JOURNAL OF PLANT PROTECTION RESEARCH
Vol. 44, No. 1 (2004)

LEAF RUST (*PUCCINIA DISPERSA* ERIKSS.) INFECTION ON SPRING TRITICALE (×*TRITICOSECALE* WITTM.) AND ITS CONTROL WITH DIFFERENT TYPES AND DOSES OF FUNGICIDES

Dalia Janusauskaite, Zenonas Dabkevicius

Lithuanian Institute of Agriculture
Instituto al. 1, Akademija, Dotnuva, 5051 Kedainiai distr., Lithuania
e-mail: daliaj@lzi.lt, dabkevicius@lzi.lt

Accepted: April 2, 2004

Abstract: Investigation of leaf rust disease on spring crops of triticale (×*Triticosecale* Wittm.), its distribution dynamics, as well as the efficacy of two fungicides, different application doses and timing was carried out at the Lithuanian Institute of Agriculture during 2000–2002. Differences in the disease development were determined by the meteorological conditions, especially the amount of rainfall, and growth stage of plants. Precipitation during 2000 was close to the mean, and the development of leaf rust was moderate. In June of 2001 the rainfall was twice as high as the norm, which created favourable conditions for pathogen development. In 2002 a long droughty period till flowering inhibited the development of leaf rust. The triazole fungicides Juventus (metkonazole 60 g l^{-1}) and triazole and strobilurine mixture Allegro (kresoxim-methyl 125 g l^{-1} + epoxikonazole 125 g l^{-1}) were used at full, two-third and half doses once and twice. Both of the fungicides were very effective against leaf rust. Biological efficacy of Juventus applied at any dose or time against leaf rust was 88.3%–99.7%. Allegro efficacy against this disease was slightly higher 94.7%–100%. Application of 1.0; 0.75 and 0.5 l ha^{-1} doses twice showed a better efficacy than a single application. The higher doses of fungicides were not markedly superior to the lower ones.

Key words: spring triticale, leaf rust, efficacy of fungicides

INTRODUCTION

Cultivation of cultivars of arable plants that have established resistance to the main diseases is one of the environmentally friendly agricultural management practices. The hybrid between rye and wheat, triticale, (×*Triticosecale* Wittmack) has a higher fungal disease resistance than wheat (Royo and Pares 1996). Although triticale tends to show a high degree of fungal disease resistance, some important diseases still have been observed on this crop (Woś et al. 1994; Arseniuk et al. 1998; Miedaner and Sperling 1995; Gontarenko et al. 1998; Gaurilčikienė 2003). Leaf rust (*Puccina dispersa* Erikss.), septoria leaf blotch [*Stagonospora nodorum* (Berk.) E. Castell. & Germano], tan spot [*Drechslera tritici-repentis* (Died.) Shoemaker] are potentially the most destructive diseases of triticale and may cause serious economic damage (Miedaner and Sperling 1995; Gontarenko et al. 1998; Gaurilčikienė 2001). Cereals are particularly susceptible to pathogens' infections at stem elongation and heading stages (Jordan and Hutcheon 1994).

Leaf rust of triticale caused by *P. dispersa* Erikss. (syn. *P. recondita* Rob. ex Desm.) is found in temperate climates throughout the world. Leaf rust has the greatest potential for damage in an area with redundant humidity and middle climatic zone. Natural infection of the disease occurs annually (Miedaner and Sperling 1995). Urediospores produced in these regions are wind borne to the adjacent areas and serve as primary inoculum. Urediospores are deposited on leaf surfaces and germinate if favourable environmental conditions occur. Temperatures of 15–26°C and dew period of six to eight hours favour germination of urediospores on the leaf surface. Secondary or recurring cycles may be completed within 7 to 10 days allowing for many generations of urediospores per season. The most common sites for symptoms to appear are on leaf blades and sheaths. When the infection is severe, leaves dry out and die (Wilson and Sharen 1989; Geagea et al. 2000).

Fungicides continue to be essential for the effective control of plant diseases and for enhancement of grain yield (Dabkevičius 1997; Bertelsen et al. 2001). The most common practice is still routine spray applications. However, under increasing social, economic and environmental pressure to pesticide inputs the reduction of fungicide use is an important issue in modern agriculture. Using reduced doses of fungicides gives a rather good control of diseases (Jørgensen and Nielsen 1998; Tamošiūnas et al. 1997). The highest efficacy of fungicides was achieved when they were used once at heading, or when reduced doses were applied twice at stem elongation and heading stages (Gaurilčikienė 2001). Triazole and strobilurine is the standard pesticide treatment used for managing fungal diseases on triticale (Bayles 1999; Sundin et al. 1999).

The objective of this study was to determine the influence of weather conditions on the disease development and investigate the effects of two types of active ingredient: triazole and strobilurine and different doses and application times on leaf rust of spring triticale in West Lithuania.

MATERIALS AND METHODS

Field plot establishment. The trial plots were established in the littoral lowland region in the experimental site of the Vezaiciai Branch of the Lithuanian Institute of Agriculture, (55°43'N, 21°27'E) during the growing seasons of 2000, 2001 and 2002. Spring triticale cultivar 'Gabo' was cultivated.

Two fungicides were used: triazole Juventus 25% (metkonazole 60 g l^{-1}) and strobilurine and triazole mixture Allegro 25% (kresoxim-methyl 125 g l^{-1} + epoxikonazole 125 g l^{-1}). The fungicides were applied at three doses (1 l ha^{-1}, 0.75 l ha^{-1} and 0.5 l ha^{-1}) once (at the end of booting BBCH 49) and twice (at the end of stem elongation BBCH 37–39 and at heading BBCH 55–59). The full trial design is given in the table 1. The use of fungicides at specific triticale growing stages was related to preventive control of other diseases.

Leaf rust developed under natural infection conditions. The disease incidence was measured visually as percentage of the number of affected leaves, and the disease severity was measured as percentage of leaf surface covered by spots on randomly chosen 15 stems on three upper leaves. The disease incidence and severity were assessed once a week from BBCH 31–32 to BBCH 81 using percentage scales. The flag leaf (F) and upper first (F-1) and second leaf below the flag leaf (F-2) were assessed separately. Two upper leaves in 2000 and 2002 were observed at late milk ripe stage (BBCH 79).

Table 1. Effect of fungicides on leaf rust development on spring triticale at heading, flowering and milk ripe stage, 2000–2002

Fungicide, Dose l ha^{-1}, Application frequency and time	2000			2001			2002		
	Growth stage BBCH								
	65	71	79	55	65	75	71	75	79
	Disease incidence %								
Untreated	5.5	16.7	84.1	9.9	34.3	99.3	1.1	36.9	88.3
Juventus 1.0×1’	0*	0*	6.6*	9.4	7.7*	14.3*	0	0*	0.8*
Juventus 1.0×2’’	0*	0*	0.8*	5.5	4.9*	1.7*	0	0*	0*
Juventus 0.75×1	0*	0*	10.8*	8.8	7.2*	14.4*	0	1.1*	0.8*
Juventus 0.75×2	0*	0*	0*	4.4	6.1*	0*	0	0*	0.8*
Juventus 0.5×1	0*	0*	5.8*	11.1	9.4*	21.7*	0	0*	0.8*
Juventus 0.5×2	0*	0.6	0*	3.3	2.7*	0.5*	0	0*	0.8*
Allegro 1.0×1	0*	0*	0.8*	11.6	6.6*	2.8*	0	0*	0*
Allegro 1.0×2	0*	0*	0*	5.5	2.7*	0*	0	0*	0*
Allegro 0.75×1	0*	0*	0.8*	9.9	9.4*	4.4*	0	0*	0*
Allegro 0.75×2	0*	0*	0*	4.9	4.4*	0*	0	0*	0*
Allegro 0.5×1	0*	0*	1.6*	12.7	9.9*	8.3*	0	0*	1.6*
Allegro 0.5×2	0*	0*	0*	8.3	3.8*	0*	0	0*	0.8*
	Disease severity %								
Untreated	0.07	0.44	4.66	0.09	0.34	9.4	0.01	0.77	3.44
Juventus 1,0×1	0	0*	0.16*	0.09	0.08*	0.44*	0	0*	0.01*
Juventus 1.0×2	0	0*	0.01*	0.05	0.04*	0.02*	0	0*	0*
Juventus 0.75×1	0	0*	0.31*	0.06	0.06*	0.63*	0	0.01*	0.01*
Juventus 0.75×2	0	0*	0*	0.05	0.05*	0*	0	0*	0.01*
Juventus 0.5×1	0	0*	0.15*	0.11	0.09*	0.31*	0	0*	0.01*
Juventus 0.5×2	0	0.03*	0*	0.03	0.02*	0.01*	0	0*	0.01*
Allegro 1.0×1	0	0*	0.01	0.11	0.06*	0.05*	0	0*	0*
Allegro 1.0×2	0	0*	0*	0.05	0.02*	0*	0	0*	0*
Allegro 0.75×1	0	0*	0.04	0.09	0.09*	0.06*	0	0*	0*
Allegro 0.75×2	0	0*	0*	0.04	0.04*	0*	0	0*	0*
Allegro 0.5×1	0	0*	0.02*	0.15	0.19*	0.19*	0	0*	0.02*
Allegro 0.5×2	0	0*	0*	0.06	0.13*	0*	0	0**	0.01*

* the data significant at 99% probability level
1’ fungicide treatment once at the end of booting BBCH 49
2’’ fungicide treatment twice at the end of stem elongation BBCH 37–39 and at heading BBCH 55–59

For the statistical analysis the raw data of disease incidence and severity were transformed using the arcsine of the square root transformation. The results were processed by the analysis of variance. Symbols * used in the text represent significance at 99% probability level.

Meteorological conditions during spring triticale growing period. Although a higher mean air temperature and amount of precipitation are characteristic of the Lithuanian littoral lowland region, the growing seasons of 2000–2002 period differed considerably (Fig. 1). For better explanation of weather peculiarities and water supply conditions we used sum of precipitation and average air temperature during the main triticale growth stages. In 2000 and 2001 there was no rain from triticale sowing to seedling emergence, in 2002 – as little as 3.8 mm. During the triticale tillering, stem elongation and heading stages the varying amount of precipitation in all experimental years affected the leaf rust infection process. There were great differences in the amount of precipitation – in 2001 during the stem elongation stage it was 127 mm. A markedly lower amount of precipitation was in 2000 and 2002 – 44.9 and 14.4, respectively. At the heading stage of triticale a higher amount of precipitation was in 2001 – 26.4 mm, in 2000 and 2002 – 3.4 and 1.0 mm, respectively. At triticale flowering, milk ripening stage the amount of precipitation did not deviate markedly and did not influence rust development appreciably.

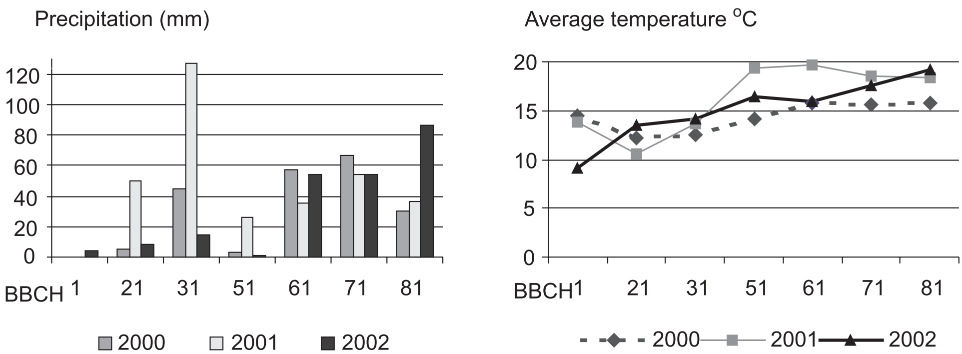
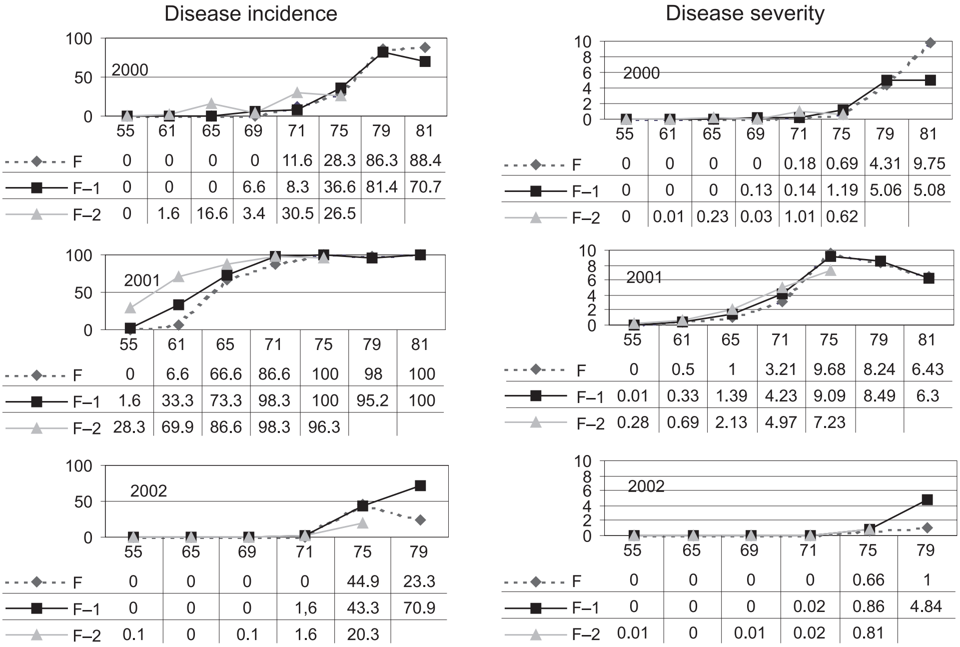


Fig. 1. Sum of precipitation (mm) and average of temperature during the main triticale growing stages in 2000–2002

Considerable differences in the average air temperature during the main growth stages between experimental years were noticed at heading, flowering and milk ripening stages. Cooler temperatures at tillering stage in 2001 did not affect later leaf rust development that year. The mean air temperature during triticale growing period was higher in 2001. During flowering and milk ripe stages the temperature was higher than usual (annual average). Thus wet and warm weather created favorable conditions for leaf rust development in 2001. Extremely dry weather persisted till the flowering stage in 2002, which inhibited pathogen development.

RESULTS AND DISCUSSION

Leaf rust occurrence on spring triticale. The weather conditions influenced leaf rust pathogenesis on spring triticale differently in each of the three study years. The development of leaf rust on F, F-1 and F-2 leaves differed in all experimental years (Fig. 2). Dry and hot weather was unfavorable for the disease development at



Disease incidence 2000

	55	61	65	69	71	75	79	81
F	0	0	0	0	11.6	28.3	86.3	88.4
F–1	0	0	0	6.6	8.3	36.6	81.4	70.7
F–2	0	1.6	16.6	3.4	30.5	26.5		

Disease severity 2000

	55	61	65	69	71	75	79	81
F	0	0	0	0	0.18	0.69	4.31	9.75
F–1	0	0	0	0.13	0.14	1.19	5.06	5.08
F–2	0	0.01	0.23	0.03	1.01	0.62		

Disease incidence 2001

	55	61	65	71	75	79	81
F	0	6.6	66.6	86.6	100	98	100
F–1	1.6	33.3	73.3	98.3	100	95.2	100
F–2	28.3	69.9	86.6	98.3	96.3		

Disease severity 2001

	55	61	65	71	75	79	81
F	0	0.5	1	3.21	9.68	8.24	6.43
F–1	0.01	0.33	1.39	4.23	9.09	8.49	6.3
F–2	0.28	0.69	2.13	4.97	7.23		

Disease incidence 2002

	55	65	69	71	75	79
F	0	0	0	0	44.9	23.3
F–1	0	0	0	1,6	43.3	70.9
F–2	0.1	0	0.1	1.6	20.3	

Disease severity 2002

	55	65	69	71	75	79
F	0	0	0	0	0.66	1
F–1	0	0	0	0.02	0.86	4.84
F–2	0.01	0	0.01	0.02	0.81	

Fig. 2. The incidence and severity of leaf rust on flag (F), upper first (F-1) and second leaf below the flag leaf (F-2) on untreated spring triticale, 2000–2002

earlier stages, therefore the first symptoms of leaf rust appeared on lower triticale leaves just at heading in 2000. The infection decreases as a function of time of dry period was reported before (Vallavieilee-Pope et al. 1996). Younger leaves were less infected than older leaves due to different starting time for the infection appearance at specific leaf levels. Till flowering stage (BBCH 65) the leaf rust pustules were detected only on third leaves (F-2). Further, leaf rust intensity positively correlated with average temperature in early spring and with cumulative precipitation in April and May, which is confirmed by other researchers (Daamen et al. 1992). The amount of precipitation was three times as low in April and slightly lower in May. The temperature in April was twice as high as long-term average, the temperature in May was slightly higher than annual mean. Eventually, due to deficiency of humidity the leaf rust development was moderate. Later development of leaf rust was gradual and at BBCH 69–75 infected upper leaves. The largest number of diseased third leaves – 30.5% was noted at the beginning of milk ripe stage. After withering of lower triticale leaves and due to increasing development of leaf rust, upper leaves were more intensively infected by the pathogen. Finally the proliferation and dispersion of rust spores by wind could cause a stronger infection on flag leaves. The leaf rust incidence on flag leaves at early dough stage was 88.4%, on second leaf – 70.7%, and the disease severity was 9.75% and 5.06%, accordingly.

More favorable conditions for the spread and development of leaf rust were in 2001. Leaf rust appeared at earlier stages and therefore had a longer time to develop. Disease progressed very rapidly. At triticale tillering stage there were affected 3.2 percent of plants, and at stem elongation stage there were attacked about half of plants. The leaf rust outspread on upper three leaves was earlier and stronger compared with the previous experimental year. Very good overwintering conditions for the pathogen in 2000–2001 and the amount of precipitation similar to the long-term average in April and lower in May resulted in the occurrence of the disease at much earlier stages. The flag leaves were diseased at the beginning of flowering. Rainy and warm weather conditions at stem elongation stage resulted in a sharp increase in the disease incidence on flag leaves from 6.6% to 86.6% within two weeks from flowering to beginning of milk ripe stage. Despite such sharp incidence of leaf rust, the disease severity developed slightly and did not reach one percent at the beginning of triticale flowering stage. There were attacked all flag and second leaves at milk ripe stage (BBCH 75), the severity on flag leaves was 9.68%. Later due to desiccation of leaves both disease incidence and severity decreased.

Under the influence of extremely dry period, initial infection of leaf rust started to spread later in 2002. The amount of precipitation was thrice as low as long-term average in April and twice as low as in May. Besides, the temperature in the December of previous year was slightly lower than long-term average, which could be relevant to the overwintering of rust causal agent. Moreover, the high temperatures in June and July might also decline humidity necessary for pathogen infection. This suggests that temperatures and precipitation in early spring rather than overwintering conditions are critical for leaf rust development. Otherwise, during experimental years the winters were favorable for leaf rust development, when the average temperatures in winters were higher than long-term average. The amount of precipitation in April was thrice as low as long-term mean, in April – twice as low. The traces of leaf rust were spotted at triticale heading stage. It was related with the lack of dew, which did not allow for rust to infect the triticale plants. However, the incubation periods of rust in unfavorable conditions is long, may also play a part in later disease increments (Vallavieille-Pope et al. 1996). Intensive leaf rust spread began at milk ripe stage. This is consistent with the positive influence of rainy days at triticale flowering stage. Within one week rust affected from 39.9% to 88.3% of leaves, but till the end of milk ripe stage its severity was only 3.4%.

Impact of fungicides on leaf rust. Knowledge of the environmental conditions favouring infection by leaf rust on cereals is crucial for the optimal timing of fungicide application (Shtienberg 2000). Due to multiple disease occurrence the fungicide application is targeted to complexity, but the time of some diseases appearance is different (Milus 1994). Therefore in our experiment fungicides were applied after the disease symptoms had occurred in 2001 and before pathogen infection in 2000 and 2002. It is known that since the prevalence of pathogens and the intensity of the diseases they cause vary from year to year, rational disease management necessitates the consideration of many factors, so reaching a sound, rational decision for disease management is a difficult task (Shtienberger 2000).

The crucial decrease of disease development was accompanied by fungicide use over all experimental years. Both of the fungicides were quite effective against leaf rust in spring triticale (Tab. 1). Due to the adverse conditions for leaf rust development, the disease did not occur on triticale upper leaves at heading stage in 2000. At flowering stage the rust development was very weak and any of the fungicide treatments gave 100% control of rust. At early milk ripe stage leaf rust began to spread on fungicide-treated triticale – there was 0.6% of diseased plants treated with Juventus once at 0.5 l ha^{-1}. At the end of milk ripe stage (BBCH 79) Juventus applied once at different doses reduced rust incidence from 84.1% in the control plot to 5.8%–10.8%, Allegro – to 0.8%–1.6%. Juventus and Allegro sprayed twice at any dose provided a full leaf rust control, except for Juventus applied at 1.0 l ha^{-1}. The leaf rust severity was decreased by the fungicides from 4.66% to 0%–0.31%.

In 2001 rust development was early and had spread in the field before the fungicides application, therefore at heading stage the impact of fungicides was not significant and inconsistent among the treatments. Smaller differences were noted in leaf rust reduction by the fungicides in the triticale plots where the fungicides had been applied at stem elongation stage compared with the control. However, at triticale flowering stage (BBCH 65) all fungicide treatments provided a significant rust control with no significant differences among individual fungicide treatments. Fungicides reduced the incidence of rust from 34.3% to 2.7%–9.9%. Half doses of Juventus and Allegro applied twice were superior to full dose applied once. Similarly kresoxim-methyl controlled major diseases satisfactorily at half dose rate in the experiments conducted in Denmark (Jørgensen and Nielsen 1998). Doses of fungicides and rapidity of leaf rust development had an impact on the persistence of the effect of the fungicides. At the milk ripe stage (BBCH 75) the efficacy of fungicides was weaker, however, all the fungicide treatments significantly reduced the disease incidence and severity. The severity of rust did not reach one percent in the fungicide-treated stand over all growing season. The fungicide efficacy tended to be slightly better in two-time applications. Due to the longer preventative period of Allegro, its eficacy against rust was more pronounced than that of Juventus. The two upper leaves were fully protected against leaf rust in the plots treated with Allegro at any doses. These results were similar to those obtained by other authors, who found that kresoxim-methyl represents a highly effective fungicide that inhibits germination and sporulation at low concentrations (Stark-Urnau et al. 1996). The rust incidence in once Juventus applied triticale was 14.3%–21.7%, while twice application had a better control of rust, especially in the plots applied with Allegro 1.0, 0.75 or 0.5 l ha^{-1}, where rust was completely exterminated. The same results on superior disease inhibition in cereals have been obtained with strobilurine treatment in comparison with efficient triazole fungicides (Jørgensen and Nielsen 1998).

Because of the dry weather conditions in 2002 the disease in the triticale crop appeared at later growing stages and the fungicide applications had been started before the disease appearance. A marked spread of rust began at milk ripe stage, but the fungicides completely controlled rust development in the middle of milk ripe stage (BBCH 75), except for the triticale treated with Juventus once 0.75 l ha^{-1}. Later, although the disease incidence was 88.3% at the end of milk ripe stage in the untreated plots, the fungicides significantly controlled leaf rust. The disease incidence in the fungicide-applied triticale plots was very weak 0%–1.6%. The leaf rust mean severity in all the fungicide-treated plots was as low as 0%–0.02%.

Biological efficacy of fungicides was calculated at the beginning (BBCH 71) and end of milk ripe stage (BBCH 77–79). All fungicide treatments showed a very high biological efficacy against leaf rust severity (Fig. 3). A slightly better efficacy was identified in two-time application. The present results are also similar to those reported by I. Gaurilcikiene, who found that leaf rust infection appears later in the growing season of spring triticale and is very effectivelly controlled by fungicides (Gaurilcikiene 2003).

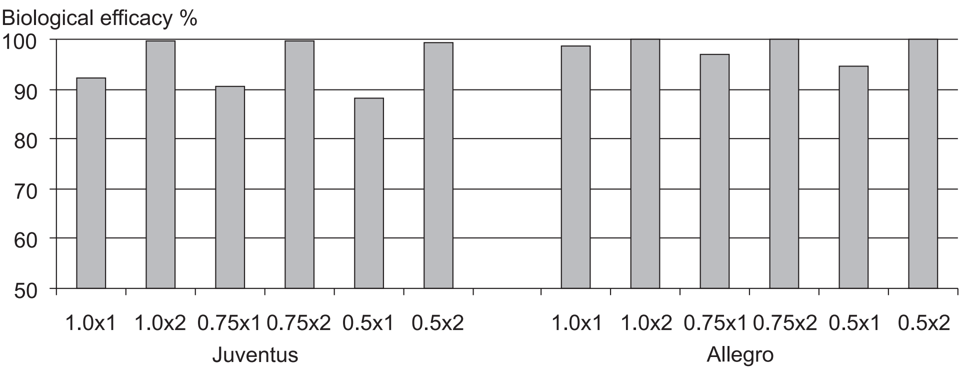


Fig. 3. The average biological efficacy of fungicides against leaf rust in spring triticale at milk ripe stage, 2000–2002

CONCLUSIONS

Leaf rust (*P. dispersa* Eriks) on spring triticale crops appeared every year. The disease spread was more rapid in the warm and rainy weather in 2001, moderate development was identified in 2000, when meteorological conditions did not deviate markedly and was late and weak in the dry and warm 2002.

The biological efficacy of the fungicides against triticale leaf rust depended on the primary disease development and triticale growth stage at application. The both tested fungicides showed a high efficacy. However, the fungicide Allegro was more effective than Juventus in preventing the spread of diseases and inhibiting their development. Application of 1.0; 0.75 and 0.5 l ha^{-1} doses twice showed a higher efficacy than a single application. But for a significant disease reduction a dose of 0.5 l ha^{-1} is sufficient.

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POLISH SUMMARY

PORAŻENIE PSZENŻYTA JAREGO (×*TRITICOSEALE* WITTM.) PRZEZ RDZĘ BRUNATNĄ (*PUCCINIA DISPERSA* ERIKSS.) I JEJ ZWALCZANIE RÓŻNYMI DAWKAMI WYBRANYCH FUNGICYDÓW

W latach 2000–2002 w Litewskim Instytucie Rolnictwa przeprowadzono doświadczenia nad dynamiką rozprzestrzeniania rdzy brunatnej *(Puccinia dispersa* Eriks.) na pszenżycie jarym (×*Triticosecale* Wittm.) oraz biologicznej skuteczności działania dwóch fungicydów zastosowanych w trzech dawkach i dwóch terminach. Rozwój choroby zależał od warunków meteorologicznych, w szczególności opadów oraz fazy rozwojowej roślin. Opady w roku 2000 kształtowały sie na poziomie średnim co spowodowało, że i rozwój rdzy brunatnej miał charakter umiarkowany. Natomiast w czerwcu roku 2001, opady były dwukrotnie wyższe od normy co stworzyło warunki sprzyjające rozwojowi patogena. Długi okres suszy, aż do kwitnienia roślin przenżyta w roku 2002, zahamował rozwój rdzy brunatnej.

Fungicyd Juventus (metkonazol 60 g l^{-1}) z grupy triazoli oraz Allegro (krezoksym metylowy 125 g l^{-1}+ epoksykonazol 125 g l^{-1}) mieszanina triazolu i strobiluryny, zostały zastosowane w pełnej dawce, w połowie dawki i w dwóch trzecich dawki jako jednorazowy zabieg i dwukrotnie. Obydwa fungicydy były bardzo skuteczne w zwalczaniu rdzy brunatnej. Biologiczna skuteczność preparatu Juventus w każdej zastosowanej dawce i terminie wynosiła 88,3%–99,7%. Skuteczność preparatu Allegro w zwalczaniu *P. dispersa* była lekko wyższa i wynosiła 94,7%–100%. Dawki 1,0; 0,75 oraz 0,5 l ha^{-1} zastosowane podwójnie gwarantowały lepszą skuteczność działania preparatu niż zabieg pojedynczy. Wyższe dawki fungicydów nie okazały się znacznie lepsze niż zastosowane dawki niższe.