Tolerance of adzuki bean to pre-emergence herbicides

Nader Soltani¹, Robert E. Nurse², Christy Shropshire¹, and Peter H. Sikkema¹

¹Department of Plant Agriculture, University of Guelph Ridgetown Campus, Ridgetown, Ontario, Canada N0P 2C0 (e-mail: soltanim@uoguelph.ca); and ²Agriculture and Agri-Food Canada, 2585 Country Rd. 20, Harrow, Ontario, Canada N0R 1G0.

Received 14 February 2015, accepted 29 April 2015. Published on the web 13 May 2015.

Soltani, N., Nurse, R. E., Shropshire, C. and Sikkema, P. H. 2015. Tolerance of adzuki bean to pre-emergence herbicides. Can. J. Plant Sci. 95: 959–963. Limited pre-emergence herbicide options are available for weed management in adzuki bean in Ontario. Eight field trials were conducted in Ontario over a 3-yr period (2012, 2013, 2014) to evaluate the tolerance of adzuki bean to pyroxasulfone (150 and 300 g a.i. ha⁻¹), flumioxazin (71 and 142 g a.i. ha⁻¹), sulfentrazone (420 and 840 g a.i. ha⁻¹), fomesafen (240 and 480 g a.i. ha⁻¹), imazethapyr (75 and 150 g a.i. ha⁻¹), and cloransulam-methyl (35 and 70 g a.i. ha⁻¹) applied pre-emergence. Pyroxasulfone and sulfentrazone applied pre-emergence at the proposed 1 × 2 and 2 × rates caused 25–96% injury and reduced plant stand up to 78%, shoot dry weight up to 95%, plant height up to 67% and seed yield up to 76% in adzuki bean. Cloransulam-methyl resulted in 1 to 9% injury with no adverse effect on plant stand, shoot dry weight, plant height, seed moisture content and seed yield of adzuki bean. Fomesafen and imazethapyr resulted in 1–3% injury with no adverse effect on plant stand, shoot dry weight, plant height, seed moisture content and seed yield of adzuki bean. Based on these results, pyroxasulfone, flumioxazin and sulfentrazone do not have an adequate margin of crop safety for weed management in adzuki bean. Cloransulam-methyl has potential for use in adzuki bean, especially at the lower rate. Imazethapyr and fomesafen at the rates evaluated can be used safely in adzuki bean production under Ontario environmental conditions.

Key words: Cloransulam-methyl, fomesafen, flumioxazin, imazethapyr, pyroxasulfone, sulfentrazone, tolerance

Soltani, N., Nurse, R. E., Shropshire, C. et Sikkema, P. H. 2015. Tolérance du haricot adzuki aux herbicides de pré-levée. Can. J. Plant Sci. 95: 959–963. Les possibilités de désherbage chimique avant la levée sont peu nombreuses pour la culture du haricot adzuki, en Ontario. Au cours d’une période de trois ans (2012, 2013, 2014), les auteurs ont réalisé huit essais sur le terrain en Ontario afin d’évaluer la tolérance du haricot adzuki à la pyroxasulfone (150 et 300 g de m.a. par hectare), à la flumioxazine (71 et 142 g de m.a. par hectare), à la sulfentrazone (420 et 840 g de m.a. par hectare), à fomesafen (240 et 480 g de m.a. par hectare), à l’imazethapyr (75 et 150 g de m.a. par hectare) et au cloransulam-méthyl (35 et 70 g de m.a. par hectare) appliqués avant la levée. L’application de pyroxasulfone, de flumioxazine et de sulfentrazone avant la levée à la dose recommandée et au double de celle-ci cause de 25 à 96% de dommages à la culture et réduit le peuplement de jusqu’à 78%, le poids sec des pousses de jusqu’à 95%, la taille du plant de jusqu’à 67% et le rendement grainier de jusqu’à 76%. Le cloransulam-méthyl entraîne des dommages de un à neuf pour cent sans que le peuplement, le poids sec des pousses, la taille du plant, la teneur en eau des graines et le rendement grainier du haricot adzuki s’en ressentent. Le fomesafen et l’imazethapyr engendrent des dommages de un à trois pour cent, sans effet secondaire sur le peuplement, le poids sec des pousses, la taille du plant, la teneur en eau des graines et le rendement grainier. D’après ces résultats, la pyroxasulfone, la flumioxazine et la sulfentrazone ne présentent pas de marge de sécurité suffisante pour qu’on s’en serve contre les mauvaises herbes dans les champs de haricot adzuki. Le cloransulam-méthyl pourrait être employé comme désherbage, surtout au taux d’application le plus bas. L’imazethapyr et le fomesafen pourraient être utilisés en toute sécurité dans les cultures de haricot adzuki aux taux d’applications examinés, dans les conditions qui prévalent en Ontario.

Mots clés: Cloransulam-méthyl, fomesafen, flumioxazine, imazethapyr, pyroxasulfone, sulfentrazone, tolérance

Adzuki bean [Vigna angularis (Willd.) Ohwi and Ohashi] is a new specialty crop grown in southwestern Ontario for export to Japan, where it is used in pastry products (Sacks 1977; McClary et al. 1989; Hang et al. 1993). Adzuki bean has short physical stature and slow early growth, which makes it prone to substantial yield losses due to weed interference. Early-season weed control is critical to ensure minimal adzuki bean yield losses due to weed competition. Many of the herbicides commonly used for weed management in dry bean (Phaseolus vulgaris L.) are not registered for use in adzuki bean due to inadequate tolerance. More research is needed to identify pre-emergence applied herbicides with an adequate margin of crop safety that provide consistent control of annual grass and broad-leaved weeds in adzuki bean.

Pyroxasulfone is an isoxazoline herbicide developed by Kumiai Chemical Industry Company in Japan for weed management in corn, soybean, cereals and cotton (Anonymous 2006). Pyroxasulfone has the potential to control a broad spectrum of weeds, including annual grasses such as barnyardgrass (Echinochloa crus-galli (P.))

Abbreviations: ALS, acetolactate synthase; WAE, weeks after crop emergence
Beauv.), Digitaria species, Panicum species and Setaria species, and broadleaved weeds such as Amaranthus species, Polygonum species, common lambsquarters (Chenopodium album L.), common ragweed (Ambrosia artemisiifolia L.) and velvetleaf (Abutilon theophrasti Medicus) (Anonymous 2006).

Flumioxazin is an N-phenylphthalimide herbicide registered for use in soybean (Glycine max) and peanut (Arachis hypogaea) that inhibits the activity of protoporphyrinogen oxidase with both soil and foliar activity (Hartzler 2004; Price et al. 2004). Flumioxazin controls common lambsquarters, redwood pigweed, common ragweed, velvetleaf, common waterhemp (Amaranthus rudis L.), and eastern black nightshade (Solanum ptycanthum Dun. ex DC. pp.), including acetolactate synthase- (ALS) and triazine-resistant biotypes, and suppresses giant ragweed (Ambrosia trifida L.) and Pennsylvania smartweed (Polygonum pensylvanicum L.) growth (Niekamp 1998; Taylor-Lovell et al. 2002; Val lent 1998; Shaner 2014).

Sulfentrazone, another protoporphyrinogen oxidase inhibitor, is an aryl triazinone herbicide developed for use in soybean that controls a broad spectrum of annual broadleaf and grass weeds including common lambsquarters, velvetleaf, common waterhemp, redroot pigweed, common ragweed, eastern black nightshade, common cocklebur (Xanthium strumarium L.), barnyardgrass and giant foxtail (Setaria faberii Herrm) [Niekamp et al. 1999; Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) 2014; Shan er 2014].

Fomesafen is a diphenyl ether herbicide with both root and shoot activity that provides control of broadleaf weeds such as redroot pigweed, common ragweed, velvetleaf, wild mustard, Xanthium species, Polygonum species and Solanum species (OMAFRA 2014; Shaner 2014).

Imazethapyr is an ALS inhibiting herbicide belonging to the imidazolinone chemical family. This herbicide is absorbed by both roots and shoots and can control many annual grass and broadleaved weeds, such as velvetleaf, common lambsquarters, redroot pigweed, wild mustard, common ragweed, eastern black nightshade, wild buckwheat (Polygonum convolulus L.) and other Polygonum spp. (Wilson and Miller 1991; Arnold et al. 1993; Bauer et al. 1995; Shaner 2014; OMAFRA 2014).

Cloransulam-methyl, another ALS inhibiting herbicide, is a triazolopyrimidine sulfonamide herbicide with both root and shoot activity that controls several broadleaved weeds, such as common lambsquarters, redroot pigweed, velvetleaf, common cocklebur, and common ragweed (Shaner 2014). Cloransulam-methyl is active at low rates and has low mammalian toxicity and soil mobility; therefore, it has little potential to contaminate groundwater and the environment (Shaner 2014).

There is little information on the tolerance of adzuki bean to pyroxasulfone, flumioxazin, sulfentrazone, fomesafen, and cloransulam-methyl applied pre-emergence under Ontario environmental conditions. These herbicides have the potential to provide broad spectrum weed control in adzuki bean in Ontario if there is an adequate margin of crop safety. Therefore, the objective of this study was to determine the tolerance of adzuki bean to pre-emergence applied pyroxasulfone, flumioxazin, sulfentrazone, fomesafen, imazethapyr, and cloransulam-methyl under Ontario environmental conditions.

**MATERIALS AND METHODS**

Field studies were conducted from 2012 to 2014 at the Huron Research Station, Exeter, Ontario, and at the University of Guelph Ridgetown Campus, Ridgetown, Ontario, and in 2013 and 2014 at the Agriculture and Agri-Food Canada Research Station, Harrow, Ontario.

The experiment was arranged in a randomized complete block design with four replications. The treatments consisted of a non-treated control, and two rates, the label rate in dry bean/soybean (1 ×) and twice that rate (2 ×) of pyroxasulfone (150 and 300 g a.i. ha⁻¹), flumioxazin (71 and 142 g a.i. ha⁻¹), sulfentrazone (420 and 840 g a.i. ha⁻¹), fomesafen (240 and 480 g a.i. ha⁻¹), imazethapyr (75 and 150 g a.i. ha⁻¹), and cloransulam-metyl (35 and 70 g a.i. ha⁻¹).

Each plot was 3 m wide and consisted of four rows of the adzuki bean cultivar ‘Erino’. Rows were spaced 0.75 m apart and were 10 m long at Exeter and 8 m long at Harrow and Ridgetown. Adzuki bean was seeded at a rate of 200 000 seeds ha⁻¹ in late May to early June of each year. All plots, including the untreated control, were maintained weed free during the growing season by inter-row cultivation and hand hoeing as required.

Herbicide treatments were applied 1–2 d after seeding to the soil surface using a CO₂-pressurized backpack sprayer calibrated to deliver 200 L ha⁻¹ at 207 kPa using flat fan 8002 nozzles (Teejet Spraying Systems Co., Wheaton, IL) at Harrow and ULD 120-02 (Hypro, New Brighton, MN) at Exeter and Ridgetown. The spray boom was 1.5 m wide with four nozzles spaced 50 cm apart.

Adzuki bean injury was visually estimated on a scale of 0 (no injury) to 100% (complete plant death) at 1, 2 and 4 wk after crop emergence (WAE). Adzuki bean plant stand and dry weight were evaluated 3 WAE by counting and cutting plants at the soil surface for 1 m of row in each plot. Plants were dried at 60°C to a constant moisture and then weighed. Bean height was measured 6 WAE on 10 random plants per plot and averaged.

Adzuki bean was harvested from the centre two rows of each plot with a small-plot combine at crop maturity, weight and seed moisture content were recorded, and seed yields were adjusted to 14% seed moisture content. The crop was considered mature when approximately 90% of pods had turned from green to golden in colour.

Data were analyzed as a RCBD using PROC MIXED in SAS software ver. 9.4. Herbicide treatment was considered a fixed effect, while environment (year-location combinations), the interaction between environment and herbicide treatment, and replicate nested within
environment were considered random effects. Significance of the fixed effect was tested using F-test 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. The untreated control (for injury ratings) was excluded from the analysis. However, all values were compared independently to zero to evaluate treatment differences with the untreated control. To satisfy the assumptions of the variance analyses, adzuki bean injury was arcsine square root transformed and dry weight was log transformed. Treatment comparisons were made using Fisher’s Protected LSD test at a level of \( P < 0.05 \). Data compared on the transformed scale were converted back to the original scale for presentation of results.

**RESULTS AND DISCUSSION**

Statistical analysis of these data showed that the random effects of location, year, year by location and interactions with treatments for injury, plant height, shoot dry weight, seed moisture content and seed yield was not significant. Therefore, data were pooled over years and locations (Table 1). Seed moisture content ranged from 10.3 to 16.6%, but treatment effect was non-significant (data not shown). Yields were adjusted to 14% seed moisture content.

**Pyroxasulfone**

Pyroxasulfone applied PRE at 150 g a.i. ha\(^{-1}\) caused 25–26% injury at 1, 2 and 4 WAE in adzuki bean (Table 1). Increasing the rate of pyroxasulfone to 300 g ha\(^{-1}\) resulted in up to 56% injury. Pyroxasulfone applied PRE reduced adzuki bean plant stand 39%, shoot dry weight (g m\(^{-1}\) row) 80% and height 30% compared with the untreated control (Table 1). Generally, there was a greater reduction in adzuki bean stand, shoot dry weight and height with pyroxasulfone at the 300 g a.i. ha\(^{-1}\) rate compared with the 150 g a.i. ha\(^{-1}\) rate. Pyroxasulfone applied PRE reduced adzuki bean seed yield 20% at 150 g a.i. ha\(^{-1}\) and 32% at 300 g a.i. ha\(^{-1}\) (Table 1). The level of injury in adzuki bean with pyroxasulfone is similar to the level of injury in *Phaseolus* species. Pyroxasulfone caused as much as 80% injury and reduced shoot dry weight 36%, plant height 63% and seed yield 38% in pinto bean and small red Mexican bean (Soltani et al. 2008).

**Flumioxazin**

Flumioxazin applied PRE at 71 g a.i. ha\(^{-1}\) caused 54–59% injury at 1, 2 and 4 WAE in adzuki bean (Table 1). The higher rate of flumioxazin (142 g a.i. ha\(^{-1}\)) caused as much as 84% injury in adzuki bean. Flumioxazin applied PRE reduced adzuki bean plant stand 78%, shoot dry weight (g m\(^{-1}\) row) 93% and height 42% compared with the untreated control (Table 1). Generally, there was a greater reduction in adzuki stand, shoot dry weight and height with flumioxazin at the 142 g ha\(^{-1}\) rate compared with the 71 g ha\(^{-1}\) rate. Flumioxazin applied PRE reduced adzuki bean seed yield 24 and 52% at 71 and 142 g ha\(^{-1}\), respectively (Table 1).

Other studies have shown variable injury in beans with flumioxazin. Renner and Powell (2002) reported as much as 40% injury with flumioxazin applied PRE at 54 g a.i. ha\(^{-1}\) in black and white bean; Niekamp et al. (1999) reported as much as 20% crop injury with flumioxazin. Renner and Powell (2002) reported as much as 40% injury with flumioxazin applied PRE at 54 g a.i. ha\(^{-1}\) in black and white bean; Niekamp et al. (1999) reported as much as 20% crop injury with flumioxazin applied PRE at 90 g a.i. ha\(^{-1}\) in soybean and Taylor-Lovell et al. (2001), studying 15 cultivars of soybeans, found less than 2% crop injury in the majority of soybean cultivars evaluated with flumioxazin applied PRE at 53 to 105 g a.i. ha\(^{-1}\).

---

**Table 1.** Percent visible injury, plant stand and dry weight at 3 wk after emergence (WAE), plant height at 6 WAE and seed yield of adzuki bean treated with various pre-emergence herbicides at Ridgetown, Exeter and Harrow, ON (2012–2014)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate (g a.i. ha(^{-1}))</th>
<th>1 WAE</th>
<th>2 WAE</th>
<th>4 WAE</th>
<th>Stand (no. m(^{-1}) row)</th>
<th>Dry weight (g m(^{-1}) row) (g plant(^{-1}))</th>
<th>Height (cm)</th>
<th>Yield (t ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated control</td>
<td>0a</td>
<td>0a</td>
<td>0a</td>
<td>18ab</td>
<td>15.2a</td>
<td>0.94a</td>
<td>43a</td>
<td>2.5a</td>
</tr>
<tr>
<td>Pyroxasulfone</td>
<td>150</td>
<td>26b</td>
<td>25c</td>
<td>25c</td>
<td>15b</td>
<td>6.2bc</td>
<td>0.49c</td>
<td>34bcd</td>
</tr>
<tr>
<td>Pyroxasulfone</td>
<td>300</td>
<td>47bc</td>
<td>56d</td>
<td>55d</td>
<td>11c</td>
<td>3.0d</td>
<td>0.38de</td>
<td>30de</td>
</tr>
<tr>
<td>Flumioxazin</td>
<td>71</td>
<td>56c</td>
<td>59d</td>
<td>54d</td>
<td>7de</td>
<td>3.5cd</td>
<td>0.74ab</td>
<td>33cd</td>
</tr>
<tr>
<td>Flumioxazin</td>
<td>142</td>
<td>78d</td>
<td>84ef</td>
<td>81ef</td>
<td>4e</td>
<td>1.1e</td>
<td>0.46cd</td>
<td>25ef</td>
</tr>
<tr>
<td>Sulfentrazole</td>
<td>420</td>
<td>53e</td>
<td>67de</td>
<td>73de</td>
<td>10cd</td>
<td>2.8d</td>
<td>0.39de</td>
<td>24f</td>
</tr>
<tr>
<td>Sulfentrazole</td>
<td>840</td>
<td>87d</td>
<td>94f</td>
<td>96f</td>
<td>4e</td>
<td>0.8e</td>
<td>0.26c</td>
<td>14g</td>
</tr>
<tr>
<td>Fomesafen</td>
<td>240</td>
<td>0a</td>
<td>0a</td>
<td>1ab</td>
<td>18ab</td>
<td>13.3a</td>
<td>0.88ab</td>
<td>43a</td>
</tr>
<tr>
<td>Fomesafen</td>
<td>480</td>
<td>0a</td>
<td>1ab</td>
<td>3ab</td>
<td>18ab</td>
<td>14.0a</td>
<td>0.89ab</td>
<td>42a</td>
</tr>
<tr>
<td>Imazethapyr</td>
<td>75</td>
<td>1a</td>
<td>1a</td>
<td>1ab</td>
<td>18ab</td>
<td>13.9a</td>
<td>0.87ab</td>
<td>43a</td>
</tr>
<tr>
<td>Imazethapyr</td>
<td>150</td>
<td>0a</td>
<td>2ab</td>
<td>2ab</td>
<td>19a</td>
<td>13.7a</td>
<td>0.84ab</td>
<td>41a</td>
</tr>
<tr>
<td>Cloransulam-methyl</td>
<td>35</td>
<td>1a</td>
<td>4b</td>
<td>5b</td>
<td>18ab</td>
<td>11.3a</td>
<td>0.74ab</td>
<td>39ab</td>
</tr>
<tr>
<td>Cloransulam-methyl</td>
<td>70</td>
<td>3a</td>
<td>6b</td>
<td>9bc</td>
<td>19a</td>
<td>10.0ab</td>
<td>0.70bc</td>
<td>38abc</td>
</tr>
</tbody>
</table>

\( P \) value <0.0001 <0.0001 <0.0001 <0.0001 <0.0001 <0.0001 <0.0001 <0.0001

\( \alpha-g \) Means followed by the same letter within a column are not significantly different according to Fisher’s Protected LSD test \( (P < 0.05) \).
Sulfentrazone
Sulfentrazone applied PRE at 420 g a.i. ha\(^{-1}\) caused 53–73% injury at 1, 2 and 4 WAE in adzuki bean (Table 1). Injury was significantly higher when sulfentrazone was applied at 840 g a.i. ha\(^{-1}\) with up to 96% injury in adzuki bean. Sulfentrazone applied PRE reduced adzuki bean plant stand 78%, shoot dry weight (g m\(^{-1}\) row) 95% and height 67% compared with the untreated control (Table 1). Generally, there was greater reduction in adzuki stand, shoot dry weight and height with sulfentrazone at the 840 g a.i. ha\(^{-1}\) rate compared with the 420 g a.i. ha\(^{-1}\) rate. Sulfentrazone applied PRE reduced adzuki bean seed yield 48 and 76% at 420 and 840 g a.i. ha\(^{-1}\), respectively (Table 1). Our results with adzuki bean are similar to those reported for other Phaseolus species and indicate that sulfentrazone is likely not safe for PRE weed control in any of these crops. Hekmat et al. (2007) found that sulfentrazone applied PRE at 420 and 840 g a.i. ha\(^{-1}\) caused up to 30% injury, reduced biomass as much as 40% and seed yield as much as 52% in black, brown, cranberry, kidney, otebo, pinto, white, and yellow eye bean.

Fomesafen
Fomesafen applied PRE at 240 and 480 g a.i. ha\(^{-1}\) caused 3% or less injury at 1, 2 and 4 WAE in adzuki bean (Table 1). There was no difference in injury between the 1 × and 2 × rates. Fomesafen applied PRE at 240 and 480 g ha\(^{-1}\) did not reduce adzuki bean plant stand, shoot dry weight (g m\(^{-1}\) row), height or seed yield compared with the untreated control (Table 1). Results are similar to those seen in Phaseolus species where fomesafen caused minimal injury with no detrimental effect on shoot dry weight, plant height and seed yield of several market classes of dry beans (Bailey et al. 2003; Wilson 2005).

Imazethapyr
Imazethapyr applied PRE at 75 and 150 g a.i. ha\(^{-1}\) caused 2% or less injury at 1, 2 and 4 WAE in adzuki bean (Table 1). There was no difference in injury between the 1 × and 2 × rates. Imazethapyr applied PRE at 75 and 150 g a.i. ha\(^{-1}\) did not reduce adzuki bean plant stand, shoot dry weight (g m\(^{-1}\) row), height and seed yield compared with the untreated control (Table 1). Imazethapyr applied PRE to adzuki bean caused 4–5% injury in previous studies in Ontario (Sikkema et al. 2006) and Michigan (Powell et al. 2004). However, there was no adverse effect on plant height, shoot dry weight, seed moisture content and seed yield of adzuki bean (Sikkema et al. 2006).

Cloransulam-methyl
At 1, 2 and 4 WAE, cloransulam-methyl applied PRE at 35 and 150 g a.i. ha\(^{-1}\) caused 1–5 and 3–9% injury in adzuki bean, respectively (Table 1). However, there were no significant reductions in adzuki bean plant stand, shoot dry weight (g m\(^{-1}\) row), height and seed yield compared with the untreated control with either rate of cloransulam-methyl (Table 1). Results from this study are similar to those from other studies that have shown that cloransulam-methyl causes minimal injury with no adverse effect on shoot dry weight, plant height or seed yield in adzuki bean (Stewart et al. 2010). In Phaseolus species, cloransulam-methyl PRE caused 5% crop injury with no detrimental effects on shoot dry weight, plant height or seed yield of pinto and small red Mexican (Sikkema et al. 2008). In contrast, other studies have shown that cloransulam-methyl applied PRE reduced shoot dry weight 58%, plant height 40% and seed yield 43% in white bean (Soltani et al. 2004).

In conclusion, pyroxsulfone, flumioxazin and sulfentrazone applied PRE at the proposed 1 × and 2 × rates caused substantial and persistent crop injury and seed yield loss in adzuki bean. There was generally higher injury, and greater reductions in plant stand, shoot dry weight, plant height and seed yield with the 2 × rate compared with the 1 × rate. Cloransulam-methyl caused moderate (1 to 9%) injury with no adverse effects on plant stand, shoot dry weight, plant height, seed moisture content or seed yield of adzuki bean. Fomesafen and imazethapyr at both rates evaluated resulted in minimal (3% or less) injury with no adverse effect on plant stand, shoot dry weight, plant height, seed moisture content or seed yield of adzuki bean. In general, adzuki bean was most sensitive to sulfentrazone followed by flumioxazin followed by pyroxsulfone followed by cloransulam-methyl and then fomesafen and imazethapyr. Based on these results, pyroxsulfone, flumioxazin and sulfentrazone do not have an adequate margin of crop safety for weed management in adzuki bean. Cloransulam-methyl has potential for use in adzuki bean at the lower rate. However, imazethapyr and fomesafen at the rates evaluated can be safely used for weed management in adzuki bean under Ontario environmental conditions.

ACKNOWLEDGEMENTS
The authors acknowledge the technical expertise of Elaine Lepp and Todd Cowan. Funding for this study was made possible through Ontario Bean Growers and the GF2 program of the Agricultural Adaptation Council.

Hang, A. N., McClary, D. C., Gilliland, G. C. and Lumpkin, T. A. 1993. Plant configuration and population effects on yield


Valent. 1998. Valor herbicide technical information bulletin. Valor U.S.A. Corp. P. O. Box 8025, Walnut Greek, CA.
