

Sowing date reduces the incidence of wheat blast disease

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Abstract – The objective of this work was to assess the effect of sowing date on the intensity of wheat blast disease, as well as the yield losses caused by this disease in different wheat (*Triticum aestivum*) genotypes. The experiments were conducted in 2013 at the Sertãozinho experimental station of Empresa de Pesquisa Agropecuária de Minas Gerais (Epamig), in the municipality of Patos de Minas, in the state of Minas Gerais, Brazil. Fourteen wheat genotypes and two sowing dates were evaluated. The experimental design was a randomized complete block with three replicates. The evaluated variables were: incidence, severity, thousand grain weight (TGW), grain yield, and yield losses. A disease index (DI) was calculated, based both on the incidence and the severity of the disease, to measure blast intensity in wheat. The sowing date significantly affected DI, TGW, and grain yield. Significant linear correlations were observed between DI and yield losses (0.89), between losses and TGW (-0.85), and between losses and grain yield (-0.93). For wheat blast, DIs greater than or equal to 0.5 indicate potential yield losses equal to or greater than 70%. The EP063030 line and the MGS Brilhante and BRS 264 cultivars are the most tolerant to blast, when exposed to high disease pressure.

Index terms: *Magnaporthe oryzae*, *Pyricularia oryzae*, *Triticum aestivum*, disease index, severity, tolerance.

Época de semeadura reduz a incidência da brusone do trigo

Resumo – O objetivo deste trabalho foi avaliar o efeito da época de semeadura sobre a intensidade da brusone, bem como as perdas na produtividade causada por essa doença em genótipos de trigo (*Triticum aestivum*). Os experimentos foram conduzidos, em 2013, na Fazenda Experimental de Sertãozinho da Empresa de Pesquisa Agropecuária de Minas Gerais (Epamig), em Patos de Minas, MG. Catorze genótipos de trigo e duas datas de semeadura foram avaliados. Utilizou-se o delineamento experimental de blocos ao acaso com três repetições. As variáveis avaliadas foram: incidência, severidade, peso de mil grãos (PMG), rendimento de grãos e perdas de produtividade. Calculou-se o índice da doença (ID), com base tanto na incidência quanto na severidade, para medir a intensidade da brusone em trigo. A data de semeadura afetou significativamente ID, PMG e rendimento de grãos. Houve forte correlação linear entre ID e danos (0,89), entre danos e PMG (-0,85) e entre danos e rendimento (-0,93). Para a brusone do trigo, IDs iguais ou maiores que 0,5 indicam potencial de danos de rendimento iguais ou superiores a 70%. A linhagem EP063030 e as cultivares MGS Brilhante e BRS 264 são as mais tolerantes à brusone quando expostas à alta intensidade da doença.

Termos para indexação: *Magnaporthe oryzae*, *Pyricularia oryzae*, *Triticum aestivum*, índice da doença, severidade, tolerância.

Introduction

Magnaporthe oryzae (anamorph *Pyricularia oryzae*) (Couch & Kohn, 2002) was first described infecting wheat (*Triticum aestivum* L.) spikes in the state of Paraná, Brazil, in 1985 (Igarashi et al., 1986). The symptoms of blast disease or “brusone”, caused by this pathogen, are lesions of different sizes and

shapes, usually elliptical with grey centers, produced under favorable environmental conditions. These symptoms may occur on all aerial wheat tissues, such as leaves, stems, spikes, rachises, and, in later stages of the disease, turn the infected spikes bleached (discolored). On the rachis, the pathogen produces a dark and brilliant lesion that indicates the penetration site, which is the infection point (Lau et al., 2011).

When grains are produced, those located above the infection point are deformed with low specific weights, and the losses in yield caused by wheat blast depend on the time of infection and on the affected plant organ (Goulart et al., 2007).

Infected seeds do not show disease symptoms and, therefore, provide the initial inoculum to new areas in which wheat is cultivated (Toledo & Escobar, 2002). Airborne conidia are one of the most important means of dissemination (Urashima et al., 2007). After spore attachment to the plant surface, the spore germinates, the germ tube differentiates into an appressorium, and the appressorium is used to penetrate host tissues. The production of macroscopic lesions occurs within a 4–5 days after penetration (Ribot et al., 2008).

The best strategy to manage wheat blast disease is to combine cultivar resistance with appropriate agronomic practices (Urashima et al., 2004). The use of genetic resistance to control plant diseases is well known as the most sustainable approach; however, few wheat cultivars are resistant to the blast fungus. In experiments with 72 isolates of *P. oryzae* and 20 wheat varieties, BR-18 Terena was the only one that showed broad-spectrum resistance (Urashima et al., 2004). Furthermore, under controlled conditions, spikes from different wheat genotypes showed variable reaction to blast (Arruda et al., 2005; Prestes et al., 2007). It should also be noted that, for the wheat producing regions in which blast frequently occurs, most of the cultivars currently recommended are susceptible to the pathogen under field conditions.

Among the fungicides recommended for wheat, products for the efficient control of wheat blast are not available, and, based on the results of studies conducted in 1990 and 1991, at most, 39% of the disease is controlled by fungicides (Goulart & Paiva, 1993). Moreover, Urashima & Kato (1994) found that sprayed applications of fungicides provided good protection in the vegetative stage but not at heading. Therefore, wheat blast is currently difficult to control.

The incidence and intensity of the disease are strongly influenced by environmental factors, particularly temperature and humidity (Cardoso et al., 2008). In tropical regions, such as the municipality of Patos de Minas, in the state of Minas Gerais, Brazil, blast was extremely aggressive for wheat sown on dates from February to March in recent years. This period is the beginning of that recommended for the

sowing of wheat, which extends from February 1st to 28th for rainfed wheat and from April 11th to May 31st for irrigated wheat (Sislegis, 2013). The potential for yield losses caused by blast disease is generally lower for wheat sown in May than for wheat sown earlier. However, regardless of the sowing date, the susceptibility of different wheat genotypes is variable under field conditions. Goulart et al. (2007) assessed yield losses caused by blast in 20 cultivars and lines of wheat in two different locations and found that the losses were genotype- and site-dependent.

Historically, the major producer of wheat in Brazil is the southern region. However, this production has not been sufficient to meet the entire domestic consumption requirement. In recent decades, the tropical regions of the country have shown great potential for wheat cultivation, with productivity exceeding 7,000 kg per hectare (Fronza et al., 2007). However, in the past few years, specifically in these regions, wheat blast has caused significant losses, and, as a result, research has increased to identify genotypes that are resistant to the pathogen or that are tolerant to the disease.

The objective of this work was to assess the effect of sowing date on the intensity of wheat blast disease, as well as the yield losses caused by this disease in different wheat (*Triticum aestivum*) genotypes.

Materials and Methods

Two experiments were conducted at the Sertãozinho experimental station of Empresa de Pesquisa Agropecuária de Minas Gerais (Epamig) in the municipality of Patos de Minas, in the state of Minas Gerais, Brazil. Experiment one was sown on March 4th, and the other experiment was sown on May 17th, 2013, hereinafter, season 1 and season 2, respectively. The wheat genotypes evaluated were ten lines introduced from the International Maize and Wheat Improvement Center (CIMMYT): EP062043, EP063030, EP063044, EP063053, EP063065, EP063134, EP064021, EP064026, EP066055, and EP066066; and four cultivars: BRS 264, CD 108, MGS1 Aliança, and MGS Brilhante. The 5.0-m² experimental plots consisted of five rows that were 5.0 m long and spaced 20 cm apart. The useful area per plot was 2.4 m² and included the three central rows, with the elimination of 1.0 m at each end line. The fertilizer (80 kg N as urea) for planting was added based on soil analyses, and was

applied on April 8th and June 20th, at 35 and 34 days after sowing, in seasons 1 and 2, respectively. The wheat was irrigated every 7 days at a 10-mm depth. The experiments were harvested from the 7th to the 17th of June, in season 1, and from the 5th to the 15th of September, in season 2.

Both experiments were sown in a randomized complete block design, with three replicates and 14 treatments (genotypes). The evaluated variables were: incidence, severity, thousand grain weight (TGW), grain yield, and yield losses. For each genotype, 100 spikes were randomly collected from the useful area per plot. Blast disease incidence was obtained by counting the number of bleached spikes among the 100 spikes collected, whereas severity was estimated by visual inspection of the collected spikes to determine the percentage discolored with blast disease. Based on these data, a disease index (DI) was calculated with the formula: [(percentage of blast incidence/100) × (percentage of blast severity/100)], as proposed for Fusarium head blight (FHB), another important disease of wheat spikes (Zhang et al., 2008). Yield losses were estimated by the difference between the productivity of season 2, with low blast incidence, and the productivity of season 1, with high blast incidence, for each wheat genotype.

Statistical analyses were performed using the SAEG software (Universidade Federal de Viçosa, Viçosa, MG, Brazil). The variables DI, TGW, and grain yield were subjected to analysis of variance, and data on yield losses were subjected to analysis considering only season 1. Because of its importance to the study, the significance of the interaction terms was examined. The means for yield of each genotype were compared

with Tukey's test, at 5% probability, and the means for genotype yields within a season were compared with the Scott-Knott test, also at 5% probability.

Results and Discussion

The interaction between genotype and season was significant for most parameters, i.e., DI, TGW, and grain yield, in both seasons, and the differences were significant among treatments (genotypes) for yield losses only in season 1 (Table 1).

In season 2, the incidence of blast was much lower than in season 1 (Table 2). The severity of the disease was significantly different between seasons 1 and 2 only for the EP064026, EP063044, and EP063065 lines. Because the incidence levels were lower in season 2 than in season 1, TGW and grain yield increased significantly. However, for severity, a similar tendency was not observed. Therefore, depending on the wheat genotype, a significant correlation between disease parameters (incidence and severity) was not apparent. To account for the variation between these disease parameters, a DI was proposed, which is also used by other groups investigating diseases of wheat (Zhang et al., 2008).

According to Cruz et al. (2009), the following conditions are favorable for the development of the disease: high precipitation, temperatures between 24 and 28°C, cloudy days, and high relative humidity. These authors found that the incidence of the disease advanced during two seasons with spray irrigation. In the present study, in season 1, sown in March, heading began on April 16th and harvest was done on June 17th, and, considering all genotypes, the period

Table 1. Joint analysis of variance of main effects and interactions for disease index (DI), thousand grain weight (TGW) and grain yield, as well as analysis of variance of potential yield losses caused by head blast for different wheat (*Triticum aestivum*) genotypes.

Source of variation	Df	Mean square of season 1 and 2 ⁽¹⁾			Df	Mean square of season 1
		DI	TGW	Grain yield		Yield losses
Replicate/Season	4	0.0051**	20.20	565,398.00	2	1,134,498
Genotype (G)	13	0.0245**	35.40**	751,641.00**	13	322,216*
Season (S)	1	3.8200**	3536.00**	200,000,000.0**	-	-
G x S interaction	13	0.0212**	17.90**	161,108.00*	-	-
Error	52	0.0027**	5.32	82,147.00	26	117,005
Estimated mean		0.2700**	33.07	2,775.00		3,087
CV (%)		19.00**	6.97	10.30		11.1

⁽¹⁾Season 1, sowing date on March 4th, 2013; and season 2, sowing date on May 17th, 2013. * and **Significant by the F test, at 5 and 1% probability, respectively.

of highest susceptibility of the wheat spikes to fungal infection occurred from April 16th to June 8th. During this period, the monthly mean minimum temperatures were above 14°C, the monthly maximums above 27°C, and the monthly mean relative humidity above 68%. In season 2, heading began after July 7th and the crop was harvested on September 15th. For season 2, the period of greatest susceptibility of the wheat spikes to fungal infection occurred from July 7th to August 29th, when the monthly mean minimum temperatures were below 14°C, the monthly maximums above 27°C, and the monthly mean relative humidity below 60%. According to these data, the mean maximum temperatures did not affect the incidence of blast disease. However, mean minimum temperatures below 14°C and relative humidity less than 60% did

Table 2. Average blast incidence, blast severity, thousand grain weight (TGW), and grain yield for different wheat (*Triticum aestivum*) genotypes sown on March 4th (season 1) and on May 17th, 2013 (season 2)⁽¹⁾.

Genotype	Season	Incidence (%)	Severity (%)	TGW (g)	Grain yield (kg ha ⁻¹)
EP064026	1	77.3a	73.3a	25.5b	754b
	2	12.7b	36.7b	37.8a	3,805a
EP063030	1	60.3a	63.3a	26.7b	1,310b
	2	11.3b	63.3a	40.3a	4,106a
EP066055	1	62.3a	70.0a	24.6b	1,298b
	2	13.7b	43.3a	34.9a	4,216a
EP063044	1	85.0a	73.3a	24.0b	908b
	2	17.0b	40.0b	37.5a	3,414a
MGS Brillhante	1	73.0a	70.0a	27.2b	1,133b
	2	14.7b	56.7a	33.9a	4,066a
EP064021	1	60.7a	56.7a	29.3b	1,521b
	2	11.7b	36.7a	38.8a	4,126a
BRS 264	1	66.0a	53.3a	29.0b	1,580b
	2	9.0b	63.3a	39.9a	5,113a
EP063065	1	84.7a	76.7a	24.2b	1,036b
	2	14.6b	30.0b	39.7a	4,148a
EP062043	1	79.0a	66.7a	25.8b	1,338b
	2	9.3b	43.3a	44.7a	4,636a
EP063134	1	79.7a	70.0a	24.3b	1,157b
	2	14.7b	56.7a	37.8a	4,149a
MGS1 Aliança	1	70.7a	70.0a	26.0b	1,292b
	2	11.3b	53.3a	42.7a	4,387a
EP063053	1	66.0a	50.0a	29.9b	1,511b
	2	8.0b	60.0a	38.9a	4,933a
CD 108	1	65.7a	53.3a	31.9b	1,531b
	2	8.7b	43.3a	46.0a	5,108a
EP066066	1	89.3a	76.7a	23.8b	870b
	2	13.7b	60.0a	41.1a	5,245a

⁽¹⁾Means followed by equal letters, for each cultivar, do not differ by Tukey's test, at 5% probability.

contribute to a reduction in the incidence of the disease in wheat. Alves & Fernandes (2006) highlighted that the production of conidia of *P. oryzae* is favored when the relative humidity is high (>90%) and the temperature is approximately 28°C.

In season 1, two distinct groups of wheat genotypes, based on TGW and grain yield, were identified (Table 3). Using the DI, the 14 evaluated genotypes were separated into three groups. The genotypes with high TGWs (EP064026, EP063030, EP066055, and EP063044) were included in the group of genotypes with high yields and low DIs, being considered the most tolerant to blast. This variability in the reaction to blast disease among wheat cultivars and lines has also been reported in other studies (Goulart et al., 2007; Prestes et al., 2007). Under controlled conditions, no cultivar was resistant to all tested isolates of *P. oryzae*, but cultivars did have different degrees of resistance to pathogen inoculation (Urashima et al., 2004; Prestes et al., 2007). In the present study, the highest DIs in season 1 – 0.625, 0.651, and 0.685, respectively (Table 3) – were observed for the CD 108 cultivar and the EP063053 and EP066066 lines. These genotypes were the most susceptible to the pathogen at the time of greatest incidence of the disease and, therefore, had lower TGWs and grain yields.

Table 3. Average disease index (DI), thousand grain weight (TGW), grain yield, and potential yield losses for different wheat (*Triticum aestivum*) genotypes sown on March 4th, 2013 (season 1)⁽¹⁾.

Genotype	DI	TWG (g)	Grain yield (kg ha ⁻¹)	Yield losses ⁽²⁾	
				(kg ha ⁻¹)	(%)
EP064026	0.330c	29.9a	1,511a	3,422a	69.4
EP063030	0.345c	29.3a	1,521a	2,605b	62.8
EP066055	0.349c	31.9a	1,531a	3,577a	69.9
EP063044	0.351c	29.0a	1,580a	3,533a	69.1
MGS Brillhante	0.422c	26.7b	1,310a	2,796b	68.1
EP064021	0.493b	26.0b	1,292a	3,095b	70.0
BRS 264	0.395c	24.6b	1,298a	2,918b	69.3
EP063065	0.524b	25.8b	1,338a	3,298a	71.1
EP062043	0.511b	27.2b	1,133b	2,933b	72.0
EP063134	0.557b	24.3b	1,557b	2,992b	72.2
MGS1 Aliança	0.569b	25.5b	754b	3,052b	80.1
EP063053	0.651a	24.2b	1,036b	3,112b	74.6
CD 108	0.625a	24.0b	908b	2,506b	73.3
EP066066	0.685a	23.8b	870b	3,375a	79.4

⁽¹⁾Means followed by equal letters, in the columns, belong to the same group by the Scott-Knott test, at 5% probability. ⁽²⁾Yield losses = ((season 2 grain yield - season 1 grain yield)/ season 2 grain yield)100 (see Table 3).

Based on the yield losses caused by blast disease, the genotypes were grouped into two distinct groups (Table 3). The losses of wheat genotypes were independent of TGW, grain yield, and DI. High losses (group A), were observed for the genotypes with a low DI (EP066055, EP063044, and EP064026 lines) but also for the EP066066 and EP063065 lines, which showed the highest and an intermediate DI of 0.685 and of 0.524, respectively. Plants that are disease tolerant produce good yields even when infected by pathogens (Barrett et al., 2009; Newton et al., 2010); therefore, it was inferred that the EP066055, EP063044, and EP064026 lines had little tolerance to blast disease. The group of genotypes with the lowest DI (group c), had yield losses less than 70%. Among the 14 evaluated genotypes, the EP063030 line stands out, since it was grouped among the genotypes with the highest TGWs and grain yields, and had low DI (0.345) and yield losses (2,605 kg ha⁻¹, 62.8%).

Generally, in the literature, a reduction in grain yield is caused by an increase in disease intensity (Trindade et al., 2006; Goulart et al., 2007). In the present study, the different DIs and agronomic parameters under high blast disease pressure reflected in variability in the resistance and tolerance of the evaluated wheat genotypes. Besides the EP063030 line, the MGS Brilhante and BRS 264 cultivars also had low DIs and, therefore, greater resistance to the pathogen, being among the most tolerant due to reduced yield losses under high blast disease pressure (Table 3).

In the evaluation of data from the 14 genotypes and the two sowing seasons, all parameters (TGW, grain yield, DI, and yield losses) showed significant linear correlations ($r > 0.85$; Table 4). TGW and grain yield had a high positive correlation coefficient (0.91), which was explained by the influence of the diseased grains on the final weights from the plots.

The DI was negatively correlated with both TGW and grain yield (-0.89 and -0.92, respectively). In the present study, this index was proposed to assess the intensity of the disease, in which blast incidence was multiplied by blast severity for each genotype. For panicle rice blast, disease incidence is directly correlated with the severity of the disease and with yield losses (Agrios, 1988). In a previous study, a highly significant correlation occurred between the incidence and the severity of wheat blast on spikes (Arruda et al., 2005). Goulart et al. (2007) found a reduction in yield

losses caused by the disease, depending on the location of the point of necrosis caused by *P. oryzae* along the rachis. These authors also observed compensation for the reduction in weight of infected grains with the better development of grains below the necrosis point on the wheat rachis.

The incidence of a disease is more quickly and easily measured than the severity, and the determination of incidence is also generally more accurate, precise, and reproducible than that of severity (Madden et al., 2007; Copes & Stevenson, 2008). By contrast, severity is more important and useful as a measure of the intensity of a disease in assays of plant performance and yield losses to determine the effectiveness of management strategies (Madden et al., 2007). For other pathosystems, the relation between incidence and severity varies according to the genotype (Dillard & Seem, 1990; De Wolf et al., 2003; Saude et al., 2014). In addition, the estimation of mean severity from incidence is more precise at low levels of severity (Obanor et al., 2005; Paul et al., 2005). Although there is no consensus on how to quantify blast in wheat, based on this information, an index of blast disease (DI) was calculated in the present study, considering both the incidence and the severity of the disease, in which a high DI reflected in reductions in TGW and grain yield. Strong correlations were found between losses caused by the disease and TGW and grain yield, and between losses and the DI (Table 4). The correlation was negative between losses and TGW (-0.85) and grain yield (-0.93), and was positive between yield losses and the DI (0.89). For a DI greater than or equal to 0.5, the expected yield losses caused by wheat blast are equal to or greater than 70%. Based on these thresholds, TGW and grain yield were significantly reduced in response to blast.

Table 4. Coefficients of Pearson's correlation between thousand grain weight (TGW), grain yield, disease index, and potential yield losses caused by blast disease in different wheat (*Triticum aestivum*) genotypes sown on March 4th, 2013 (season 1).

	TGW	Grain yield	Disease index	Yield losses
TGW	-	0.91**	-0.89**	-0.85**
Grain yield		-	-0.92**	0.93**
Disease index			-	0.89**
Yield losses				-

**Significant by the F test, at 1% probability.

Among the lines and cultivars evaluated, different levels of tolerance to the pathogen were observed. However, none of the genotypes were resistant to the disease, which indicated that further studies are required to identify resistant genotypes.

Conclusions

1. The interaction between wheat (*Triticum aestivum*) genotypes and sowing dates is significant for thousand grain weight, yield, and the wheat blast disease index.

2. There is a positive correlation between yield losses and the wheat blast disease index.

3. The reaction among the wheat genotypes is variable to blast disease.

4. The EP063030 line and the MGS Brilhante and BRS 264 cultivars are the most tolerant to *Pyricularia oryzae* under high blast disease pressure.

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