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Mini-review

History of potato wart disease in Europe – a proposal for harmonisation in defining pathotypes

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Abstract

Potato wart disease, caused by the chytridiomycete *Synchytrium endobioticum*, was first introduced into Europe in the late 19th century. It spread quickly, and today is reported in 15 European countries. Initially, only one pathotype was found, and the disease was efficiently controlled using resistant cultivars. In 1941, however, formerly resistant cultivars showed wart formation in the field simultaneously in Germany and South Bohemia (Czech Republic), indicating the occurrence of new pathotypes. New pathotypes have since been reported from Germany, The Netherlands, Czech Republic, Ukraine and Canada. Today the pathogen is present in The Netherlands (only in fields for ware and starch potatoes) but restricted to two demarcated areas and subject to official control. Outside these areas, the pathogen is absent. For pathotyping, different countries have used different sets of differential cultivars, and the usual system of numerical coding of pathotypes has not been consistently followed. In this review we propose a new standardised code to be used for the 43 pathotypes currently known and described in Europe. The code is a combination of a numerical and letter code, combining the two terminologies used by former West and East Germany, respectively. We also plead for harmonisation in the choice of differential cultivars used for pathotype identification. The set of differentials described in the international standard for diagnosis of *S. endobioticum* issued by the European and Mediterranean Plant Protection Organisation (EPPO), should serve as a basis. Through close collaboration of European countries dealing with new pathotypes of potato wart disease, a final agreed upon set of differentials, combined with a set of reference isolates, should ultimately be established, allowing a clear distinction between the most important pathotypes occurring in Europe.

Introduction

The chytridiomycete *Synchytrium endobioticum* is the causal agent of potato wart disease. The pathogen is classified as a IAII quarantine pest (pest already present in the EU; entry or spread within the EU is prohibited) in the EU Directive 2000/29/EC (European Union, 2000). *Synchytrium endobioticum* stimulates its host to produce starch-filled hypertrophic outgrowths on tubers,

stolons and sprouts. These so-called 'warts' act as a sink for nutrients (Hampson and Coombes, 1985), and increase rapidly in size at the expense of the tubers, which may be entirely transformed to warts. Losses may amount up to 50–100% (Hampson, 1993; Melnik, 1998). In Europe, *S. endobioticum* was first found in 1876 in the UK (Langerfeld, 1984; Hampson, 1993). It gradually spread over Europe and was first observed in The Netherlands in 1915 (Anon., 1921). Nowadays, potato wart disease is reported in 15 European countries (EPPO, 2005). Originally, only one pathotype of the pathogen occurred in Europe, and a good level of control was achieved using resistant potato cultivars. Since 1941, however, new pathotypes have shown up (Blattny, 1942; Braun, 1942), making efficient control of the disease more troublesome.

The first discovery of a new pathotype in Europe occurred in former East Germany (the German Democratic Republic), where new pathotypes were named by the first letter of the locality where they were found, followed by a sequential number (e.g. pathotype G1, found at Gieβübel). In former West Germany (the German Federal Republic), however, Arabic numbers were used for new pathotypes (Ullrich, 1958; Langerfeld and Stachewicz, 1993). In obligate pathogens, identification of pathotypes is usually based upon differential reaction to a strictly defined set of cultivars (Wicker et al., 2003; Trimboli, 2004). For *S. endobioticum*, different countries have used different sets of cultivars, making sound comparisons of pathotypes among countries hardly possible.

The aim of this review is to report on the pest status of potato wart disease in Europe, the occurrence of new pathotypes, and to highlight their current, confusing nomenclature/coding. It is not our first aim to give a broad overview of the occurrence of potato wart disease in countries worldwide, rather we describe the history of potato wart disease in Europe to highlight the background of the current, confusing nomenclature/coding in pathotypes. We propose a new, standardised coding system for designation of pathotypes, and plead for the establishment of an internationally harmonised set of differential potato cultivars to identify current and new pathotypes.

Potato wart disease in Europe

Occurrence of the original pathotype – pathotype 1(D1)

At the end of the 19th century, potato wart disease spread from its original range in the Andes in South America to parts of North America and Europe (Hampson and Proudfoot, 1974). The causal agent of potato wart disease was first described as *Chrysophlyctis endobiotica* in 1896 by Professor Schilbersky of Budapest University (Hampson, 1993). He discovered the pathogen on potatoes growing in the vicinity of Hornany (then a part of Hungary, currently located in Slovakia). In 1909, Percival changed the name into *Synchytrium endobioticum* (Percival, 1910). In Europe, *S. endobioticum* had first been found in 1876 in the UK (Langerfeld, 1984; Hampson, 1993). It spread gradually, and in the following decades hundreds of thousands of outbreaks occurred all over Europe including the European part of the former USSR (Hampson, 1993). In Germany, the disease was first observed in 1908 in Westphalia by Spieckermann (Köhler, 1931; Langerfeld, 1984), and subsequently, foci of potato wart were found all over Germany. In 1927, the estimated infested area in Germany was 2700 ha out of 2.8 Mha of potato production (Köhler, 1931). In the former USSR, where the pathogen was introduced in 1938 (Melnik, 1998), approximately 118,000 foci were registered by 1971 to give a total infested area of 16,352 ha (Hampson, 1993). In Poland, potato wart disease appeared first in 1925 (Leszczenko and Roguski, 1959), whereas in Sweden it did in 1912 (Köhler, 1931).

In order to limit the spread of potato wart disease, phytosanitary measures were taken including large-scale cultivation of resistant cultivars, mainly of German origin. Its eradication has been achieved in many countries through statutory means, including strict phytosanitary control and prohibition of cultivation of susceptible cultivars (Langerfeld et al., 1994), maintained over decades because of the longevity of resting sori (sporangia) in infested fields.

Potato wart disease was officially detected in The Netherlands for the first time in the autumn of 1915, by F.P. Hil, teacher at an agricultural school, in a private garden in the municipality of

Winschoten (province of Groningen), where the disease seems to have occurred since 1907 (Anon., 1921). Subsequent investigations revealed that the disease was already present in many fields in the surrounding areas. In the following years, potato wart disease was detected in many locations in the northeastern provinces of The Netherlands. Shortly after the second World War, potato wart disease foci occurred in large parts of the north and southeast of The Netherlands, and along the rivers in the central and western part of The Netherlands up to Dordrecht and Amsterdam (Stiksma, 1955; Baayen et al., 2004). Infestations were mostly found in private gardens or plots used for small scale potato production for home consumption, similar to reports from Germany (Langerfeld, 1984), Ukraine (Matskiv et al., 1998) and Canada (Hampson and Proudfoot, 1974). All strains found belong to the originally introduced pathotype 1(D1). Cultivation of susceptible potato cultivars was forbidden in the most severely affected regions, or for some cultivars the entire country. By 1970, potato wart disease seemed to have been successfully eradicated from The Netherlands.

Occurrence of new pathotypes; nomenclature, use of differential cultivars

In Europe, wart development on formerly resistant potato cultivars was first discovered in 1941 in Gießübel, Germany (Braun, 1942), and almost simultaneously in Silberhütte, South Bohemia, Czech Republic (Blattny, 1942). New pathotypes of the fungus had emerged. New pathotypes were initially found mostly in Germany, Czech Republic and the former USSR. Up to now, new pathotypes have not been reported from the UK, where potato wart disease was first found in Europe. An overview of new pathotypes cited in the literature is given in Table 1.

In former East Germany, new pathotypes were named by the first letter of the locality where they were found, followed by a sequential number (Hey, 1959). In former West Germany and Ukraine, however, Arabic numbers were used for designation of new pathotypes (Ullrich, 1958; Langerfeld and Stachewicz, 1993; Melnik, 1998). Thus, the new pathotypes detected in Gießübel and Silberhütte in 1941 were labelled '2' and '3' in former West Germany, and 'G1' and 'SB', respectively, in former East Germany (Table 1). In this paper, we propose to use a standardised coding system, combining both terminologies (for example, the pathotype originally introduced into Europe is identified as pathotype 1(D1), and the new pathotype found in Gießübel in 1941 is coded 2(G1)). At the present time, more than 40 pathotypes have been described (Table 1), more are known from the literature, but not coded (e.g. Winkelmann, 1952).

Upon the discovery of pathotype 2(G1) in Gießübel, more pathotypes were reported from former East Germany. Hey (1959) summarised the occurrence of pathotype 4(P1) from Pappenheim (1943), 9(R1) from Rudolstadt (1950), 5(K1) from Koppatz (1951) and 10(E1) found in Eulendorf (1956) (Table 1). Distinctiveness of these five pathotypes was determined by their differential reaction to six potato cultivars: Ackersegen, Blanik, Baltyk, Universal, Fortuna and Asche-Sämling (Hey, 1959). Table 2 shows an overview of a range of potato cultivars, used as differentials in pathotype identification, in The Netherlands and Germany (Table 2a), and Ukraine and Czech Republic (Table 2b). Data given are partly collated from literature, and partly originate from unpublished data of the present authors. From Table 2, it is clear that many cultivars have been used as differentials, and also that the choice of cultivars strongly differs among countries (local cultivars were often used). For example, the pathotypes occurring in The Netherlands are distinguished by a set of six cultivars (Deodara, Producent, Delcora, Miriam, Saphir and Belita), while those described from Ukraine are distinguished by cvs Zeisig, Giewont, Ora and Perlina. The number of cultivars in common among countries is very limited. For example, cv. Saphir has been used by all countries, and cv. Ora by all except The Netherlands (Table 2).

Not all the pathotypes that are listed in Table 1 are included in Table 2. Some of these, already extinct, for example pathotype 3(SB), were excluded from Table 2. Also, the Polish pathotypes 2(Ch1) + 3(M1) are not included in Table 2. The

In meetings of the European and Mediterranean Plant Protection Organisation (EPPO) Panel on potato wart in 1977 and 1982, it was decided to use the term 'pathotype' instead of 'race' or 'biotype' (EPPO, 1977; EPPO, 1982; Melnik, 1998).

Table 1. Origin, codes and occurrence of pathotypes of *Synchytrium endobioticum*

Pathotype						Importance[a]	Occurrence
Place of first finding	Letter code	Numerical code			Proposed code		
		Langerfeld (1984)	Melnik and Malakhanova (1998)	Potoček et al. (1991)			
Hornany, Slovakia[b]	D1[c]	1	1	1(D1)	1(D1)	+	Cosmopolitan
Gießübel, Germany	G1	2	2	–	2(G1)	+	Germany, The Netherlands, Czech Republic, Canada (Newfoundland)
Chromów, Poland	Ch1	–	–	–	2(Ch1)	+	Poland[d]
Silberhütte, Czech Republic	SB	3	3	–	3(SB)	Extinct	Czech Republic, Canada (Newfoundland)
Mieroszow, Poland	M1	–	–	–	3(M1)	+	Poland[d]
Pappenheim, Germany	P1	4	4	–	4(P1)	Extinct[e]	Germany
Koppatz, Germany	K1	5	5	–	5(K1)	Extinct	Germany
Olpe, Germany	O1	6	6	–	6(O1)	+	Germany, The Netherlands, Czech Republic, Canada (Newfoundland, Prince Edward Island)
Schweinsberg, Germany	S1	7	7	–	7(S1)	Extinct	Germany
Kohlhaus (Fulda), Germany	F1	8	8	–	8(F1)	+	Germany, Canada (Newfoundland)
Rudolstadt, Germany	R1	9	9	–	9(R1)	Extinct[e]	Germany
Eulendorf, Germany	E1	10	10	–	10(E1)	Extinct	Germany
Meshgorsky, Ukraine	M1	11	11	–	11(M1)	+	Ukraine
Bukovets, Ukraine	B1[f]	13	12	–	12(B1)	Extinct	Ukraine
Rakhov, Ukraine	R2	12	13	–	13(R2)	+	Ukraine
Newfoundland, Canada	–	14	–	–	14(Newfoundland)	–	Canada (Newfoundland)
Plačkov, Czech Republic	P2	15	14	15(P2)	15(P2)[g]	+	Czech Republic
Ničkov, Czech Republic	N1	16	15	16(N1)	16(N1)	+	Czech Republic
Sinevik, Ukraine	–	–	16	–	16(Sinevik)	+	Ukraine
Mirochov, Czech Republic	M2	17	17	17(M2)	17(M2)	+	Czech Republic
Yasinya, Ukraine	–	–	18	–	18(Yasinya)	+	Ukraine
Trannroda, Germany	T1	18	19	–	18(T1)	+	Germany, The Netherlands
Haag, Germany	–	19	–	–	19(Haag)[h]	–	Germany
Innernzell, Germany	–	20	–	–	20(Innernzell)[i]	–	Germany
Vilémov, Czech Republic	V1	–	–	19(V1)	19(V1)	–	Czech Republic
Sheshory, Ukraine	–	–	20	–	20(Sheshory)	+	Ukraine
Sokolovka, Ukraine	–	–	21	–	21(Sokolovka)	+	Ukraine
Bystrets, Ukraine	–	–	22	–	22(Bystrets)	+	Ukraine
Nový Rychnov, Czech Republic	NR1	–	–	23	23(NR1)	–	Czech Republic
Radčice, Czech Republic	R3	–	–	24	24(R3)	–	Czech Republic
Hanychov, Czech Republic	H1	–	–	25	25(H1)	–	Czech Republic

Table 1. Continued

Pathotype						Importance[a]	Occurrence
Place of first finding	Letter code	Numerical code			Proposed code		
		Langerfeld (1984)	Melnik and Malakhanova (1998)	Potoček et al. (1991)			
Svratouch, Czech Republic	S3	–	–	26	26(S3)	+	Czech Republic
Mor. Svratka, Czech Republic	MS1	–	–	27	27(MS1)	+	Czech Republic
Trpín, Czech Republic	T2	–	–	28	28(T2)	–	Czech Republic
Křižánky, Czech Republic	K2	–	–	29	29(K2)	–	Czech Republic
Melč, Czech Republic	M3	–	–	30	30(M3)	–	Czech Republic
Ovesná Lhota, Czech Republic	OL1	–	–	31	31(OL1)	–	Czech Republic
Vidochov, Czech Republic	V2	–	–	32	32(V2)	–	Czech Republic
Karlinky Konfršt, Czech Republic	K3	–	–	33	33(K3)	–	Czech Republic
Karlinky Bobek, Czech Republic	K4	–	–	34	34(K4)	–	Czech Republic
Líšná, Czech Republic	L1	–	–	35	35(L1)	–	Czech Republic
Zadní Zhoreč, Czech Republic	ZZ1	–	–	36	36(ZZ1)	–	Czech Republic
Krásná, Czech Republic	K5	–	–	37	37(K5)	–	Czech Republic

[a] According to Potoček et al. (1991), Melnik (1998) and Stachewicz and Langerfeld (1998); (+) important pathotype; (–) pathotype of minor relevance.
[b] At the time of finding, Hornany was part of Hungary.
[c] After Dahlem, Germany, where pathotype 1(D1) was also found.
[d] The Polish pathotypes 2(Ch1) and 3(M1) were detected by Professor K. Malec and have not yet been published officially (E. Malinowska, Plant Breeding and Acclimatisation Institute, Bydgoszcz, Poland and J. Butrymowicz, Central Laboratory of the State Plant Protection and Seed Inspection Service, Torun, Poland, personal communication).
[e] No infections since 1975; however, the infected fields from before 1975 have not yet been officially descheduled.
[f] Pathotype B1 of Malec (1974; Poland) was obtained experimentally and named after potato variety Bem and is not the same as pathotype 12(B1) from Bukovets, Ukraine (E. Malinowska, Plant Breeding and Acclimatisation Institute, Bydgoszcz, Poland and J. Butrymowicz, Central Laboratory of the State Plant Protection and Seed Inspection Service, Torun, Poland, personal communication).
[g] According to Melnik and Malakhanova (1998), the outbreak of this pathotype occurred at the site in South Bohemia where the loss of resistance to pathotype 1(D1) was first observed in 1940.
[h] Later identified as pathotype 2(G1).
[i] Later identified as pathotype 6(O1).

reaction of these pathotypes to a range of cultivars, including the cultivars used in The Netherlands and Germany (Table 2a), is currently being studied in Poland, and results will be available in due course.

Within 10–15 years of finding pathotype 2(G1), four new pathotypes were discovered in former West Germany (Ullrich, 1958). Of these, pathotype 6(O1) (found in Olpe in 1952), and pathotype 8(F1), found in Fulda in 1954, are most important today (Table 1). Maris (1961) reported that all documented German pathotypes occurring before 1959, including the one from Silberhütte, South Bohemia, could be identified with a set of 10 differential cultivars. As Table 1 shows, in the past decades new pathotypes have also been reported from Czech Republic and Ukraine (Potoček et al., 1991; Matskiv et al., 1998; Melnik, 1998).

By 1970, potato wart disease was no longer found in The Netherlands. In 1973, however, potato wart disease was rediscovered in a field in Ter Apelkanaal, province of Groningen, on a

Table 2. Response of potato cultivars from The Netherlands and Germany (a), Ukraine and the Czech Republic (b) to known pathotypes of *Synchytrium endobioticum* according to a compilation of the literature cited in this paper and unpublished data of the present authors

Differentials used in	Different pathotypes, and country of origin (first described)																																					
	Germany												Ukraine							Czech Republic																		
	1 (D1)	2 (G1)	4 (P1)	5 (K1)	6 (O1)	7 (S1)	8 (F1)	9 (R1)	10 (E1)	18 (T1)	19 (Haag)	20 (Innernzell)	11 (M1)	13 (R2)	16 (Sinevik)	18 (Yasinya)	20 (Sheshory)	21 (Sobkovka)	22 (Bystrets)	15 (P2)	17 (M2)	19 (V1)	23 (NR1)	24 (R3)	25 (H1)	30 (M3)	32 (V2)	33 (K3)	34 (K4)	37 (K5)	16 (N1)	28 (T2)	29 (K2)	31 (OL1)	35 (L1)	36 (ZZ1)	26 (S3)	27 (MS1)
a																																						
The Netherlands																																						
Deodara[a]	+	+			+		+			+																												
Producent[a]	–	+			+		+			+																												
Delcora[a]	–	–			–		+			+																												
Miriam[a]	–	–			–		–			+																												
Saphir[a]	–	+			–		–			–																												
Belita[a]	–	–			–		–			–																												
Germany																																						
Deodara[b]	+	+	+	+	+	+	+	+	+	+	+	+																										
Ackersegen	–	+	+	+	+	+	+	+	+	+	+	+																										
Universal	–	+	+	+	+	+	+	+	+	+																												
Blanik	–	+	+	+	+	+	+	+	+	+																												
Tomensa[b]	+	+	+	+	+		+	+	+	+																												
Desirée[b]	–	+	+	+	+		+	+	+	+																												
Irmgard	–	+	+	+	+		+	+	+	+																												
Sorka[b]	–	+	+	+	+		+	+	+	+																												
Xenia	–	+	+	+	+		+	+	+	+																												
Nova	–	+	+	+	+	–	+	+	+	+																												
Giewont	–	+	+	–	+		+	+	+	+	–	–																										
Asche-Sämling	+	+	–	–	+		+	+	+	+	+	+																										
Maxilla	–	+	–	–	+		+	+	+	+																												
Fram	–	+	–	–	+	+	+	–	–		–	–																										
Ultimus	–	+	–	–	–	–	+	–	–	+	–	–																										
Fortuna	–	+	–	–	–	+	–	–	+	+	–	–																										
Fontana	–	–	–	–	–	+	–	–	+	+																												
Miriam[b]	–	–	–	–	–		–	–	+	+																												
Zeisig	–	–	–	–	–		+	–	–	+																												
Sissi[b]	–	–	–	–	–		–	–	–	+																												
Hilla	–	–	–	–	–	+	–	–	–																													
Saphir[b]	–	+	–	–	–	–	–	–	–	–	+	–																										
Ora	–	–	–	–	–	–	–	–	–	–	–	–																										
Galina	–	–	–	–	–		–	–	–	–																												
Certa	–	–	–	–	–		–	–	–	–	–	–																										
Karolin[b]	–	–	–	–	–		–	–	–	–																												
b																																						
Ukraine																																						
Alma	+												+	+	+	+	+	+	+																			
L'vovski Belyi	–												+	+	+	+	+	+	+																			
Universal	–	+	+	+	+	+	+	+	+	+			+	+	+	+	+	+	+																			
Blanik	–	+	+	+	+	+	+	+	+	+			+	+	+	+	+	+	+																			
Ultimus	–	+	–	–	–	–	+	–	–	+	–	–	+	+	+	+	+	+	+																			
Zeisig	–	–	–	–	–		+	–	–	+			–	+	–	+	+	+	+																			
Giewont	–	+	+	–	+		+	+	+	+	–	–	–	+	–	+	–	–	+																			
Ora	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	+	–	–	+																			
Perlina	–												+	+	–	+	–	–	–																			
Troyanda	–												+	+	+	–	–	–	–																			

Table 2. Continued

Differentials used in	Different pathotypes, and country of origin (first described)																																					
	Germany												Ukraine							Czech Republic																		
	1 (D1)	2 (G1)	4 (P1)	5 (K1)	6 (O1)	7 (S1)	8 (F1)	9 (R1)	10 (E1)	18 (T1)	19 (Haag)	20 (Innernzell)	11 (M1)	13 (R2)	16 (Sinevik)	18 (Yasinya)	20 (Sheshory)	21 (Sobkovka)	22 (Bystrets)	15 (P2)	17 (M2)	19 (V1)	23 (NR1)	24 (R3)	25 (H1)	30 (M3)	32 (V2)	33 (K3)	34 (K4)	37 (K5)	16 (N1)	28 (T2)	29 (K2)	31 (OL1)	35 (L1)	36 (ZZ1)	26 (S3)	27 (MS1)
Barbara	–	–			–		–				–	–	+	+		–			–																			
Hilla	–	–	–	–	–	+	–	–	–				–	–	–	–	–	–	+																			
Saphir	–	+	–	–	–	–	–	–	–	–	+	–	+	+	+	+	+	+	+																			
Czech Republic																																						
Radka	–												+							+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Eta	–																			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Iva	–																			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Nela	–																			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Desirée	–	+	+	+	+		+	+	+	+										+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Gelbling	–	+			+	+	+													+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+
Maja	–			–				+	+	+										–	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+
Barbara	–	–			–		–				–	–	+	+		–			–	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Karsa	–	–	–	–				–	–	+										+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Jowicz	–	–	–	–				–	–	+										+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Borka	–																			+	+	+	+	+	+	+	+	+	+	+	–	–	+		+	+	+	+
Ora	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	+	–	–	+	–	–	–	+					+	+	+	+	+	+	–	+	+	+	+
Galina	–	–	–	–	–		–	–	–	–											–	–	+			+			+	+	–	+			+	+	+	+
Certa	–	–	–	–	–		–	–	–	–	–	–								–	–	–	–		–	–	–	–	–	+	+	–	+	+	+	+	+	+
Zeisig	–	–	–	–	–		+	–	–	+			–	+	–	+	+	+	+	–	–	–	–	–	–	+	–	–	–		+	+	–		+		+	+
Rea	–	–	–	–				–	–											–	–	–	–		–		–	–	–	+	–		–			–	+	+
Tunika	–	–	–	–				–	–											–	–	–	–	–	–	–	–	–	–	–	–		–	–		–	+	+
Duet	–																			–	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–	+	+
Saphir	–	+	–	–	–	–	–	–	–	–	+	–	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–	–	–		–	–		–

Responses were considered susceptible (+) when reports were available of wart formation or of weakly susceptible responses (formation of > 5 sporangia per sprout, while no warts present). Responses were considered resistant (–) when tests had not produced (weakly) susceptible responses. Missing data have been left open.

[a] Differential potato cultivar currently used in The Netherlands.

[b] Differential potato cultivar currently used in Germany.

cultivar known to be resistant to pathotype 1(D1). The causal agent was eventually identified, in collaboration with Dr. Langerfeld, Braunschweig, Germany, as pathotype 2(G1) (Table 1). The first findings of pathotype 2(G1) were made on fields on which debris from a potato starch factory at Ter Apelkanaal had been deposited. Subsequent findings were made at other locations in the provinces of Drenthe and Groningen, a region of intensive starch potato production with narrow crop rotation, including Roswinkel, Weerdinge, Wedde, Ter Apel, Onstwedde, Musselkanaal and Gieten. The new pathotype spread rapidly in the intensive starch potato producing provinces of Drenthe and Groningen, due to the high cropping intensity in the region and the lack of adequately resistant potato cultivars. Since 1990, pathotype 6(O1) is also present in this region (Stachewicz et al., 2002; Stachewicz and Baayen, 2003). In 1991, pathotype 1(D1) was rediscovered in the vicinity of Horst, in the southern province Limburg (Baayen et al., 2005). At present, the pathogen is contained in two demarcated regions in the northeast and southeast in The Netherlands.

Recently, pathotype 18(T1) (Table 1) has been found in The Netherlands. This pathotype was first described in Germany (Stachewicz, 1978). Composted warts from an infected field in the northeast of The Netherlands encountered in 2001 induced wart formation in Spieckermann tests on

the differential cvs Deodara, Producent, Delcora and Miriam, and not on cvs Saphir or Belita (Table 2a), indicating that pathotype 18(T1) was responsible for the infection. Since 2003, this pathotype has been confirmed in five fields in the northeastern part of The Netherlands.

New pathotypes and breeding for resistance

The success of phytosanitary measures against *S. endobioticum* in Europe since its introduction has been largely due to the discovery, in the early 1900s, of resistant potato cultivars and subsequent breeding programmes for resistance (Langerfeld et al., 1994; Stachewicz, 1996). The availability of resistant cultivars allowed governments to issue regulations prohibiting the cultivation of susceptible cultivars. Breeding for resistance was successful, thanks to the availability of a dominant resistance gene (Scheidt and Hunnius, 1981; Langerfeld, 1984; Lellbach and Effmert, 1990) that completely blocked development and reproduction of the originally introduced pathotype 1(D1) of *S. endobioticum*. In The Netherlands a single potato cultivar was acknowledged as resistant in 1920 (Anon., 1921), whereas 308 potato cultivars were listed as resistant to the originally introduced pathotype 1(D1) in 2003.

Köhler (1931) believed that *S. endobioticum* lacked the ability for racial/physiological specialisation. He stated "Susceptible cultivars show symptoms in all wart disease areas of the world, those resistant are immune everywhere" (translated from German). He must have missed the fact that cultivars resistant to potato wart disease in Europe were reported to be susceptible in Newfoundland, Canada in 1924 (Olsen, 1961). The popular cultivar Arran Victory, resistant to pathotype 1(D1), was imported from England and became heavily infected (Proudfoot, 1971). As described above, in Europe wart development on resistant potato cultivars was first discovered in 1941 in Germany and the Czech Republic (Blattny, 1942; Braun, 1942).

The new pathotypes have proved to be more difficult to control and eradicate than the original pathotype 1(D1). Breeding is hampered by a lack of dominant major genes for resistance (Maris, 1961), and resistance tests have to be performed with several pathotypes. Few potato cultivars offer adequate resistance to the new pathotypes (Langerfeld et al., 1994; Melnik, 1998; Stachewicz, 1999). For example, at present (2005) in The Netherlands only four cultivars are listed as being resistant to each of the pathotypes 2(G1), 6(O1) and 18(T1). In Germany, in 1993 only 8 of the 165 registered potato cultivars showed resistance to all or nearly all of the 'new' potato wart pathotypes.

The need for standardisation and harmonisation

Initially, when only one pathotype of *S. endobioticum* occurred, the overall picture was simple and clear. Potato cultivars were either resistant or susceptible to potato wart disease, and there was no need for pathotype determination. However, since the occurrence of new pathotypes, and concurrently the description of a vast number of sometimes poorly defined pathotypes, management of potato wart disease and inherent communication about the occurrence of the disease, has become far more complex. Below we summarise and distinguish the factors responsible for the problematic communication regarding the occurrence of different pathotypes.

First, coding of new pathotypes developed separately in each country. Sometimes, the same number (numerical coding) or letter code has been used for different pathotypes (see Table 1). As a result, recent measures of the European Commission concerning 'pathotypes 2 and 3' which form part of the Act of Accession of Poland (European Union, 2003) address Polish pathotypes, which have not been published before. The Polish pathotype '2' is most probably not the same as pathotype 2(G1) occurring in northwest Europe as defined by Langerfeld et al. (1994). Such confusion is undesirable within the European Union, where regulations concerning *S. endobioticum* and its pathotypes are fully harmonized.

Second, the lack of an internationally accepted set of differential cultivars hampers good comparison of described pathotypes. In this way, the same pathotype may have different code names. Pathotypes have been distinguished by German investigators using German cultivars, by Ukrainian scientists using Russian cultivars, etc. (Table 2). Comparison is possible to some extent, thanks to the incidental use of German differentials by investigators from the Czech Republic and Ukraine (Potoček et al., 1991; Matskiv et al.,

1998). Every EU-member state has the obligation to publish yearly a national list of potato cultivars resistant to pathotypes of potato wart disease. But how is such a list interpreted when methods to identify and name pathotypes are different among countries? All these results in confusion about the identity of pathotypes, and therefore in regulations based on erroneous assumptions concerning the identity of pathotypes and ultimately in wrong and ineffective measures that do not cover real risks on the one hand and cause undesired obstruction of production and trade on the other.

Proposal for harmonisation in defining pathotypes

For the sake of clarity and uniformity, and to aid unanimous and clear communication between scientists, officers and policymakers, we propose the following:

1. To use a new standard code for identifying pathotypes currently distinguished. In line with Potoček et al. (1991), we propose a standard coding system in which the Arabic number given by the original authors is followed in between brackets by the letter code referring to the town of the first finding, or when such a code is lacking, the full name of the town. This code is thus a combination of the letter code and the numerical code (see Table 1, sixth column). For example, the pathotype originally introduced in Europe is identified as pathotype 1(D1), and the pathotype found in Gießübel in 1941 is coded 2(G1). This will aid clarity in future communication via scientific publications, press releases, policy papers, and in official regulations and trade agreements.

2. To build up a common set of differential cultivars. With the set of differential cultivars described in the international standard for diagnosis of *S. endobioticum* issued by the European and Mediterranean Plant Protection Organisation (EPPO), Germany as well as The Netherlands are able to identify the most prominent pathotypes occurring today in northwest Europe (Baayen and Stachewicz, 2004). In The Netherlands, the cultivars Deodara, Producent, Saphir, Delcora, Miriam and Belita are used to distinguish between pathotypes 1(D1), 2(G1), 6(O1), 8(F1) and 18(T1). Theoretically, with this set of six cultivars $2^6 = 64$ different pathotypes can be characterised. Other European countries are also becoming familiar with these differentials. How large a definitive set of differential cultivars should be, and which cultivars should be included, is something which should preferably be discussed and agreed upon under the auspices of EPPO or another international body such as the IPPC. With a final, consensus set of differentials, one should be able to distinguish all important pathotypes occurring in Europe. A concerted European action, including ring tests, will most certainly be necessary, and may precede the establishment of a definitive set of differential cultivars.

Conclusion

It is primarily the task of national and regional Plant Protection Organisations to initiate and stimulate harmonisation as outlined above. Potato wart disease is an eminent disease in various EU-member states. Once general agreement in nomenclature and pathotype determination has been reached, a next step may consider issues like mutual acceptance of national lists of resistant cultivars in order to effectively control and prevent the further spread of potato wart disease.

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