RURALS: Review of Undergraduate Research in Agricultural and Life Sciences

Volume 3 *RURALS, Volume 3 -- 2008*
Issue 1

Article 2

August 2008

Weed Response to Broadcast Flaming

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Cover Page Footnote
We thank the Propane Education and Research Council and the Nebraska Propane Association for partial financial support of this project.

1. Introduction

Weeds are major problem in both conventional and organic farming throughout the world. In order to reduce yield loss, weeds must be controlled. However, ground and surface water contamination and pesticide residues in food have sparked public awareness of and restrictions on herbicide use (Mojzis and Rifai 1995). For these reasons weed scientists are considering alternative and integrated weed management practices to reduce herbicide inputs and impacts (Rifai *et al.* 2000). There is also an increasing interest in thermal methods of weed control, as they leave no residual effects on soil, water and food quality (Ascard 1998).

The use of propane for flame weeding could be one of the alternative control methods for weed control in both organic and nonorganic systems. During the flaming process, the heat from the flame is transferred to the plant tissues (Lague *et al.* 2000) and results in the coagulation of cell proteins if the temperature reaches above 50 °C (Parish 1990). Furthermore, exposing plant tissue to a temperature of about 100 °C for a split second (e.g., 0.1 second) can result in cell membrane rupture (Pelletier *et al.* 1995; Morelle 1993), resulting in loss of water and plant death (Rifai *et al*. 1996). Plants may survive flaming, either by avoidance or by heat tolerance. The extent to which heat from the flames penetrates plants depends on the flaming technique and leaf surface moisture (Lien *et al*. 1967; Vester 1988; Parish 1990).

Flame weeding is less costly than hand-weeding (Ascard 1990; Nemming 1994) and can be used when the soil is too moist for mechanical weeding. Flaming can also provide added benefits, such as insect and/or disease control (Lague *et al.* 1997). Therefore, the objective of this study was to examine the effect of broadcast flaming on four weed species: velvetleaf (*Abutilon theophrasti*), morningglory (*Ipomoea hederacea*), barnyardgrass (*Echinochloa crus-galli*), and green foxtail (*Setaria viridis*).

2. Materials and Methods

A field experiment was conducted at the Haskell Agricultural Laboratory near Concord, NE (lat 42.37°N, long 96.68°W) on Kennebec series silty clay loam soil (fine-silty mixed, mesic Cumulic Hapludolls). The experimental design was setup as a randomized complete block with six treatments (5 rates of propane and one untreated control) and three replications. Treatments were applied with a custom built flamer mounted on an ATV, which was driven across the weed rows. The flamer used propane as a source for combustion and there were four burners (LT 2 × 8) mounted 30 cm apart (Flame Engineering 2007). Burners were positioned 20 cm above the soil surface and angled back at 30˚. Flaming treatments were applied using a constant speed of about 6 km/h. Propane pressures included: 0, 69, 207, 345, 483 and 620 kPa, corresponding to 0, 10, 30, 50, 70 and 90 PSI. Combining pressure and speed, the rates of propane applied were: 0, 12, 31, 50, 68 and 87 kg/ha.

The experimental site was cultivated on August 10, 2007. Plots (2.1 m wide × 3.8 m long) were sown to grass and broadleaf species on August 16 in parallel lines using push-planter, as a single row for each species in 40 cm row spacing. Each replication had a row of each weed species and the treatments were applied across the rows. The investigated weed species were: barnyardgrass, green foxtail, velvetleaf, and morningglory. The emergence dates for the weeds were August 20 for morningglory and August 24 for barnyardgrass, green foxtail and velvetleaf. Flaming was done on September 9, which corresponded to the V3 stage (5 cm tall) in barnyardgrass, V4 stage (6 cm tall) in green foxtail, V5 stage (8 cm tall) in velvetleaf and V4 stage (11 cm tall) in morningglory. The weather conditions were: wind speed of 11 km/h (direction NNW), air and soil temperatures of 22 °C, and relative humidity of 46%.

Visual control was rated at 1, 7 and 14 days after treatment (DAT) using a scale of 0 (no weed injury based on untreated plots) to 100 (plant death). In addition to visual ratings, biomass samples were taken at 14 DAT by clipping one linear meter of each weed species from each of the treated plots. Samples were dried at 50 °C and dry matter (DM) was determined. Plant DM was expressed on a relative scale from 0 to 100, as a percentage of untreated plants.

Visual estimations and biomass data were analyzed for each rating date utilizing a log-logistic function (Knezevic *et al.* 2007):

$$Y = C + \{D - C / 1 + \exp[B(\log X - \log E)]\} \quad [1]$$

Where *Y* is the response (e.g., visual quality), *C* is the lower limit, *D* is the upper limit, *B* is the slope of the line, *X* is the propane dose and *E* is the dose giving a 50% visual damage (also known as ED_{50}). Curve fitting was done by non-linear regression using the least square method. All statistical analysis and graphs were performed with R program (R Development Core Team 2006) utilizing the Dose Response Curves (*drc*) statistical addition package (Knezevic *et al.* 2007). The values of ED_{80} (effective dose that provided 80% control) and ED_{90} (90% control) were determined from the curves and used as measures of the level of weed control by flaming treatments.

3. Results and Discussion

Weed control:

Based on visual ratings, grass weeds showed more tolerance to propane flaming than broadleaf species, thus requiring higher doses to provide the same level of weed control (Figure 1). At 14 DAT, about 90% control of velvetleaf and morningglory was achieved with 26 and 25 kg/ha of propane, respectively, compared to much higher rates of 55 kg/ha for barnyardgrass and 36 kg/ha in green foxtail (Table 1). There was no difference in the amount of propane needed to obtain similar level of control of both broadleaf species we studied. That was true for both the 80% and 90% control levels (Table 1).

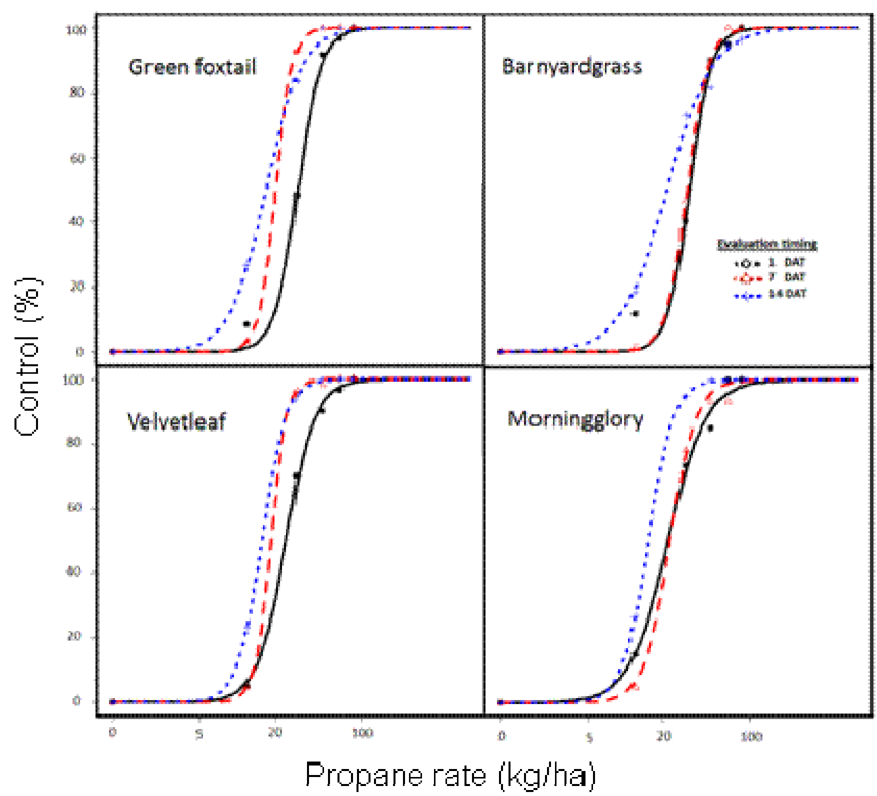

Figure 1. Weed control as influenced by propane dose based on visual injury ratings from 1 DAT to 14 DAT. Each data point represents a mean of 3 replications. Data was fitted to log-logistic equations with four parameters.

Table 1. Regression parameters (equation 1) for each weed species and propane doses (kg/ha) that provided 80 and 90% weed control (± SE) based on the visual ratings at 1, 7 and 14 DAT (Figure 1).

Weed species	DAT	[a]B	[b]D	[c]ED_{50}	ED_{80}	ED_{90}
				---------kg/ha ± SE-----------		
Barnyardgrass						
	1	-4.5	99	30 ± 3	44 ± 5	52 ± 8
	7	-3.9	102	29 ± 2	42 ± 4	49 ± 7
	14	-1.6	103	17 ± 6	39 ± 6	55 ± 12
Green foxtail						
	1	-4.4	100	29 ± 2	42 ± 4	50 ± 7
	7	-4.1	100	16 ± 4	25 ± 4	29 ± 4
	14	-2.0	104	14 ± 3	27 ± 6	36 ± 5
Velvetleaf						
	1	-2.2	104	21 ± 2	36 ± 3	45 ± 5
	7	-4.9	100	15 ± 4	23 ± 4	26 ± 6
	14	-3.5	100	14 ± 2	22 ± 3	26 ± 3
Morningglory						
	1	-1.7	108	18 ± 2	36 ± 2	48 ± 4
	7	-2.8	98	18 ± 2	32 ± 2	39 ± 3
	14	-3.4	100	14 ± 2	21 ± 2	25 ± 2

[a]B, the slope of the line
[b]D, the upper limit
[c]ED_{50}, the dose giving a 50% visual damage

The tolerance level to flaming also varied between the two grass species. Barnyardgrass was more tolerant to flaming than green foxtail; a 90% control of barnyardgrass was obtained with 55 kg/ha rate compared to 36 kg/ha in green foxtail at 14 DAT (Table 1). In fact, barnyardgrass was the most tolerant to flaming of all species studied. At 14 DAT, 55 kg/ha of propane provided 90% visual damage in barnyardgrass compared to 36, 26 and 25 kg/ha in green foxtail, velvetleaf and morningglory, respectively.

Biomass reduction:

In general, the ED values calculated from dose response curves based on visual ratings should not be significantly different from the ED values calculated from dose response curves based on plant DM, or relative DM (Knezevic *et al.* 2007). However, that was not the case in this study. More propane was needed to obtain a 90% DM reduction in morningglory compared to the other species (Figure 2), which is different from the ED values based on visual rating (Table 1). A propane rate of 41 kg/ha was required to obtain 90% DM reduction in morningglory at 14 DAT compared to 36, 20 and 24 kg/ha for barnyardgrass, green foxtail and velvetleaf, respectively (Table 2). These results were in contrast with the visual control findings where grass species were more tolerant to broadcast flaming. It is likely result from a larger biomass loss in grass species due to the burning of physically smaller grass compared to the larger broadleaves. For this reason, the relative DM of grass weeds was lower than the broadleaves. Biomass of moringglory treated with the highest propane rate remained intact at the time of harvest even though the plant was dead (Table 2). As a result, dose-response curves based on DM showed higher ED values for morningglory compared to grass species, which is misleading. It is also interesting to note that during final harvest in plots treated with the highest propane rates, there was a new re-growth occurring from the grass species, but there was no re-growth from the broadleaf weeds suggesting again that grass species were more tolerant to broadcast flaming. This re-growth was from their growing points, which were located below soil surface at the time of flaming, thus protected from the flame.

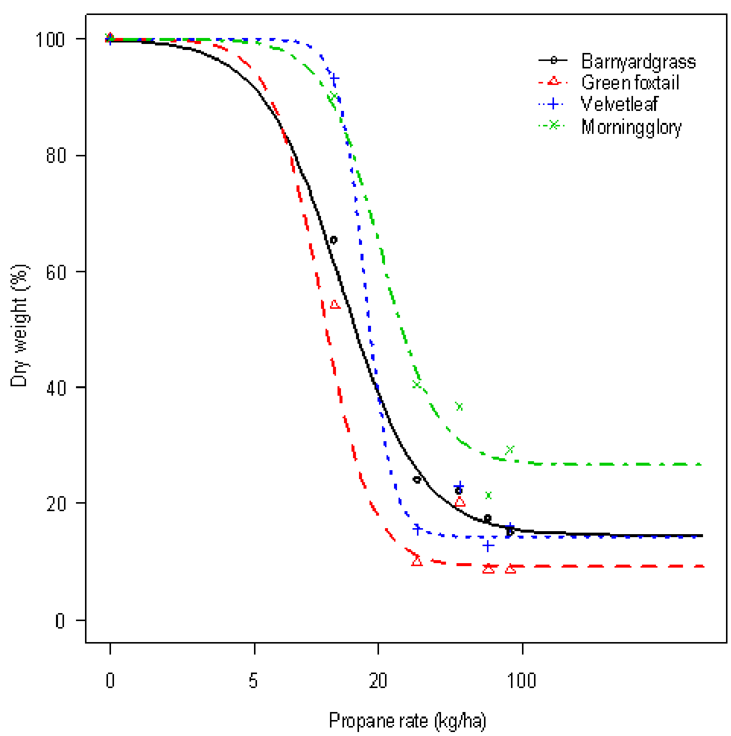

Figure 2. Dry matter (% of untreated) as influenced by the propane dose at 14 DAT. Each data point represents a mean of 3 replications. Data was fitted to log-logistic equations with four parameters.

Table 2. Regression parameters (equation 1) for each weed species and dose of propane (kg/ha) needed to obtain 80 and 90% weed control (± SE) based on dry matter reduction at 14 DAT (Figure 2).

Weed species	[a]B	[b]C	[c]ED_{50}	ED_{80}	ED_{90}
			---------kg/ha ± SE-----------		
Barnyardgrass	2.2	15	13 ± 3	24.7 ± 11	35.4 ± 23
Green foxtail	3.6	9	11 ± 3	15.6 ± 5	19.5 ± 13
Velvetleaf	6.6	14	17 ± 7	21.3 ± 10	24.1 ± 14
Morningglory	3.2	27	21 ± 6	31.7 ± 11	40.8 ± 20

[a]B, the slope of the line
[b]C, the lower limit
[c]ED_{50}, the dose giving a 50% visual damage

Table 3. Results of the regression analysis of injury rating against dry matter content for 4 weed species 14 DAT.

Weed species	Slope (± SE)	Intercept (± SE)	R^2	P value
Barnyardgrass	- 1.1 (0.1)	107 (6.2)	0.84	< 0.001
Green foxtail	- 0.86 (0.2)	97 (8.3)	0.64	< 0.001
Velvetleaf	- 0. 96 (0.1)	114 (6.8)	0.80	< 0.001
Morningglory	- 1.2 (0.1)	137 (7.7)	0.87	< 0.001

There was a strong correlation between visual injury rating and DM for the barnyardgrass, velvetleaf, and morningglory 14 DAT (Table 3). However, the correlation between for the green foxtail was not as strong as with the other species. In general, the correlation slope for all the weed species was close to 1 suggesting that the results obtained using visual injury rating in most of the cases were similar to DM 14 DAT.

Wszelaki *et al.* (2007) suggested that grasses were more tolerant to flaming than broadleaf species. Ascard (1994) reported that plant size had greater influence upon sensitivity than plant density, with small weeds being more sensitive than large weeds. Ascard (1995) also reported that grass species flamed at early growth stages exhibited initial plant stunting followed by plant recovery over a few week period. That was a result of growing point being protected below soil surface at the time of flaming (Ascard 1995), which we believe had happened in our study.

4. Conclusions

Unlike the broadleaf species, the growing points of grass species remained undisturbed below the soil surface at the time of flaming. Hence, grass species were more tolerant to propane flaming than broadleaf species. The sensitivity of grass to flaming also varied between the species, with barnyardgrass being more tolerant than green foxtail. Based on one year study, the results suggest that broadcast flaming may be used to effectively control both grass and broadleaf weeds. Teixeira *et al.* (2008) also reported that broadcast flaming has potential for use in field crops, especially in corn (*Zea mays*). In previous studies, temporary corn injury of as much as 20% was evident with propane rate of 46 kg/ha. However, such rate was highly efficient in weed control, providing as much as 90% control of broadleaf weeds, including velvetleaf and redroot pigweed (*Amaranthus retroflexus*) (Knezevic and Ulloa 2007).

More research is needed on flaming weeds and crops at various growth stages, including burner heights in relation to weed and crop growth stages, burner angle, intra-row and inter-row flaming. We believe that flaming has a potential to be included into an integrated weed management of both conventional and organic production systems. It might be repeated as needed during the growing season, or integrated with other chemical or non-chemical weed management strategies.

Acknowledgments

We thank the Propane Education and Research Council and the Nebraska Propane Association for partial financial support of this project.

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Author Biographies

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