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Research Note

Growth Regulator Herbicides Prevent Invasive Annual Grass Seed Production Under Field Conditions

Matthew J. Rinella,[1] *Robert A. Masters,*[2] *and Susan E. Bellows*[3]

Authors are [1]*Rangeland Ecologist and* [3]*Range Technician, Fort Keogh Livestock and Range Research Station, Miles City, MT 59301, USA; and* [2]*Product Development Leader, Dow AgroSciences, LLC, Indianapolis, IN 46268, USA.*

Abstract

Growth regulator herbicides, such as 2,4-D, dicamba, picloram, and aminopyralid, are commonly used to control broadleaf weeds in rangelands, noncroplands, and cereal crops. If applied to cereals at late growth stages, while the grasses are developing reproductive parts, the herbicides often reduce cereal seed production. We are researching methods for using this injury response to control invasive annual grasses in rangelands by depleting their short-lived seed banks. In a previous greenhouse study, we found picloram and dicamba reduced seed production of the invasive annual grass Japanese brome (*Bromus japonicus* Thunb.) by nearly 100%. However, this promising greenhouse finding needs to be corroborated in the field before growth regulators can be confidently recommended for invasive annual grass control. This research note describes a study conducted in eastern Montana suggesting growth regulators may provide excellent control of invasive annual grasses. Specifically, we found typical use rates of aminopyralid and picloram reduced Japanese brome seed production by more than 95% (based on sample means) when applied at three different plant growth stages. This promising result contributes to the accumulating body of evidence suggesting growth regulators may control invasive annual grasses.

Resumen

Los herbicidas reguladores del crecimiento tales como el 2-4D, dicamba, picloram y aminipyralid se utilizan comúnmente para controlar las malezas de hoja ancha en pastizales, en cultivos de cereales así como en no cultivos. Si se utilizan en cereales en las etapas finales de crecimiento, cuando los pastos están desarrollando las partes reproductivas, estos herbicidas reducen a menudo la producción de semilla de los cereales. Estamos investigando métodos para utilizar esta respuesta de lesión para controlar pastos invasivos anuales en pastizales por medio de la disminución del banco de semillas de corta duración. En estudios previos de invernadero encontramos que el picloram y dicamba disminuyen las producción de semilla del pasto anual invasivo el bromo Japonés (*Bromus japonicus* Thunb.) casi en un 100%. Sin embargo estos estudios en el invernadero que son muy prometedores necesitan corroborarse en situaciones de campo antes de que los reguladores del crecimiento puedan recomendarse con la finalidad de controlar los pastos anuales. Esta investigación describe un estudio realizado en la parte oriental de Montana que propone el uso de los reguladores de crecimiento para control efectivamente los pastos anuales invasivos. Específicamente, encontramos que niveles típicos de aminopyralid y picloram disminuyen la producción de semilla del bromo Japonés en más de 95% (basándose en el promedio de las muestras) cuando se aplicó en tres estados diferentes de crecimiento. Estos resultados son prometedores y sugieren que los reguladores de crecimiento pueden controlar las gramíneas anuales invasivas.

Key Words: Aminopyralid, *Bromus japonicus* Thunb., Japanese brome, picloram, seedbank, seed development, weed control, weeds

INTRODUCTION

Exotic annual grasses such as cheatgrass (*Bromus tectorum* L.), medusahead (Taeniatherum caput-medusae L.), and Japanese brome (*Bromus japonicus* Thunb.) are negatively impacting millions of hectares of rangeland in the western United States (Sheley and Petroff 1999; DiTomaso 2000; Sperry et al. 2006; Davies and Svejcar 2008). The most widely used classes of herbicides for controlling annual grasses are amino acid synthesis inhibitors (e.g., glyphosate, imazapic) and photosynthetic inhibitors (e.g., tebuthiuron). These herbicides are expensive to apply to large areas, but they can temporarily suppress invasive annual grasses (Whitson and Koch 1998; Shinn and Thill 2002), and desirable rangeland species often increase during periods when invasive annual grass populations are suppressed (Haferkamp and Heitschmidt 1999; Ogle et al. 2003). However, these herbicides often kill desirable forbs and shrubs in addition to sometimes injuring (e.g., stunt, discolor) and killing the desirable perennial grasses that grow with invasive annual grasses (Lym and Kirby 1991; Shinn and Thill 2004).

We are researching methods for using a different class of herbicides (growth regulators) to control invasive annual grasses. Like currently used herbicides, growth regulators often kill desirable forbs and shrubs or cause them to have reduced

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Correspondence: Matthew J. Rinella, Fort Keogh Livestock and Range Research Station, Miles City, MT 59301, USA. Email: matt.rinella@ars.usda.gov

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and undifferentiated (e.g., twisting, epinasty) growth. However, growth regulators offer the advantage of being less damaging to desirable perennial grasses (Crone et al. 2009; Rinella et al. 2009). Growth regulators are regularly used to control broadleaf weeds in rangeland, pastures, and noncropland, as well as in cereal crops, such as wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.). A downside of these herbicides in cereal production is that they reduce grain yield when applied too late in the lifecycle, that is, after initiation of grass jointing but before seeds begin to form (Friesen et al. 1968; Sikkema et al. 2007). For example, Rinella et al. (2001) found a late dicamba application caused 100% of winter wheat seeds to be underdeveloped and nongerminable.

A previous greenhouse study indicated it may be possible to harness this seed injury response to control invasive annual grasses. Specifically, we found picloram and dicamba reduced production of germinable Japanese brome seeds by nearly 100% (Rinella et al. 2010). This finding suggests growth regulators could be used to deplete invasive annual grass seed banks because seeds of these grasses tend to be short-lived in soil. Smith et al. (2008) measured cheatgrass seedling emergence after clipping inflorescences to prevent seed rain. They found that seedling emergence remained high following 1 yr of clipping, but emergence was reduced by more than 96% after two consecutive years of clipping. Hulbert (1955) conducted a similar study and found that preventing seed input for just 1 yr nearly eradicated cheatgrass from field plots. Burnside et al. (1996) buried Japanese brome and cheatgrass seeds 20 cm deep under field conditions and found that cheatgrass germination dropped from 95% to 2% after 1 yr and to 0% after 2 yr. Corresponding numbers for Japanese brome were 95%, 5%, and 1%. The short seed lives of the grasses in these studies suggest using growth regulator herbicides to reduce seed inputs for 1–3 yr could greatly reduce invasive annual grass populations.

Our prior greenhouse findings need to be confirmed in field studies before growth regulators can begin to be recommended for Japanese brome management. Differences in environmental conditions and/or plant competition can cause herbicide efficacy to differ between the greenhouse and field (e.g., Degenhardt et al. 2005; Bollman et al. 2008). A particular concern is that invasive grass development may be more synchronized in a highly controlled greenhouse experiment than in the field, and if some individuals are at herbicide-tolerant growth stages when herbicide is applied, control in the field could be far inferior to that observed under greenhouse conditions. These concerns notwithstanding, dicamba reduced winter wheat seed production similarly in the greenhouse and field (Rinella et al. 2001).

This research note describes a study that evaluated growth regulator effects on Japanese brome seed production under field conditions. Japanese brome is similar to its more well-known congeneric cheatgrass in terms of biology, ecology, and impacts (Ogle et al. 2003). Detailed information on the current and projected distribution of Japanese brome is unavailable, but it has invaded large areas in the central and northern Great Plains (Haferkamp et al. 2001a; Harmoney 2007), where it often co-occurs with cheatgrass (Ogle et al. 2004). Japanese brome is known to reduce growth and forage quality of native forage species (Haferkamp and Heitschmidt 1999; Haferkamp et al. 2001a; Perry et al. 2009) and reduce livestock performance below that obtained on noninvaded native rangeland (Haferkamp et al. 2001b).

We applied the growth regulators picloram and aminopyralid to Japanese brome and then measured seed production. We used picloram because our greenhouse study suggested it was more effective than dicamba or 2,4-D at reducing Japanese brome seed production (Rinella et al. 2010). We used aminopyralid because it is chemically similar to picloram but is considered safer to nontarget organisms and the environment (Jachetta et al. 2005).

METHODS

Plots were 3.7×3.7 m and were arranged in a randomized complete block design (3 blocks $\times$ 3 herbicide treatments $\times$ 3 plant growth stages + 9 controls = 36 plots) on the Fort Keogh Livestock and Range Research Laboratory (lat 46°22′N, long 105°5′W) near Miles City, Montana. Plots were on a silty range site dominated by a fine, montmorillonitic Typic Eutroboralfs of the Sonnett series with a 0–2% slope. The site was dominated by Japanese brome, western wheatgrass (*Pascopyrum smithii* [Rydb.] A. Löve), Sandberg bluegrass (*Poa secunda* J. Presl), blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths), and buffalograss (*Bouteloua dactyloides* [Nutt.] J. T. Columbus).

In May 2007, picloram at 0.42 kg ae $\cdot$ ha^{-1} or aminopyralid at 0.07 or 0.12 kg ae $\cdot$ ha^{-1} were applied to Japanese brome at three growth stages. These rates are common for controlling broadleaf weeds on rangelands and other noncroplands. The second aminopyralid rate provided insight into the effectiveness of reduced rates, which have lower costs and may cause less injury to desirable dicots. Herbicides were applied using a CO_2 pressurized backpack sprayer (R&D Sprayers, Opelousas, LA) with nozzles (4-XR 8200VS, TeeJet, Wheaton, IL) calibrated to deliver 131 L $\cdot$ ha^{-1}. We applied the herbicides at the three growth stages that proved most susceptible to growth regulators in earlier research (Rinella et al. 2001; Rinella et al. 2010). Application dates and growth stages were 20 May (initiation of internode elongation), 24 May (boot stage), and 27 May (shortly after heading). Precipitation and average temperature for May were 90 mm and 15°C, and corresponding long-term values are 54 mm $\pm$ 4 SE and 14°C $\pm$ 0.2 SE. Precipitation and average temperature for June were 116 mm and 18°C, and corresponding long-term values are 72 mm $\pm$ 5 SE and 19°C $\pm$ 0.2 SE.

On 15 July, after seeds had ripened but before they had fallen from plants, all Japanese brome plants were clipped to ground level from one randomly placed 20×50 cm frame in each plot. Clipped plants were bagged and dried at 60°C for 48 h. Then plants were randomly sampled from bags and seeds extracted until 400 seeds were acquired from each plot. Seed-per-plant numbers were quite low, so acquiring 400 seeds required sampling between 25 and 40 plants per plot. Seeds were subjected to a germination test by being incubated in $100 \times$ 15-mm Petri dishes (100 seeds per dish). Each dish contained a piece of filter paper supported by a polyurethane foam disc. Distilled water was supplied continuously via a cotton wick inserted in a hole in the center of the disc. Light was supplied for 12 h per day with cool-white fluorescent bulbs

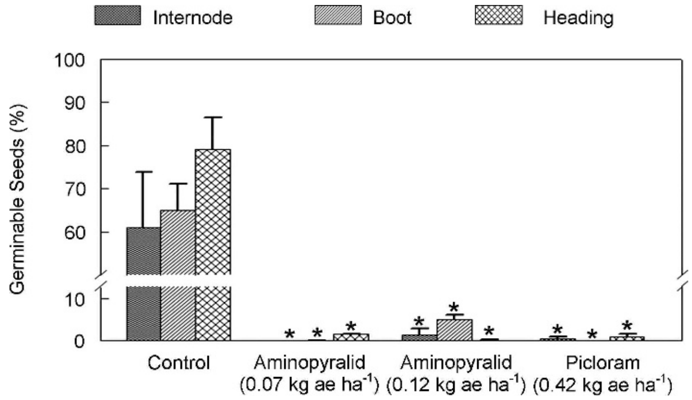

Figure 1. Effects of growth regulator herbicides on Japanese brome seed production in an eastern Montana study conducted in 2007. Two aminopyralid rates and one picloram rate were evaluated at each of three growth stages. Bars denote SE, and asterisks denote significant differences from control at the 5% level.

(PAR = 30 μmoles $\cdot$ m^{-2} $\cdot$ s^{-1}), and temperature was held at 21°C and 15°C during the light and dark periods, respectively. Seeds were recorded as germinable and removed from the Petri dishes if they developed radicals and coleoptiles exceeding 5 mm in length within a 30-d period.

Data on the numbers of seeds that germinated per plant were not well approximated by normal distributions because of a large number of zeros, so data were analyzed with a nonparametric bootstrap procedure (Efron and Tibshirani 1993; Hjorth 1994) written in Mathematica 6.0 (Wolfram Research 2007).

RESULTS AND DISCUSSION

Both aminopyralid and picloram drastically reduced germinable seed production in the field, with less than 5% of seeds proving germinable for all combinations of timing and rate (Fig. 1). These levels of seed reduction are consistent with our greenhouse observations (Rinella et al. 2010).

Japanese brome seed production responded similarly to both aminopyralid rates (Fig. 1). Likewise, Rinella et al. (2001) found that winter wheat seed production responded similarly to low and high rates of dicamba. This leaves open the possibility that rates even lower than those we tested might be sufficient for preventing invasive annual grass seed production. Lower rates would reduce costs and reduce the potential for injury to desirable dicots. The reductions in Japanese brome seed we found are similar to those reported for several crop grasses (Friesen et al. 1968; Rinella et al. 2001; Sikkema et al. 2007). That this injury response occurs in so many grasses suggests cheatgrass, medusahead, and other invasive annual grasses may also prove sensitive to growth regulators.

One advantage of growth regulators over currently used invasive grass herbicides is that they cause less injury to perennial grasses (Lym and Messersmith 1985; Lym and Kirby 1991; Sheley et al. 2000; Shin and Thill 2004). In fact, growth regulators often facilitate recovery of native grasses when they are used to control invasive plants (Lym and Messersmith 1994; Rice et al. 1997). There is evidence that growth regulators can suppress native forb and shrub populations (Crone et al. 2009; Rinella et al. 2009) or restore native grassland structure and maintain forb diversity (Rice et al. 1997). As suggested by Hickman and Derner (2007), it may be necessary to reestablish dicots after growth regulators are used. Also, growth regulator use may be unadvisable if native annual grasses such as sixweeks fescue (*Vulpia octoflora* [Walter] Rydb. var. *glauca* [Nutt.] Fernald) or desert fescue (*Vulpia microstachys* [Nutt.] Munro var. *microstachys*) are present, as growth regulators could reduce seed production of these species.

IMPLICATIONS

We tested an approach for controlling invasive annual grasses with the growth regulator herbicides picloram and aminopyralid. Our results show that growth regulators can dramatically reduce Japanese brome seed production. Therefore, it may be possible to use growth regulators to control Japanese brome and other invasive annual grasses by depleting their short-lived seed banks. The effective application timing window for preventing Japanese brome seed production with growth regulators overlaps the much wider window for using these herbicides to control broadleaf weeds such as leafy spurge (*Euphorbia esula* L.) and spotted knapweed (*Centaurea maculosa* Lam.; Lym et al. 1997; Rice et al. 1997). Therefore, it may be possible to use carefully timed growth regulator applications to simultaneously target both annual grasses and broadleaf weeds on rangelands. If effective, this would overcome the common problem of invasive annual grasses proliferating after herbicidal control of broadleaf weeds (e.g., DiTomaso et al. 2006).

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