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Article

Evaluation of broadcast and spot herbicide applications for spreading dogbane (*Apocynum androsaemifolium* L.) management in lowbush blueberry fields

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Abstract

Spreading dogbane is a creeping herbaceous perennial weed in lowbush blueberry. Management is limited primarily to spot applications of dicamba, though recent herbicide registrations facilitate the evaluation of new broadcast and spot herbicide applications. The objectives of this research were to determine (1) the effect of sequential postemergence (POST) mesotrione application interval on spreading dogbane, (2) the effect of sequential POST mesotrione and foramsulfuron applications on spreading dogbane, (3) the effect of POST herbicide tank mixtures on spreading dogbane, (4) the effect of summer and fall spot herbicide applications on spreading dogbane, and (5) the effect of spot applications of dicamba tank mixtures with sulfonylurea herbicides on spreading dogbane. Broadcast mesotrione (144 g a.i. ha^{-1}) and foramsulfuron (35 g a.i. ha^{-1}) applications did not control spreading dogbane. Control was not improved by sequential applications of either herbicide. Broadcast mesotrione + foramsulfuron applications reduced non-bearing-year density and may be more effective than either herbicide applied alone. Broadcast flazasulfuron applications reduced non-bearing-year shoot density and flazasulfuron + foramsulfuron applications reduced non-bearing-year and bearing-year shoot densities. Summer spot applications of foramsulfuron and flazasulfuron caused 70% injury to spreading dogbane but did not reduce shoot density, and dicamba continues to be the most effective spot herbicide treatment. Fall spot applications did not control spreading dogbane due to early senescence of spreading dogbane shoots. Spot applications of dicamba at 0.96 or 1.92 g a.e. L $water^{-1}$ provided equivalent spreading dogbane control and efficacy was not improved by tank mixture with foramsulfuron, flazasulfuron, or nicosulfuron + rimsulfuron.

Key words: *Apocynum androsaemifolium* L., broadcast herbicide application, creeping herbaceous perennial weed, fruit crop, lowbush blueberry, spot herbicide application, spreading dogbane, *Vaccinium angustifolium* Aiton

Résumé

L'apocyn à feuilles d'androsème ou herbe à puce est une herbacée vivace traçante qui parasite les cultures de bleuet nain. On lutte principalement contre l'adventice par l'application localisée de dicamba, mais des herbicides homologués depuis peu justifient l'évaluation de nouveaux traitements, à la volée ou localisés. Les auteurs voulaient préciser les effets (1) de l'application post-levée de mésotrione à intervalles successifs, (2) de l'application post-levée séquentielle de mésotrione et de foramsulfuron, (3) de l'application post-levée d'un mélange d'herbicides, (4) de l'application localisée d'herbicides en été et à l'automne et (5) de l'application localisée d'un mélange composé de dicamba et d'herbicides à sulfonylurée sur l'adventice. L'application de mésotrione (144 g de matière active par hectare) et de foramsulfuron (35 g m.a. par ha) à la volée n'a aucun effet sur l'herbe à puce. L'application séquentielle de ces deux herbicides n'améliore pas la lutte contre l'adventice. Appliquer à la volée du mésotrione et du foramsulfuron réduit la densité des pousses l'année végétative et ce traitement pourrait s'avérer plus efficace que l'application de l'un ou l'autre herbicide séparément. L'application de flazasulfuron à la volée diminue la densité des pousses l'année végétative, alors que l'application de flazasulfuron mélangé à du foramsulfuron réduit la densité des pousses l'année végétative et l'année de production. L'application localisée de foramsulfuron et de flazasulfuron en été cause 70 % de dommages à l'herbe à puce sans réduire pour autant la densité des pousses. Le dicamba reste l'herbicide le plus efficace pour les traitements localisés. L'application localisée d'herbicide à l'automne s'avère inefficace contre l'herbe à puce, à cause de la sénescence précoce des pousses de l'adventice. Celle de 0,96 ou de 1,92 g de matière active de dicamba par litre d'eau assure une lutte équivalente contre l'herbe à puce et l'addition de foramsulfuron, de flazasulfuron ou du mélange nicosulfuron + rimsulfuron à ce traitement n'en pas l'efficacité. [Traduit par la Rédaction]

Mots-clés : *Apocynum androsaemifolium* L., application d'herbicide à la volée, adventice herbacée vivace traçante, culture fruitière, bleuet nain, application localisée d'herbicide, apocyn à feuilles d'androsème, *Vaccinium angustifolium* Ait.

Introduction

Lowbush or wild blueberry (*Vaccinium angustifolium* Ait.) is a perennial deciduous shrub native to northeastern North America (Anonymous 2019). Lowbush blueberry fields are developed from abandoned farmland or cleared forest areas (Hall 1959). Fields are managed under a 2-year production cycle in which fields are pruned by burning or mowing to remove old plant growth and encourage vegetative growth and flower bud formation during the first year (non-bearing-year) (Jensen and Yarborough 2004; Anonymous 2019). Flowering and fruit production occur in the second year (bearing-year) (McIsaac 1997; Anonymous 2019). Canadian production exceeds 90 000 tonnes with a farm gate value of $47.4 million CAD in 2017 (Anonymous 2019). Weed management is a major production challenge (McCully et al. 1991; Jensen and Yarborough 2004) with the weed flora dominated by woody and herbaceous perennial plants (Lyu et al. 2021) whose growth is encouraged by the perennial no-till monoculture created by commercial lowbush blueberry production (Jensen and Yarborough 2004).

Spreading dogbane (*Apocynum androsaemifolium* L.) is a common creeping herbaceous perennial weed in lowbush blueberry fields (Lyu et al. 2021). The frequency of lowbush blueberry fields in Nova Scotia containing spreading dogbane increased from 2% in 1984–1985 (McCully et al. 1991) to 16% in 2017–2019 (Lyu et al. 2021). Spreading dogbane also occurred in 88% of lowbush blueberry fields in the Saguenay–Lac-Saint-Jean region of Quebec (Lapointe and Rochefort 2001) and the plant is a common weed in lowbush blueberry fields in Maine, USA (D'Appollonio and Yarborough 2018; Ayers 2020). The plant reproduces and spreads by seeds and creeping roots (Boyd and Hughes 2011; Wu et al. 2013), making eradication of established plants difficult (Wu and Boyd 2012). Shoots emerging from the roots exceed 75 cm in height and shading from this weed species can reduce lowbush blueberry yield by >80% (Yarborough and Marra 1997). Spreading dogbane management is therefore a research priority for the lowbush blueberry industry (Anonymous 2020).

The management of spreading dogbane is currently limited to spot or wiper applications of glyphosate, triclopyr, or dicamba in Canada due to lack of efficacy or crop safety from previously evaluated broadcast herbicide treatments (Wu and Boyd 2012). Broadcast mesotrione applications do not reduce shoot density (Wu and Boyd 2012); however, the recent registration of sequential mesotrione applications in Maine has shown improved control (D'Appollonio and Yarborough 2018). This use pattern is not registered for use in Canada and data to support use of sequential mesotrione applications on spreading dogbane are limited. Broadcast applications of the acetolactate synthase (ALS) inhibiting herbicides nicosulfuron (25 g a.i. ha^{-1}), nicosulfuron + rimsulfuron (13 + 13 g a.i. ha^{-1}), and nicosulfuron + rimsulfuron tank-mixed with mesotrione (13 + 13 + 101 g a.i. ha^{-1}) suppressed spreading dogbane in Nova Scotia (Wu and Boyd 2012), though growers have failed to adopt these treatments due to risk of crop injury associated with broadcast nicosulfuron + rimsulfuron applications (Jensen and Specht 2004). The recently registered ALS-inhibiting herbicide foramsulfuron, however, exhibits excellent crop tolerance (White and Kumar 2017; White 2019) and provides control of both broadleaf and grass weeds in lowbush blueberry (White and Webb 2018; White and Zhang 2019). Other recently evaluated ALS-inhibiting herbicides also provide control of broadleaf weeds in lowbush blueberry (White 2021) but none of these herbicides have been evaluated as broadcast or spot herbicide applications for spreading dogbane management.

The objective of this research was to evaluate a range of broadcast and spot herbicide applications for control of spreading dogbane in lowbush blueberry fields. Specific objectives of this research were to determine (1) the effect of sequential postemergence (POST) mesotrione application interval on spreading dogbane, (2) the effect of sequential POST mesotrione and foramsulfuron applications on spreading dogbane, (3) the effect of POST herbicide tank mixtures on spreading dogbane, (4) the effect of summer and fall spot herbicide applications on spreading dogbane, and (5) the effect of spot applications of dicamba tank mixtures with sulfonylurea herbicides on spreading dogbane.

Materials and methods

Experiment 1: evaluation of sequential POST mesotrione application interval on spreading dogbane

The objective of this experiment was to determine the effect of sequential POST mesotrione (Callisto herbicide, Syngenta, Platsville, ON, Canada) application interval on spreading dogbane. The experiment was conducted in three commercial lowbush blueberry fields located in Collingwood Corner (45° 34′ 25.32″N, 63° 53′ 52.44″W) [2017 (non-bearing-year)–2018 (bearing-year)], Rawdon (45° 5′ 16.44″N, 63° 44′ 40.92″W) [2017 (non-bearing-year)–2018 (bearing-year)], and Westchester Mt. (45° 34′ 57″N, 63° 43′ 26.4″W) [2018 (non-bearing-year)–2019 (bearing-year)] and was established in spring of the non-bearing-year at each site. The experiment was arranged as a randomized complete block design with five blocks at all three sites. Plot size was 2 m × 4 m, with a 1 m buffer between each block. Treatments consisted of (*i*) non-treated control, (*ii*) mesotrione application at the early-bud stage, (*iii*) mesotrione application at the early-bud stage followed by (fb) a sequential mesotrione application at 7 days after initial treatment (DAIT), (*iv*) mesotrione application at the early-bud stage fb a sequential mesotrione application at 14 DAIT, (*v*) mesotrione application at the early-bud stage fb a sequential mesotrione application at 21 DAIT, and (*vi*) mesotrione application at the early-bud stage fb a sequential mesotrione application at 28 DAIT. Mesotrione was applied at a rate of 144 g ai ha^{-1} in 200 L ha^{-1} water with 0.2% v/v non-ionic surfactant (NIS) (Activate Plus, WinField Agrisolutions, St. Paul, MN, USA) using a CO_2 pressurized research plot sprayer equipped with four Hypro ULD120-02 Ultra Lo-Drift Tip nozzles and operated at a spray pressure of 275 kPa. Mean spreading dogbane shoot height at the first application was 45 ± 6, 55 ± 6, and 47 ± 6 cm at Collingwood Corner, Rawdon, and Westchester Mt., respectively.

Experiment 2: evaluation of sequential POST mesotrione and foramsulfuron applications on spreading dogbane

The objective of this experiment was to determine the effect of sequential POST mesotrione and foramsulfuron (Option herbicide, Bayer CropScience Inc., Calgary, AB, Canada) applications on spreading dogbane. The experiment was conducted in three commercial lowbush blueberry fields located in Parrsboro (45° 30′ 33.12″N, 63° 44′ 40.92″W) [2017 (non-bearing-year)–2018 (bearing-year)], Windham Hill (45° 37′ 30.36″N, 63° 58′ 27.84″W) [2017 (non-bearing-year)–2018 (bearing-year)], and Westchester Mt. [2018 (non-bearing-year)–2019 (bearing-year)] and was established in spring of the non-bearing-year at each site. The experiment was a 3 × 3 factorial arrangement of early herbicide application (none, mesotrione, foramsulfuron) and late herbicide application (none, mesotrione, foramsulfuron) arranged in a randomized complete block design with six blocks at each site. Plot size was 2 m × 4 m, with a 1 m buffer between each block. Early and late herbicide applications were applied at the pre-bud and bud stages, respectively. Mesotrione was applied at a rate of 144 g a.i. ha^{-1} in 200 L ha^{-1} water with 0.2% v/v NIS and foramsulfuron was applied at a rate of 35 g a.i. ha^{-1} in 200 L ha^{-1} water with 28% urea ammonium nitrate (UAN) liquid fertilizer adjuvant at a rate of 2.5 L ha^{-1}. Treatments were applied using the research plot sprayer described in Experiment 1. Mean spreading dogbane shoot height at the early application timing was 40 ± 8, 27 ± 5, and 32 ± 4 cm at Parrsboro, Windham Hill, and Westchester Mt., respectively.

Experiment 3: evaluation of POST herbicide tank mixtures on spreading dogbane

The objective of this experiment was to determine the effect of POST herbicide tank mixtures on spreading dogbane. The experiment was conducted in two commercial lowbush blueberry fields located in Westchester Mt. (Bragg field and Staple field) in 2018 (non-bearing-year) and 2019 (bearing-year) and was established in spring of the non-bearing-year at each site. The experiment was arranged as a randomized complete block design with five blocks and nine treatments. Plot size was 2 m × 4 m with a 1 m buffer between each block. Treatments consisted of (*i*) non-treated control, (*ii*) mesotrione, (*iii*) foramsulfuron, (*iv*) flazasulfuron, (*v*) mesotrione + foramsulfuron, (*vi*) mesotrione + flazasulfuron, (*vii*) foramsulfuron + flazasulfuron, (*viii*) mesotrione fb foramsulfuron, and (*ix*) mesotrione fb flazasulfuron. Foramsulfuron, flazasulfuron, and mesotrione were applied at 35, 50, and 144 g a.i. ha^{-1}, respectively. Foramsulfuron was applied in conjunction with 2.5 L ha^{-1} 28% UAN liquid fertilizer adjuvant and flazasulfuron and mesotrione were applied in conjunction with 0.2% v/v NIS. Sequential foramsulfuron and flazasulfuron applications were applied 7 days after initial mesotrione applications. Treatments were applied as described in Experiment 1. Mean spreading dogbane shoot height at application was 32 ± 5 and 36 ± 7 cm at Bragg and Staple, respectively.

Experiment 4: effect of summer and fall spot herbicide applications on spreading dogbane

The objective of this experiment was to determine the effect of summer and fall spot herbicide applications on spreading dogbane. The summer spot herbicide application experiment was conducted at Greenfield (45° 18′ 6.48″N, 63° 10′ 56.64″W), Parrsboro, and Rawdon from 2017 (non-bearing-year) to 2018 (bearing-year) and the fall spot herbicide application was conducted at Collingwood Corner, Parrsboro, and Rawdon from 2017 (non-bearing-year) to 2018 (bearing-year). Experiments were arranged in a completely randomized design with 5 replications and 10 and 12 treatments in the summer and fall spot application experiments, respectively. Plot size was 1 m × 1 m, and plots were established in various spreading dogbane patches at each site. Treatments in the summer spot application experiment included (*i*) non-treated control, (*ii*) dicamba (Banvel Herbicide, BASF, Mississauga, ON, Canada) (1.92 g a.e. L water^{-1}), (*iii*) glyphosate (Roundup Weathermax, Monsanto Canada, Winnipeg, MB, Canada) (7.24 g a.e. L water^{-1}), (*iv*) foramsulfuron (Option Herbicide, Bayer CropScience, Regina, SK, Canada) (0.18 g a.i. L water^{-1}), (*v*) tribenuron-methyl (Spartan Herbicide, DuPont, Mississauga, ON, Canada) (0.19 g a.i. L water^{-1}), (*vi*) nicosulfuron + rimsulfuron (Ultim Herbicide, DuPont, Mississauga, ON, Canada) (0.016 g a.i. L water^{-1} + 0.016 g a.i. L water^{-1}), (*vii*) clopyralid (Lontrel Herbicide, Dow AgroSciences, Calgary, AB, Canada) (0.76 g a.i. L water^{-1}), (*viii*) pyroxsulam (Simplicity Herbicide, Dow AgroSciences, Calgary, AB, Canada) (0.08 g a.i. L water^{-1}), (*ix*) flazasulfuron (Chikara Herbicide, ISK BioSciences, Concord, OH, USA) (0.25 g a.i. L water^{-1}), and (*x*) halosulfuron (Sandea Herbicide, Gowan Canada, Winnipeg, MB, Canada) (0.17 g a.i. L water^{-1}). Treatments for the fall spot application experiment included all herbicides included in the summer experiment with two additional treatments consisting of triclopyr (Garlon Herbicide, DuPont, Mississauga, ON, Canada) (6.24 g a.i. L water^{-1}) and dicamba + diflufenzopyr (Distinct Herbicide, BASF, Mississauga, ON, Canada) (0.7 g a.e. L water^{-1} + 0.3 g a.i. L water^{-1}). Dicamba, tribenuron-methyl, nicosulfuron + rimsulfuron, clopyralid, pyroxsulam, flazasulfuron, halosulfuron, triclopyr, and dicamba + diflufenzopyr were applied in conjunction with 0.2% v/v NIS. Foramsulfuron was applied in conjunction with 28% UAN liquid fertilizer adjuvant at a rate of 12.5 mL L water^{-1}. Dicamba and glyphosate were included as industry standard spot herbicide treatments for spreading dogbane (Wu and Boyd 2012).

Foramsulfuron, tribenuron-methyl, nicosulfuron + rimsulfuron, clopyralid, flazasulfuron, and triclopyr were included as they are currently registered for use in lowbush blueberry and would be readily available for use by growers if effective. Pyroxsulam, halosulfuron, and dicamba + diflufenzopyr were included as new products that may have potential for weed control in lowbush blueberries but are not currently registered for use in lowbush blueberries in Canada. Herbicides were applied when spreading dogbane was at the early-bud and post-seed stage for the summer and fall spot application treatments, respectively. Herbicides were applied with a CO_2 pressurized research plot sprayer equipped with a single AI11002-VS AI TeeJet Air Induction Flat Fan nozzle operated at a spray pressure of 275 KPa. Herbicides were applied to spreading dogbane leaves until initial runoff of herbicide solution occurred. Mean spreading dogbane shoot height at the time of herbicide applications in the summer spot application experiment was 43.7 ± 8, 37.6 ± 8, and 43.5 ± 9 cm at Greenfield, Parrsboro, and Rawdon, respectively. Mean shoot height at the time of herbicide applications in the fall spot application experiment was 36 ± 5, 48 ± 5, and 40 ± 5 cm at Collingwood Corner, Parrsboro, and Rawdon, respectively.

Experiment 5: effect of spot applications of dicamba tank mixtures with sulfonylurea herbicides on spreading dogbane

The objective of this experiment was to determine the effect of spot applications of dicamba tank mixtures with sulfonylurea herbicides on spreading dogbane. The experiment was a 3 × 4 factorial arrangement of dicamba rate (0, 0.96, and 1.92 g a.e. L water $^{-1}$) and sulfonylurea herbicide [none, foramsulfuron (0.18 g a.i. L water $^{-1}$), flazasulfuron (0.25 g a.i. L water $^{-1}$), and nicosulfuron + rimsulfuron (0.016 + 0.016 g a.i. L water $^{-1}$)] arranged as a completely randomized design with five replications and 1 m × 1 m plot size. The experiment was established at Westchester Mt. (Bragg field and Staple field) in 2018 (non-bearing-year)–2019 (bearing-year) and plots were established in various spreading dogbane patches across each site. Herbicides were applied to the experimental plots when spreading dogbane was at the early-bud stage. Herbicides were applied as described in Experiment 4. Mean spreading dogbane shoot height at application was 29 ± 4 and 35 ± 4 cm at Westchester Mt. Bragg and Staple, respectively.

Data collection

Data collection for spreading dogbane in all experiments included spreading dogbane shoot density, shoot height, and visual injury ratings of herbicide injury. Spreading dogbane shoot density in the broadcast and summer spot application experiments was determined at the time of treatment applications, in late August or early September of the non-bearing-year where possible, and in early summer of the bearing-year. Fall non-bearing-year shoot density was not possible to collect at all sites due to unexpectedly early senescence of spreading dogbane shoots at trial sites and this is indicated where required in the results and discussion. Spreading dogbane shoot density in the fall spot application experiment was determined at the time of fall herbicide applications and in early summer of the bearing-year. Spreading dogbane shoot density was determined in two 1 m^2 quadrats per plot in all broadcast experiments and on a whole-plot basis for spot application experiments. Spreading dogbane height in all broadcast experiments was determined on 30 randomly selected spreading dogbane shoots across the entire trial area. Spreading dogbane height in all spot application experiments was determined on five shoots in each treatment plot. Visual injury ratings were collected in all experiments except the fall herbicide spot application experiment at 7, 21, and 35 days after treatment (DAT). Visual injury ratings were conducted using a scale from 0 to 100, where 0 = no plant injury and 100 = complete plant death. To ensure consistency, all visual injury ratings were conducted by the same person (H. Lyu) on each evaluation.

Data collection on lowbush blueberry included stem length, floral bud number, visual injury ratings, and yield data in the broadcast herbicide experiments at sites with sufficient blueberry coverage across the experimental area. Lowbush blueberry stem length and floral bud number were determined on 30 randomly selected blueberry stems from each plot in fall of the non-bearing-year. Lowbush blueberry yield was determined in two 1 m^2 quadrats per plot using hand rakes in mid-August of the bearing-year. Lowbush blueberry stem length and floral bud number in Experiment 1 were determined on 2 October 2017 (Collingwood Corner), 22 September 2017 (Rawdon), and 12 November 2018 (Westchester Mt.). Lowbush blueberry yield was determined on 14 August 2018 at Westchester Mt. and Collingwood Corner and on 15 August 2018 at Rawdon. Lowbush blueberry stem length and floral bud number in Experiment 2 were determined on 2 October 2017 at Windham Hill and 12 November 2018 at Westchester Mt. Lowbush blueberry yield was determined on 14 August 2019 at Westchester Mt. Lowbush blueberry stem length and floral bud number in Experiment 3 were determined on 12 November 2018 at each site. Lowbush blueberry yield was determined on 14 August 2019 at each site.

Statistical analysis

SAS (version 9.4, SAS Institute, Raleigh, NC) was used for all analyses. Objective data were initially analyzed to determine presence of a site by treatment interaction and, where lacking, data were pooled across sites for final analysis. The effect of sequential mesotrione application interval in Experiment 1, the effect of herbicide treatment in Experiment 3, and the effect of herbicide spot treatment in Experiment 4 on spreading dogbane shoot density were determined with linear mixed-effects models in PROC MIXED. Herbicide treatment was modelled as a fixed effect and blocks or replications were modelled as a random effect in the analysis. The effect of early herbicide application, late herbicide application, and the early herbicide application by late herbicide application interaction on spreading dogbane shoot density in Experiment 2 was determined with linear mixed-effects models in PROC MIXED. Main and interactive effects were modelled as fixed effects and blocks were modelled as a random effect in the analysis. Similarly, the effect of dicamba application rate, sulfonylurea herbicide, and the dicamba application rate by sulfonylurea herbicide interaction on spreading dogbane shoot density in Experiment 5 was determined with linear mixed-effects models in PROC MIXED. Main and interactive effects were modelled as fixed effects and replication was modelled as a random effect in the analysis. Main and interactive effects in all analyses were considered significant at $\alpha = 0.05$. Least-squares means were generated using the LS MEANS statement in SAS and mean separation, where necessary, was conducted using Tukey's HSD multiple means comparison test with significance set at $\alpha = 0.05$.

Analysis of variance (ANOVA) assumptions were evaluated with PROC UNIVARIATE. Differing data transformations (i.e., square root, common log) were used when needed to meet the normality and constant variance assumptions, and transformations used are indicated in results tables. Subjective data (e.g., damage ratings) were analyzed using non-parametric analysis in PROC NPAR-1-WAY, and treatment effects were determined using the Kruskal–Wallis test.

Results and discussion

Experiment 1: evaluation of sequential POST mesotrione application interval on spreading dogbane

A site by mesotrione application interval interaction on non-bearing-year spreading dogbane shoot density was not able to be assessed in this experiment as non-bearing-year spreading dogbane shoot density could only be obtained at Westchester Mt. due to early shoot senescence in all treatments at Collingwood Corner and Rawdon. It was confirmed that field owners did not apply herbicides to the plots and we are therefore uncertain what caused unexpectedly early shoot senescence at these sites. Initial spreading dogbane shoot density did not vary across treatments at Collingwood Corner or Rawdon ($P \geq 0.06$), though initial density did vary across treatments at the Westchester Mt. site ($P = 0.01$) where initial density was lower in the non-treated control and the mesotrione fb mesotrione at 14 DAIT treatments (Table 1).

Sequential mesotrione application interval had a significant effect on spreading dogbane visual injury at each site ($P \leq 0.01$) (Table 1). Sequential mesotrione applications caused higher visual injury than single mesotrione applications at each site, though injury was >80% in sequential treatments at Rawdon only (Table 1). There was, however, no significant mesotrione application interval effect on non-bearing-year spreading dogbane density at Westchester Mt. ($P = 0.24$) where mean density was 10 ± 1 stems m^{-2} at the end of the non-bearing-year. Three sequential non-bearing-year applications of 70 or 105 g mesotrione ha^{-1} similarly failed to completely control spreading dogbane in Maine and regrowth occurred from injured stems by the end of the treatment year (D'Appollonio and Yarborough 2018). Mesotrione therefore appears to cause visual injury to spreading dogbane but does not reduce shoot density, regardless of the number of applications.

There was no site by sequential mesotrione application interval interaction on bearing-year spreading dogbane shoot density ($P = 0.48$) and data were therefore pooled across sites for analysis. There was no sequential mesotrione application interval effect on bearing-year spreading dogbane density in the pooled data set ($P = 0.37$) and mean density was 10 ± 1 stems m^{-2}. These results further suggest that single and sequential mesotrione applications cause visual injury to spreading dogbane but do not reduce non-bearing or bearing-year shoot density and this herbicide is ineffective on spreading dogbane.

Sequential mesotrione applications caused <5% visual injury to lowbush blueberry (data not shown). This is similar to Farooq et al. (2019) and further confirms lowbush blueberry tolerance to sequential mesotrione applications. There was no site by sequential mesotrione application interval interaction effect on lowbush blueberry stem length ($P = 0.50$), lowbush blueberry flower bud number per stem ($P = 0.69$), or yield ($P = 0.98$), and data were therefore pooled across sites for analysis. There was no sequential mesotrione application interval effect on lowbush blueberry stem length ($P = 0.85$), lowbush blueberry flower bud number per stem ($P = 0.28$), or yield ($P = 0.32$) in the pooled data set, which is not surprising given the lack of spreading dogbane control in the treatments. Mean lowbush blueberry stem length, lowbush blueberry flower bud number per stem, and yield were 21 ± 1 cm, 3.3 ± 0.2 buds $stem^{-1}$, and 941 ± 117 kg ha^{-1}, respectively. Yarborough and Marra (1997) indicated that lowbush blueberry yield decreased from approximately 5000 to 1000 kg ha^{-1} when percent spreading dogbane cover increased from 0% to 100%, respectively, suggesting that uncontrolled spreading dogbane likely reduced yields at the sites used for this experiment.

Experiment 2: evaluation of sequential POST mesotrione and foramsulfuron applications on spreading dogbane

There was a site effect on final non-bearing-year and bearing-year spreading dogbane shoot densities ($P < 0.01$) but no effect of early herbicide application ($P \geq 0.29$), late herbicide application ($P \geq 0.14$), or the site by early herbicide application by late herbicide application interaction ($P \geq 0.19$) on final non-bearing-year and bearing-year spreading dogbane shoot densities. Visual injury rating and shoot density data were therefore pooled across sites for analysis.

Mean spreading dogbane shoot density at the time of initial herbicide applications was 14 ± 1 shoots m^{-2} across sites. There was a significant herbicide treatment effect on spreading dogbane visual injury ratings ($P < 0.01$) in the pooled data set but there was no effect of early herbicide application ($P \geq 0.24$), late herbicide application ($P \geq 0.18$), or the early herbicide application by late herbicide application interaction ($P \geq 0.19$) on final non-bearing-year and bearing-year densities in the pooled data sets. All treatments caused ≤63% visual injury to spreading dogbane and did not reduce density (data not shown), once again indicating that single and sequential mesotrione applications do not control spreading dogbane. Results also indicate that single and sequential foramsulfuron, mesotrione fb foramsulfuron, and foramsulfuron fb mesotrione applications are also ineffective on spreading dogbane. Foramsulfuron is therefore not as effec-

Table 1. Effect of sequential mesotrione application interval on spreading dogbane visual injury ratings at lowbush blueberry fields located near Collingwood Corner, Rawdon, and Westchester Mt., Nova Scotia, Canada.

Site	Treatment	Shoot density at initial application (shoots m^{-2})[a]	Visual injury ratings (%)[b]		
			7 DAT	21 DAT	35 DAT
Collingwood Corner	Non-treated control	2.6 ± 0.2a (14)	0	0	0
	Mesotrione[c]	2.8 ± 0.2a (16)	14 ± 2	26 ± 2	25 ± 5
	Mesotrione fb mesotrione (7 DAIT)	2.8 ± 0.2a (16)	13 ± 3	52 ± 5	56 ± 8
	Mesotrione fb mesotrione (14 DAIT)	2.8 ± 0.2a (18)	12 ± 3	61 ± 3	67 ± 5
	Mesotrione fb mesotrione (21DAIT)	2.6 ± 0.2a (14)	16 ± 4	31 ± 6	48 ± 9
	Mesotrione fb mesotrione (28 DAIT)	2.3 ± 0.2a (10)	16 ± 2	32 ± 3	28 ± 5
	P value[d]	0.12	<0.01	<0.01	<0.01
Rawdon	Non-treated control	8.2 ± 2a	0	0	0
	Mesotrione	7.3 ± 1a	25 ± 3	30 ± 4	31 ± 2
	Mesotrione fb mesotrione (7 DAIT)	10.1 ± 3a	29 ± 2	62 ± 5	90 ± 3
	Mesotrione fb mesotrione (14 DAIT)	5.2 ± 1a	29 ± 1	50 ± 4	88 ± 6
	Mesotrione fb mesotrione (21DAIT)	11.6 ± 1a	28 ± 4	34 ± 2	85 ± 4
	Mesotrione fb mesotrione (28 DAIT)	10.1 ± 1a	28 ± 3	30 ± 3	46 ± 13
	P value	0.06	<0.01	<0.01	<0.01
Westchester Mt.	Non-treated control	12.2 ± 4b	0	0	0
	Mesotrione	21.3 ± 5ab	20 ± 0	24 ± 2	25 ± 3
	Mesotrione fb mesotrione (7 DAIT)	31.9 ± 6a	20 ± 0	65 ± 6	71 ± 3
	Mesotrione fb mesotrione (14 DAIT)	17.3 ± 5b	20 ± 0	47 ± 5	51 ± 4
	Mesotrione fb mesotrione (21DAIT)	23.1 ± 3ab	20 ± 0	26 ± 2	48 ± 3
	Mesotrione fb mesotrione (28 DAIT)	21.7 ± 3ab	20 ± 0	24 ± 2	52 ± 7
	P value	0.01	<0.01	<0.01	<0.01

Note: Mean density at initial application within columns followed by different letters is significantly different at $P < 0.05$ according to the Tukey honestly significant difference multiple means comparison test. Values represent the mean ± 1 standard error (SE). DAT, days after treatment; fb, followed by; DAIT, days after initial treatment.

[a]Density data at Collingwood Corner were LOG(Y + 1) transformed before analysis to meet the assumptions of the ANOVA analysis. Transformed means are presented for means comparisons and variance estimates, and back-transformed means are presented in parentheses.

[b]Visual injury ratings were estimated on a 0–100 scale, where 0 is no plant death and 100 is complete plant death. Values represent the mean ± 1 SE.

[c]Mesotrione was applied at a rate of 144 g a.i. ha^{-1} in conjunction with 0.2% non-ionic surfactant.

[d]*P* value for spreading dogbane shoot density obtained from an ANOVA conducted using PROC MIXED in SAS and *P* value obtained for visual injury ratings obtained from a Kruskal–Wallis test conducted in PROC NPAR-1-WAY in SAS.

tive on spreading dogbane as nicosulfuron + rimsulfuron (Wu and Boyd 2012) and additional research will be required to identify effective broadcast treatments that exhibit acceptable crop tolerance.

Lowbush blueberry injury from herbicide treatments was <5% across sites. Lowbush blueberry stem length, floral bud number, and yield data were not available at the Parrsboro site due to limited blueberry coverage in the plots. There was a site effect on lowbush blueberry stem length and flower bud number per stem ($P < 0.01$) but no effect of early herbicide application ($P \geq 0.21$), late herbicide application ($P \geq 0.53$), or the site by early herbicide application by late herbicide application interaction ($P \geq 0.12$) on lowbush blueberry stem length and flower bud number per stem. These data were therefore pooled across sites for analysis. There was a significant effect of late herbicide application ($P = 0.02$) but no effect of early herbicide application ($P = 0.18$) or the early herbicide application by late herbicide application interaction ($P = 0.79$) on lowbush blueberry stem length and no effect of early herbicide application ($P = 0.39$), late herbicide application ($P = 0.53$), or the subsequent interaction ($P = 0.51$) on lowbush blueberry flower bud number per stem, which is not surprising given lack of spreading dogbane control in the plots. Mean blueberry stem length and flower bud number per stem were 20 ± 1 cm and 3.6 ± 0.2 buds $stem^{-1}$, respectively. Yield data were only obtained at Westchester Mt., but data were not able to be made to conform to the assumptions of the ANOVA after data transformation due to low yield and 0 values in many plots. Mean blueberry yield at Westchester Mt. was 644 ± 86 kg ha^{-1}, which again is quite low relative to other reports of lowbush blueberry yield when weeds are controlled (White 2019), further indicating that spreading dogbane reduces yields.

Experiment 3: evaluation of POST herbicide tank mixtures on spreading dogbane

There was a significant effect of treatment ($P < 0.01$) but no effect of site ($P = 0.10$) or the site by treatment interaction ($P = 0.64$) on non-bearing-year spreading dogbane shoot density. There was a significant effect of site ($P < 0.01$) and treatment ($P < 0.01$), but again no significant site by treatment interaction effect ($P = 0.14$) on bearing-year shoot density. Non-bearing-year and bearing-year shoot densities and

Table 2. Effect of herbicide tank mixture and sequential applications on spreading dogbane and lowbush blueberry visual injury ratings, non-bearing-year and bearing-year spreading dogbane shoot densities, and non-bearing-year lowbush blueberry stem length at two lowbush blueberry fields located near Westchester Mt., Nova Scotia, Canada.

	Spreading dogbane visual injury ratings (%)[a]			Spreading dogbane shoot density (shoots m^{-2})		Lowbush blueberry visual injury ratings (%)			
Treatment	7 DAT	21 DAT	35 DAT	Non-bearing-year	Bearing-year	7 DAT	21 DAT	35 DAT	Lowbush blueberry stem length (cm)
Non-treated control	0	0	0	14 ± 1a	14 ± 1a	0	0	0	18 ± 1a
Mesotrione	18 ± 2	37 ± 5	45 ± 5	11 ± 1abc	11 ± 1abc	5 ± 0	5 ± 0	6 ± 1	18 ± 1a
Foramsulfuron	12 ± 1	37 ± 5	55 ± 4	10 ± 1abc	12 ± 1abc	5 ± 0	6 ± 1	6 ± 1	18 ± 1a
Flazasulfuron	16 ± 2	63 ± 3	74 ± 4	9 ± 1bc	13 ± 1ab	8 ± 1	11 ± 1	7 ± 1	13 ± 1b
Mesotrione + foramsulfuron	15 ± 2	42 ± 5	49 ± 4	9 ± 1bc	11 ± 1abc	6 ± 1	5 ± 0	5 ± 0	18 ± 1a
Mesotrione + flazasulfuron	15 ± 2	56 ± 4	74 ± 2	11 ± 1ab	11 ± 1abc	7 ± 1	10 ± 1	7 ± 1	14 ± 1b
Foramsulfuron + flazasulfuron	19 ± 2	75 ± 3	85 ± 3	7 ± 1c	8 ± 1c	7 ± 1	16 ± 2	7 ± 1	13 ± 1b
Mesotrione fb foramsulfuron	19 ± 2	41 ± 5	58 ± 3	8 ± 1bc	9 ± 1bc	5 ± 0	5 ± 0	5 ± 0	18 ± 1a
Mesotrione fb flazasulfuron	21 ± 1	65 ± 2	79 ± 2	9 ± 1bc	11 ± 1abc	6 ± 1	15 ± 1	8 ± 1	14 ± 1b
P value[b]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Note: Mean non-bearing-year and bearing-year spreading dogbane shoot densities and lowbush blueberry stem length within columns followed by different letters are significantly different at $P < 0.05$ according to the Tukey honestly significant difference multiple means comparison test. Values represent the mean ± 1 SE. DAT, days after treatment; fb, followed by.

[a]Visual injury ratings were estimated on a 0–100 scale, where 0 is no plant death and 100 is complete plant death. Values represent the mean ± 1 SE.

[b]*P* value for spreading dogbane shoot density and lowbush blueberry stem length obtained from an ANOVA conducted using PROC MIXED in SAS and *P* value obtained for visual injury ratings obtained from a Kruskal–Wallis test conducted in PROC NPAR-1-WAY in SAS.

visual injury ratings were therefore pooled across sites for analysis.

Mean spreading dogbane shoot density at the time of initial herbicide applications was 11 ± 1 shoots m^{-2} across sites. There was a significant herbicide treatment effect on visual injury ratings ($P < 0.01$) on all rating dates (Table 2) and a significant treatment effect on both final non-bearing-year ($P < 0.01$) and bearing-year ($P < 0.01$) spreading dogbane shoot density. Mesotrione and foramsulfuron applications alone caused 18%–45% and 12%–55% visual injury, respectively, but once again did not reduce spreading dogbane shoot density (Table 2). Flazasulfuron, however, caused 16%–74% visual injury and significantly reduced non-bearing-year shoot density relative to the non-treated control (Table 2). Bearing-year density, however, was not reduced. Flazasulfuron seems more effective on spreading dogbane than mesotrione and foramsulfuron. Flazasulfuron was also more effective on narrow-leaved goldenrod (*Euthamia graminifolia* (L.) Nutt.) than mesotrione and foramsulfuron (White 2021), suggesting that this herbicide may be useful for broadleaf weed management in lowbush blueberries. The mesotrione tank mixture with foramsulfuron caused <50% visual injury but reduced non-bearing-year shoot density (Table 2). Bearing-year density, however, was not reduced, indicating that this tank mixture provides single season spreading dogbane suppression. The mesotrione tank mixture with flazasulfuron caused 15%–74% visual injury but did not reduce shoot density relative to the non-treated control (Table 2). The tank mixture of foramsulfuron and flazasulfuron, however, caused 85% visual injury by 35 DAT and reduced both non-bearing-year and bearing-year shoot densities (Table 2). This herbicide tank mixture should therefore be considered for future research as a potential broadcast or spot herbicide application for spreading dogbane. Mesotrione fb foramsulfuron reduced both non-bearing-year and bearing-year densities in this experiment (Table 2) despite being ineffective on spreading dogbane in Experiment 2. Mesotrione fb flazasulfuron caused 79% visual injury by 35 DAT and reduced non-bearing but not bearing-year density (Table 2). Reasons for variable efficacy of mesotrione fb foramsulfuron across experiments are not clear, but Wu and Boyd (2012) also noted variation in herbicide efficacy on spreading dogbane across sites and years. The related species hemp dogbane (*Apocynum cannabinum*) exhibits a similar variable response to herbicides across sites and years (Schultz and Burnside 1979; Ransom and Kells 1998) that may be due to genetic and morphological variation across populations (Ransom et al. 1998*a*, 1998*b*). Future research to assess similar variation in spreading dogbane populations in lowbush blueberry fields is warranted.

There was no significant site by treatment interaction effect on lowbush blueberry stem length ($P = 0.66$), flower bud number per stem ($P = 0.16$), or yield ($P = 0.58$), so data were pooled across sites for further analysis. There was a significant herbicide treatment effect on lowbush blueberry visual injury ratings ($P < 0.01$) and stem length ($P < 0.01$) but not flower bud number per stem ($P = 0.36$) or yield ($P = 0.05$). No treatments affected lowbush blueberry flower bud number per stem (mean of 4 ± 0.1 buds $stem^{-1}$) or yield (mean of

Table 3. Effect of non-bearing-year herbicide spot treatments on spreading dogbane visual injury ratings and bearing-year shoot density at lowbush blueberry fields located near Greenfield, Parrsboro, and Rawdon, Nova Scotia, Canada.

Treatment	Visual injury ratings (%)[a]			Bearing-year shoot density (shoots m^{-2})[b]
	7 DAT	21 DAT	35 DAT	
Non-treated control	0	0	0	3.2 ± 2 a (10)
Dicamba	50 ± 8	100	100	1.9 ± 2 b (3)
Glyphosate	75 ± 6	100	100	2.4 ± 2 ab (5)
Foramsulfuron	19 ± 3	58 ± 8	70 ± 9	2.7 ± 2 ab (7)
Tribenuron-methyl	11 ± 1	27 ± 5	25 ± 7	2.8 ± 2 ab (7)
Nicosulfuron + rimsulfuron	10 ± 2	17 ± 2	21 ± 4	3 ± 2 a (8)
Clopyralid	6 ± 2	7 ± 1	11 ± 3	2.9 ± 2 a (8)
Pyroxsulam	11 ± 2	26 ± 5	25 ± 7	2.9 ± 2 a (8)
Flazasulfuron	17 ± 3	66 ± 10	70 ± 10	3.1 ± 2 a (9)
Halosulfuron	12 ± 2	15 ± 2	17 ± 3	3.1 ± 2 a (9)
P value[c]	<0.01	<0.01	<0.01	<0.01

Note: Mean bearing-year density within columns with different letters is significantly different at $P < 0.05$ according to the Tukey honestly significant difference multiple means comparison test. Values represent the mean ± 1 SE.

[a]Visual injury ratings were estimated on a 0–100 scale, where 0 is no plant death and 100 is complete plant death. Values represent the mean ± 1 SE. DAT, days after treatment.

[b]Bearing-year density data were SQRT (Y + 1) transformed so data would conform to the assumptions of the variance analysis. Transformed data are provided for means comparisons and variance estimates and geometric means determined using PROC MEANS in SAS are provided in parentheses.

[c]*P* value for spreading dogbane shoot density obtained from an ANOVA conducted using PROC MIXED in SAS and *P* value obtained for visual injury ratings obtained from a Kruskal–Wallis test conducted in PROC NPAR-1-WAY in SAS.

1722 ± 119 kg ha^{-1}). Flazasulfuron-based treatments, however, caused the highest visual injury and reduced lowbush blueberry stem length (Table 2). Lowbush blueberry injury also occurred following broadcast flazasulfuron applications to narrow-leaved goldenrod (White 2021), indicating that this herbicide may need to be used as a spot application for spreading dogbane management to avoid crop injury.

Experiment 4: effect of summer and fall spot herbicide applications on spreading dogbane

Summer spot herbicide applications on spreading dogbane: Final non-bearing-year shoot density was not determined in this experiment as shoots in many plots (including the non-treated control) were necrotic when data collection was attempted. It was confirmed that field owners did not apply herbicides to the plots and we are therefore unclear what caused unexpectedly early shoot senescence at these sites. There was a significant site ($P < 0.01$) and herbicide treatment ($P < 0.01$) effect on bearing-year shoot density, but there was no site by treatment interaction effect on bearing-year shoot density ($P = 0.14$). Bearing-year shoot density and visual injury ratings were therefore pooled across sites for analysis.

Mean spreading dogbane shoot density at the time of non-bearing-year herbicide applications was 15 ± 1 shoots m^{-2} across sites. There was a significant herbicide treatment effect on visual injury ratings ($P < 0.01$) on all rating dates and a significant herbicide treatment effect on bearing-year density in the pooled data set ($P < 0.01$). Dicamba and glyphosate generally caused the highest visual injury to spreading dogbane though dicamba was the only treatment that reduced bearing-year shoot density (Table 3). Foramsulfuron and flazasulfuron also caused 70% visual injury to spreading dogbane by 35 DAT but did not reduce bearing-year density (Table 3). Results confirm dicamba efficacy reported by Wu and Boyd (2012) but also indicate that the newly registered herbicides foramsulfuron and flazasulfuron may not be effective spot herbicide treatments for this weed when applied alone. Future emphasis should consider spot applications of foramsulfuron + flazasulfuron based on results of the broadcast tank mix trial (Table 2) or focus on safe and effective use of dicamba for spreading dogbane control through use of carefully directed spot applications or as a wiper application. None of the other herbicides evaluated caused high levels of injury or reduced spreading dogbane shoot density (Table 3).

Fall spot herbicide applications on spreading dogbane: Spreading dogbane shoot density at the time of herbicide applications did not vary across treatments ($P \geq 0.31$) and mean shoot density at the time of herbicide applications was 9 ± 1, 24 ± 1, and 21 ± 2 shoots m^{-2} at Collingwood, Parrsboro, and Rawdon, respectively. There was, however, no significant herbicide treatment effect on spreading dogbane shoot density in the year after application at any site ($P \geq 0.15$) as no herbicides evaluated reduced density in the year after application (data not shown). Dicamba provided good control of spreading dogbane in the summer spot applications, so lack of efficacy in fall applications was unexpected as fall dicamba applications provide effective control of other perennial weeds (Wilson and Michiels 2003). Broadcast dicamba applications in mid-September also gave >80% control of spreading dogbane in lowbush blueberry fields (Wu 2010), and Wu (2010) reported high leaf retention on spreading dogbane shoots at this application timing. Fall spot applications in our experiment were also conducted in mid-September, though we observed leaf chlorosis and leaf loss on spreading dogbane shoots at the time of herbicide applications. Whaley and VanGessel (2002) reported that leaf chlorosis can reduce fall herbicide efficacy, and this likely contributed to the lack of

Table 4. Effect of non-bearing-year dicamba and sulfonylurea herbicide tank mixture spot applications on spreading dogbane visual injury and final non-bearing-year shoot density at two lowbush blueberry fields located near Westchester, Nova Scotia, Canada.

Dicamba (g a.e. L water^{-1})	Sulfonylurea herbicide	Visual injury ratings[a]			Non-bearing-year shoot density (shoots m^{-2})[b]
		7 DAT	21 DAT	35 DAT	
0	None	0	0	0	3.1 ± 0.2ab (9)
0	Foramsulfuron	8 ± 2	40 ± 11	58 ± 13	2.5 ± 0.2abc (6)
0	Flazasulfuron	17 ± 2	93 ± 4	97 ± 3	2.3 ± 0.2abcd (5)
0	Nicosulfuron + rimsulfuron	13 ± 2	33 ± 10	45 ± 10	3.2 ± 0.2a (10)
0.96	None	14 ± 1	72 ± 12	98 ± 3	2 ± 0.2cde (4)
0.96	Foramsulfuron	20 ± 2	100	94 ± 7	1.4 ± 0.2de (2)
0.96	Flazasulfuron	21 ± 1	100	100	1.4 ± 0.2de (1)
0.96	Nicosulfuron + rimsulfuron	16 ± 2	81 ± 12	80 ± 11	2.2 ± 0.2bcde (4)
1.92	None	17 ± 2	87 ± 10	93 ± 6	1.9 ± 0.2cde (3)
1.92	Foramsulfuron	19 ± 2	92 ± 8	100	1.3 ± 0.2e (1)
1.92	Flazasulfuron	21 ± 2	100	100	1.6 ± 0.2cde (2)
1.92	Nicosulfuron + rimsulfuron	17 ± 2	93 ± 6	98 ± 3	1.8 ± 0.2cde (3)
P value[c]		<0.01	<0.01	<0.01	<0.01

Note: Mean non-bearing-year shoot density within columns followed by different letters is significantly different at $P < 0.05$ according to the Tukey honestly significant difference multiple means comparison test. Values represent the mean ± 1 SE.
[a]Visual injury ratings were estimated on a 0–100 scale, where 0 is no plant death and 100 is complete plant death. Values represent the mean ± 1 SE. DAT, days after treatment.
[b]Non-bearing-year shoot density data were SQRT(Y + 1) transformed prior to analysis to help data conform to the assumptions of the variance analysis. Transformed data are provided for means comparisons and variance estimates and geometric means determined using PROC MEANS in SAS are provided in parentheses.
[c]*P* value for spreading dogbane shoot density obtained from an ANOVA conducted using PROC MIXED in SAS and *P* value obtained for visual injury ratings obtained from a Kruskal–Wallis test conducted in PROC NPAR-1-WAY in SAS.

efficacy of treatments in our experiment as well. The utilization of a fall application timing for spreading dogbane will therefore require careful observation of spreading dogbane patches within individual fields as senescence of this weed in fall may be variable across sites and onset of senescence will likely reduce herbicide efficacy.

Experiment 5: effect of spot applications of dicamba tank mixtures with sulfonylurea herbicides on spreading dogbane

There was a significant effect of site ($P < 0.01$), dicamba ($P < 0.01$), and sulfonylurea herbicide ($P < 0.01$) on final non-bearing-year spreading dogbane shoot density and a significant effect of site ($P < 0.01$) and dicamba ($P < 0.01$) but not sulfonylurea herbicide ($P = 0.29$) on bearing-year shoot density. There was, however, no interaction between site and dicamba ($P \geq 0.77$), site and sulfonylurea herbicide ($P \geq 0.08$), and no significant site by dicamba by sulfonylurea herbicide interaction ($P \geq 0.22$) on final non-bearing-year or bearing-year shoot density. Visual injury ratings and shoot density data were therefore pooled across sites for analysis.

Mean spreading dogbane shoot density at the time of non-bearing-year herbicide applications was 12 ± 1 shoots m^{-2} across sites. There was a significant effect of dicamba ($P < 0.01$) and sulfonylurea herbicide ($P < 0.01$), but no interaction effect ($P = 0.67$) on final non-bearing-year shoot density but only a significant dicamba effect ($P < 0.01$) on bearing-year shoot density. Bearing-year shoot density data were therefore pooled across dicamba treatments for analysis and there was a significant dicamba effect ($P < 0.01$) on bearing-year shoot density in the pooled data set. Flazasulfuron caused higher visual injury than foramsulfuron or nicosulfuron + rimsulfuron but none of the sulfonylurea herbicides applied alone reduced non-bearing-year shoot density (Table 4). Dicamba applications of 0.96 g a.e. L water^{-1} caused 98% visual injury by 35 DAT and reduced both non-bearing-year and bearing-year shoot densities relative to the non-treated control (Tables 4 and 5). Dicamba applications of 0.96 g a.e. L water^{-1} in tank mixture with foramsulfuron, flazasulfuron, and nicosulfuron + rimsulfuron caused similar levels of visual injury as dicamba alone and did not provide additional reductions in non-bearing-year shoot density (Table 4), suggesting limited value in tank mixing this dicamba application rate with sulfonylurea herbicides.

Table 5. Effect of non-bearing-year dicamba spot applications on spreading dogbane bearing-year shoot density at two lowbush blueberry fields located near Westchester, Nova Scotia, Canada.

Dicamba (g a.e. L water^{-1})	Bearing-year shoot density (shoots m^{-2})
0	7 ± 1a
0.96	4 ± 1b
1.92	3 ± 1b
P value[a]	<0.01

Note: Means within columns followed by different letters are significantly different at $P < 0.05$ according to the Tukey honestly significant difference multiple means comparison test. Values represent the mean ± 1 SE.
[a]*P* value for spreading dogbane shoot density obtained from an ANOVA conducted using PROC MIXED in SAS.

Dicamba applications of 1.92 g a.e. L water^{-1} caused 93% visual injury by 35 DAT and gave similar reductions in nonbearing-year and bearing-year shoot densities as 0.96 g a.e. L water^{-1} (Tables 4 and 5), suggesting that growers may be able to use the lower application rate to control spreading dogbane. Dicamba applications of 1.92 g a.e. L water^{-1} in tank mixture with foramsulfuron, flazasulfuron, and nicosulfuron + rimsulfuron once again caused similar levels of visual injury as dicamba alone and did not provide additional reductions in shoot density (Table 4). Tank mixtures of dicamba with nicosulfuron improved hemp dogbane control due to increased herbicide translocation from the tank mixture relative to each herbicide applied alone (Kalnay and Glen 2000). Similar responses in spreading dogbane, however, do not appear to occur. Results therefore suggest that growers can use 0.96 g a.e. L water^{-1} of dicamba when spot treating spreading dogbane and that tank mixtures with sulfonylurea herbicides do not improve control.

In conclusion, broadcast mesotrione and foramsulfuron applications did not control spreading dogbane and control was generally not improved by sequential applications of either herbicide. Broadcast tank mixtures of mesotrione + foramsulfuron, mesotrione + flazasulfuron, or foramsulfuron + flazasulfuron, however, may improve control and should be explored further. Dicamba continues to be the most effective herbicide spot treatment for spreading dogbane, though spot applications of foramsulfuron and flazasulfuron caused up to 70% injury to spreading dogbane and could be explored further as potential spot treatments. Fall spot herbicide applications did not control spreading dogbane due to early senescence of spreading dogbane shoots at trial sites. Spot applications of dicamba at 0.96 or 1.92 g a.e. L water^{-1} provided equivalent control of spreading dogbane and control was not improved when these application rates were applied in tank mixture with foramsulfuron, flazasulfuron, or nicosulfuron + rimsulfuron. Growers can therefore consider use of a lower dicamba rate than currently recommended and should not use dicamba tank mixtures with sulfonylurea herbicides when spot treating spreading dogbane in lowbush blueberry fields.

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Author contributions

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Competing interests

The authors declare there are no competing interests.

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