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MANAGEMENT OF PESTS AND PATHOGENS IN RYE CROP IN DRY MARGINAL ENVIRONMENT IN SOUTHERN ROMANIA

Mirela PARASCHIVU[1], Gheorghe MATEI[1], Otilia COTUNA[2, 3], Marius PARASCHIVU[1], Reta DRĂGHICI[4]

[1]University of Craiova, 10 Libertatii Street, Craiova, Romania
[2]Banat University of Agricultural Sciences and Veterinary Medicine, "King Michael I" of Romania from Timisoara, 119 Calea Aradului, Timisoara, Romania
[3]Station of Research and Development for Agriculture Lovrin, 200 Principala Street, Lovrin, Romania
[4]Research and Development Station for Plant Culture on Sands Dabuleni, 217 Petre Banita, Dolj County, Romania

Corresponding author email: matei.gheorghe@gmail.com

Abstract

*Climate change is expected to cause the spread of pathogens and pests in areas where they have not been relevant before, bringing new challenges for cropping systems based on crops diversification by minor cereals. Rye is a minor cereal that contributes to crop species diversity in Central and Eastern Europe, especially in marginal environments unfavourable for wheat production. During 2019-2020, a plant–pest-pathogen interaction profile was observed on Suceveana rye genotype in a randomized complete block design in dry area from Research and Development Station for Plant Culture on Sands Dabuleni in South of Romania. The best protection against leaf rust was provided by Dithane M 45+Bioinsekt (the 1st assessment = 2.98%; the 2nd assessment = 4.86%), while the best control against pests was provided by Mimox+Bioinsekt (the 1st assessment = 0.83%) and Mimox+ Decis Expert 100 EC (the 2nd assessment = 1.03%). For pests and leaf rust control was noticed the synergistic effect of insecticides and fungicides used in the experiment. Negative and significant correlations of attack degrees with grain yield (r =-0.7886**, respectively r = -0.8332**) were noticed.*

Key words: *leaf rust, Puccinia recondita f.sp. secalis, pests, pesticides formulation, attack degree.*

INTRODUCTION

The impact of climate change on spontaneous and cultivated plants has led to changes in floristic composition, invasive plants proliferation and variability of reproduction, adaptability and development (Răduțoiu et al., 2012; Sărățeanu et al., 2013; Sărățeanu et al., 2016; Sărățeanu et al., 2019; Cosmulescu et al., 2020; Răduţoiu, 2020; Răduţoiu and Cosmulescu, 2020; Sărățeanu et al., 2020; Răduţoiu and Băloniu, 2021).

The predictions show that global temperature will increase by 2.5 to 4.5°C by the end of 21st century as a result of the rising concentrations of greenhouses gases in the atmosphere (Bernstein et al., 2008).

In the context of climate change crop production and food security are ones of the major global challenges in the 21st century, cereal food supply being expected to increase over 70% by 2050 when global population is predicted to 9.8 billion people (Howden et al., 2007; Godfray et al., 2010; Ray et al., 2013; Tripathi et al., 2016; Bonciu, 2019c; Lal, 2021; Malhi et al., 2021). During the last decades, despite the negative impact of climate change and other global constrainers (e.g. Covid-19 pandemic) on the food supply, crop production increased significantly due to many changes in agricultural systems as a consequence of interaction among multiple factors such as globalization in food production, genetic progress, biotechnologies, improved cropping technologies, better pests, diseases and weeds management, agricultural digitalization and farmers faster access to the information (Butnariu et al., 2006; Matei, 2011; Matei, 2016; Partal et al., 2013; Partal et al., 2014; Bonciu, 2018, Diaconu et al., 2019; Dima et al., 2019; Bonciu, 2019a, Bonciu, 2019b; Bonciu, 2020a; Bonciu, 2020b; Matei et al., 2020a;

Matei et al., 2020b; Partal and Paraschivu, 2020; Bonciu et al., 2021; Dima et al., 2021a; Dima et al., 2021b; Drăghici et al., 2021; Paraschivu and Cotuna, 2021). However, this progress comes to face additional factors as climate variability and climate changes.

Agricultural systems are also affected by changes in temperatures (global warming) impacting directly crops yield and indirectly the biotic constrainers and might result in invasion of weeds, pests and pathogens in areas where they have not been relevant before (Coakley et al., 1999; Chakraborty and Pangga, 2004; Cotuna et al., 2013; Bălașu et al. 2015a, Bălașu et al., 2015b, Manole et al., 2015; Paraschivu et al., 2015; Paraschivu et al., 2017; EEA Report, 2017; Cotuna et al., 2018; Paraschivu et al., 2019; Juroszek et al., 2020; Zală, 2021).

Thus, some pathogens and pests tend to become more aggressive even in cropping systems based on crops diversification by minor cereals.

Rye (*Secale cereale*) is a minor cereal, closely related to barley and wheat, having a major role in crop species diversity in temperate regions of Central and Eastern Europe, especially in marginal environments where soil and climate are unfavourable for wheat production. In 2020 European Union (EU) produced 9.175.000 tonnes of rye grains from which 71.82% was produced in Germany and Poland (USDA, 2020).

Despite the fact that rye is an important source of resistance gene for wheat in combating leaf rust, stem rust, stripe rust, powdery mildew, Barley yellow dwarf virus (BYDV) and insect resistance to Hessian fly, Russian wheat aphids, and green bug, it is affected by various pathogens and pests (Zhang et al., 2001; Saulescu et al., 2011).

One of the most important diseases of rye in Central and Eastern Europe is Brown rust (BR), known also as Leaf rust (LR), caused by the obligate biotrophic basidiomycete *P. recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) (Roux and Wehling, 2010; Meidaner et al., 2012).

In natural conditions, yield losses can be up to 40%, but they can be as high as 80% in case of early infection (Solodukhina, 2002; Wehling et al., 2003).

Although, resistance is currently considered as the most economical and effective control measure of this disease, cereal rusts exhibit considerable capacity for generating, recombining and selecting for resistance under the impact of climate variability and they can adapt to new environment. Therefore, additional fungicides used is still remaining an important part of integrated disease management. The application of fungicides led to 29% higher yields comparatively with untreated plots (Hartleb et al., 1995). In experimental trials epoxiconazole, pyraclostrobin and fluxapyroxad showed high efficiency in controlling leaf rust in rye (Kupferund and Schröder, 2014). Little research is reported in controlling pathogens and pests in rye system in dry marginal areas.

In this context the present paper emphasises the management of rye-pest-pathogen interaction in dry marginal environment from Southern Oltenia, Romania, using different formulations of conventional and biological pesticides.

MATERIALS AND METHODS

During 2019-2020 growing season, a plant–pest-pathogen interaction profile was observed on Suceveana rye genotype using different pesticide formulations in a randomized complete block design with three replications in dry area from Research and Development Station for Plant Culture on Sands Dăbuleni, located in Southern Oltenia, Romania (43°48′04″N 24°05′31″E), on sandy soil, poorly supplied with nitrogen (between 0,04-0,06%), well supplied with phosphorus (between 54 ppm and 77 ppm), reduced to a medium supplied with potassium (between 64 ppm to 83 ppm), low in organic carbon (between 0.12-0.48%) and weakly acidic pH to neutral (between 5.6 and 6.93).

Technological measures applied included broadcasting the fertilizers at sowing time with $N_{80}P_{80}K_{80}$, one side nitrogen fertilization during vegetation with N_{70}, starter irrigation with 250 m^3 water/ha and supplemental irrigation with 300 m^3 water/ha at heading stage. Also, weeds control was done using Dicopur Top 464 SL (1 l/ha) applied in postemergence to control annual and perennial dicotyledons accordingly with the recommendations (cereals to the formation of the first internode and the weed species in the small phase of about 2-4 leaves and a maximum of 10-15 cm high for perennial weeds).

Plant–pathogen interaction was assessed in natural infection with *P. recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) in a randomized complete block design (RCBD) with three replications. Each plot had 5 m^2, a space of 1 m between blocks and 0.5 m between plots. Treatments were applied in two different moments (14.04.2020 and 05.05.2020).

Disease observations were recorded since the first appearance (booting stage) of leaf rust infection on Suceveana rye genotype and at early dough stage (Zadoks scale) (Zadoks et al., 1974).

For all assessed trail variants were determined Frequency (F%) and Intensity (I%) of leaf rust and insect's attack.

Leaf rust Intensity (%) was recorded for each trial variant assessing 10 plants randomly selected and pre-tagged plants of the central four rows of each plot and the mean of the ten plants was considered as the value for a plot. Rust severity was determined by visual observation and expressed as percentage coverage of leaves with rust pustules (from 1% to up 75%) using the sale developed by Oladiran and Oso (1983) (Table 1).

Table 1. Leaf rust intensity expressed as percentage coverage of leaves with rust pustules (Oladiran and Oso, 1983)

Category	Percentage leaf rust infection relative to susceptible check
0	0 - no attack
1	1-10% of leaf area covered with rust pustules
2	11-25% of leaf area covered with rust pustules
3	26-50% of leaf area covered with rust pustules
4	51-75% of leaf area covered with rust pustules
5	> 76% of leaf area covered with rust pustules

For assessing the intensity of insect's attack was used the following scale (Table 2).

Table 2. Intensity of insect's attack expressed as percentage of damaged leaves

Category	Percentage of damaged leaves
0	0 - no attack
1	1-3% leaves damage
2	3-10% leaves damage
3	10-25% leaves damage
4	25-50% leaves damage
5	50-75% leaves damage
6	75-100% leaves damage

The attack frequency has been set with a metric frame (50 cm x 50 cm), taking in account the relative value of the attacked plants' number in report with the total number of the analysed plants or organs.

These parameters were used to calculate Attack Degree (AD%) using the formula: AD% = (F% x I%)/100 (Cociu and Oprea, 1989).

The treatment combinations are presented in Table 3.

Table 3. Treatments used in the experimental trial

Factor A fungicides	Factor B insecticides
a1-no treatment	b1-no treatment
a2-Dithane M 45 – 2 kg/ha	b2-Decis Expert 100 EC-75 ml/ha
a3-Mimox - 3 L/ha	b3-Bioinsekt – 0.5-1 L/ha
	b4-Neemex - 1-1.25 L/ha

In order to characterize the evolution of climatic parameters (air temperature, rainfall, humidity, wind speed) into the experimental field it was used an automatic weather station (AWS).

Means were compared with the no treated genotype Suceveana (control).

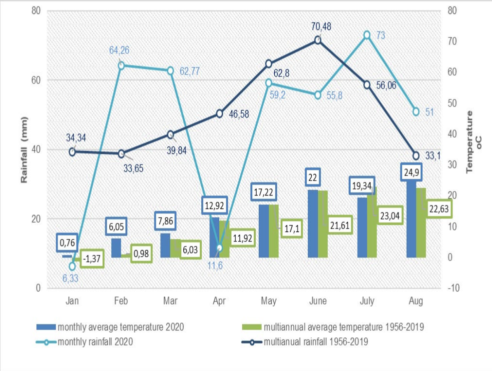
The experimental data were calculated and analysed, using MS Office 2019 facilities, while statistical analysis involved analysis of variance procedure (ANOVA) and significant differences were determined by the SD test at P<0.05 (Saulescu, 1967).

RESULTS AND DISCUSSIONS

In dry marginal areas the effects of climate change and climate variability on crops health have been associated with changes in pathogens and insects' life cycles, including many generations, increased incidence, pathogenicity, aggressiveness traits (Chakraborty and Newton, 2011; Newton et al, 2011; West et al., 2012; Elad and Pertot, 2014; Fones at al., 2020).

During 2019-2020 cropping season favourable climatic conditions led to the infection with *P. recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) and insects attack (*Schizaphis graminum*, *Eurygaster integriceps*, *Mayetiola destructor, Chlorops pumilionis*).

For scouting optimization and to predict the treatment moments rainfalls and temperatures were taken into account. Humidity was determined by the amount of rain of 383.96 mm, comparatively with multiannual average rainfall of 376.85 mm, while the monthly average temperature was 13.9°C comparatively with multiannual average temperature of 12.7°C (Figure 1).



* automatic weather station DRSPCS Dabuleni, Romania

Figure 1. Climatic conditions during the study period (2020 year)

During January to August 2020 the monthly average temperature increased up to +1.2°C comparatively with multiannual average temperature for January to August between 1956-2019 for the same geographic area. This temperature increase follows the global trend in planet warming. Thus, accordingly with a report of National Oceanic and Atmospheric Administration (NOAA, September 2020) monthly average temperature for January to August 2020 increased up to +1.03°C (+15.03°C) at the global level comparatively with average temperature recorded on Earth in the 20th century (+14°C).

Rainfall amount for evaluated period was slightly higher with 7.11 mm than multiannual amount for dry areas in Southern Romania. The humidity at leaf level cumulated with increased temperature favoured the development of Leaf rust disease, which exhibited the first symptoms at the end of April 2020.

Optimal environmental conditions for disease development are temperatures ranging from 15°C to 20°C, but the fungus can develop at the temperature of 2-35°C.

The fungus needs approximately six hours of moisture on leaves to start developing. With much moisture and suitable temperatures, lesions are formed within 7-10 days and spore production reduplicate another uredospore generation (Kolmer, 2013).

Identification of the fungus *P. recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) and its characteristics were done in the Phytopatology Laboratory of Agriculture Faculty in University of Craiova, using MOTIC BIM-151B LED (40-1000x) microscope. The diameter of uredinia can reach even 1.5 mm, their colour is orange to brown and their shape is round to ovoid. The average size of uredospores release from uredinia is 20 mm in diameter and colour orange-brown (Figure 2). Uredospores have up to eight germ pores scattered in dense walls.

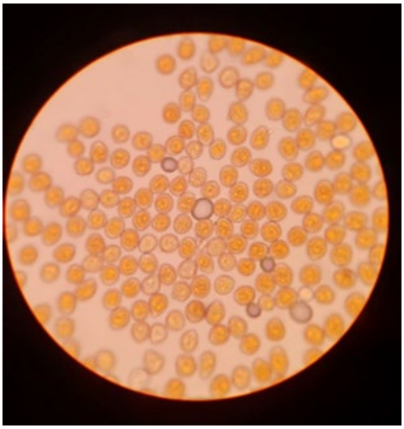


Figure 2. Uredospores of *Puccinia recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) (original photo Paraschivu Mirela, 2020)

Săvulescu (1953) showed that uredospores of leaf rust were visible on rye leaves at the end of May or the beginning of June, but the currently results show that in the context of climate change, with higher monthly average temperature and ununiform rainfalls, these fruiting bodies of the pathogen (uredinia with uredospores) appear earlier. These findings suggest a modification of life cycle of the pathogen *P. recondita* f. sp. *secalis* by many generation numbers and higher resistance of uredospores to increased temperature. Also, Harvell et al. (2002) suggested that rising temperatures will (i) increase pathogen development transmission, and generation number; (ii) increase overwinter survival and reduce growth restrictions during this period and (iii) alter host susceptibility.

P. recondita f. sp. *secalis* spores are spread by splashing water and wind leading to many successive infections. Meidaner (2012) showed that minimum wind speed for uredospores splashing is 2 m/s.

Leaf rust pustules are small, with thousands of spores within, circular to oval shape, with orange to light brown dusty spores (uredospores) on upper surface of leaves surrounded by a light-coloured halo (Figure 3).

Figure 3. Pustules with uredospores of *Puccinia recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) (original photo Paraschivu Mirela, 2020)

In case of severe attack leaf rust pustules may extend also on the leaf sheaths, stalks and husks.

Insects' determination has been done using Stereo Microscop STM-45B (7-45x). Specific attack symptoms have been assessed on rye leaves.

Previous findings emphasized that Suceveana variety is very susceptible to *P. recondita* f. sp. *secalis* and it is necessary fungicide treatment as a part of integrated crop management (Paraschivu et al., 2021).

During the cropping season 2019-2020 the most affected variant by the attack of pests and pathogens was a1b1 (control - no treatment).

The results emphasized that at the 1st determination (27.04.2020 - the beginning of booting stage) after the 1st praying was applied the incidence of leaf rust severity was low for all fungicides applied [Dithane M 45 (AD = 5.53%) and Mimox (AD = 6.89%)] comparatively with the control variant (no treatment) (AD =8.64%).

There were not find significant differences between the two fungicides applied no matter with insecticide combination. It was observed that Neemex insecticide has a slightly fungicide effect when it was applied alone (AD = 7.27%) or mixed with fungicides (Dithane M 45 + Neemex – AD= 4.88% and Mimox + Neemex - GA = 5.42%) (Table 3).

Table 3. The influence of the 1st treatment applied for controlling pathogens and insect's attack on rye during 2019-2020 cropping season

Fungicide	Insecticide	Attack degree the 1st det.- after the first treatment 27.04.2020					
		Leaf rust			Insects		
		AD%	Dif. %	Signif	AD%	Dif. %	Signif
Netratat	Netratat	8,64	Mt		2,89	Mt	
	Decis Expert 100 EC	8,03	0,61		1,10	1,79	ooo
	Bioinsekt	5,12	3,52	ooo	1,64	1,25	oo
	Neemex	7,27	1,37	o	1,32	1,57	oo
Dithane M 45 2 kg/ha	Netratat	5,53	Mt		3,16	Mt	
	Decis Expert 100 EC	5,10	0,43		1,46	1,7	ooo
	Bioinsekt	2,98	2,55	ooo	0,97	2,19	ooo
	Neemex	4,88	0,65		1,28	1,88	ooo
Mimox 3 l/ha	Netratat	6,89	Mt		2,12	Mt	
	Decis Expert 100 EC	6,23	0,66		1,28	0,84	oo
	Bioinsekt	3,76	3,13	ooo	0,83	1,29	oo
	Neemex	5,42	1,47	o	1,07	1,05	oo
	LSD 5%		1,26			0,43	
	LSD 1%		2,08			0,82	
	LSD 0,1%		2,45			1,68	

*dif. < 5% significance level
no treatment variant = control

After the 2nd treatment applied when it was done the 2nd determination it was observed that the evolution of leaf rust wasn't significant despite successive infections with uredospores suggesting that treatments applied were effective. Even for the 2nd treatment the lowest attack degrees for leaf rust were noticed for variants treated with fungicides (Table 4).

Table 4. The influence of the 2nd treatment applied for controlling pathogens and insect's attack on rye during 2019-2020 cropping season

Fungicide	Insecticide	Attack degree the 2nd det.- after the second treatment 30.05.2020					
		Leaf rust			Insects		
		AD%	Dif. %	Signif	AD%	Dif. %	Signif
Netratat	Netratat	10,89	Mt		3,67	Mt	
	Decis Expert 100 EC	9,90	0,99		1,35	2,32	ooo
	Bioinsekt	7,25	3,64	ooo	2,13	1,54	oo
	Neemex	8,72	2,17	oo	1,89	1,78	oo
Dithane M 45 2 kg/ha	Netratat	6,85	Mt		3,83	Mt	
	Decis Expert 100 EC	5,98	0,87		1,78	2,05	ooo
	Bioinsekt	4,86	1,99	oo	1,22	2,61	ooo
	Neemex	5,63	1,22	o	2.16	1,67	oo
Mimox 3 l/ha	Netratat	8,52	Mt		2,79	Mt	
	Decis Expert 100 EC	7,84	0,68		1,03	1,76	oo
	Bioinsekt	5,75	2,77	ooo	1,30	1,49	oo
	Neemex	6,83	1,69	o	1,12	1,67	oo
	LSD 5%		1,09			0,85	
	LSD 1%		1,87			1,07	
	LSD 0,1%		2,28			1,87	

*dif. < 5% significance level
no treatment variant = control

When insecticides were applied together with fungicides it was observed that insects attack

degree was lower comparatively with the control (no treatment), than when they were applied alone. Decis Expert 100 EC offered the best protection against insects attack when it was applied alone for both treatments (AD = 1.10% - the 1st determination and AD = 1.35% for the 2nd determination). When insecticides were mixed with fungicides the best control of the insects was offered by Bioinsekt for both treatments (Mimox+Bioinsekt - AD= 0.83% and Decis Expert 100 EC - AD = 1.03%).
The highest yields were obtained for the variants with fungicides mixed with Bioinsekt (Dithan M 45 + Bioinsekt = 3106.719 kg/ha and Mimox + Bioinsekt = 3041.502 kg/ha).
Negative high correlations were observed between grain yield and pathogens and insects attack in 2019-2020 cropping season. These findings indicate that yield increased due to the impact of biotic constrainers on plants which led to less healthy plant tissue available for photosynthesis.
The response of rye to treatments applied along with grain yield (t/ha) suggested the presence of inverse relation between the disease and pests' severity and grain yield. The highest significant loss percentages were found in no treated variant. The value of determination coefficient (R^2 = 0.6943) indicated that up to 69% of variation in rye yield could be explained by leaf rust attack. It was noticed a highly significant correlation between leaf rust severity and grain yield (r = -0.8332***) (Figure 4).

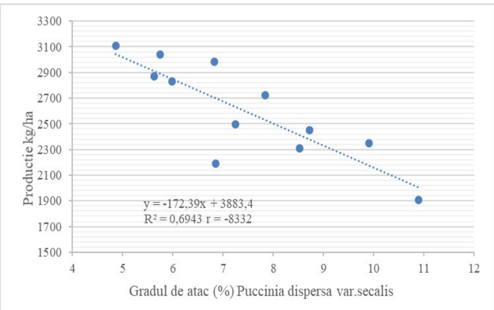


Figure 4. Relationship between Leaf rust severity and rye grain yield in 2019-2020 cropping season

Yield loses due to Leaf rust in rye in Europe were also reported previously by different authors (Solodukhina, 2002; Roux and Wehling, 2010; Meidaner et al., 2012).

The value of determination coefficient (R^2 = 0.6219) indicated that up to 62% of variation in rye yield could be explained by insects' attack. It was noticed a highly significant correlation between insects attack and grain yield (r = -0.7886**) (Figure 5).

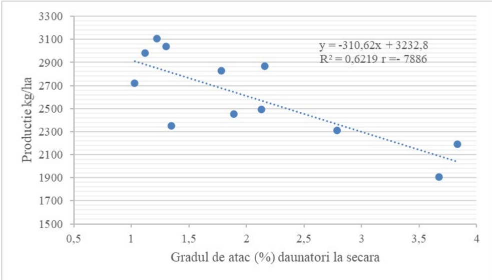


Figure 5. Relationship between insects attack and rye grain yield in 2019-2020 cropping season

Also, Matei et al. (2021) showed that thermohydric stress along biotic constrainers (pests and pathoges) have a significant negative impact on yield of Suceveana variety, especially in dry marginal areas from Romania (Matei et al., 2021).

CONCLUSIONS

The present study was carried out to assess impact of different formulations of fungicides and insecticides on the attack of *P. recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) and insects (*Schizaphis graminum, Eurygaster integriceps, Mayetiola destructor, Chlorops pumilionis*) in natural conditions in dry area from Southern Romania during 2019-2020 cropping season. The study emphasized that the increase of monthly temperature with +1°C may lead to earlier incidence of the disease and insects attack starting even with the end of April. The best protection against leaf rust was provided by Dithane M 45+Bioinsekt (the 1st assessment - attack degree = 2.98%; the 2nd assessment - attack degree = 4.86%), while the best control against pests was provided by Mimox+Bioinsekt (the 1st assessment - attack dregree = 0.83%) and Mimox+ Decis Expert 100 EC (the 2nd assessment - attack degree = 1.03%). For both pests and leaf rust control it was noticed the synergistic effect of insecticides and fungicides used in the experiment. Negative and significant correlations of pests and leaf rust attack degrees with grain yield (r = -0.7886**, respectively r = -0.8332**) were found during 2019-2020 cropping season.

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