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Susceptibility of American burnweed (*Erechtites hieraciifolius*) to herbicides and clipping in wild blueberry (*Vaccinium angustifolium* Ait.)

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Short Title: White and Webb – Burnweed susceptibility to herbicides and clipping

ABSTRACT

American burnweed is an increasingly common annual weed in wild blueberry fields in Atlantic Canada. Knowledge of susceptibility to several common herbicides used in wild blueberry, however, is lacking, and it is unclear how burnweed responds to clipping. Using greenhouse-grown plants, the objectives of this research were to evaluate burnweed susceptibility to various herbicides registered in wild blueberry and to determine the effect of clipping on burnweed lateral branch and flower production. Postemergence broadcast applications of mesotrione, flumioxazin, glufosinate, clopyralid, foramsulfuron, glyphosate, tribenuron methyl, nicosulfuron/rimsulfuron, terbacil, and hexazinone provided >90% control of burnweed. Postemergence spot applications of clopyralid, glyphosate, mesotrione, and nicosulfuron/rimsulfuron to 24 ± 0.3 cm tall burnweed plants caused 60 to 97% injury, but <50% of treated plants died. In contrast, spot applications of glufosinate, tribenuron methyl, and foramsulfuron provided complete control of treated plants. Efficacy of postemergence broadcast mesotrione and foramsulfuron applications declined with increasing burnweed plant height, though foramsulfuron provided greater control of plants >10cm in height than mesotrione. A tank mixture of mesotrione and foramsulfuron was effective on burnweed and may be useful for controlling plants of varying size with broadcast applications in the field. Removal of 25, 50, and 75% of aboveground burnweed stems with clipping increased lateral branch number relative to untreated control plants, and 100% removal of the aboveground stem was required to prevent lateral branching and flowering. Stem removal through mowing under field conditions will likely have limited effects on burnweed, and herbicides are recommended for burnweed management in wild blueberry.

Key Words: summer annual weed, herbicide evaluation, clipping, broadcast application, spot application, herbicide tank mixture, *Erechtites hieraciifolius*, *Vaccinium angustifolium*

Wild, or lowbush, blueberry (*Vaccinium angustifolium* Ait.) is a perennial, deciduous shrub native to North America (Vander Kloet 1988). It is the most important fruit crop in Nova Scotia (Strik and Yarborough 2005), contributing 22 million dollars to farm gate value in 2011 (Statistics Canada 2012). Commercial fields are developed on abandoned farmland or cleared woodland where native blueberry stands already exist (AAFC 2005). Stands are managed primarily on a two-year cycle in which fields are pruned to ground level in the first year (non-bearing year) and harvested in the second year (bearing year) (AAFC 2005). Weed management options are limited due to the perennial nature of the crop, and weeds are therefore a major yield limiting factor (Jensen 1985; McCully et al. 1991). The weed flora of wild blueberry fields has traditionally been dominated by herbaceous and woody perennial species (McCully et al. 1991), but the trend since the introduction of hexazinone has been towards shorter-lived weed species that rely on reproduction by seeds for establishment and spread (Jensen and Yarborough 2004). Herbaceous annual and monocarpic perennial species, therefore, have become increasingly common in wild blueberry fields.

American burnweed (*Erechtites hieraciifolius*) is an annual plant in the Asteraceae family (Darbyshire et al. 2012). The plant is phenotypically variable (Belcher 1956) but is generally erect (up to 300 cm tall) (Darbyshire et al. 2012) and produces abundant, wind-borne seed (Wagner 1965; Darbyshire et al. 2012). It is native to deciduous forest regions of North America and later was introduced to regions of Europe and Asia (Darbyshire et al. 2012). The distribution in Canada is from the Maritime Provinces to western Ontario (Darbyshire et al. 2012), and the plant is abundant in areas of recently cleared forest (Peterson et al. 1990; Kochenderfer and

Wendel 1983; Levin 1966), particularly following fire (Hutchinson et al. 2004). It occurs as a weed in forestry (Nelson et al. 1981), turfgrass (Atkinson et al. 2014), cranberry (Skroch and Dana 1965), and several agronomic crops (Darbyshire et al. 2012). First reported as a weed in wild blueberry fields in Maine (D. Yarborough, personal communication), the plant has since been observed in fields in Atlantic Canada (Anonymous 2017a) and appears to be increasing in abundance. The plant is susceptible to postemergence applications of mesotrione (Anonymous 2017b) and clopyralid (D. Yarborough, personal communication), though many blueberry growers report poor control of this weed species with mesotrione in wild blueberry fields in Nova Scotia. Sulfonylurea and triazine herbicides, which are important herbicides in wild blueberry production, provide postemergence and preemergence control of burnweed, respectively, in turfgrass (Atkinson et al. 2014). Research on susceptibility of this species to similar herbicides in Canada, however, is limited (Darbyshire et al. 2012), and knowledge of susceptibility to several common herbicides used in wild blueberry is lacking.

Although little is known about the competitive effects of American burnweed on wild blueberry, the tall growth habit would suggest potential impacts on blueberry growth and yield, and plants are known to interfere with harvesting (D. Yarborough, personal communication, as cited in Darbyshire et al. 2012). Clipping burnweed plants above the blueberry canopy may suppress burnweed and improve harvest efficiency, but likely would not provide complete control of this weed species. Knowledge of general herbicide susceptibility in this species is therefore important for the development of management strategies for this weed in wild blueberry. Focusing primarily on currently registered herbicides in wild blueberry, the objectives of this research were to 1) evaluate burnweed susceptibility to herbicides applied as postemergence broadcast treatments, 2) evaluate burnweed susceptibility to herbicides applied as

postemergence spot treatments, 3) determine the effect of application timing on burnweed susceptibility to postemergence mesotrione and foramsulfuron applications, 4) evaluate efficacy of a postemergence mesotrione and foramsulfuron tank mixture on burnweed, and 5) determine the effect of clipping on burnweed lateral branch and flower production.

MATERIALS AND METHODS

Source of plant material and growing conditions

All experiments were conducted using plants reared in the greenhouse. Plants were reared from seed as needed using germination protocols previously described (White et al. 2017). Seeds were sprouted, and sprouted seeds were planted in Pro-Mix BX general purpose growing medium (Premier Horticulture Inc., Quakertown, PA, USA) in 715 cm³ or 2197 cm³ plastic pots for use in the experiments outlined below. Seedlings were considered emerged at the time of planting due to presence of cotyledons that were kept above the soil surface at the time of planting. Plants were maintained in the greenhouse under a 16-h photoperiod consisting of daylight extended to 16-h by metal halide lamps providing a photosynthetic photon flux density of $61 \pm 3 \mu\text{mol m}^{-2} \text{s}^{-1}$ at plant level. The mean temperature in the greenhouse during the experiment was 22 ± 0.1 °C. Plants were watered as needed, and location of each plant in each experiment was re-randomized once every 2 weeks to minimize positional effects on plant growth. Each experiment was repeated once. Herbicides in each experiment were applied using a hand-held, CO₂ pressurized single nozzle sprayer outfitted with a Teejet XR 11002 nozzle and calibrated to deliver a water volume of 200 L ha⁻¹ at a pressure of 207 KPa, with the exception of Ultim 75DF, which was applied in a water volume of 800 L ha⁻¹.

Postemergence broadcast application evaluation

The objective of this experiment was to evaluate currently registered herbicides in wild blueberry as postemergence broadcast treatments on American burnweed. Plants reared until the 4 – 6 leaf stage in 715cm³ plastic pots under the greenhouse conditions outlined above were used for this experiment. The experiment was arranged as a completely randomized design with 7 replications and 11 treatments (Table 1). Mean plant leaf number and height at the time of herbicide applications was 4 ± 0.1 leaves plant⁻¹ and 4 ± 0.1 cm, respectively. Data collection consisted of visual estimates of herbicide injury at 7, 21, and 35 days after treatment (DAT) using a 0 – 100 scale in which 0 equals no plant injury and 100 equals complete plant death.

Postemergence spot application evaluation

The objective of this experiment was to evaluate currently registered herbicides in wild blueberry as postemergence spot treatments on American burnweed. Plants reared until the early flower bud stage in 2197 cm³ plastic pots under the greenhouse conditions outlined above were used for this experiment. The experiment was arranged as a completely randomized design with 6 replications and 9 treatments (Table 2). Mean plant leaf number and height at the time of herbicide applications was 26 ± 0.4 leaves plant⁻¹ and 24 ± 0.3 cm, respectively. Data collection consisted of visual estimates of herbicide injury at 7, 21, and 35 DAT using the visual injury scale outlined above, and scoring of each plant as alive or dead at 35 DAT.

Effect of postemergence mesotrione and foramsulfuron application timing on herbicide efficacy

The objective of this experiment was to determine the effect of American burnweed growth stage on postemergence mesotrione and foramsulfuron efficacy. Plants reared in 715cm³ plastic pots under the greenhouse conditions outlined above were used for this experiment. The

experiment was a 2 X 4 factorial arrangement of herbicide (mesotrione, foramsulfuron) and application timing [2, 4, 6, or 8 wk after emergence (WAE)] arranged in a completely randomized design with 6 replications. Mesotrione and foramsulfuron were applied at application rates outlined for experiment 1 (Table 1). Data collection consisted of plant height and leaf number at the time of each herbicide application, visual estimates of herbicide injury at 35 DAT using the visual injury scale outlined above, and scoring of each plant as alive or dead at 35 DAT.

Evaluation of a postemergence mesotrione and foramsulfuron tank mixture on American burnweed

The objective of this experiment was to evaluate a postemergence mesotrione and foramsulfuron tank mixture for efficacy on American burnweed. Plants reared until the 4 – 6 leaf stage in 715cm³ plastic pots under the greenhouse conditions outlined above were used for this experiment. The experiment was arranged in a completely randomized design with 8 replications. Mean plant leaf number and height at the time of herbicide applications was 8 ± 0.1 leaves plant⁻¹ and 10 ± 0.3 cm, respectively. Treatments consisted of 1) untreated control, 2) mesotrione, 3) foramsulfuron, and 4) mesotrione + foramsulfuron. Mesotrione and foramsulfuron, as well as both a non-ionic surfactant and 28% UAN, were applied at rates outlined in Table 1. Data collection consisted of visual estimates of herbicide injury at 7, 21, and 35 DAT using the visual injury scale outlined above.

Effect of clipping on American burnweed

The objective of this experiment was to determine the effect of clipping on American burnweed. Plants reared until the early flower bud stage in 715cm³ plastic pots under the

greenhouse conditions outlined above were used for this experiment. The experiment was arranged in a completely randomized design with 6 replications. Treatments consisted of 1) untreated control (Clip-0%), 2) clipping to remove 25% of the aboveground stem (Clip-25%), 3) clipping to remove 50% of the aboveground stem (Clip-50%), 4) clipping to remove 75% of the aboveground stem (Clip-75%), and 5) clipping to remove 100% of the aboveground stem (Clip-100%). Data collection included plant height at the time of clipping, stem length removed, number of nodes below the clipping point, and number of lateral branches and capitula (flower heads) produced by each plant at 42 days after clipping (DAC).

Statistical analysis

Subjective visual injury ratings in the broadcast application, spot application, application timing, and tank mixture experiments could not be made to conform to the assumptions for a variance analysis. Data were therefore combined across runs for each experiment and the significance of herbicide treatment on visual injury ratings on each rating date was determined using the Kruskal-Wallis test in PROC NPAR-1-WAY in SAS (SAS Version 9.3, SAS Institute, Cary, North Carolina). Significance was based on an alpha value of 0.05, and visual injury ratings for the untreated control were not included in the analysis.

Effect of herbicide treatment on burnweed mortality in the spot application experiment was determined using categorical weighted-least-squares ANOVA in the PROC CATMOD procedure of SAS. Frequency of dead plants in each treatment was considered as the dependent variable while herbicide treatment was considered as the independent variable in the analysis. Herbicide treatment was considered as a categorical variable and was modeled as a fixed effect in the analysis. Effect of herbicide, application timing, and the herbicide X application timing interaction on burnweed mortality in the application timing experiment was also determined

using PROC CATMOD. Frequency of dead plants in each treatment was considered as the dependent variable and herbicide, application timing, and the herbicide X application timing interaction were considered as fixed effects in the analysis. Significance of all statistical tests in these analyses was based on an alpha value of 0.05.

The effects of experimental run, clipping treatment, and the experimental run X clipping treatment interaction on burnweed lateral branch and capitula number were determined using ANOVA. All effects were considered as fixed effects in the analysis. Means were determined using the LSMEANS statement, and means separation, where necessary, was determined using Tukey's mean separation test. Significance of all statistical tests was based on an alpha value of 0.05. Data for the Clip-100% treatment were not included in the analysis due to zero values for all measured parameters.

RESULTS AND DISCUSSION

There was a significant effect of herbicide treatment on American burnweed visual injury ratings in the broadcast application experiment at 7 and 21 DAT but not 35 DAT (Table 1). American burnweed was susceptible to all herbicides evaluated in the broadcast herbicide evaluation (Table 1). Hexazinone and terbacil provided acceptable control by 21 DAT, indicating utility of these products for burnweed management. Many growers, however, report lack of burnweed control in wild blueberry fields following standard hexazinone applications. Reasons for this are unclear, especially given that the triazine herbicide simazine provides acceptable burnweed control in bermudagrass turf (Atkinson et al. 2014), indicating general susceptibility of burnweed to this group of herbicides. Growers, however, do not observe burnweed in fields until late June or early July. It is therefore possible that burnweed emerges after residual activity of hexazinone has dissipated as this herbicide is applied in early May and degrades rapidly in wild

blueberry soils following application (Jensen and Kimball 1987). Growers should consider terbacil or simazine as alternative preemergence herbicides for burnweed, and additional research should be conducted to determine the precise emergence timing of this weed species in an effort to help explain lack of control from hexazinone under field conditions.

Mesotrione provided effective control at the application rate and timing evaluated, similar to results reported in Maine (David Yarborough, personal communication) and New Brunswick (Anonymous 2017b), further confirming the effectiveness of this herbicide on burnweed. Foramsulfuron, however, was also effective at controlling burnweed (Table 1). This herbicide has not been previously evaluated for burnweed control in wild blueberry, and provides an additional mode of action for postemergence management of this increasingly common weed. Foramsulfuron also controlled burnweed in bermudagrass turf (Atkinson et al. 2014), though the herbicide was applied in a tank mixture with thiencarbazone and halosulfuron. Flumioxazin, glufosinate, clopyralid, glyphosate, tribenuron methyl, and nicosulfuron/rimsulfuron also provided good control of burnweed at the application rates and timing evaluated (Table 1), but these products, particularly flumioxazin, glufosinate, clopyralid, and glyphosate, pose a significant risk of injury to blueberry plants if used as postemergence broadcast applications and cannot be recommended for this use at this time. Efficacy of tribenuron methyl and nicosulfuron/rimsulfuron, however, further confirm efficacy of the sulfonylurea herbicides on this weed species, and susceptibility to clopyralid is in agreement with results from research in wild blueberry in Maine (David Yarborough, personal communication) and in turfgrass (Atkinson et al. 2014).

There was a significant effect of herbicide treatment on American burnweed visual injury ratings in the spot application experiment at all rating dates (Table 2). Glufosinate,

foramsulfuron, and tribenuron methyl were the most effective herbicides evaluated as spot applications on burnweed (Table 2). Each product caused 100% injury and mortality of treated plants by 35 DAT (Table 2). Although effective, use of glufosinate would require careful application due to high risk of injury to exposed blueberry foliage. This product should therefore only be used as a spot treatment when risk of contact with blueberry plants can be avoided. In contrast, tribenuron methyl poses limited risk of blueberry injury when used as a spot treatment in wild blueberry (Jensen and Specht 2004), and wild blueberry is generally quite tolerant to foramsulfuron (White and Kumar 2017). Growers should therefore consider either of these products when considering spot applications for burnweed control in wild blueberry. Mesotrione and nicosulfuron/rimsulfuron caused >80% injury when applied as spot treatments, but the majority of plants treated with these herbicides had survived by the end of the experiment (Table 2). Clopyralid and glyphosate did not provide acceptable control of burnweed when applied as spot applications at the application rates evaluated in this experiment (Table 2), though higher rates of each product could be evaluated. For example, clopyralid applied at a rate of 320 g a.i. ha⁻¹ (approximately 2X application rate in our study) in a tank mixture with triclopyr controlled 15 – 30 cm tall burnweed plants in bermudagrass turf (Atkinson et al. 2014).

There was a significant treatment effect on visual injury ratings at 35 DAT in the application timing experiment (Table 3), with visual injury declining with increasing burnweed leaf number and height at application. Injury on larger plants was, however, higher in the foramsulfuron treatment relative to the mesotrione treatment (Table 3). There was a significant effect of herbicide ($P < 0.0001$), application timing ($P < 0.0001$), and the herbicide X application timing interaction ($P < 0.0001$) on burnweed mortality. Mesotrione provided >80% control of burnweed plants when treated at 2 and 4 WAE (approximately 4 to 10 cm in height), but did not

control larger plants treated at 6 and 8 WAE (17 – 28 cm in height) (Table 3). In contrast, foramsulfuron caused significant mortality of burnweed plants when applied at 2, 4, and 6 WAE (4 – 19 cm in height), with significant injury to plants treated at 8 WAE as well (31 cm in height) (Table 3). These data support results of the broadcast experiment, but also indicate that foramsulfuron is more effective on larger burnweed plants than mesotrione. Some growers have reported lack of burnweed control with postemergence mesotrione applications, likely due to applications to larger plants. Burnweed is not observed until late spring or early summer in wild blueberry fields, at which time the plant needs to exceed the height of blueberry stems (10 – 20 cm) to be noticeable to a grower. Growers should therefore scout fields with known burnweed populations carefully to ensure appropriate application timing, or consider use of foramsulfuron as an alternative postemergence herbicide. The tank mixture of these products was also effective, with higher visual injury ratings in the foramsulfuron and mesotrione + foramsulfuron treatments at 7 and 21 DAT (Table 4). This tank mixture may therefore be effective for managing larger plants typical of field infestations, and additional research should be conducted to determine the effect of burnweed growth stage on efficacy.

There was a significant effect of clipping ($P < 0.0001$), but no significant effect of experimental run ($P \geq 0.6903$) or the clipping X experimental run interaction ($P \geq 0.5384$) on lateral branches or flowers produced by burnweed plants in the clipping experiment. Data were therefore combined across experimental runs for analysis. There was a significant effect of clipping on lateral branch number ($P = 0.0060$), but not flower number ($P = 0.0929$), in the combined data set. Removal of 25, 50, and 75% of the aboveground stem tended to increase lateral branch number, but not flower number, relative to the untreated control plants, and 100% removal of the aboveground stem was required to completely prevent lateral branching and

flowering (Table 5). Mowing can control annual weeds like burnweed, but requires mowing close to the soil surface (Donald 2006; 2007) or use of repeated mowing (Butler et al. 2013) to maximize effectiveness. Wild blueberry stems are generally 10 to 20 cm in height in most commercial fields (Eaton 1994; Eaton et al. 2004), with crop coverage ranging from near complete in mature fields (Hepler and Yarborough 1991) to less than 60% in younger fields (Jensen 1985; Yarborough and Bhowmik 1989; Lapointe and Rochefort 2001). The ability to mow close to the soil surface would therefore vary both within and between fields, likely limiting the potential suppressive effects of mowing. Repeated mowing is possible and may improve suppression of burnweed relative to the single cutting evaluated in our experiment, and additional research to determine the effect of repeated cutting on burnweed and other weeds is likely warranted. Repeated mowing would, however, increase the number of passes across fields and increase damage to emerged blueberry stems by machinery tires. Additional experiments could also be conducted to determine the effect of clipping on seed production, but it seems likely that the effects of clipping on burnweed are limited and that herbicides are the more effective and economical management strategy for this weed species in wild blueberry fields.

In conclusion, American burnweed was susceptible to several herbicides currently registered for use in wild blueberry. This weed was susceptible to postemergence broadcast applications of hexazinone, and lack of control of American burnweed by preemergence applications of this herbicide under field conditions warrants additional research. Postemergence broadcast applications of mesotrione and foramsulfuron, in addition to postemergence spot applications of foramsulfuron and tribenuron methyl, effectively controlled American burnweed. These herbicides can be used with low risk of crop injury (Jensen and Specht 2004; Boyd and White 2010; White and Kumar 2017) and environmental damage (Russel et al. 2002; Carles et

al. 2017) and should be considered for American burnweed management in wild blueberry. Effects of clipping on burnweed will likely be limited under field conditions, and the identification of effective herbicides should improve management of this weed species in wild blueberry.

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Table 1. Effect of various broadcast herbicide treatments on visual estimates of herbicide injury on American burnweed when treated at the 4 – 6 leaf stage.

Treatment ^a	Application rate (g a.i. or a.e. ha ⁻¹)	Visual injury (%)		
		7 DAT ^b	21 DAT	35 DAT
Control	-	0	0	0
Mesotrione	144	29 ± 9	100	100
Flumioxazin	215	98 ± 1	100	100
Glufosinate	750	95 ± 1	100	100
Clopyralid	151	13 ± 2	71 ± 7	100
Foramsulfuron	35	41 ± 10	100	100
Glyphosate	900	75 ± 6	94 ± 3	100
Terbacil	2000	96 ± 1	100	100
Tribenuron methyl	40	22 ± 6	100	100
Nicosulfuron/ rimsulfuron	13 + 13	32 ± 6	98 ± 1	100
Hexazinone	1920	32 ± 10	94 ± 6	100
<i>P</i> -Value ^c		<0.0001	<0.0001	0.5278

Note: Values for visual injury ratings represent the mean ± 1 SE.

^aHerbicide trade names: mesotrione, Callisto 480 SC; flumioxazin, Chateau WDG; glufosinate, Ignite SN; clopyralid, Lontrel 360; foramsulfuron, Option OD; glyphosate, RoundUp WeatherMax; terbacil, Sinbar WG; tribenuron methyl, Express SG; nicosulfuron/rimsulfuron, Ultim 75 DF; hexazinone, Velpar 75 DF. Callisto 480 SC, Express SG, and Ultim 75DF were

applied with non-ionic surfactant at a rate of 0.2% v/v. Option OD was applied with 28% UAN at a rate of 2.5 L ha⁻¹.

^bDAT, days after treatment.

^c*P*-Values associated with the Kruskal-Wallis test for treatment significance using PROC NPAR-1-WAY in SAS.

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Table 2. Effect of various spot herbicide treatments on visual estimates of herbicide injury on American burnweed when treated at the early flower bud stage.

Treatment ^a	Visual injury (%)				
	Application rate (g a.i. or a.e L water ⁻¹)	7 DAT ^b	21 DAT	35 DAT	Mortality at 35 DAT (%)
Control	-	0	0	0	0 _c
Mesotrione	0.72	4 ± 1	67 ± 5	92 ± 3	42 _b
Glufosinate	0.75	83 ± 1	100	100	100 _a
Clopyralid	0.08	14 ± 1	31 ± 2	64 ± 4	0 _c
Foramsulfuron	0.2	91 ± 2	100	100	100 _a
Glyphosate	7	27 ± 8	60 ± 6	73 ± 6	25 _b
Tribenuron methyl	0.2	25 ± 6	100	100	100 _a
Nicosulfuron/rimsulfuron	0.02 + 0.02	29 ± 7	68 ± 6	88 ± 3	33 _b
<i>P</i> -Value ^c		<0.0001	<0.0001	<0.0001	

Note: Values for visual injury ratings represent the mean ± 1 SE. Mortality rates followed by the same letter do not differ significantly according to pairwise contrasts conducted in PROC CATMOD in SAS.

^aHerbicide trade names: mesotrione, Callisto 480 SC; glufosinate, Ignite SN; clopyralid, Lontrel 360; foramsulfuron, Option OD; glyphosate, RoundUp WeatherMax; tribenuron methyl, Express SG; nicosulfuron/rimsulfuron, Ultim 75 DF. Callisto 480 SC, Express SG, and Ultim 75DF were applied with non-ionic surfactant at a rate of 0.2% v/v. Option OD was applied with 28% UAN at a rate of 12.5 ml L water⁻¹.

^bDAT, days after treatment.

^c*P*-Values associated with the Kruskal-Wallis test for treatment significance using PROC NPAR-1-WAY in SAS.

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Table 3. Effect of mesotrione and foramsulfuron application timing on visual injury and mortality of American burnweed.

Herbicide ^a	Time of application (weeks after planting)	Mean plant height at application (cm)	Mean leaf # at application (leaves plant ⁻¹)	Visual injury at 35 DAT ^b (%)	Mortality at 35 DAT (%)
Control	-	-	-	0	0 _c
Mesotrione	2	4 ± 0.2	4 ± 0.2	100	100 _a
	4	9.4 ± 0.5	10 ± 1	90 ± 7	83 _{ab}
	6	17 ± 1	19 ± 1	32 ± 4	0 _c
	8	28 ± 2	28 ± 1	21 ± 4	0 _c
Foramsulfuron	2	4 ± 0.2	4 ± 0.2	100	100 _a
	4	9 ± 0.3	10 ± 1	100	100 _a
	6	19 ± 1	18 ± 1	86 ± 6	58 _b
	8	31 ± 2	28 ± 1	84 ± 5	33 _b
P-value ^c				<0.0001	

Note: Values for plant height at application, leaf # at application, and visual injury ratings represent the mean ± 1 SE. Mortality rates followed by the same letter do not differ significantly according to pairwise contrasts conducted in PROC CATMOD in SAS.

^aMesotrione and foramsulfuron application rates of 144 and 35 g a.i. ha⁻¹, respectively. Trade names for mesotrione and foramsulfuron were Callisto 480 SC and Option OD, respectively.

Callisto 480 SC was applied with non-ionic surfactant at a rate of 0.2% v/v. Option OD was applied with 28% UAN at a rate of 2.5 L ha⁻¹.

^bDAT, days after treatment.

^cP-Value associated with the Kruskal-Wallis test for treatment significance using PROC NPAR-1-WAY in SAS.

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Table 4. Effect of mesotrione and foramsulfuron on American burnweed when applied alone and in tank mixture.

Treatment ^a	Visual injury (%)		
	7 DAT ^b	21 DAT	35 DAT
Control	0	0	0
Mesotrione	17 ± 1	94 ± 2	100
Foramsulfuron	72 ± 2	100	100
Mesotrione + Foramsulfuron	83 ± 2	100	100
<i>P</i> -Value ^c	<0.0001	<0.0001	1.000

Note: Values for visual injury ratings represent the mean ± 1 SE.

^aMesotrione and foramsulfuron application rates of 144 and 35 g a.i. ha⁻¹, respectively. Trade names for mesotrione and foramsulfuron were Callisto 480 SC and Option OD, respectively. Callisto 480 SC was applied with non-ionic surfactant at a rate of 0.2% v/v. Option OD was applied with 28% UAN at a rate of 2.5 L ha⁻¹.

^bDAT, days after treatment.

^c*P*-Values associated with the Kruskal-Wallis test for treatment significance using PROC NPAR-1-WAY in SAS.

Table 5. Effect of clipping to remove 0, 25, 50, 75, and 100% of aboveground stems on lateral branch formation and flower number in American burnweed.

Clipping treatment	Height at clipping (cm)	Stem length removed (cm)	Nodes below cut (# plant ⁻¹)	Lateral branches (# plant ⁻¹) ^a	Capitula (# plant ⁻¹) ^b
Clip-0%	22 ± 1	-	-	2b	9a
Clip-25%	21 ± 1	5 ± 1	16 ± 1	4a	8a
Clip-50%	21 ± 1	11 ± 1	14 ± 1	3ab	7a
Clip-75%	22 ± 1	17 ± 1	8 ± 1	3ab	6a
Clip-100%	21 ± 1	21 ± 1	0	0	0

Note: Values for plant height at clipping, stem length removed, nodes below the cut, lateral branches, and capitula represent the mean ± 1 SE. Mean lateral branch and capitula values followed by the same letter do not differ significantly according to a Tukey's multiple means comparison test at a significance level of 0.05.

^aData were SQRT(X) transformed prior to analysis to satisfy the assumptions of normality and constant variance for the ANOVA. Back-transformed means are provided.

^bData were LOG(X) transformed prior to analysis to satisfy the assumptions of normality and constant variance for the ANOVA. Back-transformed means are provided.