Distribution and Harmfulness of *Plasmopara halstedii* on Sunflower in the Czech Republic

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Abstract

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In 2007–2012 the first detailed study of *P. halstedii* distribution and severity was performed in the Czech Republic by monitoring altogether 128 localities. Incidence of the pathogen was recorded at seven localities in south-eastern (Central and South Moravia) and central parts (East and Central Bohemia) of the country; at only four localities the occurrence of sunflower downy mildew symptoms and pathogen sporulation were recorded repeatedly. In all cases the primary infection prevailed, and the severity of infections was rather low. The majority of records were for sunflower experimental fields (e.g. fields of Central Institute for Supervising and Testing in Agriculture. Brno-Chrlice, Czech Republic), one record came from a commercial field and one record from a hobby field. Results of surveys indicate that reservoirs of primary inoculum likely exist in the soil contaminated by *P. halstedii* oospores in these habitats, but additional transfer by infected seed may be possible. Historical and geographical consequences of recorded infections are discussed, as well as virulence variation in the Czech pathogen populations which is currently in the process of investigation.

Keywords: sunflower downy mildew; *Helianthus annuus*; disease incidence; disease severity; pathogen population; quarantine disease

Sunflower downy mildew represents an economically important disease reducing the crop yield in all sunflower growing areas worldwide (Gulya 2007). The disease with typical symptoms, including damping off, dwarfing or retardation of flowering in systemically infected plants or local chlorotic spots on plants with secondary infection, is caused by the biotrophic oomycete *Plasmopara halstedii* (Farl.) Berl. et de Toni 1888 (originally described as *Peronospora halstedii* Farlow in 1882).

Sunflower is native to Central America and archaeobotanists showed that the crop was domesticated in the east-central United States (Heiser 2008). Although an additional domestication event in the north of Mexico was discussed, it has not been sufficiently proved by molecular and other data (Lentz *et al.* 2008 and responding articles in PNAS). According to previous knowledge the centre of *P. halstedii* origin was placed to North America (Sackston 1981). Probably the pathogen was later spread in a plant material to other continents, excluding Australia and Antarctica (Gulya 2007). *P. halstedii* as the causal agent of sunflower downy mildew was first described in the USA in 1888 (Šindelková *et al.* 2008). The first appearance of the disease in Europe was recorded in Russia in the 1960s (Delmotte *et al.* 2008). Later it expanded from Russia to the

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Balkan Peninsula (Bulgaria, Greece, and Turkey) and consequently to many other European countries (e.g. Hungary, Italy, France, Spain, Germany, and the Czechoslovakia) (Virányi 2002). Intensive agriculture combined with suitable weather led to local epidemics of the disease throughout Europe in the second half of the 20th century. Since 1977 the spread of the disease has become serious enough to claim *P. halstedii* a dangerous harmful organism and threat to sunflower producers in Europe. Since 1992 *P. halstedii* has been a subject of quarantine regulation in the European Union (Delmotte *et al.* 2008). The paradigm that economically and epidemiologically relevant sunflower downy mildew incidences are derived from the only soil infections has been questioned (Spring 2009). Recently, a high potential for transition from local to systemic infection was found in field experiments with ornamental sunflower in Germany. These infections play a key role in the production of contaminated seeds carrying the pathogen into the next season (Spring 2009). While the local transfer of the disease is promoted by wind-borne sporangia or contaminated soil, its distinct transfer or introduction into new continents was probably enabled by seed containing the *P. halstedii* mycelium (Virányi & Spring 2011). The way of disease transfer by seed has been broadly discussed (Döken 1989).

The first occurrence of *P. halstedii* within the area of the former Czechoslovakia was reported in the 1950s by Bojňanský (1956, 1957) mainly from South Moravia and South Slovakia. Sunflower downy mildew was later found in experimental fields of Mendel University in Brno in 1999 (Veverka & Křížková-Kudlíková 2006). Since then only several observations of sunflower downy mildew were made and the distribution of the disease in the Czech Republic is considered to be rare (Kokeš & Müller 2004). This is also supported by the monitoring of harmful organisms done by State Phytosanitary Administration which proved the incidence of *P. halstedii* in the Czech Republic yearly since 2000, except for 2004 (State Phytosanitary Administration 2012). During the above-mentioned period *P. halstedii* was detected on eight localities in South Moravia (Tesařová *et al.* 2010a,b; State Phytosanitary Administration 2012), two localities in East Bohemia (State Phytosanitary Administration 2012) and one locality in West Moravia in 2011 (Fialová & Čech 2011).

Sunflower downy mildew has not been implicated in the main economic losses of sunflower yield in the Czech Republic while the most serious diseases include white mould caused by *Sclerotinia sclerotiorum* (Lib.) de Bary and grey mould caused by *Botrytis cinerea* Pers. that deteriorate the quality of the crop (Kudlíková & Veverka 1999). Since 2002 the sunflower downy mildew has been registered as quarantine disease in the Czech Republic and its occurrence has been monitored by State Phytosanitary Administration. Only resistance-certified and pathogen-free seed is allowed to be grown in the Czech Republic, and adherence to phytosanitary as well as agronomical practice is required (Šindelková *et al.* 2008).

Distribution of sunflower downy mildew and its race spectrum in the local pathogen populations have been intensively studied in several countries in Europe, such as Bulgaria (Shindrova 2010), Spain (Molinero-Ruiz *et al.* 2002), France (Sakr 2009), Germany (Rozynek & Spring 2000), Hungary (Virányi & Gulya 1995), and Italy (Tosi & Beccari 2007). However, no detailed information has been available for the Czech Republic. Although sunflower is not cultivated in the CR as extensively as in South-European countries and downy mildew is not the main threat to the crop, the position of this country in the Central European region creates conditions for the disease spread. Thus detailed and reliable information about the pathogen distribution in the Czech Republic was required.

The major objective of this paper is to present data from six-year systematic observations of the distribution and disease severity of *P. halstedii* on sunflowers grown in various areas and habitats within the Czech Republic.

MATERIAL AND METHODS

The occurrence of *Plasmopara halstedii* (Farl.) Berl. et de Toni 1888 was surveyed in the period of May–October in 2007–2011 and May–July in 2012 all over the Czech Republic with the main focus on the region of Central and South Moravia, the south-eastern part of the country, where sunflower (*Helianthus annuus* L.) is grown the most frequently, and on the region of East and Central Bohemia (Figure 1). At some localities the monitoring was repeated annually in order to determine changes in the incidence of the infection. Several characteristics were recorded at each

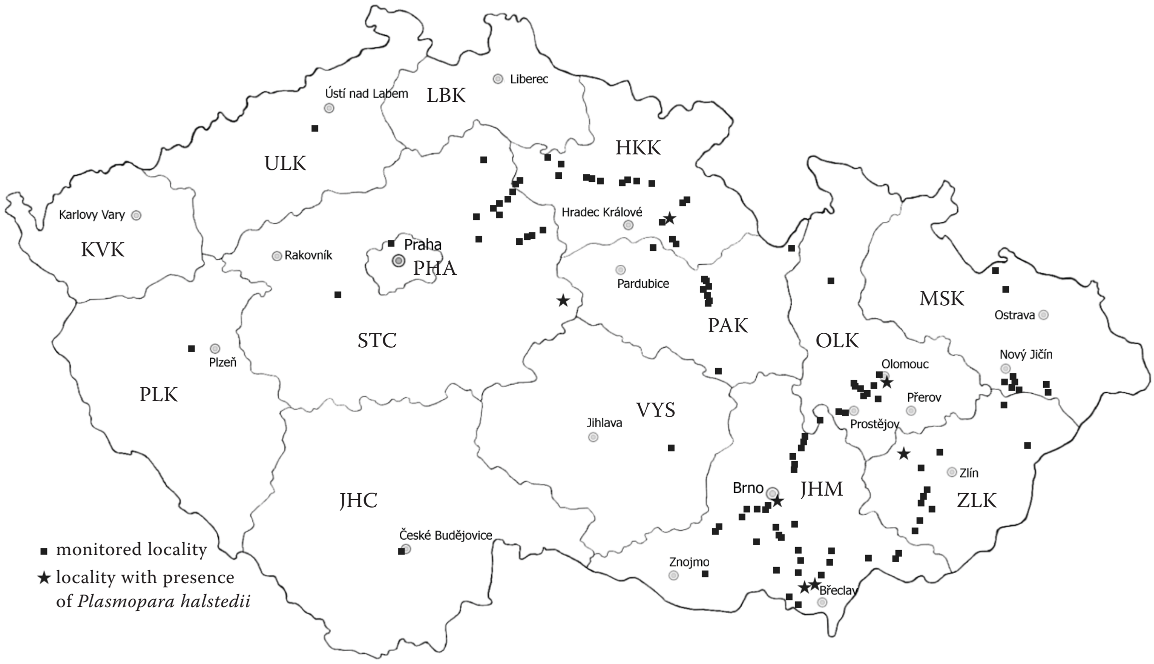

Figure 1. Map of sunflower localities monitored in the Czech Republic during 2007–2012 (squares) with records of *Plasmopara halstedii* infections (marked by asterisks)

Regions in the Czech Republic: MSK – Moravskoslezský Region, ZLK – Zlínský Region, OLK – Olomoucký Region, JHM – Jihomoravský Region, HKK – Královéhradecký Region, PAK – Pardubický Region, VYS – Vysočina Region, LBK – Liberecký Region, STC – Středočeský Region, PHA – Hlavní město Praha Region, JHC – Jihočeský Region, ULK – Ústecký Region, KVK – Karlovarský Region, PLK – Plzeňský Region

locality (date of observation, geographical location, type of habitat, approximate size of sunflower cultivar population/field, developmental stage of plants, and sunflower genotype/hybrid if known) (Table 1). Disease intensity (DI) in the population of sunflower cultivars was estimated using 0–4 scale, i.e. 0 – no plants with visible symptoms of disease in the host population; 1 – only plants with secondary infection or individual plants with systemic infection (less than 5% of plants in the host population); 2 – ca. 5–25% plants in the host population with systemic infection; 3 – ca. 25–50% systemically infected plants in the host population; 4 – more than 50% of the host population shows symptoms of systemic infection. In gardens and small fields the whole crop was surveyed for *P. halstedii* occurrence, in large fields the crop was surveyed by random transects across the field, including its margins.

RESULTS

The health status of 228 populations of sunflower cultivars grown at various types of habitats (fields, gardens, front gardens, road and field margins and others) was monitored altogether in 128 localities all over the Czech Republic in 2007–2012 (Table 1). All surveyed localities and highlighted localities with confirmed *P. halstedii* records during 2007–2012 are summarised in Figure 1. The majority of the populations of sunflower cultivars was observed in gardens (135) and in fields (47) (for details see Table 2). Most of the sunflower habitats were localised in South Moravia (eastern part of the Czech Republic) and in the eastern and central part of Bohemia (Figure 1). All these areas of the Czech Republic are mostly lowland territories with advanced agriculture and rather warm climate conditions suitable for sunflower growing.

During the six-year period (2007–2012) the presence of *P. halstedii* was confirmed at seven localities (i.e. Olomouc-Holice, Brno-Chrlice, Lednice, Podivín, Kroměříž, Čáslav, and Ledce), where host plants (*H. annuus*) with downy mildew systemic infection, mostly with the pathogen sporulation, were found (Table 1). Plants with secondary infection symptoms were reported from Olomouc every year and from Brno-Chrlice and Lednice only in 2010. Repeated occurrence

Table 1. List of localities in the Czech Republic surveyed for *Plasmopara halstedii* and assessed for disease severity in 2007–2012

Locality name	No. of cultivar populations	Habitat	Cultivar population/ field size	Occurrence of *P. h.*	DI in particular year					
					2007	2008	2009	2010	2011	2012
Moravskoslezský Region (MSK)										
Frenštát pod Radhoštěm	1	G	10 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Hodslavice	1	G	12 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Mořkov	1	G	8 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Nový Jičín-Kojetín	2	G	20 plants	–	0	n.r.	n.r.	0	n.r.	n.r.
Nový Jičín-Žilina	1	G	5 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Štítina	1	G	10 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Trojanovice	1	G	8 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Životice u Nového Jičína	1	G	2 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Zlínský Region (ZLK)										
Babice	1	RM	4 plants	–	n.r.	n.r.	0	n.r.	n.r.	n.r.
Bílovice	1	G	10 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Huslenky	2	G	20 plants	–	0	n.r.	n.r.	0	n.r.	n.r.
Huslenky	4	FM	15 plants	–	n.r.	0	0	0	0	n.r.
Kroměříž	**2**	**EF**	**0.2 ha**	+	**n.r.**	**1**	**0**	**n.r.**	**n.r.**	**nr.**
Kunovice	1	G	10 plants	–	n.r.	n.r.	n.r.	n.r.	0	n.r.
Kvasice	1	G	2 plants	–	n.r.	n.r.	n.r.	n.r.	0	0
Martinice	1	F	50–60 ha	–	n.r.	n.r.	0	n.r.	n.r.	n.r.
Ostrožská Nová Ves	1	F	25 ha	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Ostrožská Nová Ves	1	G	10 plants	–	n.r.	n.r.	n.r.	n.r.	0	n.r.
Spytihněv	1	F	25 ha	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Valašské Meziříčí	5	G	10 plants	–	0	0	0	0	0	n.r.
Olomoucký Region (OLK)										
Bystročice	2	RM	5 plants	–	0	0	n.r.	n.r.	n.r.	n.r.
Charváty	3	G	10 plants	–	0	n.r.	0	0	n.r.	n.r.
Drahanovice	1	F	20 ha	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Drahanovice	2	G	10 plants	–	0	0	n.r.	n.r.	n.r.	n.r.
Drahany	2	G	10 plants	–	0	n.r.	0	n.r.	n.r.	n.r.
Mostkovice	2	G	4–10 plants	–	n.r.	n.r.	0	n.r.	0	n.r.
Oldřichov	1	G	1 plant	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Olomouc-Holice	**6**	**EF**	**0.5–1 ha**	+	**2**	**2**	**3**	**1**	**2**	**1**
Olomouc-Lazce	2	G	7 plants	–	0	n.r.	n.r.	0	n.r.	n.r.
Olomouc-Nedvězí	1	FM	10 plants	–	n.r.	n.r.	0	n.r.	n.r.	n.r.
Olomouc-Nedvězí	1	G	50 plants	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Olšany u Prostějova	1	G	7 plants	–	n.r.	0	n.r.	n.r.	n.r.	n.r.
Plumlov	4	G	1–15 plants	–	0	0	0	0	n.r.	n.r.
Slatinice	2	G	2–5 plants	–	0	0	n.r.	n.r.	n.r.	n.r.
Jihomoravský Region (JHM)										
Blučina	4	FG	10 plants	–	0	0	0	n.r.	0	
Brno-Chrlice	**5**	**EF**	**2 ha**	+	**n.r.**	**1**	**0**	**2**	**2**	**0**
Březina	1	RM	1 plant	–	n.r.	0	n.r.	n.r.	n.r.	n.r.
Čejč	2	FM	10 plants	–	0	n.r.	n.r.	0	n.r.	n.r.
Čejkovice	1	F	50 ha	–	n.r.	0	n.r.	n.r.	n.r.	0
Hajany	1	F	50 ha	–	n.r.	n.r.	n.r.	n.r.	0	n.r.
Hustopeče	1	F	50 ha	–	n.r.	n.r.	n.r.	n.r.	0	n.r.
Jedovnice	2	G	4 plants	–	0	n.r.	n.r.	n.r.	0	n.r.
Kotvrdovice	1	G	10 plants	–	n.r.	0	n.r.	n.r.	n.r.	n.r.

Table 1 to be continued

Locality name	No. of cultivar populations	Habitat	Cultivar population/ field size	Occurrence of *P. h.*	DI in particular year					
					2007	2008	2009	2010	2011	2012
Jihomoravský Region (JHM)										
Křtiny	3	G	7–10 plants	–	n.r.	0	0	0	n.r.	n.r.
Lechovice	1	F	10 ha	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Lednice	1	FG	7 plants	–	n.r.	0	n.r.	n.r.	n.r.	n.r.
Lednice	1	F	40 ha	–	n.r.	n.r.	0	n.r.	n.r.	n.r.
Lednice	**3**	**EF**	**5 ha**	**+**	**n.r.**	**n.r.**	**n.r.**	**3**	**1**	**2**
Lipovec	3	G	5–10 plants	–	0	n.r.	0	0	n.r.	n.r.
Moravské Bránice	3	G	1–10 plants	–	0	0	n.r.	0	n.r.	n.r.
Moravský Krumlov	1	F	0.5 ha	–	n.r.	0	n.r.	n.r.	n.r.	n.r.
Moravský Krumlov	1	RM	1 plant	–	n.r.	n.r.	n.r.	n.r.	0	n.r.
Moutnice	1	F	4 plants	–	n.r.	n.r.	0	n.r.	n.r.	n.r.
Nosislav	2	G	20–50 plants	–	0	n.r.	0	n.r.	n.r.	n.r.
Nosislav	2	FG	20 plants	–	n.r.	n.r.	n.r.	0	0	n.r.
Ochoz u Brna	3	G	2–4 plants	–	n.r.	n.r.	0	0	0	0
Ořechov	2	F	80 ha	–	n.r.	0	n.r.	n.r.	0	n.r.
Ořechov	2	G	1–10 plants	–	0	0	n.r.	n.r.	n.r.	n.r.
Ořechov	1	FM	5 plants	–	n.r.	n.r.	0	n.r.	n.r.	n.r.
Podivín	**6**	**F**	**1–50 ha**	**+**	**0**	**0**	**2**	**3**	**2**	**0**
Pohořelice	2	F	15–30 ha	–	0	0	n.r.	n.r.	n.r.	n.r.
Ratíškovice	3	G	10 plants	–	0	n.r.	n.r.	0	0	n.r.
Rybníky	1	F	10 ha	–	n.r.	n.r.	n.r.	n.r.	0	n.r.
Sedlec	2	F	50 ha	–	0	0	n.r.	n.r.	n.r.	n.r.
Silůvky	1	F	40 ha	–	n.r.	n.r.	0	n.r.	n.r.	n.r.
Starovičky	4	F	0.2–100 ha	–	0	0	0	0	n.r.	n.r.
Starovičky	2	FG	1–5 plants	–	0	n.r.	n.r.	0	n.r.	n.r.
Starovičky	1	G	2 plants	–	n.r.	n.r.	n.r.	n.r.	0	n.r.
Strážnice	1	FG	15 plants	–	n.r.	n.r.	0	n.r.	n.r.	n.r.
Valtice	1	FG	10 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Velké Bílovice	1	FG	4 plants	–	n.r.	n.r.	0	n.r.	n.r.	n.r.
Velké Němčice	2	FM	20–30 plants	–	n.r.	0	0	n.r.	n.r.	n.r.
Velké Němčice	4	F	15–250 ha	–	n.r.	0	0	0	0	n.r.
Věstonice	1	F	50–60 ha	–	n.r.	0	n.r.	n.r.	n.r.	n.r.
Vnorovy	3	FM	30–40 plants	–	n.r.	n.r.	0	0	0	n.r.
Zaječí	1	F	40 ha	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Želešice	1	G	10 plants	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Královéhradecký Region (HKK)										
Albrechtice nad Orlicí	2	G	6–10 plants	–	n.r.	n.r.	0	0	n.r.	n.r.
Dětenice	1	G	4 plants	–	n.r.	n.r.	0	n.r.	n.r.	n.r.
Dobruška	1	G	10 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Holovousy	3	G	5–10 plants	–	0	n.r.	0	n.r.	0	n.r.
Hořice	2	G	10 plants	–	0	n.r.	n.r.	0	n.r.	n.r.
Jaroměř	1	G	20 plants	–	n.r.	n.r.	n.r.	0	n.r.	0
Jičín-Robousy	2	G	5 plants	–	0	n.r.	n.r.	0	n.r.	n.r.
Ledce	**3**	**G**	**4–15 plants**	**+**	**n.r.**	**n.r.**	**1**	**0**	**0**	**nr.**
Nemyčeves	1	FG	10 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Ohaveč	1	G	1 plant	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Opočno	4	G	5–10 plants	–	0	n.r.	0	0	0	0
Ostroměř	2	G	5–10 plants	–	n.r.	n.r.	n.r.	0	0	n.r.

Table 1 to be continued

Locality name	No. of cultivar populations	Habitat	Cultivar population/ field size	Occur-rence of *P. h.*	DI in particular year					
					2007	2008	2009	2010	2011	2012
Třebechovice pod Orebem	1	G	2 plants	–	n.r.	n.r.	0	n.r.	n.r.	n.r.
Velichovky	2	G	3–5 plants	–	n.r.	n.r.	0	0	n.r.	n.r.
Velký Vřešťov	2	G	3–4 plants	–	n.r.	n.r.	0	0	n.r.	n.r.
Vilantice	2	G	2–10 plants	–	n.r.	n.r.	0	0	n.r.	n.r.
Žďár nad Orlicí	1	G	10 plants	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Pardubický Region (PAK)										
Bohuňovice	1	G	5 plants	–	n.r.	0	n.r.	n.r.	n.r.	0
Chvojenec	1	F	15 ha	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
České Heřmanice	3	G	6–10 plants	–	n.r.	0	0	n.r.	0	0
Horky	1	G	10 plants	–	n.r.	n.r.	n.r.	n.r.	0	0
Kosořín	2	G	4 plants	–	0	n.r.	0	n.r.	n.r.	n.r.
Králíky	1	G	7 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Nedvězí	1	G	50 plants	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Sedliště	3	G	10 plants	–	0	0	n.r.	n.r.	0	0
Vysočina Region (VYS)										
Velké Meziříčí	3	G	5 plants	–	n.r.	n.r.	0	0	0	n.r.
Středočeský Region (STC)										
Beroun	1	G	5 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Choťánky	1	F	20 ha	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Čáslav	**1**	**EF**	**0.5 ha**	**+**	**n.r.**	**n.r.**	**1**	**n.r.**	**n.r.**	**nr.**
Dlouhopolsko	1	F	20 ha	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Kosmonosy	1	F	25 ha	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Krchleby	1	G	3 plants	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Loučeň	3	G	5–10 plants	–	n.r.	0	0	0	n.r.	n.r.
Mcely	4	G	2–10 plants	–	0	n.r.	0	0	0	0
Mcely	1	F	20 ha	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Milovice	1	G	10 plants	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Odřepsy	1	F	10 ha	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Prodašice	2	F	20 ha	–	0	n.r.	n.r.	0	n.r.	n.r.
Seletice	1	G	10 plants	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Velenka	1	F	20 ha	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Vlkov pod Oškobrhem	1	F	15 ha	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Zavadilka	1	G	2 plants	–	n.r.	n.r.	n.r.	0	n.r.	n.r.
Hlavní město Praha Region (PHA)										
Praha-Suchdol	4	G	10 plants	–	0	0	0	0	n.r.	n.r.
Jihočeský Region (JHC)										
České Budějovice	1	G	5 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Ústecký Region (ULK)										
Bořislav	1	G	15 plants	–	0	n.r.	n.r.	n.r.	n.r.	n.r.
Plzeňský Region (PLK)										
Nýřany	3	F	15–40 ha	–	0	0	0	n.r.	n.r.	n.r.

P. h. – *Plasmopara halstedii*; DI – degree of infection (disease severity) of downy mildew in the population of sunflower cultivars (for details see Material and Methods); Habitats: EF – experimental field, F – field, FM – field margin, FG – front garden, G – garden, RM – road margin; Records: + present (in bold), – not present, n.r. – not recorded; DI – degree intensity: 0 – no plants; 1 – less than 5% of plants; 2 – ca. 5–25% plants with systemic infection; 3 – ca. 25–50% systemically infected plants; 4 – more than 50% with symptoms of systemic infection

Table 2. Incidence of *Plasmopara halstedii* in the individual sunflower habitats

Habitat	Number of records/Number of infections by *P. halstedii*						
	2007	2008	2009	2010	2011	2012	total
Experimental field	**1[a]/1[b]**	**3/3**	**4/2**	**3/3**	**3/3**	**3/2**	**17/14**
Field	8/0	10/0	**8/1**	**15/1**	**6/1**	1/0	**48/3**
Field margin	1/0	2/0	5/0	3/0	2/0	0/0	13/0
Front garden	5/0	2/0	3/0	2/0	2/0	0/0	14/0
Garden	38/0	15/0	**25/1**	37/0	20/0	0/0	**135/1**
Road margin	1/0	2/0	1/0	0/0	1/0	0/0	5/0
Total	54/1	34/3	46/4	60/3	34/4	4/2	

[a]number of sunflower cultivar populations surveyed; [b]number of sunflower cultivar populations with detected infection; in bold – presence of infection

of the systemic disease symptoms and pathogen reproduction was confirmed at four localities, i.e. Olomouc-Holice, Brno-Chrlice, Lednice and Podivín. In the experimental field of the Central Institute for Supervising and Testing in Agriculture in Brno-Chrlice the absence of *P. halstedii* was recorded in 2009 and 2012, likely due to a shift of experimental fields used for sunflower testing and thus leaving the source of the pathogen inoculum in soil. It is evident that most records (i.e. five) of sunflower downy mildew come from the experimental fields (Olomouc-Holice, Brno-Chrlice, Lednice, Kroměříž, Čáslav) with purposedly grown susceptible cultivars where the resistance of newly selected sunflower varieties is tested on soil with the long-lasting contamination of pathogen oospores. Only two localities, a garden in Ledce and small fields with heavy and waterlogged soil in Podivín, can be supposed to be a natural occurrence of *P. halstedii*. Probably the main reason for these records is sunflower growing inconsistently with the recommended agronomical practice. In a six-year summary, the frequency of *P. halstedii* incidence was the highest in experimental fields (87%) and very low in commercial fields (4%) and in private gardens (1%).

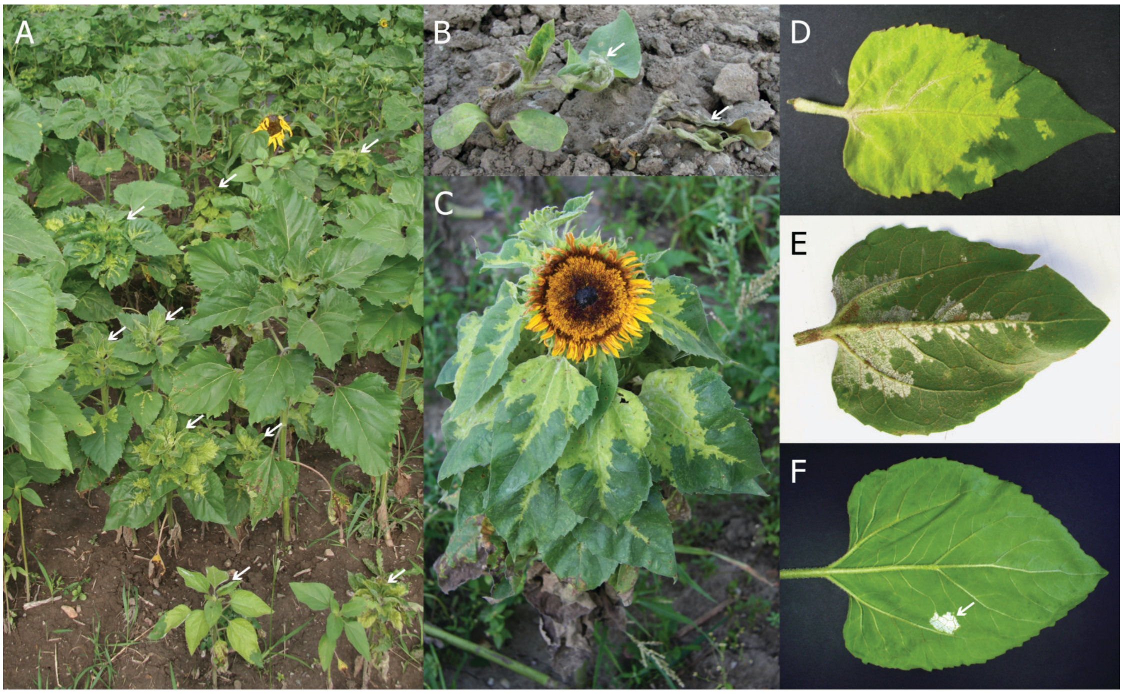

Figure 2. Symptoms of sunflower downy mildew include primary infections with A – plant dwarfing upon systemic infection, B – damping off young plants, C – failure of flowering, D – chlorosis on the adaxial side, and E – sporulation on the abaxial side of a leaf; or secondary infections characterised by F – local lesions on leaves bounded by veins

Disease severity expressed as degree of infection (DI) assessed in populations of sunflower cultivars on sites with the presence of *P. halstedii* ranged from 1 to 3 (on a 0–4 scale). Sunflower fields in Čáslav, Kroměříž, and Ledce were infected weakly (DI = 1), the other populations of sunflower cultivars were mostly infected moderately: in Podivín (DI = 2 in 2009 and 2011, or 3 in 2010), Lednice (DI = 1 in 2011 and 2012, or 3 in 2010), Brno-Chrlice (DI = 0 in 2009, 1 in 2008, or 2 in 2010-11), and Olomouc-Holice (DI = 1 in 2010 and 2012, 2 in 2007–2008 and 2011, or 3 in 2009) (for details see Table 1). Changes in the degree of infection may be attributed to variation of microclimate conditions, the level of soil contamination with pathogen oospores and genotypes of host plants. However, the variety composition of sunflower fields remained unknown in most of the localities. The observed symptoms of downy mildew primary infection included plant dwarfism (Figure 2A), seedling damping off (Figure 2B), retarded flowering (Figure 2C), deformations of the leaf blade combined with chlorotic lesions along veins on the adaxial side (Figure 2D) and frequent sporulation on the abaxial (downy) side of leaves (Figure 2E). Lesions on leaves bounded by veins (Figure 2F) indicated secondary infection. Altogether, 57 field samples of the pathogen sporulating on host plant leaves and/or stems were collected in 2007–2012 and will be used for detection of pathogen races.

DISCUSSION

According to data published by EPPO the downy mildew caused by *P. halstedii* has recently been present in the following European countries: Albania, Austria, Bulgaria, Czech Republic, Estonia, France, Germany, Greece (reported by Thanassoulopoulos & Mappas 1992), Hungary, Italy, Moldova, Romania, Slovakia, Spain, Switzerland, Turkey, Russia, and Ukraine. Within North America it is distributed in Canada, United States of America, and within South America in Argentina, Brazil, Chile, Dominican Republic, Paraguay, and Uruguay. Within Asia the pathogen was detected in China, Georgia, India, Iran, Iraq, Israel, Japan, Kazakhstan, and Pakistan. In the African continent *P. halstedii* was reported from Egypt, Ethiopia, Morocco, Kenya, and South Africa (reported by Viljoen *et al.* 1997), Uganda, and Zimbabwe.

It is evident that the global pathogenic variability of *P. halstedii* has been increasing (Gulya 2007). New hybrid cultivars evoke selection pressure which results in the emergence of new physiological races (e.g. in France, Germany, and Italy) with different virulence patterns (Sakr 2009; Virányi & Spring 2011). Phytosanitary practices are undertaken to prevent or at least reduce their spread to other countries. However, continuous and systematic monitoring of the pathogen occurrence is necessary to take appropriate preventive steps.

Our recent study has brought the first comprehensive data on *P. halstedii* incidence in the Czech Republic. It was confirmed to occur only at separate locations and mostly in sunflower experimental fields, like those of the Central Institute for Supervising and Testing in Agriculture (Brno-Chrlice, Čáslav, Lednice), Agricultural Research Institute in Kroměříž (Kroměříž) and Palacký University in Olomouc (Olomouc-Holice). Soils in these locations might be proposedly infested in the past or accidental incidence of *P. halstedii* was maintained to test new sunflower cultivars for resistance against *P. halstedii* and other diseases. Unfortunately, the source of soil contamination remains unknown. Any incidence of *P. halstedii* was detected in commercial fields unless recommended agronomical practice was omitted (i.e. in Podivín where sunflower is grown yearly on heavy and water-soaked soil). The occurrence of primary infections in commercial or hobby fields probably comes from infected sunflower seed that established *P. halstedii* in the locality some time ago. Repeated planting of seed susceptible to *P. halstedii* or inefficient fungicides might contribute to disease incidence. Wind-borne infections are not probable as *P. halstedii* is still confined to solitary and remote localities in the CR. Monitoring of harmful organisms by State Phytosanitary Administration (SPA) of the Czech Republic detected several localities mostly in South Moravia and East Bohemia (State Phytosanitary Administration 2012). Unfortunately, the records of sunflower downy mildew by SPA do not contain any information on the cultivar composition. We faced a similar task during our research and only limited information on cultivar sets was determined during the survey. Nevertheless, *P. halstedii* recorded in experimental fields of the Central Institute for Supervising and Testing in Agriculture revealed *H. annuus* cultivars lacking genes of downy mildew resistance (Labud, Oxana, Pilar and PR63A82) and cv. NK Brio bearing resistance to *P. halstedii* races 100, 703, 710 (Anonymous 2005, 2011).

The most frequent incidence of *P. halstedii* found in South Moravia in our survey is in agreement with historical records of Bojňanský (1956, 1957). It is evident from SPA annual reports that *P. halstedii* occurs scarcely also at a few more localities in the Czech Republic probably not included herein. According to our knowledge and presented results it can be assumed that preventative measures against sunflower downy mildew are effective in case that the pathogen occurrence has not been found on an epidemic scale in the Czech Republic. The detailed research focused on pathogenic variability in Czech populations of *P. halstedii* is in progress.

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