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# Effects of a New Herbicide (Aminocyclopyrachlor) on Buffalograss and Forbs in Shortgrass Prairie

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Herbicides used to control many forb species in pastures may also injure desirable native grass species. Buffalograss, a major component of shortgrass rangeland, often is injured by some growth regulator herbicides. Aminocyclopyrachlor (formerly known as DPX-MAT28 and herein termed ACPCR), a new synthetic auxin herbicide chemistry for control of broadleaf weeds, was investigated for injury to buffalograss and control of forbs in shortgrass prairie at varying rates of application. In the season of application, ACPCR at rates of 140 g ai ha$^{-1}$ or less caused buffalograss injury that was either negligible or short lived, and visual grass injury was 8% or less at the end of the growing season. At ACPCR rates of 280 g ha$^{-1}$, more injury was evident at three wk after treatment (WAT) than at the end of the season if adequate precipitation was available for new leaf growth. When precipitation was lacking, evidence of injury persisted through to the end of the season when treated at the greatest rate of ACPCR. Buffalograss injury was mainly in the form of browned leaf tips, but total buffalograss dry matter yield was not different between any treatments in either year. The year after treatment, no buffalograss injury was evident from any of the herbicide rates. Final forb control was 97% or greater each year for ACPCR at the 140 and 280 g ha$^{-1}$ rates. In this study, rates as low as ACPCR at 140 g ha$^{-1}$ provided excellent forb control and maintained buffalograss productivity.

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**Nomenclature:** 2,4-D; Aminocyclopyrachlor; Dicamba; Buffalograss, *Bouteloua dactyloides* (Nutt.) J.T. Columbus BUCDA.

**Key Words:** Dry matter yield, injury, rangeland.

Over 7.7 million hectares of Kansas consists of permanent pasture or perennial grasses for grazing or resource conservation (USDA, 2007). Approximately 3.6 million hectares of this permanent grass are native mixed and shortgrass rangelands of western Kansas. The shortgrass prairie regions of western Kansas are largely dominated by two grass species, buffalograss [*Bouteloua dactyloides* (Nutt.) J.T. Columbus] and blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.]. Musk thistle (*Carduus nutans* L.), bull thistle [*Cirsium vulgare* (Savi) Ten.], and other undesirable forb species are commonly found throughout the region. However, herbicides used to control many forb species may also injure certain native grass species. Buffalograss has been shown to be more sensitive than blue grama to some growth regulator herbicides (Huffman and Jacoby, Jr. 1984). Established buffalograss was injured for up to 15 wk by atrazine, diuron, metolachlor, and simazine, while other herbicides caused initial injury but was soon followed by full recovery (Dotray and McKenney 1996).

Native buffalograss is also a popular turfgrass, and visible injury to turfgrass is less tolerable than visible injury to the same species in agricultural animal production systems. In horticultural settings, foliar burn or discoloration to buffalograss may occur when some broadleaf herbicides are applied early in the season or under conditions of drought stress (Fagerness 2001). Buffalograss varieties were visibly injured from 20 to over 40 d after applications of herbicides containing 2,4-D and/or dicamba (McCarty and Colvin 1992). Fry and Upham (1994) also noted that certain combinations of 2,4-D, dicamba, triclopyr, clopyralid, and mecoprop caused buffalograss plant injury, which generally dissipated within 6 wk of treatment. Herbicides used to control invasive plant species in agricultural settings need to provide control without reducing stands or forage production of desirable grass species. This study investigated aminocyclopyrachlor (formerly known as DPX-MAT28 and herein termed ACPCR), a new synthetic auxin herbicide for control of a broad spectrum of broadleaf weeds, for injury to buffalograss and control of forbs at varying rates of application.

## Materials and Methods

This study was conducted at the Kansas State University Agricultural Research Center – Hays near Hays, KS in 2008 and 2009. The study sites were dominated by native vegetation consisting mostly of buffalograss, but intermixed with small populations of blue grama, sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.] and western wheatgrass (*Pascopyrum smithii* Rydb. Love). The dominant forb found throughout the test area was western ragweed (*Ambrosia psilostachya* DC.), with only isolated upright prairie coneflower [*Ratibida columnifera* (Nutt.) Woot. & Standl.], and marestail [*Connyza canadensis* (L.) Cronq.]. References to forb control and forb dry matter generally refer to western ragweed. Individual plots were 3.0 m by 9.1 m and were arranged in a randomized complete block design with three replications. Treatments were arranged as an augmented factorial arrangement and included the acid formulation of aminocyclopyrachlor (ACPCR) at 35, 70, 140, and 280 g ai $ha^{-1}$, in factorial combination with either non-ionic surfactant ([1]NIS) or methylated seed oil ([2]MSO). Other treatments included the methyl ester formulation of aminocyclopyrachlor (DPX-KJM44) at 140 g $ha^{-1}$ with MSO, a mixture of the dimethylamine salts of dicamba and 2,4-D (Rangestar[3]) at 336 and 971 g $ha^{-1}$ with NIS, respectively, and a non-treated control for a total of eleven treatments. Non-ionic surfactant was added at 0.25% v/v, and methylated seed oil was added at 1.0% v/v to their respective treatments. Treatments were applied 17 June 2008 and 30 June 2009 with a compressed $CO_2$ backpack sprayer delivering 136 L $ha^{-1}$ water carrier at 221 kPa. Low drift, flat fan spray tips with $110^{o}$ angles ([4]TeeJet TT110015) were used.

Assessing herbicide effects on buffalograss injury was the primary objective of this study; however, the emergence of a significant population of western ragweed and isolated coneflower also allowed assessment of forb control. Buffalograss injury and broadleaf forb control were evaluated at regular intervals (approximately every 18 d), with a rating of 0 equal to no visible injury and no broadleaf forb control with full vegetative growth, and 100 equal to complete injury and complete control with no live vegetation. The first rating near 3 wk after treatment (WAT) and the last rating of the growing season near 13 WAT are used in this analysis.

At the end of the growing season prior to the first frost (late September each year), two 0.1 $m^{-2}$ frames were randomly located in each plot, and forbs and grass were hand clipped separately from each frame at ground level and placed into bags. The samples were dried at 55C for 72 h, weighed, and recorded, to determine dry matter yield. Injury and control were also determined approximately one year (≈52 WAT) after herbicide application in June of 2009 and July of 2010.

General linear models ([5]SAS Institute Inc. 1995) were used for statistical analyses of visual buffalograss injury, visual forb control, and grass and forb dry matter yield. The first eight treatments were initially analyzed alone as a factorial combination of the four ACPCR rates with the two adjuvants. Adjuvant and the rate by adjuvant interaction were significant for buffalograss injury, so all eight treatments were then analyzed on an individual basis along with the three additional treatments. For visual forb control and grass and forb dry matter yield, adjuvant and the rate by adjuvant interaction were not significant, therefore data for the two adjuvants at the same ACPCR rate were pooled and analyzed as four individual rate treatments along with the three additional treatments. Year, herbicide treatment, and period were included as independent variables in the model, but data are presented by year and period if significant treatment interactions resulted. The relationship between ACPCR rate and forb dry matter yield was graphed using rate means averaged over both years, and then was analyzed with PROC NLIN to determine the relationship significance and parameters.

## Results and Discussion

In 2008, precipitation at application was nearly 15% above the long term average and remained at that level through the end of the growing season for warm-season grasses (Table 1). Precipitation at the time of treatment in 2009 was approximately only 70% of the long term average, and remained below average throughout the remainder of the season before ending at 90% of the long term average.

**Buffalograss Injury.** Adjuvants affected buffalograss injury, so all ACPCR rate and adjuvant combinations were included as individual herbicide treatments in the analysis. Adding MSO to ACPCR in 2008 increased injury by 7 to 8% over NIS with ACPCR at 70 and 140 g $ha^{-1}$ at 3 WAT. Only MSO with ACPCR at 140 g $ha^{-1}$ retained greater injury of near 6% at 13 WAT (Table 2). Herbicide adjuvant had no effect on buffalograss injury in 2009.

Buffalograss injury differed greatly between the ACPCR treatments, and the trends were slightly different each year. Initial injury in 2008 was greatest with ACPCR at 140 and 280 g $ha^{-1}$, and ranged from 12 to 28% at those rates (Table 2). Injury was less at 13 WAT than at 3 WAT in seven of the ten herbicide treatments in 2008 (Table 2). The three treatments (ACPCR at 35 and 70 g $ha^{-1}$ with NIS, and dicamba + 2,4-D) which did not have less injury at 13 WAT had almost no injury at 3 WAT. Herbicide treatments with ACPCR at 140 g $ha^{-1}$ or less had 8% or less injury at the last end-of-season rating. Herbicide treatments with ACPCR at 280 g $ha^{-1}$ had 10 to 13% injury at the end of the season. In 2008, buffalograss injury was greater 3 WAT than in 2009 when moisture was more limiting at the time of application. In 2009, treatments with ACPCR at 140 g ha$^{-1}$ or less began and ended the season with less than 7% injury (Table 2). Treatments with ACPCR at 280 g ha$^{-1}$ began and ended the season with 20 to 25% injury. The injury was evident through the remainder of the growing season after application, but less precipitation was available to produce much new growth.

Buffalograss injury with ACPCR at 140 g ha$^{-1}$ or below was either negligible or short lived. Little or no injury occurred 3 WAT, or buffalograss was able to recover and showed little sign of injury by the end of the season. This was especially true of 2008 when more precipitation was available for new leaf growth from existing tillers during the season. Injury was mainly in the form of leaf burn or browning leaf tips, except at the greatest rate of ACPCR at 280 g ha$^{-1}$, in which rare isolated plants appeared to be brown and desiccated at the first rating. Injury ratings were almost reduced by half at the end of the moist 2008 season. Browned leaf tip tissue did not recover, but rather was replaced by the presence of new leaf growth from existing tillers, thus reducing injury ratings. In irrigated buffalograss stands, mixtures of 2,4-D and dicamba also exhibited very little phytotoxicity (Van Dyke and Johnson 2009). At the same location as the current study, Timmons (1950) treated mature buffalograss stands, both irrigated and non-irrigated, with ammonium salt, sodium salt, ethyl ester, and free acid formulations of 2,4-D at 2.24 kg ha$^{-1}$, and reported almost no buffalograss injury. In the current study, no buffalograss injury was present 52 WAT in any of the herbicide treatments and was not different from the untreated control in either year, and therefore is not reported.

**Forb Control.** Herbicide adjuvant had no effect on control, so data for ACPCR rates were combined over adjuvants and analyzed. Control at 3 WAT was greater in 2008 than in 2009. In 2008, with adequate moisture at the time of application, all herbicide treatments had over 87%

control (Table 3). Near the end of the season at 13 WAT, ACPCR at either 140 or 280 g ha$^{-1}$ retained 97% or greater control. Treatments with ACPCR at 35 and 70 g ha$^{-1}$ maintained 50 to 68% control at the end of the season. In 2009, when moisture was more limited at the time of application, control 3 WAT was lower than control at 13 WAT for all herbicide treatments (Table 3). Application of ACPCR at 35 or 70 g ha$^{-1}$ had less than 60% initial control. Control 13 WAT increased to just over 80% for ACPCR at 70 g ha$^{-1}$. Control 13 WAT increased to 95% or greater for 2,4-D + dicamba and for treatments with ACPCR and DPX-KJM44 at 140 g ha$^{-1}$.

Forb control at 52 WAT resembled the pattern of control at 13 WAT. Less than 50% control resulted from ACPCR at 35 g ha$^{-1}$, while ACPCR at 70 g ha$^{-1}$ resulted in 60-78% control 52 WAT (Table 4). ACPCR at 140 and 280 g ha$^{-1}$ maintained over 88% control the year after application.

**Biomass.** Herbicide treatment had no effect on buffalograss yield at the end of the season (Table 5). However, the level of forb control from the ACPCR rates directly affected forb yield at the end of the season. As ACPCR rates increased, forb yield decreased exponentially (Figure 1). Total buffalograss production was not affected in either year of herbicide application, even at the greatest rates of ACPCR, and no evidence of injury was present the following year from any ACPCR application. ACPCR at 140 g ha$^{-1}$ appears to be optimal as it provided over 87% forb control during the season of application and the year after application with little effect of either buffalograss visual injury or production. Forb control with ACPCR at 140 g ha$^{-1}$ was equal to or greater than control with the commonly used mixture of 2,4-D + dicamba, but use rates were much lower for the ACPCR. ACPCR is absorbed rapidly through above ground plant tissue and is translocated through the xylem and phloem. ACPCR also has the ability to absorb systemically through the roots and generally sustains longer soil residual activity than 2,4-D and dicamba (Dupont 2009, EPA 1983, EPA 2005, Cox 1994, Wilson et al. 1997). ACPCR may be transferrable from field to field in plant residues, manure and urine, surface water runoff, and soil erosion sediment (Dupont 2009). However, 2,4-D and dicamba have a shorter typical half-life and less remaining residual activity in soil, and over 90% of the two herbicides ingested by ruminant animals is rapidly absorbed from the digestive tract and excreted through the urine (Clark et al. 1964, Cox 1994, Dupont 2009, EPA 1983, EPA 2005, Oehler and Ivie, 1980, Wilson et al. 1997). Although ACPCR has rapid absorption and activity in vegetation, it has low toxicity to mammals and poses low risk for handlers, applicators, and domestic animals (Dupont 2009). Of the 21 million kg of 2,4-D annually used in the U.S., 24% is applied on pasture and rangelands (EPA 2005). Use of ACPCR should be a viable alternative to 2,4-D application on pasture and rangelands. From this research, application of ACPCR up to 140 g $ha^{-1}$ appears to provide excellent forb control and poses little risk to buffalograss production and the ability to maintain potential animal stocking rates on rangelands treated with the herbicide.

## Sources of Materials

[1] Activator 90, non-ionic surfactant, Loveland Products, Inc., P.O. Box 1286, Greeley, CO 80632

[2] MSO Concentrate, methylated seed oil, Loveland Products, Inc., P.O. Box 1286, Greeley, CO 80632

[3] Rangestar, Albaugh, Inc., 1525 NE 36th Street, Ankeny, IA 50021

[4] TeeJet, TT110015 nozzles, TeeJet Technologies, P.O. Box 7900, Wheaton, IL 60189

[5] SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513-2414

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Table 1. Annual precipitation during 2008 and 2009, and the 30-year average, at Hays, KS.

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -------------------------------------------------mm------------------------------------------------- | | | | | | | | | | | | |
| 2008 | 11 | 33 | 10 | 50 | 174 | 47 | 102 | 86 | 36 | 153 | 18 | 6 | 727 |
| 2009 | 1 | 1 | 0 | 85 | 56 | 58 | 70 | 130 | 42 | 53 | 26 | 30 | 552 |
| 30 yr Avg. | 14 | 16 | 50 | 55 | 80 | 67 | 96 | 74 | 41 | 36 | 31 | 17 | 577 |

Table 2. Buffalograss injury following applications of ACPCR at different rates and with two adjuvants in 2008 and 2009 on a shortgrass rangeland at Hays, KS.

| Treatment | | | Injury | | | |
|---|---|---|---|---|---|---|
| | | | 2008 | | 2009 | |
| Herbicide | Rate | Adjuvant[b] | 3 WAT[c] | 13 WAT | 3 WAT | 13 WAT |
| | g a.i. $ha^{-1}$ | | % | | | |
| ACPCR[a] | 35 | NIS | 5 | 0 | 0 | 0 |
| ACPCR | 35 | MSO | 8 | 0 | 0 | 0 |
| ACPCR | 70 | NIS | 5 | 0 | 0 | 0 |
| ACPCR | 70 | MSO | 12 | 0 | 0 | 0 |
| ACPCR | 140 | NIS | 12 | 2 | 5 | 2 |
| ACPCR | 140 | MSO | 20 | 8 | 5 | 7 |
| ACPCR | 280 | NIS | 28 | 10 | 20 | 22 |
| ACPCR | 280 | MSO | 28 | 13 | 25 | 25 |
| DPX-KJM44 | 140 | MSO | 25 | 7 | 17 | 7 |
| Dicamba + 2,4-D [d] | 336 + 971 | NIS | 7 | 2 | 3 | 0 |
| Control | --- | none | 2 | 0 | 0 | 0 |
| $LSD_{0.05}$[e] | | | 6 | | | |

[a]ACPCR = acid formulation of aminocyclopyrachlor; DPX-KJM44 = methyl ester formulation of aminocyclopyrachlor.

[b]NIS = non-ionic surfactant; MSO = methylated seed oil.

[c]WAT = wk after treatment.

[d]Both applied as the dimethylamine salt formulation.

[e]LSD = least significant difference value for comparison of any two treatments.

Table 3. Forb control following applications of ACPCR at different rates in 2008 and 2009 on shortgrass rangeland at Hays, KS; data combined over two adjuvants.

| Treatment | | Control | | | |
|---|---|---|---|---|---|
| | | 2008 | | 2009 | |
| Herbicide[a] | Rate | 3 WAT[b] | 13 WAT | 3 WAT | 13 WAT |
| | g a.i. $ha^{-1}$ | ---------------------------- | % | ---------------------------- | |
| ACPCR | 35 | 88 | 50 | 19 | 42 |
| ACPCR | 70 | 92 | 68 | 57 | 81 |
| ACPCR | 140 | 93 | 97 | 83 | 98 |
| ACPCR | 280 | 95 | 100 | 88 | 100 |
| DPX-KJM44 | 140 | 93 | 90 | 78 | 100 |
| Dicamba + 2,4-D[c] | 336 + 971 | 92 | 75 | 73 | 95 |
| Control | --- | 0 | 0 | 0 | 0 |
| $LSD_{0.05}$[d] | | | 8 | | |

[a]ACPCR = acid formulation of aminocyclopyrachlor; DPX-KJM44 = methyl ester formulation of aminocyclopyrachlor.

[b]WAT = wk after treatment.

[c]Both applied as the dimethylamine salt formulation.

[d]LSD = least significant difference value for comparison of any two treatments.

Table 4. Forb control the year following (≈52 WAT) applications of ACPCR at different rates in 2008 and 2009 on a shortgrass rangeland at Hays, KS; data combined over two adjuvants.

| Treatment | | Control | |
|---|---|---|---|
| Herbicide[a] | Rate | 2008 | 2009 |
| | g a.i. $ha^{-1}$ | -----------%------------ | |
| ACPCR | 35 | 43 | 49 |
| ACPCR | 70 | 60 | 78 |
| ACPCR | 140 | 88 | 94 |
| ACPCR | 280 | 89 | 96 |
| DPX-KJM44 | 140 | 47 | 92 |
| Dicamba + 2,4-D[b] | 336 + 971 | 32 | 90 |
| Control | | 0 | 0 |
| $LSD_{0.05}$[c] | | 15 | |

[a]ACPCR = acid formulation of aminocyclopyrachlor; DPX-KJM44 = methyl ester formulation of aminocyclopyrachlor.

[b]Both applied as the dimethylamine salt formulation.

[c]LSD = least significant difference value for comparison of any two treatments.

Table 5. Buffalograss dry matter yield at the end of the growing season following application of ACPCR at different rates, combined over different adjuvants, in 2008 and 2009 on shortgrass rangeland at Hays, KS. Yields are averaged across both years, and were not different among treatments.

| Herbicide[a] | Rate | Buffalograss Yield[c] |
|---|---|---|
| | g a.i. $ha^{-1}$ | kg $ha^{-1}$ |
| ACPCR | 35 | 1740 |
| ACPCR | 70 | 1610 |
| ACPCR | 140 | 1680 |
| ACPCR | 280 | 1370 |
| DPX-KJM44 | 140 | 1580 |
| Dicamba + 2,4-D[b] | 336 + 971 | 1770 |
| Control | | 1430 |

[a]ACPCR = acid formulation of aminocyclopyrachlor; DPX-KJM44 = methyl ester formulation of aminocyclopyrachlor.

[b]Both applied as the dimethylamine salt formulation.

[c]Yield was not significantly influenced by any treatment according to a general linear model analysis of variance at the $P<0.05$ level.

Figure 1. Forb yield at the end of the growing season in relation to ACPCR rate following herbicide applications at different rates and with two spray adjuvants in 2008 and 2009 on a shortgrass rangeland at Hays, KS.