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Effects of fungicide application timing on the incidence and severity of *Alternaria* blight (*Alternaria brassicae*) and on the productivity of spring oilseed rape (*Brassica napus* L. ssp. *oleifera annua Metzg*.)

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Abstract. Three field experiments were carried out with the spring oilseed rape *(Brassica napus* L. ssp. *oleifera annua Metzg*.) cv. 'Star' to investigate the incidence, severity and harmfulness of *Alternaria* blight (*Alternaria brassicae*) and to test the possibility of reducing the disease pressure by fungicidal spray applications of 45% Sportak (a.i. prochloraz) 0.675 kg a.i. ha^{-1} and 25% Folicur (a.i. tebuconazole) 0.25 kg a.i. h^{-1}. The fungicides were applied at different times, i.e. after the first spots of *Alternaria* blight had appeared on the lower, middle and upper leaves or on siliques and at the end of spring oilseed rape flowering. *Alternaria* blight was present in crops of the spring oilseed rape cv. 'Star' in all the experimental years. The disease severity varied in individual years and was heavily dependent on the weather conditions (amount of precipitation and temperature). Of all the experimental years, the most conductive conditions to the spread and development of *Alternaria* blight on spring rape siliques occurred in 1998, when disease spots covered 18.65% of the surface area of siliques in the untreated plots. The tested fungicides had little effect on the disease incidence, however, prochloraz and tebuconazole applied on all dates declined the disease severity. The highest efficacy was recorded when the fungicides were applied after the first symptoms of *Alternaria* blight had been spotted on siliques. Tebuconazole suppressed the disease severity more effectively than prochloraz.

In the year most favourable for *Alternaria* blight occurrence (1998), the seed yield in the untreated plots was by up to 0.07 t ha^{-1} lower, and the disease severity on siliques was as much as 3.2 times higher than in the fungicide-sprayed treatment. The highest average spring rape seed yield increase resulting from fungicidal spray applications during the period 1997–1999 amounted to 0.040 t ha^{-1}. Fungicides declined the content of *Alternaria* blight diseased seeds per silique, increased 1,000-seed weight, however, no significant effect of fungicides was identified on the number of siliques per plant and the number of seeds per siliqua.

Key words: *Alternaria brassicae*, oilseed rape, disease incidence, disease severity, prochloraz, tebuconazole, seed yield

INTRODUCTION

Alternaria blight (*Alternaria brassicae* (Berk.) Sacc.) is a world-widely distributed and economically important disease on oilseed rape (*Brassica napus*), mustard (*B.campestris*) and other brassicas (Bolton & Adam, 1992; Tewari & Conn, 1993; Barman & Bhagwati, 1995; Kumar, 1997; Meah et al., 2002). All varieties of

Brassica napus, *B. campestris* and *B. juncea* are susceptible to *Alternaria* blight, or differences among varieties are minimum (Evans et al., 1988; Krüger, 1991). Qualitative changes in oilseed rape varieties (varieties with a low erucic acid content have been superseded by varieties with a low erucic acid and glucosinolate content) had an appreciable effect on the disease occurrence and harmfulness (Frencel et al., 1991; Paul & Beinecke, 1991; Church & Fitt, 1993). It was found that the level of *Alternaria* infection of both leaves and pods was positively correlated with the glucosinolate content (Giamoustaris & Mithen, 1997). Glucosinolates and products of glucosinolate hydrolysis have been shown to be toxic or inhibitory to several *Brassica* pathogens, including *Alternaria* spp. (Milford et al., 1989; Doughty et al., 1991).

Alternaria blight is a late oilseed rape disease, which is most harmful when it spreads on siliques. Siliques affected by *Alternaria* blight mature earlier, the seeds are small and rugose (Maude & Humpherson-Jones, 1980; Verma & Saharan, 1994; Meah et al., 1999). Medium *Alternaria* blight severity on siliques corresponds to a 20%, and high severity – to a 50% seed yield loss (Daebeler et al., 1988). Many authors have studied the feasibility to control various diseases in oilseed rape crops, using fungicides (Sutherland et al., 1990; Howlider et al., 1991; Sadowski & Klepin, 1991; Bolton & Adam, 1992; Thurwachter et al., 1995). A lot of research has been done in England to ascertain the efficacy of fungicide use against *Botrytis* stem rot, *Sclerotinia* stem rot, and *Alternaria* blight. Experimental evidence has shown that economic effect was achieved only in 11 trials out of the total 33 trials (Sutherland et al., 1990). By application of Rovral (a.i. iprodion) it was succeeded to decline the incidence of *Alternaria* blight on winter rape siliques from 20% to 5% and to obtain a seed yield increase of 0.13 t ha^{-1} (Evans et al., 1988). In Poland the use of fungicides resulted in winter rapeseed yield increase of 0.40 t ha^{-1} (Sadowski & Klepin, 1991). Oilseed rape varieties intended for food (double-low type) produced a higher seed yield increase resulting from fungicide application compared with technical varieties (0 type) (Rawlinson et al., 1989). In Germany the seed yield losses of winter rape caused by *Alternaria* blight amounted to 30% (Daebeler & Seidel, 1989). The efficacy of fungicides against *Alternaria* blight has been investigated by a number of authors, and promising results have been achieved. However, the fungicide application timing is still a subject of controversy (Ansari et al., 1990; Sadowski & Klepin, 1991; Church & Fitt 1993; Thurwachter et al., 1995).

There is a lot of experimental evidence on the incidence, severity and harmfulness of *Alternaria* blight on winter oilseed rape (*B. napus* L. *biennis*) and mustard (*B. campestris*), however, there is little evidence on harmfulness on spring rape and possibilities of controlling this disease by fungicides. However, there is no unanimous opinion among the various researchers, concerning fungicide application timing against *Alternaria* blight. This paper presents the data from the field experiments on the effects of fungicide application timing on the incidence and severity of *Alternaria* blight in spring rape and on the seed yield and other productivity parameters.

MATERIALS AND METHODS

Field experiments

Field experiments were performed in 1997, 1998 and 1999 at the Plant Pathology and Protection Department of the Lithuanian Institute of Agriculture with the spring oilseed rape (SOSR) cv. 'Star'. SOSR was cultivated according to the conventional technology. The region's mean annual rainfall is about 700 mm, about 40% of which is received between May and August, during the growing season of SOSR. The mean daily temperature in May is 12.5°C, in June – 15.9°C, in July – 17.6°C and in August – 16.7°C. The weather conditions for growing of SOSR are less or more favourable every year. Two fungicides and five application dates were tested in three field experiments. Details of the fungicide treatments are presented in Table 1.

Table 1. Fungicide treatments in the spring oilseed rape 'Star' in 1997–1999.

Treatment	Fungicide active ingredient	Application time – first spots of *Alternaria* blight appeared	a.i. g per ha
PLL	Prochloraz (P)	on lower leaves (LL)	675
TLL	Tebuconazole (T)	on lower leaves (LL)	250
PML	Prochloraz (P)	on middle leaves (ML)	675
TML	Tebuconazole (T)	on middle leaves (ML)	250
PUL	Prochloraz (P)	on upper leaves (UL)	675
TUL	Tebuconazole (T)	on upper leaves (UL)	250
PS	Prochloraz (P)	on siliques (S)	675
TS	Tebuconazole (T)	on siliques (S)	250
PEF	Prochloraz (P)	end of flowering (EF)	675
TEF	Tebuconazole (T)	end of flowering (EF)	250

Table 2. Dates of fungicide application in 1997–1999, growth stages (BBCH Lancashire et al., 1991) at application and the dates of SOSR harvesting.

First spots of *Alternaria* blight appeared on:	1997		1998		1999	
	BBCH	Date	BBCH	Date	BBCH	Date
lower leaves (LL)	63	July 3	63	June 22	63	June 23
middle leaves (ML)	64	July 7	65	July 9	69	July 3
upper leaves (UL)	70	July 21	70	July 23	71	July 8
siliques (S)	79	July 26	79	July30	79	July 12
end of flowering (EF)	69	July 16	69	July 17	69	July 3
harvesting date	87	Sept. 1	87	Sept. 7	87	August 18

The time of fungicide application was chosen according to the appearance of the first visible symptoms of *Alternaria* blight on lower, middle, and upper leaves or siliques of SOSR plants, and one treatment was determined according to the growth stage of SOSR – at the end of flowering (less than 10% of buds left not flowering). Plant growth stage was recorded using the BBCH identification key (Lancashire et al., 1991). The dates of fungicide treatments, growth stages (BBCH) of SOSR and dates of seed harvesting are provided in Table 2. The plot size was 10 m x 3 m, record plot 10 m x 2.2 m, row spacing 12 cm. Each year plots were randomly arranged, with four replications.

Each plot was separately combine harvested, in 1997 – at 125, in 1998 – at 140 and in 1999 – at 114 days of age. The seed yield was adjusted to 9% moisture content, and 1,000-seed (THS) weight was calculated. Before harvesting the samples from each plot, containing 10 randomly uprooted plants, were collected. The number of productive siliques and the number of productive racemes on each plant were identified (productive siliques – siliques with one or more seeds, productive racemes – racemes with one or more productive siliques).

Disease assessments

Disease incidence (DI) and severity (DS) of *Alternaria* blight on leaves were assessed weekly on 10 marked plants per plot on lower, middle and upper leaves. The assessments were started at the end of the budding stage (BBCH 59) and completed, when all the leaves had fallen (BBCH 75–81). DI and DS on siliques were estimated by assessing 5 siliques on the primary stem of each marked plant (totaly 50 siliques per plot). DS of leaves and siliques was determined according to the scale described by Conn et al., 1990 (percent of the surface of leaf or silique, affected by *Alternaria* blight). The number of seeds per silique and the number of visually *Alternaria*-diseased (shrivelled, small) seeds per silique were determined by analysing 30 siliques per plot (120 siliques per treatment), sampled before harvesting.

The samples of 30 randomly selected stems per each plot were uprooted (branches with siliques were left on the plot) at BBCH 85 for identification and assessment of DI and DS on the stems. DS was determined in the % of disease-affected area of each stem.

The economic efficacy of the fungicides was calculated by deducting fungicide costs per ha from the income obtained through SOSR seed yield increase. Rapeseed purchasing price in Lithuania in 2003 was 220 Euros t^{-1}. The cost of fungicide with a.i. prochloraz (1.5 l ha^{-1}) was 25.6 Euros ha^{-1}, fungicide with a.i. tebuconazole (1.0 l ha^{-1}) – 30 Euros ha^{-1}.

Statistical analysis

The experimental data were compared by using an analysis of variance (ANOVA) and, where the *F*-ratio was significant, the least significant difference (LSD) was calculated for $P < 0.05$. The experimental findings were processed by the correlation regression analysis method.

RESULTS AND DISCUSSION

In all the experimental years, *Alternaria* blight occurred on the spring rape cv. 'Star' on leaves, stems, siliques, and seeds. DI and DS varied appreciably in individual years, changed during the season and were very dependent on the weather conditions of the period, especially precipitation. Of the three experimental years during the SOSR flowering stage, DI and DS on lower leaves were high (93.9 and 5.42%, respectively) only in 1997 (Table 3). In that year the largest amount of precipitation (94.2 mm) was identified in June, which had a very favourable effect on the disease development on lower leaves. However, in July of the same year, the amount of precipitation was low – 22.3 mm (30% of the mean perennial rate of July), and *Alternaria* blight occurrence and development slowed down. Although almost all siliques were with spots at the end of the ripening stage, DS on siliques was low – 1.46% (the lowest of all the experimental years). In 1998 due to the dry weather in June (29.5 mm precipitation), DI and DS on lower leaves were low (30.9 and 0.39%), however, abundant rainfall in July (2.8 times higher than the perennial mean) created favourable conditions for the spread and development of the disease at later growth stages of rape plants. At the end of the silique development stage, DS on siliques was almost twice as high as in 1997. During the ripening stage, 99% of siliques were diseased, *Alternaria* blight spots had covered almost one fifth of all siliques' surface area (DS on siliques was 18.65%). In 1999 conditions for *Alternaria* blight spread on leaves were the most unfavourable of all the experimental years, however, at the end of ripening stage, the disease had spread on all siliques, and DS amounted to 13.9%.

Table 3. Disease incidence (DI)% and severity (DS)% of *Alternaria* blight on leaves andsiliques of SOSR in untreated plots and precipitation during the period of the disease spread.

Year	Precipitation mm			On lower leaves[1]		On middle leaves[2]		On siliques[3]	
	June	July	August	DI	DS	DI	DS	DI	DS
1997	94.2	22.3	41.3	93.9	5.42	90.0	5.41	94.5	1.46
1998	29.5	202.8	69.0	30.9	0.39	100.0	10.28	99.0	18.65
1999	59.4	26.1	91.5	95.0	2.15	90.0	1.32	100.0	13.90

[1] assessments BBCH 63-64 – 09/07/1997, 30/06/1998 and 01/07/1999.
[2] assessments BBCH 79-81 – 29/07/1997, 05/08/1998 and 17/07/1999.
[3] assessments BBCH 81-85 – 20/08/1997, 25/08/1998 and 03/08/1999.

Table 4. Disease incidence (DI)% and severity (DS)% of *Alternaria* blight on siliques of SOSR at BBCH 85 according to different fungicide regimes in 1997–1999.

Treatment*	DI			DS		
	1997	1998	1999	1997	1998	1999
PLL	92.5	99.8	100	1.20	16.43	7.24
TLL	85.5	99.8	100	1.06	13.25	5.69
PML	89.5	99.8	100	1.15	12.13	5.64
TML	27.0	99.2	100	0.29	9.85	3.52
PUL	90.0	100	100	1.06	8.25	5.35
TUL	31.5	98.0	99.0	0.40	6.22	2.33
PS	94.5	99.2	100	1.18	10.38	4.89
TS	24.0	98.2	66.5	0.22	2.88	0.67
PEF	92.5	100	100	1.04	12.35	7.01
TEF	28.7	99.8	70.0	0.29	5.83	0.70
Untreated	94.5	99.0	100	1.46	18.65	13.90
LSD_{05}	17.01	1.25	4.02	2.28	3.005	0.954

* – see Table 1

Table 5. Influence of different fungicide regimes on the number of siliques per plant and the number of productive racemes per plant of SOSR in 1997 and 1999.

Treatment*	Siliques/plant		Productive racemes/plant		Siliques/raceme	
	1997	1999	1997	1999	1997	1999
PLL	73.0	37.4	5.0	3.2	14.4	11.7
TLL	65.1	38.9	4.7	3.0	13.8	13.0
PML	75.2	38.5	5.0	3.3	15.0	11.7
TML	79.6	36.8	5.3	3.0	15.0	12.3
PUL	74.6	38.5	4.8	3.0	15.3	12.8
TUL	81.0	37.3	5.3	3.1	15.2	12.0
PS	81.2	38.2	5.1	3.0	15.8	12.7
TS	70.8	39.0	5.0	3.2	13.2	12.2
PEF	69.5	36.7	4.5	3.0	13.1	12.2
TEF	73.0	40.6	4.9	3.1	14.9	13.1
Control	67.7	33.2	4.7	3.0	14.2	11.1
LSD_{05}	20.09	9.62	0.84	0.53	2.70	2.40

* – see Table 1

Table 6. Influence of different fungicide regimes on the number of seeds/silique, THS weight and the percentages of *Alternaria* blight diseased seeds/silique of SOSR in 1997–1999.

Treatment*	Seeds/silique			THS weight g			% diseased seeds/silique		
	1997	1998	1999	1997	1998	1999	1997	1998	1999
PLL	26.1	25.3	22.9	3.69	3.70	3.55	3.9	1.5	3.8
TLL	27.0	26.8	23.8	3.53	3.90	3.44	1.8	5.2	4.0
PML	28.3	25.6	24.9	3.67	3.83	3.56	4.0	1.5	6.1
TML	27.3	26.2	24.6	3.75	3.69	3.63	0.3	4.8	1.2
PUL	26.6	27.4	24.3	3.50	3.89	3.55	3.5	4.0	6.0
TUL	27.4	25.8	23.1	3.56	3.99	3.67	2.3	4.4	6.6
PS	28.0	26.6	24.2	3.55	3.87	3.62	0.7	0.7	1.4
TS	28.6	25.7	25.5	3.62	3.88	3.70	0.3	1.8	1.0
PEF	27.5	25.9	24.6	3.64	3.89	3.64	3.2	2.4	7.6
TEF	27.1	25.3	24.8	3.61	3.98	3.67	1.2	0.7	1.9
Control	26.6	25.6	24.4	3.66	3.80	3.50	5.3	13.9	8.5
LSD_{05}	2.21	2.14	2.37	0.125	0.134	0.044	0.57	0.88	0.90

* – see Table 1

Table 7. Seed yield (t ha^{-1}) of SOSR in 1997–1999 according to different fungicide regimes.

Treatment*	Seed yield					
	1997		1998		1999	
	t ha^{-1}	± to control	t ha^{-1}	± to control	t ha^{-1}	± to control
PLL	2.38	+0.10	2.20	+0.13	2.37	+0.05
TLL	2.63	+0.35	2.63	+0.30	2.46	+0.14
PML	2.33	+0.05	2.76	+0.43	2.47	+0.15
TML	2.60	+0.32	2.72	+0.39	2.58	+0.26
PUL	2.24	+0.04	2.76	+0.43	2.38	+0.06
TUL	2.32	+0.04	3.02	+0.69	2.47	+0.14
PS	2.25	-0.03	2.88	+0.55	2.56	+0.24
TS	2.38	+0.10	2.72	+0.39	2.53	+0.21
PEF	2.51	+0.23	2.86	+0.53	2.48	+0.16
TEF	2.58	+0.30	3.01	+0.68	2.56	+0.24
Control	2.28	-	2.33	-	2.32	
LSD_{05}	0.01		0.26		0.14	

* – see Table 1

Table 8. Increased (+) or decreased (-) income (Euros ha^{-1}) according to different treatment times of prochloraz and tebuconazole against *Alternaria* blight in SOSRin 1997–1999 (compared with the untreated plots).

Treatment time*	Prochloraz			Tebuconazole		
	1997	1998	1999	1997	1998	1999
LL	- 3.6	+3.0	- 14.6	+47.0	+36.0	+0.8
ML	- 14.6	+69.0	+7.4	+40.4	+55.8	+27.2
UL	- 16.8	+69.0	-12.4	- 21.2	+121.8	+0.8
S	- 25.6	+95.4	+27.2	- 8.0	+55.8	+16.2
EF	+25.0	+91.0	+9.6	+36.0	+119.6	+22.8

* – see Table 2

In all the experimental years, the first spots of *Alternaria* blight on spring rape lower leaves appeared at the same growth stage of plants – the period of full flowering, and DI on lower leaves had reached 100 % within 12–15 days. Having sprayed SOSR with fungicides at the time when the first spots appeared on lower leaves (LL), DI on lower leaves did not decline, although DS in 1999 declined by half. Fungicides did not extend the life of spring rape lower leaves – at the end of flowering (1998) or in the middle of the silique development stage (1997 and 1999) all lower leaves of spring rape had fallen. By that time the disease had already spread on spring rape middle leaves.

Fungicide application at the time when the first spots appeared on middle leaves (ML) did not have any effect on DI, however, in some cases, it declined DS on middle leaves. Within several days, at the end of the silique development stage – the beginning of ripening, spring rape plants shattered middle leaves in all experimental treatments irrespective of DS. A week after the first disease spots had appeared on middle leaves, the first spots were noticed also on the upper leaves in all the experimental years - at the beginning of the silique development stage. In all treatments in individual experimental years the upper leaves fell at the same time. The time of leaves preservation on plants differed in separate years and was more dependent on the weather conditions than DS on the leaves.

During the experimental years, DI on siliques in unsprayed plots was 94.5–100%. In all the experimental years, none of the prochloraz treatment dates gave a statistically significant decline in DI on siliques (Table 4). However, tebuconazole in 1997, when the conditions for the spread of *Alternaria* blight were not very favourable, applied both at early and later dates, statistically significantly suppressed DI on siliques, except for the earliest fungicide application date – when the first spots had appeared on lower leaves. This does not always conform to the experimental findings obtained in Poland, which suggest that, in seasons of a low disease pressure, differences between dates of fungicides application were not significant (Maszynska et al., 2001). In our experiments this proposition proved out with prochloraz, however, after spraying with tebuconazole, statistically significant differences in DI were obtained between the dates of spray applications in the year of low disease pressure, whereas no differences were obtained in the years of a high disease pressure, which occurred in 1998. Unlike DI, the differences in DS were revealed only at a higher *Alternaria* blight pressure, which occurred in 1998 and 1999. However, the best results were obtained when fungicides had been used later but not early, which was performed by other authors (Maszynska et al., 2001). In 1999 tebuconazole suppressed DI on siliques only when applied on later dates – at the end of flowering (EF) or when the first spots of the disease had appeared on siliques (S). In 1998 when the conditions were the most favourable for the spread of *Alternaria* blight on siliques, no marked effect of tebuconazole on DI on siliques was identified. However, in all the experimental years, prochloraz and tebuconazole declined DS on siliques both when applied early and later. Prochloraz, depending on the application date, declined DS by 17.6–58.2%. Much more effective was tebuconazole, whose earliest application (after the first symptoms of the disease had appeared on lower leaves), suppressed DS by 40%. The highest efficacy of tebuconazole on DS on siliques was achieved having sprayed SOSR at the end of flowering or even later (after the first spots had appeared on siliques): compared with the unsprayed plots, DS declined by 81.4 and 88.2%, respectively. Our results corroborate the data obtained by other researchers in winter rape, where *Alternaria* infection on siliques was best controlled by post-flowering applications (Bolton & Adam, 1992).

Alternaria blight occurred on stems in all the experimental years. Although DI in 1997 was as low as 0–40%, all stems in all treatment plots were diseased in 1998 and 1999. In 1998 DS on stems in the plots without fungicides was 30 times, and in 1999 – 8.3 times as high as in 1997. Fungicides applied on all dates declined DS on stems, however, the best results were achieved when the fungicides were applied later (Brazauskiene & Petraitiene, 2003).

Some biometrical yield data of SOSR were identified in our experiments: the number of siliques per plant, the length of silique, the number of productive racemes per plant, the number of seeds per pod, 1,000 seed weight (g), the number of visually diseased seeds per silique. Our experimental evidence suggests that fungicides did not have any effect on the length of silique. The average number of siliques per plant differed considerably in 1997 and 1999 (Table 5). In 1997 one plant produced twice as many siliques as in 1999 (in 1999 the number of rape plants per $1m^2$ was 1.5 times higher than in 1997). A trend was established that after spraying with fungicides the number of siliques per plant increased by 2.7–19.9% (1997) and 10.5–22.3% (1999), compared with the fungicide untreated plots. No appreciable effect of individual fungicides and their application dates on the number of siliques per plant was identified. In many cases fungicides had a positive effect on the development of spring rape –on average a slightly higher number of productive racemes was formed per plant in the fungicide-treated plots and a higher number of productive siliques per productive raceme, however, no significant differences between the treatments were identified. In 1997, the percentage of productive siliques formed at the top of the plant was 34.3–43.7%, and their number at the top and on three upper lateral branches was 63.1–76.2%. In 1999 as much as 51.3–66.3% of siliques formed at the top and the rest of the siliques on 2–3 upper lateral branches. No significant differences were identified between treatments according to the location of siliques on a plant.

In 1997 a trend of increasing number of seeds per silique through fungicide application was observed. However, in 1998 and 1999 this trend was not revealed (Table 6). In 1997 fungicides did not have any effect on 1,000 seed weight. In 1998, in many cases when fungicides were sprayed, a trend of increasing 1,000 seed weight was observed. Tebuconazole, applied when the first *Alternaria* blight spots had appeared on upper leaves (UL) and at the end of spring rape flowering (EF) significantly increased 1,000 seed weight, and in 1999 a significant 1,000 seed weight increase was identified in all experimental treatments compared with the untreated. Early infection of siliques leads to seed infection, which can cause discolouration and death of seeds (Howlider et al., 1991). During the experimental years, on average 5.3–13.9% *Alternaria* spp. diseased seed were identified per silique in the plots not applied with fungicides. Prochloraz and tebuconazole declined disease infestation on seeds in all the experimental years, however, the largest reduction in the number of diseased seeds was identified on the plots sprayed with fungicides when the first disease symptoms had been identified on siliques (prochloraz reduced the number of diseased seeds per silique by 83.5–95.0%, and tebuconazole by 87.0–94.3%, compared with the untreated plots).

In all the experimental years in the treatments where fungicides were applied at the end of flowering (EF) or when *Alternaria* blight symptoms had appeared on siliques (S), SOSR matured 4–7 days later than in the plots without fungicides. In 1997 and 1998 seed moisture content was identified shortly after harvesting. The lowest seed moisture content was determined in the seed harvested from the untreated plots, while the highest moisture content was identified in the seed harvested from the treatments where fungicides were applied on the latest date. In 1997, the year unfavourable for the spread of *Alternaria* blight, in many cases only a trend of seed yield increase was identified in the treatments applied with fungicides (Table 7). In 1998 and 1999 fungicides gave a significant seed yield increase in all treatments, except for the treatment where fungicides were applied early (after *Alternaria* blight spots had appeared on LL). In 1998 the greatest seed yield increase due to fungicide application was 0.69 t ha^{-1} (29.6%), in 1999 – 0.26 t ha^{-1} (11.2%).

Fungicide application in SOSR in 1997, especially that of prochloraz, was loss-making. Fungicides gave the highest extra income in 1998 – prochloraz up to 95.4 and tebuconazole up to 121.8 Euros ha^{-1} (Table 8).

A correlation-regression data analysis revealed that markedly increasing DS on stems and siliques had a clear trend of reducing SOSR seed yield, but only in the years conducive to the disease development, which occurred in 1998 and 1999 (Fig.1). These changes were statistically described by a linear regression equation. The relationship between the analysed indicators in 1998 and 1999 was negative, strong and statistically significant at a 99% probability level. However, in 1997 only trends of this relationship were determined, which were not statistically significant. A strong relationship was identified between DS on leaves and the yield of mustard by other authors; DS on leaves was very strongly related to DI of silique, although the correlation between the other parameters of the disease was inconsistent (Meach et al., 2002). The results obtained in our experiments coincide with the results of these researchers and highlight even more the fact that SOSR seed yield is more dependent on DS (not DI) on stems and siliques. Similar research is continued with winter rape and spring turnip rape.

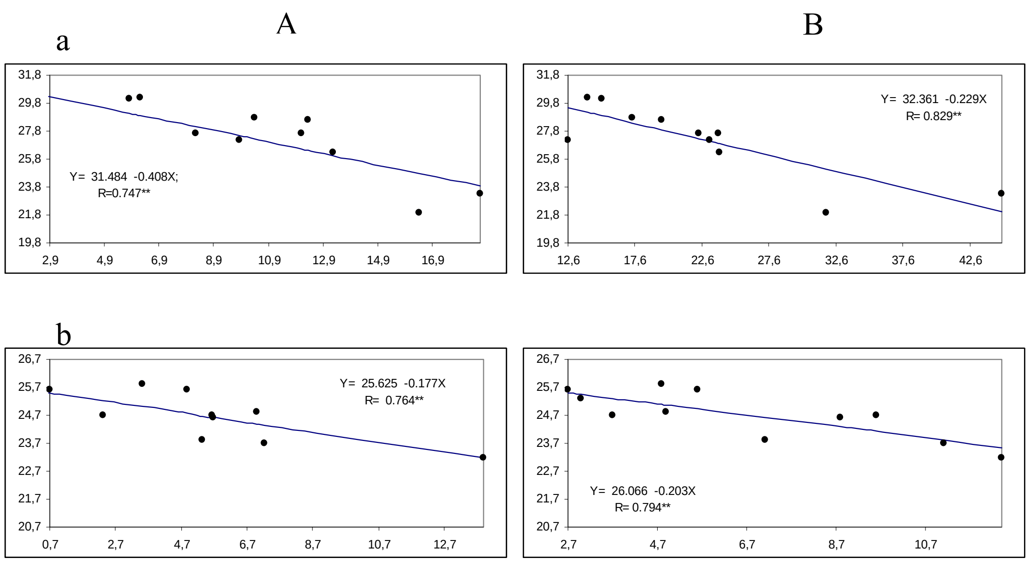

Fig. 1. Relationship between disease severity (%) of *Alternaria* blight on siliques (A) and stems (B) and SOSR seed yield in 1998 (a) and 1999 (b).

CONCLUSIONS

Alternaria blight (*A. brassicae*) occurred on spring rape crops of the cv. 'Star' in all the experimental years. DS on leaves, stems, siliques and seed significantly differed between years, varied within the season and was dependent on the period's weather conditions, especially the amount of precipitation. *Alternaria* blight is a late disease of SOSR; DI and DS on leaves did not have any more marked effect on the morbidity of siliques and seeds. Prochloraz and tebuconazole, used early when the first disease symptoms had appeared on lower and middle leaves, declined DS on leaves but did not help preserve the leaves longer than in the untreated plots.

In the years favourable for the disease spread on siliques, fungicide application, regardless of the application dates, had little effect on DI, however, fungicides effectively declined DS on siliques. The best results were obtained having used fungicides later, after flowering, when the first Alternaria blight spots had appeared on young siliques. The greatest reduction in the number of Alternaria diseased seed per silique was also identified in the plots where fungicides had been applied on the latest dates.

Fungicides gave a significant increase in SOSR seed yield, compared with the untreated plots, only in years favourable for Alternaria blight – 1998 and 1999, when applied on all dates, except for the earliest date (when the first disease spots had appeared on LL). During the experimental years, the highest SOSR seed yield increase resulting from fungicide application amounted to 0.69 t ha^{-1} (29.6%). The highest extra income using fungicides was obtained in 1998 when DS on siliques and stems in untreated plots was the highest (prochloraz – up to 95.4, tebuconazole – up to 121.8 Euros ha^{-1}).

A correlation regression data analysis revealed that markedly increasing DS incidence on stems and siliques had a clear trend of reducing SOSR seed yield.

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