 11th of June.

Key words: potato, PVY, PVM, PVS, PLRV, occurrence

INTRODUCTION

A key factor for good economic results in the production of potatoes is to achieve a high tuber yield with the desired utility characteristics. To meet this condition, a constant supply of valuable seed material to the seed production fields is needed.

The quality of the seed material has a much more significant meaning for potato crop than field production of crops propagated by seeds. The potato tuber is the vegetative organ. In practice, this means that seed-borne diseases have a strong influence on the quality of produced seed material. Viral diseases are particularly severe in the production of seed potatoes.

According to Salazar (1996), over 30 viruses can infect potato crop, while in the opinion of Brunt *et al*. (1996), there may be more than 50 viruses. Four of them are common in Poland: *Potato virus Y* (PVY), *Potato virus M* (PVM), *Potato virus S* (PVS), and *Potato leafroll virus* (PLRV). Currently, PVY is without a doubt of the greatest importance. This pathogen infects potato crops in all regions of the world where the species is grown. Typically it evokes severe infections. Therefore, a significant drop in potato tuber yields, of up to 80% can take place. The level of loss is clearly dependent on the potato variety, virus strain, the date of infection, severity of symptoms and other factors (Whitworth *et al*. 2006).

Chrzanowska (2004, 2009) reported that PVY risk is greater in Poland. This is mainly due to the increasing amounts of foreign potato varieties used for cultivation. Foreign varieties usually have a lower resistance level to the pathogen than Polish bred varieties. Changes in virus strain populations, resulting from recombination, may have an influences as well (Nie and Singh 2003; Chigh *et al*. 2010). In Poland, visible changes have been recorded in the last 30 years (Chrzanowska 2009). The incidence of a new variant of strain PVY^N which was mild for potato, was observed in 1983. It was named PVY^NW (after isolated from Wilga potato cultivar). That strain was considered to be different from the up-to-date so-called *necrotic* ones – and originated by recombination between strains PVY^N and PVY^0. It was proved, that PVY^NW is highly infective and spreads very quickly. PVY^NW does, however, evoke weak symptoms in potato crops; much weaker than the normal strain (PVY^0). These symptoms are often difficult to recognize and their intensity greatly depends on the potato cultivar (Chrzanowska 2009). The PVY^{NTN} first found in Poland in 1994 (Chrzanowska 2009) i.e. necrotic virulent strain also originated by recombination (Chrzanowska and Doroszewska 1997). It is characterized by higher pathogenicity than PVY^NW. It usually causes severe symptoms, often in the form of necrosis in the crop. Moreover, it is able to evoke symptoms of potato tuber necrotic ring dis-

*Corresponding address:
michalkostiw@o2.pl

ease (PTNRD), which is particularly harmful for the potato food processing industry.

Another virus that causes severe plant diseases, hence large losses in the yield of potato tubers, is the *Potato leafroll virus* (PLRV). In Poland, this virus reached maximum economic importance (comparable to the PVY) in the 1970s (Gabriel 1989). Significance of this pathogen has fallen for many years, although the reasons for this are not known yet. It is supposed that the decreasing number of sources of the virus in the field, due to a reduction in potato crops, could be an important reason. PLRV has become almost 6-fold lower than in 1963 (Kostiw and Robak 2010). Another reason may be a significantly limited number of the virus vectors. Currently, only one aphid species (*Myzus persicae* Sulz.) transmits PLRV in Poland and determines its economic importance. This virus is transmitted in a persistent manner, *i.e.* both acquisition and inoculation has to last long enough (24–48 hours) for the aphid to become an effective virus vector. Such a mechanism of transmission means that protection of potato against PLRV infection, by means of chemical control of aphids, is highly efficient. This is unlike the protection against viruses transmitted by aphids in a nonpersistent manner (*e.g.* PVY). In addition to a decreasing potato cultivation area, the spatial isolation between particular farm fields has grown. Aphid raids from outside the plantation are thus made difficult. The significance of the resistance by variety, should also be emphasized. According to Chrzanowska (verbal information), as much as 43% of varieties being currently entered into the register in Poland, stand out with resistance to PLRV at a level 6 or higher (on a scale of 1–9). It is a resistance high enough to protect the varieties against spread of that virus.

PVM and PVS are much less dangerous viruses. Both are common on potato plantations, but they do not cause any significant losses of tuber yields. Losses due to PVM and PVS range from 0 to 30%, depending on the reaction of the cultivar to the virus. PVM may cause considerable damage among cultivars. Such strong symptoms as leaf deformation and inhibition of the growth of whole plants may occur as a strong reaction to the virus. However, all symptoms disappear after some time and plants regain their normal looks.

The importance of PVS is negligible. In practice, plants infected by the virus show barely visible or lack of disease symptoms. Hence, no considerable yield decrease is recorded. The lack of serious harm means that PVS is not a subject of diagnostic research, when verification of the potato seed material is done by the State Inspectorate of Plant Health and Seed Inspection.

The purpose of this study was to compare PVY, PVM, PVS and PLRV spread in the years 1996–2009 in Bonin as well as in the years 2008 and 2009 in these three locations: in Bonin, Przechlewo and Stare Olesno. Another objective was to determine the date of the first tuber infections by these viruses in Bonin, and the date the virusl threat peaks in these locations.

MATERIALS AND METHODS

The studies aimed to investigate (I) the spread of PVY, PVM, PVS and PLRV; (II) the date of the first infection of tubers and (III) the period in which tubers infected with these viruses was the highest. The research was conducted under field conditions in Bonin, West Pomeranian Voivodeship, Poland. In the 21st of May to the 1st of September period of each study year, 20 potato plants (in 1996–2007, excluding years 2001 and 2004) or 30 plants (in 2008 and 2009) were exhibited on the field every 10 days. Healthy 7–10 day old plants were used (derived from *in vitro* plantlets). They were grown from minitubers in the greenhouse in pots. The diameter of the pots was 18 cm. Pots were filled with a mixture of peat soil with compost. The potato cultivars used were: in 2006 the cv Amerykany (considered to be susceptible to PVY and moderately sensitive to PLRV) and in 2007–2008 the cv Dalia (resistance to PVY and PLRV, 5.0 and 5.0 in the 9-grade scale, respectively). These cultivars were specially chosen, due to their low resistance to PVY and PLRV. After 10 days of exposure in the field, plants were transferred to an insect-free greenhouse and treated with insecticide to kill any possible aphids present on the plants. After completion of the growing season, daughter tubers were harvested from each plant and placed in a storage-house at 4-6°C. In the spring of the following year, eye-fragments were cut out from each tuber and planted in a greenhouse, in pots filled with peat. After about six weeks, two leaves were collected from the mid-section of each plant. Then, juice was squeezed out for diagnostic research in an ELISA test, with antibodies from Bioreba. They were tested for presence of PVY, PVM, PVS and PLRV. ELISA results were used for calculating the percentage of tubers affected by different viruses in different periods of exposure of the test plants. The study, which aimed only to compare the spread of the investigated viruses, was conducted in 2008 (cultivar Cekin, resistance to PVY, PVM and PLRV; 5, 3 and 5.5, respectively) and 2009 (Adam and Justa varieties with resistance to PVY and PLRV; 3–4 and 5–6, respectively cv Adam and cv Justa; 5–6 and 5–6, respectively). This study took place in three places: Bonin, West Pomeranian voivodeship; Przechlewo, Pomeranian Voivodeship and Stare Olesno, Opolskie Voivodeship. In both years, 300 minitubers derived from *in vitro* plants were planted in the field. After the growing season, one mid-sized daughter tuber was harvested from each plant. All tubers were stored at 4–6°C. In the spring of the following year, tubers were tested for the presence of PVY, PVM, PVS and PLRV as described above. All calculations were performed using the numbers transformed according to the formula: arc. sinVx, where "x" stands for infection. The results were then re-transformed to percentages.

RESULTS AND DISCUSSION

Table 1 presents the percentage of progeny tubers infected by PVY, PVM, PVS and PLRV. These tubers were harvested from plants subjected to a 10-day exposure in the field within different periods of the growing season (from the 21st of May to the 1st of September) in 1996–2009 (excluding the years 2001 and 2004) in Bonin. Mean values of all 10 exposure dates in particular years as well as averages of the years for the 1996–2009 period, were included. PVY was the most dangerous for potato

Table 1. Share of tubers infected with PVY, PVM, PVS and PLRV after a 10-day field exposure of plants in various periods of the vegetation season (from 21st of May to the 1st of September) in Bonin, in 1996–2009

Year	Cultivar	Share of tubers infected [%] from all 10 dates of plant exposure			
		PVY	PVM	PVS	PLRV
1996	Lotos	23.2	10.4	16.7	–
1997	Lotos	42.3	12.2	27.5	–
1998	Lotos	40.9	15.3	23.4	–
1999	Lotos	23.2	14.1	26.3	–
2000	Lotos	31.9	11.1	12.8	–
2002	Liwia	32.9	22.6	22.8	26.6
2003	Liwia	22.0	29.4	34.4	13.1
2005	Amerykany	46.6	47.4	45.0	58.9
2006	Amerykany	35.0	18.0	18.8	2.6
2007	Dalia	53.0	16.4	24.0	3.6
2008	Dalia	26.7	15.9	8.9	0
2009	Dalia	12.3	6.1	5.1	2.3
Mean		32.5	18.2	22.1	15.3

PVY – *Potato virus Y*; PVM – *Potato virus M*; PVS – *Potato virus S*; PLRV – *Potato leafroll virus*

Table 2. Share of tubers infected with PVY, PVM, PVS and PLRV (2008–2009) in three localities

Locality	Cultivar	Year	Share of tubers infected [%]			
			PVY	PVM	PVS	PLRV
Bonin	Cekin	2008	18.6	20.6	9.8	0
	Adam	2009	11.9	12.3	2.1	1.0
	Justa	2009	1.8	3.3	1.5	0
Mean			10.8	12.1	4.5	0.3
Przechlewo	Cekin	2008	16.6	11.8	53.0	0
	Adam	2009	0.5	0.5	0	0
	Justa	2009	0.3	1.4	0.3	0
Mean			5.8	4.6	17.8	0
Stare Olesno	Cekin	2008	59.8	14.7	39.3	1.4
	Adam	2009	11.0	42.8	7.0	3.3
	Justa	2009	0	6.0	8.0	1.7
Mean			23.6	21.2	18.1	2.1

Table 3. Share of tubers infected with PVY, PVM, PVS and PLRV in the earliest periods of field exposure of plants

Year	Cultivar	Share of tubers infected with PVY, PVM, PVS and PLRV [%] Term of field exposure of plants			
		PVY	PVM	PVS	PLRV
1996	Lotos	9.1 21.06–1.07	18.4 11.07–21.07	9.1 1.06–11.06	9.1 21.06–1.07
1997	Lotos	22.8 11.06–21.06	9.1 21.06–1.07	9.1 11.06–21.06	–
1998	Lotos	9.1 21.05–1.06	9.1 21.05–1.06	37.8 1.06–11.06	–
1999	Lotos	20.7 1.06–11.06	9.1 11.06–21.06	33.2 11.06–21.06	–
2000	Lotos	9.1 21.05–1.06	9.1 21.05–1.06	30.4 1.06–11.06	–
2002	Liwia	40.2 21.05–1.06	43.3 1.06–11.06	90.0 1.06–11.06	38.3 21.05–1.06
2003	Liwia	22.8 11.06–21.06	26.6 21.05–1.06	26.6 1.06–11.06	18.4 11.06–21.06
2005	Amerykany	33.2 1.06–11.06	36.3 1.06–11.06	26.6 1.06–11.06	12.9 21.05–1.06
2006	Amerykany	12.9 21.05–1.06	18.4 21.05–1.06	18.4 21.05–1.06	12.9 11.07–21.07
2007	Dalia	46.9 21.05–1.06	50.8 21.05–1.06	35.2 21.05–1.06	10.5 11.07–21.07
2008	Dalia	19.1 21.05–1.06	10.5 1.06–11.06	21.4 11.06–21.06	0
2009	Dalia	10.9 21.05–1.06	10.9 21.05–1.06	16.1 11.06–21.06	23.1 11.06–21.06

Table 4. Comparison of frequencies of the first tuber infection [+] with PVY, PVM, PVS, and PLRV in different periods of the growing season in Bonin, in 1996–2009

Term of field exposure of plants	21.05–1.06				1.06–11.06				11.06–21.06			
	PVY	PVM	PVS	PLRV	PVY	PVM	PVS	PLRV	PVY	PVM	PVS	PLRV
Years												
1996							+					
1997									+		+	
1998	+	+					+					
1999					+					+	+	
2000	+	+					+					
2002	+			+		+	+					
2003		+					+		+			+
2005				+	+	+	+					
2006	+	+	+									
2007	+	+	+									
2008	+					+					+	
2009	+	+									+	+

plants. The highest percentage of tubers infected by this pathogen was recorded in 2007 (53%). Infection was also high in 2005 (46.6%), 1997 (42.3%), and in 1998 (40.9%). The average of the years for tubers infected by PVY was 32.5% and was much higher compared to the data for PVM (18.2%) and PVS (22.1%). The pressure of both viruses (PVM and PVS) was usually similar in particular years. The greatest threat was recorded in 2005, when the share of infected tubers amounted to 47.4% and 45%, respectively. In most other years, these values were lower or significantly lower than those given above. The highest and the lowest percentage of tubers infected by PVM and PVS were observed in the same years and ranged from 6.1% and 5.1% in 2009 to 29.4% and 34.4% in 2003, respectively. Similarity of PVM and PVS pressure may indicate that the epidemiology of both viruses is affected by similar factors, which is consistent with previous results of Kostiw 2002; Kostiw and Robak 2010.

The average of the years, for the percentage of tubers infected by PLRV was low (15.3%): more than 3-fold and about 2-fold lower when compared respectively to PVY (32.5%) or to PVM (18.2%) and PVS (22.1%). The highest percentage of tubers infected by PLRV was recorded in 2005 (58.9%). Significant but much lower percentages were observed in the years 2002 (26.6%) and 2003 (13.1%). In all other years, it did not exceeded 4%, and ranged from 0% in the year 2008 to 3.6% in 2007. Thus, PLRV was a serious threat for potatoes only in the years 2002–2003 and its importance reached a peak in 2005 (that year the pressure of PVY, PVM and PVS was also very strong). In other years, the economic significance of this virus was very low, and in 1997–2000 PLRV did not pose any threat. However, it should be stressed that data obtained for PLRV in the years 1996–2000 are not exactly comparable with those from the other years because the cultivar Lotos was used in the study during that period. Lotus has a strong resistance to the virus (7.5 in 9-grade scale). Based on the results of another experiment conducted in 2008 and 2009, in three localities (Table 2) with the three potato cultivars with low resistance to PLRV (Cekin, Adam and Justa), it was found that the pressure of the pathogen was also very low in all localities and during both tested years. In Przechlewo, PLRV was not detected at all in progeny tubers. In Stare Olesno and particularly in Bonin, the percentage of PLRV-infected tubers was very small. The average for the years and the average for the localities amounted to 2.1 and 0.3%, respectively. Results of other studies (Kostiw and Sekrecka 2009) whose aim was to evaluate the infection of potato tubers by PVY, PVM, PVS and PLRV in organic farming in 2006–2008 in northern Poland, showed a complete absence of PLRV in progeny tubers of eight tested varieties of potatoes. These quoted data confirm the results of the present study, indicating that the threat of this virus was low in recent years. At the same time, in the above discussed localities, the presence of PVY, PVM and PVS was significantly higher than PLRV during both studied years (Table 2). In 2008, the variety Cekin recored a particularly high share of tubers infected by PVY, PVM and PVS. Infection amounted to 18.6%, 20.6%, 9.8% in Bonin; 16.6%, 11.8%, 53% in Przechlewo and 59.8%, 14.7%, 39.3% in Stare Olesno, respectively. The average values for the years 2008 and 2009 for these viruses, were as follows: 10.8; 12.1 and 4.5% in Bonin; 5.8; 4.6 and 17.8% in Przechlewo and 23.6; 21.2 and 18.1% in Stare Olesno, respectively. It is worth noting, that in Bonin and Przechlewo, PVY and PVM spread in the same cultivar with similar intensity in both years. In Stare Olesno, no similar correlations were found. In 2008, the percentage of tubers of Cekin cv. infected by PVY (59.8%) was four times higher than PVM (14.7%). In turn, almost four times more tubers infected by PVM (42.8%) than by PVY (11%) were found for Adam cv. in 2009. That year, the share of tubers infected by PVM (6%) was higher than infection by PVY (0%) for Justa cv. as well.

In the epidemiology of potato virus diseases, the time of infection is important. Early infections are especially dangerous because they relate to young plants that have not yet acquired mature-plant resistance to viruses. The results of this study (Table 3) showed that the progeny tubers were infected at an early period of plant vegetation, this was especially true for infection of PVY and PVM. Only 9.1% of tubers harvested in 1998 and 2000 from plants exposed in the field at the earliest term (from the 21st of May to the 1st of June), were infected by PVY. In 2002, the percentage was much higher (40.2%), while in other experimental years, the shares were as follows: 12% in 2006, 46.9% in 2007, 19.1% in 2008, and 10.9% in 2009. Considering PVM, equally early crop exposure to the virus (the 21st of May to the 1st of June) caused the progeny tuber infection that occurred in 1998 and 2000 (the same 9.1% share of infected tubers), as well as in 2003 (26.6%), 2006 (18.4%), 2007 (50.8%), and 2009 (10.9%). In the case of PVS, the symptoms were present only in 2006 (18.4%) and 2007 (35.2%).

The tuber infection caused by PLRV at the early plant vegetation stage, was recorded only in 2002 and 2005. The percentage of tubers infected by this pathogen, and harvested from plants exposed since May 21st till June 1st, amounted to 38.3% and 12.9%, respectively.

Table 4 compares the frequencies of the progeny tubers infection by PVY, PVM, PVS, and PLRV and harvested from the 3 earliest exposure dates in particular years. It was found that the first infections of tubers due to PVY and PVM (7 and 6 cases among 12 observation years) occurred at the earliest date when plants were exposed (from the 21st of May to the 1st of June) in 1998, 2000, 2002 (valid only to PVY), 2003 (valid only to PVM), 2006, 2007, 2008, and in 2009. The first infections of tubers due to PVS were observed most often (6 cases) in the second period (1st of June – 11th of June) of 1996, 1997, 2000, 2002, 2003, and 2005, as well as at the third date (11th of June – 21st of June) – 4 cases. The similar frequency of first infections of progeny tubers caused by PVY and PVM (7 and 6 cases for 12 years of observation) at the earliest date of plants exposure (21st of May to the 1st of June), may indicate that the general model of spread for these viruses is similar. Thus, their epidemiology may also be similar. However, it is a little different from PVS epidemiology. PVS spread the most intensively (6 cases over the 12 years of the experiment) slightly later – at the second date of crop exposure that persisted from the 1st of June till June 11th. Only in 2 cases in 2 years, were the first infection symptoms detected in tubers harvested from plants exposed in the earliest period (from 21st of May to the 1st of June). Four cases of infection of the first progeny tubers were recorded for plants, when their exposure persisted from the 11th of June – 21st of June.

The observed differences between PVY and PVM vs PVS may suggest that for the transmission of PVS, perhaps a slightly different species of aphids are responsible than for the transmission of PVY and PVM. However, this phenomenon requires further explanation. The results of previous studies by the author (Kostiw 2002) revealed that aphids which do not typically colonize potato crop were mainly responsible for early infections caused by PVY, PVM, and PVS, in Poland. In spring, they fly to potato fields about 14 days earlier than "potato aphids". There is not much information in the literature about the possibility of PVS transmission by aphids, due to the low economic importance of this virus.

Referring to PLRV, 2 cases of tuber infection at the earliest crop exposure date (21st of May to the 1st of June) were recorded in 2002 and 2005, and also 2 cases in the subsequent period (11th of June – 21st of June) in 2003 and 2009. As it was mentioned above, actually only the *M. persicae* aphid are responsible for PLRV epidemiology in Poland, and the virus threat depends on their pressure.

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POLISH SUMMARY

WYSTĘPOWANIE WAŻNIEJSZYCH WIRUSÓW ZIEMNIAKA W POLSCE

W badaniach polowych przeprowadzonych w latach 1996–2009 w Boninie na północy Polski oraz dodatkowo w latach 2008 i 2009 w Boninie, Przechlewie (również na północy kraju) i Starym Oleśnie, położonym w południowej Polsce stwierdzono, że największe zagrożenie dla ziemniaków stanowił wirus PVY. Średni (z lat 1996–2009) odsetek bulw potomnych porażonych tym wirusem wyniósł 32,5% i był znacznie wyższy w porównaniu do zakażonych PVM (18,2%) i PVS (22,1%), a szczególnie PLRV (15,3%). Wyniki innego doświadczenia, przeprowadzonego w latach 2008 i 2009 w 3 miejscowościach: Bonin, Przechlewo (położone na północy Polski) oraz Stare Olesno (południe kraju), z uwzględnieniem 3 odmian ziemniaka o niskiej odporności na PLRV, wykazały również bardzo niską presję tego wirusa we wszystkich miejscowościach i obydwóch latach badań. W Przechlewie w ogóle nie stwierdzono jego obecności w bulwach potomnych. Natomiast w Starym Oleśnie, a szczególnie w Boninie, udział bulw porażonych był bardzo mały i wyniósł zaledwie, odpowiednio 2,1 i 0,3%. Tymczasem udział bulw porażonych PVY, PVM i PVS był o wiele wyższy i wahał się od 11,8 do 59,8% zależnie od odmiany, roku i miejscowości. Infekcję bulw potomnych PVY i PVM stwierdzano najczęściej już w bardzo wczesnym terminie ekspozycji roślin zdrowych w polu (od 21 maja do 1 czerwca). Natomiast PVS stanowił największe zagrożenie w terminie nieco późniejszym, bo podczas ekspozycji roślin trwającej od 1 do 11 czerwca.