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The peculiarities of phoma stem canker (*Leptosphaeria maculans* / *L. biglobosa* complex) infections in winter and spring oilseed rape (*Brassica napus* L.)

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Abstract

Phoma stem canker is an important and damaging disease of oilseed rape worldwide. The disease is caused by *Leptosphaeria maculans* / *L. biglobosa* species complex, with one or the other species prevailing. The two *Leptosphaeria* species produce different disease symptoms on rape plants, *L. maculans* is the main fungus, causing a severe basal phoma canker. The present study provides the data of research into the peculiarities of phoma stem canker infections in 119 stands of winter and 63 stands of spring oilseed rape during the 2004–2007 cropping seasons. The incidence and severity of phoma stem canker varied greatly among the stands, crops and cropping seasons. Winter oilseed rape exhibited a higher susceptibility to phoma stem canker compared with spring oilseed rape. Commonly, the diseased winter rape stems had both basal stem canker and upper stem lesions, while those of spring oilseed rape contained only upper stem lesions. The implications that *Leptosphaeria maculans* and *L. biglobosa* co-exist in Lithuania are discussed.

Key words: incidence, severity, disease severity index, basal canker, upper stem lesions.

Introduction

Phoma stem canker is a devastating oilseed rape fungal disease, which is widespread in all countries involved in rapeseed production (West et al., 2001; Fitt et al., 2006). The evidence of previous research suggests that phoma stem canker is caused by *Leptosphaeria maculans* fungus, containing isolates of different virulence in its population. The isolates have been divided into two groups – A and B, or aggressive and non-aggressive, or Tox⁺ and Tox^o, depending on their capability to cause phoma stem canker (Balesdent et al., 1992; Brun et al., 1997; Rouxel, Balesdent, 2005). Later it was established that isolates differing in virulence are attributable to different fungi – *Leptosphaeria maculans* (A group, aggressive isolates) and *L. biglobosa* (B group, non-aggressive isolates) (Shoemaker, Brun, 2001). Thus, now it is known that phoma stem canker is caused by *Leptosphaeria* species complex, of which the most important and damaging is *Leptosphaeria maculans* (Fitt et al., 2006). *L. maculans* causes basal canker, which results in stem breaking, premature ripening and crop lodging, *L. biglobosa* can cause upper stem lesions (Balesdent et al., 1992; Brun et al., 1997; Fitt et al., 2006).

Leptosphaeria maculans and *L. biglobosa* can infect the same host-plant and have similar-looking spores; however, both fungi differ genetically, are characterized by different metabolism and cause different leaf and stem lesions. The distribution of *Leptosphaeria maculans* and *L. biglobosa* fungi depends on the geographical region, the dominance of one or the other group is observed

(Jedryczka et al., 1997; 1999). However, in some regions the distribution of both fungi is very similar. Our research was aimed to establish the differences in phoma stem canker incidence and severity between winter and spring rape and according to the characteristics of lesions to preliminarily determine which of the phoma stem canker-causing fungus prevails.

Materials and methods

Expeditionary research was carried out during winter (WOSR) and spring oilseed rape (SOSR) ripening stage (BBCH 85–87) over the 2004–2007 period. Plant samples were collected from different regions – Kėdainiai, Panevėžys, Jonava, Kaunas, Radviliškis, Klaipėda, Utena, Biržai and Šakiai. Stem samples were taken from five representative places in each field. A total of 119 crops of WOSR and 63 crops of SOSR were assessed. Plants (100–500 per site) were uprooted and analysed at the Lithuanian Institute of Agriculture. Assessments were carried out for basal stem canker and upper stem lesions (5 cm above the stem base). The severity of basal canker was assessed using a 1–6 score scale (Aubertot et al., 2004). The disease severity scores were: 1 = healthy plant, 2 = less than 25% of the cross sectioned stem girdled by lesion, 3 = 25–50% of stem girdled by lesion, 4 = 50–75% of stem girdled by lesion, 5 = 75–90% of stem girdled by lesion and 6 = 90–100% of the cross sectioned stem girdled by lesion.

Average phoma stem canker incidence (DI) was calculated according to the formula: $DI = DP \times 100/PA$, where DP – diseased plants (stems with phoma stem canker spots), PA – all plants of a specific sample analysed. Disease severity index (DSI) for the plants with basal phoma canker was calculated according to the formula: $DSI = (0 \times n_1) + (1 \times n_2) + (3 \times n_3) + (5 \times n_4) + (7 \times n_5) + (9 \times n_6) / \text{total number of examined plants}$, where n – number of plants within each specific score, 0–9 recalculating coefficients (Kuusk et al., 2002).

A detailed analysis was carried out on the severity of upper stem lesions (<25, 26–50, 51–75, >75% of the stem perimeter girdled by upper stem lesion), on the deployment of upper stem lesions also on the number and total length of upper stem lesions. Percent of stems with one to six upper stem lesions, percent of upper stem lesions at a stem height of 5–20, 20–35, 35–50 and >50 cm among the infected stems was calculated. Also percent of stems with a total length of upper stem lesions up to 10, 10–20, 20–30 and >30 cm and the distribution of upper stem lesions according to the percent of stem perimeter girdled by lesion was calculated.

Statistical analysis. Experimental data were $\log(x + 1)$ transformed before statistical analysis. Descriptive statistics – the coefficient of variation (CV%) and relative standard error (RSE%) were performed using routine methods (Clever, Scarisbrick, 2001). The statistical analysis was performed using the *Statistica 6.0*

(StatSoft Inc.) for *Windows*.

Results and discussion

Our experimental evidence indicated that the incidence and severity of phoma stem canker differed greatly among the stands, crops and between the cropping seasons. During 2004–2007 in the stands from various regions phoma stem canker affected on average 42.9–96.1% of WOSR and only 15.0–37.1% of SOSR plants (Table 1). In WOSR in 2004 and 2005, the plants with dual phoma stem canker symptoms – basal canker and upper stem lesions accounted for the largest share (61.1% and 69.4%, respectively) of the total affected plants, while in 2006 and 2007, the plants only with basal canker were prevailing (38.2% and 44.8%, respectively). In 2004, 2005 and 2007, the plants with only upper stem lesions accounted for the lowest share of the total affected plants (5.3, 5.7 and 15.0 %, respectively); however, in 2006 as much as 31.0% of phoma stem canker-affected WOSR plants were entirely with upper stem lesions. In SOSR only in 2004, the plants with solely basal canker accounted for the largest share (80.4%) of the total affected plants. During other cropping seasons, the plants with solely upper stem lesions dominated among the affected plants. Disease severity index differed markedly between the crops and mean disease severity index differed between the cropping seasons, the highest being in WOSR in 2005

Table 1. The incidence of basal phoma stem canker and upper stem lesions in winter (WOSR) and spring oilseed rape (SOSR) crops before harvesting (GS 85) in 2004–2007

Parameter	WOSR					SOSR							
	Diseased stems %	Among them %			Total stems with basal canker %	Disease severity index	Diseased stems %	Among them %			Total stems with basal canker %	Disease severity index	
		A	B	C			A	B	C				
		2004 (n = 24)					2004 (n = 14)						
Min	83.2	24.2	32.1	1.0	77.0	5.0	26.0	0.0	0.0	0.0	8.2	0.17	
Max	99.0	59.5	72.4	9.5	95.0	44.3	54.0	100.0	23.3	76.7	48.0	2.80	
Mean	92.8	33.6	61.1	5.3	87.8	11.5	37.1	80.4	5.5	14.1	31.7	1.34	
RSE%	0.4	2.5	1.3	1.8	0.4	3.0	1.5	2.7	3.1	1.9	3.1	2.4	
CV%	1.9	9.4	6.2	8.6	1.8	8.9	5.6	5.4	9.6	4.5	11.5	9.3	
		2005 (n = 26)					2005 (n = 23)						
Min	75.0	2.0	43.5	0.0	67.5	9.0	5.0	0.0	0.0	14.3	0.0	0.0	
Max	100.0	53.9	98.0	18.4	100.0	51.6	76.0	53.8	57.1	100.0	30.0	1.59	
Mean	96.1	24.9	69.4	5.7	90.8	37.0	32.7	10.4	12.6	77.0	7.4	0.67	
RSE%	0.3	3.0	1.1	4.2	0.5	1.6	3.6	4.9	6.4	2.1	6.4	4.6	
CV%	1.5	6.2	5.6	6.1	2.6	8.2	11.4	15.9	11.7	10.1	10.8	11.4	
		2006 (n = 24)					2006 (n = 7)						
Min	22.0	11.3	13.6	1.0	12.0	0.6	2.0	4.3	0.0	20.0	1.0	0.02	
Max	97.0	78.6	87.6	66.7	96.0	35.4	24.0	66.7	26.1	70.8	12.0	3.75	
Mean	42.9	38.2	30.8	31.0	28.7	6.1	15.0	34.5	14.1	51.4	6.9	1.34	
RSE%	1.4	1.7	1.8	3.6	2.7	3.5	4.4	4.2	6.0	4.1	4.9	4.5	
CV%	6.4	8.1	8.7	10.0	9.9	8.8	13.0	13.5	10.7	10.8	13.3	17.9	
		2007 (n = 46)					2007 (n = 19)						
Min	37.0	2.0	10.8	0.0	20.0	2.4	2.0	0.0	0.0	12.0	0.0	0.0	
Max	100.0	86.8	89.8	52.6	100.0	49.1	62.0	66.7	50.0	100.0	23.0	3.46	
Mean	75.9	44.8	40.2	15.0	65.2	19.8	27.8	23.8	15.3	60.9	10.3	0.96	
RSE%	0.7	2.0	1.8	2.8	1.3	2.0	5.3	6.5	6.8	3.7	6.4	5.7	
CV%	4.9	6.2	3.8	5.8	8.7	8.8	10.1	14.6	13.9	12.7	13.5	15.8	

Notes. A – stems only with basal canker, B – stems with dual phoma stem canker symptoms (basal canker and upper stem lesions), C – plants with upper stem lesions (more than 5 cm above stem base); n – number of winter and spring oilseed rape crops assessed; RSE% – relative standard error, CV% – coefficient of variation. Data were $\log(x + 1)$ transformed before analysis, but non-transformed data are presented.

(37.0), followed by 2007 (19.8) and the lowest disease severity index was estimated in 2006 (6.1). The mean disease severity index in SOSR during the experimental period was very low (0.67–1.34) compared with that of WOSR. The variation of disease parameters during the experimental period in WOSR was low and those in SOSR was low to moderate (Table 1).

The detailed analysis of WOSR and SOSR stems showed that from one to six phoma upper stem lesions developed on affected stems; however, during experimental period among the affected stems the most numerous were those with one upper stem lesion (on average 38.0–63.5% in WOSR and 57.9–88.9% in

SOSR) (Table 2). The highest average number of upper stem lesions per affected stem in WOSR was recorded in 2005 and 2006 (2.3 lesions), although the highest average number of lesions per assessed stem was identified in 2005 (1.6 lesions). However, the variation of the number of upper stem lesions per affected or per assessed stem between the stands in 2006 and 2007 was high (>20%). In SOSR, the highest average number of upper stem lesions per affected stem (1.7 lesions) was established in 2005; however, the average number of upper lesions per assessed stem during experimental period was very low (0.1–0.5 lesions).

Table 2. Variation of the number of upper stem lesions of phoma stem canker on rape stems (5 cm above stem base) in winter (WOSR) and spring oilseed rape (SOSR) crops before harvesting (GS 85) in 2004–2007

Parameter	A	% of stems with the number of upper stem lesions						Average number of upper stem lesions	
		1	2	3	4	5	≥6	per assessed stem	per affected stem
WOSR									
2004 (n = 24)									
Min	34.0	17.4	12.2	3.7	0.0	0.0	0.0	0.7	1.3
Max	77.0	77.2	39.1	22.1	15.9	7.3	12.5	2.0	3.1
Mean	61.3	54.0	26.4	10.6	4.8	2.9	1.3	1.1	1.9
RSE%	0.9	1.4	1.3	2.4	6.9	7.2	5.3	3.6	2.9
CV%	4.4	6.9	6.2	11.6	15.2	14.0	18.8	17.7	14.1
2005 (n = 26)									
Min	42.5	0.0	4.1	3.5	0.0	0.0	0.0	0.6	1.0
Max	98.0	63.5	50.0	32.5	20.4	26.5	26.5	4.4	5.9
Mean	72.4	38.0	32.1	19.0	7.0	2.4	1.5	1.6	2.3
RSE%	1.1	4.1	2.4	3.2	5.5	5.6	5.5	4.4	2.8
CV%	5.5	14.6	12.2	16.1	17.0	18.2	18.4	19.4	14.1
2006 (n = 24)									
Min	6.0	16.3	13.3	0.0	0.0	0.0	0.0	0.2	0.2
Max	86.0	86.7	46.7	30.8	27.3	15.8	5.3	1.1	6.6
Mean	27.6	51.2	27.0	14.0	6.4	1.2	0.2	0.5	2.3
RSE%	2.6	2.0	1.9	5.1	4.5	6.9	5.2	6.3	6.1
CV%	12.5	10.0	9.2	15.1	14.4	18.2	25.4	24.3	23.0
2007 (n = 46)									
Min	10.0	26.2	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Max	96.0	96.9	47.7	32.3	12.0	3.7	0.0	2.1	5.9
Mean	41.5	63.5	26.4	8.4	1.4	0.3	0.0	0.6	1.8
RSE%	1.2	1.0	2.3	4.4	3.2	2.6	–	3.7	3.5
CV%	8.1	6.7	15.7	13.5	21.6	17.4	–	25.1	23.6
SOSR									
2004 (n = 14)									
Min	2.0	44.3	14.3	0.0	0.0	0.0	0.0	0.0	1.0
Max	35.2	100.0	50.0	15.9	15.1	4.5	0.0	0.7	2.0
Mean	7.4	88.9	9.2	1.2	0.4	0.3	0.0	0.1	1.2
RSE%	4.8	4.7	4.2	1.8	3.8	2.8	–	2.4	8.4
CV%	13.4	7.7	11.8	16.2	26.0	10.5	–	11.3	22.3
2005 (n = 23)									
Min	3.0	13.2	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Max	76.0	100.0	42.6	22.4	19.7	11.8	6.6	2.4	3.1
Mean	29.9	57.9	24.9	11.5	3.8	1.6	0.3	0.5	1.7
RSE%	4.9	1.9	5.0	4.9	9.0	8.6	8.8	4.2	3.0
CV%	15.4	9.3	9.0	19.2	17.4	16.6	11.2	11.4	14.2
2006 (n = 7)									
Min	1.0	47.6	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Max	22.0	100.0	40.0	14.3	13.6	0.0	0.0	0.4	1.8
Mean	10.7	69.3	24.8	4.0	1.9	0.0	0.0	0.2	1.4
RSE%	4.5	2.1	6.8	8.7	8.4	–	–	8.8	4.4
CV%	14.0	5.6	14.3	14.8	19.3	–	–	23.8	11.5
2007 (n = 19)									
Min	2.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Max	58.0	100.0	39.6	25.0	2.3	0.0	0.0	0.7	1.8
Mean	22.2	74.8	22.0	3.1	0.1	0.0	0.0	0.3	1.3
RSE%	4.1	1.1	5.8	7.6	9.0	–	–	10.8	2.5
CV%	17.8	4.8	19.0	18.8	23.0	–	–	26.1	10.9

Notes. A – % of stems with upper stem lesions; n – number of winter and spring oilseed rape crops assessed; RSE% – relative standard error, CV% – coefficient of variation. Data were $\log(x + 1)$ transformed before analysis, but non-transformed data are presented.

Assessment of the deployment of upper stem lesions on the stems of WOSR and SOSR indicated that during the experimental period the highest number of phoma lesions had developed at the 5–20 cm stem height (Table 3). In SOSR in 2004, 2006 and 2007, on average 71.7–82.9% of upper phoma stem lesions were identified at the 5–20 cm stem height. In WOSR in 2007, they accounted in average for 74.9%, in other experimental

years – for 34.9–51.0% of the total upper stem lesions identified. The variation of this disease parameter was low between the stands of WOSR and SOSR in almost all the cropping seasons. During the experimental period, upper phoma stem lesions were identified at the highest 50 cm height only on individual stems of WOSR and SOSR.

Table 3. Position of upper stem lesions on phoma stem canker damaged stems of winter (WOSR) and spring oilseed rape (SOSR) before harvesting (GS 85) in 2004–2007

Parameter	WOSR					SOSR				
	A	% of lesions at different stem height				A	% of lesions at different stem height			
		5–20 cm	20–35 cm	35–50 cm	>50 cm		5–20 cm	20–35 cm	35–50 cm	>50 cm
		2004 (n = 24)					2004 (n = 14)			
Min	49.0	10.5	28.1	1.1	0.0	2.0	33.7	12.5	0.0	0.0
Max	198.0	63.2	57.1	35.1	25.7	69.0	100.0	100.0	25.0	23.5
Mean	111.9	44.7	38.8	13.5	3.0	10.3	74.0	20.8	3.4	1.8
RSE%	1.4	2.0	1.0	4.8	5.6	4.1	3.2	9.2	8.3	9.4
CV%	7.1	10.0	4.9	17.9	20.2	15.3	4.5	16.5	20.1	14.2
		2005 (n = 26)					2005 (n = 23)			
Min	61.0	16.1	25.2	2.0	0.0	3.0	6.8	13.6	0.0	0.0
Max	440.0	53.0	50.0	37.5	32.3	236.0	68.8	66.7	47.1	30.7
Mean	156	34.9	34.7	21.2	9.2	54.8	34.9	38.0	19.7	7.4
RSE%	1.6	1.7	1.0	3.1	5.0	4.6	3.7	2.1	5.2	7.9
CV%	8.3	8.8	5.3	15.8	15.7	22.2	17.7	9.9	18.2	20.8
		2006 (n = 24)					2006 (n = 7)			
Min	10.0	24.0	17.6	0.0	0.0	1.0	40.0	0.0	0.0	0.0
Max	222.0	82.4	48.4	40.0	9.4	40.0	100.0	47.5	14.3	0.0
Mean	52.2	51.0	33.2	14.0	1.8	16.6	71.7	23.3	5.0	0.0
RSE%	3.2	1.8	1.6	5.4	5.2	10.5	2.9	7.6	5.0	–
CV%	15.6	8.8	7.8	17.6	18.2	22.0	7.6	18.0	15.1	–
		2007 (n = 46)					2007 (n = 19)			
Min	7.0	19.5	0.0	0.0	0.0	2.0	57.1	0.0	0.0	0.0
Max	209.0	100.0	45.5	39.0	2.4	86.0	100.0	42.9	4.7	0.0
Mean	64.5	74.9	20.7	4.3	0.1	29.5	82.9	16.8	0.4	0.0
RSE%	2.1	0.9	3.2	5.7	4.2	4.5	1.0	8.0	10.8	–
CV%	14.5	6.0	22.0	23.2	28.8	19.6	4.2	19.1	24.7	–

Notes. A – total number of upper stem lesions per 100 stems assessed; n – number of winter and spring oilseed rape crops assessed; RSE% – relative standard error; CV% – coefficient of variation. Data were log(x + 1) transformed before analysis, but non-transformed data are presented.

Among the phoma stem canker-affected stems of WOSR and SOSR the most numerous were those with a total upper stem lesions length up to 10 cm (Table 4). In SOSR during 2004–2007, suchlike stems accounted for 94.2, 80.1, 94.0 and 89.7 %, respectively of the total average annual number of phoma affected stems. In WOSR in 2004, 2006 and 2007 suchlike stems accounted for 77.7, 79.6 and 73.4 %, respectively. During the study period, phoma affected stems with upper stem lesions total length of 10–20 cm in WOSR accounted for 16.9–34.3% and in SOSR for 5.6–17.3%. Stems with total lesions length >20 cm accounted for a small share of the total affected stems in both WOSR and SOSR.

The severity of upper phoma stem lesions was established according to the percent of stem perimeter girdled by lesion. Phoma stem canker is highly damaging when it covers the whole perimeter of the stem. Our research evidence suggests that in all experimental years, in WOSR the most prevalent were upper stem lesions covering less than 50% of the stem perimeter (Table 5).

In 2004, suchlike lesions accounted for 64.6%, in 2005 for 85.5%, in 2006 for 97.9 % and in 2007 for 81.3% of the total number of upper stem lesions. Lesions covering nearly the whole perimeter (>75%) of a stem made up on average as little as 0.8–15.3%. In SOSR in 2004, upper phoma stem lesions covering 25–50% of stem perimeter were most prevalent (61.0%). However, in 2005–2007, among the upper stem lesions the most prevalent were those covering only up to 25% of stem perimeter. Variability of distribution of upper stem lesions according to their severity was low to moderate in WOSR and SOSR during experimental period.

The incidence and severity of phoma stem canker on WOSR in Lithuania were investigated during the period 1997–2000 and it was assumed, that the disease was not very harmful (Brazauskiene, Petraitiene, 2004). The disease incidence in the untreated plots was 30.0–37.9%, and the mean disease severity score in these seasons reached only 0.48–0.51, respectively (0–4 score scale). However, due to the significant increase in oilseed

Table 4. The distribution of winter (WOSR) and spring oilseed rape (SOSR) stems according to the total length of phoma stem canker spots on stems in 2004–2007

Parameter	WOSR				SOSR			
	Diseased stems % with total length of upper stem lesions				Diseased stems % with total length of upper stem lesions			
	up to 10 cm	10–20 cm	20–30 cm	>30 cm	up to 10 cm	10–20 cm	20–30 cm	>30 cm
	2004 (n = 24)				2004 (n = 14)			
Min	65.2	6.3	0.0	0.0	66.7	19.3	0.0	0.0
Max	93.8	32.0	4.8	1.6	100.0	33.3	2.3	0.0
Mean	77.8	20.8	1.3	0.1	94.2	5.6	0.2	0.0
RSE%	0.4	2.1	6.1	7.9	7.7	8.4	10.0	–
CV%	2.0	10.1	18.8	17.3	12.4	13.9	14.4	–
	2005 (n = 26)				2005 (n = 23)			
Min	14.3	18.7	0.0	0.0	36.8	0.0	0.0	0.0
Max	78.0	59.4	38.8	10.2	100.0	50.0	15.8	2.6
Mean	55.2	34.3	8.5	2.1	80.1	17.3	2.5	0.1
RSE%	1.8	1.5	5.3	4.7	1.1	5.5	10.0	10.9
CV%	9.0	7.7	20.0	18.8	5.4	19.5	17.9	23.6
	2006 (n = 24)				2006 (n = 7)			
Min	36.8	0.0	0.0	0.0	81.8	0.0	0.0	0.0
Max	100.0	33.3	36.8	3.1	100.0	18.2	0.0	0.0
Mean	79.6	16.9	3.3	0.2	94.0	6.0	0.0	0.0
RSE%	1.1	5.4	4.6	6.8	0.7	17.6	–	–
CV%	5.3	13.6	18.4	19.4	1.9	46.5	–	–
	2007 (n = 46)				2007 (n = 19)			
Min	32.3	4.2	0.0	0.0	74.1	0.0	0.0	0.0
Max	94.1	47.9	21.4	4.6	100.0	24.1	1.7	0.6
Mean	73.4	22.4	3.8	0.4	89.7	10.1	0.1	0.1
RSE%	0.8	2.5	5.2	3.5	0.5	9.8	6.8	16.0
CV%	5.4	16.9	19.6	18.9	2.3	12.2	16.7	17.7

Note. Explanations under Table 3.

rape production area and climate warming, the disease has started to rapidly spread in Lithuania and has become much more severe, especially for WOSR. During the study period, phoma stem canker incidence and severity in WOSR and SOSR were found to vary depending on oilseed rape seasonal type (winter or spring), cropping season and the field. West et al. (2002) also showed that the severity of crown cankers at the stem base differed between seasons. Nevertheless, regional variation in the severity of phoma stem canker epidemics is also influenced indirectly by interactions between the host, pathogen and abiotic factors (Evans et al., 2008). Definitely, severity and incidence of phoma stem canker depends on many factors, such as survival of inoculum, maturation of fruiting bodies, timing of ascospore release, infection conditions, host growth stage and host resistance (Li et al., 2004; Huang et al., 2005; Sprague et al., 2006; Khangura et al., 2007; Travadon et al., 2007).

All parts of the oilseed rape plant can be infected by the phoma pathogens, including the tap root, stem base, upper stem parts (Paul, Rawlinson, 1992). Thürwächter et al. (1999) indicated that under field conditions aggressive and non-aggressive isolates cause different symptoms. It is known, that stem base canker phase is associated with *L. maculans*, while less damaging upper stem lesions are associated with the less damaging species of *L. biglobosa* (West et al., 1999;

2001; Fitt et al., 2006). The predominance of *L. biglobosa* higher up the stem and *L. maculans* at the stem base was confirmed by numerous authors, since winter leaf lesions are likely to be associated with basal cankers and spring lesions with upper stem lesions (West et al., 2002; Huang et al., 2003). Therefore, the proportion of the two species in local populations has been shown to affect the severity of stem canker epidemics (Stonard et al., 2010). It is likely that changes in the severity of phoma stem canker in our country have occurred as a result of the changes in the population structure of the pathogen. This might have been accompanied by an increase in the proportion of the more damaging *L. maculans* in the pathogen population (Evans et al., 2008). Other authors also reported that the numbers of plants with stem-base cankers increased and phoma stem canker became more severe (Liu et al., 2006). In most cases, reports do not distinguish between *L. maculans* and *L. biglobosa* or provide information on the brassica crop on which the pathogen was identified. Reports that distinguish between both species are almost entirely based on characteristics of isolates cultured from oilseed rape (Fitt et al., 2006).

Phoma stem canker was not a very severe disease in our neighbouring countries Poland and Sweden and it was assumed that only avirulent, group B isolates (currently – *L. maculans*) were present. In addition, there are indications that *L. maculans* is currently expanding

its geographical distribution and is in the progress of replacing the less damaging related species, *L. biglobosa*. Investigations on the population structure of the pathogen using molecular techniques showed that isolates of both (virulent and avirulent) groups are spread in Poland and Sweden and the proportion of *L. maculans* is increasing (Jedryczka et al., 1999; Karolewski et al., 2002; Kuusk et al., 2002).

Table 5. The distribution of upper stem lesions according to the severity of phoma stem canker (% of cross sectioned stem girdled by lesion) in winter (WOSR) and spring oilseed rape (SOSR) in 2004–2007

Parameter	WOSR				SOSR			
	% of lesions girdled stem perimeter							
	0–25%	25–50%	50–75%	75–100%	0–25%	25–50%	50–75%	75–100%
	2004 (n = 24)				2004 (n = 14)			
Min	18.4	15.8	7.7	0.0	0.0	0.0	0.0	0.0
Max	54.1	62.4	34.5	35.6	100.0	100.0	50.0	75.0
Mean	34.0	30.6	19.8	15.3	19.5	61.0	8.7	10.8
RSE%	1.6	1.7	2.4	4.8	9.3	8.0	8.7	7.9
CV%	7.8	8.5	11.5	12.4	12.7	15.9	16.9	16.1
	2005 (n = 26)				2005 (n = 23)			
Min	20.0	9.7	1.3	0.5	37.5	10.3	0.0	0.0
Max	85.7	51.2	16.1	35.7	89.7	53.3	18.8	9.4
Mean	53.8	31.7	5.9	8.6	54.5	38.5	4.9	2.1
RSE%	1.7	2.2	3.8	5.1	1.1	2.0	7.0	9.9
CV%	8.5	11.3	17.2	19.8	5.4	9.5	17.8	17.4
	2006 (n = 24)				2006 (n = 7)			
Min	26.8	4.0	0.0	0.0	41.7	0.0	0.0	0.0
Max	96.0	69.6	10.0	5.3	100.0	50.0	28.6	0.0
Mean	61.1	36.8	1.3	0.8	65.9	28.5	5.6	0.0
RSE%	1.5	2.8	9.6	5.4	2.5	5.7	8.1	–
CV%	7.3	13.6	17.8	16.8	6.6	15.0	16.8	–
	2007 (n = 46)				2007 (n = 19)			
Min	0.0	6.3	0.0	0.0	6.1	0.0	0.0	0.0
Max	93.9	84.6	28.3	46.3	100.0	89.8	11.5	9.1
Mean	40.1	41.2	8.7	10.0	62.6	33.5	2.4	1.5
RSE%	3.7	2.3	3.0	3.1	3.6	6.6	7.3	5.9
CV%	15.6	15.5	18.4	15.6	15.5	18.5	15.4	17.4

Note. Explanations under Table 3.

During our research, it was frequently observed that in WOSR crops, before harvesting, most of the phoma stem canker-affected plants had typical symptoms on the stem base, which are most often caused by *L. maculans*. Assessments made in 119 WOSR crops in various districts of Lithuania in 2004, 2005 and 2007 indicated that on average 65.2–90.8% of WOSR stems assessed had phoma dry rot infections on the stem base (it is likely that it was caused by *L. maculans*). Disease severity index on the stem base in WOSR differed considerably between the cropping seasons. Milder winters in the future may favour disease severity by lack of leaf shedding, enabling the fungus to grow from lesions systemically into the stem and to cause stem canker in the following spring (Siebold, von Tiedemann, 2012). It was reported that the severity of phoma stem canker epidemics in summer depended on the timing of phoma leaf spot epidemics in the previous autumn, and hence on the timing of *L. maculans* ascospore release (Steed et al., 2007) and that the risk of severe stem base canker epidemics is the greatest when there is a high incidence of phoma leaf spotting early in the autumn (West et al., 2002).

During our research it was observed that WOSR and SOSR plants had also numerous upper phoma stem

lesions (it is likely that it was caused by *L. biglobosa*). In WOSR, phoma lesions were mostly concentrated on the stem base or both on the stem base and on the upper stem, while in SOSR disease lesions were concentrated only on the upper stem. It is likely that *L. maculans* was more damaging in WOSR compared with SOSR. Mahuku et al. (1996) observed that expression of lesion size and infection type may be dependent on the growing conditions in different climatic regions. Our findings of phoma cankers on the stem base and upper stem lesions indicated the likely presence of both species *Leptosphaeria maculans* and *L. biglobosa* in the pathogen population in Lithuania. This assumption has been confirmed after the analysis of *Leptosphaeria* spp. population structure using species-specific PCR analysis (Brazauskienė et al., 2011).

Conclusions

1. During the study period, phoma stem canker incidence and severity in winter (WOSR) and spring oilseed rape (SOSR) crops were found to vary depending on oilseed rape seasonal type (winter or spring), cropping season and the field.

2. In WOSR, phoma lesions most often were concentrated on the stem base or both on the stem base and on the upper stem, while in SOSR disease lesions developed mainly on the upper stem. The mean disease severity index in WOSR differed considerably between the cropping seasons (from 6.1 in 2006 to 37.0 in 2005). For SOSR, the mean disease severity index values (0.67–1.34) were markedly lower than those for WOSR.

3. During the experimental period among the phoma affected stems the most numerous were those with one upper stem lesion (on average 38.0–63.5% in WOSR and 57.9–88.9% in SOSR). The highest number of phoma lesions had developed at the 5–20 cm stem height (34.9–74.9% of upper stem lesions in WOSR and 34.9–82.9% in SOSR) and the most numerous were those with a total upper stem lesions length up to 10 cm (55.2–79.6% of diseased stems in WOSR and 80.1–94.2% in SOSR).

4. According to the morphological symptoms of phoma stem base cankers and upper stem lesions, it was preliminary determined that both species of *Leptosphaeria* fungus – *Leptosphaeria maculans* and *Leptosphaeria biglobosa* co-exist on SOSR and WOSR in our country.

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Fomozės (*Leptosphaeria maculans* / *L. biglobosa* kompleksas) pažeidimų ypatumai žieminiame ir vasariniame rapsuose (*Brassica napus* L.)

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Santrauka

Fomozė yra reikšminga ir žalinga rapsų liga, išplitusi visame pasaulyje. Ją sukelia grybų *Leptosphaeria maculans* ir *L. biglobosa* rūšių kompleksas, kuriame, priklausomai nuo daugelio veiksnių, viena arba kita rūšis yra vyraujanti. Šių dviejų *Leptosphaeria* rūšių pažeisti rapsų augalai būna su skirtingais fomozinio sausojo puvinio požymiais, tačiau *L. maculans* yra žalingesnis grybas, sukeliantis sunkius pažeidimus stiebo apatinėje dalyje. Straipsnyje pateikti Lietuvos žemdirbystės institute 2004–2007 m. atliktų žieminių ir vasarinių rapsų fomozės sausojo puvinio pažeidimų tyrimų duomenys. Ekspediciniai tyrimai daryti 119-oje žieminių ir 63-juose vasarinių rapsų pasėliuose įvairiuose šalies regionuose. Fomozės išplitimui ir intensyvumui turėjo įtakos augalo forma (žieminė ar vasarinė), pasėlis ir auginimo metai. Fomozės pažeidimams buvo jautresni žieminiai rapsai nei vasariniai. Žieminių rapsų ligoti stiebai dažniausiai buvo su dvejopais ligos pažeidimais – šaknies kaklelio srityje ir aukščiau ant stiebo, o ant vasarinių rapsų vyravo fomozės pažeidimai aukščiau ant stiebo. Išanalizavus morfologinius stiebų pažeidimo požymius darytina prielaida, kad *Leptosphaeria maculans* ir *L. biglobosa* rūšys Lietuvoje egzistuoja kartu.

Reikšminiai žodžiai: išplitimas, intensyvumas, ligos intensyvumo indeksas, dėmės stiebo apačioje, dėmės aukščiau ant stiebo.