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Purple Loosestrife (*Lythrum salicaria*) Control with Herbicides: Single-Year Application[1]

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Abstract: The introduction and spread of exotic plant species is one of the most serious threats to biodiversity. It is estimated that over 40 million ha of U.S. land are already infested with invasive plants. Purple loosestrife is one such species that is currently invading wetlands and waterways in Midwestern states including 5,000 ha in Nebraska. Field studies were conducted in 2000 and 2001 at two locations in each year with the primary objective to evaluate performance of a single application of 16 herbicide treatments. A secondary objective was to document the impact of those herbicides on the total ground cover of local vegetation for two seasons after herbicide application. Evaluation at 10 wk after treatment showed that excellent season-long control (≥90%) of purple loosestrife was achieved with glyphosate at 3.36 kg ae/ha; 2,4-D dimethylamine at 2.66 kg ae/ha; triclopyr at 2.1 kg ae/ha; imazapyr at 1.68 kg ae/ha; and with the two mixtures of 2,4-D plus triclopyr at 1.33 + 1.26 kg/ha and 2,4-D plus metsulfuron at 1.33 ae/ha + 0.042 kg ai/ha. Evaluation at 1 yr after treatment (YAT) showed excellent control (≥90%), with imazapyr at 0.33, 0.66, 1.12, and 1.68 kg/ha and metsulfuron at 0.084 and 0.168 kg/ha. Evaluation at 2 YAT suggested that excellent control (≥90%) was achieved with imazapyr at 1.12 and 1.68 kg/ha and metsulfuron at 0.084 and 0.168 kg/ha. High rates of imazapyr caused negative effects on the local vegetation, indicating that use of these rates should be limited. Results suggest that a single application of more than half of the tested herbicides did not provide satisfactory control of purple loosestrife that lasts more than two seasons. However, the selective herbicides integrated with other control methods (e.g., mechanical, biocontrol) may be a valuable strategy for longer term control. Further studies are needed to evaluate the long-term effects of multiyear herbicide applications.

Nomenclature: 2,4-D; glyphosate; imazapyr; metsulfuron; triclopyr; purple loosestrife, *Lythrum salicaria* L. #[3] LYTSA.

Additional index words: Integrated weed management, invasive species, noxious weeds.

Abbreviations: WAT, weeks after treatment; YAT, years after treatment.

INTRODUCTION

The introduction and spread of exotic plant species is one of the most serious threats to biodiversity. It is estimated that over 40 million ha of U.S. land are already infested with invasive plants. Approximately 1.2 million ha are infested with various invasive plants each year, with an estimated economic impact of US$123 billion per year (Balogh 1986; Mullin 2000). Purple loosestrife is one perennial species that is currently invading wetlands and waterways in Midwestern states including Nebraska. Our survey from 2001 suggested that about 5,000 ha of Nebraska's wetlands are infested with this species, mostly along the main rivers and waterways (Knezevic 2003). Purple loosestrife was introduced from Euro-Asia in the late 1800s; it has no natural enemies in North America, and therefore its spread is hard to stop (Mullin 1998). The biggest challenge in Nebraska is to stop the spread of the current infestations (Knezevic 2003). It was indicated that a single management tactic cannot provide long-term, sustainable control of this weed (Thompson et al. 1987). Therefore, an integrated approach based on several control practices integrated in

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[3] Letters following this symbol are a WSSA-approved computer code available from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th street, Lawrence, KS 66044-8897.

a systematic manner is needed. An integrated management approach includes use of a variety of mechanical, cultural, biological, and chemical control methods (Knezevic 2003; Knezevic and Smith 2001).

Using herbicides integrated with other control methods can be a very effective strategy for site-specific management of this perennial weed. However, herbicide use in wetland habitats has been criticized for having potential detrimental effects on nontarget wetland plants and aquatic invertebrates (Skinner et al. 2000). We suggest that herbicides are a necessary part of an integrated approach to stop the expansion of currently infested hectares, especially considering the fact that biocontrol agents are very slow in achieving desired control (Knezevic and Smith 2001; J. Corrigan, personal communication). Herbicides can be used along roadsides, rights of ways, and ditches, which are common corridors for purple loosestrife spread (Wilcox 1989). In reality, the goal is to manage purple loosestrife because complete eradication is likely not possible (Mullin 1998). Therefore, the primary objective of this study was to evaluate efficacy of a single application of selected postemergence herbicides for purple loosestrife control for a 3-yr period. The secondary objective was to describe the impact of those herbicides on the total ground cover of local vegetation for two seasons after herbicide application.

MATERIALS AND METHODS

Site Description. Field experiments were conducted at four sites in Nebraska. In 2000, the sites were along the Missouri River near Newcastle (Dixon county) and along the Niobrara River near Atkinson (Holt county). In 2001, the sites were along the Platte River near Kearney (Buffalo county) and along the Niobrara River north of Johnstown (Brown county). The selected sites were part of a larger wetland habitat that was under standing water for at least 2 to 3 mo of the season (March to May). Sites had been known to be infested with purple loosestrife 3 to 5 yr before the initiation of these experiments, with infestations levels (percent ground cover) ranging from 80 to 95% depending on the site.

In addition to the presence of purple loosestrife, other commonly found species within the sites were American germander, *Teucrium canadense* L. # TEUCA; partridge pea, *Cassia fasciculata* Michx. # CASFA; yellow sweet clover, *Melilotus officinalis* (L.) Lam. # MEUOF; yellow nutsedge, *Cyperus esculentus* L. # CYPES; common cattail, *Typha latifolia* L. # TYHLA; river bulrush, *Scirpus fluviatilis* (Torr.) Gray # SCPFV; hoary vervain, *Verbena stricta* Vent. # VEBST; reed canarygrass, *Phalaris arundinacea* L. # TYPAR; green foxtail, *Setaria viridis* (L.) Beauv. # SETVI; common waterhemp, *Amaranthus rubis* Sauer. # AMATA; curly dock, *Rumex crispus* L. # RUMCR; and smooth brome, *Bromus inermis* Leyss. # BROIN. These species represent local vegetation present at the sites in the beginning of the experiments or resulting from secondary succession attributed to the selective nature of the herbicides used. All four sites had soils containing >70% sand. The aboveground water level ranged from 30 cm of water depth during the March to May period to none for the rest of the year. The underground water table across all sites was within 50 cm of the soil surface.

Monthly rainfall from April to October varied in total amount between years and locations. Total rainfall was less than the 30-yr average in 2000 but greater in 2001. For example, in 2000 there was 373 and 263 mm rainfall compared with 30-yr averages of 472 and 443 mm for the Newcastle and Atkinson sites, respectively. In 2001, there was 526 and 430 mm compared with 30-yr averages of 474 and 420 mm for the Kearney and Johnstown sites, respectively. Average daily temperatures for the 3-yr study were similar to the 30-yr averages. For example, in 2000, the daily average temperatures at Newcastle for June, July, and August were 20, 23, and 25 C compared with 30-yr averages of 21, 25, and 23 C, respectively. Similar temperatures were observed at other locations.

Experimental Design. The experiments were established as a randomized complete block design with 17 treatments, including a nontreated control, with four replications (Table 1). Each plot was 10 m long and 2 m wide. The treatments were glyphosate at 2.24 and 3.36 kg/ha; 2,4-D dimethylamine at 1.33 and 2.66 kg/ha; triclopyr at 1.26 and 2.1 kg/ha; imazapyr at 0.33, 0.66, 1.12, and 1.68 kg/ha; metsulfuron at 0.084 and 0.168 kg/ha; fosamine at 13.44 and 22.4 kg/ha; and triclopyr at 1.26 plus 2,4-D amine at 1.33 kg/ha, and metsulfuron at 0.042 kg/ha plus 2,4-D amine at 1.33 kg/ha. Herbicides were applied when at least 50% of purple loosestrife plants were blooming, which was approximately the third week of June. Application at this time facilitates identification of plants (purple flowers) by landowners or herbicide applicators. Furthermore, perennial plants are very vulnerable to chemical control during flowering. Herbicide solutions were applied using a backpack sprayer pressurized with CO_2 at a total solution volume rate of 200 L/ha. Lower spray volumes (<100 L/ha) have been less effective in previous research (Katovich et al. 1996) and were not examined in this study. Weath-

Table 1. Purple loosestrife control with time resulting from selected treatments: means of 2 yr and two locations in Nebraska.[a]

Herbicide	Rate[b]	Purple loosestrife control 10 WAT	1 YAT	2 YAT
	(kg ae/ha)	%		
Glyphosate	2.24	85	80	70
Glyphosate	3.36	95	85	75
2,4-D dimethylamine	1.33	75	40	25
2,4-D dimethylamine	2.66	90	60	40
Triclopyr	1.26	78	45	30
Triclopyr	2.10	90	60	46
Imazapyr	0.33	75	93	40
Imazapyr	0.66	80	95	60
Imazapyr	1.12	85	99	97
Imazapyr	1.68	90	100	100
Metsulfuron	0.084	75	92	90
Metsulfuron	0.168	85	95	92
Fosamine	13.44	50	65	63
Fosamine	22.40	65	70	68
Triclopyr + 2,4-D	1.26 + 1.33	95	60	53
Metsulfuron + 2,4-D	0.042 + 1.33	90	75	65
Nontreated		0	0	0
LSD (0.05)[c]		12	18	26

[a] Abbreviations: WAT, weeks after treatment; YAT, years after treatment.
[b] Rates for metsulfuron are in ai/ha, all other herbicides are in ae/ha.
[c] Fisher's protected LSD excluding the nontreated control (P = 0.05).

er conditions shortly before, during, and after herbicide applications were favorable for herbicide uptake.

Visual ratings of percent suppression of all major plant species, including purple loosestrife, were conducted at approximately 4 and 10 wk after treatment (WAT), as well as 1 and 2 yr after treatment (YAT). Control ratings were based on a scale from 0 to 100 (where 0 = no injury and 100 = plant death). The rating at 10 WAT was considered a season-long control. The ratings from the 1 and 2 YAT provided a basis for determining the level of purple loosestrife control in the second and third season, respectively.

There was also an overall ground cover rating done at 1 and 2 YAT, which included all plant species present at the site. These data provided information on the overall effect of these herbicides on plant species composition at the site. Species composition was reported based on the plant categories (grasses and broadleaf). Species composition and ground cover were assessed three times during a 3-yr period of the study: (1) before herbicide application, (2) 1 YAT, and (3) 2 YAT, using a visual percentage scale ranging from 0 to 100%. A species composition rating of 100% indicates a complete ground cover by plant biomass, whereas a 30% rating represents the level of ground cover indicating a 70% bare ground (no vegetation).

Data Analysis. ANOVA of visual ratings data was performed using PROC GLM (SAS 2003) to test data normality and significance ($P < 0.05$) of the year, location, replication, treatments, and their interactions. There was not a significant location- or year-by-treatment interaction; thus, data from all sites were pooled across years and locations into a single data set. Treatment differences were based on Fisher's protected LSD test ($P = 0.05$). To reduce the LSD values the nontreated control, which provided no weed control, was excluded from data analysis.

RESULTS AND DISCUSSION

Purple Loosestrife Control. Herbicide treatments significantly ($P = 0.001$) suppressed purple loosestrife. Some treatments provided excellent control (≥90%) that lasted only one season, whereas others suppressed its growth for two or three seasons (Table 1).

Excellent season-long control (≥90%) was achieved with higher rates of glyphosate, 2,4-D dimethylamine, triclopyr, and metsulfuron (Table 1). For example, 95% control was achieved at 10 WAT with glyphosate at 3.36 kg/ha and a mix of 2,4-D amine plus triclopyr at 1.26 plus 1.33 kg/ha.

Excellent purple loosestrife control (>90%) that lasted more than 1 yr was achieved with all four rates of imazapyr and both rates of metsulfuron. For example, imazapyr rates ranging from 0.33 to 1.68 kg/ha provided control levels ranging from 93 to 100% at 1 YAT. Data from the 1 YAT also suggest that the level of purple loosestrife control at 1 yr after application was greater than at 10 WAT for imazapyr, metsulfuron, and fosamine treatments. The delay in purple loosestrife response is likely due to the slower activity of these herbicides, thus requiring more time to observe their potential phytotoxicity (Vencill 2002).

Excellent purple loosestrife control that lasted for more than 2 yr was achieved with fewer treatments. Two higher rates of imazapyr and both rates of metsulfuron provided 90 to 100% control. For example, 92% control at 2 YAT was achieved with metsulfuron at 0.084 kg/ha compared with 100% with imazapyr at 1.68 kg/ha. Data from 2 YAT also suggest that there was good purple loosestrife control (≥70%) from nonresidual herbicides such as glyphosate. We speculate that continued control is the result of herbicide activity in the first year and competition from other plant species in the second and third years. Perhaps, this is an area for additional research.

Table 2. Composition of major plant species and ground cover in each treatment at 1 and 2 yr after treatment (YAT); means from 2 yr and 2 locations in Nebraska.

Treatments		1 YAT				2 YAT			
Herbicide	Rate[a]	LYTSA[b]	Grass[c]	Broad[d]	Cover[e]	LYTSA	Grassy	Broad	Cover
	(kg ae/ha)	% of total							
Glyphosate	2.24	20	40	40	100	30	30	40	100
Glyphosate	3.36	15	30	55	100	25	25	50	100
2,4-D dimethylamine	1.33	60	30	10	100	72	25	3	100
2,4-D dimethylamine	2.66	40	50	10	100	50	45	5	100
Triclopyr	1.26	55	35	10	100	67	30	3	100
Triclopyr	2.10	40	55	5	100	54	40	6	100
Imazapyr	0.33	7	30	40	77	60	15	25	100
Imazapyr	0.66	5	20	30	55	40	20	30	90
Imazapyr	1.12	1	5	20	26	3	10	55	68
Imazapyr	1.68	0	0	10	10	0	5	35	40
Metsulfuron	0.084	10	70	20	100	11	85	4	100
Metsulfuron	0.168	5	80	15	100	10	88	2	100
Fosamine	13.44	35	40	25	100	37	40	13	100
Fosamine	22.40	30	50	20	100	32	60	8	100
Triclopyr + 2,4-D	1.26 + 1.33	40	50	10	100	46	47	7	100
Metsulfuron + 2,4-D	0.042 + 1.33	25	70	5	100	35	61	4	100
Nontreated control		95	3	2	100	98	1	1	100
LSD (0.05)[f]		11	18	5	19	12	16	6	19

[a] Rates for metsulfuron are in ai/ha, all other herbicides are in ae/ha.

[b] LYTSA, purple loosestrife.

[c] Grass and grasslike species included green foxtail, common cattail, river bulrush, yellow nutsedge, reed canarygrass, smooth brome, and annual bluegrass (*Poa annua* L.).

[d] Broad leaf species included American germander, partridge pea, yellow sweet clover, hoary vervain, common waterhemp, and curly dock.

[e] Cover indicates percentage of ground cover.

[f] Fisher's protected LSD excluding the nontreated control (P = 0.05).

Herbicide Effects on Local Vegetation. Local vegetation was considered a mixture of plant species present at the sites, including purple loosestrife. In general, herbicide treatments significantly affected purple loosestrife stand and overall composition of grass vs. broadleaf species (Table 2).

One year after herbicide application, the percentage of purple loosestrife stand ranged from 0 to 60%, depending on the treatment. For example, at 1 YAT there was no purple loosestrife plants in plots treated with imazapyr at 1.68 kg/ha, compared with 60% in the 2,4-D treatment plots (Table 2). Similar effects were observed with other treatments in the second year after herbicide application.

With time, there was a general increase in the purple loosestrife population from the first year compared with the second year after herbicide application. For example, at 1 YAT, purple loosestrife accounted for 20% of stand compared with 30% at 2 YAT in glyphosate treatments. Similar observations were recorded with other treatments (Table 2), except for the highest rate of imazapyr. An increase in purple loosestrife population with time was expected, considering the differences in soil residual activities of these compounds. Apparently, imazapyr at 1.68 kg/ha had the longest soil residual activity and provided the longest purple loosestrife control.

Composition of grass vs. broadleaf species was also affected during a 3-yr period. In general, there was a higher percentage of grasses or grasslike species in the 2,4-D, triclopyr, metsulfuron, and fosamine treatments compared with a higher percentage of broadleaf species in the glyphosate- and imazapyr-treated plots. An increase in grassy species is to be expected considering the nature of these herbicides. For example, using a herbicide that controls broadleaf species would be expected to produce an increase in grass cover. A similar response was also documented in other studies (Rice et al. 1997; Tyser et al. 1998).

Herbicide Effects on Total Ground Cover. There were significant differences in total ground cover between treated and nontreated plots only in 4 of 16 treatments, in both 1 and 2 YAT. Of all herbicides tested, the four rates of imazapyr were the only treatments that affected the total ground cover at both 1 and 2 YAT (Table 2). For example, glyphosate, 2,4-D dimethylamine, triclopyr, or metsulfuron applied at both rates did not negatively affect total ground cover; thus, the cover rating remained at 100%. In contrast, the high rate of imazapyr resulted in a 10% ground cover rating, indicating that there was 90% bare ground (Table 2). A similar trend was observed with the two highest rates of imazapyr at the 2 YAT but to a lesser level (Table 2). Of all tested herbicides, the two highest rates of imazapyr had the most negative impact on the total ground cover for the longest time.

From a practical and ecological standpoint, each herbicide used in this study has benefits and concerns. For example, 2,4-D, triclopyr, or the mixture of the two provided good purple loosestrife control in the year of application. However, these treatments did not provide adequate control in the following season, indicating the need for repeated applications. We speculate that the poor control is likely because of poor translocation of these herbicides into and throughout the rhizome, which is the main source of purple loosestrife regrowth. Additional studies must be conducted to test such hypothesis.

Several treatments provided effective control of purple loosestrife not only in the season of application but also in the following 2 yr. Such treatments included glyphosate, metsulfuron, imazapyr, and mixture of metsulfuron and 2,4-D.

Metsulfuron was the only herbicide that provided satisfactory purple loosestrife control lasting more than one season without detrimental effects on the grassy vegetation. Grasses are the desired type of vegetation for wildlife habitats along waterways, providing easily accessible landing sites and food for migratory birds.

Imazapyr, at lower rates, provided excellent control of purple loosestrife and was safe on many plant species. However, imazapyr at higher rates had the greatest negative impact on local vegetation; therefore, this treatment should be used in conjunction with careful observation of susceptible species. This approach would allow land managers to determine whether the benefits of purple loosestrife control are greater than the side effects on their land. However, higher rates of imazapyr can be used for creating sites with little or no vegetation (e.g., bare sandbars). Such sites are needed for nesting grounds for endangered bird species, such as piping plover (*Charadrius melodus*), or migratory waterfowl species including whooping cranes (*Grus canadensis*).

Implications for Integrated Weed Management. Data presented indicate the potential for herbicide use as a part of an integrated approach for site-specific management of purple loosestrife. For example, the use of herbicides once in a 3- to 5-yr period integrated with other control methods may prove to be a sound management strategy. The goal is to manage the weed below the threshold level because complete eradication is not possible (Mullin 1998).

Triclopyr and 2,4-D dimethylamine applied alone or in a mixture can provide short-term control with the hope that the native grass and cattail populations would become predominant. Longer term control can be achieved with glyphosate, metsulfuron, and lower rates of imazapyr.

Desirable local vegetation, especially grass species, recovered much better in the plots treated with metsulfuron than with any other herbicides. It is possible that multiyear applications of metsulfuron could control purple loosestrife without reducing stands of grass plants. However, long-term studies must be conducted to test such hypothesis.

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