

Effects of Aminocyclopyrachlor Herbicide on Downy Brome (*Bromus tectorum*) Seed Production under Field Conditions

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Previous research has shown that pyridine growth regulator herbicides can affect seed production in annual grasses including downy brome, Japanese brome, wheat, and other cereal grain crops. Aminocyclopyrachlor is a pyridine carboxylic acid growth regulator herbicide that has recently been registered for broadleaf weed and brush control in nonagricultural areas, which may help facilitate release of native perennial grasses in native plant restoration sites. The influence of aminocyclopyrachlor on downy brome seed production was evaluated at multiple application rates and timings under controlled field conditions. The effect of aminocyclopyrachlor on seed production was compared with aminopyralid, another pyridine growth regulator herbicide. When applied to downy brome plants in the early vegetative stage (EPOST) at approximately 580 growing degree days (GDD), aminocyclopyrachlor at 320 g ae ha⁻¹ reduced seed germination by 50 to 88% in the first and second study years, respectively. Aminopyralid reduced seed germination by 94% in the first study year, but only 20% in the second year. When applied to downy brome plants in the early heading stage at approximately 1,235 GDD (LPOST), aminocyclopyrachlor at 320 g ae ha⁻¹ reduced seed germination by 100% both years. Aminopyralid reduced seed germination by 95% in the first year, and 81% in the second year. Other than the observed reduction in seed germination, herbicides did not produce any visible changes in downy brome aboveground plant growth or development. Because downy brome seeds are relatively short-lived in soil, aminocyclopyrachlor and aminopyralid applications to downy brome-infested rangelands and other natural areas could result in reductions in downy brome population densities over time. No published data exist on the effect of aminocyclopyrachlor on seed production of desirable perennial grasses in natural ecosystems, thereby suggesting the need for further research.

Nomenclature: Aminocyclopyrachlor, formerly DPX MAT28, 6-amino-5-chloro-2-cyclopropylpyrimidine-4-carboxylic acid; aminopyralid, 4-amino-3,6-dichloropyridine-2-carboxylic acid; downy brome, *Bromus tectorum* L. BROTE; Japanese brome, *Bromus japonicus* Thunb. ex Murr. BROJA; wheat, *Triticum aestivum* L.

Key words: Chemical control, growing degree day, growth regulator herbicide, invasive species, native plant communities, pyridine carboxylic acid, pyridine herbicide, rangeland.

Millions of hectares of U.S. grasslands are negatively affected by invasive annual grasses, including downy brome (*Bromus tectorum* L.). These grasses can reduce native plant diversity and change wildfire frequencies, and it is postulated that a successional retrogression due to invasive annual grasses may permanently alter native grassland communities (Billings 1990; Young and Evans 1978). Herbicide treatments are increasingly used as management tools to reduce the frequency of invasive annual grasses with the hopes of favoring native plant communities. It is

well recognized that growth regulator herbicides such as 2,4-D, dicamba, and picloram, used for control of undesirable broadleaf weeds, can decrease seed production in cereal grain crops (Friesen et al. 1968; Martin et al. 1989; Schroeder and Banks 1989) and certain other grasses (Canode and Robocker 1966; Vanden Born 1965). More recently, the pyridine carboxylic acid herbicide aminopyralid has been shown to affect seed production in exotic annual grass weeds such as downy brome (Rinella et al. 2013) and Japanese brome (*Bromus japonicus* Thunb. ex Murr.) (Rinella et al. 2010a, 2010b). Aminocyclopyrachlor is another pyridine carboxylic acid growth regulator herbicide that has recently been registered for broadleaf weed and brush control in rangelands and noncrop areas. Earlier work demonstrated

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Management Implications

Aminocyclopyrachlor (formerly DPX MAT28) is a growth regulator herbicide that has been registered for broadleaf weed and brush control in nonagricultural areas, which can facilitate the release of native perennial grasses in native or improved plant community sites. In addition to controlling many invasive broadleaf weeds in rangeland and other natural areas, this herbicide may significantly reduce seed production in downy brome. In this controlled study, application of aminocyclopyrachlor to downy brome plants in the vegetative stage reduced seed germination by 50 to 88%. When applied to downy brome plants in the early heading stage, aminocyclopyrachlor reduced seed germination by 100%, even though aboveground biomass of downy brome was not significantly reduced. Because aminocyclopyrachlor has soil residual properties and because of the relatively short viability of downy brome seeds in the seed bank, it may be possible to use this herbicide to reduce downy brome in infested rangeland areas. A reduction in the downy brome seed bank caused by aminocyclopyrachlor may facilitate the restoration of native or improved plant communities. How aminocyclopyrachlor will affect plant community composition may be difficult to predict, because this herbicide also affects native forbs and shrubs, and may reduce seed production of desired, perennial grasses. Further field testing is needed to assess the effects of aminocyclopyrachlor on long-term changes in plant community composition.

that aminocyclopyrachlor, like other pyridine herbicides, can reduce seed production of smooth crabgrass [*Digitaria ischaemum* (Schreb. ex Schweig.) Schreb. ex Muhl.] (Reed et al. 2013), and wheat (*Triticum aestivum* L.), even when applied to fallow ground before planting winter wheat (Kniss and Lyon 2011). Because of the observed effect of aminocyclopyrachlor on reducing seed production in these graminoids, a study was conducted to evaluate the potential effect of aminocyclopyrachlor on the important exotic annual grass downy brome.

Materials and Methods

Experiments were established at the Columbia Basin Agricultural Research Station near Pendleton, OR, beginning in autumn 2011 and repeated in autumn 2012 to determine the effect of aminocyclopyrachlor application rate and timing on seed production and germinability of downy brome. Field plot areas with previously negligible levels of downy brome were sprinkler irrigated, and a finely tilled seed bed was prepared by rototilling. Afterripened downy brome seeds were sown in early autumn to 2 cm depth into moist soil. Seeds were planted in rows spaced 1.8 m apart with individual plots consisting of one row by 3 m in length arranged as a randomized complete block design with four replications. Each plot received a seeding rate of 10 g. In the first study year, treatments were applied when downy brome was in the three to four tiller stage

Table 1. Aminocyclopyrachlor and aminopyralid application rates applied to downy brome at two timings.

Treatment	Rate	Timing ^a
	g ae ha ⁻¹	
Untreated check	—	—
Aminocyclopyrachlor ^b	40	EPOST
Aminocyclopyrachlor	80	EPOST
Aminocyclopyrachlor	160	EPOST
Aminocyclopyrachlor	320	EPOST
Aminopyralid ^c	120	EPOST
Aminocyclopyrachlor	40	LPOST
Aminocyclopyrachlor	80	LPOST
Aminocyclopyrachlor	160	LPOST
Aminocyclopyrachlor	320	LPOST
Aminopyralid	120	LPOST

^aEPOST, early postemergence application timing; LPOST, late postemergence application timing. All treatments included a non-ionic surfactant at 0.25% (v/v).

^bAminocyclopyrachlor, Method 50 SG, E.I. DuPont.

^cAminopyralid, Milestone, Dow AgroSciences.

on April 2 (early postemergence [EPOST]), or at the beginning of panicle emergence on May 8 (late postemergence [LPOST]). These treatment dates corresponded to cumulative growing degree days (GDD) of 580 and 1,235 GDD when calculated from a January 1 start date, respectively. Earlier research has shown that for a given location, stage of downy brome growth and development can be predicted on the basis of cumulative GDD (Ball et al. 2004). Treatment dates in the second study year (April 1 and May 2, 2013) were timed to correspond with the same cumulative GDD as in the first study year. Treatment rates and timings are summarized in Table 1. Herbicides were applied in 150 L ha⁻¹ (16 gal ac⁻¹) of water using a CO₂-pressurized sprayer with a 180-cm-wide hand-held boom equipped with flat fan nozzles (Teejet XR 8002). A non-ionic surfactant was included with all herbicide treatments at 0.25% (v/v). An untreated control treatment was included to evaluate potential downy brome seed production. After maturity of downy brome panicles, but before seeds dropped from mature panicles, 20 panicles were clipped and collected per experimental unit. A head smut fungus (*Ustilago bullata* Berk. in Hook.) infesting some downy brome panicles in the first year study was avoided while collecting the 20 panicle samples. This smut fungus prompted us to treat downy brome seeds with a fungicide before planting in the second study year. The seed treatment contained difenoconazole {1-[[2-[2-chloro-4-(4-chlorophenoxy)phenyl]-4-methyl-1,3-dioxolan-2-yl]methyl]-1*H*-1,2,4-triazole}, metalaxyl-M [methyl *N*-(2,6-dimethylphenyl)-*N*-(methoxyacetyl)-D-alaninate],

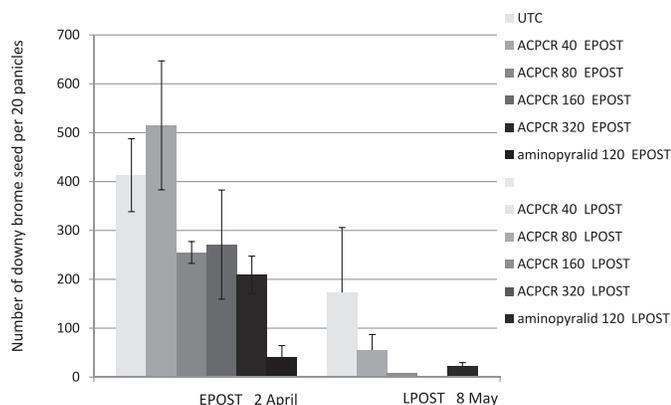


Figure 1. Downy brome seedling emergence as influenced by treatment with aminocyclopyrachlor (ACPCR) and aminopyralid at two application timings in 2011. Values are mean seedling emergence \pm standard error ($n = 4$) 14 d after planting. UTC, untreated control.

ipconazole {2-[(4-chlorophenyl)methyl]-5-(1-methylethyl)-1-(1*H*-1,2,4-triazol-1-ylmethyl)cyclopentanol}, and thiamethoxam {3-[(2-chloro-5-thiazolyl)methyl]tetrahydro-5-methyl-*N*-nitro-4*H*-1,3,5-oxadiazin-4-imine} at 180, 44, 15, and 129 mg ai kg⁻¹ (3.0, 3.9, 0.05, and 0.33 fl oz cut⁻¹ of seed) of seed, respectively (Cruiser Maxx Custom Blend, Pendleton Grain Growers, Pendleton, OR).

Harvested downy brome seeds were separated by gently rubbing panicles on a textured rubber mat. Collected seeds were dry stored in paper bags at approximately 20 C for approximately 4 mo to afterripen (Thill et al. 1980). Seeds were then sown in flats containing a standard greenhouse soil mix (Sunshine Mix #4, Sun Gro Horticulture Canada Ltd.) and covered with the soil mix to a depth of about 1 cm, placed in a greenhouse with a constant temperature of approximately 21 C, and watered to germinate seeds. The number of emerged seedlings per flat was recorded about 14 d after planting. Seedling count data were analyzed using ANOVA, and means separated using LSD at $P = 0.05$. Seedling count data were transformed using a $\log(n + 1)$ transformation to normalize error variance in the seedling count data. Nontransformed mean values were used for graphical presentation.

Results and Discussion

The recommended use rate of aminocyclopyrachlor is 40 to 140 g ae ha⁻¹, with a maximum allowed application rate of 320 g ae ha⁻¹ per year. In the first study year, early aminocyclopyrachlor applications (EPOST) tended to reduce germinable downy brome seed production compared with the untreated control, but the difference was not statistically significant because of a high degree of germination variability (Figure 1). A head smut fungus

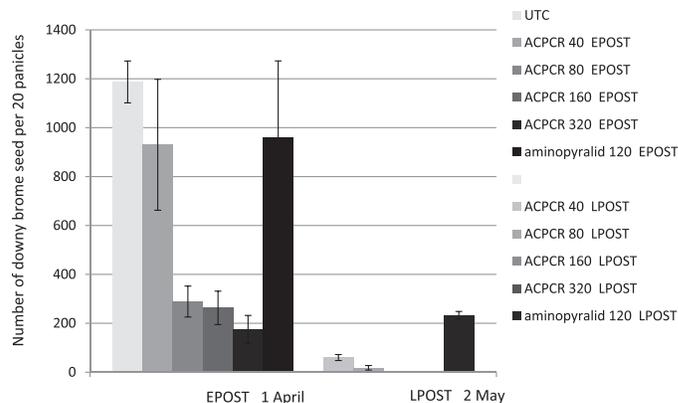


Figure 2. Downy brome seedling emergence as influenced by treatment with aminocyclopyrachlor (ACPCR) and aminopyralid at two application timings in 2012. Values are mean seedling emergence \pm standard error ($n = 4$) at 14 d after planting. UTC, untreated control.

infesting downy brome panicles possibly contributed to this germination variability.

At the LPOST application timing in the first study year, aminocyclopyrachlor reduced seed germination compared with the untreated control (Figure 1). Application of aminopyralid in the first study year also significantly reduced seed germination at both the EPOST and LPOST application timings (Figure 1). Despite the reduction in seed germination, herbicide treatments did not have a visible effect on downy brome biomass or plant height.

The influence of aminocyclopyrachlor on seed germination was more significant in the second than the first year. In the second year, aminocyclopyrachlor treatment showed a significant reduction in seed germination at the EPOST application timing (Figure 2). It is possible that the use of fungicide in the second year may have contributed to the greater seed production of untreated controls that year (Figure 2). Unlike the first year, aminopyralid applied at the EPOST timing did not significantly reduce seed germination in the second year (Figure 2). However, all late herbicide treatments dramatically reduced germination in both years. As in the first year, herbicide treatments did not have a visible effect on downy brome biomass or plant height.

The LPOST treatment timing corresponded to early panicle emergence of downy brome under field conditions. The GDD corresponding to this stage of downy brome plant development can be predicted in advance for a given locality, so that applications could be timed to provide maximum reduction of downy brome seed production (Ball et al. 2004).

Because aminocyclopyrachlor (Anonymous 2009, Lindenmayer et al. 2011) and aminopyralid (Senseman 2007) have soil residual properties, it may be possible to use these herbicides to reduce the downy brome seed bank and

facilitate the restoration of native or improved plant communities (Harmony et al. 2012). How aminocyclopyrachlor or aminopyralid treatments will affect plant community composition may be difficult to predict. Aminopyralid can have significant effects on native grassland forbs and shrubs (Wallace and Prather 2012a, 2012b). Research has indicated that aminopyralid has little effect on native grass biomass production (Harmony et al. 2012, Wallace and Prather 2012a, b), but little data exist on the effect of aminopyralid or aminocyclopyrachlor on seed production of desirable perennial grasses in natural ecosystems, thereby suggesting the need for further research. However, since previous research has shown a rather poor correlation between seedling recruitment of new perennial grass plants and subsequent changes in plant community composition (Peart 1989), the possible reduction in seed production of perennial grasses treated with aminocyclopyrachlor or other growth regulator herbicides might not have a major bearing on desirable, perennial grass frequency in a restoration project unless abundant safe sites for seedling recruitment are present (Anderson 1989).

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Literature Cited

Anderson AF (1989) How important is seed predation to recruitment in stable populations of long-lived perennials? *Oecologia* 81:310–315

Anonymous (2009) DuPont: DPX-MAT28 Technical Bulletin. E.I. du Pont de Nemours and Company. <https://lists.alaska.edu/pipermail/cnipm-l/attachments/20090310/f10dfb94/MAT28TechBulletin.pdf>. Accessed: May 28, 2014

Ball DA, Frost SM, Gitelman AI (2004) Predicting timing of downy brome (*Bromus tectorum*) seed production using growing degree-days. *Weed Sci* 52:518–524

Billings WD (1990) *Bromus tectorum*, a biotic cause of ecosystem impoverishment in the Great Basin. Pages 310–322 in Woodwell GM, ed. *Patterns and Processes of Biotic Impoverishment*. New York: Cambridge University Press

Canode CL, Robocker WC (1966) Annual weed control in seedling grasses. *Weeds* 14:306–309

Friesen HA, Born WHV, Keys CH, Dryden RD, Molberg ES, Siemens B (1968) Effect of time of application and dosage of dicamba on tolerance of wheat, oats and barley. *Can J Plant Sci* 48:213–215

Harmony KR, Stahlman PW, Geier PW, Rupp R (2012) Effects of a new herbicide (aminocyclopyrachlor) on buffalograss and forbs in shortgrass prairie. *Weed Technol* 26:455–459

Kniss AR, Lyon DJ (2011) Winter wheat response to preplant applications of aminocyclopyrachlor. *Weed Technol* 25:51–57

Lindenmayer B, Westra P, Nissen S, Shaner D (2011) Characterization of aminocyclopyrachlor, aminopyralid, and clopyralid soil activity. Pages 64 in 2011 Proceedings Western Society of Weed Science. Spokane, WA: Western Society of Weed Science

Martin DA, Miller SD, Alley HP (1989) Winter wheat (*Triticum aestivum*) response to herbicides applied at three growth stages. *Weed Technol* 3:90–94

Peart DR (1989) Species interactions in a successional grassland, I. Seed rain and seedling recruitment. *J Ecol* 77:236–251

Reed TV, Yu J, McCullough RE (2013) Aminocyclopyrachlor efficacy for controlling Virginia buttonweed (*Diodia virginiana*) and smooth crabgrass (*Digitaria ischaemum*) in tall fescue. *Weed Technol* 27:488–491

Rinella MJ, Haferkamp MR, Masters RA, Muscha JM, Bellows SE, Vermeire LT (2010a) Growth regulator herbicides prevent invasive annual grass seed production. *Invasive Plant Sci Manag* 3:12–16

Rinella MJ, Masters RA, Bellows SE (2010b) Growth regulator herbicides prevent invasive annual grass seed production under field conditions. *Rangeland Ecol Manag* 63:487–490

Rinella MJ, Masters RA, Bellows SE (2013) Effects of growth regulator herbicides on downy brome (*Bromus tectorum*) seed production. *Invasive Plant Sci Manag* 6:60–64

Schroeder J, Banks PA (1989) Soft red winter wheat (*Triticum aestivum*) response to dicamba and dicamba plus 2,4-D. *Weed Technol* 3:67–71

Senseman SA (ed.) (2007) *Herbicide Handbook*, 9th edn. Champaign, IL: Weed Science Society of America. Pp. 331–332

Thill DC, Schirman RD, Appleby AP (1980) Influence of afterripening temperature and endogenous rhythms on downy brome (*Bromus tectorum*) germination. *Weed Sci* 28:321–323

Vanden Born WH (1965) The effect of dicamba and picloram on quackgrass, brome grass and Kentucky bluegrass. *Weeds* 13:309–312

Wallace J, Prather T (2012a) Response of native grassland forbs and shrubs to various rates of aminocyclopyrachlor. Pages 15–16 in 2012 Research Progress Report. Las Cruces, NM: Western Society of Weed Science

Wallace J, Prather T (2012b) Tolerance of perennial pasture grass seedlings to aminocyclopyrachlor at two growth stages. Pages 17–19 in 2012 Research Progress Report. Las Cruces, NM: Western Society of Weed Science

Young JA, Evans RA (1978) Population dynamics after wildfires in sagebrush grasslands. *J Range Manage* 31(4):283–289

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