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Efficacy of Saflufenacil for Dry Bean and Annual Weed Desiccation

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Abstract

The efficacy of saflufenacil for desiccating dry bean and annual weeds may be influenced by application rate, single or sequential applications, adjuvant selection and rate, and water carrier volume. Five field experiments were conducted from 2021 to 2023 near Exeter and Ridgetown, Ontario, Canada to evaluate the efficacy of saflufenacil applied at two rates, applied once or sequentially, with four adjuvants at various rates, and three water carrier volumes for desiccating dry bean and common weed escapes in Ontario dry bean production. Saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) applied with a 200 L ha^{-1} water carrier volume desiccated dry bean 96, 100, and 100% at 5, 8, and 14 days after application (DAA), respectively; there was no improvement in dry bean desiccation by increasing the rate of Merge to 2.0 L ha^{-1} or with a sequential application. With saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}), there was no impact on dry bean desiccation with water carrier volumes of 100, 200, or 300 L ha^{-1}. Dry bean desiccation with saflufenacil (50 g ai ha^{-1}) plus the adjuvants Merge, MSO, AMS, or Merge + AMS was similar. Sequential applications of saflufenacil (25 g ai ha^{-1}) applied twice at a 1-week interval did not improve dry bean desiccation. For weed species desiccation, saflufenacil + Merge desiccated green pigweed (38-100%) and common ragweed (65-96%) most effectively. However, it was less effective on common lambsquarters (0-48%), barnyardgrass (9-24%), and green foxtail (6-14%), with no significant effect of saflufenacil rate, adjuvant selection, adjuvant rate, single vs sequential application, or water carrier volume. This study highlights the potential and limitations of saflufenacil for desiccating dry bean and common weed escapes in Ontario dry bean production.

Keywords: dry bean desiccation, dry down, herbicide efficacy, maturity, seed moisture content, weed desiccation, *Phaseolus vulgaris* L.

1. Introduction

Canada has become a leading global producer and exporter of dry bean, distributing to over 70 countries around the globe (Goodwin, 2005). In 2023, Canada exported nearly 392,000 tons of dry bean valued at $421 million, ranking it among the top five dry bean exporters in the world (IndexBox, 2024). A crucial aspect of dry bean production is ensuring seed maturity at harvest, typically identified when 80% of pods change color from green to yellow, tan, purple, or striped (Smith, 1996; Subedi et al., 2017; Wilson & Smith, 2002). However, achieving uniform maturity can be challenging due to variations within fields and the indeterminate nature of the crop. To mitigate these variations and manage weeds that can stain dry bean seed and complicate harvesting, growers often use herbicides as harvest aids (desiccants) (Baig et al., 2003; McNaughton et al., 2015a, b). These desiccants ensure uniform and rapid dry-down of bean and weeds (Subedi et al., 2017; Wilson & Smith, 2002). The selection and timing of desiccant application are critical, as they can affect crop yield and leave herbicide residues in seeds when applied incorrectly (Azlin & McWhorter, 1981; Cerkauskas et al., 1982; Smith, 1996; Subedi et al., 2017; Wilson & Smith, 2002).

In Ontario, dry bean growers have access to a limited number of registered harvest-aid herbicides, including carfentrazone-ethyl, diquat, flumioxazin, glufosinate, glyphosate, and saflufenacil (OMAFRA, 2024). Glyphosate has traditionally been the most used herbicide for desiccation due to its effectiveness and low cost (Baig et al., 2003; McNaughton et al., 2015a, b). However, concerns about glyphosate residues have led to restrictions on its use (Hensall District Co-operative, 2012), limiting options for growers. Similarly, the use of glufosinate is not allowed by some purchasers of dry beans. Further research is needed to identify herbicides or combinations that ensure uniform and rapid desiccation with effective crop and weed desiccation, minimal seed residue, and low environmental impact.

Saflufenacil is a relatively new protoporphyrinogen oxidase (PPO) inhibitor herbicide that can be used as a harvest aid for weed and dry bean desiccation (Gaultier & Gulden, 2016; Grossmann et al., 2010; Liebl et al., 2008; Soltani et al., 2010, 2013). It offers several advantages, including rapid and effective desiccation of dry bean, lower use rates compared to other desiccants, effective desiccation of some weed species, and minimal impact on dry bean seed quality and yield (Gaultier & Gulden, 2016; Grossmann et al., 2010; Liebl et al., 2008; Soltani et al., 2013). Saflufenacil promotes uniform dry bean desiccation and maturity facilitating more efficient harvesting in the autumn (McNaughton et al., 2015a, 2015b). Saflufenacil has been shown to cause as much as 87% dry bean leaf desiccation (McNaughton et al., 2015a, 2015b; Soltani et al., 2013). Additionally, saflufenacil did not adversely affect dry bean seed yield or hundred-seed weight when applied at full crop maturity (McNaughton et al., 2015a, 2015b). Saflufenacil effectively desiccates some annual broadleaf weed species, reduces potential staining of dry bean, and improves combining efficiency (Grossmann et al., 2010; Liebl et al., 2008; Silva et al., 2021). Gaultier and Gulden (2016) reported 41-73% broadleaf weed desiccation of and 41% desiccation of grass weeds with saflufenacil in dry bean. Saflufenacil can be tank-mixed with glyphosate or other herbicides or adjuvants to enhance weed desiccation (McNaughton et al., 2015a, 2015b). Saflufenacil is effective at lower application rates than some other desiccants, reducing overall chemical loading in the environment and potential environmental impact (McCoy et al., 2021; Soltani et al., 2013). Among four desiccants evaluated that are available in Ontario, saflufenacil provided the most consistent desiccation of dry bean and weeds with the least environmental impact, followed by flumioxazin, glufosinate, and diquat (Soltani et al., 2013). Proper use of saflufenacil results in minimal herbicide residues in the seeds, ensuring compliance with safety and quality standards (McNaughton et al., 2015a, 2015b).

To our knowledge, no published studies have cumulatively compared the efficacy of saflufenacil applied at two rates, single compared to sequential applications, adjuvant selection and rate, and water carrier volumes on dry bean and weed desiccation. Understanding how these variables interact will provide valuable insights into optimizing dry bean and weed desiccation. Investigating these factors can also help provide practical recommendations to enhance Ontario's dry bean production.

This study aims to evaluate the effectiveness of saflufenacil in desiccating dry bean and weed desiccation when applied at two rates, with four different adjuvants and rates, two application timings, and three water carrier volumes.

2. Materials and Methods

Five field experiments were established from 2021 to 2023 at the Huron Research Station, Exeter, Ontario, Canada, and the University of Guelph, Ridgetown Campus, Ridgetown, Ontario, Canada. Seedbed preparation included moldboard plowing in the autumn followed by two passes with a field cultivator with rolling basket harrows in the spring.

Experiments were arranged in a randomized complete block design with four replications. There was a total of thirteen treatments as listed in Tables 1-3. All plots were 3 m wide (4 dry bean rows spaced 75 cm apart) by 10 m long at Exeter and 8 m long in Ridgetown. White bean seeds ('T9905') were seeded 3-5 cm deep at a density of approximately 230,000 seeds ha^{-1} in late May to early June of each year. Herbicide applications were made with a CO_2-pressurized backpack sprayer calibrated to deliver 100/200/300 L per ha^{-1} aqueous solution at approximately 210 kPa (listed in Tables 1-3). Herbicide application (A) was applied at ~30% dry bean seed moisture content. For the sequential application of saflufenacil + Merge, the second application (B) was applied 7 days after application A (as shown in Tables 1-3). The boom was 1.5 m wide with four ultra-low drift nozzles (ULD120-02, Hypro, New Brighton, MN) spaced 50 cm apart producing a spray width of 2.0 m.

Desiccation of dry bean (leaf, stem, and pods) as well as weed desiccation, was visually estimated on a scale from 0 (no desiccation) to 100% (complete dry bean/weed desiccation compared to the non-treated control) at 5, 8, and 14 days after herbicide application (DAA).

Data were analyzed using the GLIMMIX procedure via SAS Studio v9.4 (SAS OnDemand for Academics, SAS Institute, Cary, NC). The non-treated control (for weed desiccation data) and treatments with a mean and variance of zero were excluded from analyses. Similarly, treatments with a mean of 100% and variance of zero were excluded. However, each treatment was compared to the non-treated control by independently comparing each mean to zero. Dry bean and weed desiccation data were analyzed with the distribution that met the assumptions of normality best. The fixed effect was herbicide treatment, and the random effects were environment, replication nested within environment, and the environment-by-treatment interaction. The significance of the fixed effect and random effects were tested using an F-test and Z-tests, respectively. Data was pooled across environments where environment-by-treatment interactions were non-significant. Assumptions of normality and homogeneity of variance were confirmed using plots of studentized residuals for treatment, replication, and environment. Chi-Square df and Shapiro-Wilk statistics were used to evaluate goodness-of-fit and normality, respectively. Evaluation of studentized residual boxplots identified extreme observations that significantly affected treatment means and were therefore removed. Non-orthogonal contrasts were constructed to compare single and two-pass desiccation treatments further. Data subject to transformations for analysis were back-transformed for presentation. An alpha level of 0.05 was carried through all analyses and means were separated using the Tukey-Kramer multiple range test.

3. Results and Discussion

The dominant weed species in plots evaluated included common lambsquarters (*Chenopodium album* L.), green pigweed (*Amaranthus powellii* L.), common ragweed (*Ambrosia artemisiifolia* L.), barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], and green foxtail (*Setaria viridis* L.). There was no significant interaction between environments and treatments, therefore data were pooled and averaged over environments.

3.1 Dry Bean Desiccation

Across all treatments, dry bean desiccation was consistently high, ranging from 92 to 100% (Table 1). The non-treated control plots showed 92 to 99% desiccation, indicating that natural senescence likely played a role (Table 1). Saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) desiccated dry bean at rates of 96, 100, and 100% at 5, 8, and 14 days after application (DAA), respectively (Table 1). Increasing the rate of saflufenacil to 50 g ai ha^{-1} did not improve dry bean desiccation. Increasing the rate of Merge to 2.0 L ha^{-1} did not improve dry bean desiccation. There was no effect of water carrier volume (100, 200, or 300 L ha^{-1}) on dry bean desiccation with saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}). Sequential applications of saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) applied 7 days apart did not enhance dry bean desiccation. Replacing Merge with MSO or AMS at various rates (2.5, 12.5, or 25 L ha^{-1}) yielded similar desiccation results. Adding AMS (2.5 L ha^{-1}) to saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) did not improve dry bean desiccation. These findings align with those of Sprague (2015), who reported excellent dry bean desiccation with saflufenacil (70 g ai ha^{-1}) + MSO (1.0% v/v) + AMS. In another study, saflufenacil (50 g ai ha^{-1}) + Merge (0.5% v/v) caused 87% dry bean leaf desiccation at 8 DAA (Soltani et al., 2013). Goffnett el al. (2016) also found 76-98% desiccation and no adverse effect on seed yield of various black bean cultivars with saflufenacil (50 g ai ha^{-1}) + MSO (1.0% v/v).

Table 1. Dry-bean (*Phaseolus vulgaris*) and common lambsquarters (*Chenopodium album*) desiccation with saflufenacil from five field trials conducted in Ontario, Canada in 2021, 2022 and 2023

Herbicide treatment	Rate[a]	App timing[b]	App volume	Weed desiccation (DAA)					
				Dry bean desiccation (DAA)[c]			Common lambsquarters		
				5	8	14	5	8	14
	g ai ha^{-1} + L ha^{-1}		L ha^{-1}	%					
Non-treated desiccation	-	-	-	92 ab	95 a	99 a	0 a	0 c	0c
Saflufenacil + Merge	25 + 1	A	200	96 ab	100 a	100 a	0 a	23 ab	48 ab
Saflufenacil + Merge	25 + 2	A	200	98 ab	100 a	99 a	0 a	3 abc	63 a
Saflufenacil + Merge	50 + 1	A	100	98 ab	99 a	100 a	0 a	5 abc	12 abc
Saflufenacil + Merge	50 + 1	A	200	98 ab	100 a	100 a	5 a	16 ab	55 a
Saflufenacil + Merge	50 + 1	A	300	98 ab	100 a	99 a	4 a	7 ab	30 ab
Saflufenacil + Merge	25 + 1	B	200	92 ab	95 a	99 a	0 a	0 c	0 c
Saflufenacil + Merge fb saflufenacil + Merge	25 + 1 fb 25 + 1	A fb B	200	97 ab	100 a	100 a	0 a	2 bc	44 ab
Saflufenacil + MSO	50 + 1	A	200	98 a	100 a	99 a	0 a	0 c	8 abc
Saflufenacil + AMS	50 + 2.5	A	200	96 ab	99 a	99 a	4 a	2 bc	3 bc
Saflufenacil + AMS	50 + 12.5	A	200	96 ab	99 a	99 a	0 a	0 c	0 c
Saflufenacil + AMS	50 + 25	A	200	96 ab	99 a	99 a	0 a	0 c	0 c
Saflufenacil + Merge + AMS	50 + 1 + 2.5	A	200	97 ab	99 a	99 a	0 a	30 a	68 a

Note. Abbreviations: AMS, ammonium sulfate; App, application; DAA, days after application; fb, followed by.

[a] Rate of saflufenacil presented in g ai ha^{-1} and Merge (BASF Canada Inc., Mississauga, ON, Canada), MSO™ Concentrate (Loveland Products Inc., Loveland, CO, USA) and AMS presented in L ha^{-1}.

[b] Application A was applied at 30% seed moisture content and B was applied 7 days after application A.

[c] Means followed by the same letter within a column are not significantly different according to Tukey-Kramer multiple range test (P > 0.05).

3.2 Common Lambsquarters

Saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) desiccated common lambsquarters 0, 23, and 48% at 5, 8, and 14 DAA, respectively (Table 1). Increasing the saflufenacil rate to 50 g ai ha^{-1} or increasing the Merge rate to 2.0 L ha^{-1} did not significantly improve common lambsquarters desiccation. Water carrier volume (100, 200, or 300 L ha^{-1}) did not affect common lambsquarters desiccation when saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) was used. Sequential applications of saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) applied 7 days apart did not enhance common lambsquarters desiccation. Replacing Merge with MSO or AMS at various rates generally yielded similar results. Adding AMS (2.5 L ha^{-1}) to saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) numerically improved common lambsquarters desiccation but the differences were not always statistically significant (Table 1). In other studies, saflufenacil (50 g ai ha^{-1}) + Merge (0.5% v/v) provided 25 and 41% desiccation of common lambsquarters in dry bean at 4 and 8 DAA, respectively (Soltani et al., 2013). Other reports have shown 46% desiccation of common lambsquarters 8 DAA with saflufenacil + Merge in dry bean (OMAFRA, 2017). Other desiccants, including glyphosate, diquat, glufosinate ammonium, carfentrazone-ethyl, and flumioxazin, provided as much as 25, 77, 71, 27, and 36% desiccation of common lambsquarters at 8 DAA in dry bean, respectively (Soltani et al., 2013).

3.3 Green Pigweed

At 5, 8, and 14 DAA, saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) desiccated green pigweed 38, 100, and 100%, respectively (Table 2). Increasing the saflufenacil rate to 50 g ai ha^{-1} or increasing the Merge rate to 2.0 L ha^{-1} did not significantly improve green pigweed desiccation. Water carrier volume (100, 200, or 300 L ha^{-1}) also did not affect green pigweed desiccation with saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}). Sequential applications of saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) applied 7 days apart did not enhance green pigweed desiccation. Replacing Merge with MSO yielded similar results. Adding AMS (2.5 L ha^{-1}) to saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) did not improve green pigweed desiccation. There was a trend to improved green pigweed desiccation with saflufenacil (50 g ai ha^{-1}) when the rate of AMS was increased from 2.5, to 12.5 to 25 1.0 L ha^{-1} although results were not always statistically significant. In other studies, saflufenacil (50 g ai ha^{-1}) + Merge (0.5% v/v) provided 48 and 66% desiccation of redroot pigweed in dry bean at 4 and 8 DAA, respectively (Soltani et al., 2013). Others have reported 64% desiccation of pigweed 8 DAA with saflufenacil + Merge in dry bean (OMAFRA, 2017). Other desiccants, including glyphosate, diquat, glufosinate, carfentrazone-ethyl, and flumioxazin, provided as much as 44, 78, 68, 34, and 44% desiccation of pigweed at 8 WAA in dry bean, respectively (Soltani et al., 2013).

Table 2. Green pigweed (*Amaranthus powellii*) and common ragweed (*Ambrosia artemisiifolia*) desiccation with saflufenacil from five field trials conducted in Ontario, Canada in 2021, 2022 and 2023

Herbicide treatment	Rate[a]	App timing[b]	App volume	Weed desiccation (DAA)[c]					
				Green pigweed			Common ragweed		
				5	8	14	5	8	14
	g ai ha^{-1} + L ha^{-1}		L ha^{-1}	---	---	---	%	---	---
Non-treated desiccation	-	-	-	0 c	0 c	0 b	0 d	0 c	0 c
Saflufenacil + Merge	25 + 1	A	200	38 ab	100	100	65 abc	90 a	96 ab
Saflufenacil + Merge	25 + 2	A	200	37 ab	100	100	72 a	91 a	97 ab
Saflufenacil + Merge	50 + 1	A	100	20 ab	43 ab	77 a	69 ab	91 a	97 a
Saflufenacil + Merge	50 + 1	A	200	43 a	94 a	95 a	70 ab	92 a	97 a
Saflufenacil + Merge	50 + 1	A	300	13 ab	72 ab	95 a	70 ab	92 a	97 ab
Saflufenacil + Merge	25 + 1	B	200	0 c	0 c	83 a	0 d	8 b	92 b
Saflufenacil + Merge fb saflufenacil + Merge	25 + 1 fb 25 + 1	A fb B	200	29 ab	100	100	69 ab	91 a	98 a
Saflufenacil + MSO	50 + 1	A	200	30 ab	100	100	73 a	92 a	97 a
Saflufenacil + AMS	50 + 2.5	A	200	8 b	20 b	59 a	62 bc	89 a	96 ab
Saflufenacil + AMS	50 + 12.5	A	200	10 ab	90 a	96 a	59 c	89 a	96 ab
Saflufenacil + AMS	50 + 25	A	200	10 ab	55 ab	82 a	65 abc	90 a	96 ab
Saflufenacil + Merge + AMS	50 + 1 + 2.5	A	200	36 ab	92 a	100	69 ab	91 a	97 a

Note. Abbreviations: AMS, ammonium sulfate; App, application; DAA, days after application; fb, followed by.

[a] Rate of saflufenacil presented in g ai ha^{-1} and Merge (BASF Canada Inc., Mississauga, ON, Canada), MSO™ Concentrate (Loveland Products Inc., Loveland, CO, USA) and AMS presented in L ha^{-1}.

[b] Application A was applied at 30% seed moisture content and B was applied 7 days after application A.

[c] Means followed by the same letter within a column are not significantly different according to Tukey-Kramer multiple range test (P > 0.05).

3.4 Common Ragweed

At 5, 8, and 14 DAA, saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) desiccated common ragweed 65, 90, and 96%, respectively (Table 2). Increasing the saflufenacil rate to 50 g ai ha^{-1} or increasing the Merge rate to 2.0 L ha^{-1} did not improve common ragweed desiccation. Water carrier volume (100, 200, or 300 L ha^{-1}) did not affect common ragweed desiccation when saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) was used. Sequential applications of saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) applied 7 days apart did not enhance desiccation of common ragweed. Replacing Merge with MSO or AMS at various rates generally yielded similar results at 8 and 14 DAA. Adding AMS (2.5 L ha^{-1}) to saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) did not improve common ragweed desiccation. In other studies, saflufenacil (50 g ai ha^{-1}) + Merge (0.5% v/v) provided 58 and 73% desiccation of common ragweed in dry bean at 4 and 8 DAA, respectively (Soltani et al., 2013). Others have reported 46 to 73% desiccation of common ragweed 8 DAA with saflufenacil + Merge in dry bean (OMAFRA, 2017). Other desiccants, including glyphosate, diquat, glufosinate, carfentrazone-ethyl, and flumioxazin, provided as much as 17, 80, 66, 12, and 52% desiccation of common ragweed at 8 DAA in dry bean, respectively (Soltani et al., 2013).

3.5 Barnyardgrass

At 5, 8, and 14 DAA, saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) desiccated barnyardgrass 9, 14, and 24%, respectively (Table 3). Increasing the saflufenacil rate to 50 g ai ha^{-1} or increasing the Merge rate to 2.0 L ha^{-1} did not significantly improve barnyardgrass desiccation. Increasing water carrier volume (100, 200, or 300 L ha^{-1}) did not affect barnyardgrass desiccation when saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) was used. Sequential applications of saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) applied 7 days apart did not enhance barnyardgrass desiccation. Replacing Merge with MSO or AMS at various rates yielded similar results. Adding AMS (2.5 L ha^{-1}) to saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) did not improve barnyardgrass desiccation. In other studies, Gaultier and Gulden (2016) reported 18, 65, 42, 64, 58, 41, and 55% desiccation of grasses with carfentrazone-ethyl, diquat, flumioxazin, glufosinate, glyphosate, saflufenacil, and carfentrazone-ethyl + glyphosate in dry bean, respectively.

Table 3. Barnyardgrass (*Echinochloa crus-gali*) and green foxtail (*Setaria viridis*) desiccation with saflufenacil from five field trials conducted in Ontario, Canada in 2021, 2022 and 2023

Herbicide treatment	Rate[a]	App timing[b]	App volume	Weed desiccation (DAA)[c]					
				Barnyardgrass			Green foxtail		
				5	8	14	5	8	14
	g ai ha^{-1} + L ha^{-1}		L ha^{-1}	%					
Non-treated desiccation	-	-	-	0 b	0 b	0 b	0 c	0 b	0 b
Saflufenacil + Merge	25 + 1	A	200	9 a	14 a	24 a	6 ab	7 a	14 a
Saflufenacil + Merge	25 + 2	A	200	10 a	11 a	14 a	5 ab	5 a	10 a
Saflufenacil + Merge	50 + 1	A	100	10 a	15 a	15 a	6 ab	5 a	15 a
Saflufenacil + Merge	50 + 1	A	200	10 a	19 a	18 a	7 ab	7 a	13 a
Saflufenacil + Merge	50 + 1	A	300	14 a	22 a	38 a	7 ab	7 a	14 a
Saflufenacil + Merge	25 + 1	B	200	0 b	2 b	15 a	0 c	4 b	14 a
Saflufenacil + Merge fb saflufenacil + Merge	25 + 1 fb 25 + 1	A fb B	200	9 a	17 a	32 a	7 ab	7 a	20 a
Saflufenacil + MSO	50 + 1	A	200	11 a	20 a	22 a	8 a	5 a	12 a
Saflufenacil + AMS	50 + 2.5	A	200	8 a	15 a	19 a	5 ab	5 a	13 a
Saflufenacil + AMS	50 + 12.5	A	200	8 a	14 a	17 a	5 ab	5 a	10 a
Saflufenacil + AMS	50 + 25	A	200	8 a	11 a	13 a	4 b	4 a	9 a
Saflufenacil + Merge + AMS	50 + 1 + 2.5	A	200	10 a	16 a	26 a	6 ab	6 a	15 a

Note. Abbreviations: AMS, ammonium sulfate; App, application; DAA, days after application; fb, followed by.

[a] Rate of saflufenacil presented in g ai ha^{-1} and Merge (BASF Canada Inc., Mississauga, ON, Canada), MSO™ Concentrate (Loveland Products Inc., Loveland, CO, USA) and AMS presented in L ha^{-1}.

[b] Application A was applied at 30% seed moisture content and B was applied 7 days after application A.

[c] Means followed by the same letter within a column are not significantly different according to Tukey-Kramer multiple range test ($P > 0.05$).

3.5 Green Foxtail

At 5, 8, and 14 DAA, saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) desiccated green foxtail 6, 7, and 14%, respectively (Table 3). Increasing the saflufenacil rate to 50 g ai ha^{-1} or increasing the Merge rate to 2.0 L ha^{-1} did not improve green foxtail desiccation. Water carrier volume (100, 200, or 300 L ha^{-1}) did not affect green foxtail desiccation with saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}). Sequential applications of saflufenacil (25 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) applied 7 days apart did not enhance green foxtail desiccation. Replacing Merge with MSO or AMS at various rates resulted in similar green foxtail desiccation. Adding AMS (2.5 L ha^{-1}) to saflufenacil (50 g ai ha^{-1}) + Merge (1.0 L ha^{-1}) did not improve green foxtail desiccation. In other studies, saflufenacil (50 g ai ha^{-1}) + Merge (0.5% v/v) provided 34 and 41% desiccation of green foxtail in dry bean at 4 and 8 DAA, respectively (Soltani et al., 2013). Other reports have shown 26% desiccation of foxtails 8 DAA with saflufenacil + Merge in dry bean (OMAFRA, 2017). Other desiccants, including glyphosate, diquat, glufosinate ammonium, carfentrazone-ethyl, and flumioxazin, provided as much as 58, 65, 64, 18, and 42% desiccation of green foxtail at 8 WAA in dry bean, respectively (Soltani et al., 2013).

4. Conclusions

Based on these results, saflufenacil (25 g ai ha^{-1}) combined with Merge (1.0 L ha^{-1}) effectively desiccates dry bean, reaching 99% desiccation at 14 DAA. Increasing saflufenacil rate, Merge rate, or varying water carrier volume did not enhance dry bean desiccation. Similarly, sequential applications and substitutions of Merge with MSO or AMS or adding AMS to Merge did not improve in dry bean desiccation.

For weed desiccation, saflufenacil + Merge was most effective on green pigweed and common ragweed, providing near-complete desiccation by 14 DAA. However, saflufenacil + Merge was less effective on common lambsquarters, barnyardgrass, and green foxtail. Higher saflufenacil rates, Merge rates, different water volumes, different adjuvants, or sequential applications addition generally did not improve common lambsquarters, barnyardgrass, and green foxtail desiccation.

These findings underscore the potential and limitations of using saflufenacil + Merge for dry bean and weed desiccation.

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Drs. Peter Sikkema and Nader Soltani were responsible for this manuscript's study design and writing. Christian Willemse conducted the statistical analysis of the data collected.

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