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Interseeding Kura Clover and Birdsfoot Trefoil into Existing Cool-Season Grass Pastures

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ABSTRACT

Legumes in cool-season grass pastures can improve productivity and quality. In May of 1997 and 1998, a split-split plot field experiment with six replications was planted in Morris, MN to evaluate the effect of sod suppression, planting method, and legume species on establishment of legumes into existing cool-season grass pastures and to evaluate kura clover (*Trifolium ambiguum* Bieb.) and birdsfoot trefoil (*Lotus corniculatus* L.) as potential species for interseeding in the North Central region. Whole-plot sod suppression treatments were (i) 0.62 kg a.i. ha^{-1} glyphosate [isopropylamine of *N*-(phosphonomethyl) glycine] or (ii) no glyphosate. Subplot planting methods were (i) no-till drilling, (ii) broadcasting seed on the soil, (iii) broadcasting seed followed by harrowing, and (iv) broadcasting seed followed by a light disking. Legume species sub-subplots were (i) alfalfa (*Medicago sativa* L.), (ii) red clover (*Trifolium pratense* L.), (iii) kura clover, and (iv) birdsfoot trefoil. Stand data were collected in the fall of the planting year and in the spring of the second growing season. Averaged across planting methods and species, legume stands were 38% where glyphosate was used and 3% where it was not. No differences or interactions were detected for planting method ($P > 0.12$). In this study, if competing vegetation was suppressed, stands were >31% regardless of planting method. When sod was suppressed, alfalfa established better stands than the other legume species. The overriding factor in the ability to establish legumes in this study was the suppression of existing vegetation during establishment.

Cool-season grasses dominate many pastures in the North-Central USA. They generally provide abundant high quality forage during spring and early summer, and if rainfall is adequate, in early fall. The inclusion of legumes in cool-season grass pastures can improve the productivity and quality of pastures, particularly during late summer (Sheaffer et al., 1990; Gerrish, 1991; Belesky and Wright, 1994); increase the forage intake by grazing animals (Moseley and Jones, 1979; Posler et al., 1993); and improve animal performance (Burns and Standaert, 1985; Seo et al., 1997). Legumes can also provide 80 to 110 kg N ha^{-1} to grasses in a pasture (Matches, 1989; Burton and DeVane, 1992).

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Alfalfa and red clover are the two legumes most commonly used for interseeding in the North-Central region. However, alfalfa does not persist well in acid or wet soils, and red clover is susceptible to drought (Hill and Hoveland, 1993). Other perennial legumes could provide adaptation to poor soils or drought conditions.

Kura clover shows great promise as a persistent, competitive legume under a wide range of environmental conditions. It can tolerate low winter temperatures and recovers quickly after drought (Dear and Zorin, 1985; Woodman, 1993). Kura clover also has an extensive root and rhizome system (Daly and Mason, 1987) and appears to persist well under a wide range of grazing management systems because its growing points and rhizomes are below the soil surface (Moorhead et al., 1994). However, reports of poor establishment have limited the use of kura clover (Lucas et al., 1980; Scott, 1985).

Birdsfoot trefoil is a nonbloating legume that is adapted to many soil types and will grow on poorly drained, droughty, infertile, acid, or slightly alkaline soils (Seaney, 1980). It is this combination of characteristics that makes birdsfoot trefoil a desirable legume for interseeding into existing pastures. However, difficulty with establishment is one of the factors that have limited its use (Seaney, 1980).

In addition to selecting the proper species, both the suppression of competing vegetation and the planting method affect establishment success in interseeded pastures. Poor results from interseeding legumes into pastures have previously been reported (Campbell et al., 1987; Sheaffer, 1989; Lowther and Patrick, 1992; Awan et al., 1993). Campbell et al. (1987) attributed the poor establishment of interseeded pastures to low seedling vigor and competition from existing pasture plants. The use of herbicides to suppress competing vegetation has greatly increased the success of interseeding legumes (Moshier and Penner, 1978; Olsen et al., 1981). Blowes et al. (1985) demonstrated that, under field conditions, glyphosate did not reduce the growth of planted legumes when they were planted after glyphosate was applied at 0.54 and 1.08 kg a.i. ha^{-1}. There have also been reports of successful establishment of legumes into existing pastures without using herbicides to suppress competing vegetation (Decker et al., 1969; Taylor and Allinson, 1983).

Competition from existing vegetation may also affect species differently. Hill and Hoveland (1993) reported that kura clover was more severely affected by competition from grasses than was birdsfoot trefoil.

There are many planting techniques for renovating pastures. Conventional tillage removes established competition and can provide a good environment for establishing new pastures. However, conventional tillage destroys beneficial plants and removes pastures from use for a relatively long period of time. Interseeding into existing pastures can reduce the amount of time that a pasture is not in use. In contrast to tilled seedbeds, planting into an existing sod has a greater risk of seedling mortality as a result of competition from established plants (White et al., 1985).

When planting into an existing sod, drilling into the soil to achieve good seed-to-soil contact has generally had greater success than broadcasting seed on the soil surface. Moorhead et al. (1994) reported that 38% of kura clover seeds no-till drilled into a grass sod established compared with 9% kura clover seeds broadcast on the soil surface. They also reported that at the end of the establishment growing season, the root weight (326 g plant^{-1}) and the percent of plants with rhizomes (43) was greater for kura clover seed drilled into sod compared with being broadcast at planting (root weight = 150 g plant^{-1}; plants with rhizomes = 1%).

This study was conducted to evaluate (i) the impact of sod suppression and planting methods on the establishment of legumes interseeded into existing cool-season grass pastures and (ii) the potential of kura clover and birdsfoot trefoil for interseeding into pastures in the North-Central region compared with alfalfa and red clover.

MATERIALS AND METHODS

The experimental site was located at the University of Minnesota's West Central Research and Outreach Center near Morris, MN. Average precipitation is 60 cm yr^{-1} with about 40 cm falling during the growing season. The experiment was conducted on a pasture with Doland silt loam (fine loamy, mixed, Udic Haploboroll) soils, which are undulating, well-drained soils formed in silty material underlain by glacial till. The A horizon extends to about 25 cm, and glacial till begins at about 60 cm.

A split-split plot experiment with six replications was planted in the first week of May 1997 and 1998. Whole-plot sod suppression treatments consisted of (i) applying 0.62 kg a.i. ha^{-1} glyphosate [isopropyl amine of *N*-(phosphono-methyl) glycine] or (ii) applying no glyphosate. Subplot planting method treatments were applied 1 d after glyphosate application and consisted of (i) using a no-till drill, (ii) broadcasting seed on the soil surface, (iii) broadcasting seed followed by harrowing, and (iv) broadcasting seed followed by a light disking. All broadcast treatments were applied by mixing the appropriate amount of seed for each treatment with about 0.45 kg of sand and hand-spreading the mixture on plots. Legume species sub subplots were (i) alfalfa, (ii) red clover, (iii) kura clover, and (iv) birdsfoot trefoil. Alfalfa was planted at 7.8 kg ha^{-1} while the other legume species were planted at 6.7 kg ha^{-1}. Whole-plot sod suppression treatments were 12 by 16 m. Subplot planting method treatments were 4 by 12 m, and sub subplot legume species treatments were 3 by 4 m.

For at least 30 yr before 1994, the experimental pasture had been grazed with little rotation by beef cattle from May through September. Beginning in 1995, lactating dairy cattle grazed flexibly-sized paddocks for 12 h at a stocking rate of 56 000 kg of lactating Holstein cow ha $^{-1}$ five or six times per 5-mo grazing season. Grazing was initiated when forage height was 25 to 40 cm. When the trial was initiated in 1997, the pasture consisted of primarily smooth bromegrass (*Bromus inermis* Leyss.), quackgrass [*Elytrigia repens* (L.) Nevski.], and Kentucky bluegrass (*Poa pratensis* L.).

After planting, the research area was fenced to exclude grazing for 8 wk per the instructions on the glyphosate label. Thus, the experimental area was first grazed in early July and was grazed three times during the planting year.

Stand data were collected in the fall of the planting year and in the spring of the second growing season to evaluate establishment. Data were collected during two periods in an attempt to determine whether difficulties with establishing legumes in existing pastures were the result of poor germination and development in the planting year or of individual plants not being vigorous enough to survive winter after the seeding year.

Stand data were collected 10 d after the last grazing event in the fall of the seeding year and the first grazing event in spring of the second growing season. Collecting data 10 d after a grazing event was done to optimize the visibility of legume regrowth. Stand data were collected using a 30- by 90-cm frame that had been divided into twenty-seven 10- by 10-cm quadrats. The number of quadrats that contained live-rooted plants of the planted species were tallied and divided by 27 to attain a percentage value. The frame was randomly placed in two locations within each plot. Therefore, 12 frames were evaluated for each sub-subplot treatment over the six replications.

In this study, an acceptable stand was defined as one with at least 20% of the potential 10- by 10-cm frames having a live-rooted plant in them. If it is assumed that one plant was present in each 10- by 10-cm quadrat (there was often >1 rooted plant quadrat^{-1}), a 20% stand would be 20 plants m^{-1}.

The experiment was a randomized complete block arranged in split-split plot design and replicated over years. All statistical analyses were performed using GLM procedures of SAS (SAS Inst., 1996). The error term used to test year whole-plot treatment effects was replication within year; the error term used to test differences between sod suppression treatments and year × sod suppression interactions was replication within year × sod suppression; the error term used to test differences among planting methods, planting method × year interactions, and planting method × sod suppression interactions was replication within year × sod suppression × planting method; residual error was used to test differences among species and species interactions. Appropriate LSD values were calculated and used for mean comparisons. All differences reported are significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

Climate Data

Monthly temperature and total precipitation data for May through August 1997 and 1998 are presented in Table 1 along with 100-yr averages for Morris, MN. Temperatures were at or near normal in both years. In 1997, precipitation was below normal in May and June

Table 1. Average maximum temperature and precipitation data for May through August 1997 and 1998 and 100-yr average for Morris, MN.

Month	Year 1997	Year 1998	100-yr mean
	Mean max. temperature		
	°C		
May	11	17	13
June	22	21	19
July	21	22	22
Aug.	19	22	21
	Precipitation		
	mm		
May	104	201	193
June	163	368	259
July	330	272	226
Aug.	251	231	193

and above normal during late summer. In 1998, precipitation was at or above normal from May through September.

Sod Suppression

Interactions of sod suppression × species for stand development (Table 2) appear to be the result of differences in rankings between stands where glyphosate was used to suppress competing vegetation compared with those where glyphosate was not used. These differences in rankings were driven by numerically small but proportionally large changes where glyphosate was not used. These data indicate that the overriding factor in the ability to establish legumes in this study was the suppression of existing vegetation with glyphosate. This concurs with Sheaffer (1989) who concluded that the control of competing vegetation was a critical factor during the establishment of legumes in sod.

Stands of legumes planted into suppressed sod in 1997 were greater in the fall of the planting year and declined over winter (Table 3). Stands of legumes planted in 1998 increased over winter. Perhaps conditions during the 1997 establishment year resulted in individual plants that established but did not over-winter. Although both winters were relatively mild (Table 4), a cold period with no snow cover in January 1998 and 8 d of soil temperatures below −9°C at 5 cm could have affected legume persistence. Increased stand percentage over winter following the 1998 planting may have resulted from seeds not germinating until the second spring or from small, low-vigor plants (perhaps grazed and not regrowing quickly) that were not detected by fall stand evaluations in the seeding year (Table 3). However, in both planting years of this study, if plants emerged and developed satisfactorily in the seeding year, stands were still satisfactory in the second growing season (Table 3). This is in agreement with Awan et al. (1993) who concluded that the poor establishment of legumes in existing sods resulted from the loss of plants or potential plants during establishment. They reported nonappearance for approximately 80% of the seed sown.

Table 2. Species × sod suppression interactions for percent stand. Data presented are averaged over planting method, planting year, and sampling period.

Species	Sod suppression	No sod suppression
	% stand	
Alfalfa	52	4
Birdsfoot trefoil	33	0
Kura clover	25	1
Red clover	42	2
LSD(0.05)†	3.6	

† LSD value is suitable for comparisons within and between columns.

Table 3. Planting year × sod suppression interactions for percent stand. Data presented are averaged over planting method and planting years.

Planting year	Sod suppression	Fall establishment year	Spring 2nd year
		% stand	
1997	No	0	0
1997	Yes	57	33
1998	No	1	6
1998	Yes	25	37
LSD(0.05)†		5.1	

† LSD value is suitable for comparisons within and between columns.

Species

Species × planting year interactions were the result of alfalfa and birdsfoot trefoil developing similar stands following both the 1997 and 1998 plantings (Table 5). Kura and red clover stands were poorer following the 1998 planting compared with the 1997 planting. Although this is only 2 yr in a single location, it does indicate some stability in alfalfa and birdsfoot trefoil for establishment across environments. However, even with reduced red clover establishment following the 1998 planting, red clover still had similar stands to those of birdsfoot trefoil and better stands than those of kura clover. These results were unexpected because red clover is considered an aggressive-establishing legume (Smith et al., 1985), and birdsfoot trefoil is considered more difficult to establish (Seaney, 1980).

The poorer establishment of kura clover compared with the other species (Tables 2, 5, and 6) is in agreement with Bryant (1974), who reported that the limited top growth of kura in the first growing season could make it more susceptible to competition. However, the relatively low levels of establishment for kura clover may or may not be a long-term problem. Individual kura clover plants were spreading and producing secondary crowns from rhizomes in the second growing season (personal observation). If kura clover can continue to

Table 4. Number of days with <2 cm of snow cover, mean soil temperature at a depth of 5 cm, and number of days when soil temperature at 5 cm was below −9°C for November through March in the winters of 1997–1998 and 1998–1999 near Morris, MN.

	1997–1998			1998–1999		
	Days <2 cm snow cover	Mean 5 cm soil temp. °C	Days soil temp. <−9°C	Days <2 cm snow cover	Mean 5 cm soil temp.	Days soil temp. <−9°C
Nov.	26	−1	0	21	0	0
Dec.	29	−4	1	31	−4	1
Jan.	8	−6	8	1	−5	0
Feb.	9	−1	0	12	−4	2
Mar.	30	−1	0	26	−1	0

Table 5. Species by planting year interactions for percent stand. Data presented are averaged over sod suppression treatments, planting methods, and sampling periods.

Species	Planting year 1997	Planting year 1998
	% stand	
Alfalfa	28	29
Birdsfoot trefoil	18	15
Kura clover	17	8
Red clover	27	17
LSD(0.05)†	3.6	

† LSD value is suitable for comparisons within and between columns.

spread after establishment, relatively poor initial stands may not be as important for kura clover as for other legume species.

Birdsfoot trefoil did not establish as well as red clover or alfalfa (Tables 2, 5, and 6). Birdsfoot trefoil has a slower seedling growth rate than alfalfa (Seaney, 1980). Once perennial grasses begin to regrow after glyphosate suppression, slower seedling growth by birdsfoot trefoil may reduce establishment when planting into an existing sod as a result of competition.

A species × sampling period interaction was detected for stand development (Table 6). In the establishment year, alfalfa and red clover stands developed more successfully than birdsfoot trefoil, which was intermediate, or kura clover, which developed more poorly than the other species. In the spring of the second growing season, all species had similar stands compared with the fall of the seeding year, except for red clover. Red clover is considered a short-lived perennial (Smith et al., 1985). Perhaps the shorter life cycle of red clover led to more individual plants that did not survive between the establishment year and the second growing season.

Planting Method

The lack of planting method treatment effects ($P > 0.25$) or interactions ($P > 0.12$) coupled with the large impact of sod suppression found in this study (Tables 2 and 3) indicates that if existing sod were suppressed, any method of planting was successful. This was somewhat surprising. Other research has documented the importance of getting good seed-to-soil contact when establishing forages (Moorhead et al., 1994). Perhaps the generally favorable environmental conditions encountered in this study (Table 1) may have minimized the impact of planting method. When more marginal environmental conditions for establishment are encountered, larger differences may occur as a result of planting methods.

Table 6. Species by sampling period interactions for percent stand. Data presented are averaged over sod suppression treatments, planting methods, and planting years.

Species	Sampling period: Fall, establishment year	Sampling period: Spring, 2nd growing season
	% stand	
Alfalfa	28	29
Birdsfoot trefoil	18	15
Kura clover	13	13
Red clover	25	19
LSD(0.05)†	3.6	

† LSD value is suitable for comparisons within and between columns.

Averaged over species and years, when sod was suppressed, stands averaged 34, 37, 31, and 42% for no-till drilled, broadcast, broadcast followed by harrowing, and broadcast followed by light disking, respectively. When sod was not suppressed with glyphosate, stands averaged <3%, regardless of planting method.

SUMMARY

The use of glyphosate for sod suppression had an overriding impact on the success of legume establishment. When averaged over species, planting methods, planting years, and planting year and second growing-season evaluations, legume stands were 38% when sod suppression was used compared with 3% when competing vegetation was not suppressed. All species had acceptable stands (>20%) when competing vegetation was suppressed with glyphosate.

Averaged over sod suppression treatments, planting methods, planting years, and planting year and second-growing season evaluations, alfalfa produced better stands [28%; $P > 0.001$; LSD(0.05) = 3.1], red clover produced intermediate stands (22%), and birdsfoot trefoil and kura clover produced poorer stands (16 and 13%, respectively). This may be, in part, why alfalfa and red clover are the preferred species for interseeding into existing pastures in the North-Central region. However, if kura clover spreads and increases in mixed stands, relatively low establishment may or may not be a critical factor in the usefulness of kura clover in pastures. Birdsfoot trefoil stands, while 33% when sod was suppressed, were lower than alfalfa or red clover (Table 2). This indicates that improvements in birdsfoot trefoil seedling vigor could increase its use for interseeding into existing cool-season grass pastures.

Legume stands that established satisfactorily during the planting year had acceptable stands during the second growing season. This indicates that initial emergence and growth were more important than winter survival in establishing legumes in grass sods in this study.

The results from this study indicate that interseeding legumes into existing cool-season pastures in the North-Central region can be successful as long as sod is suppressed before planting. Alfalfa was the most aggressive establishing legume; however, when sod was suppressed, all legumes established at least 24%.

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