(3)
Weed Technology. 2006. Volume 20:646-650

Burning Nettle, Common Purslane, and Rye Response to a Clove Oil Herbicide [1]

NATHAN S. BOYD and ERIC B. BRENNAN [2]

Abstract: Weed management is often difficult and expensive in organic production systems. Clove oil is an essential oil that functions as a contact herbicide and may provide an additional weed management tool for use on organic farms. Burning nettle, purslane, and rye responses to 5, 10, 20, 40, and 80% v/v clove oil mixture applied in spray volumes of 281 and 468 L/ha were examined. Log-logistic curves were fitted to the nettle and purslane data to determine the herbicide dose required to reduce plant dry weight 50% (GR_{50}) and 90% (GR_{90}). A three-parameter Gaussian curve was fitted to the rye data. The GR_{50} and GR_{90} were largely unaffected by spray volume. Nettle dry weight was reduced by 90% with 12 to 61 L clove oil/ha, whereas 21 to 38 L clove oil/ha were required to reduce purslane biomass to the same level. Rye was not effectively controlled by clove oil. Clove oil controls broadleaf weeds at high concentrations, but its cost makes broadcast applications prohibitive; even in high-value vegetable production systems.
Nomenclature: Burning nettle, *Urtica urens* L. URTUR; purslane, *Portulaca oleracea* L. POROL; rye, *Secale cereale* L. 'Merced'.
Additional index words: Log-logistic, spray volume, contact herbicide, organic.
Abbreviations: GDD, growing degree days; OMRI, organic materials review institute.

INTRODUCTION

Weed control in organic vegetable production systems can be a significant portion of production costs (Tourte et al. 2004). Organic producers rely on cultivation, crop rotation, cover crops, water management, crop competition, flamers, mulches, and other techniques to manage weeds (Gaskell et al. 2000). Botanical pesticides may be used but must not be the primary method of weed control and must be used in a manner that is least toxic and least ecologically disruptive (CCOF 2003). Organically compliant herbicides could potentially play an important role in an integrated weed management system on organic vegetable farms. However, few organically compliant herbicides exist, and even fewer have been tested adequately.

Essential oils are natural plant products that break down quickly in the environment and are generally regarded as safe (Tworkoski 2002). Clove oil is an essential oil that is approved by the organic materials review institute (OMRI) and may be used as a nonselective contact herbicide that disrupts plant cell membranes (Tworkoski 2002). The oil could be applied before planting, in directed sprays between crop plants, or even as a broadcast postemergence treatment in some crop species (Smith 2004).

Weed control with clove oil depends on plant size, spray volume, and clove oil concentration. Ferguson (2004) reported that a 10 or 20% clove oil mixture applied at 76 L/ha achieved inconsistent control, ranging from 10 to 40% versus 100% control with glyphosate. Poor control was attributed to large weed size (some exceeding 10-cm heights) and maturity (some producing seeds). Other authors have reported high efficacy with clove oil. Curran (2004) reported 99% control of pigweed (*Amaranthus* spp.) and velvetleaf (*Abutilon theophrasti* Medicus) with 23 to 47% clove oil mixture in a spray volume of 281 or 12 to 23% clove oil mixture in a spray volume of 562 L/ha on weeds less than 7.6 cm tall. Smith (2004) reported 76 to 93% weed control with 10% clove oil and 97 to 99.5% control with 20% clove oil in a spray volume of 337 L/ha. Smith noted that the best weed control occurred on small weeds with 1 to 2 leaves. Increasing clove oil concentration from 0 to 20% usually increases weed control.

The objectives of this research were to examine the effects of spray volume and a range of clove oil doses on burning nettle, common purslane, and rye.

MATERIALS AND METHODS

Purslane seeds collected from USDA-ARS fields in the previous season and Merced rye were planted and

[1] Received for publication September 26, 2005, and in revised form January 3, 2006.
[2] Postdoctoral Research Agronomist and Research Horticulturalist, USDA-ARS, Salinas, CA, 93905. Corresponding author's E-mail: nboyd@nsac.ca.

grown outdoors in 10.5 by 10.5 by 9-cm pots containing a Chualar loam (fine—loamy, mixed thermic Typic Argixerolls) soil with 1.5% organic matter, 55% sand, 24% silt, and 21% clay. The soil was kept consistently moist with subsurface irrigation. Weeds were thinned to 10 plants per pot. Resident seeds of burning nettle were germinated in the field with sprinkler irrigation and thinned to even densities of 15 plants per 15 by 15-cm quadrat. All treatments were applied in September with a backpack sprayer' equipped with two 8002V5 nozzles with application lines pressurized with CO, at 345 kPa. A clove oil mixture (45% clove oil)[4] was applied in a spray volume of 281 L/ha at 6.4, 12.8, 25.6, 51.2, and 102.4 L ai/ha and also applied in a spray volume of 468 L/ha at 10.7, 21.3, 42.6, 85.3, and 170.6 L ai/ha. These doses represented 0, 5, 10, 20, 40, and 80% v/v clove oil doses. The herbicide spray mix included a humic acid surfactant (0.01% humic acid derived from leonardite)5 at 0.25% (v/v) that passes OMRI and the National Organic Program standards.

Nettle, purslane, and rye seedlings were sprayed at the one to two—leaf, cotyledon to one—leaf, and one-leaf growth stages, respectively. Live weeds were counted 2 wk after herbicide application. The presence of green on any part of the plant constituted a live count. Aboveground biomass of live seedlings were harvested the same day, dried at 65 C for at least 48 h, and weighed to determine dry biomass.

The experimental design was a nested design with five herbicide doses and a control nested within two application volumes with four replicates. The experiment was repeated in time (two iterations—one occurring in early September and the other occurring in late September) for each species. Plant survival presented as percent control was analyzed with the use of PROC GLIMMIX in SASE and Bonferonni-adjusted least-squares means comparisons. Burning nettle, purslane, and rye shoot dry weight (as a percentage of the mean of the nontreated control) were initially subjected to an analysis of variance to detect treatment by experiment interactions. Interactions were significant and thus the percent of the mean of the nontreated control for the shoot dry weight was regressed over the log of herbicide dose for each iteration of the experiment. Dose response curves were calculated with the use of the log-logistic function (Seefeldt et al. 1995):

$$Y = 100/1 + \exp\{b(\log[x] - \log[a])\} \quad [1]$$

where Y is the response (percent of the mean control of the shoot dry weight), a is the dose giving 50% response, x is the herbicide dose, and b is the slope of the line. Greater values of b indicate a greater response of biomass to increasing rates of herbicide. The upper limit of the model was set at 100 and the lower limit at 0. GR_{50} and GR_{90} were calculated in SAS from the regression equations. First-order Taylor series expansions were used to estimate the confidence intervals for the dose estimates. Rye shoot dry weight (as a percentage of the mean of the control) was regressed over the log of herbicide dose with the use of the three-parameter Gaussian model in Sigmaplot7:

$$Y = a * \exp\{-0.5([x - x_o]/b)^2\} \quad [2]$$

Growing degree days (GDD) between the spray and harvest dates were calculated from weather date with the use of the formula:

$$GDD = E([T_{max} + T_{min}1]/2) - 4 \quad [3]$$

where T_{max} is the daily maximum temperature and T_{min} is the daily minimum temperature.

RESULTS AND DISCUSSION

Weed Control. Nettle and purslane control increased with higher clove oil doses at both spray volumes, but rye control was unaffected (Table 1). Forty and ten percent clove oil in spray volumes of 281 and 468 L/ha, respectively, were required to attain significant levels ($P < 0.05$) of nettle control. Twenty percent clove oil in spray volumes of 281 and 468 L/ha was required to obtain significant ($P < 0.05$) levels of purslane control. Clove oil was not effective on rye.

Dose Response Curves. The log-logistic model accurately described the response of nettle and purslane biomass to clove oil dose (Figures 1 and 2). Spray volume had no affect on weed biomass except for one iteration where the nettle GR_{90} was lower at higher volumes. Other authors have reported increased control with higher clove oil concentrations and spray volume (Curran et al. 2005). High spray volume is needed to ensure better cov-

[3] R&D sprayers, 419 Highway 104, Opelousas, LA 70570.

4 MatranTM 2, EcoSmart Technologies, 318 Seaboard Lane, Suite 208, Franklin, TN 37067.

5 Integrate, The Catalyst Product Group, 26201 West Baseline Road, Buckeye, AZ 85326.

[6] SAS, Statistical Analysis System Software, Version 9.1, SAS Institute, Inc., SAS Campus Drive, Cary, NC 27513-2414.

6 Systat Software, Inc., 501 Canal Boulevard, Suite E, Point Richmond, CA 94804-2028.

7 Weather data were collected from the California Irrigation Management Information System (CIMIS) Web site: http://wwwcimis.water.ca.gov/cimis/welcome/jsp.

Table 1. Percent control of burning nettle, purslane, and rye seedlings at two application volumes and five clove oil doses.

Volume	Dose	URTUR	POROL	RYE
281	0	0 c[a]	0 b	0[b]
	5.0	1 c	15 b	1.2
	10.0	38 c	6 b	1.2
	20.0	53 bc	65 a	1.2
	40.0	82 ab	100 a	4.3
	80.0	99 a	92 a	7.3
468	0	0 b	0 b	1.2
	5.0	12 b	33 b	6.2
	10.0	67 a	52 b	0
	20.0	90 a	100 a	1.2
	40.0	100 a	100 a	6.2
	80.0	99 a	100 a	2.5

[a] Within each species and spray volume, values that are followed by the same letters are not significantly different at the $P < 0.05$ level based on Bonferonni-adjusted least-squares means.

[b] Values with no letters are nonsignificant at $P < 0.05$.

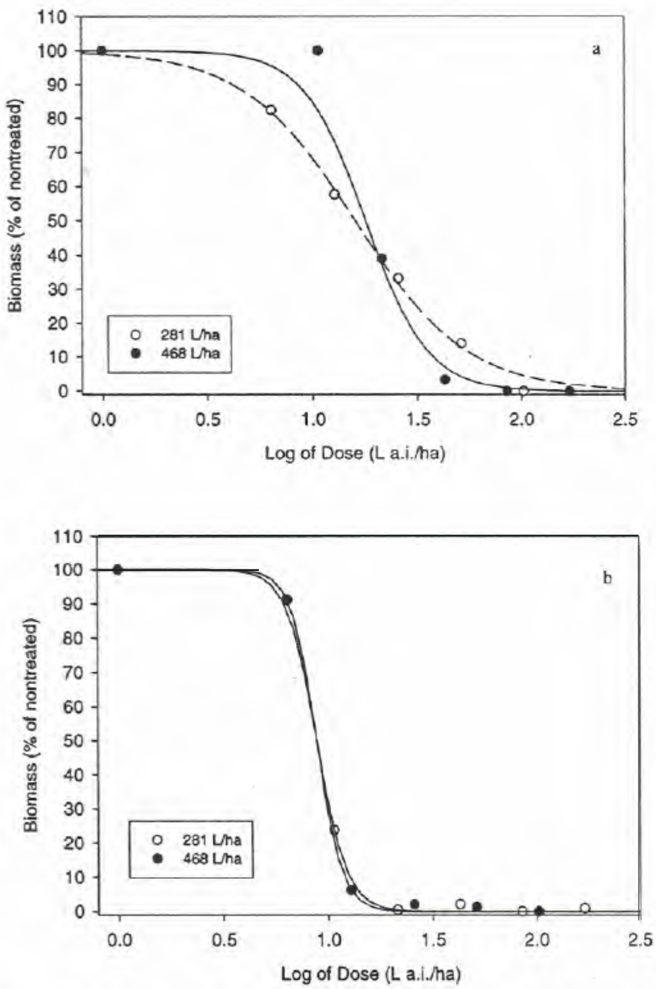

Figure 1. Log-logistic dose response of burning nettle biomass expressed as a percentage of the nontreated control to clove oil at two spray volumes in (a) Iteration 1 and (b) Iteration 2.

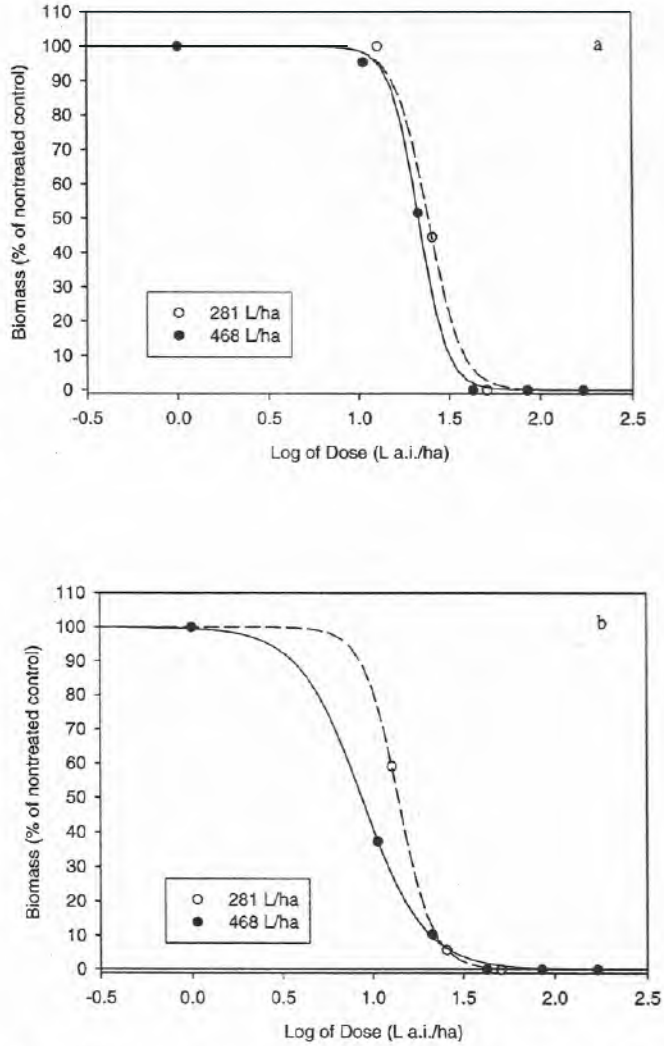

Figure 2. Log-logistic dose response of purslane biomass expressed as a percentage of the nontreated control to clove oil at two spray volumes in (a) Iteration 1 and (b) Iteration 2.

erage and greater damage to the weeds. The size of the weed has a large impact on the effectiveness of clove oil (Ferguson 2004) with the best control of weeds at the one to two-leaf stage (Smith 2004). The effectiveness of spray volume probably increases with plant size and may not have been as effective in our experiment because the seedlings had only one to two leaves.

The GR_{50} and GR_{90} values varied between species and terations of the experiment. The GR_{50} ranged between 9 and 18 L/ha for nettle, and between 9 and 24 L/ha for purslane. Doses required to reduce nettle and purslane biomass by 90% were more variable for Iteration 1 than Iteration 2 (Table 2). The GR_{90} for nettle ranged from 37 to 61 in Iterations 1 and 12 to 13 L/ha in Iteration 2 (Table 2). The GR_{90} for purslane ranged from 31 to 38

Table 2. Estimates of fixed effect parameters and confidence intervals (95% CI) for burning nettle, purslane, and rye at two application volumes and two iterations.

		281 L/ha				468 L/ha			
		Iteration 1		Iteration 2		Iteration 1		Iteration 2	
Species	Parameter	Estimate	CI	Estimate	CI	Estimate	CI	Estimate	CI
URTUR	GR_{50}	16.0	±6.9	8.8	±3.5	17.9	±7.6	8.8	±8.8
	GR_{90}	60.6	±6.3	11.9	±3.5	37.4	±7.7	12.6	±8.7
	b	3.8	±1.9	16.7	±14.1	6.9	±4.2	14.2	±20.0
POROL	GR_{50}	24.3	±4.2	13.9	±3.8	21.5	±4.6	8.7	±3.3
	GR_{90}	38.3	±4.3	22.4	±3.8	31.5	±4.6	20.8	±3.4
	b	11.2	±7.4	10.6	±6.1	13.2	±13.3	5.8	±3.8
Rye	a	125.2	±10.7	156.6	±19.1	114.3	±24.5	110.5	±14.2
	b	1.2	±0.4	0.9	±0.2	1.2	±0.5	1.7	±0.8
	x_0	0.8	±0.2	0.9	±0.1	0.6	±0.4	0.8	±0.4

and 21 to 22 Uha in Runs I and 2, respectively. The greater accumulation of GDD in Iteration 1 versus Iteration 2 in the 2 wk following spraying may have increased plant recovery in Iteration 1 and thus reduced the apparent impact of the clove oil dose (Table 3).

A three-parameter Gaussian curve provided the best fit for the rye data (Figure 3). Clove oil increased biomass production at low concentrations. Clove oil concentrations of 80% in a spray volume of 281 L/ha only reduced rye biomass by 7% in Run 1. Rye growth was reduced by a maximum of 36% with the higher spray volume and a clove oil concentration of 80%. Boyd et al. (unpublished data) found 8 to 64% rye control with 15% clove oil applied with a spray volume of 467 L/ha. Our data show that clove oil is not a viable herbicide for grass weed control, although Curran (2004) reported that high concentrations may reduce some grass weed populations.

Clove oil effectively controls broadleaved weeds when applied at high concentrations but does not effectively control some grass species. It may be used for a variety of purposes on organic farms including the creation of stale seedbeds. Doses of 10 to 40% clove oil are required to obtain maximum weed kill and based on

Table 3. The maximum and average temperatures (C), solar radiation (W/m²) and relative humidity (%) on the spray date and the number of growing degree days (GDD) from spray to harvest.

	URTUR		POROL		Rye	
	Iteration 1	Iteration 2	Iteration 1	Iteration 2	Iteration 1	Iteration 2
Max. temperature	75	69	75	79	75	83
Avg. temperature	16	16	16	16	16	18
Solar radiation	234	197	251	242	251	248
Relative humidity	82	75	83	—	83	62
GDD	200	178	198	183	198	190

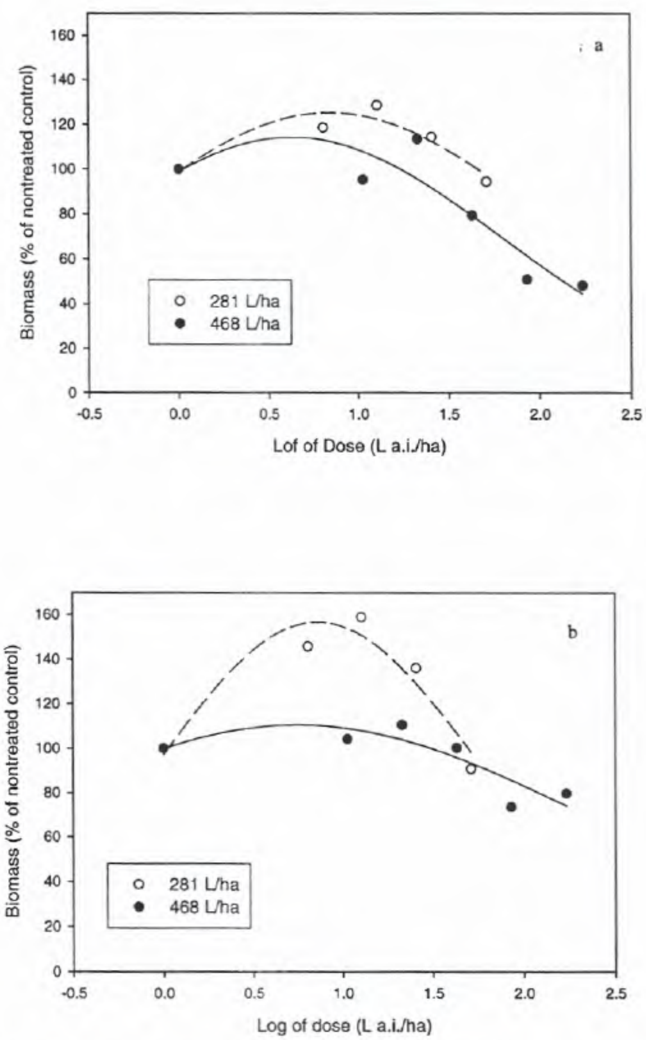

Figure 3. Three-parameter Gaussian dose response of rye biomass expressed as a percentage of the nontreated control to clove oil at two spray volumes in (a) Iteration 1 and (b) Iteration 2.

current prices[9] would cost between $880 and $2,140/ha. Application costs to reduce weed biomass by 90% range between $500 to $2,500/ha for nettle and $880 to $1,600/ha for purslane. The higher application rates should be used to ensure adequate control. The current price of clove oil products will probably prohibit broadcast application, but clove oil may have potential as a directed or spot application treatment in high-value organic vegetables.

ACKNOWLEDGMENTS

We thank Maria Zepeda for her technical assistance. We also thank Richard Smith of the University of California Cooperative Extension in Monterey County for his advice on application rates. Many thanks to Steve Fennimore and John Teasdale for reviewing this article.

[9] The current price of Matran[Tm] 2 is $19.11 per liter in California.

LITERATURE CITED

CCOE 2003. Manual three: CCOF international standards and other standards. Web page: http://www.ccof.org/pdf/CCOFman3.pdf.

Curran, W. S. 2004. The Pennsylvania State University 2004 herbicide field trials. Final Report. Vol. 4. Pp. 200-206. Web page: http://www.weeds.cas.psu.edu/pdf/trials04.pdf.

Curran, W. S., D. D. Lingenfelter, and C. B. Muse. 2005. Effectiveness of vinegar and clove oil for control of annual weeds. WSSA Abstr. 45:16.

Ferguson, J. 2004. Evaluation of organic herbicides. Hortscience 39:876.

Gaskell, M., B. Fouche, S. Koike, T. Lanini, J. Mitchell, and R. Smith. 2000. Organic vegetable production in California—science and practice. HortTechnology 10:699-713.

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

Smith, R. 2004. Post emergence organic weed control in onions and broccoli. Crop Notes. November–December. Pp. 10-12. http://cemonterey.ucdavis.edu/newsletterfiles/newsletter85.htm.

Tourte, L., R. E Smith, K. M. Klonsky, and R. L. DeMoura. 2004. Sample costs to produce organic leaf lettuce. Monterey and Santa Cruz Counties. University of California Cooperative Extension. Web page: http://www.agecon.ucdavis.edu.

Tworkoski, T. 2002. Herbicide effects of essential oils. Weed Sci. 50:425-431_