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Response of cranberry and kidney beans to linuron

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ABSTRACT

Field studies were conducted in 2009 and 2010 at the Huron Research Station, Exeter, Ontario and the University of Guelph Ridgetown Campus, Ridgetown, Ontario to determine the tolerance of four cultivars of cranberry bean ("Etna", "Hooter", "SVM Taylor", and "Capri") and four cultivars of kidney bean ("Red Hawk", "Pink Panther", "Calmont", and "Majesty") to linuron applied preemergence at 1125 and 2250 g·ai·ha^{-1}. One week after emergence (WAE), linuron applied PRE caused 0.4% to 1.2% injury in "Etna", "Hooter", "SVM Tayler", and "Capri" cranberry bean and 3.1% to 3.6% injury in "Red Hawk", "Pink Panther", "Calmont", and "Majesty" kidney bean. At 2 and 4 WAE, there was no difference in injury among the dry bean cultivars. Contrast comparing injury due to linuron in cranberry vs kidney bean cultivars indicated 2.3%, 1.7%, and 1.2% greater injury in kidney bean compared to cranberry bean at 1, 2, and 4 WAE, respectively. Linuron PRE caused slightly greater injury in kidney bean compared to cranberry bean but crop injury was minimal with no adverse effect on plant height, shoot dry weight, seed moisture content, and yield under the environments evaluated. Based on this research, linuron applied PRE at the proposed rate of 1125 g·ai·ha^{-1} can be safely used in cranberry and kidney beans in Ontario.

Keywords: Cranberry Bean; Height; Injury; Seed Moisture; Kidney Bean; Yield

1. INTRODUCTION

Canada, a major producer of dry bean, produces nearly 10% of the world's dry bean valued at $226 million dollars annually [1]. Ontario, one the leading provinces in Canada in dry bean production, produces 129,000 MT of dry bean with a farm-gate value of approximately $90 million [2]. Major market classes of dry bean grown in Ontario include black, cranberry, kidney, and white (navy) bean.

Dry bean is a short season crop with short physical stature and therefore is very sensitive to weed interference [3-7]. Dry bean seed yield has been reduced as much as 70% due to weed interference [8]. Presence of weeds at the harvest time can also cause seed staining and interfere with harvesting efficiency in dry bean [9-12].

There are few herbicides registered for broadleaf weed control in dry bean in Ontario. Imazethapyr is the only soil applied herbicide for annual broadleaf weed control. Imazethapyr can cause significant dry bean injury under some environmental conditions and provides marginal control of common ragweed (*Ambrosiaartemisiifolia* L.) and common lambsquarters (*Chenopodium album* L.). More research is needed to identify new herbicide options that provide consistent broadleaf weed control and have adequate margin of crop safety in various cultivars within different market classes of dry bean.

Linuron is a substituted urea herbicide registered for use in a number of crops including corn and soybean [13]. Linuron is readily absorbed through roots following a soil application [14]. Linuron applied pre-emergence (PRE) controls many broadleaf weeds such as velvetleaf (*Abutilon theophrasti* Medicus), redwood pigweed (*Amaranthus retroflexus* L.), common lambsquarters (*Chenopodium album* L.), common ragweed (*Ambrosiaartemisiifolia* L.), common chickweed [*Stellaria media* (L.) Cyrillo], field pennycress (*Thlaspi arvense* L.), prostrate knotweed (*Polygonum arenastrum* L.), purslane (*Portulaca oleracea* L.), shepherd's purse [*Capsella bursa-pastoris* (L.) Medic.], smartweed (*Polygonum* spp.), annual sowthistle (*Sonchus oleraceus* L.), wild buckwheat (*Polygonum convovulus* L.) and wormseed mustard (*Erysimum cheiranthoides* L.), including acetolactate synthase- and triazine-resistant biotypes [13-15]. Linuron is

registered at a rate of 1125 to 2250 g·ai·ha^{-1} in soybean in Ontario with rate applied dependent on soil texture and organic matter. Linuron has the potential to provide broad spectrum broadleaf weed control in some market classes of dry bean [16].

Tolerance of dry beans to various soil applied herbicides is influenced by herbicide rate, market class, cultivar and environmental conditions [4,7,15,17]. There is little published data on the sensitivity of "Etna", "Hooter", "SVM Taylor", and "Capri" cranberry bean cultivars and "Red Hawk", "Pink Panther", "Calmont", and Majesty kidney bean cultivars to linuron.

The objective of this study was to evaluate the tolerance "Etna", "Hooter", "SVM Taylor", and "Capri" cranberry bean and "Red Hawk", "Pink Panther", "Calmont", and "Majesty" kidney bean to linuron applied pre-emergence at 1125 and 2250 g·ai·ha^{-1}, representing the 1X and 2X manufacturer's recommended rate in soybean under Ontario environmental conditions.

2. MATERIALS AND METHODS

Field studies were conducted in 2009 and 2010 at the Huron Research Station, Exeter, Ontario and the University of Guelph, Ridgetown Campus, Ridgetown, Ontario. The soil at Exeter was a Brookston clay loam (Orthic Humic Gleysol, mixed, mesic, and poorly drained) with 38% sand, 41% silt, 21% clay, 3.7% organic matter and pH of 7.8 in 2009, and 36% sand, 39% silt, 25% clay, 3.6% organic matter and pH of 7.8 in 2010. The soil at Ridgetown was a Wattford (Grey-Brown Brunisolic, mixed, mesic, sandy, and imperfectly drained)-Brady (Gleyed Brunisolic Grey-Brown Luvisol, mixed, mesic, sandy, and imperfectly drained) with 54% sand, 27% silt, 19% clay, 5.6% organic matter and pH of 6.4 in 2009, and 40% sand, 35% silt, 25% clay, 7.1% organic matter and pH of 6.6 in 2010. Seedbed preparation at all sites consisted of fall moldboard plowing followed by two passes with a field cultivator in the spring.

The experiments were established as a 2-way factorial design arranged in a completely randomized block with four replications. Factor 1 was cultivar (variety) of dry bean (Cranberry: "Etna", "Hooter", "SVM Taylor", and "Capri"; Kidney: "Red Hawk", "Pink Panther", "Calmont", and "Majesty") and Factor 2 was rate of linuron (0, 1125 and 2250 g·ai·ha^{-1}), applied preemergence. Plots were 6 m wide (8 rows spaced 0.75 m apart) and 10 m long at Exeter and 8 m long at Ridgetown. Within each plot there was one row of "Etna", "Hooter", "SVM Taylor", "Capri", "Red Hawk", "Pink Panther", "Calmont", and "Majesty" beans. Beans were planted in late May to early June of each year.

Herbicide applications were made with a CO_2-pressurized backpack sprayer calibrated to deliver 200 L·ha^{-1} of spray solution at a pressure of 240 kPa using ultra low drift nozzles (ULD120-02, Hypro, New Brighton, MN). Treatments were applied at one day after seeding and were left undisturbed on the surface of soil. All plots were maintained weed-free during the season with hand hoeing and cultivation as required.

Dry bean injury was visually estimated on a scale of 0 (no injury) to 100% (complete plant death) at 1, 2 and 4 weeks after crop emergence (WAE). Bean shoot dry weight was evaluated 4 WAE by cutting plants at the soil surface from 1m of row per plot. Plants were dried at 60 C to a constant moisture and then weighed. Dry bean height was measured for 10 plants in each plot 6 WAE and the average height was recorded. Dry bean was considered mature when 90% of the pods in the weed-free check had turned from green to a golden colour. Beans were harvested from each plot with a small plot combine, weight and moisture were recorded, and yields were adjusted to 18% moisture.

Data were analyzed as a 2-way factorial using PROC MIXED in SAS 9.2. The two treatment factors, dry bean cultivar and herbicide rate, as well as their interaction were considered fixed effects, while environment (year-location combinations), interactions between environments and the fixed effects, and replicate nested within environment were considered random effects. Significance of fixed effects was tested using F-tests and random effects were tested using a Z-test of the variance estimate. Environments were combined for a given variable if the environment by cultivar by rate interaction was not significant. The UNIVARIATE procedure was used to test data for normality and homogeneity of variance. 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. To satisfy the assumptions of the variance analyses, injury and moisture were log transformed. Treatment comparisons were made using Fisher's Protected LSD at a level of $P < 0.05$. Additionally, a contrast was performed for each variable comparing dry bean type (four cranberry vs four kidney bean cultivars) to determine if bean market class influenced responses. Data compared on the transformed scale were converted back to the original scale for presentation of results.

3. RESULTS AND DISCUSSION

Environment by Cultivar by Rate interaction was not significant for injury 2 and 4 WAE, shoot dry weight, height, moisture and yield and all four datasets were analyzed together. Environment by Cultivar by Rate interaction was significant for injury 1 WAE: Exeter 2009 and Ridgetown 2010 were all zero (not shown in **Table 1**) and were separated from Exeter 2010 and Ridgetown 2009.

Table 1. Significance of main effects and interactions for percent visual injury, height, shoot dry weight, moisture and seed yield of dry bean when linuron was applied PRE. 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[z].

Main effects[y]	Dry bean injury						
	1 WAE[x]	2 WAE	4 WAE	Dry weight	Height	Moisture	Yield
	%			g	cm	%	MT ha^{-1}
Cultivar of dry bean	**	NS	NS	NS	**	NS	NS
Etna	0.4 a	0.2	0.2	68	51 bc	17.4	2.0
Hooter	0.8 ab	0.6	0.2	70	53 ab	17.9	2.5
SVM Taylor	0.6 ab	0.1	0.3	70	50 c	20.3	1.9
Capri	1.2 b	0.6	0.2	69	54 a	17.7	2.2
Red Hawk	3.1 c	1.7	1.0	68	55 a	17.9	2.2
Pink Panther	3.2 c	2.7	1.6	69	53 ab	17.4	2.2
Calmont	2.6 c	1.9	1.7	68	53 ab	18.7	2.2
Majesty	3.6 c	2.1	1.5	61	52 ab	16.8	2.3
SE	0.2	0.2	0.2	1.4	0.3	0.1	0.1
Linuron rate (g·ai·ha^{-1})	NS	NS	NS	NS	NS	NS	NS
0	0	0	0	67	52	18.1	2.1
1125	0.6	0.6	0.5	70	53	17.7	2.2
2250	3.3	1.8	1.2	67	52	18.2	2.3
SE	0.2	0.2	0.2	1.4	0.3	0.1	0.1
Interaction							
V × R	NS	NS	NS	NS	NS	NS	NS
Contrast							
Cranberry vs kidney bean	0.8 vs 3.1**	0.4 vs 2.1*	0.2 vs 1.4*	70 vs 66	52 vs 53*	18.4 vs 17.9	2.1 vs 2.2

[z]Abbreviations: WAE, week after crop emergence; NS, not significant at $P = 0.05$ level; PRE, preemergence; R, linuron rate; V, variety (cultivar) of dry bean. [y]Significance at $P < 0.05$ and $P < 0.01$ levels denoted by * and **, respectively; [x]Ridgetown 2009 and Exeter 2010.

3.1. Crop Injury

At 1 WAE, linuron caused lower injury in cranberry bean compared to kidney bean (**Table 1**). Linuron applied PRE caused 0.4% to 1.2% injury in "Etna", "Hooter", "SVM Tayler", and "Capri" cranberry bean and 2.6 to 3.6% injury in "Red Hawk", "Pink Panther", "Calmont", and "Majesty" kidney bean (**Table 1**). At 2 and 4 WAE, there was no significant difference in injury among dry bean cultivars. Contrasts comparing cranberry verses kidney bean cultivars indicated 2.3%, 1.7%, and 1.2% greater injury in kidney bean compared to cranberry bean due to linuron PRE at 1, 2, and 4 WAE, respectively.

In other studies, linuron applied PRE caused as much as 12% injury in cranberry and kidney beans [16]. The minimal injury observed in this study is similar to studies with other soil-applied herbicides in dry bean [3,6,17-20]. Also, the variation seen in visible crop injury among cultivars or market classes of dry bean is consistent with other studies that have shown differential sensitivity with soil applied herbicides in dry bean [7,4,21]. Market classes of dry beans have different geographic origins and consequently have different gene pool which affects their tolerance to herbicides [22-24].

3.2. Plant Height and Shoot Dry Weight

Among dry bean cultivars evaluated "SVM Taylor" and "Etna" had the lowest height, however, there was no significant difference in height of "Hooter", "Capri", "Red Hawk", "Pink Panther", "Calmont", and "Majesty" dry beans (**Table 1**). The kidney bean cultivars were on average 1 cm taller than cranberry bean cultivars evalu-

ated in this study (**Table 1**).

Linuron applied PRE did not have any adverse effect on shoot dry weight of "Etna", "Hooter", "SVM Taylor", "Capri", "Red Hawk", "Pink Panther", "Calmont", and "Majesty" beans (**Table 1**). There was no difference in shoot dry weight of the cranberry and kidney bean cultivars included in this study (**Table 1**).

In other studies linuron applied PRE at 500 to 2500 g·ai·ha^{-1} did not affect plant height of cranberry and kidney bean but plant height decreased as much 15% in black bean at 2500 g·ai·ha^{-1} and 10%, 13% and 23% in white bean with linuron applied PRE at 1500, 2000 and 2500 g·ai·ha^{-1}, respectively [16]. Studies with other soil applied studies have shown no adverse effect on cranberry and kidney bean height [18-20].

3.3. Seed Moisture Content and Yield

Linuron applied PRE at 1125 and 2250 g·ai·ha^{-1} did not have any adverse effect on the seed moisture content and yield of "Etna", "Hooter", "SVM Taylor", "Capri", "Red Hawk", "Pink Panther", "Calmont", and "Majesty" beans (**Table 1**). In addition, there were no significant differences in seed moisture content and yield of cranberry and kidney bean. In other studies, linuron applied PRE at various doses did not cause any adverse affect on the yield of cranberry, kidney, and white beans but yield of black bean was reduced 16% compared to the non-treated control at 2500 g·ha^{-1} [16]. These results are similar to other studies in which flumioxazin, pyroxasulfone, and alachlor applied preemergence which caused no losses in cranberry and kidney bean seed yield [6, 25,26].

4. CONCLUSIONS

Based on this research, linuron applied PRE at the proposed rate of 1125 g·ai·ha^{-1} has an adequate margin of crop safety in "Etna", "Hooter", "SVM Taylor", "Capri", "Red Hawk", "Pink Panther", "Calmont", and "Majesty" dry beans. There is slight differential sensitivity between dry bean cultivars and market classes to linuron. Linuron PRE caused slightly greater injury in kidney bean compared to cranberry bean but crop injury was minimal with no adverse effect on plant height, shoot dry weight, seed moisture content, and yield under the environmental condition in this study. Availability of linuron for weed management would provide dry bean growers with a new herbicide option for the control of troublesome weeds such as common lambsquarters, common pigweed, common ragweed, and other annual broadleaf weeds.

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