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THE CONTROL OF FLAX ANTHRACNOSE [*COLLETOTRICHUM LINI* (WEST.) TOCH.] BY FUNGICIDAL SEED TREATMENT

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Abstract: One of the most serious seed-borne diseases of flax is anthracnose or seedling blight caused by *Colletotrichum lini* (West.) Toch. This disease affects flax seedlings, leaves, stems, and fruit bags. It causes reductions in linseed germination power, stand density, stem and linseed yield, fibre output and quality.
During 1999–2001 experiments were carried out at the Lithuanian Institute of Agriculture Upyte Experimental Station to test the efficacy of seven fungicides used for seed dressing against flax anthracnose and other seedborne diseases.
Experimental findings indicated that 19.0% to 34.0% of flax seeds were annually infected with *C. lini* (West.) Toch. causing flax anthracnose. As the disease can spread through the soil, on control plots sown with untreated with fungicides seeds 33.0% to 79.5% of seedlings showed symptoms of anthracnose. Seed treatment with Sportak 45 EC used at the dose 0.8 l t^{-1} and Maxim Star 025 FS used at the dose 1.5 l t^{-1} gave the best control of seedling blight causal agents. Their biological efficacy was as follows: against seed anthracnose 97.3% and 96.3%, at seedling stage, 76.5% and 76.3%, at 'fir-tree' stage – 67.8% and 60.4%. Biological efficacy of the other seed treaters was lower. The highest straw yield increases resulted from seed treatment with the Maxim Star 025 FS and Sportak 45 EC – 0.5 and 0.3 t ha^{-1} or 11.0% and 6.2%, respectively. The effect of fungicides used for seed treatment on linseed yield was similar. Maxim Star 025 FS increased the yield on average by 22.1%, and Sportak 45 EC and Premis 25 FS by 13.7% and 13.3%. The other fungicides, except for Raxil 2 WS and Rovral FLO, also had a positive effect on flax straw and linseed yield, however, in all experimental years the increases were not higher than the least significant difference.

Key words: flax, anthracnose, seed treatment, straw and linseed yield

INTRODUCTION

Flax cultivation has a long history in Lithuania. However, the area sown with flax recently declined. During the period 1950–1990 the flax area declined from 76.2 to 22.3 thousand hectares, and during the last decade it has been around 9 thousand hectares. Flax productivity is low due to various reasons. Average flax straw yield in Lithuania is 3.4 t ha^{-1}, and that of long fibre 0.8 t ha^{-1}, of linseed 0.5 t ha^{-1} (Magyla et al. 2001). One of the reasons responsible for the reductions in flax yield are fungal diseases: pasmo [*Septoria linicola* (Speg.) Garr.], stem break and browning [*Kabatiella lini* (Laff.) Karak], rust [*Melampsora lini* (Shum.) Desm]. One of the most harmful flax diseases – seedling blight or anthracnose (causal agent *Colletotrichum lini* (West.) Toch./syn.: *Gloeosporium lini* West.) generally spreads through the infected seed or soil. This disease affects flax seedlings, roots, stems, and declines fibre and linseed yield and its quality (Mercer et al. 1994; Pavlov et al. 2000).

Pathogenic micromycetes present on linseed can significantly reduce seed germination power if the conditions are favourable for their development (Luchina 1981; Pavlov et al. 2000). Evenly emerged and matured, homogeneous flax stands can secure a higher yield and quality of fibre and linseed (Pavlov et al. 2000).

Phytosanitary analysis of flax seed conducted in Lithuania revealed that 15%–39% of sown flax seeds is infected with anthracnose (Balčiuniene and Gruzdeviene 2001). In flax stands sown with treated seeds, anthracnose affected on average 2% to 30% of plants, depending on the environmental conditions in different years (Gruzdeviene 2001; Mineikienė and Ežerinskienė 2003).

In order to reduce anthracnose damage it is recommended to grow resistant varieties (Loschakova and Kudriavtseva 1998). However, variety testing results of the currently Lithuania-registered and grown varieties show that there are no *C. lini*- resistant flax varieties (Bačelis and Gruzdeviene 2000). Other researchers recommend flax seed treatment with prochloraze, benzimidazole, thiram and other fungicides as a control means of anthracnose and other diseases (Paul et al. 1991; Kubarev 2000).

Flax seed treatment tests were conducted in Lithuania in 1981 and 1984, however, the investigated seed treatment products were found ineffective and were excluded from the Lithuanian list of registered pesticides.

The objective of the experiment involving flax seed treatment with various fungicides was to test their efficacy against seed-borne causal agent of anthracnose and the effect on the disease incidence on flax seedlings and plants, and on straw and linseed yield.

MATERIAL AND METHODS

Experiments were carried out at the Lithuanian Institute of Agriculture, Upyte Experimental Station (Panevežys district) during the period 1999–2001. Various fungicides used for the protection of other crops were used for linseed treatment: Vitavax 200 FF (carboxin 200 g l^{-1}, thiram 200 g l^{-1}) – 2.0 l t^{-1}; Raxil 2 WS (tebuconazole 20 g kg^{-1}) – 1.5 kg t^{-1}; Maxim Star 025 FS (fludioxonil 18.75 g l^{-1}, cyproconazole 6.25 g l^{-1}) – 1.5 l t^{-1}; Fundazol 50WP (benomyl 500 g kg^{-1}) – 2 kg t^{-1};

Sportak 45 EC (prochloraz 450 g l^{-1}) – 0.8 l t^{-1}; Rovral FLO (iprodion 250 g l^{-1}) – 2 l t^{-1}; Premis 25 FS (triticonazole 25 g l^{-1}) – 2 l t^{-1}. Flax seed was treated 3–5 days prior to sowing in the field. The locally bred flax cv. 'Baltuèiai' was used in the experiment.

The experiment was established in randomised block design, in four replications. Flax was sown at a seed rate of 22 million germinable seed per hectare (120–140 kg ha^{-1}) using a narrow-row drill SL–16, at row spacing 10 cm. The plot size was 24.0 m^2, record plot area – 10.0 m^2. The preceding crop were winter cereals sown after perennial grasses of the second year of use. The soil pH was 7.4–7.6. Conventional soil tillage was applied. Flea beetles were controlled at the seedling stage of flax with Fastac (alfa-cipermetrin 100 g l^{-1}) 0.1 l ha^{-1}. During flax growing period weeds were controlled with Glin (chlorsulfuron 75 g kg^{-1}) 7 g ha^{-1} with 0.1% Citowett (surfactant).

Per cent of healthy seed and the seed infected with pathogenic fungi: *C. lini*, *Fusarium spp., mycelia sterilia* and others was identified in Petri dishes in moist chamber. Damage by *C. lini* on flax plants was assessed at seedling, 'fir tree' (when the plants were 6–8 cm high) and maturity stages. Randomly selected 200 plants per plot were taken for phytopathological analysis, leaves, stems and roots were inspected, per cent of disease-affected plants and disease severity were identified.

Weight of flax straw yield adjusted to 19% moisture was determined. Linseed yield was measured by weighing the thrashed linseed adjusted to 12% moisture.

Statistical analysis data was performed using the programme ANOVA.

RESULTS AND DISCUSSION

During the experimental years it was revealed that before treatment 39%–79% of flax seeds were affected by various fungal and bacterial pathogens: of which 19%–34% were infected with the *C. lini*, 1–16% with *mycelia sterilia*, and in 2001 6% with *Fusarium* spp. Symptoms of the disease caused by bacteria were identified on 13%–28% of linseed. The highest per cent (34%) of linseed affected by *C. lini* was identified in 1999 (Tab. 1). Maxim Star 025 FS and Sportak 45 EC were the most ef-

Table 1. The influence of fungicides used for seed treatment on the infection of flax seeds with *Colletotrichum lini* (West.) Toch.

Fungicide	Active ingredients	Dosage t^{-1}	% of affected seeds			
			1999	2000	2001	Average
1. Untreated	–	–	34.0	24.0	19.0	25.6
2. Vitavax 200 FF	carboxin 200 g l^{-1}, thiram 200 g l^{-1}	2.0 l	29.0	9.0	14.0	17.3
3. Raxil 2 WS	tebuconazole 20 g kg^{-1}	1.5 kg	2.0	14.0	19.0	11.7
4. Maxim Star 025 FS	fludioxonil 18,75 g l^{-1}, cyproconazole 6,25 g l^{-1}	1.5 l	0.0	1.0	2.0	1.0
5. Fundazol 50 WP	benomyl 500 g kg^{-1}	2.0 kg	9.0	9.0	18.0	12.0
6. Sportak 45 EC	prochloraz 450 g l^{-1}	0.8 l	0.0	0.0	2.0	0.7
7. Rovral FLO	iprodion 250 g l^{-1}	2.0 l	6.0	15.0	18.0	13.0
8. Premis 25 FS	triticonazole 25g l^{-1}	2.0 l	8.0	17.0	18.0	14.3
LSD (0.5)			1.53	3.27	2.11	2.41

fective against this pathogen in all experimental years. The linseed treated with these products contained as little as 0%–2% of affected seeds. The efficacy of the other plant protection products was significantly lower. Averaged three years' data suggest that the biological efficacy of the only seed treater Vitavax 200 FF registered for flax seed treatment against anthracnose in Lithuania before the present trials was as low as 32.4%, while that of Sportak 45 EC and Maxim Star 025 FS – 97.3% and 96.1%, respectively. The other products declined the amount of anthracnose – affected seeds by 44.1%–54.3%.

Raxil 2 WS used at the dose 1.5 kg t^{-1} also gave a good control of disease causal agents on linseed. However, it was noticed that this product had a retardant effect on flax growth: the rootlets of the seedlings emerged from the seeds treated with Raxil 2 WS were shorter and the seed germination power was lower.

In 1999 flax was sown early, at the end of April. The weather during the first and second ten-day period of May was rather cool and dry. This resulted in long and uneven emergence, the seedlings were weak and heavily affected with *C. lini* (Tab. 2). In the control plots sown with untreated seeds the percentage of seedlings affected with various pathogens accounted for 79.5%, although the linseed infection was only 34%. The remaining seedlings could be infected with *C. lini* as a result of secondary infection from the already diseased plants, or from the infectious agent present in the soil. The causal agent of anthracnose can survive in the winter in the soil on flax plant residues (Luchina 1981).

In 2000 the conditions for flax emergence were favourable – the weather was warm and moderately wet, the linseed was healthier than in the other years, therefore the seedlings were less affected by *C. lini*. In 2001 flax was sown early in May. The month was dry as the amount of precipitation was less than half of long term monthly average. This had an effect on flax emergence and establishment, as well as on the spread of anthracnose, since weaker plants were more susceptible to the disease. The disease incidence strongly correlated with the disease severity.

Seed treatment with fungicides declined both the disease incidence and severity of flax seedlings. In all experimental years the lowest number of anthracnose-affected seedlings were found in the plots sown with the seeds treated with Maxim

Table 2. The influence of fungicides used for seed treatment on the occurrence of anthracnose on seedlings

Fungicide	Dosage t^{-1}	% of affected seedlings				Disease severity %			
		1999	2000	2001	Average	1999	2000	2001	Average
1. Untreated		79.5	33.0	68.5	60.3	8.92	2.94	6.11	5.99
2. Vitavax 200 FF	2.0 l	39.0	6.6	52.0	32.5	3.42	0.59	4.64	2.88
3. Raxil 2 WS	1.5 kg	69.7	20.7	55.5	48.6	6.91	1.85	4.95	4.57
4. Maxim Star 025 FS	1.5 l	16.5	3.1	34.0	17.9	0.97	0.28	3.03	1.42
5. Fundazol 50 WP	2.0 kg	57.0	10.2	60.3	42.5	5.00	0.91	5.38	3.76
6. Sportak 45 EC	0.8 l	10.7	0.5	37.7	16.3	0.80	0.04	3.38	1.41
7. Rovral FLO	2.0 l	73.3	11.1	55.5	46.6	7.78	0.99	4.95	4.57
8. Premis 25 FS	2.0 l	64.0	28.3	56.5	49.6	6.66	2.52	5.04	4.74
LSD (0.5)		11.45	3.69	6.83	7.99	1.419	0.405	1.771	1.33

Star 025 FS and Sportak 45 EC 3.1 – 34.0% and 0.5 – 37.7%, respectively. The disease severity was 0.97 – 3.03% and 0.80 – 3.36%, respectively. Of the other products used for flax seed treatment Vitavax 200 FF gave a relatively good protection of seedlings against anthracnose, its biological efficacy was 51.9%.

At flax 'fir-tree' stage as well as at seedling stage the highest number of anthracnose – affected plants was identified in 1999 and 2001, while the lowest number was recorded in 2000. The same trend persisted during the whole experimental period. A significantly lower number of anthracnose-affected plants were found in the plots sown with the seeds treated with Maxim Star 025 FS and Sportak 45 EC, the differences between the treatments were the highest in 1999 and 2000 (Tab. 3). In 2001 the differences between the treatments were smaller than in the other experimental years, however, the same trend remained.

Table 3. The influence of fungicides used for seed treatment on the occurrence of anthracnose on flax plants at 'fir tree' stage

Fungicide	Dosage t^{-1}	% of affected plants				Disease severity %			
		1999	2000	2001	Average	1999	2000	2001	Average
1. Utreated		79.7	17.8	51.0	49.5	7.11	1.59	4.55	4.42
2. Vitavax 200 FF	2.0 l	47.3	7.0	44.7	33.0	4.22	0.62	3.99	2.94
3. Raxil 2 WS	1.5 kg	73.5	10.7	44.0	42.7	6.56	0.95	3.92	3.81
4. Maxim Star 025 FS	1.5 l	28.7	1.5	28.7	19.6	2.56	0.13	2.56	1.75
5. Fundazol 50 WP	2.0 kg	78.7	7.7	46.7	44.4	6.57	0.69	4.17	3.81
6. Sportak 45 EC	0.8 l	16.0	2.1	29.7	15.9	1.43	0.17	2.65	1.42
7. Rovral FLO	2.0 l	69.5	6.3	44.7	40.2	6.20	0.56	3.99	3.58
8. Premis 25 FS	2.0 l	78.3	8.3	47.5	44.7	6.98	0.74	4.24	3.96
LSD (0.5)		10.17	3.73	3.70	6.609	1.271	0.392	1.337	1.089

The last disease assessment was conducted at the stage of early yellow ripeness of flax. In 1999 the stems were most heavily affected by anthracnose, on control plots 20.0% of affected stems were recorded and the disease severity was 2.0%. Even at that time a positive protective effect of fungicides used for seed treatment was identified, as only 10.7%–18.7% of the flax stems grown from the treated seeds, were affected by anthracnose and the disease severity was 0.75%–1.81%. Like in earlier flax growth stages, the most effective were Maxim Star 025 FS, and especially Sportak 45 EC (Fig. 1).

In 2000 and 2001 wet weather prevailed, which resulted in a heavy infestation of stems with pasmo (*S. linicola*). In the control plots, pasmo affected 60.8%–82.0% of the stems, while the occurrence of anthracnose was very low, and it was difficult to identify the disease. The causal agent of pasmo is very aggressive and in the years favourable for its development it outnumbered anthracnose. The effect of fungicides used for seed treatment against pasmo was also appreciable. Although the incidence of this disease hardly declined, its severity was by 26.0%–45.8% lower as compared with the plots sown with untreated seeds.

Within the experimental period the weather conditions during the flax growing season varied considerably. This resulted in more noticeable soil unevenness on ex-

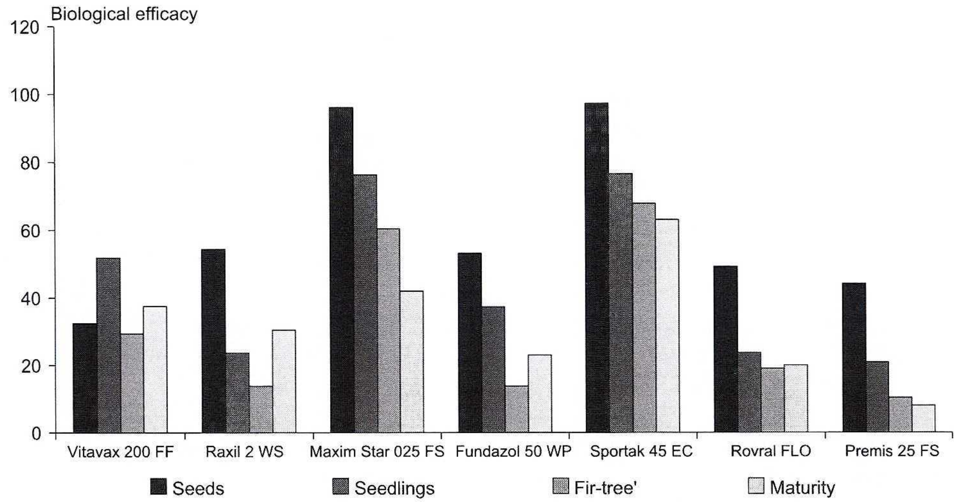

Fig. 1. The biological efficacy (%) of fungicides used for seed treatment on anthracnose at different growth stages of flax

perimental plots, more noticeable yield differences in individual replications, and greater flax straw and seed yield experimental error. Despite all this, fungicidal seed treatment tended to increase straw yield in all experimental years (Tab. 4). Significant yield increases were obtained in 1999 and 2001 (the years favourable for anthracnose spread) in the plots sown with the seeds treated with Maxim Star 025 FS and in 1999 – with Sportak 45 EC. Averaged three years' data suggest that these products increased the straw yield by 0.5 and 0.3 t ha^{-1} and 11.0% and 6.2%, respectively. With Vitavax 200 FF, Fundazol 50 WP and Premis 25 FS application the straw yield tended to increase every year, on average the increase by 0.28–0.34 t ha^{-1} or 5.8%–7.0% were recorded. Only Raxil 2 WS and Rovral FLO did not have any effect on flax straw yield. The effect of fungicides used for seed treatment on linseed yield was similar. Maxim Star 025 FS increased the yield on average by 22.1%, Sportak 45 EC and Premis 25 FS by 13.7% and 13.3%, respectively.

Table 4. The influence of fungicides used for seed treatment on straw and linseed yield

Seed treater	Dosage t^{-1}	Yield t ha^{-1}							
		straw				linseed			
		1999	2000	2001	Average	1999	2000	2001	Average
1. Untreated		2.91	6.72	4.91	4.84	0.28	0.80	0.39	0.49
2. Vitavax 200 FF	2.0 l	2.98	7.24	5.16	5.13	0.25	0.96	0.43	0.55
3. Raxil 2 WS	1.5 kg	3.12	6.36	4.97	4.82	0.37	0.69	0.39	0.48
4. Maxim Star 025 FS	1.5 l	3.66	6.99	5.37	5.34	0.34	0.97	0.47	0.60
5. Fundazol 50 WP	2.0 kg	3.22	6.98	5.17	5.12	0.30	0.85	0.41	0.52
6. Sportak 45 EC	0.8 l	3.58	6.64	5.20	5.14	0.39	0.78	0.49	0.56
7. Rovral FLO	2.0 l	2.91	6.69	4.93	4.84	0.27	0.72	0.36	0.45
8. Premis 25 FS	2.0 l	3.38	7.05	5.10	5.18	0.34	0.88	0.44	0.55
LSD (0.5)		0.51	0.76	0.35	0.566	0.116	0.142	0.098	0.120

CONCLUSIONS:

1. During the experimental years 1999–2001, 39%–79% of flax seeds were affected by various fungal and bacterial pathogens, of which 19% to 34% were infected with the causal agent of anthracnose, *Colletotrichum lini* (West.) Toch. In the control plots sown with untreated seeds *C. lini* – affected seedlings accounted for 33.0%–79.5%.
2. Sportak 45 EC (prochloraz) 0.8 l t^{-1} and Maxim Star 025 FS (fludioxonil and ciproconazol) 1.5 l t^{-1} gave the best control of *C. lini*, their biological efficacy was the following: against seed anthracnose 97.3% and 96.3%, at the seedling stage 76.5% and 76.3%, at the 'fir tree' stage 67.8% and 60.4%. Biological efficacy of the other fungicidal seed treaters was lower: against seed anthracnose 32.4%–54.3%, at the seedling stage 20.9%–51.9% and at the 'fir tree' stage 10.4%–29.4%.
3. Averaged three years' experimental evidence shows that the fungicide Maxim Star 025 FS used for seed treatment and the fungicide Sportak 45 EC contributed to the highest straw yield increases – 0.5 and 0.3 t ha^{-1} or 11.0% and 6.2%, respectively. The effect of these preparations on linseed yield was similar. Maxim Star 025 FS increased the linseed yield on average by 22.1%, and Sportak 45 EC and Premis 25 FS by 13.7% and 13.3%. The other fungicides used for seed treatment, except for Raxil 2 WS and Rovral FLO, also had a positive effect on flax straw and linseed yield, however, the increases did not exceed the least significant difference in any of the experimental years.

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POLISH SUMMARY

KONTROLA ANTRAKNOZY LNU [*COLLETOTRICHUM LINI* (WEST.) TOCH.] POPRZEZ ZAPRAWIANIE NASION FUNGICYDAMI

W latach 1999–2001 na Stacji Doświadczalnej Litewskiego Instytutu Rolnictwa w Upite badano efektywność fungicydów używanych do zaprawiania nasion lnu w celu ochrony roślin przed antraknozą i innymi chorobami.

Ustalono, że nasiona lnu co roku były w 19–34% zakażone przez *Colletotrichum lini* (West.) Toch. – grzyb wywołujący antraknozę lnu. Najlepszą skuteczność w zwalczaniu antraknozy wykazał Sportak 45 EC (0,8 l t^{-1}) oraz Maxim Star 025 FS (1,5 l t^{-1}). Ich biologiczna aktywność wynosiła odpowiednio: antraknoza nasion – 97,3–96,3%, rośliny w stadium siewki – 76,5%–76,3%, stadium jodełki – 67,8%–60,4%. Efektywność innych zapraw była niższa. Wzrost plonu słomy był również najwyższy w przypadku zastosowania preparatów Maxim Star 025 FS i Sportak 45 EC i wynosił odpowiednio 0,5 i 0,3 t ha^{-1} (11,0% i 6,2%). Analogiczny wpływ na plon siemienia lnianego miały także preparaty Maxim Star 025 FS i Sportak 45 EC, a wzrost plonu nasion po ich zastosowaniu wyniósł odpowiedno 22,1% i 13,7%. Wzrost plonu nasion w wyniku zastosowania preparatu Premis 25 FS wynosił 13,3%. Inne fungicydy, z wyjątkiem preparatów Raxil 2 WS i Rovral FLO również miały dodatni wpływ na plon słomy i siemienia lnianego, ale średni wzrost plonu w wyniku ich zastosowania w żadnym roku nie przewyższał granic istotności.