

# Influence of Herbicide Carrier on the Tolerance of White Bean to Preplant Incorporated and Preemergence Herbicides

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## Abstract

Nine field trials (five with PPI and four with PRE herbicides) were conducted at Exeter and Ridgetown, Ontario during 2013 to 2015 to determine if the tolerance of white bean to preplant incorporated (PPI) and preemergence (PRE) herbicides is influenced by the herbicide carrier (water vs. UAN at 200 L·ha<sup>-1</sup>). There was no significant interaction between the carrier and herbicide for visible injury, plant stand, plant height, shoot dry weight, seed moisture content and yield. There was also no significant difference between the herbicide carriers for all parameters measured except for the shoot dry weight which was 6.5% greater when UAN was used as the carrier with PPI herbicides. Dimethenamid-p, pendimethalin, imazethapyr and halosulfuron applied PPI or PRE caused no visible injury except for imazethapyr PPI which caused 2% visible injury and dime-thenamid-p PRE which caused 7% - 14% injury in white bean. There was no effect of the PPI and PRE herbicides evaluated on white bean stand, shoot dry weight, height, maturity and yield. Based on these results, using water or UAN could be used as the carrier for PPI and PRE herbicides in white bean.

## Keywords

Dimethenamid-p, Imazethapyr, Navy Bean, Pendimethalin, Halosulfuron

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## 1. Introduction

North America is the largest producer of white bean (*Phaseolus vulgaris* L.) in the world [1]. Most of the white bean produced in Canada is grown in Ontario. In 2014, Ontario white bean growers seeded approximately

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30,000 hectares and produced more than 80,000 tonnes of white bean with a farm gate value of approximately \$55,000,000 [2]. Short stature of white bean makes it not a strong competitor with weeds which can result in substantial seed yield losses, reduce harvest efficiency, and cause staining of the bean [3]-[5]. Common annual weeds in dry bean production in Ontario include redroot pigweed (*Amaranthus retroflexus* L.), common lambsquarters (*Cheno-podium album* L.), common ragweed (*Ambrosia artemisiifolia* L.), velvetleaf (*Abutilon theophrasti* Medicus), ladythumb (*Polygonum persicaria* L.), eastern black nightshade (*Solanum ptycanthum* Dun.), and annual grasses such as *Setaria*, *Digitaria*, *Echinochloa*, and *Panicum* species [6]. Research is needed to identify herbicides that have an adequate margin of crop safety, provide consistent weed control, have low environmental impact and maximize dry bean yield and net returns to white bean growers in Ontario.

Dimethenamid-p is a chloroacetamide herbicide that controls annual grasses such as green foxtail (*Setaria viridis* L.), yellow foxtail (*Setaria glauca* auct., non (L.) P. Beauv.), giant foxtail (*Setaria faberi* R. A. W. Herrm.), barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.), witchgrass (*Panicum capillare* L.), fall panicum (*Panicum dichotomiflorum* Michx.), smooth crabgrass (*Digitaria ischaemum* (Schreb.) ex Muhl.), large crabgrass (*Digitaria sanguinalis* (L.) Scop.) and some small-seeded broadleaf weeds such as redroot pigweed and eastern black nightshade including triazine- and acetolactate synthase-resistant biotypes [6] [7].

Pendimethalin is a dinitroaniline herbicide that can control annual grasses such as green foxtail, giant foxtail, yellow foxtail, barnyardgrass, smooth crabgrass, large crabgrass, fall panicum and small seeded annual broadleaf weed such as redroot pigweed and common lambsquarters including acetolactate synthase and triazine-resistant biotypes [6] [7].

Imazethapyr is an imidiazolinone herbicide that can control annual broadleaf and grass weeds including velvetleaf, redroot pigweed, common lambsquarters, wild mustard (*Sinapsis arvensis* L.), common ragweed, Eastern black nightshade, wild buckwheat (*Polygonum convolvulus* L.) including triazine-tolerant biotypes [6] [7].

Halosulfuron is a sulfonylurea herbicide that controls nutsedge species (*Cyperus spp.*), redroot pigweed, common lambsquarters, wild mustard, ladythumb, velvetleaf and cocklebur (*Xanthium strumarium* L.), including triazine resistant biotypes [6] [7].

Nitrogen fertilizer such as 28% liquid urea-ammonium nitrate solution (UAN) is often used at low rates with postemergence (POST) herbicides to improve herbicide absorption [8]. The use of UAN with POST herbicides has been shown to increase injury in some crops under some environments [8]-[14]. There is little information on the influence of UAN at 200 L·ha<sup>-1</sup> as the carrier for the PPI or PRE application of dimethenamid-p, pendimethalin, imazethapyr or halosulfuron in white bean under Ontario environmental conditions. In addition, co-application of UAN with herbicides such as dimethenamid-p, pendimethalin, imazethapyr and halosulfuron will reduce the number of trips across the field resulting in fuel and labour savings as well as reducing wear and tear on machinery and soil compaction. Determining the influence of UAN as the herbicide carrier with these herbicides can help maximize herbicide application efficiency, dry bean yield and net returns to Ontario dry bean producers.

The objectives of this study are to determine if the tolerance of white bean to dimethenamid-p, pendimethalin, imazethapyr and halosulfuron applied preplant incorporated or preemergence are influenced by the herbicide carrier (water vs. UAN at 200 L·ha<sup>-1</sup>).

## 2. Materials and Methods

Nine field trials (five with PPI and four with PRE herbicides) were conducted at the Huron Research Station, Exeter, Ontario and University of Guelph Ridgetown Campus, Ridgetown, Ontario during 2013 to 2015. The soil at Exeter was a Brookston clay loam (Orthic Humic Gleysol, mixed, mesic, and poorly drained) and the soil at Ridgetown was a Watford (Grey to Brown Brunisolic, mixed, mesic, sandy, and imperfectly drained)-Brady (Gleyed Brunisolic Grey to Brown Luvisol, mixed, mesic, sandy, and imperfectly drained) sandy loam. Seedbed preparation at all sites consisted of autumn moldboard plowing followed by seedbed preparation and herbicide incorporation with a S-tine cultivator with rolling basket harrows in the spring.

The experiments were arranged in a randomized complete block design with treatments replicated four times. PPI and PRE trials were side by side. Treatments for PPI and PRE trials included a weed-free control and dimethenamid-p (693 g ai ha<sup>-1</sup>), pendimethalin (1080 g ai ha<sup>-1</sup>), imazethapyr (75 g ai ha<sup>-1</sup>) and halosulfuron (35 g ai ha<sup>-1</sup>) applied with UAN or water as the carrier at 200 L·ha<sup>-1</sup>. Each plot was 3.0 m wide and 10 m (Exeter) or 8 m (Ridgetown) long and consisted of four rows of "T9905" white bean spaced 0.75 m apart. White bean was

planted at approximately 250,000 seeds·ha<sup>-1</sup> in late May to early June.

Herbicide treatments were applied using a CO<sub>2</sub>-pressurized backpack sprayer calibrated to deliver 200 L·ha<sup>-1</sup> at 240 kPa. The boom was 1.5 m long with four ultra-low drift nozzles (ULD120-02, Hypro, New Brighton, MN) spaced 50 cm apart. The surface area sprayed was the center 2.0 m of each plot by 10.0 m (Exeter) or 8 m (Ridgetown) in length. There was a 1.0 m unsprayed area between adjacent plots. PPI and PRE herbicides were applied 1 - 2 days before planting (incorporated immediately) and 1 - 2 days after planting, respectively. Weed-free controls were maintained with inter-row cultivation and hand hoeing during the growing season.

Estimates of white bean injury were visually estimated on a scale of 0 (no injury) to 100% (complete plant death) at 1, 2 and 4 weeks after crop emergence (WAE). White bean stand and dry weight were determined 3 WAE by counting and cutting the plants from 1 m of row per plot at the soil surface, drying at 60 C to constant moisture and then weighing. From this information, white bean weight per plant was also calculated. At 6 WAE, white bean height was measured for 10 plants per plot. The bean crop was harvested with a small plot combine, weight and seed moisture were recorded, and yields were adjusted to 18% moisture.

Data were analyzed as a 2-way factorial using PROC MIXED in SAS 9.4. Factor 1 was herbicide carrier (water or UAN) and factor 2 was herbicide treatment (dimethenamid-p, pendimethalin, imazethapyr, halosulfuron). Trials in which herbicides were applied PPI were analyzed separately from those applied PRE. Fixed effects included the two treatment factors, herbicide carrier and herbicide treatment, as well as their interaction; random effects included year-location combinations (environment), interactions between environment and the fixed effects, and replicate nested within environment. Significance of fixed effects was tested using F-tests and random effects were tested using a Z-test of the variance estimate. The UNIVARIATE procedure was used to test data for normality and homogeneity of variance. To satisfy the assumptions of the variance analyses, injury 1, 2 and 4 WAE (PRE application) and injury 1 WAE (PPI application) were square root transformed, injury 4 WAE (PPI application) was arcsine square root transformed, and dry weights and seed moisture (PRE and PPI applications) were log transformed. For all injury ratings, the untreated check (assigned a value of zero) was excluded from the analysis. However, all values were compared independently to zero to evaluate treatment differences with the untreated check. Treatment comparisons were made using Fisher's Protected LSD at a level of  $P < 0.05$  and any data compared on the transformed scale were converted back to the original scale for presentation of results.

### 3. Results and Discussion

There were no visible incompatibility problems in respect to the herbicide carrier (water or UAN) and the herbicides evaluated in this study (data not shown).

#### 3.1. Preplant Incorporated Herbicides

There was no significant interaction between the carrier and herbicide for visible injury, plant stand, plant height, shoot dry weight, seed moisture content and yield (**Table 1**). There was also no significant difference between the herbicide carriers for visible injury, plant stand, plant height, seed moisture content and yield. However, shoot dry weight was 6.5% greater when UAN was used as the herbicide carrier compared to the water carrier (**Table 1**).

Dimethenamid-p, pendimethalin, imazethapyr and halosulfuron applied preplant incorporated caused no injury in white at 1 and 2 WAE. However, at 4 WAE imazethapyr caused slightly more injury than dimethenamid-p, pendimethalin and halosulfuron (**Table 1**). There was no effect of the herbicides evaluated on white bean stand, shoot dry weight, height, maturity and yield (**Table 1**). Results are similar to other studies that have shown no injury in white bean with halosulfuron applied PPI with water as the carrier [15]-[19]. However, in other studies, halosulfuron, applied PPI with water as the carrier caused 58% to 70% injury in adzuki bean and reduced adzuki bean height 52% to 70% and caused as much as 8% injury in snap bean and reduced yield as much as 15% [15] [20].

#### 3.2. Preemergence Herbicides

There was no significant interaction between the carrier and herbicide for white bean visible injury, plant stand,

**Table 1.** Main effects and interaction for white bean injury, plant stand, dry weight, height, seed moisture at harvest and yield with herbicides applied PPI in water or UAN. Means followed by the same letter within a column are not significantly different according to Fisher's Protected LSD at  $P < 0.05$ . Means for a main effect were separated only if there was no significant interaction involving that main effect.<sup>a</sup>

Main Effects <sup>b</sup>		Injury								
		1 WAE	2 WAE	4 WAE	Plant Stand	Dry Weight		Height	Moisture	Yield
			%		no m <sup>-1</sup> row <sup>-1</sup>	g m <sup>-1</sup> row <sup>-1</sup>	g plant <sup>-1</sup>	cm	%	MT ha <sup>-1</sup>
<i>Herbicide carrier</i>		NS	NS	NS	NS	*	NS	NS	NS	NS
	Water	0	1	0	18	30 b	1.8	56	18.9	3.45
	UAN	1	1	0	18	32 a	1.9	57	19.0	3.53
<i>Herbicide treatment</i>	<i>Rate (g ai ha<sup>-1</sup>)</i>	NS	NS	*	NS	NS	NS	NS	NS	NS
	Untreated check	0	0	0 a	18	32	1.9	56	19.0	3.48
	Dimethenamid-p 693	1	1	0 a	19	29	1.7	56	18.9	3.48
	Pendimethalin 1080	0	0	0 a	18	34	2.0	58	18.6	3.53
	Imazethapyr 75	0	1	2 b	18	30	1.7	54	19.5	3.47
	Halosulfuron 35	0	1	0 a	18	30	1.8	58	18.8	3.49
<b>Interaction</b>										
	C × H	NS	NS	NS	NS	NS	NS	NS	NS	NS

<sup>a</sup>Abbreviations: C, herbicide carrier; H, herbicide treatment; NS, not significant at  $P = 0.05$  level; PPI, preplant incorporated. <sup>b</sup>Significance at  $P < 0.05$  and  $P < 0.01$  levels denoted by \* and \*\*, respectively.

plant height, shoot dry weight, seed moisture content and yield (Table 2). There was also no significant difference between the herbicide carriers for white bean visible injury, plant stand, shoot dry weight, plant height, seed moisture content and yield (Table 2).

Dimethenamid-p applied PRE caused 14%, 11% and 7% visible injury at 1, 2 and 4 WAE in white bean, respectively. However, there was a minimal visible injury (2% or less) with pendimethalin, imazethapyr and halosulfuron applied PRE in white bean at 1, 2 and 4 WAE. Dimethenamid-p, pendimethalin, imazethapyr and halosulfuron applied PRE caused no adverse effect on white bean stand, shoot dry weight, height, seed moisture content and yield (Table 2).

Results are similar to other studies with pendimethalin, dimethenamid-p, imazethapyr and halosulfuron, applied PRE with water as the carrier which showed minimal crop injury and yield reduction in white bean [21]-[24]. Pendimethalin applied PRE has also been shown to cause as little as 1% crop injury and no yield reduction in white bean [25].

#### 4. Conclusion

This study concludes that UAN can be used as the carrier solution for dimethenamid-p, pendimethalin, imazethapyr and halosulfuron applied PPI or PRE and does not cause any incompatibility problems in respect to the spray solution. Herbicide carrier (water or UAN at 200 L·ha<sup>-1</sup>) has minimal effect on the tolerance of white bean to dimethenamid-p, pendimethalin, imazethapyr and halosulfuron applied preplant incorporated or pre-mergence under Ontario environmental conditions.

**Table 2.** Main effects and interaction for white bean injury, plant stand, dry weight, height, seed moisture at harvest and yield with various herbicides applied PRE in water or UAN. Means followed by the same letter within a column are not significantly different according to Fisher's Protected LSD at  $P < 0.05$ . Means for a main effect were separated only if there was no significant interaction involving that main effect.<sup>a</sup>

Main Effects <sup>b</sup>		Injury								
		1 WAE	2 WAE	4 WAE	Plant Stand	Dry Weight		Height	Moisture	Yield
			%		no m <sup>-1</sup> row <sup>-1</sup>	g m <sup>-1</sup> row <sup>-1</sup>	g plant <sup>-1</sup>	cm	%	MT ha <sup>-1</sup>
<i>Herbicide carrier</i>		NS	NS	NS	NS	NS	NS	NS	NS	NS
	Water	2	1	2	17	28	1.9	55	18.8	3.61
	UAN	3	1	2	17	28	1.9	55	18.8	3.63
<i>Herbicide treatment</i>	<i>Rate (g ai ha<sup>-1</sup>)</i>	**	**	*	NS	NS	NS	NS	NS	NS
	Untreated check	0 a	0 a	0 a	17	26	1.8	54	18.7	3.21
	Dimethenamid-p 693	14 b	11 b	7 b	16	23	1.6	53	19.0	3.06
	Pendimethalin 1080	0 a	0 a	0 a	16	29	2.0	56	18.8	3.21
	Imazethapyr 75	0 a	0 a	2 ab	17	30	2.0	55	18.6	3.27
	Halosulfuron 35	0 a	0 a	0 a	18	32	2.0	56	18.7	3.35
<b>Interaction</b>										
	C × H	NS	NS	NS	NS	NS	NS	NS	NS	NS

<sup>a</sup>Abbreviations: C, herbicide carrier; H, herbicide treatment; NS, not significant at  $P = 0.05$  level; PRE, preemergence. <sup>b</sup>Significance at  $P < 0.05$  and  $P < 0.01$  levels denoted by \* and \*\*, respectively.

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