Grassland Legume Establishment with Imazethapyr and Imazapic

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ABSTRACT

Legumes are important components of grassland communities in North America and have potential to improve grassland productivity and diversity. Weeds can interfere with the establishment of legumes and increase probability of stand failure. Four experiments were conducted from 1994 to 1997 to determine if the imidazolinone herbicides imazethapyr [2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid] and imazapic [(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid] applied preemergence at 70 g a.i. ha^{-1} could reduce weed interference and improve establishment of seeded grassland legumes. Six native legumes and one introduced legume, crownvetch (*Coronilla varia* L.), were planted into prepared seedbeds at sites near Mead, NE. Legume response to the herbicides varied among species and sites. Crownvetch, partridgepea [*Chamaecrista fasciculata* (Michx.) Greene; syn. *Cassia chamaecrista* L.), and purple prairieclover (*Dalea purpurea* Vent.) exhibited tolerance to both imazethapyr and imazapic in most experiments and their establishment, as indicated by stem density and/or forage yield collected 14 mo after planting, was improved when treated with the herbicides in weedy environments. Imazapic treatment injured leadplant (*Amorpha canescens* Pursh), Canada tickclover [*Desmodium canadense* (L.) DC.], and roundhead lespedeza (*Lespedeza capitata* Michx.), resulting in lower stem densities and/or forage yields than when imazethapyr was applied. Based on these findings, preemergence application of imazethapyr and imazapic can be used to reduce weed interference and improve the establishment of certain grassland legumes.

Several native legumes are commonly found in tallgrass and mixed-grass prairies of the Great Plains. Native species, such as purple prairieclover and leadplant, are important components of these communities and provide high quality forage and symbiotically fixed N_2 (Becker and Crockett, 1976; Weaver, 1954). Overgrazing, encroachment of undesirable introduced species, and the exclusion of fire have contributed to grassland degradation and a reduction in legume abundance. Herbicides, such as picloram (4-amino-3,5,6,-trichloro-2-pyridinecarboxylic acid) and 2,4-D [2,4-(dichlorophenoxy)acetic acid], that are used to control broadleaf weeds in grasslands can have a negative impact on native broadleaf species (Masters et al., 1992).

Native legumes have potential to improve available forage quality and production, wildlife habitat quality, and grassland community diversity. Purple prairieclover, Illinois bundleflower [*Desmanthus illinoensis* (Michx.) MacMill. ex B.L. Rob. & Fernald], roundhead lespedeza, and catclaw sensitivebrier [*Mimosa quadrivalvis* var. *nuttallii* (DC.) L.S. Beard ex Barneby; syn. *Schrankia nuttallii* (DC.) Standl.], legumes native to the central Great Plains, improved forage yields and crude protein levels when seeded with native warm-season grasses (Posler et al., 1993). Illinois bundleflower interseeded into established kleingrass (*Panicum coloratum* L.) improved total yields for 4 yr after establishment (Dovel et al., 1990). Partridgepea, an annual native legume, has been shown to provide N to pearl millet [*Pennisetum glaucum* (L.) R. Br.] (Redmon et al., 1995), and its seed is an important food for wildlife (Robel et al., 1974; Stubbendieck and Conard, 1989).

Weed interference can reduce the establishment of grassland legumes and other prairie species. Severe annual weed infestations after planting of native grasses can result in poor stands or even complete stand failure (Cox and McCarty, 1958; Martin et al., 1982; Masters et al., 1996). Likewise, many perennial grassland legumes are susceptible to weed competition after planting, because of their slow rate of seedling growth compared with that of annual weeds. Reducing weed interference with herbicides has improved establishment of the introduced perennial legumes crownvetch and cicer milkvetch (*Astragalus cicer* L.) (Linscott and Hagin, 1974; Moyer 1989).

Methods to reduce weed interference and improve establishment of native prairie species have been investigated, but have focused primarily on grasses. Atrazine [6-chloro-*N*-ethyl-*N*′-(1-methylethyl)-1,3,5-triazine-2,4-diamine), metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide], and 2,4-D are herbicides that have been used to improve the establishment of native grasses (Cox and McCarty, 1958; Martin et al., 1982; Masters, 1995). While these herbicides have potential for improving grass establishment, their utility in establishing legumes and other forbs is limited. Forb establishment was reduced where atrazine or 2,4-D was applied, compared with mowed areas (Bragg and Sutherland, 1989). Preemergence application of the imidazolinone herbicides, imazethapyr and imazapic, improved Illinois bundleflower and purple prairieclover as well as big bluestem (*Andropogon gerardii* Vitman var. *gerardii*), indiangrass [*Sorghastrum nutans* (L.) Nash ex Small], and little bluestem [*Schizachyrium scoparium* (Michx.) Nash] establishment (Masters et al., 1996).

Imidazolinone herbicides control many broadleaf and grassy weeds and exhibit foliar and soil activity (Little and Shaner, 1991; Shaner and Mallipudi, 1991). A wide range of selectivity exists among imidazolinone herbicides. Several legumes, including soybean [*Glycine max* (L.) Moench], alfalfa (*Medicago sativa* L.), and peanut (*Arachis hypogaea* L.), exhibit tolerance to this class of herbicides (Fales and Hoover, 1990; Richburg et al.,

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Abbreviations: PLS, pure live seed; UAN, urea ammonium nitrate.

1995). Application timing of imidazolinone herbicides can effect weed control efficacy and crop injury. Imazethapyr applied preemergence or preplant-incorporated reduced establishment and increased injury to seeded alfalfa, compared with early postemergence applications (Hartberg and Harvey, 1987; Proost and Buhler, 1987). In contrast, delayed applications of imazethapyr reduced the control of common lambsquarters (*Chenopodium album* L.) in soybean (Buhler and Proost, 1992), and was less effective for establishment of seeded big bluestem and little bluestem (Masters et al., 1996).

By identifying grassland legumes that are tolerant to imidazolinone herbicides, an important weed control option could be developed that would reduce weed interference and improve the reliability of legume establishment for grassland interseeding, revegetation, and restoration. This research was conducted to determine the influence of imazethapyr and imazapic on establishment of selected native and introduced legumes.

MATERIALS AND METHODS

Four experiments were initiated from 1994 to 1996 at the University of Nebraska Agricultural Research and Development Center near Mead, NE. The soil at all sites was a Sharpsburg silty clay loam (fine, smectitic, mesic Typic Argiudolls). Experiments were designed as randomized complete blocks with four replications in the 1994 and 1996 experiments, and three replications in the experiment initiated in 1995. A factorial treatment arrangement was used in each experiment, with three to six legume species and three weed control treatments.

1994 Experiments

Two experiments were conducted in 1994 on an irrigated and a nonirrigated site that had previously been maintained as tall fescue (*Festuca arundinacea* Schreb.) sod. On the irrigated site, sprinkler irrigation applied 6 mm of water four times per week, resulting in a minimum of 25 mm of water for the 4 wk after planting by irrigation and/or rainfall. Sites were tilled and cultipacked prior to planting. A 60-cm border of Kentucky bluegrass (*Poa pratensis* L.) sod was planted around each 1- by 2-m plot. Within each plot, a single species was seeded to a maximum depth of 1.2 cm into three rows that were 20 cm apart. Crownvetch at 11.8 kg pure live seed (PLS) ha^{-1} (285 PLS m^{-2}), purple prairieclover at 8.4 kg PLS ha^{-1} (580 PLS m^{-2}), and Illinois bundleflower at 16.3 kg PLS ha^{-1} (260 PLS m^{-2}) were planted at both sites on 8 June 1994.

Herbicide treatments were applied to individual plots on 10 June 1994.[1] The herbicide treatments were no herbicide and imazethapyr or imazapic applied at 70 g a.i. ha^{-1}. Methylated sunflower (*Helianthus* sp.) seed oil and 28% urea ammonium nitrate (UAN) at 1.25% v/v were added to the spray solution to enhance foliar uptake by emerged weeds. Herbicides were applied with a back-pack sprayer that delivered 163 mL m^{-2} at 0.24 MPa. The dominant weed species at both sites was smooth crabgrass [*Digitaria ischaemum* (Schreb. ex Schweig) Schreb. ex Muhl.].

1995 Experiment

An experiment was initiated on an irrigated site that had previously been maintained as a Kentucky bluegrass sod. Site preparation, plot size, planting method, and irrigation method were similar to that of the 1994 irrigated experiment. Crownvetch, Illinois bundleflower, purple prairieclover, Canada tickclover, partridgepea, leadplant, and roundhead lespedeza were seeded to individual plots at 300 PLS m^{-2} on 28 June 1995. The planting date was delayed and relatively late, because of excessive rainfall during May and June 1995. Herbicide treatments were applied to individual plots on 29 June 1995. Treatments were no herbicide and imazapic or imazethapyr applied at 70 g a.i. ha^{-1}. Methylated sunflower seed oil and 28% UAN were added to the spray solution and applied at 380 mL ha^{-1}. The primary weed species present at the site were swamp smartweed (*Polygonum amphibium* var. *emersum* Michx.; syn. *P. coccineum* Muhl. ex Willd.), horseweed [*Conyza canadensis* (L.) Cronquist], large crabgrass [*Digitaria sanguinalis* (L.) Scop.], and smooth crabgrass.

1996 Experiment

An experiment was initiated on an irrigated site that had previously been maintained as a tall fescue sod. Site preparation, plot size, planting method, and irrigation method were similar to that of the 1995 experiment. Purple prairieclover, Canada tickclover, partridgepea, roundhead lespedeza, and leadplant were seeded to individual plots at 300 PLS m^{-2} on 19 May 1996. Weed control treatments were no herbicide and imazethapyr or imazapic applied at 70 g a.i. ha^{-1} on 20 May 1996. Dominant weeds at the site were common lambsquarters, redroot pigweed (*Amaranthus retroflexus* L.), and smooth crabgrass.

In the 1994 experiments, smooth crabgrass control was visually estimated at 4 wk after herbicide treatment. Due to nonhomogeneous distribution of weed species, weed control ratings by species at the 1995 and 1996 sites could not be reliably measured. At all sites, legume seedling stands were visually rated on a 0-to-10 scale at 4 wk after herbicide treatment. The seedling stand rating integrated emergence and seedling abundance within the planted rows, with 0 representing no emergence and 10 representing complete, uniform emergence.

Stand establishment of the perennial legumes was assessed about 14 months after planting with density and yield measurements. Stem density was determined by placing a 0.5-m^2 quadrat across the three rows of each plot and counting the number of rooted stems within the quadrat. Forage yield was estimated by clipping legume herbage rooted within a 0.5-m^2 quadrat to a 1-cm height and drying the herbage at 60°C to a constant weight. The stem density and yield of partridgepea, the only annual legume in the study, was collected at the end of the first growing season. Yield of partridgepea was not collected in the experiment initiated in 1995, because of the late planting date. Flowering stem density of purple prairieclover, Canada tickclover, and roundhead lespedeza was estimated by counting the number of flowering stems rooted within the quadrat.

To reduce annual grass weed interference during the second growing season, a uniform application of fluazifop-p-butyl {butyl(*R*)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy] propanoate} was applied to all plot areas at 0.4 kg a.i. ha^{-1} with a backpack sprayer once annual grasses had reached a 2.5-cm height. This herbicide is registered for use to control annual grass weeds in broadleaf ornamentals and is tolerated by established legumes.

Experiments from each year were analyzed separately, because of significant herbicide × site interactions for several

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[1] Mention of a particular pesticide does not imply registration under FIFRA, nor does it constitute a recommendation by the Univ. of Nebraska–Lincoln or the USDA-ARS.

Table 1. Legume seedling stands at 4 wk after planting, and stem density and forage yield at 14 mo after planting and herbicide treatment in 1994 at irrigated (IR) and nonirrigated (NIR) sites near Mead, NE. Herbicides were applied preemergent within 2 d after planting (rate: 70 g ha^{-1}).

							Forage yield				
	Seedling stand†‡			Stem density‡			CRV		IBF		
Herbicide	CRV§	IBF	PPC	CRV	IBF	PPC	IR	NIR	IR	NIR	PPC‡
				no. m^{-2}			Mg ha^{-1}				
Imazapic	5.9	5.7	1.3	164	134	152	13.0	8.6	15.4	3.0	1.8§
Imazethapyr	6.4	7.1	3.4	134	164	142	10.4	7.2	16.5	3.4	2.1
Nontreated	0.1	2.5	1.0	10	48	6	0.1	0.1	3.8	1.6	0.0
LSD (0.05)	1.5	2.3	1.7	28	46	77	2.4		4.7		1.1

† Legume seedling stands were visually rated on a scale of 0 to 10, where 0 = no emergence and 10 = complete, uniform emergence.
‡ Values shown are averaged across irrigated and nonirrigated sites.
§ CRV, crownvetch; IBF, Illinois bundleflower; PPC, purple prairieclover.

variables. If error variances were determined to be homogeneous according to Hartley's *F*-max test (Hartley, 1950), data were pooled across irrigated and nonirrigated experiments initiated in 1994. Smooth crabgrass control data from the experiments initiated in 1994 were combined across legume species; all other variables were analyzed by legume species. Arcsine transformation (Lentner and Bishop, 1993) was performed on smooth crabgrass control and seedling stand rating data. Nontransformed data are presented for these variables, because the results between transformed and nontransformed analyses were similar. Purple prairieclover flowering stem density data from the 1994 irrigated experiment, and Illinois bundleflower and Canada tickclover yield and density data from the 1995 experiment were transformed to stabilize error variances among treatments. For these variables, yield data were log-transformed, and density data were square-root-transformed (Lentner and Bishop 1993). Means were separated with Fisher's protected LSD ($P \leq 0.05$).

RESULTS AND DISCUSSION

1994 Experiments

Weed interference from smooth crabgrass, the dominant weed species, was severe with 100% foliar cover at 4 wk after planting in the nontreated plots. Analysis of smooth crabgrass control data revealed homogenous error variances and no legume or site interactions; therefore, smooth crabgrass control data were pooled across legume species and the irrigated and nonirrigated sites. At 4 wk after application of the herbicide treatments, imazapic provided greater control of smooth crabgrass (96%) than imazethapyr (66%). Rapid growth of the smooth crabgrass resulted in poor emergence and/or seedling survival of crownvetch and purple prairieclover in the nontreated areas, which resulted in lower seedling stand ratings (Table 1). Both imazethapyr and imazapic improved seedling stands of crownvetch and Illinois bundleflower, whereas only imazethapyr improved purple prairieclover seedling stands.

Table 2. Flowering stem density at 14 mo after planting of purple prairieclover from 1994, 1995, and 1996 planted sites, Canada tickclover from 1995 and 1996 planted sites, and roundhead lespedeza from 1996 planted site. Herbicides were applied preemergent within 2 d after planting (rate: 70 g ha^{-1}).

	Stem density						
	1994		1995		1996		
Herbicide	PPC† (IR)‡	PPC (NIR)	PPC	CTC	PPC	CTC	RHL
	no. m^{-2}						
Imazapic	92a§	17	109	0b§	365	30	1
Imazethapyr	87a	10	397	98a	327	154	103
Nontreated	0b	0	72	38b	0	78	2
LSD (0.05)		NS	NS		227	76	26

† PPC, purple prairieclover; CTC, Canada tickclover; RHL, roundhead lespedeza.
‡ Flowering stem density data of purple prairieclover from irrigated (IR) and (NIR) sites were analyzed separately due to nonhomogeneous error variances.
§ Flowering stem densities of purple prairieclover from the 1994 irrigated site and Canada tickclover from the 1995 site were square-root-transformed to stabilize error variance. Within species nontransformed means followed by different letters are significantly different based on transformed means separation with Fisher's protected LSD (0.05).

Fourteen months after planting, imazethapyr and imazapic treatments resulted in greater stem density for all three legumes, compared with no herbicide treatment (Table 1). Legume forage yields were usually increased where the herbicides were applied. Forage yield response of purple prairieclover was similar across irrigated and nonirrigated sites and was improved with imazapic or imazethapyr. Herbicide × site interactions were detected for crownvetch and Illinois bundleflower yields. Crownvetch yields were improved by the herbicides in both environments, whereas Illinois bundleflower yields were improved by the herbicide treatments only on the irrigated site (Table 1). Similarly, purple prairieclover flowering was increased by herbicide application only on the irrigated site (Table 2).

1995 Experiment

Due to the nonhomogeneous distribution of weed species on the site, weed control rating by weed species could not be reliably measured. Weed interference was less than that observed in the experiments initiated in 1994, and was probably reduced by planting on 28 June 1995. Lack of severe weed infestations resulted in good emergence and seedling stand ratings that were >5 for of all legumes planted, except leadplant in nontreated and imazapic-treated plots (Table 3). Stem density of partridgepea, measured at the end of the growing season, was >100 stems m^{-2} for all treatments. Roundhead lespedeza could not be evaluated, because the seedlot planted contained seeds of sericea lespedeza [*Lespedeza cuneata* (Dumont-Cours.) G. Don], which was not apparent until seedlings began to emerge.

Table 3. Legume seedling stands at 4 wk after planting, and stem density and forage yield at 14 mo after planting and herbicide treatment in from an experiment initiated in 1995 near Mead, NE. Herbicides were applied preemergent 1 d after planting (rate: 70 g ha^{-1}).

Herbicide	CRV†	IBF	PPC	CTC	PPEA	LPT
		Seedling stand‡				
Imazapic	7.3	8.7	7.0	7.8	8.3	4.0
Imazethapyr	8.8	9.3	6.5	8.2	9.5	8.0
Nontreated	5.7	8.7	7.0	8.2	8.5	2.7
LSD (0.05)	1.8	NS	NS	NS	NS	2.0
		Stem density, no m^{-2}				
Imazapic	229	5b§	117	0b§	113¶	1
Imazethapyr	168	7b	391	147a	129	25
Nontreated	222	64a	132	138a	101	11
LSD (0.05)	NS		187		NS	13
		Forage yield, Mg ha^{-1}				
Imazapic	8.6	0.5b§	2.5	0.0b§	—#	—
Imazethapyr	8.4	0.7b	7.6	4.1a	—	—
Nontreated	8.2	4.7a	1.9	1.4a	—	—
LSD (0.05)	NS		2.0			

† CRV, crownvetch; IBF, Illinois bundleflower; PPC, purple prairieclover; CTC, Canada tickclover; PPEA, partridgepea; LPT, leadplant.

‡ Legume seedling stands were visually rated on a scale of 0 to 10, where 0 = no emergence and 10 = complete, uniform emergence.

§ Illinois bundleflower and Canada tickclover stem density were square-root-transformed and forage yield data were log-transformed, to stabilize error variances. Within species nontransformed means followed by different letters are significantly different based on transformed means separation with Fisher's protected LSD (0.05).

¶ Stem density of partridgepea was measured at 12 wk after planting.

Yields of partridgepea and leadplant were not collected from experiment initiated in 1995.

Table 4. Legume seedling stands at 4 wk after planting, and stem density and forage yield at 14 mo after planting and herbicide treatment from an experiment initiated in 1996 near Mead, NE. Herbicides were applied preemergent 1 d after planting (rate: 70 g ha^{-1}).

Herbicide	PPC†	CTC	PPEA	179.00
		Seedling stand‡		
Imazapic	3.8	3.8	8.3	4.0
Imazethapyr	8.0	8.0	8.8	8.3
Nontreated	6.8	7.3	9.0	8.7
LSD (0.05)	2.1	2.3	NS	NS
		Stem density, no. m^{-2}		
Imazapic	291	37	124§	7
Imazethapyr	341	246	135	179
Nontreated	8	184	79	15
LSD (0.05)	196	101	NS	74
		Forage yield, Mg ha^{-1}		
Imazapic	4.7	3.4	9.1§	0.0
Imazethapyr	4.3	11.6	12.3	3.9
Nontreated	0.0	4.6	1.1	0.0
LSD (0.05)	2.6	3.0	3.9	0.6

† PPC, purple prairieclover; CTC, Canada tickclover; PPEA, partridgepea; RHL, roundhead lespedeza.

‡ Legume seedling stands were visually rated on a scale of 0 to 10, where 0 = no emergence and 10 = complete, uniform emergence.

§ Stem density and forage yield of partridgepea were measured at 16 wk after planting.

Stem density and forage yield of crownvetch were similar across all treatments and did not reveal any negative response to herbicide treatments (Table 3). Purple prairieclover also had similar stem densities across treatments; however, yield was greatest where imazethapyr was applied. During the year of establishment, injury to Canada tickclover from imazapic was apparent, causing stunted seedlings that failed to survive the winter after planting. In contrast, imazethapyr treatment improved Canada tickclover establishment, as indicated by a forage yield that was >4.0 Mg ha^{-1} and by increased flowering stem density (Table 2).

Illinois bundleflower stem densities were lower in herbicide-treated areas (Table 3); however, injury symptoms were not observed and many of the plants in the herbicide-treated plots were flowering within 10 wk after planting. In spring 1996, many Illinois bundleflower plants failed to resprout, unlike those in the 1994 experiments. Most of the plants observed in the second year appeared to have originated from seed produced during the first year or from planted dormant seed that germinated in spring 1996. The late planting date (28 June 1995) and an early frost on 21 Sept. 1995 may explain the poor survival of Illinois bundleflower.

1996 Experiment

As with the 1995 site, weed species were not distributed homogeneously and individual weed control ratings were not recorded. Weed interference was moderate, with <50% canopy cover in nontreated areas, which was not as severe as that observed in the 1994-initiated experiments. Injury to purple prairieclover and Canada tickclover seedlings from imazapic resulted in reduced emergence and a lower seedling stand rating, compared with the imazethapyr and no herbicide treatments (Table 4). Despite initial stunting caused by imazapic, purple prairieclover stem density, forage yield, and flowering stem density (Table 2) did not differ between imazapic and imazethapyr treatments, and were greater than the nontreated control. Treatment with imazethapyr usually resulted in the greatest stem density, flowering stem density, and forage yield of Canada tickclover and roundhead lespedeza. Herbicide treatments did not reduce partridgepea stem density, and forage yields were >9.0 Mg ha^{-1} within four months after planting. Leadplant was not evaluated, because the leadplant seedlot was contaminated with alfalfa seed.

Of all legumes evaluated, crownvetch and partridgepea exhibited the greatest degree of tolerance to both imazethapyr and imazapic. In the 1995 site, where weed interference was light, crownvetch and partridgepea exhibited no injury symptoms and responded similarly to plants in the nontreated control. When weed pressure was moderate to severe, the establishment of crownvetch and partridgepea was improved by imazapic or imazethapyr. Treatment with imidazolinone herbicides usually improved purple prairieclover establishment. Some reduction in purple prairieclover emergence following imazapic treatment occurred, but did not reduce forage yields in the 1994 or 1996 sites. Canada tickclover and roundhead lespedeza exhibited improved establishment when treated with imazethapyr, but were severely injured when treated with imazapic.

In general, imazethapyr was less injurious to the seeded legumes than imazapic. Imazapic injury was most evident in the 1995 site where weed populations were low. Grass establishment studies conducted in eastern

Nebraska and Kansas have indicated that increased activity of the imidazolinone herbicides may occur in areas with low weed competition. Imazapyr [(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid] improved stand establishment of switchgrass (*Panicum virgatum* L.) at a site with severe annual grass pressure, but reduced establishment at a site with low weed pressure (Masters et al., 1996). Likewise injury of buffalograss [*Buchloë dactyloides* (Nutt.) Engelm.] seedlings from imazapic was more severe at sites where weed infestations were at a low or moderate level (Fry et al., 1997). Thus, in this region, the rate of imazapic used could potentially be lowered in areas with less weed interference to reduce the risk of injury to planted legumes. Another approach to reducing injury to seeded legumes that merits consideration is early postemergence applications, which have been shown to reduce the risk of crop injury to newly seeded alfalfa treated with imazethapyr (Hartberg and Harvey, 1987; Proost and Buhler, 1987).

This study provides evidence that imidazolinone herbicides are a promising weed management option for establishing certain legumes. Illinois bundleflower, crownvetch, purple prairieclover, and partridgepea establishment was enhanced with imazethapyr or imazapic in sites with moderate to severe weed infestations. Imazethapyr provided less control of smooth crabgrass at two sites, but was also less injurious to Canada tickclover and roundhead lespedeza. A primary benefit of these herbicides is their ability to reduce weed interference and improve establishment in areas such as marginal cropland sites and roadside rights of way, where weed competition is often severe.

Native legumes are usually not incorporated into grassland revegetation programs for various reasons, and key among these are the scarcity of weed control options and limited information on their benefits and management. We determined that the imidazolinone herbicides improved establishment of selected legumes. Given this finding and the documented tolerance of several native warm-season grasses to the imidazolinone herbicides (Masters et al., 1996), these herbicides could be effective components of systems to improve grassland forage resources by facilitating establishment of legumes and warm-season grasses in seeded mixtures. Research is needed to quantify the contribution of native legumes to grassland forage quality and yield and to identify management practices that optimize legume persistence. This information is needed to determine how native legumes can be integrated into grassland improvement strategies.

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