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Nitrogen concentration and application timing affect imazamox efficacy in winter wheat

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ABSTRACT

Field experiments were conducted at four locations in two years in Kansas to determine the effects of urea ammonium nitrate concentrations and application timings on imazamox control of *Aegilops cylindrica* Host and feral *Secale cereale* L. in imidazolinone-tolerant winter wheat (*Triticum aestivum* L.). Based on regression analysis, *A. cylindrica* was controlled 66–73% with imazamox at 35 g ai. ha^{-1} plus urea ammonium nitrate at 1–50% v/v. Averaged over urea ammonium nitrate concentrations, fall post-emergence applications of imazamox were 37–45% more efficacious on *A. cylindrica* than spring post-emergence treatments. Feral *S. cereale* control increased linearly when imazamox treatments contained urea ammonium nitrate at 1–100%, and fall treatments were more effective than spring treatments at one of two locations. Early applications of imazamox increased wheat yield compared to later applications in two of four experiments, and increased gross profits \$69–168 ha^{-2}. However, yields did not differ between imazamox treatments containing different urea ammonium nitrate concentrations at any location.

1. Introduction

Aegilops cylindrica and feral (volunteer) *Secale cereale* are two common winter annual grass weeds infesting winter wheat-producing areas of the United States and Canada. Due to genetic and life cycle similarities to winter wheat, selective herbicidal control of these weeds has been difficult (Donald and Ogg, 1991; White et al., 2006). Prior to the introduction of imidazolinone-tolerant wheat cultivars, crop management practices were the only way to reduce the impact of *A. cylindrica* and feral *S. cereale* in wheat. Practices that favor *A. cylindrica* and/or feral *S. cereale* persistence in wheat include conservation tillage, continuous wheat production, short-statured cultivars, and low seeding rates (Donald and Ogg, 1991; Miller et al., 2004; White et al., 2006). Rotation to spring-seeded crops has the greatest effect on reducing *A. cylindrica* and *S. cereale* competition by allowing for increased tillage operations and the use of herbicides to control these weeds prior to seeding wheat (Lyon et al., 2002; Wicks et al., 2004; White et al., 2006).

Feral *S. cereale* and *A. cylindrica* reduce producer profits by decreasing wheat yields (interference) and contamination of harvested grain (dockage). Pester et al. (2000) reported that economic thresholds for feral *S. cereale* ranged from 0.9 to 43 plants m^{-2} across 17 site-years in the Great Plains of the United States. Densities of 4–5 *S. cereale* plants m^{-2} reduced net profits 50% of the time. In Oklahoma, 50 *S. cereale* plants m^{-2} reduced winter wheat yields 95% (White et al., 2006). It is estimated that feral *S. cereale* has reduced net profits by \$27 million in the Western United States (White et al., 2006). *A. cylindrica* at 25 plants m^{-2} decreased winter wheat yields 5–30% in Colorado and Wyoming (Anderson et al., 2002), while in Oregon, 54–86 *A. cylindrica* plants m^{-2} reduced yields 25–29% (Donald and Ogg, 1991). On average, producers can expect about a 1% yield reduction for each *A. cylindrica* plant m^{-2} (Anderson et al., 2002). Differences in *A. cylindrica* competitiveness between regions are likely due to environmental conditions.

Imidazolinone-tolerant wheat cultivars were introduced to producers in 2003 (White et al., 2006). These cultivars allow for the use of imazamox to selectively control winter annual grass weeds in wheat. Since the introduction of this technology, most research has focused on determining the optimum imazamox rate and application timings needed to effectively control grass weeds in wheat. In Oregon, imazamox at 36 g ha^{-2} or higher controlled *A. cylindrica* 61–97%, and imazamox at 27 g ha^{-2} or more reduced dockage associated with *A. cylindrica* contamination (Ball et al., 1999). Furthermore, wheat yields increased with imazamox treatments in three of four experiments. In the central Great Plains, *A. cylindrica* was controlled 95% or more, regardless of imazamox rate or application timing (Geier et al., 2004). In that study,

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imazamox controlled feral *S. cereale* 71–85% in Nebraska and Wyoming, and 95% or more in Kansas.

When feral *S. cereale* is the target species, it is generally recommended that imazamox be applied at the higher labeled rates and early in the growing season for optimal performance (Geier et al., 2004; Lyon et al., 2002; Miller et al., 2004). Imazamox application to wheat requires the addition of surfactant and nitrogen fertilizer solution at 2.5% v/v (Anon., 2004). However, there is a lack of information indicating that 2.5% v/v is the optimal nitrogen concentration for controlling winter annual grasses in winter wheat. Therefore, the objective of experiments in this study was to determine the effect of urea ammonium nitrate concentration in the spray solution on imazamox efficacy at two application timings.

2. Materials and methods

Field experiments were conducted at Colby, Hays, and St. John, Kansas during the 2002–2003 winter wheat-growing season, and at Great Bend, Kansas during the 2003–2004 season. Soil characteristics for each experiment are shown in Table 1. Imazamox rate in all experiments was 35 g ha^{-2}. The experiments were randomized complete blocks with factorial arrangements of six nitrogen concentrations: 1, 5, 10, 25, 50, or 100% v/v; and two application timings: fall post-emergence or spring post-emergence. All treatments were replicated four times. The nitrogen source used for all treatments was 28% urea ammonium nitrate. Each treatment also contained an ammoniated nonionic surfactant at 0.25% v/v, and a non-treated control was included. Herbicides were applied using either a tractor-mounted, compressed-air plot sprayer or a compressed-CO_2 backpack sprayer delivering 112 or 115 L ha^{-2} at 193 or 206 kPa. Application dates, plant growth stages, and weed densities for each experiment are shown in Table 2. Plots were 3 by 10 m.

'AP502CL' imidazolinone-tolerant winter wheat was seeded in each experiment in 2002. Dates and seeding rates were: Colby, September 17, 2002, 58 kg ha^{-2}; Hays, September 27, 2002, 54 kg ha^{-2}, and St. John, September 26, 2002, 67 kg ha^{-2}. At Great Bend, 'Above' imidazolinone-tolerant winter wheat was seeded at 67 kg ha^{-2} on September 20, 2003. Weed control was estimated visually using a scale of 0 (no control) to 100% (plant death). *A. cylindrica* control was determined on May 30, 2003 at Colby and on May 21, 2003 at Hays. These ratings were 26 and 34 days after application of the spring post-emergence herbicides, respectively. Feral *S. cereale* control was determined on June 16, 2003 at St. John and on May 27, 2004 at Great Bend. These evaluations were 83 and 77 days after spring post-emergence treatments. Wheat in the treated area of all plots was machine harvested, and grain yields adjusted to 12.5% moisture. Harvest dates were: Colby, July 1, 2003; Hays, June 26, 2003; St. John, June 24, 2003; and Great Bend, June 14, 2004. No dockage information was collected from harvested grain samples.

Weed control and yield data were analyzed without the non-treated controls to test for differences between experiments, nitrogen concentrations, and application timings. For grain yield, data were also analyzed with the non-treated control data included to test for differences between herbicide-treated and non-treated wheat. In all the cases, ANOVA and general linear model procedures were used, and means separation was at the 5% significance level. Where urea ammonium nitrate concentration was significant, regression analysis was used to describe the response of weeds and grain yield to nitrogen rate. Transformation of visually derived data did not affect analysis for weed control, thus nontransformed values are shown.

Table 2
Application dates, plant growth stages, and weed densities at the time of treatment.

Experiment and species	Application dates and growth stages	
	Fall post-emergence	Spring post-emergence
Colby, Kansas	November 11, 2002	March 26, 2003
Wheat (stage)	3–4 tillers	6–10 tillers
Aegilops cylindrica (stage)	4 tillers	4–7 tillers
Aegilops cylindrica (no. m^{-2})	75	75
Hays, Kansas	November 7, 2002	March 12, 2003
Wheat (stage)	0–2 tillers	4–8 tillers
Aegilops cylindrica (stage)	0–2 tillers	3–6 tillers
Aegilops cylindrica (no. m^{-2})	20	20
St. John, Kansas	December 10, 2002	March 25, 2003
Wheat (stage)	0–2 tillers	3–5 tillers
Feral *Secale cereale* (stage)	2–4 tillers	8–20 tillers
Feral *Secale cereale* (no. m^{-2})	8	8
Great Bend, Kansas	November 6, 2003	March 11, 2004
Wheat (stage)	3–5 tillers	8–12 tillers
Feral *Secale cereale* (stage)	5–12 tillers	10–20 tillers
Feral *Secale cereale* (no. m^{-2})	10	20

3. Results and discussion

For *A. cylindrica* and feral *S. cereale* visible control, statistical analysis showed that the interaction of experiment by application timing to be significant ($P = 0.0036$ and 0.0001, respectively), and the main effect of urea ammonium nitrate rate to be significant ($P = 0.0024$ and 0.0001, respectively). When wheat yield was analyzed as a factorial without the non-treated control data, only the interaction of experiment by application timing was significant ($P = 0.0026$). However, an experiment by nitrogen rate interaction occurred when analysis of yield data included the non-treated controls to test for differences between treated and non-treated wheat ($P = 0.0047$). However, no regression relationship occurred for wheat yield response to nitrogen concentration.

Based on regression analysis, a quadratic increase in *A. cylindrica* control occurred as nitrogen concentration increased from 1 to 50% (Fig. 1). The maximum *A. cylindrica* control was 73% with 50% urea ammonium nitrate, but control began to decline with 100% nitrogen (70%). Imazamox applied fall post-emergence was 37–45% more efficacious on *A. cylindrica* than spring post-emergence treatments, regardless of experiment, when averaged over urea ammonium nitrate concentrations (Fig. 2). The large control differences between application timings in these studies highlight

Table 1
Soil characteristics of experimental sites in Kansas.

Experiment	Soil type	Soil classification	Organic matter (%)	pH	CEC (Meq 100 g^{-1})
Colby	Keith silt loam	Fine-silty, mixed, superactive, mesic Aridic Argiustolls	2.2	7.0	18
Hays	Roxbury silt loam	Fine-silty, mixed, superactive, mesic Aridic Argiustolls	2.4	7.8	16
St. John	Carwile loamy fine sand	Fine, mixed, superactive, thermic Typic Argiaquolls	0.7	5.5	4
Great Bend	Carwile loamy fine sand	Fine, mixed, superactive, thermic Typic Argiaquolls	1.5	5.3	8