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Trinexapac-ethyl rate and application timing effects on seed yield and yield components in tall fescue

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ABSTRACT

Trinexapac-ethyl (TE) has been used for lodging control and seed yield enhancement in several grass seed crop species but little is known about how this plant growth regulator (PGR) performs in tall fescue [*Schedonorus arundinaceus* (Shreb.) Dumort.]. The objective of this study was to determine how TE application rate and timing influences seed productivity over six diverse lodging environments in Oregon's Willamette Valley. Three field trials were conducted to examine TE effects on seed yield and yield components. Stem length, a key factor in lodging control, was reduced incrementally with increasing TE rate from 17% reduction at 200 g TE ha^{-1} to a maximum of 39% reduction at 600 g TE ha^{-1}. Lodging was consistently reduced by TE but had no effect on above-ground biomass and panicles m^{-2}. Over environments, TE increased seed yield by an average 40% over the untreated control. However, TE rate or application timing did not differentially affect seed yield across environments. Increases in tall fescue seed yield attributable to TE were the result of increased seed number m^{-2} and improved harvest index (HI), but not seed weight. A better understanding of TE-induced seed yield increases will aid in improving use efficiency and economy of this important PGR.

1. Introduction

Tall fescue is a widely-grown cool-season forage and turf grass seed crop with global production on more than 200,000 ha annually in the USA, Argentina, Canada, France, Denmark, Netherlands, New Zealand and other countries. Cool-season grasses produce only a fraction of their potential seed yield and tall fescue is no exception producing only 37 to 53% of potential seed yield (Young et al., 1998b). There are many reasons for the low seed yield in tall fescue but lodging of the crop during flowering has been shown to be an impediment for achieving high seed yield (Griffith, 2000). Lodging reduced seed yield in tall fescue by as much as 31% compared to the crop when artificially supported in the upright position.

Trinexapac-ethyl [4-(cyclopropyl-α-hydroxymethylene)-3,5-dioxo-cyclohexanecarboxylic acid ethylester] (TE) is an acylcyclohexanedione inhibitor of the 3β-hydroxylation of gibberellic acid (King et al., 2004). Trinexapac-ethyl has been developed as a plant growth regulator (PGR) and has been widely adopted for use as a lodging control agent in forage and turf grass seed production (Zapiola et al., 2006; Rolston et al., 2010). Reduction in stem length and lodging by TE resulted in increased seed yield in perennial ryegrass (*Lolium perenne* L.) seed crops (Borm and van den Berg, 2008; Rolston et al., 2010; Koeritz et al., 2013; Chastain et al., 2014a).

While the effects of TE on lodging control and seed yield in perennial ryegrass (Rolston et al., 2010; Koeritz et al., 2013; Chastain et al., 2014a) and strong creeping red fescue (*Festuca rubra* L. subsp. *rubra*) seed crops (Zapiola et al., 2006, 2014) are well known, there have only been three investigations on these effects of TE in tall fescue. While these studies have reported that TE increased seed yield in tall fescue seed crops, there is limited information available on the effects of TE rate and application timing on seed yield and yield components across diverse lodging environments (Silberstein et al., 2000; Rolston et al., 2004; Chastain et al., 2014b). Though widely used, a better understanding of how TE applications affect seed yield and yield characteristics in tall fescue would allow a greater use efficiency and economy.

Zapiola et al. (2006) found that a combination of TE and open-field burning of crop residues produced the highest seed yield in strong creeping red fescue. Partitioning of dry matter in the crop canopy was manipulated by this combination of residue removal practices after the previous seed harvest and application of TE in

Abbreviations: TE, trinexapac-ethyl; HI, harvest index; PGR, plant growth regulator; BBCH, Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie.

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the following spring resulted in significant increases in HI. Nitrogen x TE interaction effects have been reported to produce increases in seed yield in both tall fescue and perennial ryegrass seed crops (Rolston et al., 2007; Chastain et al., 2014b).

The objectives of this study were to determine how TE application rate and timing in tall fescue seed crops influences (i) lodging and stem length reduction, (ii) seed yield components, and (iii) seed productivity over diverse lodging environments in Oregon's Willamette Valley.

2. Materials and methods

2.1. Experimental design and plot maintenance

Three field trials were conducted at Oregon State University's Hyslop Crop Science Research Farm near Corvallis, Oregon, to characterize the effects of TE on seed yield and yield components of tall fescue (Table 1). Trial 1 was conducted in a single year, 1999; Trial 2 was conducted from 2000 until 2001, and Trial 3 was conducted from 2010 until 2012. The soil at the site is a Woodburn silt loam (fine-silty, mixed, mesic, Aquultic Argixeroll).

Crop management was based on common production practices for tall fescue seed production in Oregon's Willamette Valley (Young et al., 1998a,b; Anderson et al., 2014a,b). Development stages of the tall fescue seed crops in relation to management practices and experimental treatments were characterized by using the BBCH scale (Hess et al., 1997). All trials were sown in October (1998—Trial 1, 1999—Trial 2, 2009—Trial 3) at rate of 9 kg ha^{-1} by using an eight-row plot-sized drill with 30-cm spaced rows. A pre-plant application of fertilizer (16–20–0) was made at a rate of 224 kg ha^{-1} during seedbed preparation. Applications of 45 kg N ha^{-1} (applied as 16–20–0) were made in October of each crop year on established crops (BBCH 20–29). Spring nitrogen needs were met by splitting applications over two dates during March prior to stem elongation (no later than BBCH 29) in each of the years for a total N rate of 135 kg N ha^{-1} (applied as 33–0–0–12). For each crop year in the study, the total applied nutrient amounts on the experimental trials were 180 kg N ha^{-1}, 25 kg P ha^{-1}, and 49 kg S ha^{-1}. These are typical nutrient applications for tall fescue seed production in Oregon's Willamette Valley.

The experimental design in each trial of the three trials was a randomized complete block with four replications. Plots in each trial were 3 by 30 m. Three rates of TE and an untreated control were examined in the trials: 0, 200, 400, and 600 g ai ha^{-1}. The PGR was applied by using a bicycle-type boom sprayer operated at 138 kPa with XR Teejet 8003VS nozzles. The spray volume used in the PGR applications was 194 L ha^{-1}. The effect of TE timing was tested with applications made at the following 3 stages of crop development: BBCH 32 (2 nodes), BBCH 37 (initial flag leaf emergence), and BBCH 51 (panicles 10% emerged).

2.2. Canopy modification and lodging

Above-ground biomass was determined on two crop rows hand harvested at peak anthesis (BBCH 65) in 30-cm^2 quadrats and oven-dried at 65 °C for 48 h in all 3 trials. Stem length reduction by TE was determined by comparing the untreated control with TE-treated plots on samples taken at the same time as biomass. Lodging severity was assessed during late anthesis (BBCH 69) on a five-point scale (Young et al., 1999a,b) where 1 = not lodged (fully upright) and 5 = most severe lodging (horizontal).

2.3. Panicles m^{-2}

Panicles m^{-2} was determined in all trials. Two samples were taken from each plot at ground level using a 30-cm^2 quadrat at the onset of anthesis (BBCH 60). The number of panicles in each sample was recorded and used to determine panicles m^{-2}.

2.4. Seed yield components

The number of spikelets panicles^{-1} and florets spikelet^{-1} were determined in Trial 2. Ten panicles were collected near peak anthesis (BBCH 65) from each plot in Trial 2. Panicles were frozen at −15 °C before analysis. The number of spikelets panicle^{-1} was counted. Paired spikelets were selected from apical, medial, and basal regions of each panicle for determination of the number of florets spikelet^{-1} at these positions within the panicle.

2.5. Seed yield, seed weight, seed number, and harvest index

Seed yield, seed weight, seed number, and harvest index was determined in all trials. The crop was harvested by swathing when seed moisture content reached approximately 430 g kg^{-1} FW in July of each crop year. A plot combine was used to thresh seed when seed moisture in the swath had decreased to 120 g kg^{-1} FW. Harvested yield was measured directly in the field with a sub-sample being collected for further analysis in the laboratory. Sub-samples were cleaned to marketable yield using a laboratory size Clipper M-2B (A.T. Farrell, Saginaw, MI). Cleanout from the conditioning process was used to calculate clean yield. Samples to determine seed weight and seed number m^{-2} were hand cleaned using screens and a blower prior to counting. Two 1000 seed samples from each plot were counted by an electric seed counter (The Old Mill Company, Savage, MD) and weighed. Harvest index was calculated as the ratio of clean seed yield to above-ground biomass. Seed number m^{-2} was calculated for each plot by dividing the clean seed yield harvested from that plot by the individual seed weight.

2.6. Statistical analysis

Statistical analysis for the three trials was conducted by using the mixed procedure of SAS Institute (2006). Trinexapac-ethyl application rate and timing were considered fixed effects, while lodging environments (cultivar and crop stand age), were considered random effects. Treatment effects on lodging severity, stem length reduction, above-ground biomass, panicles m^{-2}, HI, seed yield, seed weight and seed number m^{-2} were analyzed on the combined data from the trials by using ANOVA and means were separated by Fisher's protected LSD values. ANOVA was also conducted on seed yield components, and other seed characteristics from Trial 2. Linear correlation coefficients were calculated for seed production characteristics and seed yield.

3. Results and discussion

Rainfall during the during the April–June period varied from 67% to 179% of the of the 122-year mean for the area (Table 1). Six distinct lodging environments were observed during the three field trials. Conditions ranged from drought to excessive precipitation over these six environments, but the incidence and severity of lodging in tall fescue was similar among the environments. Temperatures were either near normal or somewhat below normal in the environments. No interactions of lodging environment and TE rate or timing for any of the seed productivity characteristics were measured ($P > 0.05$).

3.1. Canopy modification and lodging

All rates of TE tested reduced lodging in comparison with the untreated control in tall fescue ($P < 0.05$) (Fig. 1). Reductions in lodging were large with the 200 g TE ha^{-1} rate (46%) but the reductions in lodging were similar among the higher rates of TE (400 g ha^{-1},