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Assessing the utility of the growth regulator trinexapac-ethyl and fungicides in mid-Atlantic soft red winter wheat production systems

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ABSTRACT

Soft red winter wheat (SRWW) is an important crop in the mid-Atlantic. The use of growth regulators such as trinexapac-ethyl (TE) applied with nitrogen applications at pseudo-stem erection [Zadocks (ZGS) 30] has gained more interest in the region as a means to reduce lodging and potentially improve yields. Fungicide use has also increased, with many growers applying fungicides at ZGS 30 and again at ZGS 37 or ZGS 60. The safety and utility of TE in SRWW production systems, used alone or in combination with fungicides, is unknown. We evaluated the utility and safety of TE, applied alone, tank mixed with a fungicide at ZGS 30, and in combination with a foliar fungicide at ZGS 37 or ZGS 60 for utility and safety in mid-Atlantic SRWW. Three replicated field experiments were conducted over two growing seasons in Delaware, and yield, test weight, and disease severity on the flag leaf, were assessed. No phytotoxicity was noted in any of the TE or TE x fungicide treatments tested. TE applied alone reduced plant height by nearly 7 cm, but the application of fungicide at ZGS 37 or 60 slightly negated this effect. No lodging was observed. The addition of a fungicide at ZGS 30 followed by Prosaro (prothioconazole + tebuconazole) at ZGS 60 resulted in the greatest yields and test weights. All fungicide programs significantly reduced leaf blotch complex on the flag leaves relative to untreated controls; however, no difference was detected between ZGS 37 and ZGS 60 treatments. These results indicate that TE can be used safely in SRWW production when applied alone or when tank mixed with a fungicide; however, the effect on plant height reduction and potential impact on lodging may be reduced in situations where fungicides are used.

1. Introduction

Soft red winter wheat (SRWW) is an important crop in the mid-Atlantic states, including Delaware, North Carolina, Maryland, and Virginia. From 2014 through 2016, SRWW production in this region averaged over 18 million bu and 457 million $US in economic value (USDA NASS accessed 5/9/17). Due to the importance of this crop in the region, many growers utilize high input management systems to maximize SRWW yield and quality. Intensive management of wheat in this region includes applying fungicides to control diseases; however, plant growth regulators have not historically been included in these programs.

The use of growth regulators in SRWW production has increased in recent years, with the release of TE [[4-(cyclopropyl-α-hydroxymethylene)-3, 5-dioxo-cyclohexanecarboxylic acid ethylester] (TE) marketed as Palisade® (Syngenta Inc.) for use in small grain production systems in the United States. TE belongs to the class of growth regulators called cyclohexandiones, which inhibit gibberellin biosynthesis (Grijalva-Contreras et al., 2012; Na et al., 2011). Studies indicate that TE can be useful in small grain production, as it can reduce lodging by reducing stem length (Grijalva-Contreras et al., 2012; Hawerroth et al., 2015; Na et al., 2011; Nolte, 2007; ÜNAN et al., 2013; Wiersma et al., 2011), and by increasing the strength of the stem by increasing lignin content (Matysiak, 2006; Wiersma et al., 2011). This could be potentially useful in tall, lodging-prone varieties, or when excessive amounts of nitrogen are applied to fields. Unlike older plant growth regulators, TE often has the advantage of longer-lasting effects and more flexibility in timing of application (Swoish and Steinke, 2017). The direct effects of TE on wheat yields are variable, with studies showing an association with increased (Marchese et al., 2016) decreased (Grijalva-Contreras et al., 2012) or no impacts (da Silva et al., 2011; Miziniak and Matysiak, 2016; Pagliosa et al., 2013) on grain yield. Wheat lodging also may be reduced with TE application, thereby increasing potential yield and test weights in lodging prone varieties.

The increased use of TE may impact fungicide use patterns in wheat production systems in the mid-Atlantic. In the mid-Atlantic, fungicide use is aimed at limiting damage from common fungal diseases of the foliage and head, such as Stagonospora leaf and glume blotch

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(*Parastagonospora nodorum* [teleomorph: *Phaeosphaeria* (Hedjar.) syn. *Leptosphaeria nodorum* (Müll.), syn. *Septoria nodorum* (Berk.), syn. *Stagonospora nodorum* (Berk.)], tan spot *Pyrenophora tritici-repentis* (Died.) collectively called leaf blotch complex (LBC), and Fusarium head blight (FHB; *Fusarium graminearum* (Schwabe). Powdery mildew, caused by *Blumeria graminis* (DC.) Speer f. sp *tritici* emend. E. J Marchal (syn *Erysiphe graminis* DC) also has become increasingly problematic in the region. These diseases can damage the flag leaf and occasionally the head, reducing grain quality and yield (Willyerd et al., 2015). The traditional timing for fungicide application for foliar fungal disease suppression occurs at Zadocks growth stage (ZGS) 30, when the flag leaf has started to emerge from 50% of main tillers. However, an increase in corn production, coupled with widespread use of no till agriculture, has increased issues with FHB in wheat production areas of the United States, including the mid-Atlantic (McMullen et al., 2012; Schmale and Bergstrom, 2003). Consequently, recent outbreaks of Fusarium head blight (FHB) and associated vomitoxin contamination have resulted in more growers in the region applying fungicides prophylactically at anthesis (ZGS 60). There is concern that this late fungicide application timing may not be sufficient in some high production fields where residue-borne diseases such as LBC and powdery mildew may occur earlier in the season and potentially impact yield. Consequently many growers in the region are considering utilizing a low rate application of a fungicide early in the growing season, between ZGS 30–32, along with their nitrogen applications, as insurance against early season diseases. The inclusion of a fungicide application at this timing may help provide foliar protection that could carry over until flowering (ZGS 60) and promote higher yield. The use of TE in combination with fungicides, has not been evaluated in SRWW production systems in the mid-Atlantic for efficacy, yield, quality, impacts on foliar disease control, and crop safety.

The objective of this study was to examine the combined effects of TE, and different fungicide application programs on foliar diseases, phytotoxicity, height, yield, test weight, and SRWW health. To address this objective, a set of replicated field studies were conducted in a mid-Atlantic SRWW production system over a two year period.

2. Materials and methods

2.1. Location and study design

All studies were conducted at the Warrington Irrigation Research Farm (22,301 Cool Spring Road, Harbenson, DE, 19951). The variety 'Southern States, SS8500', a tall, medium-late maturity, soft red winter wheat adapted to the mid-Atlantic region was planted at the recommended rate of 4.45 million seeds/ha. The previous crop was corn preceded by soybean double cropped behind wheat. Treatments were arranged in a randomized complete block design with eight treatment replicates per study. Treatments are listed in Table 1. The entire study was replicated three times, twice in 2015 and once in 2016. In 2015, one study site received 13.9 additional cm of overhead irrigation from 4/20/2015 through 6/15/2015. A total of 11 irrigation events occurred over this period in time, with each event providing 1.37 cm of water. Plots were 7.01 m long and 1.52 m wide, with 0.76 m boarders separating plots along the plot length and a 2.28 m alleyway at plot ends. Nitrogen was applied as a split application, with a total of 22,027 g ha^{-1} applied as a split application at FGS 2 (50%) and ZGS 30 (50%).

Table 1
Treatments applied to the wheat variety SS8500 in Delaware.

Treatment	Timing (ZGS)[a]	Rate (L ha^{-1})
untreated control		
TE	30	0.77
TE + Quilt Xcel	30	0.77 + 0.51
TE FB[b] Quilt Xcel	30 FB 37	0.77 FB 0.77
TE FB Prosaro	30 FB 60	0.77 FB 0.48
TE + QXL FB Prosaro	30 FB 60	0.77 + 0.51 FB 0.48

[a] ZGS = Zadocks Growth Stage.
[b] FB = followed by.

2.2. Application of treatments

Treatments were applied at 241 kPa and 188 L ha^{-1} with a CO_2 – pressurized backpack sprayer equipped with 4, Turbo TeeJet 80V02 flat fan nozzles. Treatments applied at ZGS 37 or ZGS 60 included non-ionic surfactant at 0.125% vol/vol. Quilt Xcel® [(propiconazole 11.7% + azoxystrobin 13.5%) Syngenta; Basel, Switzerland] was used as the standard for ZGS 30 and ZGS 37 applications as it is a commonly used fungicide in the region and local data indicate excellent efficacy and residual control of foliar diseases encountered in the region (Sylvester and Kleczewski, 2017). Prosaro® [(prothioconazole 19% + tebuconazole 19%) Bayer; Leverkusen, Germany] was used as the standard ZGS 60 fungicide due to its efficacy on FHB (D'Angelo et al., 2014; Paul et al., 2010). Height and disease assessed at soft dough (ZGS 75). Plant heights were assessed on twenty main tillers randomly selected throughout each plot. Disease severity, the percentage of the diseased tissue, was rated on the flag leaves of ten plants per plot. Plots were harvested with a Massey Ferguson Model 8 × 10 small plot research combine and yields and test weights determined. Yields were adjusted to 13.5% moisture.

2.3. Statistical analysis

All data were analyzed using JMP Pro v 12.1 (SAS Inc.). Data were assessed for normality prior to analysis. Disease severity data were arcsin (square root) transformed to normalize error variances. A random effects mixed model was used to assess treatment effects on measured variables, with site (block) as the random factor and treatment, and the site x treatment interaction as fixed factors. Means were separated using Fisher's Protected LSD ($\alpha = 0.05$). Relationships between measured variables were compared using non parametric Spearman's correlations.

3. Results

No site × treatment interactions were detected and therefore only main effects are discussed when significant effects were detected. No phytotoxicity was noted for any of the tested treatments, nor were any issues with tank mix compatibility between TE and Quilt Xcel applied at ZGS 30.

3.1. Treatment effects on plant height

Analysis indicated significant main effects of study and treatment on plant height (Table 2). Plants were approximately 25 cm shorter in 2015 when compared to 2016 (Table 3). TE applied alone reduced plant height by nearly 7 cm. All other treatments receiving TE significantly

Table 2
F values and significance levels for measured variables measured on wheat variety SS8500 grown in Delaware over two seasons.

Variable	Study		Treatment		S x T	
	F	*P*	*F*	*P*	*F*	*P*
Height (cm)	78.3	< 0.0001	9.2	< 0.0001	0.3	0.98
Yield (kg ha^{-1})	21.6	< 0.001	14.6	< 0.0001	0.8	0.67
Test Weight (kg hL^{-1})	17.3	< 0.001	23.9	< 0.0001	1.6	0.12
Disease Severity (%)	21.7	< 0.001	31.6	< 0.0001	1.7	0.09