Trumpet creeper Control with Various Indole-3-Acetic Acid Mimics and Diflufenzopyr

Joseph E. Beeler, Gregory R. Armel, James T. Brosnan¹, Jose J. Vargas, William E. Klingeman, Rebecca M. Koepke-Hill, Gary E. Bates, Dean A. Kopsell, and Phillip C. Flanagan

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SUMMARY. Trumpet creeper (*Campsis radicans*) is a native, perennial, weedy vine of pastures, row crops, fence rows, and right-of-ways throughout most of the eastern United States. Field and greenhouse studies were conducted in 2008 and 2009 near Newport, TN, and in Knoxville, TN, to evaluate aminocyclopyrachlor-methyl and aminopyralid alone and in mixtures with 2,4-D and diflufenzopyr for selective trumpet creeper control when applied postemergence in an abandoned nursery. These treatments were compared with commercial standards of dicamba and a prepackaged mixture of triclopyr plus 2,4-D. In the field, aminocyclopyrachlor-methyl alone controlled trumpet creeper 77% to 93%, while aminopyralid alone only controlled trumpet creeper 0% to 20% by 12 months after treatment (MAT). The addition of diflufenzopyr or 2,4-D to aminocyclopyrachlor-methyl did not improve trumpet creeper control in the field; however, the addition of 2,4-D to aminopyralid improved control of trumpet creeper from 50% to 58%. All aminocyclopyrachlor-methyl treatments controlled trumpet creeper greater than or equal to dicamba and the prepackaged mixture of triclopyr plus 2,4-D. In the greenhouse, aminocyclopyrachlor and aminocyclopyrachlor-methyl applied at 8.75 to 35 g·ha⁻¹ controlled trumpet creeper 58% to 72% by 1 MAT. When both herbicides were applied at 70 g·ha⁻¹, aminocyclopyrachlor controlled trumpet creeper 64%, while aminocyclopyrachlor-methyl controlled trumpet creeper 99%, similar to dicamba.

Trumpet creeper is a native, perennial, weedy vine of pastures, row crops, fence rows, and right-of-ways throughout most of the eastern United States. This vine has the potential to cause significant interference in cultivated fields with fine textured soils (Elmore et al., 1989). Trumpet creeper is highly competitive and is capable of growing several meters in length across the span of a single growing season (Elmore, 1984). Plants germinate from papery-textured, winged seeds that are ≈15 mm long and are contained in pods (Bryson and DeFelice, 2009). Chachalis and Reddy (2000) determined that there are about 20 to 40 pods produced on each individual trumpet creeper plant

with each pod containing ≈700 seeds. These researchers also determined that trumpet creeper seed laying on the soil surface germinated about 68% but these same seeds would not germinate when incorporated 4 cm deep in the soil. Regardless, once established in an area trumpet creeper primarily propagates and spreads from rhizomes (Bryson and DeFelice, 2009; Elmore et al., 1989). Trumpet creeper is listed by Webster and Nichols (2012) as one of the most troublesome weeds in corn (*Zea mays*), cotton (*Gossypium hirsutum*), and soybean (*Glycine max*) in the midsouthern United States. It has been reported that just one plant

per 0.5 m² can reduce soybean yield by 18% (Edwards and Oliver, 2001).

Once established in an area, trumpet creeper control is difficult with non-chemical weed management tools. In fact, various methods of deep tillage and other forms of soil cultivation have proven inadequate. Edwards and Oliver (2004) found that both deep placement (23 cm) of trumpet creeper rhizomes and reducing rhizome size delayed shoot emergence but did not affect shoot growth after emergence. In soybean, evaluations of deep tillage (≈45 cm) did not reduce trumpet creeper densities the following year (Reddy, 2005).

Herbicides have been the primary tool for controlling trumpet creeper; however, the results of their use have been variable. Contact herbicides like glufosinate have provided only above-ground control of trumpet creeper with little or no effect on rhizomes (Reddy and Chachalis, 2004). Additional studies have examined the use of the systemic herbicide glyphosate for control of trumpet creeper (Boyette et al., 2008; Bradley et al., 2004; DeFelice and Oliver, 1980; Edwards and Oliver, 2001; Reddy, 2005; Reddy and Chachalis, 2004). However, well-established stands of trumpet creeper often have extensive rhizome mass which dilutes absorbed systemic herbicides like glyphosate. This morphology hampers herbicide accumulation within rhizomes at sufficient concentrations to prevent reinfestation (Reddy, 2005; Reddy and Chachalis, 2004). One study found that an early postemergence application of glyphosate (1.26 kg·ha⁻¹) followed by a late postemergence application of glyphosate (1.26 kg·ha⁻¹) reduced trumpet creeper from 2.7 to 0.9 stems/m² following three consecutive years of this treatment regime (Reddy, 2005). A recent study found a synergistic interaction between mixtures

Plant Sciences Department, The University of Tennessee, 2431 Joe Johnson Drive, 252 Ellington Plant Sciences Building, Knoxville, TN 37996

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¹Corresponding author. E-mail: jrbrosnan@utk.edu.

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.0929	ft ²	m ²	10.7639
9.3540	gal/acre	L·ha ⁻¹	0.1069
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
1.1209	lb/acre	kg·ha ⁻¹	0.8922
28.3495	oz	g	0.0353
70.0532	oz/acre	g·ha ⁻¹	0.0143
6.8948	psi	kPa	0.1450
(°F - 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

of glyphosate and the bioherbicide *Myrothecium verucaria*; this combination provided 90% control of trumpetcreeper at 12 d after treatment while glyphosate (1.12 kg·ha⁻¹ acid equivalent) or *Myrothecium verucaria* alone controlled trumpetcreeper 45% and 30%, respectively (Boyette et al., 2008). Bradley et al. (2003) reported that reduced rates of two mimics of indole-3-acetic acid, dicamba (280 g·ha⁻¹) and 2,4-D (280 g·ha⁻¹), controlled trumpetcreeper 65% and 69%, respectively when applied in corn. However, in non-crop areas where crop competition with trumpetcreeper is not involved, greater rates of a prepackaged mixture of two mimics of indole-3-acetic acid (i.e., triclopyr plus 2,4-D) applied at 3360 to 5040 g·ha⁻¹ was required to provide 60% to 79% trumpetcreeper control (Nice et al., 2006). Therefore, while older chemicals that mimic indole-3-acetic acid can suppress trumpetcreeper, it is important to evaluate new, more potent chemistries that target this mode of action for trumpetcreeper control.

Aminocyclopyrachlor and aminopyralid are recently registered mimics of indole-3-acetic acid (Herbicide Resistance Action Committee Group O) that are used for control of perennial broadleaf plants in non-crop areas (Koepke-Hill et al., 2011; Senseman, 2007). Aminocyclopyrachlor has been evaluated in both its free acid and methyl ester forms, while aminopyralid has been primarily evaluated in its free acid form (Senseman, 2007; Turner et al., 2009). Both herbicides are systemic and readily absorbed through leaves and roots of susceptible plants (Bukun et al., 2010; Senseman, 2007). Several perennial weeds species have been controlled by each of these herbicides applied between 60 and 280 g·ha⁻¹ (Enloe and Kniss, 2009; Ferrell et al., 2006; Koepke-Hill et al., 2011; Westra et al., 2008). In addition, each of these materials can often be applied in mixtures with other herbicides to broaden the spectrum of weeds controlled by a single application (Senseman, 2007; Turner et al., 2009). However, there have been no published reports to date on trumpetcreeper control with aminocyclopyrachlor or aminopyralid applied alone or in mixtures with other common herbicides.

The primary objective of this research was to evaluate aminocyclopyrachlor-methyl and aminopyralid alone and in mixtures with another mimic of

indole-3-acetic acid (i.e., 2,4-D) and the auxin transport inhibitor diflufenzopyr for control of trumpetcreeper in the field compared with commercial standards of dicamba and a prepackaged mixture of triclopyr plus 2,4-D. A secondary objective was to evaluate reduced rates of aminocyclopyrachlor in both the free acid and methyl ester form with and without 2,4-D compared with the commercial standard dicamba for control of trumpetcreeper in a greenhouse controlled environment.

Materials and methods

FIELD STUDY. Field studies were initiated at two adjacent sites in 2008 in an abandoned nursery near Newport, TN. These sites had been abandoned because of the aggressive competition of trumpetcreeper vine with previously planted nursery stock. Both study locations contained a Waynesboro loam soil (clayey, kaolinitic, thermic typic paleudults). Treatments were applied on 10 × 25-ft plots arranged in a randomized complete block design (RCBD), with three replications, in areas already infested with trumpetcreeper. Herbicide treatments were applied postemergence with a carbon dioxide (CO₂) powered backpack sprayer calibrated to deliver 23 gal/acre at 60 psi. The spray boom contained four flat fan nozzles (Teejet 8002 flat fan nozzle; Spraying Systems, Wheaton, IL) spaced 18 inches apart. The spray swath was 8.5 ft with the boom positioned at a height of 18 inches above the trumpetcreeper plants. Applications were made on 11 July 2008 for study 1 and 25 July 2008 for study 2 to trumpetcreeper 9.5 inches in height.

Herbicide treatments included aminocyclopyrachlor-methyl (DuPont Crop Protection, Wilmington, DE) at 70, 140, and 280 g·ha⁻¹, aminocyclopyrachlor (free carboxylic acid, DuPont Crop Protection) at 70, 140, and 280 g·ha⁻¹, aminopyralid (Milestone®; Dow AgroSciences, Indianapolis, IN) at 70 and 140 g·ha⁻¹, 2,4-D (Weedone® LV4 EC; Nufarm, Burr Ridge, IL) at 1080 g·ha⁻¹, and diflufenzopyr (25% WP, DuPont Crop Protection) at 70 g·ha⁻¹. Also included as treatments were the mixtures of aminocyclopyrachlor-methyl at 70 g·ha⁻¹ plus 2,4-D at 1080 g·ha⁻¹, aminopyralid at 140 g·ha⁻¹ plus 2,4-D at 1080 g·ha⁻¹, aminocyclopyrachlor-methyl at 70 g·ha⁻¹

plus diflufenzopyr at 70 g·ha⁻¹, and aminopyralid at 140 g·ha⁻¹ plus diflufenzopyr at 70 g·ha⁻¹. These treatments were compared with the commercial standards dicamba (Clarity®; BASF, Research Triangle Park, NC) at 2240 g·ha⁻¹ and a prepackaged mixture of triclopyr plus 2,4-D (Crossbow®; Dow AgroSciences) at 2242 g·ha⁻¹ plus 4483 g·ha⁻¹, respectively. All treatments in these field studies included a methylated seed oil surfactant (Universal Crop Protection Alliance, Eagan, MN) at 1% v/v.

Trumpetcreeper control was visually rated on a 0% (no injury) to 100% (complete kill) scale at 2 and 12 MAT. Trumpetcreeper stem density and length were recorded from two randomly positioned 0.25-m² areas within each plot at 12 MAT. All trumpetcreeper vines present in each 0.25-m² area were counted and lengths were recorded. After this data had been collected, trumpetcreeper harvested from each 0.25-m² area was dried at 134 °F for 72 h. Aboveground biomass values were then recorded for each sample.

GREENHOUSE STUDY. Greenhouse studies were initiated in 2009 in Knoxville, TN, to confirm visual observations from the aforementioned field studies. Trumpetcreeper stems (4 inches long, two mature leaves) were harvested from the field sites, dipped in a solution of indole-3-butyric acid (Hormodin #1; OHP, Mainland, PA), and maintained under mist for 2 months. Rooted plants were transplanted into 9.5 × 9.5-cm pots (Dillen 4" traditional greenhouse pots; Myers Industry, Sparks, NV) filled with a Sequatchie loam soil (fine-loamy, siliceous, semiactive, thermic humic Hapludult) blended in a 3:1 ratio with a clay mineral soil amendment (Turface; Profile Products, Buffalo Grove, IL). Plants were allowed to acclimate to greenhouse conditions during which time they were fertilized (Plantex 20N-20P-20K water soluble fertilizer; Plant Products, Brampton, ON, Canada) and watered when needed to maximize growth and vigor. Treatments in greenhouse studies were arranged in a RCBD with three replications and repeated in time during 2009.

Herbicide treatments were applied plants with at least two shoots measuring between 24 and 36 inches in length. Herbicides included: aminocyclopyrachlor-methyl at 8.75, 17.5, 35, and 70 g·ha⁻¹,

aminocyclopyrachlor at 8.75, 17.5, 35, and 70 g·ha⁻¹, 2,4-D at 135, 270, and 540 g·ha⁻¹, and dicamba at 1919 g·ha⁻¹. Also included were the following tank mixture treatments: 1) aminocyclopyrachlor-methyl at 8.75 g·ha⁻¹ plus 2,4-D at 135 g·ha⁻¹, 2) aminocyclopyrachlor-methyl at 17.5 g·ha⁻¹ plus 2,4-D at 270 g·ha⁻¹, 3) aminocyclopyrachlor-methyl at 35 g·ha⁻¹ plus 2,4-D at 540 g·ha⁻¹, 4) aminocyclopyrachlor at 8.75 g·ha⁻¹ plus 2,4-D at 135 g·ha⁻¹, 5) aminocyclopyrachlor at 17.5 g·ha⁻¹ plus 2,4-D at 270 g·ha⁻¹, and 6) aminocyclopyrachlor at 35 g·ha⁻¹ plus 2,4-D at 540 g·ha⁻¹. Aminocyclopyrachlor and aminocyclopyrachlor-methyl rates in the greenhouse studies were lower than those evaluated in the field to evaluate potential synergy of 2,4-D tank mixtures for trumpetcreeper control. All treatments in the greenhouse studies included a methylated seed oil surfactant at 1% v/v. Treatments were applied postemergence with a CO₂-powered backpack sprayer calibrated to deliver 23 gal/acre at 40 psi through flat fan nozzles at a height of 30 inches above the plant canopy. All greenhouse applications were made on 18 Apr. 2009.

Trumpetcreeper control was rated visually on a 0% (no injury) to

100% (complete kill) scale at 1 MAT. Plants were harvested following the 1 MAT visual evaluation and plant fresh weight (FW) biomass was recorded.

STATISTICAL ANALYSIS. Data for all studies were arcsine transformed before being subjected to analysis of variance in SAS (version 9.1.3; SAS Institute, Cary, NC), with main effects and all possible interactions tested using the appropriate expected mean square values described by McIntosh (1983). Interpretations were not different from non-transformed data; therefore, non-transformed means are presented for clarity. Fisher's protected least significant difference test was used for mean separation at the $P < 0.05$ level. Data were pooled over studies when no treatment-by-study interaction occurred.

Results and discussion

FIELD STUDY. No treatment-by-study interactions occurred for stem length or density measurements; therefore, these data were pooled over studies (Table 1). All other data from the field studies are presented individually. Aminocyclopyrachlor-methyl alone or in combination with 2,4-D or diflufenzopyr provided at least 90% control of trumpetcreeper in both studies by 2 MAT (Table 1). The

herbicidal response observed in our studies was similar to other research describing aminocyclopyrachlor or aminocyclopyrachlor-methyl activity on other herbaceous perennial weeds (Koepke-Hill et al., 2011; Westra et al., 2008). In contrast, aminopyralid alone did not provide greater than 37% control of trumpetcreeper by 2 MAT. The addition of 2,4-D to aminocyclopyrachlor-methyl did not improve trumpetcreeper control because aminocyclopyrachlor-methyl alone provided >90% control; however, the addition of 2,4-D to aminopyralid provided improved trumpetcreeper control to 93% by 2 MAT. The addition of diflufenzopyr did not improve trumpetcreeper control when applied in combinations with aminocyclopyrachlor-methyl or aminopyralid. Similarly, other researchers have noted a differential response from combinations of diflufenzopyr with various mimics of indole-3-acetic acid (Enloe and Kniss, 2009). Both dicamba and the prepackaged mixture of triclopyr and 2,4-D provided 86% to 97% control of trumpetcreeper vine by 2 MAT.

By 12 MAT, all aminocyclopyrachlor-methyl treatments controlled trumpetcreeper 77% to 93%, while all aminopyralid treatments provided less than 59% control (Table 1). Dicamba,

Table 1. Trumpetcreeper control, biomass, stem length, and stem density following postemergence applications of several mimics of indole-3-acetic acid and diflufenzopyr during two field studies conducted on an abandoned nursery outside of Newport, TN, during 2008. Biomass, stem length, and stem density data were collected 12 mo. after treatment (MAT). No year by treatment interaction occurred for stem length and stand density; therefore, these data are pooled over studies.

Treatments ^z	Rate (g·ha ⁻¹) ^y	Trumpet creeper control						Stem length (cm) ^y	Stem density (stems/m ²) ^y
		2 MAT (%)		12 MAT (%)		Biomass (g) ^y			
		Study 1	Study 2	Study 1	Study 2	Study 1	Study 2		
Aminocyclopyrachlor-methyl	70	94	90	77	87	3	1	31	2
Aminocyclopyrachlor-methyl	140	96	96	77	82	0	0	0	0
Aminocyclopyrachlor-methyl	280	98	99	77	93	9	0	31	4
Aminopyralid	70	27	28	0	3	132	29	173	8
Aminopyralid	140	30	37	20	18	57	32	109	8
2,4-D	1080	95	87	45	54	0	7	18	1
Diflufenzopyr	70	25	3	0	0	96	72	160	20
Aminocyclopyrachlor-methyl + 2,4-D	70 + 1080	98	95	82	87	0	1	5	1
Aminopyralid + 2,4-D	70 + 1080	93	93	58	50	5	0	46	4
Aminocyclopyrachlor-methyl + diflufenzopyr	70 + 70	99	94	77	87	0	0	0	0
Aminopyralid + diflufenzopyr	70 + 70	25	35	10	15	42	99	188	12
Triclopyr + 2,4-D	2242 + 4483	87	95	35	72	35	3	81	4
Dicamba	2240	86	97	53	83	4	0	28	4
Untreated control	—	0	0	0	0	54	103	127	16
LSD _{0.05} ^x		10	9	16	13	70	31	71	8

^zAll treatments included 1% v/v methylated seed oil surfactant.

^y1 g·ha⁻¹ = 0.0143 oz/acre, 1 g = 0.0353 oz, 1 cm = 0.3937 inch, 1 stem/m² = 0.0929 stem/ft².

^xLeast significant difference at $P = 0.05$.

2,4-D, and the prepackaged mixture of triclopyr plus 2,4-D provided variable control of trumpet creeper vine (35% to 83%) over studies by 12 MAT. Dicamba and 2,4-D alone, aminopyralid plus 2,4-D, and all rates and mixtures of aminocyclopyrachlor-methyl were the only treatments that reduced both stem length and density compared with the untreated control. Similarly, these same treatments held trumpet creeper dry weight biomass to below 10 g per plot in both field studies, while the untreated control contained 54 to 103 g of trumpet creeper dry weight biomass.

GREENHOUSE STUDY. No study-by-treatment interaction occurred for trumpet creeper control or FW biomass data; therefore, these data were pooled over studies (Table 2). By 1 MAT, aminocyclopyrachlor or aminocyclopyrachlor-methyl alone at 8.75 and 35 g·ha⁻¹ controlled trumpet creeper 58% to 72%. However, at 70 g·ha⁻¹ aminocyclopyrachlor provided 63% control of trumpet creeper, while aminocyclopyrachlor-methyl controlled trumpet creeper 99%, similar to dicamba. Differences in efficacy

with aminocyclopyrachlor and aminocyclopyrachlor-methyl in the greenhouse could potentially be related to the lipophilic nature of the methyl ester formulation allowing for greater absorption into trumpet creeper foliage (Bukun et al., 2010). When aminocyclopyrachlor or aminocyclopyrachlor-methyl was applied at 17.5 to 35 g·ha⁻¹ with 2,4-D, trumpet creeper was controlled 94% to 99%. Applications of 2,4-D alone at 135 to 540 g·ha⁻¹ controlled trumpet creeper 74% to 91%. Treatment with dicamba (1919 g·ha⁻¹), 2,4-D (540 g·ha⁻¹), and tank mixtures of aminocyclopyrachlor or aminocyclopyrachlor-methyl applied at 35 g·ha⁻¹ plus 2,4-D all reduced trumpet creeper FW biomass in comparison with the untreated control. When applied alone aminocyclopyrachlor-methyl at 35 and 70 g·ha⁻¹ also reduced trumpet creeper FW biomass in comparison with the untreated control. However, aminocyclopyrachlor alone at the same rates did not reduce trumpet creeper FW biomass.

In both the field and greenhouse studies, aminocyclopyrachlor-methyl provided excellent trumpet creeper control while aminopyralid was ineffective.

Aminocyclopyrachlor-methyl controlled trumpet creeper greater than or equal to commercial standards of dicamba and the prepackaged mixture of triclopyr plus 2,4-D. The addition of 2,4-D or diflufenopyr to aminocyclopyrachlor-methyl did not improve control of trumpet creeper in the field, but when aminocyclopyrachlor-methyl was applied at lower rates in the greenhouse environment there was an obvious increase in activity associated with these mixtures. When aminocyclopyrachlor and aminocyclopyrachlor-methyl were applied at 70 g·ha⁻¹ in the greenhouse, aminocyclopyrachlor-methyl was more effective at controlling trumpet creeper and reducing FW biomass. Results of these studies demonstrate that aminocyclopyrachlor-methyl has the potential to provide excellent control of trumpet creeper in non-crop areas, especially as a part of a reclamation project in abandoned nursery fields. However, future research must be conducted to determine the number of applications needed to eradicate trumpet creeper and what type of replanting restrictions would be required to safely re-establish nursery stock following these applications.

Table 2. Trumpet creeper control and fresh weight biomass following postemergence applications of aminocyclopyrachlor, aminocyclopyrachlor-methyl, 2,4-D, and dicamba at 1 mo. after treatment. Data were collected during two greenhouse studies conducted in Knoxville, TN during 2009. No treatment-by-study interactions were detected; therefore, data from each study were pooled.

Treatments ^a	Rate (g·ha ⁻¹) ^y	Trumpet creeper control (%)	Fresh wt biomass (g) ^y
Aminocyclopyrachlor	8.75	58	3.28
Aminocyclopyrachlor	17.5	72	2.52
Aminocyclopyrachlor	35	69	3.32
Aminocyclopyrachlor	70	63	3.88
Aminocyclopyrachlor-methyl	8.75	58	3.68
Aminocyclopyrachlor-methyl	17.5	63	3.35
Aminocyclopyrachlor-methyl	35	72	1.62
Aminocyclopyrachlor-methyl	70	99	1.33
2,4-D	135	74	2.57
2,4-D	270	75	2.08
2,4-D	540	91	1.38
Aminocyclopyrachlor + 2,4-D	8.75 + 135	63	3.20
Aminocyclopyrachlor + 2,4-D	17.5 + 270	94	1.25
Aminocyclopyrachlor + 2,4-D	35 + 540	95	1.48
Aminocyclopyrachlor-methyl + 2,4-D	8.75 + 135	82	2.13
Aminocyclopyrachlor-methyl + 2,4-D	17.5 + 270	99	0.47
Aminocyclopyrachlor-methyl + 2,4-D	35 + 540	99	0.25
Dicamba	1919	99	0.45
Untreated control	—	0	3.80
LSD _{0.05} ^x		13	1.75

^aAll treatments included 1% v/v methylated seed oil surfactant.

^y1 g·ha⁻¹ = 0.0143 oz/acre, 1 g = 0.0353 oz.

^xLeast significant difference at *P* = 0.05.

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