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Effect of Method of Application, Herbicide Rate and Cultivar on Processing Pea Tolerance to Saflufenacil

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Abstract

The purpose of this work was to determine the effect of method of application, herbicide rate and cultivar on tolerance of processing pea tolerance to saflufenacil. Two field experiments were established to address this—each experiment was conducted over a 3-year period. The first experiment, conducted in 2014, 2015 and 2016, was arranged in a split-plot design with method of application (pre-plant incorporation (PPI) or preemergence (PRE)) as the main plot factor, and saflufenacil rate (0, 75 and 150 g ai ha^{-1}) as the subplot factor. Pea (*Pisum sativum* L.) was not injured, and dry matter, pea tenderness and yield were not less than the untreated check when saflufenacil was applied either PPI or PRE, at 75 and 150 g ai ha^{-1} of the herbicide. The second experiment was conducted from 2017 to 2019, at two locations each year; each repetition of this experiment was arranged in a factorial design to determine the effect of two factors on processing pea: saflufenacil rate (0, 75 and 150 g ai ha^{-1}) and cultivar. Saflufenacil did not cause more than 5% visible injury to pea, nor did it reduce pea dry matter, tenderness or marketable yield of the eight cultivars included in the experiment. Application method, saflufenacil rate and cultivar did not affect pea tolerance across a wide range of soil and environmental conditions. Registration of saflufenacil in processing pea would significantly improve growers' options for control of Group 2 resistant broadleaf weeds such as common lamb's-quarters (*Chenopodium album* L.), eastern black nightshade (*Solanum ptycanthum* Dunal.) and common ragweed (*Ambrosia artemisiifolia* L.).

Keywords: cultivar sensitivity, herbicide tolerance, pre-plant incorporation, preemergence, *Pisum sativum* L., saflufenacil

1. Introduction

In the province of Ontario, succulent field pea (*Pisum sativum* L.) grown for the canning and frozen pea markets offers field crop growers an opportunity to diversify farm operations and increase overall profit on farm. Approximately 6,200 ha of succulent pea were grown in Ontario in 2016, this high value crop provided on-farm income of $11.8 M (OMAFRA, 2017). Pea is considered to be a poor competitor, since cultivars grown for these markets are semi-leafless (*i.e.*, tendrils replace leaflets at shoot tips), so they intercept less light than leafy cultivars (Martin et al., 1994; Semere & Froud-Williams, 2001). Effective control of weeds is an important part of successful production of succulent pea.

The most problematic weeds pea growers must control are annual broadleaf weed species. This includes species such as eastern black nightshade (*Solanum ptycanthum* Dunal.), common lamb's-quarters (*Chenopodium album* L.) and common ragweed (*Ambrosia artemisiifolia* L.). These weeds can reduce yield of pea as much as 67%, interfere with harvest, and in extreme circumstances result in results in not harvesting some fields (Lutman et al., 1994; Townley-Smith & Wright, 1994). Management of these weeds in succulent pea is further complicated by the development of resistance a commonly used broadleaf herbicide, imazethapyr (OMAFRA, 2016), an herbicide the inhibits the function of the acetolactate synthase (ALS) enzyme (Shaner et al., 1984). The prevalence of annual broadleaf weed species resistant to ALS-inhibiting herbicides (*i.e.*, Group 2 herbicides) provides a basis for including herbicides with alternate modes-of-action that are capable of controlling these problematic weeds as part of a management strategy.

Saflufenacil is a preemergence herbicide registered in corn and soybean that controls a wide range of annual weeds (Grossmann et al., 2010), including Group 2 resistant biotype of those species mentioned in the previous paragraph. Saflufenacil is a pyrimidinedione, a Group 14 herbicide that inhibits protoporphyrinogen-IX oxidase

(PPO) in the chloroplast, ultimately leading to the accumulation of singlet oxygen radicals in the cytoplasm, which disrupt the cell membrane (Grossman et al., 2010). Since saflufenacil has a different mode-of-action than imazethapyr, it could potentially offer growers a means to control Group 2-resistant biotypes of eastern black nightshade, common lamb's-quarters and common ragweed in succulent pea. While preliminary research suggests that processing pea has tolerance to soil applications of saflufenacil (Soltani et al., 2010), the effect of application method and pea cultivar has yet to be reported upon in the literature.

Incorporation may affect pea response to soil applied herbicides. Incorporation generally will improve control in growing season when rain fails to fall within a couple of weeks of application, because it moves the herbicide into soil water solution (Sikkema & Robinson, 2005). However, incorporation also moves the herbicide into the zone where crop root development begins. In pea, incorporation resulted in injury and yield loss when planted after *s*-metolachlor; however, when the herbicide was left undisturbed on the soil surface, injury and yield loss were not observed (Sikkema & Lambgrets, 1995). The first objective of this research was to develop an understanding of the effect of incorporation on pea response to saflufenacil.

The substantial genetic diversity that exists among pea cultivars grown in North America (Tar'an et al., 2005; Kwon et al., 2011) is an important consideration in any attempt to characterize pea response to herbicides. Some research has shown that little variation in herbicide sensitivity exists among pea cultivars to bentazon and MCPA (Jensen, 1993); however, Hicks (2003) showed pea cultivars possessed varying levels of sensitivity to PRE applications of cyanazine, metribuzin, terbuthylazine and trifluralin. These latter findings suggest that understanding herbicide tolerance in pea should include a range of cultivars.

Though differences in cultivar sensitivity to saflufenacil in pea are unknown, the response of other important crops to this herbicide has been elucidated. Miller et al. (2012) demonstrated differences in soybean (*Glycine max* L.) emergence, visible injury, plant dry weight and yield of 12 soybean cultivars planted after PRE applications of 25 to 200 g ai ha^{-1} saflufenacil. In contrast, sweet maize (*Zea mays* L.) hybrids possessed no differential response to PRE applications of saflufenacil at rates ranging from 75 to 150 g ai ha^{-1} (Robinson et al., 2012). The second objective of this research was to determine whether response to soil applied saflufenacil varied among eight commercially-grown pea cultivars.

2. Materials and Methods

2.1 Experiment 1: Influence of Application Method and Herbicide Rate on Processing Pea Tolerance to Saflufenacil

The first experiment was conducted on a Maplewood/Normandale sandy clay loam with 54% sand, 25% silt, 21% clay, 5.2% organic matter and pH of 6.7 in 2014, a Normandale sandy loam with 58% sand, 24% silt, 18% clay, 3.2% organic matter and pH 6.9 in 2015, and a Watford Brady sandy clay loam with 52% sand, 28% silt, 20% clay, 5.9% organic matter and pH of 7.2 in 2016. Each site was mouldboard plowed in the fall of year prior to establishment, and fertilizer was applied to provide 38 kg ha^{-1} of actual nitrogen. Phosphorous and potassium were amended as needed based on soil tests. The sites were then worked once with an S-tine cultivator prior to planting.

The experiment was arranged in a split-plot design with all treatments replicated four times. Main plots were 8.0 m wide by 8.0 m long, and each sub-plot was 2.0 m wide by 8.0 m long—a 1.0 m wide untreated boundary was left between each sub-plot. The main plot factor was method of application (pre-plant incorporation (PPI) or preemergence (PRE)), and the subplot factor was saflufenacil rate (0, 75 and 150 g ai ha^{-1}). The rates were chosen based upon the current dose registered in maize: 75 g ai ha^{-1}. Herbicides were applied two to three days before pea planting with a CO_2-pressurized backpack sprayer calibrated to deliver 210 L ha^{-1} spray solution at 200 kPa using Teejet 8002 flat-fan nozzles (Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60188). The boom was 2.0 m long with five nozzles spaced 50 cm apart. Incorporation of the PPI treatments was done the day of application with two passes in opposite directions of an S-tine cultivator with rolling basket harrows. 'Spring' pea was planted to a depth of 5.0 cm using 18- and 5-cm between- and within-row spacings, respectively, at a rate of 300 kg seed ha^{-1}. Pea was planted on 2 April, 2014, 8 April, 2015 and 9 April, 2016. All plots were hand-weeded as required until pea vines covered the inter-rows.

Crop injury was rated 1, 2 and 4 weeks after pea emergence (WAE) on a scale of 0 to 100%. A rating of 0 denoted no visible plant injury, while 100 indicated complete plant death. At 4 WAE, ten plants were randomly sampled from each plot and placed into a paper bag, dried for four days at 60 °C, and dry weight of the ten plants combined was determined. As pea approached maturity, a random sample of deshelled pea fruit from ten pea pods in the untreated strips between plots was collected each day. Tenderometer readings of these samples were made using a tenderometer (TU-12, manufactured by Food Technology Corporation, 45921 Maries Road, Sterling, VA 20166), to determine when pea was ready to harvest. Pea was harvested when tenderometer readings in the untreated strips reached 100 tenderness units (TUs), a value considered optimal for processing (*i.e.*, mature), and thus ready for harvest (Everaarts & Sukkel, 2000). At maturity, two 1 m^2 quadrats of plants were harvested by hand from each plot and combined, immediately put through a stationary pea thresher to separate pea fruit from the shells, and fresh weight of deshelled pea fruit was measured. From this, a 50 g sample of pea fruit was placed into the tenderometer to determine pea tenderness.

The general linear mixed model (GLIMMIX) of SAS 9.3 (SAS 2011) was used to analyze fixed effects of application method, saflufenacil rate, the interaction between fixed effects, as well as random effects of year, and the year-by-treatment interactions. Shapiro-Wilk, Durban-Watson and Levene's tests were used to confirm normality, independence of errors and homogeneity of variances. Percent injury data were not normal, so estimates and standard errors were obtained using the logit ILINK. Plant dry weight, tenderometer readings and yield at maturity met all three assumptions of analysis of variance. Tukey's HSD test ($\alpha = 0.05$) was used to separate treatment means.

2.2 Experiment 2: Influence of Cultivar and Herbicide Rate on Processing Pea Tolerance to Saflufenacil

A second experiment examined the interaction between pea cultivar and saflufenacil rate from 2017 to 2019. Each year, the experiment was established at two randomly chosen locations at the Ridgetown Campus. In 2017, the soil at one of the locations was a Normandale loamy fine sand (78% sand, 13% silt, 9% clay; 3.5% OM, pH 6.6 and CEC 8 meq 100 g^{-1} soil), and at the second site was a Watford Brady clay loam (38% sand, 30% silt, 32% clay; 4.3% OM, pH 6.9 and 14 meq 100 g^{-1} soil). In 2018, the experiment was established on a Watford Brady loam (50% sand, 28% silt, 22% clay; 4.7% OM, pH 6.0 and 12 meq 100 g^{-1} soil) and Normandale loamy fine sand (82% sand, 10% silt and 8% clay; 3.9% OM, pH 6.5 and 7 meq 100 g^{-1} soil). In the third year, soil types were Watford Brady loam (46% sand, 27% silt and 27% clay; 4.2% OM, pH 7.1 and 12 meq 100 g^{-1} soil) and Normandale very fine sandy loam (72% sand, 15% silt, 13% clay; 5.4% OM, pH 7.1 and 11 meq 100 g^{-1} soil). All sites were plowed, fertilized and seedbed prepared as in the first experiment. Pea was planted to a depth of 5.0 cm using 18- and 5-cm between- and within-row spacings, respectively, at a rate of 300 kg seed ha^{-1}. Pea was planted on 4 April, 2017, 12 April, 2018 and 6 April, 2019. All plots were hand-weeded as required until pea vines covered the inter-rows. Plots were 2 m wide by 8 m long, and the experiment was arranged in a factorial design with two factors. The first factor was saflufenacil rate (0, 75 and 150 g ai ha^{-1}), and the second factor was pea cultivar ('Tyne, 'Sweet Savour', 'Reliance', 'Lil Mo', 'Gallant', 'Salerno', 'Naches', 'Spring'). The cultivars were chosen to reflect a diversity of different genotypes of cultivars grown commercially in the province of Ontario. Herbicides were applied PRE, two to three days before planting, using the same application procedure and equipment from Experiment 1. All plots were kept weed-free with hand-weeding.

Data collection, confirmation of assumptions of ANOVA and statistical procedures were conducted using the same methods as in Experiment 1. As in the first experiment, the logit ILINK was to obtain estimates of percent injury. In this experiment, fixed effects were saflufenacil rate, pea cultivar, and the interaction between the two variables, while random effects of year and year-by-treatment interactions were also included in the analysis.

3. Results and Discussion

3.1 Experiment 1: Influence of Application Method and Herbicide Rate on Pea Tolerance to Saflufenacil

Mean monthly temperature and precipitation data during the course of this study are shown in Table 1. Pea response to soil applications of saflufenacil was combined over years and locations, as there were no interactions between random effects of year and fixed effects of application method or herbicide rate. Across years, rainfall in the month of April ranged from 32 to 102 mm, and mean monthly soil temperature varied from 6.2 to 7.0 ^oC (Table 1), suggesting that pea tolerance to PRE herbicides was consistent among years, despite variable soil moisture and temperature levels.

Table 1. Monthly rainfall and mean daily temperature in each year (2014 to 2016) of the method of application experiment (Experiment 1) from the start of the month of herbicide application to the end of the month of crop harvest, as well as 30-yr averages for monthly rainfall and daily mean temperature at Ridgetown, Ontario.

Month	2014		2015		2016		30-year average	
	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)
April	32	7.0	102	6.2	66	6.6	76	7.8
May	34	15.5	64	15.1	97	13.4	80	14.0
June	45	22.6	102	18.6	48	19.8	70	19.2
July	156	22.1	78	21.2	130	19.1	74	21.6

Note. Monthly precipitation and mean temperature data were obtained from the on-site weather station located at Ridgetown, Ontario.

Visible injury and dry weight of ten plants per plot were similar to the untreated check treatments in all instances. Pea visible injury ranged from 0 to 3% and 0 to 4% in the pre-plant incorporated (PPI) and preemergence (PRE) treatments as saflufenacil rate increased from 0 to 150 g ai ha^{-1}, respectively (Table 2). There was not an effect of application method ($p = 0.2022$), saflufenacil rate ($p = 0.5059$) or their interaction ($p = 0.1397$) on visible injury in pea. Corresponding to the lack of visible injury observed, dry weight was not influenced by application method ($p = 0.2681$), herbicide rate ($p = 0.4720$), or their interaction ($p = 0.901$). Dry weights were 10.7 and 11.3 g plant^{-1} at saflufenacil rates of 0 and 150 g ai ha^{-1} in the PPI treatments, and 11.4 and 11.0 g plant^{-1} at 0 and 150 g ai ha^{-1} rates of saflufenacil (Table 2), respectively, in the PRE applications. These results are similar to those of Soltani et al. (2010), who found that PRE applications of saflufenacil neither injured nor reduced growth of pea at rates of 100 and 200 g ai ha^{-1}.

Table 2. Effect of method of application and saflufenacil rate on pea visible injury at 28 days after emergence (DAE), average dry weight of ten plants per plot, tenderometer reading at harvest and shelled yield averaged over three years (*i.e.*, 2014 to 2016) and two locations at Ridgetown, Ontario

Method of Application	Saflufenacil Rate (g ai ha^{-1})	Visible Injury (%)	Dry Weight (g plant^{-1})	Tenderometer Reading (TUs)	Yield (T ha^{-1})
Pre-plant Incorporation	0	0	10.7 a	100 a	4.5 a
	75	1 a	10.8 a	100 a	4.2 a
	150	3 a	11.3 a	100 a	4.8 a
Premergence	0	0	11.4 a	100 a	4.8 a
	75	2 a	11.7 a	104 a	4.6 a
	150	4 a	11.0 a	101 a	4.5 a
Standard Error		4	1.3	7	0.6

Note. Pea tenderometer readings are measured in tenderness units (TUs) on a scale of 0 to 160, which is used by the processing pea industry to estimate maturity. Tenderometer readings of 100 to 105 are optimal at harvest.

In addition to no effect of application method or saflufenacil rate on pea visible injury and dry matter production, pea tenderometer readings and marketable yield also were unaffected. Pea tenderness was 100 and ranged from 100 to 104 tenderness units at saflufenacil rates of 0 and 150 g ai ha^{-1} in the PPI and PRE application timings, respectively (Table 2). Application method ($p = 0.1598$), saflufenacil rate ($p = 0.0884$) and the interaction between them ($p = 0.1843$) did not have an effect on pea tenderness. This has important implications for making harvesting decisions, as tenderness is considered an accurate estimate of fresh pea maturity (Wisscher & Lovink, 1999). Pea yield varied from 4.2 to 4.8 t ha^{-1} and from 4.5 to 4.8 t ha^{-1} in the PPI and PRE application timings, respectively. Pea yield was not influenced by application method ($p = 0.2555$), saflufenacil rate ($p = 0.3807$), or the interaction between application method and saflufenacil rate ($p = 0.8941$). Similar to what was observed in for pea injury and dry matter, pea tenderness and yield were not different from the untreated controls.

This experiment showed pea responded similarly to the untreated check, when saflufenacil was applied either PPI or PRE, at 75 and 150 g ai ha^{-1} of the herbicide. This is in contrast to previous work with *s*-metolachlor, which caused significant injury to pea when incorporated, but not when left on the soil surface (Sikkema &

Lambgrets, 1995), and that injury increased with herbicide rate in PPI applications. The differential response of pea to these herbicides may occur because differential metabolism, though differential uptake may be partially responsible for this finding. Saflufenacil is taken up through the root (Frihauf et al., 2010), while *s*-metolachlor is absorbed through the elongating hypocotyl as well as roots (Deal & Hess, 1980). Incorporation places the herbicide into the region of the soil where hypocotyls grow, which may therefore increase the potential for injury from *s*-metolachlor but not saflufenacil.

The results and limitations of this experiment were used to guide the design of the second experiment on different pea cultivars. Since application method (PPI versus PRE) did not affect pea tolerance to saflufenacil, and given that pea growers in Ontario generally prefer not to incorporate soil applied herbicides due to the extra time, fuel and equipment needed, the second experiment was conducted using only PRE applications of saflufenacil. One limitation of Experiment 1 was the inclusion of a single pea cultivar, which limits the applicability of the results to a relatively small portion of the genome among commercially-grown pea cultivars (Tar'an et al., 2005). We did not find prior research that examined whether pea cultivar influences tolerance to saflufenacil; however, tolerance to trifluralin differed among pea cultivars (Hicks, 2003). Furthermore, Miller et al. (2012) observed variable tolerance to saflufenacil among soybean cultivars. As a result, a second experiment was planned to include several pea cultivars.

In addition to the limitation of a single cultivar, Experiment 1 was only conducted on one soil type in each year of study, which also limits the applicability of the results. Gannon et al. (2014) showed that saflufenacil toxicity in canola (*Brassica napus* L.) was strongly correlated ($r = 0.85$) to soil organic matter. This is common for other soil-applied, residual herbicides with the same mode-of-action, such as sulfentrazone (Grey et al., 1997) and flumioxazin (Ferrell et al., 2005). As a result, further analysis of the response of pea to saflufenacil was conducted on different soil types and weather conditions.

3.2 Experiment 2: Influence of Saflufenacil Rate and Cultivar on Pea Tolerance to Saflufenacil

Mean monthly temperature and monthly precipitation from 2017 to 2019 are presented in Table 3. Since random effects of site, year, and their interactions with either application method or saflufenacil rate were not significant, data were combined over sites and years. The fact that data could be combined across all sites and years is notable, given that the amount of rainfall in April varied from 54 to 113 mm, and mean soil temperature ranged from 5.8 to 10.1 ^{o}C; (Table 3). In addition, the experiment was repeated on a variety of soil textures, ranging from a loamy fine sand to clay loam soils, organic matter (3.5 to 5.4%), pH (6.0 to 7.1) and CEC (7 to 14 meq 100 g^{-1} soil), suggesting that pea cultivar response to PRE herbicide applications of saflufenacil was consistent across the range of environments experienced in the trials.

Table 3. Monthly rainfall and mean daily temperature in each year (2017 to 2019) of the pea cultivar experiment (Experiment 2) from the start of the month of herbicide application to the end of the month of crop harvest, as well as 30-yr averages for monthly rainfall and daily mean temperature at Ridgetown, Ontario

Month	2017		2018		2019		30-year average	
	Rainfall (mm)	Temperature (^{o}C)	Rainfall (mm)	Temperature (^{o}C)	Rainfall (mm)	Temperature (^{o}C)	Rainfall (mm)	Temperature (^{o}C)
April	54	7.2	92	5.8	113	10.1	76	7.5
May	90	16.2	106	13.8	102	12.6	80	13.9
June	98	18.1	51	18.9	45	19.7	70	19.2
July	62	19.8	79	21.8	36	21.2	74	21.4

Note. Monthly precipitation and mean temperature data were obtained from the on-site weather station located at Ridgetown, Ontario.

Visible injury and dry weight of pea in the herbicide treated plots were similar to the untreated check treatments, for all cultivars across all sites and years. Pea visible injury was less than 10% in all treatments (Table 4). There was not an effect of pea cultivar ($p = 0.2511$), saflufenacil rate ($p = 0.2527$) or their interaction ($p = 0.6481$) on visible injury in pea. Pea dry weight was not reduced by PRE applications of saflufenacil at either 75 or 150 g ai ha^{-1} ($p = 0.9400$). Dry weights varied from 10.8 to 14.5 g plant^{-1} (Table 4) across all cultivars ($p = 0.0081$), but the interaction between saflufenacil rate and cultivar was not significant ($p = 0.2635$). The difference in plant dry weight may among pea cultivars in this trial is not unexpected, and is likely explained by the significant variability in the genome among pea cultivars grown in Canada (Ta'ran et al., 2005).

Table 4. Effect of pea cultivar on visible injury at 28 days after emergence (DAE), average dry weight of ten plants per plot, tenderometer reading at harvest and shelled yield averaged over three years (*i.e.*, 2017 to 2019) and two locations at the Ridgetown Campus field research station in Ridgetown, Ontario

Cultivar	Visible Injury (%)	Dry Weight (g plant^{-1})	Tenderometer Reading (TUs)	Yield (T ha^{-1})
Salerno	4 a	12.8 b	100 a	3.3 b
Gallant	4 a	14.5 a	101 a	3.8 ab
Lil Mo	3 a	10.8 d	100 a	3.8 ab
Naches	4 a	12.8 b	101 a	2.8 c
Reliance	2 a	12.6 b	100 a	3.6 b
Spring	2 a	12.2 bc	101 a	4.1 a
Sweet Savour	4 a	11.6 cd	100 a	3.2 bc
Tyne	0 a	13.8 a	102 a	3.3 b
Standard error	5	0.8	7	0.3

Note. Within each column, means that are different than one another are denoted by different letters according to Tukey's test ($\alpha = 0.05$).

In addition to having no negative effect on pea visible injury or dry matter production, saflufenacil rate did not reduce pea tenderometer readings or marketable yield. Pea tenderness was similar across all three saflufenacil rates ($p = 0.8908$), and the interaction between pea cultivar and saflufenacil rate was not significant ($p = 0.9929$); indicating that herbicide treatments did not alter maturity among any of the pea cultivars in the experiment. Pea yield varied among cultivars ($p < 0.0001$); yield ranged from 2.8 in 'Naches' to 4.1 t ha^{-1} in 'Spring' (Table 4). This difference among pea cultivars is likely due to genomic differences that exist among pea cultivars grown in Canada (Ta'ran et al., 2005). Pea yield was not different between the untreated check and either rate of saflufenacil ($p = 0.2070$), and was unaffected by the interaction between pea cultivar and saflufenacil rate ($p = 0.9332$).

4. Conclusion

The purpose of this work was to determine how method of application, saflufenacil rate, and pea cultivar affected the tolerance of processing pea to saflufenacil. Saflufencil was selected for this work because of its efficacy on Group 2 resistant biotypes of common lambsquarters, eastern black nightshade and redroot pigweed (Grossmann et al., 2010), all of which are prevalent in the processing pea production region of Ontario. Additionally, previous work (Soltani et al., 2010) suggested a good level of tolerance in processing pea might exist. The main limitation of prior research was that it was conducted on a single cultivar, and on a limited range of soil types. The research presented in this paper shows that tolerance to saflufenacil in processing pea was not affected by application method (ie. pre-plant incorporated versus preemergence), cultivar, or saflufenacil rate up to 150 g ai ha^{-1} under a wide range of weather and soil conditions. Currently, saflufenacil is registered in field pea in Canada, and a minor use submission is being prepared to register this herbicide in processing pea. The work has significant implications for the management of Group 2-resistant broadleaf weeds, which are difficult-to-control in processing pea, limit yield and may impede harvest (Lutman et al., 1996). The knowledge that application method and cultivar did not affect pea tolerance under a wide range of environmental conditions, increases our confidence that this herbicide would be a safe, effective option to manage several broadleaf weeds in this important crop.

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