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Does the Inclusion of Atrazine in S-Metolachlor/Mesotrione/Bicyclopyrone Improve Glyphosate-Resistant Canada Fleabane Control in Corn?

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Abstract

A total of seven field studies were conducted in southwestern Ontario from 2018 to 2020 to evaluate S-metolachlor/mesotrione/bicyclopyrone (Acuron Flexi®) and S-metolachlor/atrazine/mesotrione/bicyclopyrone (Acuron®) for the control of glyphosate-resistant (GR) Canada fleabane in corn. Acuron Flexi® and Acuron® applied preplant (PP) controlled GR Canada fleabane 90-97% and 99-100%, respectively. Commonly used PP herbicides in Ontario, dicamba/atrazine + glyphosate and tolpyralate + atrazine + glyphosate controlled GR Canada fleabane 97-99%. Acuron Flexi® and Acuron® applied postemergence (POST) provided 75-92% and 92-99% control of GR Canada fleabane, respectively. Dicamba/atrazine + glyphosate and tolpyralate + atrazine + glyphosate applied POST provided 84-97% and 94-98% control of GR Canada fleabane, respectively. Glyphosate applied POST at 900 ae ha^{-1} provided only 35-38% control of Canada fleabane in corn. Orthogonal contrasts indicated that herbicides applied PP provided up to 10% greater control of GR Canada fleabane than POST. There was no significant difference between the low and high rates of Acuron® or Acuron Flexi® in controlling GR Canada fleabane. Acuron® controlled GR Canada fleabane 14, 9 and 7% greater than Acuron Flexi® at 4, 8, and 12 WAA, respectively. GR Canada fleabane interference with corn reduced yield up to 42%. However, there was no difference in corn yield between herbicides treatments evaluated. Orthogonal contrasts indicated that reduced GR Canada fleabane interference with PP herbicides evaluated provided 0.9 t ha^{-1} greater corn yield than the POST herbicides evaluated. There was no significant difference in corn yield with Acuron® or Acuron Flexi® at the lower rate or higher rates. Additionally, Acuron Flexi® applied PP provided a similar corn yield as when applied POST. Based on these results, the use of Acuron® results in improved GR Canada fleabane control than Acuron Flexi® but this did not result in an increase in corn yield. The study concludes that there is potential for Acuron Flexi® for GR Canada fleabane control in corn especially in areas where atrazine use is restricted, however additional weed control tactics may be required for acceptable control.

Keywords: Canada fleabane, *Erigeron canadensis* (L.) Cronq., glyphosate resistance, horseweed, postemergence herbicides, preplant herbicides, visible control, yield, *Zea mays* L.

1. Introduction

Corn is one of the most important crops grown in the world (Statista, 2021). Canada produced nearly 14 million metric tons of corn in 2020 (Statista, 2021). Most of the corn grown in Canada is produced in Ontario. In 2020, Ontario corn growers seeded nearly 900,000 ha and produced nearly 9 million tonnes of corn with a farm gate value of approximately $1.8 billion (OMAFRA, 2021). One of the main production concerns of corn growers is weed control. A study conducted by the Weed Science Society of America (WSSA) has found an average corn yield loss of 50% if weeds were not controlled (Soltani et al., 2016).

In recent years glyphosate-resistant (GR) weeds such as Canada fleabane (*Erigeron canadensis* (L.) Cronq.) have become a major concern in corn production in Ontario. GR Canada fleabane was first found in Essex County, Ontario in 2010 and has now been detected in at least 30 counties across southern Ontario (Budd et al., 2016). Canada fleabane is a winter or summer annual weed that is native to North America (Loux et al., 2006; Weaver, 2001). Its seed does not require dormancy and can germinate in autumn after maturation and seed shed (Buhler & Owen, 1997). Research in Ontario has shown that most of the Canada fleabane emerges late August/early

September or in late May (Tozzi & Van Acker, 2014). Each Canada fleabane plant can produce as much as 200,000 seeds per plant and the seed with its 2-3 mm pappus can disperse more than 100 km away from the mother plant (Davis and Johnson, 2008; Royer and Dickenson, 1999; Shields et al., 2006; Weaver, 2001).

Earlier studies have shown that residual herbicides applied in the spring provide better control of spring-emerging Canada fleabane than herbicides applied in the fall (Loux et al., 2006). There are currently few options to effectively control GR Canada fleabane in the spring. More research is needed to assess new herbicide premixes/tankmixes for the control of GR Canada fleabane in corn. Herbicide mixtures with multiple modes of action are commonly recommended for resistance management in agricultural crops (Beckie et al., 2009; Norsworthy et al., 2012).

Acuron® (S-metolachlor, bicyclopyrone, mesotrione and atrazine) is a residual herbicide from Syngenta (Syngenta Crop Protection, LLC, Greensboro, NC) that includes four active ingredients and three modes of action (Groups 5, 15 and 27) in a single herbicide for broad-spectrum weed control in corn (Syngenta, 2020). Acuron® controls broadleaved weeds such as American nightshade (*Solanum americanum*), Eastern black nightshade (*Solanum ptycanthum*), common ragweed (*Ambrosia artemisiifolia*), giant ragweed (*Ambrosia trifida*), ladysthumb (*Polygonum persicaria*), common lambsquarters (*Chenopodium album*), redroot pigweed (*Amaranthus retroflexus*), velvetleaf (*Abutilon theophrasti*), wild buckwheat (*Polygonum convolvulus*), wild mustard (*Sinapis arvensis*), waterhemp (*Amaranthus rudis*), cocklebur (*Xanthium strumarium* L.) and hairy galinsoga (*Galinsoga parviflora*), including Group 2-, 5-, and 9-resistant biotypes (Syngenta 2020). Acuron® also controls grass weeds including barnyardgrass (*Echinochloa crus-galli*), crabgrass (*Digitaria sanguinalis*), fall panicum (*Panicum dichotomiflorum*), foxtails (*Setaria* species), witchgrass (*Panicum capillare*) and yellow nutsedge (*Cyperus esculentus*) (Syngenta, 2020).

Acuron Flexi® (S-metolachlor, bicyclopyrone and mesotrione) is a new herbicide premix from Syngenta that includes three active ingredients and two modes of action (Groups 15 and 27) that can control grass and broadleaved weeds in corn (Syngenta, 2021). Acuron Flexi® provides similar broad-spectrum control of weeds as Acuron® in corn production (Syngenta, 2021). Acuron Flexi® does not contain atrazine and can be a valuable tool for weed management in areas where there is a restriction for the use of atrazine in agricultural fields. There are no soil type restrictions with Acuron Flexi® and features tank-mix flexibility allowing farmers/applicators to include additional tankmix partners such as atrazine or glyphosate if needed. Acuron Flexi® is labeled for application from 28 days prior to seeding up to 75-cm-high corn.

The efficacy of Acuron Flexi® and Acuron® to control GR Canada fleabane in corn has not been compared under Ontario environmental conditions. The objective of this study was to evaluate the crop safety and efficacy of Acuron Flexi® and Acuron® applied preplant (PP) and postemergence (POST) for the control of GR Canada fleabane in corn.

2. Materials and Methods

A total of seven field studies were conducted in southwestern Ontario from 2018 to 2020. Field trials were conducted in fields that had a heavy, consistent infestation of GR Canada fleabane throughout the trial location. Environment, crop stage at application, weed size, and weed density at PP and POST herbicide applications, and GR Canada fleabane resistance profile at each site are listed in Table 1. All experiments consisted of 14 treatments arranged in a randomized complete block design (RBCD) with 4 replications. Treatments evaluated are listed in Table 2. Plots were 2.25 wide (3 rows spaced 0.75 m apart) by 8 m in length with a 2 m walkway between blocks. Corn was seeded in May at approximately 80,000 seeds per ha^{-1} to a depth of 4 cm.

Table 1. Environment, crop stage at application, weed size, and weed density at PP and POST herbicide applications, and GR Canada fleabane resistance profile at each site where PP and POST herbicides were evaluated for the control of glyphosate-resistant Canada fleabane in Ontario

Env	Crop stage PP App.	PP App. avg	Min/max	density	Crop stage POST App.	POST App. avg	Min/max	Density	% Resistant 8 WAA
		---------- cm ----------		Plants m^{-2}		---------- cm ----------		Plants m^{-2}	---- Glyphosate ----
1	PP	1	1/4	100	-	2	1/7	72	n/a
2	PP	2	1/7	224	-	3	1/12	248	n/a
3	PP	-	-	-	-	-	-	-	n/a
4	PP	8	1/26	488	V4	15	1/38	407	40-60
5	PP	7	1/16	72	V5	21	2/52	54	0-20
6	PP	8	5/10	-	V4	14	12/15	-	50-100
7	PP	8	4/10	40	V3	15	10/20	40	0-50

Note. PP: preplant; App.: application; min: minimum; max: maximum; POST: postemergence.

Table 2. Means for glyphosate-resistant Canada fleabane control [4, 8, and 12 weeks after POST application (WAA)] and corn grain yield treated with herbicide tank mixtures applied PP and POST in Ontario

Treatment[a]	Rate	App Timing	4 WAA[b]	8 WAA	12 WAA	Yield
	-------- g a.i. ha^{-1} --------		---------- % ----------			----- t ha^{-1} -----
Untreated Control	-	-	0 f	0 d	0 d	7.4 b
S-metolachlor/atrazine/mesotrione/bicyclopyrone + glyphosate	1016/474/113/28 + 900	PP	99 ab	100 a	100 a	11.7 a
S-metolachlor/atrazine/mesotrione/bicyclopyrone + glyphosate	1259/588/140/35 + 900	PP	99 a	100 a	100 a	12.7 a
S-metolachlor/mesotrione/bicyclopyrone + glyphosate	1020/113/28 + 900	PP	90 bcd	96 ab	96 ab	12.4 a
S-metolachlor/mesotrione/bicyclopyrone + glyphosate	1258/140/35 + 900	PP	91 abcd	96 ab	97 ab	12.1 a
Dicamba/atrazine + glyphosate	497/983 + 900	PP	97 abc	98 a	98 ab	12.2 a
Tolpyralate + atrazine + glyphosate	35 + 560 + 900	PP	98ab	99 a	99 ab	12.4 a
S-metolachlor/atrazine/mesotrione/bicyclopyrone + glyphosate	1016/474/113/28 + 900	POST	92 abcd	98 a	99 ab	11.3 a
S-metolachlor/atrazine/mesotrione/bicyclopyrone + glyphosate	1259/588/140/35 + 900	POST	96abc	99 a	99 ab	11.6 a
S-metolachlor/mesotrione/bicyclopyrone + glyphosate	1020/113/28 + 900	POST	76 d	84 b	92 ab	11.4 a
S-metolachlor/mesotrione/bicyclopyrone + glyphosate	1258/140/35 + 900	POST	75 d	83 b	88 b	11.5 a
Dicamba/atrazine + glyphosate	497/983 + 900	POST	84 cd	94 ab	97 ab	11.2 a
Tolpyralate + atrazine + glyphosate	35 + 560 + 900	POST	94 abc	98 a	98 ab	11.1 a
Glyphosate	900	POST	35 e	36 c	38 c	11.6 a
Contrasts						
PP vs. POST			96 vs. 86 **	98 vs. 93 *	98 vs. 96 *	12.3 vs. 11.4 *
S-metolachlor/atrazine/mesotrione/bicyclopyrone + glyphosate PP VS. POST			99 vs. 94 *	100 vs. 99	100 vs. 99	12.2 vs. 11.5
S-metolachlor/mesotrione/bicyclopyrone + glyphosate PP VS. POST			91 vs. 76 *	96 vs. 84 *	97 vs. 90 *	12.3 vs. 11.5
S-metolachlor/atrazine/mesotrione/bicyclopyrone + glyphosate HIGH VS. LOW Rate			98 vs. 96	100 vs. 99	100 vs. 100	12.2 vs. 11.5
S-metolachlor/mesotrione/bicyclopyrone + glyphosate HIGH VS. LOW Rate			83 vs. 83	90 vs. 90	93 vs. 94	11.8 vs. 11.9
S-metolachlor/atrazine/mesotrione/bicyclopyrone + glyphosate VS. *S*-metolachlor/mesotrione/bicyclopyrone + glyphosate			97 vs. 83 **	99 vs. 90 *	100 vs. 93 **	11.8 vs. 11.9

Note. ** Significant at $P < 0.0001$; * significant at $P < 0.05$.

[a] Herbicide treatments tolpyralate + atrazine + glyphosate included methylated seed oil (MSO Concentrate®) (Loveland Products Inc., 3005 Rocky Mountain Ave., Loveland, CO.) (0.5% v/v) and urea ammonium nitrate (UAN 28-0-0) (Sylvite, 3221 North Service Road, Burlington, ON) (2.5% v/v).

[b] Means followed by a different letter within a column are significantly different according to a Tukey-Kramer multiple range test at $P < 0.05$.

Herbicides were sprayed PP or POST at application timings shown in Table 1 with a CO_2 pressurized backpack sprayer (1.5 m spray boom, with 4 ULD-120-02 nozzles spaced 0.5 m apart that produced a 2.0 m spray width) calibrated to deliver 200 L ha^{-1} water volume at 240 kPa.

Corn injury was evaluated 2 and 4 weeks after POST application (WAA) on a scale of 0 to 100%, where 0 was no visible injury and 100 was plant death compared to the untreated control. Canada fleabane control was

assessed 4, 8, and 12 WAA on a scale of 0 to 100, where 0 represented no control and 100 was complete GR Canada fleabane control. Corn yield was determined by harvesting the middle two rows within each plot at maturity with a small-plot combine. Corn yields were adjusted to 15.5% seed moisture content.

Data were analyzed using the GLIMMIX procedure in SAS Studio, OnDemand for Academics (The SAS System for Windows, Release 9.2, Cary, NC, USA). The fixed effect was herbicide treatment and the random effects were year-location (environment), replicate within the environment, and treatment-by-environment. The Shapiro-Wilk statistics, fit statistics, residual plots, and the potential distributions were used to identify the best distribution and associated link function for each parameter. Least square means (LSMEANS) were calculated on the data scale using the inverse link function, and pairwise comparisons were subjected to Tukey's adjustment before determining treatment differences at $P < 0.05$. Control data was Arcsine square root transformed before analysis with the normal distribution and identity link. The untreated control was assigned a value of 0 for weed control; this treatment was excluded from the analyses due to zero variance. Zero value treatments were compared to all other treatments using the Pr > |t| value in the LSMEANS output. Yield data were analyzed using the normal distribution and identity link. Yield data was not collected at sites 3, 6, and 7; therefore, these sites were excluded from the analysis. Treatment means were compared using a Tukey-Kramer multiple range test with a significance of $P < 0.05$. Arcsine square root transformed data were back-transformed and the means are presented. Non-orthogonal contrasts were used to compare groups of treatments to evaluate application timing, herbicide treatment, and the addition of atrazine. An alpha level of 0.05 was used for all statistical comparisons.

3. Results and Discussion

3.1 Injury

There was no corn injury with treatments evaluated (data not shown). Results are similar to other studies that have shown no/minimal visible field or sweet corn injury with Acuron® and Acuron Flexi® (Jha, 2021; Lawson, 2017; Richburg et al., 2019; Sarangi & Jhala, 2017). Similar to this study, Metzger et al. (2019) and Langdon et al. (2020) found no or minimal injury with tolpyralate + atrazine + glyphosate and dicamba/atrazine + glyphosate applied PP or POST in corn.

3.2 Canada Fleabane Control

Acuron® applied PP at the low and high rate controlled GR Canada fleabane 99-100% at 4, 8, and 12 WAA (Table 2). Acuron Flexi® applied PP at the low rate provided 90-96% and at the high rate provided 91-97% control of the GR Canada fleabane at 4, 8, and 12 WAA (Table 2). Commonly used PP herbicides in Ontario dicamba/atrazine + glyphosate and tolpyralate + atrazine + glyphosate controlled Canada fleabane 97-99% at 4, 8, and 12 WAA (Table 2).

Acuron® applied POST at the low and high rate controlled GR Canada fleabane 92-99% and 96-99%, respectively at 4, 8, and 12 WAA (Table 2). Acuron Flexi® at the low rate provided 76-92% and at the high rate provided 75-88% control of GR Canada fleabane at 4, 8, and 12 WAA (Table 2). Commonly used POST herbicides in corn, dicamba/atrazine + glyphosate provided 84-97% and tolpyralate + atrazine + glyphosate provided 94-98% control of GR Canada fleabane at 4, 8, and 12 WAA (Table 2). Glyphosate applied POST at 900 ae ha^{-1} provided only 35-38% control of GR Canada fleabane indicating that this was a mixed population of both glyphosate-susceptible and glyphosate-resistant Canada fleabane as would be expected in commercial fields in Ontario (Table 2).

The results from this study show that Acuron® and Acuron Flexi®, applied PP and POST, can provide good to excellent residual control of GR Canada fleabane in corn. In other studies, Acuron® applied PP was predicted to provide 91, 90, and 88% control of GR Canada fleabane at 2, 5, and 9 WAT in corn, respectively (Sarangi & Jhala, 2017). Acuron® applied POST was predicted to provide 85, 87, and 86% control of GR Canada fleabane (8-10 cm tall) at 2, 5, and 9 WAT in corn, respectively (Sarangi & Jhala. 2017). Acuron® applied POST was predicted to provide only 68, 62 and 54% control when applied to 15-18 cm tall GR Canada fleabane at 2, 5, and 9 WAT, respectively (Sarangi & Jhala, 2017). Metzger et al. (2019) and Langdon et al. (2020) found up to 98% control GR Canada fleabane with tolpyralate + atrazine + glyphosate or dicamba/atrazine + glyphosate in corn which is similar to the results from this study. Brown et al. (2016) also found 99, 97, and 97% control of GR Canada fleabane with dicamba/atrazine, mesotrione + atrazine, and saflufenacil/dimethenamid-p, applied PP to corn, respectively. The efficacy of Acuron® and Acuron Flexi® for GR Canada fleabane control is similar to other studies that have shown excellent control of grass and broadleaved weeds such as crabgrass, green foxtail, carpetweed, purslane, common lambsquarters, morning glory, redroot pigweed, and velvetleaf with Acuron® and Acuron Flexi® applied PRE in sweet corn (Lawson, 2017). Jha (2021) also found 97-99% control of giant foxtail, velvetleaf, and common waterhemp with Acuron® and Acuron Flexi® applied PRE and POST in corn.

Orthogonal contrasts indicated that PP herbicides provided 10, 5, and 2% greater control of GR Canada fleabane than POST at 4, 8, and 12 WAA, respectively (Table 2). Acuron Flexi® applied PP compared to POST provided 15, 12, and 7% greater control evaluated 4, 8, and 12 WAA, respectively (Table 2). There was no significant difference between the low and high rates of Acuron® or Acuron Flexi® for GR Canada fleabane control at 4, 8 and 12 WAA (Table 2). Acuron® controlled Canada fleabane 14, 9, and 7% greater than Acuron Flexi® at 4, 8, and 12 WAA, respectively (Table 2).

3.3 Corn Yield

GR Canada fleabane interference reduced corn yield up to 42% (Table 2); there was no difference in corn yield between herbicides treatments evaluated (Table 2). Orthogonal contrasts indicated that reduced GR Canada fleabane interference with herbicides applied PP resulted in 0.9 t ha^{-1} greater corn yield than POST applied herbicide (Table 2). There was no significant difference in corn yield with Acuron® or Acuron Flexi® applied at the low or high rates (Table 2). Results are similar to other studies that have shown no seed yield reduction with Acuron® and Acuron Flexi® applied PP or POST in corn (Jha, 2021; Lawson, 2017; Richburg et al., 2019).

In conclusion, Acuron® or Acuron Flexi® applied PP or POST at rates evaluated do not injure corn and can provide adequate control of GR Canada fleabane in corn. PP herbicides provided greater control of GR Canada fleabane than POST. Acuron Flexi® applied PP provided greater control of GR Canada fleabane than POST. There was no significant difference in GR Canada fleabane control between the low rate and high rates of Acuron® and Acuron Flexi® in controlling GR Canada fleabane. In general, Acuron® controlled GR Canada fleabane slightly greater than the Acuron Flexi® and PP applications provided slightly better control than POST. Results indicate that Acuron Flexi® can be used to control GR Canada fleabane in regions where the use of atrazine is prohibited, however control is slightly lower and additional weed management tactics may be needed. Additionally, Acuron® and Acuron Flexi® herbicides with their multiple modes of action can be a desirable complement to the current weed control strategies for weed resistance management in corn production in Ontario.

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References

Beckie, H. J., & Reboud, X. (2009). Selecting for weed resistance: herbicide rotation and mixture. *Weed Technol., 23*, 363-370. https://doi.org/10.1614/WT-09-008.1

Brown, L. R., Shropshire, C., & Sikkema, P. H. (2016). Control of Glyphosate-Resistant Canada Fleabane in Corn with Preplant Herbicides. *Can. J. of Plant Sci., 96*, 932-934. https://doi.org/10.1139/cjps-2016-0049

Budd, C. M., Soltani, N., Robinson, D. E., Hooker, D. C., Miller, R. T., & Sikkema, P. H. (2016). *Improving the Consistency of Glyphosate-resistant Canada fleabane (Conyza canadensis) Control with Saflufenacil: Distribution and Control in Soybean (Glycine max)* (p. 51, M.Sc., thesis, University of Guelph, Guelph, ON).

Buhler, D. D., & Owen, M. D. (1997). Emergence and survival of horseweed (*Conyza canadensis*). *Weed Sci., 45*, 98-101. https://doi.org/10.1017/S0043174500092535

Davis, V. M., & Johnson, W. G. (2008). Glyphosate-resistant horseweed (*Conyza canadensis*) emergence, survival, and fecundity in no-till soybean. *Weed Sci., 56*, 231-236. https://doi.org/10.1614/WS-07-093.1

Jha, P. (2021). *Comparisons of One and Two-Pass Herbicide Programs for Weed Control in Corn* (Iowa State University, Ag Engineering/Agronomy, Central Iowa, and BioCentury Research Farms ISRF20-16, 30).

Langdon, N., Soltani, N., Raedar, A., Hooker, D., Robinson, D. E., & Sikkema, P. H. (2020) Tolpyralate + Atrazine Applied Preemergence Provides Residual GR Canada Fleabane [*Conyza canadensis* (L.) Cronq.] Control Similar to Current Industry Standards. *Agricultural Sciences, 11*, 417-424. https://doi.org/10.4236/as.2020.114024

Lawson, V. (2017). *Evaluation of New Sweet Corn Herbicides* (Issue 1, 2016 Farm Progress Reports, Number RFR-A1603, Iowa State University, USA). https://doi.org/10.31274/farmprogressreports-180814-1620

Loux, M., Stachler, J., Johnson, B., Nice, G., Davis, V., & Nordby, D. (2006). *Biology and Management of Horseweed*. Purdue University Extension. Retrieved from https://www.extension.purdue.edu/extmedia/gwc/gwc-9-w.pdf

Metzger, B., Soltani, N., Raeder, A., Hooker, D., Robinson, D., & Sikkema, P. H. (2019). Multiple herbicide-resistant horseweed (*Conyza canadensis*) dose response to tolpyralate and tolpyralate plus atrazine and comparison to industry standard herbicides in corn. *Weed Technology, 33*(2), 366-373. https://doi.org/10.1017/wet.2019.20

Norsworthy, J. K., Ward, S. M., Shaw, D. R., Llewellyn, R. S., Nichols, R. L., Webster, T. M., … Barrett, M. (2012). Reducing the risks of herbicide resistance: Best management practices and recommendations. *Weed Sci., 60*, 31-62. https://doi.org/10.1614/WS-D-11-00155.1

OMAFRA (Ontario Ministry of Agriculture and Food and Rural Affairs). (2021). *Area, Yield, Production and Farm Value of Specified Field Crops, Ontario, 2012-2021*.

Richburg, J. T., Norsworthy, J. K., & Barber, L. T. (2019). *Herbicide Programs with and without Atrazine in Corn*. Retrieved from https://scholarworks.uark.edu/cgi/viewcontent.cgi?article=1161&context=aaesser#page=45

Royer, F., & Dickinson, R. (1999). *Weeds of Canada and the Northern United States: A guide for identification*. University of Alberta, Canada.

Sarangi, D., & Jhala, A. J. (2017). Response of glyphosate-resistant horseweed [*Conyza canadensis* (L.) Cronq.] to a premix of atrazine, bicyclopyrone, mesotrione, and S-metolachlor. *Can. J. of Plant Sci., 97*(4), 702-714. https://doi.org/10.1139/CJPS-2016-0358

Shields, E. J., Dauer, J. T., VanGessel, M. J., & Neumann, G. (2006). Horseweed (*Conyza canadensis*) seed collected in the planetary boundary layer. *Weed Sci., 54*, 1063-1067. https://doi.org/10.1614/WS-06-097R1.1

Soltani, N., Dille, J. A., Burke, I. C., Everman, W. J., VanGessel, M. J., Davis, V. M., & Sikkema, P. H. (2016). Potential corn yield losses from weeds in North America. *Weed Technol., 30*, 979-984. https://doi.org/10.1614/WT-D-16-00046.1

Statista. (2021). *Global corn production in 2020/2021, by country*. Retrieved from https://www.statista.com/statistics/254292/global-corn-production-by-country

Syngenta. (2020). *Acuron® Label*. Retrieved from https://www.syngenta-us.com/current-label/acuron_flexi

Syngenta. (2021). *Acuron® Flexi Label*. Retrieved from https://www.syngenta-us.com/current-label/acuron_flexi

Tozzi, E., & Van Acker, R. C. (2014). Effects of seedling emergence timing on the population dynamics of horseweed (*Conyza canadensis* var. canadensis). *Weed Sci., 62*, 451-456. https://doi.org/10.1614/WS-D-13-00150.1

Weaver, S. E. (2001). The biology of Canadian weeds. 115. *Conyza canadensis*. *Can. J. Plant Sci., 81*, 867-875. https://doi.org/10.4141/P00-196