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REACTION OF WINTER WHEAT GENOTYPES ON THE YELLOW (STRIPE) RUST *PUCCINIA STRIIFORMIS*, WES

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Yellow rust, caused by *Puccinia striiformis* Wes. is one of the most significant diseases constraint to winter wheat production in the world. Since 2011 in Europe have appeared distinct new races – Warrior, Kranich, Warrior (-) that have caused wide epidemics on different cultivars of wheat. Grain yield losses can be prevented by using a combination of varietal resistance and fungicides. Information on wheat variety susceptibility to local yellow (stripe) rust *Puccinia striiformis* Wes. races can help to reduce the risk of yield losses in high disease pressure situations. Field trials with eight most popular and perspective winter wheat varieties in Latvia were established in the North-Western part of Latvia (Stende Research Centre) in autumn of 2016. The trial was designed as two randomized complete blocks (treated and untreated) and data were statistically interpreted. Two applications of fungicides at BBCH 29–32 by T1 (prothioconazol 53 g L^{-1}, spiroxamin 224 g L^{-1}, tebucanazole 148 g L^{-1}) and at BBCH 37-39 – T2 (bixafen 65 g L^{-1}, prothioconazol 130 g L^{-1}, fluopyram 65 g L^{-1}– 1.5 L ha^{-1}) were used to control the YR. Yield and 1000 kernel weight (TKW) were determined. Preliminary results indicated the difference between genotypes resistance/susceptibility to YR. The severity of infection level was 1–80% depending on genotype resistance. Application of fungicides increased grain yield by 2.9 % to 33.0% and TKW by 3.4% – 33.2 % depending on variety. Observations showed the difference in the occurrence of symptoms on YR in different varieties of winter wheat under conditions of 2017 in Stende.

Keywords: yellow rust, yield, TKW, wheat

INTRODUCTION

In recent year´s yellow (stripe) rust (YR) caused by the fungus *Puccinia striiformis* Wes. showed a worldwide distribution occurring in wheat cultivation areas with cool and humid weather conditions causing yield losses. Partly it has been associated with genetical diversity of the fungus. Since 2011 in Europe has appeared several new distinct YR races – Warrior, Kranich, Warrior (-) and others that have caused wide epidemics on different cultivars of wheat. The presence of a new *Puccinia striiformis* (*Pst*) race Warrior/Ambition was first described during 2009/2010 in the United Kingdom, Germany, Denmark, France and Scandinavia. The Warrior/Ambition race has severely affected winter wheat production in recent years (Hansen, 2012). Warrior/Ambition race is virulent for most of the resistance genes and can infected the winter wheat varieties grown all over the world (Chen et al., 2014).

Cool and humid weather conditions promote the spred of YR which is one of the most dangerous wheat leaf disease recently in Latvia. As reported in multiple studies YR can reduce yield up to 50% in untreated crops (Al-Maaroof, 2014; Sharma et al., 2013; Ziyaev et al., 2011). Grain yield losses can be prevented using a combination of varietal resistance and fungicides application. Information of winter wheat variety susceptibility can help to reduce the risk of spread in high disease pressure situations (Hodson, Nazari, 2010).

The aim of the study was to investigate the reaction of different winter wheat genotypes to the local YR population during vegetation period and effect of fungicide treatment on yield and quality traits.

RESEARCH METHODS

Field trial with eight most popular and perspective winter wheat varieties in Latvia (´Fredis´, ´Edvins´, ´Skagen´, ´Olivin´, ´Talsis´, ´Zeppelin´, ´Ceylon´, and ´SW Magnifik´ were set up at second decade of September 2016 in Stende

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Research Centre, Latvia (Stende). Soil characterization: sandy loam soil, containing 1.9 % humus, available phosphorus (P_2O_5) 161 mg kg $^{-1}$ and available potassium (K_2O) 218 mg kg $^{-1}$, pH $_{kcl}$ between 5.3 and 5.6. Before sowing a basic fertilizer NPK 8:20:30 300 kg ha^{-1} was used. In spring 2017 after wheat vegetation resumption additional fertilization with ammonium nitrate (N30+S7) was applied. First time at rate 250 kg ha^{-1} (N75) and the second time 150 kg ha^{-1} (N 40). The trial was designed as two randomized complete blocks (treated and untreated) with plot size 12 m^2 at three replications. The sowing rate was 450 germinated seeds m^{-2}. During the vegetation period two applications of fungicides at rate- 0.6 L ha^{-1}: T1 (prothioconazol 53 g L^{-1}, spiroxamin 224 g L^{-1}, tebucanazole 148 g L^{-1} – 0.6 L ha^{-1}) at BBCH 29-32 and T2 (bixafen 65 g L^{-1}, prothioconazol 130 g L^{-1}, fluopyram 65 g L^{-1}– 1.5 L ha^{-1}) at BBCH 37-39 were used to control the YR.

Severity of the infection level of was assessed visually (%), by using the following scale: 1) 0%, 2) 1%, 3) 5%, 4) 10%, 5) 20%, 6) 30%, 7) 40%, 8) 50%, 9) 60%, 10) 70%, 11) 80%, 12) 90%, 13) 100%. Grain yield was assessed from all plot and corrected for dry matter 14%. Representative samples from each replicate were analysed by using ISTA (International Seed Testing Association) standard methods for thousand kernel weight (TKW).

RESULTS

Meteorological conditions were favourable for development of the YR on 2016/2017. It was positively influenced by a long warm autumn, mild winter and cool, humid summer. The assessment data clearly demonstrated that winter wheat genotypes were differently affected by occurrence of YR symptoms and infection severity. Under meteorological conditions of 2017, occurrence of YR symptoms on winter wheat genotypes was detected several times.
The first symptoms of YR were detected on the earliest winter wheat varieties ´Fredis´ and ´Edvins´ in untreated plots. During the vegetation period susceptibility of winter wheat genotypes were significantly different (Table 1).

Table 1. Severity of the infection level of *Puccinia striiformis*, Wes. Stende, Latvia, 2017

Winter wheat	First assessment 23.05.2017			Second assessment 14.07.2017		
	Growth stage	Infection level,%		Growth stage	Infection level,%	
	BBCH	Treated	Untreated	BBCH	Treated	Untreated
Fredis	57-59	1	80	61-69	5	80
Edvins	57-59	1	70	61-69	5	70
Skagen	41- 49	0	1	51-59	1	5
Olivin	51-55	1	20	51-59	3	30
Talsis	51-55	1	60	51-59	1	60
Zeppelin	51-55	0	1	51-59	1	5
Ceylon	41- 49	0	10	51-59	3	10
SW Magnifik	41- 49	1	70	51-59	5	80
Mean		0.62	39		3	42.5
Min.		0	1		1	5
Max.		1	80		5	80

The first observation showed that infection level of YR was 0-1% in the treated variant (mean 0.62 %). A cool and humid summer prolonged the wheat vegetation period and promoted the YR distribution. The second observation demonstrated that the infection level raised up to 3–5 % in the treated plots and up to 5–80% in untreated. The difference in YR severity level between variants (treated and untreated) and genotypes was found.

Table 2. Grain yield of winter wheat varieties, Stende, Latvia, 2017.

Variety	Yield ha^{-1}				
	Treated		Untreated		Yield increase t ha^{-1} in treated
		± mean		± mean	
Fredis	7.26	-3.24	4.94	-3.52	2.32
Edvins	10.31	-0.19	6.86	-1.6	3.45
Skagen	10.07	-0.43	9.78	+1.32	0.29
Olivin	11.54	+1.04	9.24	+0.78	2.30
Talsis	10.00	-0.50	6.98	-1.48	3.02
Zeppelin	11.76	+1.26	10.84	+2.38	0.92
Ceylon	12.03	+1.53	10.47	+2.01	1.56
SW Magnifik	11.01	+0.51	8.59	+0.13	2.42
Mean	10.50		8.46		2.04
Min.	7.26		4.94		
Max.	12.03		10.84		
	LSD_{05}=0.48		**LSD_{05}=0.63**		**$LSD_{.05}$=0.57**

According to our results, the susceptible to the YR were varieties: ´Fredis´, ´Edvins´, ´Talsis´ and ´SW Magnifik´. Our results indicate that disease tolerant varieties were: ´Skagen´ and ´Zeppelin´ (infection level 0–1% in the treated; more than 5 % in the untreated). Infection level of varieties ´Olivin´ and ´Ceylon´ was 10–20% in the untreated plots and lower than 3% in plots with fungicide treatment what indicates that these are moderately tolerant varieties to YR.

Our data showed that severe YR infection caused significant yield decrease of tested varieties. There was determined yield increased compared to the untreated in ´Edvins´ (+3.45 t ha^{-1}), ´Talsis´ (+3.02 t ha^{-1}), ´SW Magnifik´ (+2.42 t ha^{-1}), ´Fredis´ (+2.32 t ha^{-1}), ´Olivin´ (+2.30 t ha^{-1}), ´Ceylon´ (+1.56 t ha^{-1}) and ´Zeppelin´ (+0.92 t ha^{-1}) (Table 2). Application of fungicides in varieties moderately tolerant to YR gave lower effect on yield increase. A significant effect of the application of fungicides to the tolerant YR variety ´Skagen´ was not recorded (Table 2).

The relative yield losses in untreated plots: ´Edvins´, ´Fredis´ and ´Talsis´: 30 - 33%, ´SW Magnifik´ 22.9%, ´Olivin´ 19.9%, ´Ceylon´ 12.96%, ´Zeppelin´ 7.82% and ´Skagen´ 2.87%.

The results of field trials showed that in untreated plots TKW varied from 33.59 to 54.17 g (mean 42.04 g) and 42.82-54.17 g (mean 47.80 g; +5.76g) in treated plots (Table 3). Susceptible to YR varieties reduced TKW up to 22-25%, while mean TKW decrease in untreated in all genotypes was 12%.

The application of fungicides had a significant effect ($P < 0.001$) on TKW of tested winter wheat varieties. Highest increase of TKW showed susceptible to YR varieties ´Edvins´ (12.45 g) ´Fredis´ (9.63 g) and ´SW Magnifik´ (9.98 g). Lower TKW increase was recorded in varieties ´Zeppelin´ (1.70 g) and ´Skagen´ (2.60 g) (Table 3).

Table 3. TKW of winter wheat varieties, Stende, Latvia, 2017.

Variety	**TKW, g**				
	Treated		**Untreated**		**Increase of TKW, g in treated**
		± mean		**± mean**	
Fredis	43.22	-4.58	33.59	-8.43	9.63
Edvins	49.91	+2.11	37.46	-4.58	12.45
Skagen	54.17	+6.37	51.57	+9.53	2.60
Olivin	42.82	-4.98	38.45	-3.59	4.37
Talsis	49.84	+2.04	42.72	+0.68	7.12
Zeppelin	51.00	+3.20	49.30	+7.26	1.70
Ceylon	48.15	+0.35	43.92	-1.88	4.23
SW Magnifik	43.32	-4.48	39.34	-2.70	9.98
Mean	47.80		42.04		5.76
Min.	42.82		33.59	x	
Max.	54.17		51.57	x	
	LSD_{05}=1.84		*LSD_{05}=1.46*		*LSD_{05}=1.68*

The grain test weight (TW) in winter wheat characterizes its quality. The results showed that from untreated plots grain test weight varied from 74.02 to 83.01 kg L^{-1} (mean 79.38 kg L^{-1}) and 78.85- 82.76 kg L^{-1} (mean 80.60 g; +1.22 kg L^{-1}) in treated (Table 4). Application of fungicides had a significant effect ($P < 0.001$) on TW to susceptible to YR varieties: ´Edvins´ (4.83 kg L^{-1}), ´Fredis´ (4.94 kg L^{-1}), and ´Talsis´ (4.53 kg L^{-1}). The ´Zeppelin´, ´Skagen´, ´Olivin´ and ´Ceylon´ had an opposite reaction - TW was higher in untreated in comparison with treated. Results obtained in current field trial are first-year data and more data are necessary to draw conclusions regarding TW.

Table 4. Grain test weight of winter wheat varieties, Stende, Latvia,2017

Variety	**Grain test weight**				
	Treated		**Unteated**		**Increase of grain test weight, kg L^{-1} in treated**
		±mean		±mean	
Fredis	79.13	-1.47	74.19	-5.19	4.94
Edvins	78.85	-1.75	74.02	-5.36	4.83
Skagen	79.86	-0.74	80.21	+0.83	-0.35
Olivin	80.84	+0.24	81.68	+2.30	-0.84
Talsis	80.78	+0.18	79.25	-0.13	4.53
Zeppelin	82.76	+2.16	83.01	+3.63	-0.25
Ceylon	81.50	+0.90	82.12	+2.74	-0.62
SW Magnifik	81.09	+0.49	80.56	+1.18	0.53
Mean	**80.60**		**79.38**		**1.22**
Min.	**78.85**		**74.02**		
Max.	**82.76**		**83.01**		
	LSD_{05}=0.69		***LSD_{05}=0.69***		***LSD_{05}=0.72***

CONCLUSIONS AND DISCUSSIONS

In the wheat breeding experimental site Stende YR was found episodically on several winter wheat genotypes in 1970–1980. Monitoring of winter wheat in 2010 showed that distribution of YR occurred in most parts of wheat cultivation areas in the North-West regions of Latvia. In mild winters, YR survives on wheat plants affecting it on next season. YR spreads by wind, germinates at low temperatures (7–10°C) and infects wheat crops at a relatively early growth stage. Air temperature 10–15°C and moisture on the leaves are required for infection (Hovmøller, 2002). In Latvia meteorological conditions were suitable for YR development and wide spread of infection was recorded in all wheat growing regions of Latvia in 2015–2016.

Our observations confirm Johnson and Lupton (1987) investigations, about different susceptibility of varieties on the infection of YR. Resistance of variety to YR is determined by a simply inherited major genes and they can be severely attacked by a newly arising physiologic races of the pathogen. Our data in Stende indicate that most popular and perspective winter wheat varieties showed difference between genotypes resistance/susceptibly to YR.

Reaction of different winter wheat genotypes to YR severity show significant grain yield loss and also reduction of TKW. In experiment by Sharma et al (2016), YR reduced grain yield from 24 to 39% and TKW from 16 to 24 %. YR can reduce yield of the susceptible wheat varieties up to 50 % (Rakesh et al., 2014; Sharma et al., 2016). In our study we observed the highest yield loss of 33 % caused by YR infection to ´Edvins´ and lowest for ´Skagen´ – 2.87%.

One of the yield and quality traits and a wheat grading parameter is TKW and TW. TKW of wheat is determined genetically. The environmental conditions such as biotic and abiotic stress factors can affect the size and quality of the grain (Al- Maaroof et al., 2014; Sharma et al., 2013; Ziyaev et al., 2011). The results of the TKW and TW reductions recorded in this study are comparable to other reports (Hodson, 2010, Sharma et al., 2014). Our study demonstrated reduction of TKW by 22–25% in untreated.

Test weight is a measurement which estimate the weight of a specific volume of the grain. The value is influenced by various factors – moisture content, shape of kernels, environmental and soil conditions (Posner, 2009). Investigations in Stende showed that application of fungicides increased TW of winter wheat mean 1.52 %, but for susceptible to YR genotypes – 6.25%.

Based on results of our study we can conclude that application of fungicides controlled disease and increased grain yield and TKW for all tested genotypes. In the same time application of fungicides for tolerant varieties to control only YR is questionable, as significant yield increase was not determined.

Results obtained in current experiments demonstrates a possibility to minimize risk of YR by using resistant/tolerant varieties in integrated disease management strategy for control winter wheat diseases.

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