PROCEEDINGS OF THE LATVIAN ACADEMY OF SCIENCES. Section B, Vol. 67 (2013), No. 3 (684), pp. 259–263.
DOI: 10.2478/prolas-2013-0045

DEVELOPMENT OF RYE LEAF DISEASES AND POSSIBILITIES FOR THEIR CONTROL

Biruta Bankina*, Arta Kronberga**, Aina Kokare**, Solveiga Maļecka***, and Gunita Bimšteine*

* Institute of Soil and Plant Science, Latvia University of Agriculture, Lielā iela, Jelgava LV-3001, LATVIA; Biruta.Bankina@llu.lv

** State Priekuļi Plant Breeding Institute, Zinātnes iela 1a, Priekuļi LV-4126, LATVIA

*** State Stende Cereals Breeding Institute, "Dižzemes", Dižstende, Libagi parish, Talsi County LV-3258, LATVIA

Communicated by Zinta Gaile

*Diseases of rye (*Secale cereale*), an important crop in Latvia, might be a risk factor for rye production. The aim of the study was to determine features of rye leaf diseases, to estimate the risk of rye diseases under conditions of Latvia, and to compare various schemes of fungicide treatment that possibly might be useful for integrated disease control. Field trials were carried out from 2009 to 2012 in two locations in Latvia — State Stende Cereals Breeding Institute and State Priekuļi Plant Breeding Institute. Sixteen trials (two cultivars each year, two sites, and four years) were established during the investigations. Each trial was one-factor design with three variants of fungicide treatment: control (without fungicides), standard treatment during heading (GS 51–55), and DSS (Decision support system). Leaf scald caused by Rhynchosporium secalis and brown rust, caused by* Puccinia recondita*, were found to be the most important rye diseases during the study. Average additional yield achieved by fungicide application was 8%. Number of rainy days (more than seven, starting from GS 31) was not a sufficient threshold for the control of rye diseases. It was necessary to make assessment of the disease development in the the field. Fungicide application might be necessary if symptoms of leaf scald appear on the youngest leaves after beginning of stem elongation (GS 31–32).*

Key words: Rhynchosporium graminicola, Puccinia recondita, Blumeria graminis*, decision support system.*

INTRODUCTION

Rye (*Secale cereale*) is an important crop in Europe. In terms of overall global cereal production, rye shares sixth position with oats (1% each). Over 90% of rye is produced in European countries, and Poland and Germany are the leaders in rye cultivation. Rye is an important cereal in Latvia. In 2010, its total growing area was 28 400 ha, which was 5.4% of the total cereal production area in Latvia (Anonymous, 2012). Diseases are an important risk factor that can decrease the yield.

Brown rust, synonym leaf rust (caused by *Puccinia recondita* f.sp. *secalis* Roberge ex Desmaz), is one of the most important leaf diseases of rye in Central and Eastern Europe (Miedaner *et al.*, 2012), including Germany (Selhorst and Hindorf, 1996); yield losses can reach 14–29% (Räder *et al.*, 2007). Occurrence of leaf rust is high in all regions where rye is produced. Rust appears in almost all growing seasons and is observed in five years out of six. Opinions are contradictory concerning resistance of cultivars. Lõiveke (1997) found that severity of brown rust does not depend on the cultivar and that all cultivars are susceptible to the disease in Estonia. Similar results were obtained in Finland: differences in resistance of cultivars were not expressed clearly: in some regions and some years they were observed, in some they were not (Serenius *et al.*, 2005). An opposite view is held by researchers from Poland, where hybrids are considered most susceptible to fungal pathogens compared with open pollinated cultivars (Szemplinski, Dubis, 2005). Severity and harmfulness of the disease depend on time of infection — earlier appearance of brown rust leads to more severe yield losses.

Leaf scald is caused by *Rhynchosporium secalis* (Oudem.) Davis. Different names of this pathogen and different opinions about its possible hosts are mentioned in the literature. Zaffarano *et al.* (2011) confirmed that this species is a pathogen of rye and triticale. Leaf scald together with mildew and rust have been recognized as harmful pathogens of rye in Lithuania (Smatas and Gaurilcikiene, 2005) and Germany (Werres and Hindorf, 1993), but in Poland it has caused only insignificant yield losses (Szemplinski and Dubis, 2005). Researchers have found that the main factors for disease development are air temperature 15–20 °C and leaf wetness. The incubation period of *R. secalis* can range from 10 to 16 days if conditions are favourable (Werres and Hindorf, 1991).

Mildew caused by *Blumeria graminis* (DC.) Speer is recognised as an important rye disease in Lithuania and Estonia (Lõiveke, 1997; Smatas and Gaurilcikiene, 2005).

Leaf scald, mildew and rusts are the most important diseases of rye throughout the world and also in Latvia. Damage from leaf diseases and possibilities for their control have not been investigated in Latvia.

The aim of the present investigation was to determine characteristics of rye leaf diseases, to estimate the risk of rye diseases in Latvia, and to compare various schemes of fungicide treatment which possibly might be useful for integrated disease control in rye.

MATERIALS AND METHODS

Trial site, conditions and management. Field trials were carried out in two different places of Latvia — State Stende Cereals Breeding Institute and State Priekuļi Plant Breeding Institute. The experiments started in autumn 2008 and continued till autumn 2012.

Soil in Stende was suitable for rye production: sod-podzolic sandy loam, loam soil and sod-podzolic gley loam. In Priekuļi, the soil type was sod-podzolic sandy loam soil, and fertility was lower (Table 1). All agronomic measures, including seed dressing, herbicides and fertilisation, were provided according to common practise for winter rye production in both sites of trials, but schemes of fertilisation slightly differed (Table 1).

Experimental design. In total 16 trials (two cultivars each year, two sites, and four years) were carried out. One-factor design with three variants of fungicide treatment were conducted: control (without fungicides), standard treatment during heading (GS 51–55), and DSS (Decision support system). Treatments according to DSS were based on the number of rainy days after beginning of stem elongation (more than seven days) and/or on the incidence (>30%) of

Table 1

SOIL PROPERTIES AND FERTILISATION SCHEMES OF TRIAL FIELDS IN PRIEKUĻI AND STENDE

Parameters	Priekuļi	Stende
pH KCl	4.7–5.9	5.8–6.9
Organic matter, g kg^{-1}	14–31	21–26
Available P mg kg^{-1}	31–74	45–70
Available K mg kg^{-1}	76–130	86–159
Background fertiliser: N, kg ha^{-1}	18	15
P, kg ha^{-1}	40	12–23
K, kg ha-^{1}	68	63–75
N after resumption of vegetative growth, kg ha^{-1}	70	50
N at stem elongation (GS 31–32), kg ha^{-1}	20	40

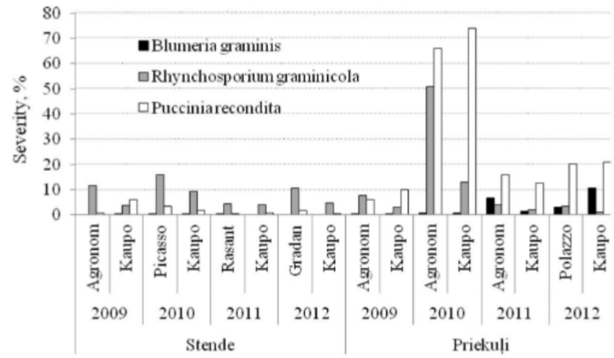

Fig. 1. The severity of rye diseases at growth stage 70–71 in the control.

diseases. Registered doses of Tango Super s. e. (epoxiconazole, 84 g L^{-1}, fenpropiomorph, 250 g L^{-1}) were used.

Two types of rye cultivars were used in the trials: open pollinated cultivar 'Kaupo' (in all years and in both sites) and hybrids 'Agronom', 'Palazzo', 'Picasso' and 'Gradan' (Fig. 1).

The trials were arranged in randomised blocks in four replications; plot size 20 m^2.

Incidence and severity of diseases were determined each week. Assessments of diseases were carried out on the whole plant until GS 31, and at GS 32–69 on three upper leaves, and at later stages (after GS 69) on two upper leaves.

The area under diseases progress curve (AUDPC) was calculated to characterise impact of the disease during the vegetation season (Bankina and Turka, 2013).

Yield was determined by direct harvesting, followed by calculations based on 14% standard moisture and 100% purity.

Significance of the differences among the yields was assessed using one-way ANOVA.

Meteorological conditions. The winter of 2008/2009 was generally favourable for rye wintering in both sites of trials. May was dry, but precipitation in June and July exceeded the long-term average. Temperature during the summer only slightly differed from the long-term average. Different conditions were observed during winter 2009/2010: the winter was favourable for overwintering of rye, but thick cover of snow and fluctuations in temperature in spring promoted development of snow mould (causal agents were not determined, but complex infection was possible). The summer of 2010 was the warmest in the history of Latvian meteorological observations and was characterised by thermal stability and high precipitation that exceeded the long-term average. The period of overwintering in 2010/2011 differed depending on the site: in Stende, conditions for rye were poor, and high incidence of snow mould was observed, but in Priekuļi, in contrast, the conditions were favourable for rye development. Spring and summer were warm, with precipitation close to the long-term average. In 2011/2012, winter conditions were favourable for rye in

Priekuļi and Stende. During the growth period from April to August, temperature was generally close to the average, but precipitation exceeded the long-term average in both trial sites.

RESULTS

The spectrum of rye diseases and their severity varied depending on year, trial site and cultivar during the investigations are shown in Figure 1.

Leaf scald (caused by *Rhynchosporium graminicola*) was the most important disease during the study in both trail sites. Significant severity of mildew (caused by *Blumeria graminis*) was observed only in Priekuļi, 2012. The severity of brown rust (caused by *Puccinia recondita*) varied among years and sites. Leaf blotch, caused by *Septoria* spp. was observed only in some cases, and the severity of this disease did not reach 1%. Stem rust caused by *Puccinia graminis* was observed only in 2010, in both trial sites. The severity of this disease was 3–10% depending on the trial.

The most significant disease development was observed for cultivar 'Kaupo' (Fig. 2), which was sown in both sites and in all years of investigations.

The first symptoms of leaf scald were observed at the beginning of stem elongation, and disease incidence and severity gradually increased during the vegetation season. Leaf rust infection occurred only after flowering of rye, i. e. last days of May or first days of June.

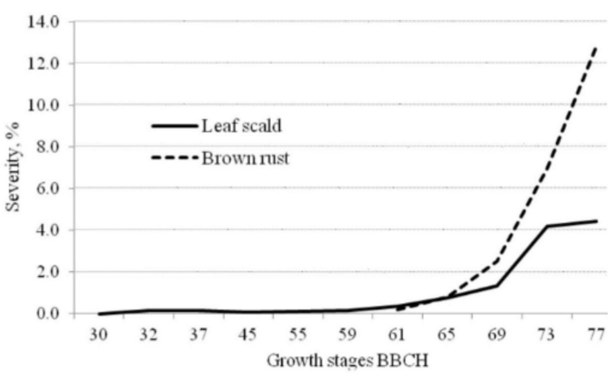

Fig. 2. Development of rye diseases for cultivar 'Kaupo' (average from both sites and from 2009–2012).

Table 2

FUNGICIDE TREATMENT RECOMMENDATIONS MADE ACCORDING TO THE DECISION SUPPORT SYSTEM, COMPARED WITH STANDARD TREATMENT

Year	Site of treatment	Time of treatments (data and BBCH of rye)	
		standard	decision support system
2009	Priekuļi	22.05; 51–55	not treated
	Stende	25.05; 51–55	01.06; 55–59
2010	Priekuļi	25.05; 51–55	02.06; 55–59
	Stende	02.06; 55–59	02.06; 55–59
2011	Priekuļi	02.06; 51–55	23.06; 69–71
	Stende	26.05; 51–55	28.06; 69–71
2012	Priekuļi	22.05; 51–55	22.05; 51–55
	Stende	25.05; 51–55	03.07; 69–71

During the investigation period, 2009 was the only year in which using the DSS approach, application of fungicides was not recommended in Priekuli, as the summer was dry. In other years, treatments were conducted at the same time as standard treatment (S) or later (Table 2).

Total impact of diseases during the whole vegetation season can be demonstrated by the values of AUDPC. The highest pressure of diseases was observed in 2010 and 2012 (total values of AUDPC exceeded 600–800 units). In 2009 and 2011, this indicator was only 230 units (specific data depending on diseases and cultivars are not shown in this paper). The values of AUDPC demonstrated the effect of fungicides on disease development, as application of fungicides decreased disease development in all cases. Differences between untreated and treated plots were more distinct when pressure of diseases was higher, which was especially pronounced in Priekuļi, in 2010 (Fig. 3). Efficacy of DSS appeared to be similar with that of the standard treatment.

In general, high yield levels were achieved during the study: yields in control variants varied from 2.2 to 8.5 t ha^{-1}. The lowest yields were observed in 2010 due to the high incidence of snow mould that year. On average, hybrids were more productive than 'Kaupo'.

Application of fungicides increased yield by 8% on average, but additional yield was not achieved in each case. Differ-

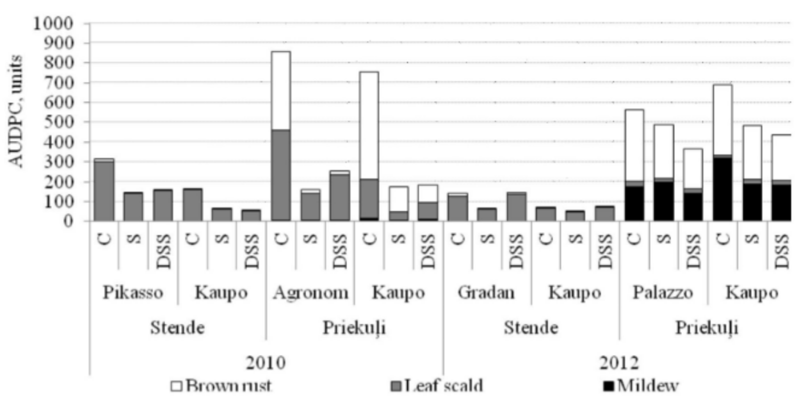

Fig. 3. Total area under diseases progress curve (AUDPC) value, depending on year, site, cultivar, and treatment.

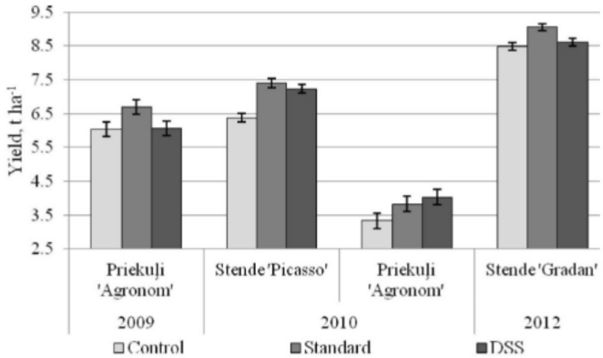

Fig. 4. Yields of rye hybrids, depending on treatment schemes, site of trials and years.

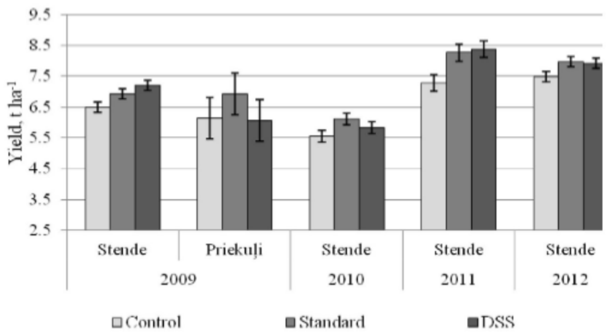

Fig. 5. Yield of rye cultivar 'Kaupo', depending on treatment schemes, site of trials and years.

ences in yield were significant in only nine trials of 16. In seven trials, significance of differences in yield was not observed ($F_{fact} < F_{crit}$). The effectiveness of fungicide treatment schemes is reflected in Figs. 4 and 5 (results of trials with insignificant differences in yield are not shown).

Treatments according to the DSS recommendations did not prove to be more effective than standard treatment; the differences were insignificant in most of cases (Figs. 4 and 5). Recommendations made according to DSS were incorrect in Priekuļi in 2009 (fungicide was not used) and in Stende in 2012 (too late fungicide treatment).

DISCUSSION

The spectrum of rye diseases observed during our study was similar ot that in other European countries, excepting occurrence and harmfulness of mildew. Although mildew is one of the most wide-spread rye diseases, in our investigations its severity did not reach even 10% in most of the trials. The highest severity was observed for the cultivar 'Kaupo' in Priekuļi, 2012 (Fig. 1). Differences in resistance against mildew among the cultivars were not apparent; development of the disease was determined by year and site of trial. It is difficult to explain the different levels of mildew among the trials, as meteorological conditions were favourable for disease development also in all years, not only 2012. In our opinion, the possible reason for this is the structure of the population of the causal agent.

Brown rust proved to be one of the more important diseases in Latvia. The same situation has been observed in Estonia (Lõiveke, 1997; Tupits and Sooväli, 2010), Poland (Szemplinski and Dubis, 2005) and Germany (Miedaner and Sperling, 1995). In our study, severity of rust varied between 0.5–73.8% at the growth stage 70–71. The highest level of the disease (severity exceeded 65%) was observed in 2010, when the summer was warmer compared with the long-term average.

Brown rust epidemic started only after flowering in Latvia, which is the reason why leaf scald is potentially more harmful due to its earlier development. It has been observed in Estonia that brown rust infection starts at the end of May or early in June (Lõiveke, 1997), which agrees with the results obtained in our investigations. Similar results have been obtained by Miedaner and Sperling (1995) in Germany: natural leaf rust epidemics start at the time of ripening, and the first symptoms are observed at flowering. The results obtained in different countries indicate that the critical period of leaf rust development is the period after flowering.

In our investigations severity of brown rust differed depending on the cultivar, but clear differences were not found. Similar conclusions were made in Finland, where contradictory results were obtained (Serenius *et al*., 2005).

Stem rust was not found to be an important disease in our study, but it is a potentially very harmful disease and therefore its distribution should be evaluated very carefully.

Different researchers have reported inconsistent results on the harmfulness of leaf scald. Scientists from Poland have described only insignificant yield losses caused by *R. graminicola* (Szemplinski and Dubis, 2005), but in Germany it is one of the most harmful diseases (Werres and Hindorf, 1993). Our research suggests that leaf scald is the most important rye disease in Latvia, as this disease was observed each year and in both trial sites. It is important to note that the first symptoms of leaf scald were found early in the vegetation season, at the stage of stem elongation. Values of the leaf scald AUDPC were higher than those of other diseases in most cases.

Calculation of AUDPC is suitable for evaluation of disease impact on plants and a medium to high correlation has been found between AUDPC value and the relative yield of rye (Miedaner and Sperling, 1995). The largest total AUDPC (sum of the AUDPC of leaf rust, leaf scald and mildew) was noted in 2010, when the highest relative additional yield was obtained by application of fungicides; the yield increase was 13–21%.

Several studies have been carried out to clarify efficiency of fungicide applications. Researchers from Lithuania obtained an additional yield of 0.38–0.40 t ha^{-1} by fungicide application (Smatas and Gaurilcikiene, 2005). In Germany, use of fungicides provided 0.8–0.9 t ha^{-1} of additional yield, when yield without fungicides application was about 4.7–6.6 t ha^{-1} (Werres and Hindorf, 1993). In our study, additional yield fluctuated depending on year and site, and on average reached 0.45 t ha^{-1}. According to data of Werres and Hindorf (1993) prophylactic treatment at the stage of tillering and at the end of heading is economically ineffective, and the best time of fungicide treatment is when severity of leaf scald reaches 2.5% on the third leaf. In our study, the threshold for fungicide application was 30% leaf scald incidence; however, this was shown to be too high and application of fungicide is required earlier.

The need for fungicide application in rye sowings is disputable under conditions of Latvia. It is necessary to calculate the potential price of rye grain and expenses of fungicide treatment. Fungicide might be necessary if sowings have good density and potential yield is high, and early appearance of leaf scald symptoms is a reason to decide to spray fungicides.

Efficiency of fungicide treatment depended on the pressure of diseases, especially on the severity and time of leaf scald infection. Average additional yield was 8%, but was not obtained in all cases. Number of rainy days (more than seven, starting from GS 31) is not a sufficient threshold for the control of rye diseases, and it is necessary to conduct assessment of each disease in each field. Fungicide application might be necessary if symptoms of leaf scald after beginning of stem elongation (GS 31–32) appear on the youngest leaves and/or infection of other diseases starts before flowering.

ACKNOWLEDGEMENTS

The research was supported by the Ministry of Agriculture of the Republic of Latvia (ELFLA 020311/C – 31).

REFERENCES

Anonymous (2011). Agriculture production report of 2011. Retrieved on 13 February 2013 from http://www.csb.gov.lv/notikumi/par-lauksaimniecibas-kulturu-sejumu-platibam-koprazu-un-videjo-razibu-2011gada-33250.html.

Received 28 March 2013

Bankina, B., Turka, I. (2013). *Augu slimību un kaitēkļu uzskaites metodes* [Sampling Methods of Plant Diseases and Pests]. Jelgava: Latvia University of Agriculture. 24 lpp. (in Latvian).

Lõiveke, H. (1997). Rye diseases and their control caused by microfungi in Estonia. *Transactions of the Estonian Academic Agricultural Society*, **4**, 69–70 (in Estonian).

Miedaner, T., Sperling, U. (1995). Effect of leaf rust on yield components of winter rye hybrids and assessment of quantitative resistance. *J. Phytopathol.,* **143**, 725–730.

Miedaner, T., Klocke, B., Flath, K., Geiger, H. H. Weber, W. E. (2012). Diversity, spatial variation, and temporal dynamics of virulences in the German leaf rust (*Puccinia recondita* f. sp. *secalis*) population in winter rye. *Eur. J. Plant Pathol.*, **132**, 23–35.

Räder, T., Racca, P., Jörg, E., Hau, B. (2007). PUCRE/PUCTRI: A decision support system for the control of leaf rust of winter wheat and winter rye. *Bulletin OEPP/EPPO Bulletin*, **37**, 378–382.

Sawinska, Z. (2011). Influence of powdery mildew and brown rust on winter rye yielding. *Progr. Plant Protect.,* **51** (3), 1193–1197.

Selhorst, T., Hindorf, H. (1996). Simulation of the disease incidence of *Puccinia dispersa* in rye. *Bulletin OEPP/EPPO Bulletin*, 26, 447–452.

Serenius, M., Huusela-Veistola, E., Avikainen, H., Pahkala, K. (2005). Effects of sowing time on pink snow mould, leaf rust and winter damage in winter rye varieties in Finland. *Agr. Food Sci.*, **14**, 362–376.

Smatas, R., Gaurilcikiene, I. (2005). Pest and disease management in winter rye crop. *Latvian J. Agron.,* **8**, 179–184.

Szemplinski, W., Dubis, B. (2005). Rye infection by fungal pathogens under conditions of various sowing rates and disease control methods. *Polish J. Nat. Sci.,* **2** (19), 243–254.

Tupits, I., Sooväli, P. (2010). The occurrence and severity of rust diseases of winter rye in Estonian climatic conditions. *Agron. Res.,* **8** (Special issue III), 735–742.

Zaffarano, P. I., McDonald, B. A., Linde, C. C. (2011). Two new species of *Rhynchosporium*. *Mycologia*, **103** (1), 195–202.

Werres, G., Hindorf, H. (1991). Development of a forecasting model for scald, *Rhynchosporium secalis*, on rye in relation to climatic conditions. *Bulletin OEPP/EPPO Bulletin*, **21**, 485–493.

Werres, G., Hindorf, H. (1993). Evaluation of a system for optimizing fungicide application to control *Rhynchosporium secalis* on winter rye. *Bulletin OEPP/EPPO Bulletin*, **23**, 565–576.

RUDZU LAPU SLIMĪBU ATTĪSTĪBA UN TO IEROBEŽOŠANAS IESPĒJAS

Rudzi (*Secale cereale*) ir nozīmīgs kultūraugs Latvijā, tādēļ slimības var būt riska faktors rudzu audzēšanā. Pētījumu mērķis ir skaidrot rudzu lapu slimību attīstības īpatnības, to postīgumu Latvijas apstākļos un pārbaudīt dažādas fungicīdu lietošanas shēmas, kas var būt izmantojamas integrētajā rudzu slimību aizsardzībā. Lauka izmēģinājumi iekārtoti divās dažādās vietās: Stendes Valsts graudaugu selekcijas institūtā un Priekuļu Valsts laukaugu institūtā, laikā no 2009. gada līdz 2012. gadam. Pavisam bija 16 izmēģinājumi (divas šķirnes katru gadu, divas vietas un četri gadi). Vienfaktoru izmēģinājums bija iekārtots ar trim variantiem: kontrole (bez fungicīdiem), standarta smidzinājums (AE 51–55) un smidzinājums saskaņā ar Lēmumu atbalsta sistēmu (LAS). Gredzenplankumainība (ierosinātājs *Rhynchosporium secalis*) un brūnā rūsa (ierosinātājs *Puccinia recondita*) bija nozīmīgākās slimības izmēģinājumu laikā. Vidēji fungicīdu lietošanas rezultātā raža palielinājās par 8%. Fungicīdu smidzināšanas slieksnis (septiņas lietainas dienas pēc stiebrošanas sākuma (AE 31) nav piemērots rudzu slimību ierobežošanai. Nepieciešama slimību uzskaite konkrētā laukā. Fungicīdu lietošana ir nepieciešama, ja gredzenplankumainības simptomi pēc stiebrošanas sākuma parādās uz jaunākajām lapām.