Crop Protection 103 (2018) 103–110

Contents lists available at ScienceDirect

Crop Protection

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

Evaluation of foliar fungicide programs in mid-Atlantic winter wheat production systems

Phillip N. Sylvester [a, *], Nathan M. Kleczewski [a, b]

[a] University of Delaware, Cooperative Extension Service, 113 Townsend Hall, Newark, DE 19716, USA
[b] University of Delaware, Department of Plant and Soil Sciences, 152 Townsend Hall, Newark, 19716, USA

ARTICLE INFO

Article history:
Received 19 July 2017
Received in revised form
18 September 2017
Accepted 22 September 2017
Available online 9 October 2017

Keywords:
Stagonospora
Disease
Grain quality
Pesticide
NDVI
Fungus
Residue

ABSTRACT

Foliar fungicides are commonly used to manage foliar fungal diseases of soft-red winter wheat (SRWW) grown in the mid-Atlantic region, but data on the overall performance and utility of various products and application timings on yield and quality is lacking. Eight replicated experiments were conducted in Delaware and Maryland in 2015 and 2016 to evaluate the effects of 13 fungicide programs, consisting of five commercially-available fungicides applied at flag leaf emergence ([Zadoks growth stage (ZGS) 37], anthesis (ZGS 60), or in two-pass programs with the first application at green-up (ZGS 30) followed by applications at either ZGS 37 or ZGS 60, for utility on naturally occurring foliar diseases on the flag leaf and head, yield, and test weight compared to an untreated check. All fungicide programs reduced disease severity on the flag leaf and resulted in higher test weight and yield compared to the untreated check. Foliar disease on the flag leaf and glume blotch were best managed with ZGS 60 applications. Two-pass programs (ZGS 30 + ZGS 37 or ZGS 30 + ZGS 60) did not result in significantly lower disease severity compared to single applications at ZGS 37 or ZGS 60. Yield was highest within the ZGS 30 + ZGS 60 timing, and while significant, increases were small, ranging from 111 to 198 kg ha^{-1}. Within a given application timing, Priaxor® (ZGS 37), Quilt Xcel® (ZGS 30 + ZGS 37), and Quilt Xcel® (ZGS 30) + Prosaro® (ZGS 60) provided the greatest yields. This information will help guide Integrated Disease Management (IDM) systems in the mid-Atlantic region and assist growers in avoiding unnecessary fungicide applications in SRWW.

1. Introduction

In the United States, wheat (*Triticum aestivum* L.) is grown on nearly 17.8 million ha and valued at over $9 billion (NASS, February 2017, September 2016). In Delaware and Maryland, soft-red winter wheat (SRWW) is an important rotational crop planted in the fall after grain corn, soybean, or high-value processing vegetable crops, and is grown on 174 thousand ha with an average yield of 4300 kg ha^{-1} valued at over $78 million (NASS, February 2017, September 2016). SRWW is an important part of the agricultural economy in the mid-Atlantic, as it is used to supply the large flour-mill industry in the region, particularly in Pennsylvania (NASS, May 2017).

The health of the photosynthetic tissues including the head, flag leaf, flag leaf sheath, and sheath above the flag-leaf are critical for wheat yield, as they contribute approximately 95% of the carbohydrates for grain fill (Lupton, 1972). Diseases affecting the foliage and head of wheat can reduce photosynthetic area and grain fill; impacting both yield and test weight (Milus, 1994; Milus and Chalkley, 1997). In the mid-Atlantic, leaf blotch complex (LBC), including the residue-borne diseases Stagonospora nodorum blotch (*Parastagonospora nodorum* (Berk.) Quaedvlieg, Verkley & Crous), Septoria tritici blotch (*Zymoseptoria tritici* (Desm.) Quaedvlieg & Crous), and tan spot (*Pyrenophora tritici-repentis* (Died.) Drechsler), is the most common foliar disease encountered in grower fields. A major reason for this is the recent shift towards no-till and conservation tillage in the region (Mehra et al., 2015; Schuh, 1990). LBC may result in yield reductions between 20 and 48% when they reach the flag leaf or above (Bergstrom, 2010; McMullen, 2010; Wegulo et al., 2009). However, yield impacts of

* Corresponding author. 69 Transportation Circle, Dover, DE 19901, USA.
E-mail address: phillip@udel.edu (P.N. Sylvester).

https://doi.org/10.1016/j.cropro.2017.09.012

LBC in the mid-Atlantic are not well established, and evidence suggests that these diseases do not reach these tissues until later in the growing season, potentially limiting their overall yield impact (Grybauskas and Reed, 2011; Kleczewski, 2017a, b). Other foliar diseases such as powdery mildew (*Blumeria graminis* (DC.) Speer.), leaf rust (*Puccinia triticina* Erikss.), and stripe rust (*Puccinia striiformis* Westend.) may occasionally impact yield and grain quality in the mid-Atlantic (Bowen et al., 1991; Cowger et al., 2016a; Green et al., 2014). Fungal diseases affecting wheat heads include Stagonospora glume blotch (*Parastagonospora nodorum*) and Fusarium head blight (FHB) (*Fusarium graminearum* Schwabe). In addition to causing significant yield losses, the pathogen that causes FHB infections also produces mycotoxins, which are toxic to livestock and humans (Payros et al., 2016).

Fungicides are one component of Integrated Disease Management (IDM) used by growers to protect the flag leaf and head from fungal diseases (Kelley, 2001). Traditionally, fungicides are applied between flag leaf emergence (ZGS 37) and heading (ZGS 45) (Willyerd et al., 2015). However, threats to regional wheat production by FHB and glume blotch have forced growers to re-evaluate fungicide application timings. The use of a fungicide application for FHB management, which needs to occur within 5–6 days after the start of ZGS 60, has become more common (D'Angelo et al., 2014; Wegulo et al., 2011). Although several studies have examined the impact of ZGS 60 applications for FHB control in manipulated experimental settings, none have evaluated the utility of this timing for overall control of foliar disease and yield in typical, mid-Atlantic production setting. In addition, many producers include a fungicide early in the season at greenup (ZGS 30) as insurance against the early onset of foliar diseases. Fungicide applications at ZGS 30 will not provide protection of the flag leaf and head and therefore, are combined with an application at ZGS 37 or ZGS 60. These sequential fungicide application programs have not been adequately assessed for their utility and yield compared to standard, ZGS 37 applications in mid-Atlantic wheat production systems. In addition, although there has been some research addressing sequential applications of fungicides for foliar diseases of wheat in other parts of the United States (Wegulo et al., 2009; Willyerd et al., 2015), to our knowledge, the use of a ZGS 60 fungicide application in sequential fungicides programs has not been thoroughly evaluated in the mid-Atlantic region.

Growers have many choices when it comes to selecting a fungicide product. However, the majority of fungicides used in small grain production contain active ingredients belonging to the triazole (Fungicide Resistance Action Committee (FRAC) group 3), strobilurin (FRAC group 11), SDHI (FRAC group 7) classes, or combinations thereof. In the mid-Atlantic states of Virginia and North Carolina, Weisz et al. (2011) analyzed fungicides programs containing active ingredients belonging to the triazole or strobilurin class and found the yield response to a fungicide to be highly variable, ranging from 1680 kg ha^{-1} to −540 kg ha^{-1}, with a mean response of 310 kg ha^{-1}. Our data will contribute to this research by conducting a planned experiment, using a commercially available, moderately resistant variety, with commonly encountered fungicides used in the mid-Atlantic at specific timings. A better understanding of how fungicide timing in relation to the product used is essential in promoting wheat production while potentially avoiding unneeded application costs and environmental impact.

The goals of this project were to 1) evaluate the utility of commonly used fungicides for managing foliar diseases in the mid-Atlantic, 2) determine if sequential fungicide programs are more efficacious than a single fungicide application at ZGS 37 or ZGS 60 for management of fungal diseases of the foliage and the head, and 3) determine the impact of fungicide applications at ZGS 60 for foliar disease control, grain quality, and yield. To address these questions, we conducted a replicated field study across eight sites and two years.

2. Materials and methods

2.1. Field experiments

Trials were conducted at four sites in 2015 and 2016 as described in Table 1. The experimental design was a randomized complete block (RCB) with six replications. The SRWW variety 'Growmark FS815' was planted at a rate of 4.4 × 10^6 seeds ha^{-1} with no-till drills. FS815 was selected because it represents a commercially available, high yielding variety planted throughout the region (University of Delaware, 2012–2014; University of Maryland, 2012–2014). The variety is characterized by medium maturity, with average test weight and height, and moderately resistant to leaf rust, powdery mildew, and LBC (Kleczewski, 2013, 2014a). Plots were similar in size though varied with equipment (Table 1). Untreated border rows between adjacent plots and at plot ends were used at all sites. Fields with typical crop rotations of the region were selected to provide a broad range of residue and conditions (Table 1). Standard nutrient management and pest management practices were followed for each state (Coale, 2010; Curran et al., 2016; Shober et al., 2017). In addition to rainfall, irrigation was used at three sites in 2015 (5.1 cm at GT15, 7.2 cm at FT15, and 14.4 cm at HB15) and two sites in 2016 (3.6 cm at HB16, 3.8 cm at GT16) ensuring some disease.

2.2. Fungicide programs

Thirteen fungicide programs, consisting of five fungicides and three timings, were evaluated according to Table 2. The fungicides tested were propiconazole (Tilt®, Syngenta Crop Protection, Greensboro, NC), azoxystrobin + propiconazole (Quilt Xcel®, Syngenta Crop Protection, Greensboro, NC), fluxapyroxad + pyraclostrobin (Priaxor®, BASF Corporation, Research Triangle Park, NC), prothioconazole + trifloxystrobin (Stratego® YLD, Bayer CropScience, Research Triangle Park, NC), and prothioconazole + tebuconazole (Prosaro® 421SC, Bayer Crop Science, Research Triangle Park, NC). The fungicides tested represented commonly used products in the region and differed in initial cost and mode of action. Fungicide application timings tested included Zadoks Growth Stage (ZGS) 37/39 (flag leaf emergence), ZGS 60 (flowering) and split applications at ZGS 30 (leaf sheaths strongly erect) followed by either ZGS 37 or ZGS 60 (Table 2). ZGS 30 applications are used because growers believe they may reduce yield losses due to early season disease development; however, these programs have not been adequately tested in this region. ZGS 37 applications are used to protect the flag leaf from foliar diseases but provide limited protection of the glumes, sheath, or flowering head. The use of ZGS 60 applications are the newest fungicide application timing used in the region. This timing enables suppression of Fusarium head blight (FHB) and glume blotch, and also can protect the flag leaves, sheath, and glumes from other late-season foliar diseases (Kleczewski, 2014b, c, d; 2017a, b).

All fungicide treatments included 0.125% of a nonionic surfactant (Induce®, Helena Chm. Company, Collierville, TN). Treatments were applied using a CO_2 pressurized backpack sprayer (R&D Sprayers, Opelousas, LA) and offset handheld boom equipped with three XR8002 flat fan nozzles (TeeJet Technologies, Wheaton, IL) spaced 50.8 cm apart. Treatments were made at a spray pressure of 234 kPA to deliver 187 liters ha^{-1} of spray solution.