Effects of 2,4-D with and without wiper-applied glyphosate on leafy spurge *(Euphorbia esula)* treated-shoot, shoot regrowth, and root biomass

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Introduction

Leafy spurge (*Euphorbia esula* L.) is a perennial broadleaf weed that inhabits various disturbed habitats, especially pasture and rangelands (Lym 1998). Management efforts need to be intensive and extensive since leafy spurge can spread through seeds and by underground root growth that emerge as additional plants (Lym 1998; Morrow 1979). Therefore, simply killing plants to prevent seed production will probably not be effective (Wicks and Derscheid 1964). Few herbicides applied alone are effective on leafy spurge; effective herbicides include aminocyclopyrachlor (Method; Herbicide Group 4), imazapic (Plateau; Herbicide Group 2) and picloram (Tordon; Herbicide Group 4) (Lym 2014; Markle and Lym 2001). 2,4-D (Herbicide Group 4) is not effective alone to manage leafy spurge, but previous research has shown that the addition of 2,4-D in combination with other herbicides can additively increase the effectiveness (Al-Henaid et al. 1993; Gylling and Arnold 1985; Lym 2000) (Figure 1).

Glyphosate (Roundup; Herbicide Group 9) is a nonselective herbicide that controls a wide spectrum of weed species. Due to non-selectivity, this herbicide is rarely applied in pasture or rangeland due to concern of suppressing or killing desirable grasses and forbs. Additionally, glyphosate applied alone is not recommended for leafy spurge management as the herbicide results in molecular changes that can also induce additional root and shoot growth when applied alone (Doğramacı et al. 2014; Doğramacı et al. 2016; Maxwell et al. 1987). Mixing glyphosate and 2,4-D can be effective for leafy spurge management, but desirable vegetation is injured or killed during broadcast sprays which can contribute to economic and ecosystem services losses (Gylling and Arnold 1985). Wiper-applied herbicide applications are utilized to selectively manage weeds and allow for higher herbicide concentrations to be applied in grassland settings while reducing off-target injury to desirable vegetation (Grekul et al. 2005; Leif and Oelke 1990).

Figure 1. Nontreated (left) and 2,4-D-treated (right) leafy spurge plants 21 days after application. The 2,4-D-treated vegetation has died but substantial new regrowth is present.

Wiper-applied glyphosate has effectively managed Canada thistle (*Cirsium arvense* L.) in sensitive areas containing desirable vegetation (Krueger-Mangold et al. 2002). Since the desirable vegetation is uninjured, the plants can still be competitive with later emerging weeds (Lamb et al. 2024).

Despite lack of effectiveness of the broadcast glyphosate application on leafy spurge, the greater herbicide concentrations associated with a wiper application as a follow up to a broadcast application of an herbicide could increase the longevity of management. Since 2,4-D effectiveness is largely dependent on being mixed with another herbicide, glyphosate could be sequentially applied with a wiper to manage leafy spurge. The objective of this research was to determine leafy spurge biomass reductions, including treated shoots, and shoot and root regrowth resulting from broadcast application of 2,4-D alone and in combination with sequential wiper-applied glyphosate at various labeled concentrations.

Materials and methods

Plant establishment

Leafy spurge plants were collected from a field site located at South Dakota State University in Brookings County, South Dakota in mid-June 2024. Plants were selected if yellow bracts were present and approximately 16 inches in height. Plants were carefully dug and transplanted into an 8-inch pot containing an equal mixture of Miracle-Gro® (The Scotts Company LLC, Marysville, OH, USA) and field soil from the weed collection site. Plants were maintained outdoors under realized temperatures (average temperature: 77°F day/60°F night) and photoperiod (15 hr day/9 hr night) for the duration of the 4 month study. Pots were watered to saturation daily for two weeks. Watering of pots to saturation thereafter occurred approximately every 2 days for the duration of the study.

Broadcast and Wiper application

Treatments were arranged as a randomized complete block design with three replications. The experiment was conducted twice where the plant collection and run initiation was separated by one week. After the plants were acclimated for 2 weeks, plants were treated (excluding non-treated controls) with 2,4-D ester (Weedone® LV4 Solventless [Nufarm, Cary, NC, USA; 3.84 pounds acid equivalent per gallon) applied at a rate of 2 quarts per acre. 2,4-D was applied using a CO2-powered backpack sprayer at an output of 20 gallons per acre using Turbo TeeJet® 8003 (TeeJet Technologies, Wheaton, IL, USA) nozzles 20 inches above the target plant. Leafy spurge plants were treated at approximately 16 inches in height and yellow bracts were present. The wiper-applied glyphosate treatments occurred 24 hrs following the initial 2,4-D application. This delay was implemented to ensure the applied 2,4-D was absorbed into the plant and not transferred onto the wiper. The wiper applicator was positioned approximately halfway up the plant (8 inches) to simulate an application of herbicide above desirable vegetation growth height. The upper portion of the plant was treated-to-wet, but not to where herbicide was running off the plants. The frame of the wiper applicator was constructed with PVC pipes and a schematic is provided in Figure 2. Two cotton ropes attached to the PVC frame acted as the wiper. The glyphosate (Roundup® Powermax 3, Bayer Cropscience, St. Louis, MO, USA; 5.88 pounds acid equivalent per gallon) concentrations included were 0 (no glyphosate), 33, 50, and 75%, where the various concentrate dilutions were achieved by mixing glyphosate with distilled water. These concentrations were selected based on the herbicide label. Separate wiper applicators were constructed for each glyphosate concentration tested. The wiper frames were disassembled prior to treatment and the wiper was submerged in a 10 fl oz solution of the respective concentrations until saturation.

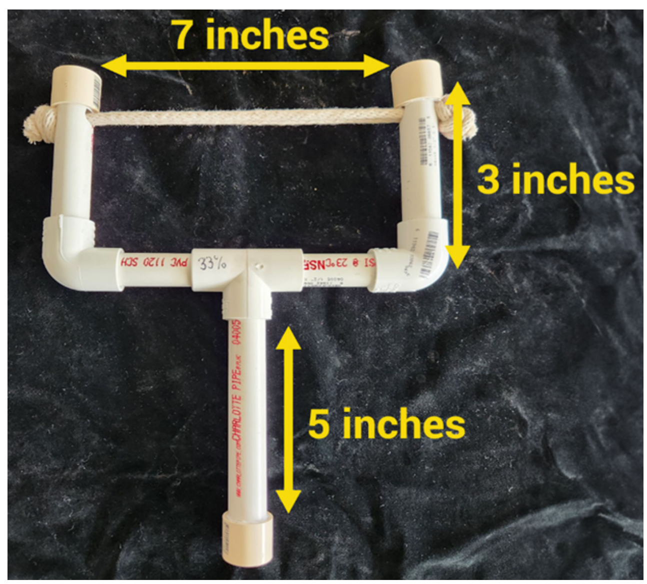

Figure 2. Wiper applicator schematic for the experiment.

Injury to leafy spurge was estimated 21 days after the 2,4-D treatment using a rating scale ranging from 0 to 100%; where 0 equals no injury observed and 100 equals plant death. After the injury evaluations, plants were cut at the surface of the potting media and oven-dried at 120°F for 48 hrs. All plant samples were then weighed to collect the dry biomass of the treated shoots. Pots were maintained as described above for an additional 3 months after 2,4-D treatment.

Shoot regrowth was collected, dried and weighed as described above. After shoot regrowth was collected, pots were not watered for 1 week to dehydrate the soil. Roots were extracted from the dried potting media and additional potting media was cleaned from the roots via a water rinse. Roots were subsequently dried and weighed as described above. Dry biomass reduction for the treated shoot (21 days after treatment), shoot regrowth (3 months after treatment), and roots (3 months after treatment) was calculated by dividing the dry biomass of the treated plants by dry biomass of the nontreated plants.

Statistical analysis

Glyphosate concentration–response curves for dry biomass reductions of shoot, shoot regrowth, and root were fit with a three-parameter log-logistic equation. These nonlinear regression models were utilized to determine how leafy spurge plants respond to the various concentrations of wiper-applied glyphosate when broadcast treated with 2,4-D. The GR_{50} (concentration to reduce biomass by 50%) and GR_{90} (concentration to reduce biomass by 90%) values were derived from the equations for treated shoot, shoot regrowth, and root biomass. While the logistic equation is not discussed in detail within this fact sheet, the parameters are provided in Table 1.

Results and Discussion

Treated Shoot biomass injury and biomass

Injury estimates were approximately 94% for all treatments and therefore the response across the tested concentrations could not be modeled (Figure 3). All herbicide-treated shoot biomass ranged from 60 to 120% of nontreated plants on average (Figure 4). These results suggest that 2,4-D applied alone as broadcast, or in combination with wiper-applied glyphosate, does provide greater than 90% injury but no shoot biomass reduction on leafy spurge within 21 DAT.

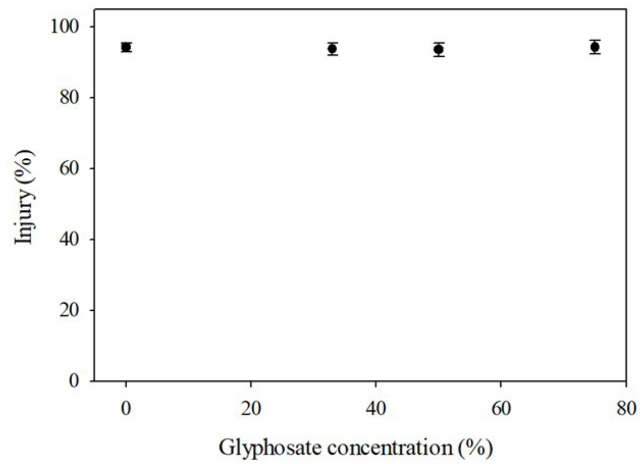

Figure 3. Injury estimates for leafy spurge treated with 2,4-D ester (0%) and the addition of various concentrations of wiper-applied glyphosate 21 days after treatment. Injury estimates could not be modeled across glyphosate concentrations due to a lack of differential response. The injury estimates of nontreated plants are not included. Error bars represent the standard error of the mean.

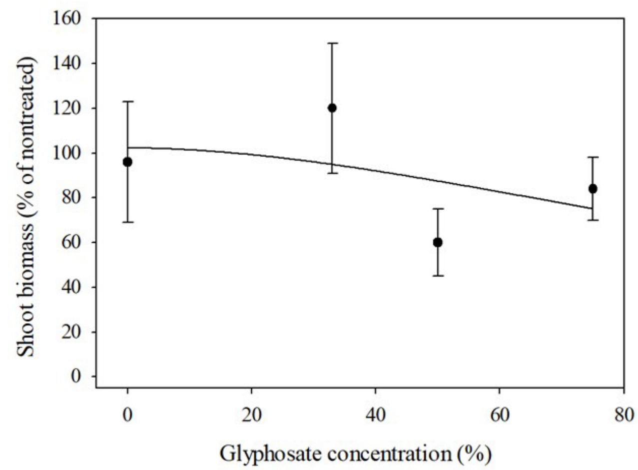

Figure 4. Concentration-response curve fit to a three-parameter log-logistic equation for shoot biomass of leafy spurge treated with 2,4-D and the addition of various concentrations of wiper-applied glyphosate 21 days after treatment. Error bars represent the standard error of the mean.

Table 1. Parameter estimates from the three-parameter log-logistic equations for biomass of treated-shoots, shoot regrowth, and roots[a].

	Regression parameters[b]					
	a	*x0*	*b*	GR_{50}	GR_{90}	r^2
Shoot	102.3	129.4	1.9	129[c]	NA	0.2
Shoot regrowth	560	6.1	2.6	6	28	0.99
Root	160	7.6	0.5	8	NA	0.99

[a] Abbreviations: GR50, concentration (% diluted concentrate) to reduce biomass by 50%; GR90, concentration to reduce biomass by 90%; NA, not achieved.
[b] a is the upper asymptote, x0 equals the GR50, and b is the slope at x0.
[c] The GR50 value is not achievable and therefore should not be considered reliable.

Shoot regrowth biomass

When only treated with 2,4-D, leafy spurge shoot regrowth biomass was approximately 560% of the biomass of nontreated plants (Figure 5). When a glyphosate wiper application followed the 2,4-D application, leafy spurge shoot regrowth was <10% of the biomass of nontreated plants. This high-level of control was achieved regardless of the glyphosate concentration (Figures 5 and 6). The GR_{50} and GR_{90} values for shoot regrowth were glyphosate concentrations of 7 and 28%, respectively. (Figure 5; Table 1). These results suggest that wiper-applied glyphosate, even when diluted to 33% of the mixture, can significantly reduce leafy spurge regrowth following a 2,4-D broadcast application (Figure 6).

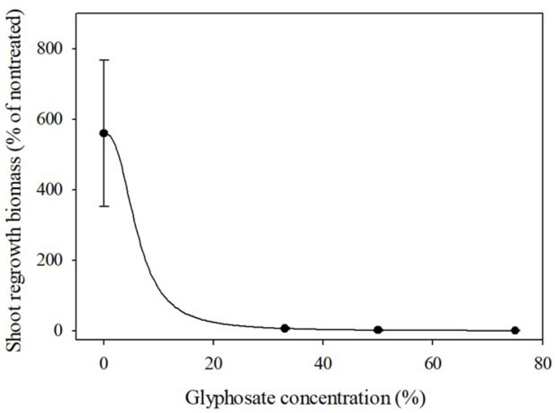

Figure 5. Concentration-response curve fit to a three-parameter log-logistic equation for shoot regrowth biomass of leafy spurge treated with 2,4-D and the addition of various concentrations of wiper-applied glyphosate 3 months after treatment. Error bars represent the standard error of the mean.

Figure 6. Visual representation of shoot regrowth of leafy spurge that were nontreated (A), 2,4-D-treated (B), and 2,4-D followed by 33% glyphosate wiper-applied (C) 3 months after treatment. 2,4-D followed by 50 and 75% glyphosate wiper-applied are not shown as no regrowth occurred.

Root biomass

Similar to shoots, when 2,4-D was applied alone, the biomass of roots increased. This increase was approximately160% greater than the nontreated plants. When 2,4-D was followed by a glyphosate wiper application, leafy spurge root biomass was only 35 to 49% of the root biomass of nontreated plants (Figures 7 and 8). The GR_{50} value was a glyphosate concentration of 8%, while a GR_{90} value could not be calculated due to a lack of root biomass reductions (Figure 7; Table 1).

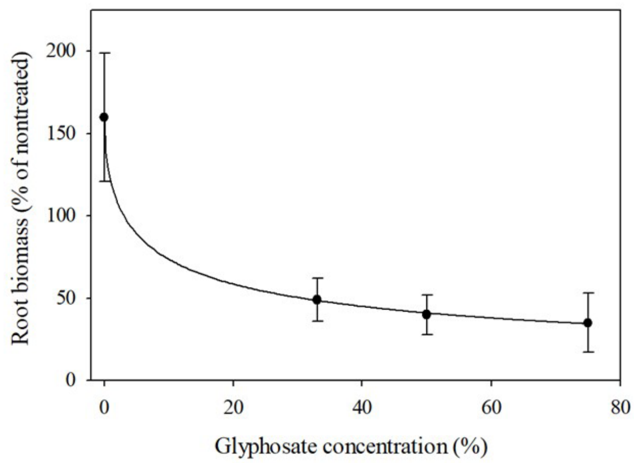

Figure 7. Concentration-response curve fit to a three-parameter log-logistic equation for root biomass of leafy spurge treated with 2,4-D and the addition of various concentrations of wiper-applied glyphosate 3 months after treatment. Error bars represent the standard error of the mean.

Figure 8. Visual representation of root biomass of leafy spurge that were nontreated (A), 2,4-D-treated (B), 2,4-D followed by 33% (C), 50% (D), and 75% (E) glyphosate wiper-applied 3 months after treatment.

Conclusion

Single applications of 2,4-D significantly injured leafy spurge, but biomass reductions were not evident 21 days after treatment. However, at 3 months after application, 2,4-D applied alone increased shoot and root regrowth that exceed the biomass of nontreated plants. Adding a glyphosate wiper application on the day following the 2,4-D application helped improve leafy spurge management. Since the various concentrations of glyphosate tested in this trial (33, 50, and 75%) resulted in similar shoot regrowth and root biomass reductions, land managers can utilize the lower concentration (33%) to decrease costs and the amount of herbicide entering the environment. Higher concentrations (50 and 75%) may warrant use where infestations are dense, and plants are larger (>16 inches). Glyphosate provides an additional herbicide that is rarely used in pasture/rangeland settings or around sensitive sites for targeted weed management (Gylling and Arnold 1985; Krueger-Mangold et al. 2002). Since the wiper provides a means of selective control with a non-selective herbicide, the leafy spurge plants are managed without injuring or killing desirable vegetation and serves to promote desirable vegetation competition, species richness, and increased land value (Krueger-Mangold et al. 2002; Lamb et al. 2024). While a 2,4-D broadcast application followed by wiper-applied glyphosate was effective in managing leafy spurge in this experiment, this program is likely more feasible to manage small patches to cease the spread rather than a large acre treatment. More research is needed to determine the effectiveness of this herbicide program on established stands of leafy spurge.

Acknowledgements

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