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Cost-Effectiveness of Glyphosate, 2,4-D, and Triclopyr, Alone and in Select Mixtures for Poison Ivy Control

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Dermatitis from poison ivy is a significant health problem. Considerable effort is devoted to the control of this invasive and virulent weed in urban areas. Glyphosate, triclopyr, 2,4-D, a 1 : 1 mixture of glyphosate and 2,4-D, and a 9 : 1 mixture of glyphosate and triclopyr were evaluated for poison ivy control. Each of these three herbicides and two mixtures were applied at nine or ten rates, which ranged in phytotoxicity from none to death. Poison ivy plants had been propagated and container-grown. Percent control, as determined from plant fresh weight reduction, was determined at 1 and 4 mo after treatment (MAT). Data were subjected to ANOVA followed by nonlinear regression. Rates required for 95% control at 1 and 4 MAT and the associated costs were determined for each of the three herbicides and two mixtures. Acceptable control (i.e., ≥ 95%) at 1 and 4 MAT could be obtained at a much lower cost with either triclopyr or 2,4-D than with either glyphosate alone or with the two glyphosate-containing mixtures. Nonlinear regression also was used to evaluate whether the two mixtures were interactive (i.e., synergistic or antagonistic) or not (i.e., additive). Glyphosate plus triclopyr was synergistic for control at both 1 and 4 MAT. Glyphosate plus 2,4-D was synergistic for control at 4 MAT only. However, for both mixtures, synergism was only evident at rates that controlled poison ivy ≤ 80%. Both mixtures were noninteractive at rates required for acceptable control.
Nomenclature: 2,4-D amine; glyphosate; triclopyr; poison ivy *Toxicodendron radican* (L.) Kuntze.
Key words: Herbicide interactions, nonlinear regression, virulent weeds.

La dermatitis causada por *Toxicodendron radican* es un problema de salud importante. En áreas urbanas se realizan esfuerzos considerables para el control de esta maleza invasiva y virulenta. Se evaluó el control de *T. radican* con glyphosate, triclopyr, 2,4-D, una mezcla 1:1 de glyphosate y 2,4-D y una mezcla 9:1 de glyphosate y triclopyr. Cada uno de estos tres herbicidas y dos mezclas fueron aplicados a nueve o diez dosis, las cuales variaron en fitotoxicidad desde ningún daño hasta la muerte. Las plantas de *T. radican* habían sido propagadas y crecidas en contenedores. El porcentaje de control, determinado como la reducción en el peso fresco de la planta, fue determinado a 1 y 4 meses después del tratamiento (MAT). Los datos fueron sometidos a análisis de varianza (ANOVA) seguido de regresiones no-lineales. Las dosis requeridas para alcanzar 95% de control a 1 y 4 MAT y los costos asociados fueron determinados para cada uno de los tres herbicidas y las dos mezclas. Un nivel aceptable de control (i.e. ≥ 95%) a 1 y 4 MAT se pudo obtener con triclopyr o 2,4-D a un costo más bajo que con glyphosate solo o que con las mezclas que contenían glyphosate. Regresiones no-lineales también fueron usadas para evaluar si las dos mezclas fueron interactivas (i.e. sinérgica o antagónica) o no (i.e. aditiva). Glyphosate más triclopyr fue sinérgico para el control a 1 y 4 MAT. Glyphosate más 2,4-D fue sinérgico para el control solamente a 4 MAT. Sin embargo, para ambas mezclas, la sinergia fue solamente evidente a dosis que controlaron *T. radican* ≤80%. Ninguna de las mezclas fueron interactivas a las dosis requeridas para alcanzar un control aceptable.

Poison ivy is a high-climbing woody vine native to North America and prevalent in nearly all forested areas of the United States and southern Canada. It is also problematic in the landscape and forested sites in urban areas. Poison ivy produces clusters of flowers. The mature fruits are eaten and the seeds spread by birds. Poison ivy sap contains urushiol, a yellowish, slightly volatile, oily allergen. Crushing and/or bruising of the foliage releases the sap, and when this sap contacts skin, it can result in skin dermatitis, a blistering and painful rash. It is estimated that about 50% of the population is sensitive, and about 15% is extremely sensitive to poison ivy-based dermatitis. In this latter category, the amount of urushiol within a single poison ivy leaf is often sufficient to produce medically significant dermatitis (Epstein and Byers 1981). About 2 million cases of poison ivy-induced dermatitis occur annually in the United States. Dermatitis from poison ivy and similar virulent weeds such as poison oak (*Toxicodendron pubescens* P. Mill) and poison sumac [*Toxicodendron vernix* (L.) Kuntze] is the leading cause of field injuries and workers' compensation claims among U.S. Forest Service personnel (Mitich 1995).

Very little research has been conducted on its control, even though poison ivy-based dermatitis is a significant health factor. Yonce and Skroch (1989) evaluated glyphosate at 1.1 and 2.2 kg ha^{-1} (ae or ai not specified), applied at three different dates during the growing season for the control of native poison ivy stands at two locations in North Carolina. A single application of glyphosate at 2.2 kg ha^{-1} applied at any time between mid-June and mid-August controlled poison ivy approximately 87%. A literature search recovered no other published studies addressing poison ivy control.

Weed control practitioners involved in urban forestry management recommend a 1 : 1 mixture of glyphosate and 2,4-D (typically an amine formulation) for poison ivy control (S. Fenn, personal communication). Research evaluating the efficacy of this mixture; or the efficacy of 2,4-D applied alone,

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has not been published. A glyphosate plus triclopyr mixture is marketed throughout the United States under various trade names specifically for poison ivy control. The ratio of glyphosate to triclopyr ratio is 9 : 1 by weight. Similarly, research evaluating the efficacy of this mixture or the efficacy of triclopyr applied alone has not been published.

There is no consensus among researchers as to the best method to evaluate herbicide mixtures. An excellent review of this topic, including merits and weakness of various approaches to identify antagonistic and/or synergistic interactions has been published by Streibig and Jensen (2000). These authors suggested that an excellent method is to evaluate both the mixture, and the components of the mixture over a range of rates that produce results extending from none to maximum phytotoxicity. The mixture is held to a predetermined and constant ratio of the components. Through linear and/or nonlinear regression, an equally-effective rate (e.g., the rate required for 95% control) for each herbicide and herbicide mixture then can be determined and its cost calculated. We chose this approach to evaluate and compare the two mixtures and their respective components.

Research that utilizes herbicide rate response curves in conjunction with nonlinear regression also can be used to investigate mixture interactions. Mixtures can be classified as either noninteractive or interactive; and if interactive, whether the interaction is either antagonistic or synergistic. This procedure has its basis in the evaluation of drug interactions for antagonism and/or synergism as described by Tallarida (2001). The dose-response curves of two drugs administered separately and the response curve of a 50 : 50 mixture of these two drugs are graphed. The response curve of the mixture should fall exactly midway in between the response curves of the individual components if they are noninteractive when combined. However, if the actual response curve of the mixture falls to the left of the predicted additive curve, the mixture is more active than anticipated. In this case, the mixture can be deemed synergistic. Conversely, the mixture is considered antagonistic if the actual response curve of the mixture falls to the right of the predicted additive curve. This methodology has been used previously by the authors to evaluate a glyphosate–flumioxazin mixture (Wehtje et al. 2010a) and a flumioxazin–prodiamine mixture (Wehtje et al. 2010b).

Our first research objective was to evaluate and compare the two aforementioned mixtures to their components applied alone for poison ivy control. Our second objective was to determine if these mixtures were interactive or not.

Materials and Methods

Test Plant Production. Poison ivy was propagated and grown in a manner comparable to that used to commercially propagate container-grown landscape plants. Plants were propagated in the growing season year prior to the year in which the experiment was conducted. Poison ivy vines were collected from forested sites near the campus of Auburn University in late June through early July. Cuttings with aerial rootlets and two to four leaves were prepared from these vines. Cuttings were placed in 10-cm^2 plastic containers, filled with a 6 : 1 (v/v) pine bark–sand substrate. This substrate had been amended with a controlled-release granular fertilizer (Polyon® 17N–6P–12K, Harrell's LLC, 720 Kraft Road, Lakeland, FL 33815), dolomitic limestone and a micronutrient fertilizer (Micromax®, O. M. Scott Corp., 14111 Scotts Lawn Rd., Marysville, OH 43401) at 8.3, 3.0, and 0.9 kg m^{-3}, respectively. Cuttings were maintained in a mist propagation bed for approximately 8 wk. Cuttings with new growth were planted in 2.5 L plastic pots using soil (surface horizon, Pacolet sandy loam) supplemented with composted hardwood sawdust. Plants were maintained in an outdoor area with natural shade. Plants received approximately 0.6 cm of irrigation three times a week. Plants went dormant in the fall, and were covered with polyethylene film during periods of extreme cold during the following winter. Plants resumed growth the following spring. Using these procedures, a population of actively-growing and established plants was obtained. Plants were further sorted for uniformity in size and appearance prior to experimental use.

Experimental Procedures. Five herbicides and/or herbicide mixtures were included: (1) glyphosate (Roundup Pro Concentrate®, isopropylamine salt of glyphosate, Monsanto Co., 800 N Lindbergh Blvd., St. Louis, MO 63167); (2) 2,4-D (2,4-D, dimethylamine salt, Agri Supply Comp. P.O. Box 799, Garner, NC 27529); (3) triclopyr (Garlon 3A®, triethylamine salt of triclopyr, Dow AgroSciences, LLC, 9330 Zionsville Rd., Indianapolis, IN 46268); (4) a mixture with nine parts glyphosate to one part triclopyr; and (5) a mixture with equal parts glyphosate and 2,4-D dimethyl amine. Mixture preparation was based on acid equivalent weight. Glyphosate was applied at nine rates ranging from 0.25 to 2.24 kg ae ha^{-1}; 2,4-D was applied at 10 rates from 0.05 to 2.24 kg ae ha^{-1}; triclopyr was applied at 10 rates from 0.001 to 1.12 kg ae ha^{-1}; the glyphosate plus 2,4-D mixture was applied at nine rates from 0.025 to 1.68 kg ae ha^{-1}, and the glyphosate plus triclopyr mixture was applied at nine rates from 0.011 to 2.24 kg ae ha^{-1}. A nontreated control also was included, resulting in a 48-treatment experiment. All herbicide-containing treatments included a nonionic adjuvant (Agri-Dex® nonionic spray adjuvant, Helena Chemical Company, 225 Schilling Blvd., Suite 300, Collierville, TN 38017) at 0.25% v/v. Treatments were applied during the first week of June using an enclosed-cabinet sprayer calibrated to deliver 280 L ha^{-1} at 193 kPa. Treatments were applied to four, single-pot replicates. A completely random design was used. Two identical experiments were conducted; the first in 2010 using plants propagated in 2009, and the second in 2011 using plants propagated in 2010.

Data Collection and Statistical Aspects. At 1 mo after treatment (MAT), plants were clipped at approximately 5 cm above the soil line and the weight of any remaining nondesiccated foliage determined. Plants were then allowed to regrow for the remainder of the growing season. At 4 MAT (or 3 mo after clipping) plants again were clipped and the weight of any regrowth determined. This second evaluation occurred during the second week of October and therefore immediately prior to the first expected killing frost. Treated plant weights were expressed as a percent of the nontreated

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Table 1. Regression parameters from log-logistic analysis, and estimated rates and associated costs for 95% poison ivy control with glyphosate, 2,4-D, triclopyr, and two glyphosate-containing mixtures. Data pooled over two experiments conducted in 2010 and 2011, respectively.

Herbicide or herbicide mixture[a]	r^2 coefficient	Parameter estimates[b]		LD_{95}		
					Treatment cost	
		LD_{50}	Slope	Rate	Proprietary products[c]	Generic products[d]
		kg ae ha^{-1}		kg ae ha^{-1}	$ ha^{-1}	
Control at 1 MAT:						
Glyphosate	0.92	0.75	4.39	1.49	31.96	15.27
2,4-D	0.78	0.15	2.12	0.50	7.25	7.25
Triclopyr	0.88	0.01	2.30	0.04	2.76	1.53
Glyphosate + 2,4-D (1 : 1)	0.74	0.27	2.15	1.01	18.71	12.40
Glyphosate + triclopyr (9 : 1)	0.79	0.12	1.08	1.57	41.15	20.46
Control at 4 MAT, and 3 mo after clipping:						
Glyphosate	0.82	0.41	3.64	0.92	19.74	9.43
2,4-D	0.80	0.21	2.89	0.57	8.27	8.27
Triclopyr	0.74	0.01	1.39	0.11	7.59	4.20
Glyphosate + 2,4-D (1 : 1)	0.71	0.15	1.21	1.49	26.80	18.30
Glyphosate + triclopyr (9 : 1)	0.69	0.06	1.18	0.77	20.18	10.03

[a] Isopropylamine salt of glyphosate; dimethyl salt of 2,4-D; triethylamine salt of triclopyr. Mixtures were author-prepared and based upon acid equivalent weight.

[b] The four-parameter, log-logistic equation was used. Maximum and minimum parameters were constrained to 100 and 0, respectively, because for all three herbicides and the two mixtures the rate extremes resulted in 100% and 0% control.

[c] Based upon $21.45, $14.51, and $69.01kg ae ha^{-1} for glyphosate, 2,4-D, and triclopyr, respectively; and $17.99 and $26.21 kg ae ha^{-1} for the glyphosate plus 2,4-D and glyphosate plus triclopyr mixtures, respectively.

[d] Based upon $10.25, $14.51, and $38.21 kg ae ha^{-1} for glyphosate, 2,4-D, and triclopyr, respectively; and $12.28 and $13.03 kg ae ha^{-1} for the glyphosate plus 2,4-D and glyphosate plus triclopyr mixtures, respectively.

control; subtracting this value from 100 resulted in a percent control value. Thus a treatment that had foliage weight equal to the nontreated control at both 1 MAT and 4 MAT had 0% control at both 1 and 4 MAT. Conversely, a treatment that resulted in complete foliage desiccation and prevented any regrowth had 100% control at both 1 and 4 MAT.

Data were first subjected to analysis of variance (ANOVA) using the PROC MIXED procedure in SAS (SAS® Statistical Analysis System Software, Release 8.3, SAS Institute, Inc., Box 8000, SAS Circle, Cary, NC 27513). Year was treated as a random effect. No interactions of treatment by year interaction were detected ($P > 0.05$); consequently, data were pooled for further analysis. Specifically, data for each herbicide and herbicide mixture were subjected to nonlinear regression and fitted to the four-parameter log-logistic model using Prism software (Prism® GraphPad Software, Inc., 2236 Avenida de la Playa, La Jolla CA 92037). This model is as follows:

$$y = C + \frac{D - C}{1 + (x/I_{50})^b} \quad [1]$$

y = the measured response (i.e., control), C and D are the lower and upper limits of the response, respectively; I_{50} = rate resulting in 50% of the observed response, b = slope near the I_{50} value, and x = the herbicide rate. The log-logistic model has been demonstrated to be effective in modeling herbicide efficacy (Seefeldt et al. 1995). Selected rates of each of the three herbicides applied alone and the two mixtures were sufficiently low and high so as to result in zero and complete control, respectively (data not shown). Consequently, the lower and upper limits were constrained to 0 and 100, respectively. This allows for more accurate estimations of the remaining two parameters (Motulsky and Christopoulos 2004). The rate necessary to provide 95% control (i.e., the LD_{95} value) was calculated for each herbicide and herbicide mixture using the preceding equation and the parameter estimates as generated by Prism. Prism also was used for graphic data presentation.

Cost for the estimated LD_{95} rate was also determined. Experiments had been conducted using proprietary glyphosate (Roundup Pro Concentrate, Monsanto) and triclopyr (Garlon 3A, Dow AgroSciences) products, and generic 2,4-D (Agri Supply Company). However, generic glyphosate and triclopyr products are available. Therefore, the cost was determined for both proprietary and generic products. Costs of both the proprietary and generic products were based upon an internet search for suppliers from which single, 3.8- or 9.5-L containers of the products could be purchased.

Results and Discussion

Poison ivy control at both evaluations with all three herbicides and the two mixtures could be described by the four-parameter log-logistic model. Values for r^2 were at least 0.74 for control at 1 MAT, or 0.69 for control at 4 MAT (Table 1). Averaging the LD_{50} and LD_{95} values for both control evaluations (Table 1) resulted in 0.89, 0.36, and 0.04 kg ae ha^{-1} for glyphosate, 2,4-D and triclopyr, respectively. Therefore triclopyr and 2,4-D were approximately 22 and 2.5 times more phytotoxic to poison ivy than glyphosate. Triclopyr was approximately nine times more phytotoxic than 2,4-D.

As described previously, dose-response curves can be used to ascertain whether combinations are interactive or not. The

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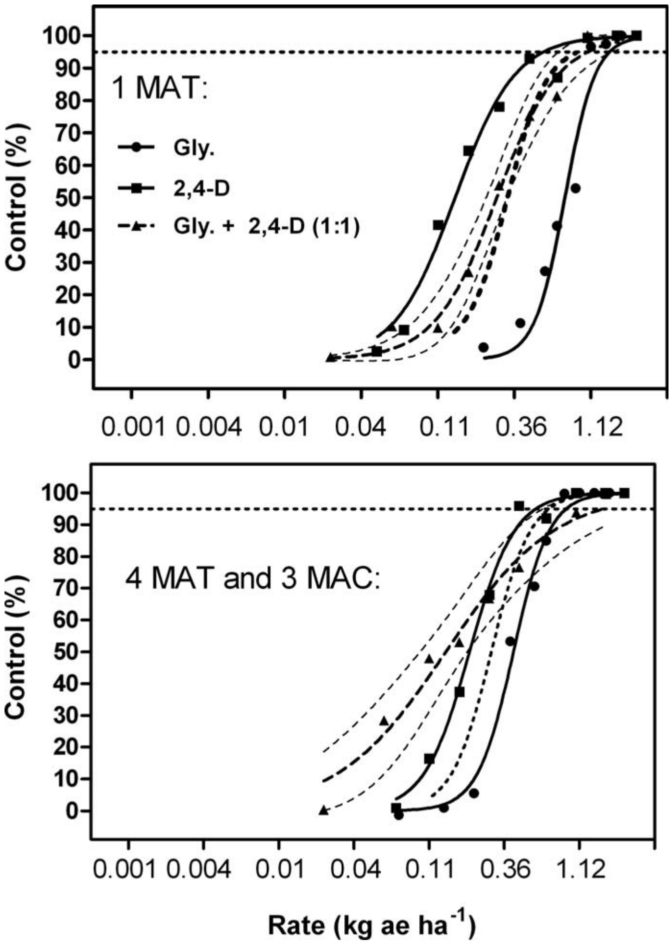

Figure 1. Response of poison ivy to glyphosate, 2,4-D, and a 1 : 1 mixture of the two. Control at (top) 1 mo after treatment (MAT) and (bottom) at 4 MAT = percent reduction in weight relative to the nontreated. Control at 4 MAT also is 3 mo after clipping (MAC) for the 1 MAT evaluation. Dotted line void of data points is the predicted additive response curve as described in the text. Response curve of the mixture includes a 95% confidence band.

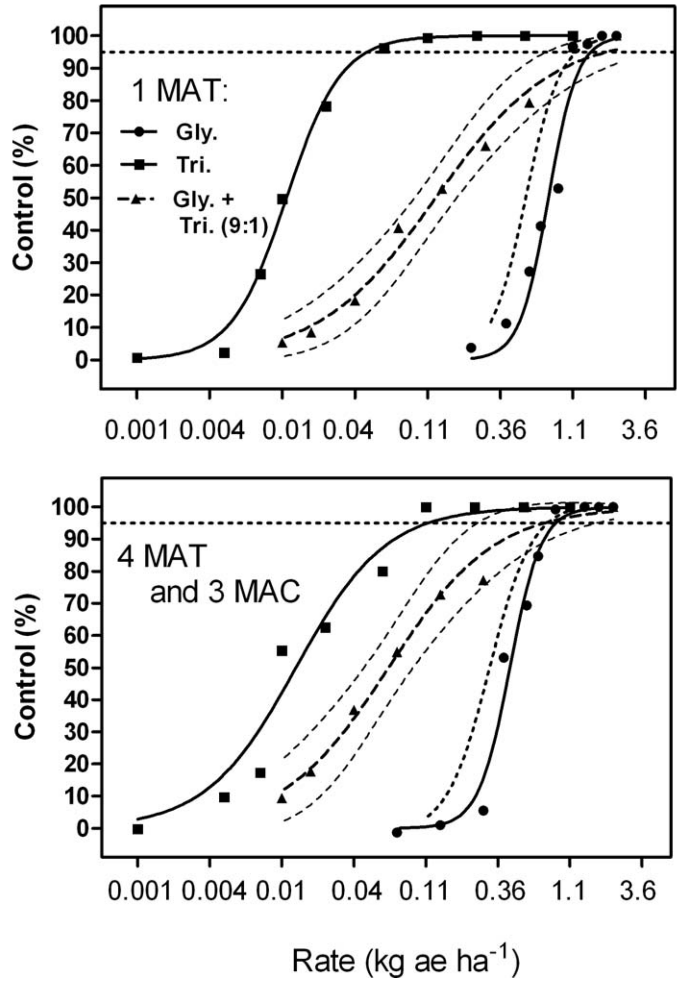

Figure 2. Response of poison ivy to glyphosate, triclopyr, and a 9 : 1 mixture of the two. Control at (top) 1 mo after treatment (MAT) and (bottom) at 4 MAT = percent reduction in weight relative to the nontreated. Control at 4 MAT also is 3 mo after the clipping (MAC) for the 1 MAT evaluation. Dotted line void of data points is the predicted additive response curve as described in the text. Response curve of the mixture includes a 95% confidence band.

predicted additive response curve was included in the graphs as the dotted line void of any data points. To facilitate comparison, a 95% confidence band was included with the response curve of the mixture. For control at 1 MAT, the actual response curve of the glyphosate plus 2,4-D mixture followed nearly parallel to the predicted response curve (Figure 1, top). The confidence band of the actual response curve encompassed the predicted response over nearly its entire length. Thus the glyphosate plus 2,4-D mixture was deemed noninteractive and additive with respect to poison ivy control at 1MAT.

Different results were obtained with control at 4 MAT. The actual response curve of the glyphosate plus 2,4-D mixture was oblique to the predicted response curve (Figure 1, bottom). Consequently, the actual response transected the predicted response at approximately 0.40 kg ae ha^{-1} and 80% control 4 MAT. Therefore the mixture became progressively more synergistic as the rate decreased below 0.40 kg ae ha^{-1}. This synergism was sufficiently strong that at rates below approximately 0.25 kg ae ha^{-1}, the mixture was more active than 2,4-D alone. At rates above approximately 0.40 kg ae ha^{-1}, the response curve of the mixture became equivalent to predicted response. However the LD_{95} for the mixture was 1.49 kg ae ha^{-1}, which was higher than either glyphosate (0.92 kg ae ha^{-1}) or 2,4-D (0.57 kg ae ha^{-1}) alone (Table 1).

The predicted additive response curve of glyphosate plus triclopyr should fall in between the response curves of the components applied alone. But because this mixture was a 9 : 1 ratio in favor of glyphosate, the predicted response should fall 90% to the right of triclopyr, and 10% to the left of glyphosate (Figure 2). For both the control at 1 MAT and 4 MAT, the actual response of the mixture was oblique to, and transected the predicted response. For control at 1 MAT, the intersection point fell at approximately 0.95 kg ae ha^{-1} and 90% control (Figure 2, top). For control at 4 MAT, the intersection fell at approximately 0.80 kg ae ha^{-1} and 95% control (Figure 2, bottom). Below these two rates, the mixture became progressively more synergistic. However, the phytotoxicity of the mixture never exceeded that of triclopyr alone.

At rates above the intersection point, the response curve of the mixture became indistinguishable from the predicted response for control at both 1 and 4 MAT. Therefore, at rates sufficient to provide at least 90% control at both 1 and 4 MAT, the glyphosate plus triclopyr mixture was deemed noninteractive and additive.

Attempting to determine whether the two mixtures were interactive or not was rendered of minimal importance when treatment costs were considered. As estimated through nonlinear regression, the rate required for 95% control at 1 MAT was 0.50, 0.04, 1.49, 1.01, and 1.57 kg ae ha^{-1} for 2,4-D, triclopyr, glyphoste, glyphosate plus 2,4-D, and glyphosate plus triclopyr, respectively (Table 1). These treatments cost 7.25, 2.76, 31.96, 18.71, and 41.15 \$ ha^{-1}, respectively, for proprietary products; or 7.25, 1.53, 15.27, 12.40, and 20.46 \$ ha^{-1}, respectively, for generic products (Table 1). Cost of the 2,4-D treatment was identical because only generic products are available. The cheapest glyphosate-based treatment (i.e., glyphosate plus 2,4-D) was more than either five times (proprietary products) or six times (generic) more expensive than the cheapest nonglyphosate option (i.e., triclopyr). Glyphosate was approximately 10 times (proprietary) or nine times (generic) more expensive than triclopyr. The second most cost-effective treatment was 2,4-D, which was approximately two times more expensive than proprietary triclopyr; and three times more expensive than generic triclopyr. Similar cost trends were evident with control at 4 MAT. All glyphosate-based treatments were considerably more expensive than either triclopyr or 2,4-D alone, regardless of whether the cost was based upon proprietary or generic glyphosate. Ability to selectively control poison ivy within grasses is an additional benefit of triclopyr and 2,4-D. Conversely, all glyphosate-based treatments would be nonselective in terms of the plant species controlled.

Our results revealed that triclopyr and 2,4-D applied alone were more cost effective than any glyphosate-based treatment. These results were somewhat surprising because in our area glyphosate-based control is the favored option for poison ivy control. Most inquiries directed to the authors focus only on the merits and trade-offs of glyphosate applied alone vs. the aforementioned mixtures. Typically, neither 2,4-D nor triclopyr alone are considered as viable options. A possible explanation as to why the glyphosate-based mixtures remain popular became evident when the shapes of the response curves were considered. For both evaluations, the response curves of both mixtures had significantly ($P \leq 0.05$) lower slopes than glyphosate alone. Slope values were compared using the lack-of-fit test as described by Seefeldt et al. (1995) and is included within the Prism software. This reduced slope was responsible for low rates of the mixtures frequently being synergistic relative to the components applied alone. But this also means that as rates are decreased below that required for adequate control, the mixtures would tend to provide more visually-evident activity than glyphosate alone. Therefore, under conditions of faulty application and/or weather-compromised applications, the mixtures would tend to appear to be more efficacious than glyphosate alone. Thus unwittingly, the mixtures likely provide some degree of protection against complete failure and applicator dissatisfaction. However, this protection is expensive when the costs of the glyphosate-containing mixtures are compared to either triclopyr or 2,4-D applied alone. Another potential merit of the mixtures is that they challenge the target weed with two different modes of action. Avoidance of treatments with a single mode of action is considered to be effective in delaying and/or preventing the emergence of herbicide resistant biotypes (Gressel and Segal 1982).

Literature Cited

Epstein, W. L. and V. S. Byers. 1981. Poison Oak and Poison Ivy Dermatitis: Prevention and Treatment in Forest Service Work. Missoula, MT: U.S. Forest Service, Equipment Development Center. 13 p.

Gressel, L. and L. A. Segal. 1982. Interrelating factors controlling the rate of appearance of resistance: the outlook for the future. Pages 325–347 *in* H. M. LeBaron and J. Gressel, eds. Herbicide Resistance in Plants. New York, NY: John Wiley and Sons.

Mitich, L. W. 1995. Poison-ivy/poison-oak/poison-sumac—the virulent weeds. Weed Technol. 9:653–656.

Motulsky, H. and A. Christopoulos. 2004. Fitting Models to Biological Data Using Nonlinear Regression. New York: Oxford University Press. 351 p.

Seefeldt, S. S., J. E. Jensen, and E. P. Fuerst. 1995. Log-logistic analysis of herbicide dose-response relationships. Weed Technol. 9:218–227.

Streibig, J. C. and J. E. Jensen. 2000. Actions of herbicides in mixtures. Pages 153–180 *in* A. H. Cobb and R. C. Kirkwood, eds. Herbicides and Their Mechanisms of Action. Boca Raton, FL: CRC Press.

Tallarida, R. J. 2001. Drug synergism: its detection and applications. Perspect. in Pharmacol. 3:865–872.

Wehtje, G., C. H. Gilliam, and S. C. Marble. 2010a. Interaction of prodiamine and flumioxazin for nursery weed control. Weed Technol. 24:504–509.

Wehtje, G., C. H. Gilliam, and S. C. Marble. 2010b. Postemergence weed control with glyphosate plus flumioxazin combinations. Weed Technol. 24:356–360.

Yonce, M. H. and W. A. Skroch. 1989. Control of selected perennial weeds with glyphosate. Weed Sci. 37:360–364.

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