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CONTROL OF RYE PESTS AND PATHOGENS ON SANDY SOILS IN SOUTH OF ROMANIA

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Abstract

*Due to climate change and human activity, biotic constrainers are anticipated to expand to regions where they were previously irrelevant. This will present new management challenges for crops, particularly in cropping systems dependent on minor cereals diversification. In Central and Eastern Europe, Secale cereale is a minor cereal that contributes to the diversity of crop species, particularly in marginal areas where wheat cultivation is unfavourable. During 2020-2021, using different chemical and biological pesticide formulations, a plant-pest-pathogen interaction profile was observed on Suceveana rye genotype in a randomized complete block design with three replications in dry area from South of Romania. The best protection against leaf rust (Puccinia recondita f. sp. secalis) was provided by Poliversum (Pythium oligandrum M1, 1×10.000.000 oospors/g product) for the 1st assessment - attack degree = 0.65% and for the 2nd assessment - attack degree = 1.42%, while against pests was provided by Bioinsekt and deltametrin (0.75 ml/ha). Negative and significant correlation of leaf rust attack with grain yield (r =-0.8561***) and pests attack with grain yield (r =-0.8631***) were found during 2020-2021 cropping season.*

Key words: *Secale cereale, attack degree, leaf rust, pesticides formulation, pests.*

INTRODUCTION

Climate change, the risk of epidemics and pandemics, the biodiversity created by invasive species, biotic and abiotic stresses, technological and genetic advancements have all had an impact on natural systems and agricultural and horticultural production around the world (Cotuna et al., 2021; Paraschivu & Cotuna, 2021; Răduţoiu, 2020; Răduţoiu & Băloniu, 2021; Răduţoiu & Stan, 2022. Răduţoiu & Ștefănescu, 2022; Velea et al., 2021; Zală, 2021). As a result, natural constrainers have grown up in importance posing a serious danger to global food security due to its numerous negative effects on the crops management, economy, society, technology, environment, especially in marginal areas characterized mainly by limited biophysical quality of the land (Durău et al., 2021; Matei et al., 2022a; Paraschivu et al., 2022a; Sărățeanu et al., 2023).

Worldwide, new cropping techniques, precise farming equipment, biotechnology, breeding for more resistant types, and high-tech solutions for controlling biotic and abiotic constrainers have profoundly transformed agriculture over the past three decades (Bălașu et al., 2015a; Matei et al., 2022b; Păunescu et al., 2022; Popescu et al., 2022; Zală et al., 2023). The conservation of genetic resources in agriculture and food security is a long-term challenge that transcends the borders of national interests (Bonciu, 2020; De Souza and Bonciu, 2022a; De Souza and Bonciu, 2022b). Maintaining access to safe, disease - and pest-free and affordable agricultural products and raw materials and ensuring sustainable agricultural production are challenges that must be faced in the context of increasing demand for agricultural products (Bonciu et al., 2021; Bonciu, 2022a; Bonciu 2022b; Paunescu et al. 2021).

By 2080, global temperature is anticipated to increase by 4,5-degree Celsius declining by 6% in productivity per each degree Celsius (Asseng et al., 2015).

Previous findings emphasised that climate change poses a serious danger to the health of wild and cultivated plants leading to food insecurity due to pathogens life cycles, increased incidence, pathogenicity, genetically recombination and aggressiveness traits (Bălașu et al., 2015b; Cotuna et al., 2022a; Cotuna et al., 2022b; Cotuna et al., 2022c; Cristea et al., 2015; Paraschivu et al., 2017; Paraschivu et al., 2019).

In this context, with 1.5 billion hectares of farmland and 3.4 billion hectares of pastures, agriculture occupies about 38% of the planet's surface (Alexandratos & Bruinsma, 2012). At the same time there are 2.7 billion ha of marginal land of which 1.5 billion ha are uncultivated, usable area for agricultural use, but an effective management could sort them out of this category (Tilman et al., 2011).

Development of land evaluation systems based on biophysical conditions have been started in the 20th century (Doran et al., 2018; Karlen et al., 1997).

The classification of land as prime, marginal, or unproductive often depends on the land's management or type of agriculture.

The marginal lands can be turned into productive land by appropriate land management or cultivation of suitable crops. In marginal areas from Central and Eastern Europe, where soil and climate are unfavourable for wheat production, rye (*Secale cereale*) is a minor cereal who plays a significant role in crop species diversity.

Ones of the most important biotic constrainers 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) and pests (Meidaner et al., 2012).

Rye is susceptible to a number of pathogens and pests, despite being a significant source of resistance genes for wheat (Zhang et al., 2001; Saulescu et al., 2011).

Actually, genetic resistance is the disease's most cost-efficient and successful control strategy for Leaf rust (LR), but all-stage resistance is often not durable, because new pathogen`s virulent races evolve to overcome this type of resistance (race non-specific resistance) adapting to new environments.

Therefore, additional fungicides used is still remaining an important part of integrated disease management.

Little previous research is reported in controlling pathogens and pests in rye system in dry marginal areas. Therefore, the aim of the study was to evaluate the management of rye-pathogen-pests interactions in dry marginal environments from Southern Oltenia, Romania, using diverse formulations of conventional and biological pesticides.

MATERIALS AND METHODS

During 2020-2021 growing season, a plant-pest-pathogen interaction profile was observed on Suceveana rye genotype using different chemical and biological 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 N80P80K80, 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.

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).

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

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- Poliversum -100 g/300 l water/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

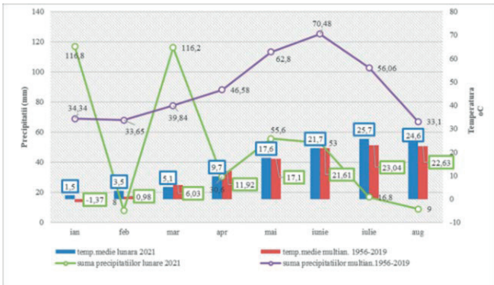
In order to characterize the evolution of climatic parameters (air temperature, rainfall, humidity, wind speed) into the experimental field it was used an automatic weather station (AWS).

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

Sandy soils in the dry south of Romania have insufficient natural resources for the growth of conventional crops, so it is necessary to grow crops that can cope with climate changes effects. Ones of the most suitable crops for these lands are sweet sorghum, sweet potato, rye, triticale, peanuts, cowpea, Jerusalem artichoke (Prioteasa et al., 2018; Prioteasa et al., 2019; Matei et al, 2020a; Matei et al., 2020b; Dima et al., 2021a; Dima et al. 2021b; Drăghici et al., 2021; Matei et al., 2021). During 2019-2020 cropping season favourable climatic conditions led to the infection of rye with *P. recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) and insects attack (*Schizaphis graminum, Eurygaster integriceps, Mayetiola destructor, Chlorops pumilionis*). Humidity was determined by the amount of rain of 406.00 mm, comparatively with multiannual average rainfall of 376.85 mm, while the monthly average temperature was 13.68°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 (2021 year)

During January to August 2021 the monthly average temperature increased up to +0.93°C comparatively with multiannual average temperature for January to August between 1956-2019 for the same geographic area (+12.74°C), while rainfall amount for evaluated period was higher with 29.16 mm than multiannual amount for dry areas in Southern Romania. The rainfalls were higher in January and March, while for all other months the amount was lower than multiannual monthly average, impacting the leaf rust and pest's attack. The symptoms of Leaf rust disease exhibited for the first time at the end of April 2021. 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.

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

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.

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 2).

Figure 2. Pustules with uredospores of *Puccinia recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) (original photo Paraschivu Mirela, 2021)

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; Paraschivu et al., 2022b).

During the cropping season 2020-2021 the most affected variant by the attack of pests and pathogens was a1b1 (control - no treatment).

The results showed that after the 1st applying was applied the incidence of leaf rust severity was low for all fungicides applied comparatively with the control variant (no treatment) (AD =2.64%). There were not find significant differences between the two fungicides applied no matter insecticide combination (Table 4).

Table 4. The influence of the 1st treatment applied for controlling pathogens and insect's attack on rye during 2020-2021 cropping season

Fungi-cide	Insecti-cide	Attack degree the 1st det.- after the first treatment					
		Leaf rust			Insects		
		AD%	Dif. %	Signif	AD%	Dif. %	Signif
Untreated	Control	2.64	Mt		0.92	Mt	
	Decis Expert 100 EC	2.23	0.41	o	0.32	0.6	o
	Bioinsekt	2.37	0.27	o	0.46	0.46	o
	Neemex	2.04	0.6	o	0.60	0.32	
Poliversum -100 g/300 l water/ha	Control	0.98	Mt		0.85	Mt	
	Decis Expert 100 EC	0.65	0.33	o	0.41	0.44	o
	Bioinsekt	0.86	0.12	o	0.32	0.53	o
	Neemex	0.74	0.24	o	0.48	0.37	
Mimox 3 l/ha	Control	1.12	Mt		0.79	Mt	
	Decis Expert 100 EC	0.85	0.27	o	0.28	0.51	o
	Bioinsekt	0.96	0.16	o	0.35	0.44	o
	Neemex	1.06	0.06		0.72	0.07	
	LSD 5%		0.10			0.38	
	LSD 1%		0.45			0.87	
	LSD 0.1%		0.81			1.02	

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

It was observed that Neemex insecticide has a slightly fungicide effect when it was applied alone (AD = 2.04%).

The best protection against leaf rust attack was noticed for Poliversum (AD = 0.65%) and Mimox (AD = 0.85%) mixed with Decis Expert 100 EC when the treatment has done at the beginning of booting stage.

After 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 5).

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 = 0.32%, AD = 1.12%),

When insecticides were mixed with fungicides the best control of the insects was offered by Mimox+Decis Expert 100 EC (AD = 0.28%) for the 1st treatment and Poliversum -100 g/300 l water/ha + Bioinsekt (AD=0.54%) for the 2nd treatment.

Table 5. The influence of the 2nd treatment applied for controlling pathogens and insect's attack on rye during 2020-2021 cropping season

Fungi-cide	Insecti-cide	Attack degree the 2nd det.- after the second treatment					
		Leaf rust			Insects		
		AD%	Dif. %	Signif	AD%	Dif. %	Signif
Untreated	Control	4.76	Mt		2.76	Mt	
	Decis Expert 100 EC	4.12	0.64	oo	1.12	1.64	ooo
	Bioinsekt	3.86	0.9	oo	1.33	1.43	oo
	Neemex	3.62	1.14	oo	2.09	0.67	o
Poliversum -100 g/300 l water/ha	Control	2.03	Mt		2.14	Mt	
	Decis Expert 100 EC	1.57	0.46	o	0.87	1.27	oo
	Bioinsekt	1.42	0.61	o	0.54	1.60	ooo
	Neemex	1.88	0.15		1.25	0.89	o
Mimox 3 l/ha	Control	3.10	Mt		1.86	Mt	
	Decis Expert 100 EC	2.84	0.26		0.97	0.89	o
	Bioinsekt	2.61	0.49	o	0.62	1.24	oo
	Neemex	2.73	0.37	o	1.10	0.76	o
	LSD 5%		0.32			0.51	
	LSD 1%		0.61			1.21	
	LSD 0,1%		1.15			1.45	

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

The highest yields were obtained for the variants with fungicides mixed with Bioinsekt (Poliversum + Bioinsekt = 3533.3 kg/ha and Mimox + Bioinsekt = 3266.7 kg/ha), while among variants treated only with insecticides the highest yield was recorded for Decis Expert 100 EC (2600 kg/ha) and Bioinsekt (2533.3 kg/ha).

Negative high correlations were observed between grain yield and pathogens and insects attack in 2020-2021 cropping season.

These results suggest that the influence of biotic constraints on plants, which reduced the amount of healthy plant tissue available for photosynthesis, decreased the output.

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 = 0.7329) indicated that up to 73% 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 = -0.8561***) (Figure 3).

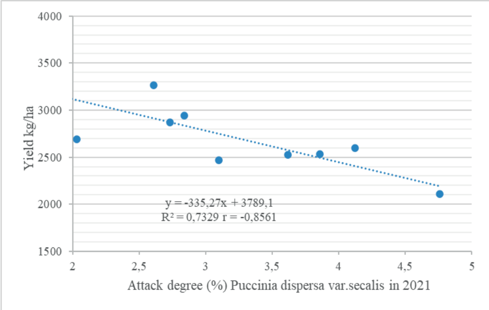


Figure 3. Relationship between Leaf rust severity and rye grain yield in 2020-2021 cropping season

Previous authors reported in Europe high yield losses due to Leaf rust in rye (Roux & Wehling, 2010; Meidaner et al., 2012).

Also, other authors showed that 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)

The results showed that some pathogens and pests tend to become more aggressive even in cropping systems based on crops diversification by minor cereals.

The experiment's findings demonstrate that Leaf Rust is a major disease of rye in arid marginal areas of Romania, and climate variability can cause more outbreaks. The value of determination coefficient (R^2 = 0.745) indicated that up to 74% 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 = -0.8631***) (Figure 4).

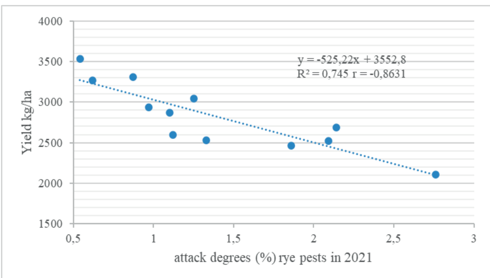


Figure 4. Relationship between insects' attack and rye grain yield in 2020-2021 cropping season

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 2020-2021 cropping season. The increase of monthly temperature with +0.93°C lead to earlier incidence of the disease and insects attack starting even with the third week of April. The best protection against leaf rust was provided by Poliversum -100 g/300 l water/ha + Bioinsekt while the best control against pests was provided by Mimox+Decis Expert 100 EC (AD = 0.28%) for the 1st treatment and Poliversum -100 g/300 l water/ha + Bioinsekt (AD = 0.54%) for the 2nd treatment. 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 = -0.8561***, respectively r = -0.8631***) were found during 2020-2021 cropping season.

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