Crop Protection 106 (2018) 201–209

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Breadmaking quality and yield response to the green leaf area duration caused by fluxapyroxad under three nitrogen rates in wheat affected with tan spot

María Constanza Fleitas[a,b,*], Matías Schierenbeck[a,b], Guillermo Sebastián Gerard[a,b], Juan Ignacio Dietz[a,b], Silvina Inés Golik[a], María Rosa Simón[a,c]

[a] Cerealicultura, Facultad de Ciencias Agrarias y Forestales, Universidad Nacional de La Plata, La Plata (1900), Buenos Aires, Argentina
[b] CONICET CCT La Plata, La Plata (1900), Buenos Aires, Argentina
[c] CIC, La Plata (1900), Buenos Aires, Argentina

ARTICLE INFO

Keywords:
Wheat breadmaking quality
Green leaf area duration
Fungicides
Nitrogen fertilization
Tan spot

ABSTRACT

Tan spot caused by the necrotroph pathogen *Pyrenophora tritici-repentis* (Died.) Drechs. [anamorph *Drechslera tritici-repentis*) (Died.) Shoem] causes reductions in yield and grain quality of wheat (*Triticum aestivum* L.) by affecting the photosynthetically active area of the crop which could affect grain protein content (GPC) and breadmaking parameters. Nitrogen (N) fertilization is required for achieving high yields and quality in wheat but can exert a profound effect on disease development and fungicide efficacy. The active ingredient fluxapyroxad, belonging to the carboxamides chemical group, not only control fungal pathogens and reduce disease progression but also, might increase green leaf area duration of the crop. We evaluated the effect of fungicide applications containing a carboxamide, in a mixture with triazole and strobilurin (TSC), above a double-mixture (triazole and strobilurin) (TS) under three N rates, on tan spot severity, healthy area duration (HAD), flag leaf healthy area duration (FLHAD) and grain yield. We also assessed its impact on GPC, wet gluten content, loaf volume and dough rheological parameters in wheat. Two field experiments were conducted during 2014 and 2015 in a split-split plot design with three fungicide treatments as main plots and three N fertilization rates as sub-plots using a susceptible cultivar (Baguette 11, Nidera). Treatment TSC significantly reduced the area under disease progress curve (AUDPC) and this was associated with increased HAD and FLHAD resulting in higher yields when compared to the TS treatment and the untreated control. The AUDPC values were lower with higher N rates in the untreated plots. The GPC and wet gluten content increased in untreated plots under 0 kg N ha^{-1} and 70 kg N ha^{-1} rate and was reduced following fungicide applications, however, this was reverted with the maximum N rate (140 kg N ha^{-1}). Increases in GPC and wet gluten content in the untreated plots did not improve loaf volume and breadmaking parameters of wheat which only enhanced following fungicide application and N fertilization.

1. Introduction

Tan spot caused by the necrotroph pathogen *Pyrenophora tritici-repentis* (Died.) Drechs. [anamorph *Drechslera tritici-repentis*) (Died.) Shoem] is a key foliar disease of wheat (*Triticum aestivum* L.) in Argentina and in many wheat production areas in the world, causing yield and quality reductions in this crop (Schierenbeck et al., 2016). The increasing importance of the disease has been attributed to the use of susceptible cultivars under conservation tillage systems, shorter crop rotations and continuous wheat cultivation that leads to inoculum increments (Moreno et al., 2012). Symptoms include well-defined necrotic blotching, often surrounded by yellow halos (Lamari and Bernier, 1991), through the secretion of toxins and cell wall degrading enzymes (Ney et al., 2013). According to Boote et al. (1983), *Py. tritici-repentis* is classified as "light stealer" because the pathogen not only stops carbon uptake in the affected areas, but also, interfere with photosynthesis in other leaves by intercepting light before it reaches those leaves. Thus, tan spot may cause grain shrivelling which are undesirable because they are associated with low flour extraction rates in milling (Rose et al., 2001). Some studies have hypothesized that other impacts on wheat quality might be increases in grain protein content (GPC) given a much larger effect of the pathogen on carbon

* Corresponding author. Cerealicultura, Facultad de Ciencias Agrarias y Forestales, Universidad Nacional de La Plata, La Plata (1900), Buenos Aires, Argentina.
E-mail address: constanzafleitas@gmail.com (M.C. Fleitas).

https://doi.org/10.1016/j.cropro.2018.01.004
Received 16 March 2017; Received in revised form 4 November 2017; Accepted 3 January 2018
0261-2194/

accumulation than on nitrogen (N) accumulation (Dimmock and Gooding, 2002). This same response has been confirmed in several studies focused on Septoria leaf blotch caused by the hemibiotrophic fungus *Zymoseptoria tritici* (formerly *Mycosphaerella graminicola*) (Mc Kendry et al., 1995; Rodrigo et al., 2015; Castro and Simón, 2016), but there is very little information considering the necrotic pathogen *Py. tritici-repentis*. In fact, in an important review (Dimmock and Gooding, 2002) regarding the influence of foliar diseases and their control by fungicides on GPC in wheat, from the thirty-six reports from North America, Australia, Africa and Europe, only one (Rees et al., 1982) corresponded to tan spot, which tended to decrease GPC under fungicide applications. Contrary, in the same review, the control of Septoria leaf blotch by fungicides caused increases, decreases or had no effects on GPC, probably due to the hemibiotrophic conditions of the pathogen. Therefore, it would be expected that the effect of tan spot on GPC be more consistent, given that Septoria leaf blotch is considered a hemibiotrophic, whilst tan spot is a pure necrotroph.

On the other hand, N fertilization is required for achieving high yields but is particularly important in wheat as the content and composition of the grain proteins determine the suitability and quality for producing bread and other food products (Godfrey et al., 2010). However, N fertilization may also influence the development of foliar diseases such as tan spot and the effectiveness of fungicide applications. Few studies have been carried out so far to investigate the effect of N on the severity of the disease. Increased N fertilization has been reported to decrease tan spot severity (Krupinsky et al., 2007; Carignano et al., 2008; Simón et al., 2011; Gerard et al., 2015).

In Argentina, the most common fungicides used to control foliar fungal diseases of wheat are triazoles [a Quinone Outside Inhibitor (QoI)], strobilurins [a Demethylation Inhibitor (DMI)] and more recently, carboxamides [a Succinate Dehydrogenase Inhibitor (SDHI)]. Yield increases attributed to the application of certain fungicides such as strobilurins have been observed in wheat and have been reported to be greater than those arising purely from fungicidal properties of the product (Koehle et al., 2002). Gerhard (2001) reported that the application of strobilurins not only prevented the fungal disease but also, had a direct effect on plant physiology inducing an increase in assimilation intensity, optimize transpiration and improve water use efficiency as well, compared with other fungicides. Recent studies have shown that similar to strobilurins, the yield increase in a crop treated with a carboxamide is often greater than the explained simply through good disease control. Evidence collected by Smith et al. (2013) from across multiple trials suggested that, in addition to controlling visible disease symptoms, the SDHI fluxapyroxad could exert positive physiological effects on the plant including increased leaf greening, delayed senescence, reduced cell damage, reduced stomatal conductance, improved photosynthetic rate and increased water use efficiency. Similarly, Berdugo et al. (2012) verified that another SDHI (bixafen), delayed senescence of spikes and leaves in spring wheat during grain filling by enhancing physiological activities leading to increased grain yield. However, this evidence has been obtained under greenhouse conditions which differ from field environments since plants do not grow as communities under fluctuating environmental conditions. Extending canopy life would be of great importance to moderns high-yielding cultivars that have become terminally source-limited and this aspect could be improved with fungicide use (Pepler et al., 2005).

Despite the positive influence of fungicides on grain yield and milling quality, there are concerns that substantial yield gains may compromise GPC, with the suggestion that protein levels might be diluted by additional carbohydrate production which in turn, could affect breadmaking quality. Concerns are heightened by the recent introduction and widespread use of carboxamides which offers unprecedented levels of disease control, delays in senescence and yield responses. Grain yield has often been found to be negatively associated with GPC, but this relation is not true for a single genotype because N supply and irrigation strongly influence the relation between grain yield and GPC (Fischer et al., 1993). In this sense, some authors have suggested that when *Z. tritici* is the dominant pathogen, the use of fungicides can reduce GPC, however, such losses can be diminished or eliminated through application of foliar urea during grain filling (Dimmock and Gooding, 2002). Nevertheless, no information is available regarding this situation when *Py. tritici-repentis* is the main pathogen controlled.

There are many articles covering the effect of foliar diseases on breadmaking parameters of wheat such as Septoria leaf blotch or leaf rust caused by the biotroph *Puccinia triticina* Eriks. However, most of these studies have been carried out under natural infections where the effect of the pathogen type cannot be distinguished individually. In addition, the majority of them, have assessed the disease through the area under disease progress curve (AUDPC) which does not provide aspects related to crop canopy size, limiting the extrapolation to a wide range of genotypes, environments, years and locations. Moreover, the effect of fungicides containing triazoles and their combination with strobilurins on GPC and breadmaking quality parameters have been extensively studied (Ruske et al., 2003; Wang et al., 2004; Castro, 2016). However, there is no evidence of the effect of a fungicide treatment containing the SDHI fluxapyroxad.

From the above said, the aim of this study was to evaluate the influence of adding the SDHI fluxapyroxad (carboxamide) to a triazole-strobilurin combination under three N fertilization rates on the progress of tan spot, healthy area duration, flag leaf healthy area duration and its effect on grain yield, GPC and breadmaking parameters of wheat.

2. Materials and methods

2.1. Field trials and experimental design

Two field experiments were conducted under artificial inoculations at the J. Hirschhorn Experimental Station, Faculty of Agricultural and Forestry Sciences, National University of La Plata, Argentina; during 2014 and 2015. The trials were sown on July 28 and June 16 respectively under conventional tillage. The soil was a typic Argiudoll, analysis of the soil samples indicated the following mean values by weight in each year: (i) top-0.20 m, organic matter: 3.59%; N: 0.20%; N-NO_3: 10,4 ppm; P: 28.3 ppm and pH: 5.8; (ii) 0.20–0.40 m, N-NO_3: 5.1 ppm and pH: 6.0. Weather data (monthly precipitation; relative humidity and minimum, maximum and mean temperatures) were recorded at a Davis Meteorological Station located 100 m from the experiments.

The experimental design was a split-split plot with three replications. Within every year, main plots were the fungicide treatments and sub-plots were the N rates applied as granulated urea (Table 1). The genotype used in the experiments was Baguette Premium 11 (Nidera), moderately susceptible to tan spot (according to the information provided by the breeder) and classified in the Argentinean breadmaking quality grade as quality group 2 which corresponds to traditional breadmaking cultivars suitable for major long fermentations (higher than eight hours) (Steffolani et al., 2007). Each sub-subplot was 7.7 m^2 (5.5 m long × 1.4 m wide). The experiments were fertilized with 50 kg P_2O_5 ha^{-1} as calcium triple superphosphate at sowing. Glyphosate (2 L ha^{-1}) was used for weed control 15 days before sowing. In addition, Misil® herbicide [(metsulfuron methyl, dry flowable 60% + Dicamba (Dimethylamine 2-Metoxi-3,6 diclorobenzoic acid) soluble liquid 57.1%, Dupont, Rosario, Argentina)] at 100 cm^3 Dicamba + 6.7 g metsulfuron methyl in 120 L water ha^{-1} was applied at the three-leaf stage (GS 13).

2.2. Fungicide applications and inoculation

Fungicides were applied at tillering (GS 23) and at flag leaf (GS 39) using an application rate of 140 L ha^{-1}. The experiment was inoculated at the beginning of tillering (GS 21) and at the beginning of shoot development (GS 31) with a mixture of virulent isolates of *Py. tritici-repentis* grown on V8® media at 23 °C ± 2 °C with 12 h alternating light