White oat agronomic performance and cultivar reactions to leaf rust and leaf spot

Sebastião Soares de Oliveira Neto[1], Douglas Mariani Zeffa[2,*], Klever Marcio Antunes Arruda[3] and Carlos Roberto Riede[3]

[1]Faculdade de Ciências Agronômicas (UNESP), Botucatu, São Paulo, Brazil. [2]Universidade Estadual de Maringá (UEM), Maringá, Paraná, Brazil. [3]Instituto Agronômico do Paraná, Londrina, Paraná, Brazil. *Corresponding author, E-mail: douglas.mz@hotmail.com

ABSTRACT

The objective of this work was to evaluate the agronomic performance of white oat cultivars available in the Brazilian market, under distinct environments, to identify genotypes resistant to leaf rust and leaf spot. The study evaluated 22 white oat cultivars originated from several Brazilian breedingprograms. Independent experiments were conducted during the winter crop of 2013 in Londrina and Mauá da Serra, Paraná state, being the cultivars tested under two conditions: with and without the application of fungicides. The incidence of leaf rust, leaf spot, grain yield and hectoliter weight were evaluated. The following cultivars showed genetic resistance to leaf rust: URS Charrua, URS Corona, and URS Guará. Cultivar IPR Afrodite stood out for its high yield and hectoliter weight, with values of 4950 $kg.ha^{-1}$ and 49.6 $kg.hL^{-1}$, respectively, under fungicides application conditions. Cultivar URS Corona remained stable in the two environments, showing less yield reduction and greater resistance to diseases. Cultivars UFFA Gauderia, UPFAFPS Farroupilha, URS Fapa Slava, FAEM Carlasul, URS 21, and URS Taura showed average grain yield over 4000 $kg.ha^{-1}$ with the fungicides use.

Key words: *Avena sativa* L., stability, resistance to diseases.

INTRODUCTION

White oat (*Avena sativa* L.) is a cereal from the *Poaceae* family, originated from Asia and the Middle East, with great national and global importance (De Mori et al., 2012). In recent years, winter crop cultivation areas for this cereal have expanded, mainly due to the potential application of this culture in different ways, as in human and animal consumption (Baier et al., 1988; De Mori et al., 2012; Silva et al., 2015).

In Brazil, oat cultivation is concentrated in the Rio Grande do Sul, Santa Catarina, and Paraná states, having, in recent years, expanded to Mato Grosso do Sul, São Paulo, and Minas Gerais. In the 2016 crop, oat national production was 827.8 thousand tons, in a cultivated area of 296.1 thousand hectares with an average yield of 2840 $kg.ha^{-1}$ (Conab 2017).

In addition to the edaphoclimatic factors, managing the interaction between biotic factors and plant genotypes is considered one of the most limiting factors for yield and grain quality (Yokomizo et al., 2013). In oat culture, leaf rust (*Puccinia coronata* f. sp. *avenae*) is the most important disease, mainly due to its great incidence and severity, occurring in all cultivation regions (Forcelini and Reis 2005). In turn, leaf spot (*Drechslera avenae*) is also a problem whenever oat growing is done by the no-till system and monoculture, causing less expressive damages in relation to leaf rust (Reis and Casa 2007).

The resistant oat cultivars use is the key control measure against leaf rust and leaf spot, since genetic resistance adds no extra costs to the crop and brings no damages to the environment (Nerbass et al., 2010). Therefore, the objective of the present study was to evaluate the agronomic performance of white oat cultivars available in the Brazilian market, under different environments, as well as to identify resistant genotypes to leaf rust and leaf spot.

MATERIALS AND METHODS

Experiments were conducted at Instituto Agronômico do Paraná (IAPAR) experimental station, in Londrina and at Fazenda 3M, located in Mauá da Serra, in 2013 growing season. The IAPAR experimental station in Londrina is located in the northern region of the Paraná State (23º22'S, 51º10'W and altitude of

585 m). The soil is characterized as typical Dystrophic Red Latosol and the region climate is classified as Cfa, according to the Köppen classification. Mauá da Serra is also located in northern Paraná and Fazenda 3M coordinates are 23°58' S and 51°19' W and altitude of 847 m.

For each experiment, the soil was prepared through plowing and slight soil removal, fertilized with 400 $kg.ha^{-1}$ of the commercial formulated 05-20-10 (N-P-K) at seeding. Experiments were displayed in a randomized complete blocks design, with three replications, and set in a subdivided plots scheme, being fungicides application (with or without application) randomized in the plots and, in the sub-plots, the 22 Brazilian white oat cultivars (Table 1). Experimental sub-plots were composed by lines of 5 m, spaced at 0.17 m, with seeding density of 300 $seeds.m^2$. Usable area was constituted by two central lines, eliminating 0.5 m at the extremities.

For the experimental plots that received fungicides, the application was done monthly until the vegetative phase ends, as soon as the first evidences of the disease were detected. The following fungicides were used: Juno® (active ingredient: propiconazole, from the triazole chemical group) (0.5 $L.ha^{-1}$) and Guapo® (active ingredient: resoxim-methyl + epoxiconazole, from the triazoles and strobilurin chemica groups) (0.7 $L.ha^{-1}$). Parcels without chemical poducts applications received no treatment for the incident pests control.

Leaf rust (LR) and Leaf spot (LS) incidence determination was realized through visual observations in the plots in order to estimate the disease incidence percentage in the cultivar. Percentage grades from 0 to 100% were attributed during two distinct readings: the first at flowering stage and the second at physiological maturation, in the plots, with and without pesticides application. In addition, grain yield (YIELD, $kg.ha^{-1}$) and hectoliter weight (HW, $kg.hL^{-1}$) were also determined.

For the variables YIELD and HW, individual analysis of variance ($p<0.05$) to estimate residues associated to the plots and sub-plots and Scott- Knott cluster test ($p<0.05$), were conducted (Scott and Knott 1974). Interaction among factors was unfolded regardless of its significance by the *F* test. Independent Spearman correlation analyses were realized for the Londrina and Mauá da Serra locations, in the presence or absence fungicides application. Data were analyzed by Genes computer program (Cruz 2013).

RESULTS AND DISCUSSION

Table 2 shows the LR and LS incidence evaluations results for the Londrina and Mauá da Serra experiments. The experiment conducted at Mauá da Serra, cultivars UPFPS Farroupilha, IPR Afrodite, FAEM Chiarasul, and FAEM Dilmasul showed the lowest rates for LS, with 5% of disease incidence in the pesticides absence. Under the same conditions, 11 cultivars showed no incidence of LR (UPFA Ouro, UPFA Farroupilha, IPR Afrodite, Brisasul, FAEM Carlasul, FAEM Chiarasul, FAEM Dilmasul, URS Charrua, URS Corona, URS Guará, and URS Brava). For LS, the pesticides use reduced the disease incidence to a maximum of 20%. However, all cultivars showed incidence of this disease. In regards to LR, there was a reduction in the infected cultivars number and in the disease incidence.

The Londrina experiment showed that, cultivars from the plots without fungicides application was an incidence LS incidence, especially URS Charrua (1% of incidence), URS Corona (10%), and URS Guará (10%). In regards to LS, URS Brava showed less disease incidence (10%), considering that the cultivars showed an incidence between 20% and 30%. The fungicides application showed little efficiency in reducing LS incidence. The low efficacy of some chemical molecules currently available in the market to control LS in cereals during the winter has been reported by producers and technicians in the last crops (De Mori et al., 2012). Therefore, the selection process of resistant genotypes realized by breeding programs is extremely important. As for LR, the fungicides application was more efficient, because nine cultivars showed no disease incidence.

Experiments realized in Rio Grande do Sul state, Tragnago et al. (2011) also reported a high incidence of LR in the same cultivars, that showed 80% of incidence during the Londrina experiment (URS Fapa Slava, URS Guapa, URS Taura, and IAC 7), inferring that, these cultivars show high susceptibility to LR. The same authors also observed that URS Charrua and URS Guará cutivars were more resistant, since they showed 1 and 5% of disease incidence, respectively. In the present study, these two cultivars also proved to be LR resistence.

Table 3 shows results for the individual variance analyses for YIELD and HW. In regards to YIELD, the analyses of variance showed significant effects ($p<0.01$) between cultivar and fungicide application, in both locations, indicating that cultivar behavior differential is dependent on the application or non-application of fungicides.

Table 1. Evaluated white oat cultivars and their respective breeding institutions.

Cultivars	Origen
UPFA Gaudéria	Universidade de Passo Fundo
UPFA Ouro	Universidade de Passo Fundo
UPFPS Farroupilha	Universidade de Passo Fundo / Fundação Pró Sementes
IPR Afrodite	Instituto Agronômico do Paraná
URS Fapa Slava	Universidade Federal do Rio Grande do Sul
URS Guria	Universidade Federal do Rio Grande do Sul
URS Charrua	Universidade Federal do Rio Grande do Sul
URS Torena	Universidade Federal do Rio Grande do Sul
URS Corona	Universidade Federal do Rio Grande do Sul
URS Estampa	Universidade Federal do Rio Grande do Sul
URS Guará	Universidade Federal do Rio Grande do Sul
URS Tarimba	Universidade Federal do Rio Grande do Sul
URS Guapa	Universidade Federal do Rio Grande do Sul
URS 21	Universidade Federal do Rio Grande do Sul
IAC 7	Instituto Agronômico de Campinas
FAEM Carlasul	Universidade Federal de Pelotas
FAEM Chiarasul	Universidade Federal de Pelotas
FAEM Dilmasul	Universidade Federal de Pelotas
Barbarasul	Universidade Federal de Pelotas
Brisasul	Universidade Federal de Pelotas

Unfolding of fungicides application inside cultivars (Fung/Cult) showed significant differences in most cultivars for both locations. In Mauá da Serra, cultivars that showed no difference in regards to fungicides application were FAEM Carlasul, FAEM Chiarasul, FAEM Dilmasul, URS 21, URS Tarimba, URS Torena, URS Estampa, URS Guará and, IAC 7. On the other hand, in Londrina, cultivars URS Charrua and URS Guará showed no significant differences.

In regards to HW, the analyses of variance revealed significant effect ($p<0.01$) of the interaction between cultivars and fungicides application only for the Londrina experiment (Table 3). Significant effects ($p<0.01$) were detected in Mauá da Serra only between the evaluated cultivars, with no significant effects of fungicides application. The unfolding of the cultivars versus fungicides application was realized despite the non-significant effect of the interaction detected in Mauá da Serra. According to Barbin (2013), although the interaction was non-significant, many times the unfolding of the degrees of freedom is recommended to detect some significance, which in the mean (interaction) remains diluted. This way, through the unfolding of the fungicides uses inside the cultivars (F/G) in Londrina, it was possible to observe significant differences ($p<0.05$) for UPFA Ouro, URS Fava Slava, URS Guapa, URS Taura, URS Tarimba, IAC 7, UPFA Gauderia, IPR Afrodite, Barbarasul and URS Charrua. In Mauá da Serra, only UPFPS Farroupilha, IPR Afrodite and FAEM Chiarasul showed significant effects ($p<0.01$).

Means clustering through the Skott and Knott (1974) test for the YIELD and HW traits, during the Londrina and Mauá da Serra trials is shown in Figure 1. In Mauá da Serra experiment, the YIELD average for cultivars with fungicides application was 4095 $kg.ha^{-1}$ compared to the 3773 $kg.ha^{-1}$ for the cultivars with no fungicides application. IPR Afrodite, URS Fapa Slava, Brisasul, URS Taura and URS Corona stood out from the others for showing the highest YIELD in the presence and absence of fungicides (Figure 1a). Silva et al. (2015) observed similar results for these same cultivars.

In Londrina, YIELD average for fungicides applications cultivars was 3745 $kg.ha^{-1}$ and 2376 $kg.ha^{-1}$ for those that received no fungicides applications. Cultivars UPFPS Farroupilha, IPR Afrodite, FAEM Carlasul,

URS 21 and URS Corona sttod out for showing the highest averages in the presence and absence of fungicides (Figure 1b). URS Charrua and IAC 7 were below the general average of trials with and without fungicides application. Yield reduction in this case can be associated with the high diseases incidence such as LR, which, according to Nerbass et al. (2010), grain yield reduces by 57 to 62% in susceptible cultivars.

Table 2. Leaf rust (LR) and Leaf spot (LS) incidence in white oat cultivars, without fungicides (-F) and with fungicides (+F).

Cultivars	Londrina				Mauá da Serra			
	LR		LS		LR		LS	
	-F	+F	-F	+F	-F	+F	-F	+F
	---------- % ----------				---------- % ----------			
UPFA Gauderia	40	0	30	10	5	1	20	10
UPFA Ouro	30	1	20	10	0	0	10	2
UPFPS Farroupilha	30	0	30	10	0	0	5	5
IPR Afrodite	30	1	30	20	0	1	5	10
URS Fapa Slava	80	5	30	20	30	1	30	10
Barbarasul	50	5	30	20	5	2	20	5
Brisasul	40	0	20	20	0	0	20	10
FAEM Carlasul	40	0	30	20	0	0	10	5
FAEM Chiarasul	40	0	20	20	0	0	5	2
FAEM Dilmasul	50	0	20	20	0	0	5	5
URS 21	40	0	30	20	1	5	20	5
URS Guapa	80	20	30	30	40	10	40	10
URS Taura	80	10	20	20	5	0	30	10
URS Tarimba	50	10	30	20	1	0	20	10
URS Guria	40	1	30	20	1	0	10	2
URS Charrua	1	0	20	20	0	0	10	5
URS Torena	50	5	20	20	5	0	20	10
URS Corona	5	0	30	20	0	5	20	10
URS Estampa	60	10	30	30	5	0	30	5
URS Guará	5	5	30	20	0	0	10	20
URS Brava	40	10	10	10	0	0	30	20
IAC 7	80	20	30	30	40	5	40	20

In regards to HW, the average for Mauá da Serra cultivars with or without fungicides application was 49.3 $kg.hL^{-1}$. IPR Afrodite, Barbarasul, FAEM Chiarasul, URS Estampa, URS Guara, and URS Brava stood out for their highest averages in the fungicides presence and absence (Figure 1c). In Londrina, HW average for cultivars was 43.9 and 45.5 $kg.hL^{-1}$ in the fungicides presence and absence, respectively. Cultivars IPR Afrodite, Barbarasul, FAEM Chiarasul, URS Estampa, and URS Guará stood out for their highest averages in fungicides presence and absence (Figure 1d). Among them, cultivar IPR Afrodite has stood out in several cultivars competition experiments (Riede et al., 2015).

The Spearman correlation analyses (Table 4), showed positive correlations (r=0.75) between LS × LR in Mauá da Serra in the fungicides absence. In Londrina, variables LS × LR also showed positive correations (r=0.43); however, under fungicides application conditions. In the fungicides absence, positive correlations were verified between YIELD × HW (r=0.63) and negative, between YIELD × LR (r=-0.80) and HW × LR (-0.62).

Caierão et al. (2001) verified the influence of LR severity levels on white oar yield and negative correlations between both variables (r=-0.34; p<0.01), indicating that the increase in LR incidence, influences white oat yield negatively under the fungicides absence.

Table 3. Summary of the individual variance for grain yield (YIELD, kg.ha^{-1}) and hectoliter weight (HW, kg.hL^{-1}) in experiments conducted in Londrina and Mauá da Serra during the 2013 crop season.

Variation	DF	Mean Square			
		Londrina		Mauá da Serra	
		YIELD	HW	YIELD	HW
Blocks	2	35678.6	1.10	92277.8	0.27
Genotype (G)	21	355505.3 **[1]	21.58 **	435057.4 **	24.85 **
Fungicides (F)	1	15477575.6 **	78.66 *	851212.1 **	1.82 ns
G x F	21	225711.0 **	11.95 **	53768.0 **	4.80 ns
G/F	42	290608.2 **	16.76 **	244412.7 **	14.83 **
G/F (With Fungicides)	21	248369.4 **	13.98 **	257538.6 **	14.62 **
G/F (Without Fungicides)	21	332846.9 **	19.54 **	231286.8 **	15.04 **
F/G	22	918977.6 **	14.98 **	90015.5 **	4.67 ns
F/UPFA Gauderia	1	1881600.0 **	14.41 *	48600.0 **	0.17 ns
F/UPFA Ouro	1	281666.6 **	35.04 **	585937.5 **	0.37 ns
F/ UPFPS Farroupilha	1	676704.1 **	0.37 ns	26666.6 **	5.04 **
F/IPR Afrodite	1	976066.6 **	16.00 *	144150.0 **	7.48 **
F/URS Fava Slava	1	4125104.1 **	21.28 **	117600.0 **	0.88 ns
F/Barbarasul	1	1041666.6 **	13.20 *	70416.6 **	1.21 ns
F/Brisasul	1	498816.6 **	5.41 ns	147266.6 ns	6.41 ns
F/FAEM Carlasul	1	624037.5 **	1.70 ns	3037.5 ns	6.41 ns
F/FAEM Chiarasul	1	362604.6 **	2.16 ns	18150.0 ns	26.04 **
F/FAEM Dilmasul	1	558150.0 **	0.04 ns	66.6 ns	10.93 ns
F/URS 21	1	920416.7 **	0.01 ns	704.1 **	6.41 ns
F/URS Guapa	1	2747266.7 **	69.36 **	281666.6 **	10.14 ns
F/URS Taura	1	1372816.6 **	53.40 **	142604.6 ns	0.81 ns
F/URS Tarimba	1	680066.6 **	21.28 **	5400.0 **	0.88 ns
F/URS Guria	1	437400.0 ns	20.90 **	68266.6 **	0.43 ns
F/URS Charrua	1	337.5 **	11.76 *	234037.5 ns	5.41 ns
F/URS Torena	1	317400.0 **	0.06 ns	150.0 **	2.28 ns
F/URS Corona	1	510416.6 **	1.40 ns	48600.0 ns	0.42 ns
F/URS Estampa	1	745537.5 ns	7.48 ns	600.0 ns	0.54 ns
F/URS Guará	1	33750.0 **	0.00 ns	150.0 **	4.00 ns
F/URS Brava	1	350416.6 **	0.16 ns	33004.1 ns	0.06 ns
F/IAC 7	1	1075266.6 **	34.08 **	3266.6 **	6.40 ns
Residue	86	32163.4	2.77	26414.4	4.67
Total	131				
Mean		1530.30	44.71	1967.0	49.27
Coefficient of variation		11.72	3.72	8.26	4.39

[1] ns non significant; **/* significant at 1 and 5% level of significance, respectively, by the F test.

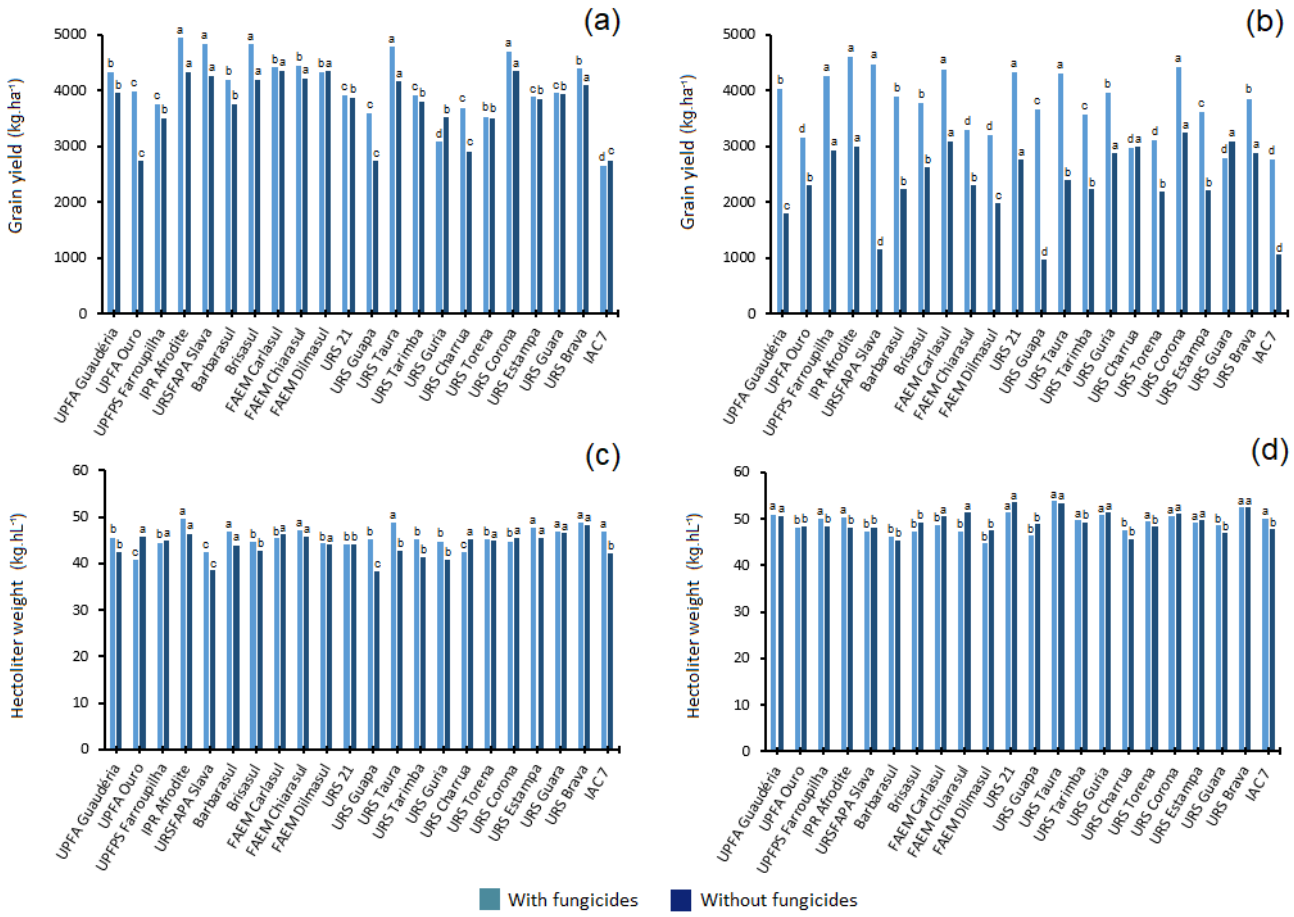

Figure 1. Teste de Scott e Knott (1974) test for grain yield traits (kg.ha^{-1}) and hectoliter weight (kg.hL^{-1}) of 22 white oat cultivars conducted in Londrina [(a) and (b), respectively], and Mauá da Serra [(c) and (d), respectively] in 2013. For the same condition (with or without fungicides application), genotype means with the same letters belong to the same group by the Scott Knott test (1974) at 5% of significance.

Table 4. Spearman correlations estimates between grain yield traits (YIELD), hectoliter weight (HW), leaf rust (LR) incidence, and Leaf spot (LS) incidence evaluated in white oat cultivars in Londrina and Mauá da Serra under the presence (upper diagonal) and absence of fungicides applications (lower diagonal).

Trait	Mauá da Serra			
	YIELD	HW	LR	LS
YIELD	1.00	-0.04 ^{ns}	-0.02 ^{ns}	0.13 ^{ns}
HW	0.25 ^{ns1}	1.00	0.04 ^{ns}	0.28 ^{ns}
LR	-0.38 ^{ns}	-0.04 ^{ns}	1.00	0.27 ^{ns}
LS	-0.23 ^{ns}	0.19 ^{ns}	0.75 **	1.00
Trait	Londrina			
	YIELD	HW	LR	LS
YIELD	1.00	0.04 ^{ns}	-0.25 ^{ns}	-0.20 ^{ns}
HW	0.63 **	1.00	0.16 ^{ns}	0.22 ^{ns}
LR	-0.80 **	-0.62**	1.00	0.43 *
LS	-0.01 ^{ns}	-0.29 ^{ns}	0.07 ^{ns}	1.00

[1] ^{ns} non significant; **/* significant at 1 and 5% of significance , respectively, by the t test.

CONCLUSIONS

Cultivars URS Charrua, URS Corona and URS Guará showed genetic resistance to leaf rust.

Cultivar IPR Afrodite stood out for its high yields and hectoliter weight, mainly during fungicides application.

In the absence of fungicides treatment, cultivar URS Corona remained stable in both environments, showing low grain yield reduction.

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