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(*Amaranthus tuberculatus* var *rudis*) with dicamba and
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Complete List of Authors:	Schryver, Mike; University of Guelph, Ridgetown Campus Soltani, Nader; University of Guelph, Ridgetown Campus Hooker, David; University of Guelph Ridgetown Campus,, Plant Agriculture; University of Guelph Robinson, Darren; University of Guelph, Dept. Plant Agriculture Tranel, Patrick; University of Illinois, Crop Sciences Sikkema, Peter; University of Guelph, Dept. Plant Agriculture
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Control of glyphosate-resistant common waterhemp (*Amaranthus tuberculatus* var *rudis*) with dicamba and dimethenamid-P in Ontario

Mike G. Schryver, Nader Soltani, David C. Hooker, Darren E. Robinson, Patrick J. Tranel and Peter H. Sikkema

Abstract: Glyphosate-resistant (GR) common waterhemp is the fifth confirmed GR weed in Canada and was first confirmed in 2014 in the province of Ontario. In 2015 and 2016, two field experiments were conducted across 4 site-years each to determine the effectiveness of dicamba at two rates (300 and 600 g ai ha⁻¹) in addition to dimethenamid-P (693 g ai ha⁻¹) in a single and sequential management program. Due to limited soybean seed availability, all treatments were applied in corn. Waterhemp density, biomass, visual control estimates and corn yield were collected. Waterhemp density and dryweight were found to be lower in treatments including a sequential application of dicamba and those that included dimethenamid-P. The sequential management strategy provided >95% control of GR waterhemp at 12 WAA. Dicamba applied POST at 300 and 600 g ai ha⁻¹ controlled GR waterhemp 80 and 91%, respectively; in contrast, dicamba applied PRE at 300 and 600 g ai ha⁻¹ provided only 9 and 30% control of GR waterhemp, respectively. Dimethenamid-p controlled waterhemp better than dicamba when

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M.G. Schryver, N. Soltani, D.C. Hooker, D.E. Robinson, and P.H. Sikkema. University of Guelph Ridgetown Campus, Ridgetown, ON N0P 2C0, Canada.

P.J. Tranel, Department of Crop Science. University of Illinois at Urbana-Champaign, 1201 W. Gregory Dr. Urbana, IL 61801, USA.

Corresponding author: Nader Soltani (e-mail: soltanin@uoguelph.ca).

Abbreviations: GR, glyphosate resistant; WAA, weeks after application; WH, waterhemp

applied PRE. Corn yield was also impacted by herbicide timing as corn yield was reduced by 17-23% comparing to PRE vs POST applications in the experiments presented.

Key words: Glyphosate resistance, distribution, multiple-resistant, waterhemp

Introduction

Glyphosate resistant (GR) common waterhemp, (*Amaranthus tuberculatus* var. *rudis*) is the fifth confirmed GR weed in Canada, first discovered in Lambton County, Ontario from seed collected in 2014. This small-seeded, summer annual, broadleaf weed has become very problematic in the United States and is seen as one of the most troublesome weeds in the Midwestern United States Corn Belt (Hager and Sprague 2002). A recent waterhemp survey in Ontario has identified thirty-nine additional fields with GR biotypes as of 2015 (Schryver et al. 2017a). The resistance factor in GR populations in Ontario was found to be 5-28 fold 4 weeks after application (WAA) in field and greenhouse experiments (Schryver et al. 2017b). These findings were based on visual control estimates and differed when conducted in the greenhouse and in a field settings (Schryver et al. 2017b). Glyphosate-resistant waterhemp in Ontario is also resistant to Group 2 and Group 5 herbicides; 61% of all populations surveyed were found to show resistance to herbicide Groups 2, 5 and 9 (Schryver et al. 2017a). In the US, resistance in waterhemp has been documented in herbicide Groups 2, 4, 5, 9, 14, and 27 across different populations; one population in Illinois was found to have resistance to 5 of the 6 herbicide groups, all but Group 4 (Heap 2016). With an increasing number of herbicides that are no longer effective for the control of waterhemp, growers are left with fewer herbicide options.

Waterhemp is a very persistent weed that has adapted to a wide range of growing conditions. As summarized by Costea et al. in 2005, waterhemp thrives under warm temperatures, moderate

to high moisture, high light intensities, and nitrogen-rich soils. Research conducted by Burnside et al. (1996) found that 3% of waterhemp seed was still viable after seventeen years in the soil. Waterhemp seedlings emerge April to October in Ontario; plants at the cotyledon stage have been observed into late fall (Vyn et al. 2007; Schryver et al. 2017b). The weed has an erect structure, is a C₄ plant and has been documented with the ability to grow 1.6 mm for every growing degree day (Horak and Loughin 2000). Waterhemp is dioecious (Costea et al. 2005); this enables high genetic diversity through wind dispersed pollen and has been one of the reasons for rapid evolution of herbicide resistance (Wu and Owen 2014). Hartzler et al. (2004) reported that a single female waterhemp plant can produce up to 4.8 million seeds under ideal conditions. In summary, GR waterhemp is difficult to control because of long-term seed viability in the soil seedbank, a wide emergence window, rapid vegetative growth, and prolific seed production.

The approval of dicamba/glyphosate resistant (Roundup Ready 2Xtend[®]) soybean provides an additional tool for the control of GR waterhemp and has been found to be more effective in waterhemp control than currently available technologies (Meyer et al. 2015). Soybean is very sensitive to dicamba; for example, Anderson et al. reported up to 80% soybean injury and 83% yield loss at 56 g ae ha⁻¹ (2004). Dicamba is a Group 4 herbicide known as a synthetic auxin or growth regulator. Group 4 herbicides mimic naturally occurring plant auxins by inducing rapid growth and expressing genes that were otherwise suppressed (Grossman 2000; Staswick et al. 2005; Kelley and Riechers 2007). Injury symptoms on susceptible soybean and weeds include leaf and stem epinasty, inhibition of root growth, leaf chlorosis, reduced stomatal function, and shorter internodes (Bromilow and Chamberlain 1991; Grossman 2000). Severe plant injury or death from dicamba results from the destruction of vascular tissue, compromising plant membrane integrity, damage to chloroplasts and desiccation (Grossman 2000). This group of

herbicides are particularly effective on dicot species, such as waterhemp, in contrast to monocots due to the vascular structure of grass species and differential metabolism between grass and broadleaf weeds (Subramanian et al. 1997). Darrow and Haas (1961) reported that dicamba was first registered in 1965 and has been used historically in monocot crops such as corn, sugarcane and many small grain cereals (Devine et al. 1993). With the recent registration for use in transgenic soybean resistant to glyphosate and dicamba, growers may be able to use dicamba for controlling GR waterhemp and reduce the reliance on other herbicide groups for controlling broadleaf weed species. The use of multiple herbicide modes of action reduces the evolution of herbicide resistance (Norsworthy et al. 2012). The dicamba-resistant soybean system may be an excellent management strategy to control GR waterhemp.

The objectives of this research were to: 1) determine the level of GR waterhemp control using different rates and timings of dicamba and 2) ascertain the level of GR waterhemp control using dimethenamid-P plus dicamba.

Materials and Methods

Two experiments were established to investigate various management strategies for controlling GR waterhemp with dicamba and dimethenamid-P. Each experiment was conducted on two field sites over 2 years (2015, 2016) for a total of 4 sites. In 2015, experiments were conducted on the same location, on Walpole Island, but were separated by herbicide application date (Table 1). Glyphosate-resistant waterhemp was first found in Canada on the Walpole Island field site (Heap et al. 2016; Schryver et al. 2017a). In 2016, experimental sites were in two different counties, one on Walpole Island and another with confirmed GR waterhemp near

Cottam, in Essex County. Soil characteristics, waterhemp densities, and herbicide application dates are presented in Table 1.

The first experiment consisted of 13 treatments arranged in a randomized complete block design with 4 replications, which included: weedy and weed-free controls, glyphosate (900 g ai ha⁻¹) alone, dicamba applied preemergence (PRE) at 300 and 600 g ai ha⁻¹, glyphosate (900 g ai ha⁻¹) plus dicamba applied postemergence (POST) at 300 and 600 g ai ha⁻¹, and finally, dicamba applied PRE at 300 and 600 g ai ha⁻¹ followed by either POST glyphosate (900 g ai ha⁻¹) alone or tankmixed with dicamba at 300 g ai ha⁻¹ or 600 g ai ha⁻¹ (Table 2). No added adjuvants were used.

The second experiment followed a similar protocol to Experiment One, but tested 17 treatments. Purpose of this experiment was to compare dimethenamid-P (693 g ai ha⁻¹) and dicamba (600 g ai ha⁻¹) alone and in combination PRE in addition to testing sequential applications with dicamba. The herbicides compared POST included glyphosate (900 g ai ha⁻¹) alone and tankmixed with either 300 or 600 g ai ha⁻¹. Sequential weed control treatments included either dimethenamid-P (693 g ai ha⁻¹), dicamba (600 g ai ha⁻¹) or the combination of the two PRE followed by each of the three POST options (Table 3).

Glyphosate (1800 g ai ha⁻¹) was applied over the entire trial area to remove potential confounding weeds, and disked twice for proper seed bed preparation. Trials were planted to corn as a test crop because dicamba-resistant soybean was not available. Dekalb DKC53-56 was planted in rows spaced 76 cm apart at a depth of 5 cm. Each plot was 2.25 m (3 corn rows) wide by 8 m in length. Treatments included a weedy and weed-free control. Weed-free plots were maintained with s-metolachlor/atrazine/mesotrione (2,068 g ai ha⁻¹) applied PRE followed by hand hoeing weed escapes during the growing season. Preemergence herbicide treatments were

applied before corn emergence within 5 days after planting, and POST herbicide treatments were applied when waterhemp escapes in the PRE treatments were approximately 10 cm tall (Table 1). Herbicides were applied with a CO₂ pressurized backpack sprayer calibrated to deliver 200 L ha⁻¹ at 240 kPa equipped with a 1.5 m boom with four ULD 120-02 nozzles (Hypro, New Brighton, MN) spaced 50 cm apart.

Data collection consisted of visual estimations of crop injury, visual estimations of waterhemp control, waterhemp population density, waterhemp dry weight and crop yield. Crop injury evaluations were conducted at 1, 2, 4, 8 weeks after application (WAA) using the untreated corn stand as the uninjured check (0%) and complete plant death denoted as 100%. Similarly, visual estimates of waterhemp control were conducted at 2, 4, 8, and 12 WAA relative to both the weedy check (0% control) and the weed-free (100% control) within each block. Evaluation intervals were calculated based on the POST application timing date. At 4 WAA, waterhemp density and biomass was estimated in each plot by cutting a 0.5 m² subsample of waterhemp from each plot. The subsample was obtained using a 0.25 m² quadrat placed randomly in two places between rows 2 and 3 of corn. Waterhemp plants were counted, cut at the soil surface, placed into paper bags, dried in a kiln at 60°C and weighed. Finally, grain corn yield was measured by threshing ears from a 1 m subsample of corn from rows 2 and 3, of each plot. The grain weights and moisture were recorded and grain yield was adjusted to 15.5% moisture.

Statistical analysis was conducted using the PROC MIXED procedure in SAS (SAS Institute, Cary, NC) where fixed effects of herbicide treatments were compared. Random effects were partitioned into block, site-year, and treatment nested in site-year. Residuals were plotted by each variable and assessed for normality using PROC UNIVARIATE Shapiro-Wilk Test.

Weed population density and dry weights were converted to the percentage of the weedy control in each block. To meet the assumptions of variance, an arcsine square-root transformation was conducted prior to analysis for all variables with the exception of corn grain yield for Experiment 1 which remained untransformed. Means were compared using non orthogonal contrasts with significance set at $P = 0.05$. Results presented have been back transformed.

Results and Discussion

In Experiment One, PRE applications of dicamba provided 19% control when compared to 86% control POST. The use of dicamba at 300 g ai ha⁻¹ provided 9% control PRE, but 78% POST (Table 4). The same trend is observed at 600 g ai ha⁻¹ with 33 and 92% control at PRE and POST, respectively (Table 4). Among POST applications, there was little difference in the level of control at 300 or 600 g ai ha⁻¹ with the only statistical difference found at 8 WAA with an improved level of control with the higher rate by 23% (Table 4). The sequential (PRE fb POST) management strategy controlled GR waterhemp by 95% compared to 19 and 86% control using dicamba applied at PRE and POST alone, respectively. There was little significance in yield. The only difference found was when comparing PRE and POST with 8.44 and 10.16 T ha⁻¹ respectively ($P < 0.05$) representing a 20% reduction. Average grain corn yields were reduced by 20% due to lack of GR waterhemp control in PRE treatments when compared to POST treatments ($P < 0.001$; Table 4). Although there was a 12% decrease in yield in PRE treatments when compared to PRE fb POST 9.55, the difference was not significant ($P = 0.0508$) (Table 4).

In the second experiment, GR waterhemp control was improved with the use of dimethenamid-P when compared to dicamba PRE and, similarly to the previous experiment, dicamba performed greater with a POST timing (Table 5). Herbicide timing was again found to

be highly significant with all parameters, with the exception of yield, when comparing POST vs PRE fb POST. The control of GR waterhemp was 97% with the application of a PRE fb POST (Table 5). Dimethenamid-p controlled GR waterhemp 33% better than dicamba 12 WAA and was found to be statistically greater in all parameters with the exception of yield (Table 5). The addition of dicamba to dimethenamid-P was no better than when dimethenamid-P was applied alone. The same results were found when comparing PRE dicamba alone with the tankmix of dimethenamid-P plus dicamba, with greater control for all parameters with the exception of yield (Table 5). When comparing POST dicamba at 300 and 600 g ai ha⁻¹, as in the previous experiment, there was little difference with exception of density, where 600 g ai ha⁻¹ was found to be similar to the weed-free control.

Crop injury was observed throughout the season but was most evident following the application of dicamba POST at the evaluation timing of 3 WAA. Crop injury was observed up to 20% with 'Sheppard's crook' and roping visible particularly in treatments with high rates of dicamba PRE and POST. Once developed, brace root malformation was also particularly evident due to the amount of dicamba applied in some of the treatments which included the fusing and upward twisting of these structures. Injury symptoms improved over time and were not as apparent 12 WAA.

The use of corn as a test crop for soybean may have affected GR waterhemp control with the various treatments. It has been documented in Ontario that corn is more competitive with waterhemp than soybean; seed yield loss in soybean in weedy checks was 73% (Vyn et al. 2007), compared to 38% in corn (Soltani et al. 2009). In a study conducted on waterhemp growth and fecundity in corn, a sharp decrease in biomass and seed production was observed from 80 to 99% when introduced at corn stages V3 to V8 respectively compared to 20% when planted at corn

stage VE (Nordby and Hartzler 2004). Although the same decreasing trend in waterhemp survival was observed in a similar study conducted in soybean, the rate of decrease was not as rapid, with an initial decrease of 10% when planted at soybean stage VE followed by a further decrease of 20-30% survival at soybean stage (V2, V4, and V6) (Hartzler et al. 2004). Nordby and Hartzler (2004) also compared their results to those of Hartzler et al. (2004) in soybean and found waterhemp biomass and seed production were much lower when grown in competition with corn (2004). Therefore, it may be hypothesized that waterhemp control in dicamba-resistant soybean may be less compared to the control observed in this study with corn.

Poor control of GR waterhemp with a PRE application of dicamba may have resulted from inadequate rainfall after application. Although the herbicide received adequate moisture for herbicide activation, 2016 was particularly dry. The activation and persistence of dicamba is variable and depends on several factors including pH, soil temperature and moisture, and microbial activity (Grover 1988). Future research is suggested to gain a better understanding on how dicamba performs under a soybean cropping system and with subsequent years of data to gain understanding as to how dicamba performs under different environmental conditions.

In conclusion, control of GR waterhemp, through the simulated use of the newly approved dicamba-resistant soybean technology provided greater than 95% control of GR waterhemp at 12 WAA. Glyphosate-resistant waterhemp control with a sequential weed management strategy including dicamba was found to be similar to the weed-free control at 4 WAA. Dicamba was found to be most effective on waterhemp when applied POST with an average control of 80 and 91% in contrast to 9 and 30% when applied PRE at 300 and 600 g ai ha⁻¹, respectively. In general, dicamba applied at either 300 or 600 g ai ha⁻¹ was very similar in a sequential control strategy. Dimethenamid-p applied PRE increased control of waterhemp and was not improved

with the addition of dicamba. Although this new technology is valuable for the mitigation of GR waterhemp in soybean, an integrated weed management approach is necessary to reduce the reliance of herbicides for controlling weeds. Diversity in weed management is recommended to ensure longevity of herbicide efficacy. Such an approach may include the use of cover crops, narrow rows, high crop population densities, use of strategic tillage and companion crops, which would reduce the reliance on herbicides for controlling weeds.

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Table 1. Field site and herbicide application information with dicamba and dimethenamid-P in single and sequential weed control research conducted on glyphosate resistant waterhemp in 2015 and 2016 in Ontario.

Soil Characteristics							Herbicide Application ^a				
							PRE		POST		
									App. Date	Size (cm) ^b	Density (no. m ⁻²) ^b
Experiment	Location	Year	Nearest City	Texture	OM ^a	pH	Seeding Date	App. Date	App. Date	Size (cm) ^b	Density (no. m ⁻²) ^b
1. dicamba	Walpole 1	2015	Wallaceburg	Sandy Loam	5.5	7.7	May 28	May 29	July 2	12	386
	Walpole 2	2015	Wallaceburg	Sandy Loam	5.5	7.7	May 28	June 2	July 8	15	445
	Walpole	2016	Wallaceburg	Sandy Loam	6.4	7.6	May 30	June 1	July 11	24	37
	Nelson	2016	Cottam	Sandy Loam	2.9	6.5	May 23	May 24	June 21	16	92
2. dicamba + dimethenamid-P	Walpole 1	2015	Wallaceburg	Sandy Loam	5.5	7.7	May 28	May 29	July 10	29	406
	Walpole 2	2015	Wallaceburg	Sandy Loam	5.5	7.7	May 28	June 2	July 15	33	200
	Walpole 1	2016	Wallaceburg	Sandy Loam	6.4	7.6	May 30	June 1	July 11	23	85
	Nelson	2016	Cottam	Sandy Loam	2.9	6.5	May 23	May 24	June 21	11	53

^aAbbreviations: PRE, preemergent; POST, postemergent; OM, percent organic matter; App., application.

^bSize and density assessments were conducted in the untreated check plots.

Table 2. Means and non-orthogonal contrasts for glyphosate-resistant waterhemp control using dicamba at two different rates and timings across 4 site-years in Ontario.^a

Treatment	Rate (g ai ha ⁻¹)	App. Timing	Visual control estimate timing (%)				4 WAA		Grain corn yield (T ha ⁻¹)
			2 WAA	4 WAA	8 WAA	12 WAA	Population density (% of weedy check)	Weed dry weight (% of weedy check)	
Weedy check			0	0	0	0	100	100	7.88
Weed-free			100	100	100	100	0	0	9.94
dicamba	300	PRE	29	19	13	9	104	69	8.23
dicamba	600	PRE	48	42	39	33	76	35	8.65
glyphosate	900	POST	37	39	25	18	77	35	9.59
glyphosate	900	POST	76	79	70	78	30	7	9.54
dicamba	300	POST							
glyphosate	900	POST	87	91	93	92	7	1	10.79
dicamba	600	POST							
dicamba	300	PRE	57	55	49	44	120	37	9.16
glyphosate	900	POST							
dicamba	300	PRE	86	87	90	90	18	3	9.91
glyphosate +	900	POST							
dicamba	300	POST							
dicamba	300	PRE	94	98	99	98	5	1	9.63
glyphosate +	900	POST							
dicamba	600	POST							
dicamba	600	PRE	82	79	75	71	75	9	9.62
glyphosate	900	POST							
dicamba	600	PRE	91	93	94	94	17	2	9.84
glyphosate +	900	POST							
dicamba	300	POST							
dicamba	600	PRE	96	97	98	97	2	1	8.80
glyphosate +	900	POST							
dicamba	600	POST							

^aabbreviations: WAA, weeks after application; fb, followed by; vs, versus; PRE, preemergent; POST, postemergent.

Table 3. Means and non-orthogonal contrasts for glyphosate-resistant waterhemp control using dimethenamid-P and dicamba

across 4 site-years in Ontario.

Treatment	Rate (g ai ha ⁻¹)	App. ^a Timing	Visual control estimate timing (%)				4 WAA		Grain corn yield (T ha ⁻¹)
			2 WAA	4 WAA	8 WAA	12 WAA	Population density (% of weedy check)	Dry weight (% of weedy check)	
Weedy check			0	0	0	0	100	100	5.78
Weed-free			100	100	100	100	0	0	10.22
Dimethenamid-P	693	PRE	76	71	64	60	26	8	9.12
Dicamba	600	PRE	42	45	32	27	56	31	7.46
Dimethenamid-P	693	PRE	85	82	77	72	26	7	8.70
Dicamba	600	PRE							
Glyphosate	900	POST	37	36	29	32	75	22	9.88
Glyphosate	900	POST							
Dicamba	300	POST	78	83	83	82	29	7	10.71
Glyphosate	900	POST							
Dicamba	600	POST	86	89	90	90	10	2	9.99
Dimethenamid-P	693	PRE							
Glyphosate	900	POST	93	91	90	88	24	1	10.04
Dimethenamid-P	693	PRE							
Glyphosate	900	POST	96	99	99	99	2	0	9.41
Dicamba	300	POST							
Dimethenamid-P	693	PRE							
Glyphosate	900	POST	96	99	99	98	1	1	9.45
Dicamba	600	POST							
Dicamba	600	PRE							
Glyphosate	900	POST	81	77	72	67	50	6	9.56
Dicamba	600	PRE							
Glyphosate	900	POST	87	91	92	91	14	3	9.69
Dicamba	300	POST							
Dicamba	600	PRE							
Glyphosate	900	POST	95	98	98	98	4	0	10.00
Dicamba	600	POST							
Dimethenamid-P	693	PRE							
Dicamba	600	PRE	93	92	92	91	19	1	9.28
Glyphosate	900	POST							
Dimethenamid-P	693	PRE							
Dicamba	600	PRE							
Glyphosate	900	POST	98	99	99	99	2	0	10.29
Dicamba	300	POST							
Dimethenamid-P	693	PRE							
Dicamba	600	PRE							
Glyphosate	900	POST	98	99	99	98	1	0	9.65
Dicamba	600	POST							

^a abbreviations: App., Application; WAA, weeks after application; fb, followed by; vs, versus; PRE, preemergent; POST, postemergent; dm, dimethenamid-pdimethenamid-P; di, dicamba;

^b denotes g ai ha⁻¹ of dicamba

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Table 4. Non-orthogonal contrasts for glyphosate-resistant waterhemp control using dicamba at two different rates and timings across 4 site-years in Ontario.^a

Contrasts	Visual control estimate timing (%)												4 WAA						Grain corn yield (T ha ⁻¹)		
	2 WAA			4 WAA			8 WAA			12 WAA			Population density (% of weedy check)		Weed dry weight (% of weedy check)						
PRE 300 g vs PRE 600 g	29	vs	48	19	vs	42*	13	vs	39*	9	vs	33*	104	vs	76	69	vs	35*	8.23	vs	8.65
POST 300 g vs POST 600 g	76	vs	87	79	vs	91	70	vs	93*	78	vs	92	30	vs	7	7	vs	1	9.54	vs	10.79
PRE (300 g) fb POST (300 g) vs PRE (300 g) fb POST (600 g)	86	vs	94	87	vs	93*	90	vs	94	90	vs	94	18	vs	17	3	vs	2	9.91	vs	9.84
PRE (600 g) fb POST (300 g) vs PRE (600 g) fb POST (600 g)	91	vs	96	98	vs	97	99	vs	98	98	vs	97	5	vs	2	1	vs	1	9.63	vs	8.80
PRE vs POST	38	vs	82**	30	vs	86**	25	vs	83**	19	vs	86**	89	vs	17**	50	vs	4**	8.44	vs	10.16*
PRE vs PRE fb POST	38	vs	92**	30	vs	95**	25	vs	96**	19	vs	95**	89	vs	9**	50	vs	2**	8.44	vs	9.55
POST vs PRE fb POST	82	vs	92*	86	vs	95*	83	vs	96*	86	vs	95*	17	vs	9	4	vs	2	10.16	vs	9.55

^a abbreviations: WAA, weeks after application; fb, followed by; vs, versus; PRE, preemergent; POST, postemergent.

* and ** indicate a statistical difference at P=0.05 and P=0.001, respectively.

Table 5. Non-orthogonal contrasts for glyphosate-resistant waterhemp control using dimethenamid-P and dicamba across 4 site-years in Ontario.

Contrasts	Visual control estimate timing (%)										4 WAA						Grain corn yield (T ha ⁻¹)				
	2 WAA			4 WAA			8 WAA			12 WAA			Population density (% of weedy check)		Dry weight (% of weedy check)						
PRE dm vs PRE di	76	vs	42*	71	vs	45*	64	vs	32*	60	vs	27*	26	vs	56*	8	vs	31**	9.12	vs	7.46
PRE dm vs PRE dm + di	76	vs	85	71	vs	82	64	vs	77	60	vs	72	26	vs	26	8	vs	7	9.12	vs	8.70
PRE di vs PRE dm + di	42	vs	85**	45	vs	82**	32	vs	77**	27	vs	72*	56	vs	26*	31	vs	7**	7.46	vs	8.70
POST di 300 ^z vs POST di 600 ^b	78	vs	86	83	vs	89	83	vs	90	82	vs	90	29	vs	10*	7	vs	2	10.71	vs	9.99
PRE dm vs PRE dm POST di 300 + PRE dm POST di 600	76	vs	96*	71	vs	99**	64	vs	99**	60	vs	98**	26	vs	1**	8	vs	0*	9.12	vs	9.43
PRE dm POST di 300 vs PRE dm POST di 600	96	vs	96	99	vs	99	99	vs	99	99	vs	98	2	vs	1	0	vs	1	9.41	vs	9.45
PRE di vs PRE di fb POST di 300 + PRE di fb POST di 600	42	vs	91**	45	vs	95**	32	vs	95**	27	vs	95**	56	vs	8**	31	vs	1**	7.46	vs	9.85*
PRE di POST di 300 vs PRE di POST di 600	87	vs	95	91	vs	98	92	vs	98	91	vs	98	14	vs	4	3	vs	0	9.69	vs	10.00
PRE dm+di vs PRE dm+di POST di 300 + PRE dm+di POST di 300	85	vs	98*	82	vs	99**	77	vs	99**	72	vs	99*	26	vs	1**	7	vs	0*	8.70	vs	9.96
PRE dm+ di POST di 300 vs PRE dm+ di POST di 600	98	vs	98	99	vs	99	99	vs	99	99	vs	98	2	vs	1	0	vs	0	10.29	vs	9.65
PRE vs POST	69	vs	82*	67	vs	86*	58	vs	87**	53	vs	87**	35	vs	19*	13	vs	4*	8.41	vs	10.34*
PRE vs PRE fb POST	69	vs	95**	67	vs	98**	58	vs	98**	53	vs	97**	35	vs	3**	13	vs	0**	8.41	vs	9.75*
POST vs PRE fb POST	82	vs	95**	86	vs	98**	87	vs	98*	87	vs	97*	19	vs	3**	4	vs	0*	10.34	vs	9.75

^a abbreviations: App., Application; WAA, weeks after application; fb, followed by; vs, versus; PRE, preemergent; POST, postemergent; dm, dimethenamid-P; di, dicamba;

^b denotes g ai ha⁻¹ of dicamba

* and ** indicate a statistical difference at P=0.05 and P=0.001, respectively.