Crop Protection 90 (2016) 66–76

Contents lists available at ScienceDirect

Crop Protection

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

Effect of tolerance to Septoria tritici blotch on grain yield, yield components and grain quality in Argentinean wheat cultivars

Ana Carolina Castro [a,*], María Rosa Simón [b]

[a] National University of La Plata, Council for Scientific and Technological Research (CONICET), Faculty of Agriculture and Forestry Sciences, Cereals, 60 y 119., CC 31, 1900 La Plata, Argentina

[b] National University of La Plata, Faculty of Agriculture and Forestry Sciences-Cereals, 60 y 119., CC 31, 1900 La Plata, Argentina

ARTICLE INFO

Article history:
Received 25 April 2015
Received in revised form
13 August 2016
Accepted 19 August 2016

Keywords:
Wheat
Zymoseptoria tritici
Tolerance
Grain yield
Grain protein concentration
Gluten concentration

ABSTRACT

Septoria tritici blotch (STB) caused by *Zymoseptoria tritici* (*Mycosphaerella graminicola*) is a major disease of wheat worldwide due to significant losses in grain yield and quality. Disease tolerance is the ability to maintain yield performance in the presence of disease symptoms. Therefore, it could be a useful tool in the management of the disease. Although it is known, that there is disease tolerance to STB in some wheat cultivars, this aspect has not been studied among Argentinean cultivars. The aims of this study were to evaluate genotypic differences in tolerance to STB among Argentinean cultivars, considering the relationship between the area under disease progress curve or the green leaf area or the non-green leaf area duration with the grain yield. In addition the effect of the disease on yield, yield components, test weight, grain protein concentration, wet and dry gluten concentration and the influence of tolerance on these traits was investigated. Field experiments were carried out with ten cultivars in a split-split-plot design during 2010 and 2011. Inoculation treatments were the main plots and cultivars, the subplots. STB significantly reduced grain yield, their components, test weight and increase grain protein and gluten concentration. Cultivar Baguette 10 showed major tolerance to STB, indicated by a consistent low regression slope between the green area duration and yield, while Klein Chaja was non-tolerant due to a high regression slope. However, many cultivars such as Buck Brasil, Buck 75 Aniversario, Klein Escorpion and Klein Flecha had considerably similar regression slopes to Baguette 10, provided good levels of tolerance. Other cultivars presented no significant differences. The correlation coefficient between tolerance and grain yield potential was not significant, suggesting that tolerant high-yielding cultivars can be obtained. No relationship was found between quality group or tolerance with the increase in protein and gluten concentration due to STB either.

1. Introduction

Bread wheat (*Triticum aestivum* L.) is a major cereal crop grown in most regions of the globe due to its importance as a food source, and its enormous genetic variability in phenological response to photoperiod and temperature, including vernalization (Slafer and Rawson, 1994). Foliar diseases are among factors that reduce yield and quality in wheat crops in the Argentinean Pampas (Annone et al., 2001) and in many other regions around the world characterized by mild climate and high rainfall conditions during the growing season. Septoria tritici blotch (STB) caused by *Zymoseptoria tritici* (Desm.) (teleomorph: *Mycosphaerella graminicola* (Fuckel) J. Schröt. in Cohn) is one of the most important diseases worldwide because of yield reduction and quality loss (Gilbert and Tekauz, 1990, 1992; Bailey et al., 1993; Rodrigo et al., 2015). Severe infections can cause losses of up to 60% of total yield (Arraiano et al., 2001). In Argentina, Annone et al. (1991) and Simón et al. (2002) reported yield losses from 20 to 50%, and Simón et al. (1996, 2002) found reductions in thousand kernel weights (TKW) up to 22%.

Breeding for resistance to STB is complicated by variability of the pathogen, partly caused by the presence of both asexual and sexual reproduction (Simón et al., 2012), and because of a large effective population size and substantial gene flow (Zhan and McDonald, 2004). These traits enable an adaptation to the host resistance (Mundt et al., 1999; Mundt, 2002) and fungicides (Torriani et al., 2009; Cools and Fraaije, 2013). A continuous increase in azole resistance has been reported in European populations of *Zymoseptoria tritici* during the last 10–15 years, as it has also been observed to quinone-outside inhibitors (strobilurins) (Estep et al.,

* Corresponding author.
E-mail addresses: ingeniera.anacastro@gmail.com (A.C. Castro), mrsimon@agro.unlp.edu.ar (M.R. Simón).

http://dx.doi.org/10.1016/j.cropro.2016.08.015
0261-2194/

2015). Consequently, STB tolerance could be a useful tool in the management of the disease. Tolerance is a quantitative trait, and its expression depends on both the genotype and the environment (Parker et al., 2004). It has been demonstrated that there is disease tolerance in some wheat cultivars (Ziv and Eyal, 1978), although progress towards understanding and exploiting the mechanisms that confer tolerance has been slow (Parker et al., 2004) due to the wide and inconsistent use of the term tolerance and the practical difficulties in quantifying it. Many authors have defined tolerance maintaining multiple interpretations (Schafer, 1971) (Clarke, 1984; Parker et al., 2004; Foulkes et al., 2006). Tolerance to STB has not been studied in Argentinean wheat cultivars until now, which in this study is considered, as the ability to maintain yield performance in the presence of disease symptoms (Foulkes et al., 2006).

In spite of the fact that tolerance has been quantified from the slope of the relationship between area under disease progress curve (AUDPC) and grain yield (GY) (Kramer et al., 1980; Inglese and Paul, 2006), this approach provides no information on the absolute size of the canopy, which is likely to differ between sites and seasons and hence affects the remaining area of functional healthy tissue.

Damage functions, which quantify the relationship between injuries and yield loss (Zadoks, 1985), can be determined experimentally. Statistical models of disease-induced yield loss based on absolute measurements of green leaf area duration (GLAD) or light interception have shown to be more robust across sites and seasons than those based on percentage AUDPC or non-green leaf area index (NGLAI) scores (Johnson, 1987; Waggoner and Berger, 1987; Madden and Nutter, 1995; Bryson et al., 1997). Tolerance of several wheat varieties to STB has been quantified as the slope of the relationship between GLAD and GY across treatments of contrasting disease pressure within each cultivar (Parker et al., 2004; Paveley et al., 2005; Foulkes et al., 2006).

Statistical models provide information about the relationship between AUDPC or GLAD with GY under specific conditions. However, simulation models can obtain information about the effect of wheat diseases on mechanisms of biomass generation and its influence on GY, even though they need validation. Damage function can be determined from crop loss simulation models, because they represent processes that are underpinned by subprocesses: damage mechanisms. Different mechanisms can usually be described (Rabbinge and Rijsdijk, 1981; Boote et al., 1983; Rabbinge et al., 1989), in relation to the nutritional habit of the pathogens. WHEATPEST is a simulation model developed in order to simulate yield losses caused by pests (diseases, insects, weeds), individually or in combination, under a range of production situations (Willocquet et al., 2008; Savary and Willocquet, 2014). The WHEATPEST simulation model has incorporated damage functions to simulate the effects caused by *Zymoseptoria tritici* on yield.

Furthermore, tolerance against STB in wheat could have an impact on other variables such as the parameters of wheat quality due to a lower reduction in yield. The STB influence on grain proteins has received little attention despite the fact that these proteins are important in determining the quality and end use of the grain (Shewry and Halford, 2002). Nutritional strategies of pathogens produce different effects on the physiology of crops and thus influence grain protein concentration (GPC) and both wet (WGC) and dry gluten concentration (DGC).

Dimmock and Gooding (2002) observed that when classic biotrophs are controlled, the concentration of grain protein often increases. Therefore, the pathogen has a more damaging effect on the accumulation and partitioning of nitrogen to the grain than it does on the accumulation and partitioning of the dry matter. GPC is often reduced with infection by rusts and, therefore, increased by methods adopted to control rusts (Phipps, 1938; Keed and White, 1970; Clare et al., 1990). On the other hand, Myram and Kelly (1981), Penny et al. (1983) found that the use of fungicide reduces GPC, indicating that the pathogen increases it.

Conversely, most reports of the effect of controlling necrotrophic pathogens as *Drechslera tritici repentis* or hemibiotrophic pathogens (becomes necrotrophic after an initial biotrophic phase) such as *Zymoseptoria tritici* found that fungicide use is associated with a reduction in protein concentration, thus the pathogen increases it (Rees et al., 1982; Ishikawa et al., 2001; Ruske et al., 2001). However, Puppala et al. (1998) reported large increases in protein concentration following fungicide use on a cultivar specifically bred for high protein concentration. Thus, it is reasonable to suppose that cultivars specially bred for bread making may be able to maintain grain nitrogen accumulation more effectively as senescence is delayed and yield increases compared with cultivars for biscuits where protein concentration is much less important (Dimmock and Gooding, 2002). This indicates that Argentinean wheat cultivars belonging to a high quality group could have less reduction in quality variables when affected by STB. The hypothesis of this work is that there is tolerance to STB among wheat cultivars cropped in Argentina and that the STB infection leads to losses in GY and increased protein and gluten concentration.

The aims of the present study are: 1-to evaluate genotypic differences in tolerance to STB tested taking into account the relationship between the AUDPC, GLAD and NGLAD with the GY; 2-to test the effect of the disease on GY, yield components, TW (test weight), GPC, WGC and DWC; and 3-to investigate if tolerance and the quality group of the wheat cultivars can influence these traits.

2. Materials and methods

2.1. Field trials and experimental design

Two experiments were conducted at the Experimental Station Julio Hirschhorn in La Plata, Faculty of Agricultural and Forestry Sciences, National University of La Plata during 2010 and 2011. The trials were sown on 15 July and 16 June respectively under conventional tillage. The soil was a Typic Argiudoll. Analysis of the soil samples (top-0.20 m) indicated the following values by weight: organic matter: 3.55%, N: 0.139%, P: 15 ppm, pH: 5.75. Weather data were recorded at a meteorological station situated 100 m from the experiments.

The experimental design was a split-split-plot design with three replications. Main plots were the inoculum concentrations: 1-Non-inoculated treatment (NI), 2-Low concentration (LC) (5×10^5 spores ml^{-1} suspension) and 3-High concentration (HC) (5×10^6 spores ml^{-1}suspension). Sub-plots were the cultivars: Klein Zorro (K. Zorro), Buck 75 Aniversario (B.75 Aniversario), Buck Brasil (B. Brasil), Buck Guapo (B. Guapo) (all of them belonging to quality group 1, G1), Klein Escorpion (K. Escorpion), Klein Flecha (K. Flecha), ACA 801 and Relmo Centinela (R. Centinela) (G2), Nidera Baguette 10 (Bag 10) and Klein Chaja (K. Chaja) (G3). In Argentina, the Committee of Winter Grain classifies wheat cultivars into three groups, GC 1 corresponds to the highest quality cultivars, suitable for industrial bread making, GC 2 includes traditional bread making cultivars suitable for major long fermentations higher than eight hours, while GC 3 includes cultivars with the lowest quality with short fermentation times up to eight hours (PRONACATRI, 2006). Between the main plots, plots of oats were sown to diminish interplot interferences (James et al., 1973). The entire experiment was fertilized with 50 kg P_2O_5 ha^{-1} as calcium triple superphosphate plus 100 kg ha^{-1} N as urea at the time of sowing and 80 kg ha^{-1} at the end of tillering.

2.2. Inoculum preparation

A mix of virulent isolates (FALP14707, FALP20107-FALP20207,