

Mixtures of Kura Clover with Small Grains or Italian Ryegrass to Extend the Forage Production Season in the Northern USA

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ABSTRACT

Kura clover (*Trifolium ambiguum* M. Bieb.) has demonstrated excellent persistence in the northern USA but initiates dormancy earlier in autumn and breaks dormancy later in spring than other adapted legumes. The objective of this study was to determine if combinations of kura clover and small grains or ryegrass (*Lolium multiflorum* Lam.) could extend the production season for high quality forage in autumn and spring. The study was conducted from 1998 to 2000 in Arlington and Lancaster, WI. Oat (*Avena sativa* L.), barley (*Hordeum vulgare* L.), winter wheat (*Triticum aestivum* L.), winter rye (*Secale cereale* L.), and Italian ryegrass, were sown in August in monoculture and in binary mixtures with previously established kura clover. In autumn, monoculture kura clover and all mixtures had similar forage yield, but 1.5 Mg ha⁻¹ lower yield than monoculture oat. In spring, binary mixtures of kura clover with winter wheat or winter rye yielded 0.88 Mg ha⁻¹ more than monoculture kura clover. In spring, mixtures with winter wheat or winter rye contained about 60% kura clover. Binary mixtures and monoculture kura clover had 35% greater crude protein, similar in vitro true digestibility, and 32% lower neutral detergent fiber than monoculture small grains and ryegrass in autumn and spring. Oat, barley, or ryegrass sown into kura clover in autumn provide no yield advantage over monoculture kura clover. Winter small grains sown into kura clover in autumn increased forage yield in early spring, but had no impact on full-season production compared with monoculture kura clover. Ryegrass did not affect spring yield, but did increase full-season production by 15% compared with monoculture kura clover. Winter small grains and ryegrass can successfully be sown into monoculture kura clover in autumn without the use of herbicides and can increase early spring or total season forage production the following year.

MAJOR LIMITATIONS to production of high quality forage in the northern USA are the short growing season and short stand life of legumes because of disease and winterkill. Kura clover has demonstrated significantly better persistence than other commonly grown legumes (Sheaffer and Marten, 1991), but has the limitation of relatively early fall dormancy and slower initiation of spring growth (K.A. Albrecht, unpublished observations, 1998).

Yield of kura clover is generally lower than that of alfalfa (*Medicago sativa* L.) but similar to red clover (*Trifolium pratense* L.) and birdsfoot trefoil (*Lotus corniculatus* L.) (Sheaffer and Marten, 1991). Nutritive value, measured as neutral detergent fiber, digestibility, and crude protein, is better than other legumes (Allinson et al., 1985; Sheaffer and Marten, 1991), providing

the opportunity to grow this legume with grasses and still maintain feeding value similar to that of first flower alfalfa (Zemenchik et al., 2002; Kim, 1996). This discovery provides opportunities contrary to the recent tradition of producing and feeding monoculture legume hay or silage to dairy cattle (*Bos taurus*) to minimize neutral detergent fiber (NDF) and maximize intake of the forage component.

Kura clover is most often grown in combination with perennial grasses for pasture to reduce incidence of bloat (Mouriño et al., 2003) and improve yields (Kim, 1996) or for silage to improve sward structure for ease of mechanical harvest (K.A. Albrecht, unpublished observations, 1998). But there are situations when grass proportions in the sward diminish because of grazing management (Mouriño et al., 2003) or winter kill (K.A. Albrecht, unpublished observations, 1998). Corn production in kura clover living mulch (Zemenchik et al., 2000; Affeldt et al., 2003) also results in monoculture clover. Easily established grasses, such as small grains or Italian ryegrass, could provide the “grass benefit” on a short-term basis in situations where perennial grasses are missing from the kura clover sward either by chance or design.

Earlier research has demonstrated that spring and winter small grains sown in late summer in the northern USA can supplement forage production in autumn and early spring, respectively (Maloney et al., 1999). Spring oat and barley sown in late summer and harvested near the first killing frost produced 3.5 Mg ha⁻¹ of forage that contained 420 g kg⁻¹ NDF in Wisconsin. Winter wheat or winter rye sown in late summer and harvested in the late boot stage produced 8.5 Mg ha⁻¹ of forage containing 580 to 660 g kg⁻¹ NDF (Maloney et al., 1999).

The feasibility of sowing small grains or Italian ryegrass into kura clover in late summer to enhance autumn or early spring forage production has not been tested, but intercropping other annual grasses with kura clover has been studied. Corn has been successfully intercropped into kura clover in spring with the use of herbicides to suppress the clover (Zemenchik et al., 2000; Affeldt et al., 2004). Sorghum–sudangrass has been sown into kura clover in June, but with varying success because of kura clover competition with the developing grass seedlings (Affeldt, 2003). Because kura clover growth slows in late August, there may be an opportunity to establish cool season grasses into the clover without herbicide suppression.

The objective of this research was to determine if small grains or Italian ryegrass sown into living kura

Department of Agronomy, 1575 Linden Dr., Univ. of Wisconsin, Madison, WI 53706. Funding has been partially provided for this research and publication from the USDA Cooperative State Research, Education and Extension Service (CSREES) Hatch project WIS04802. Received 18 Mar. 2004. *Corresponding author (kaalbrech@wisc.edu).

Published in *Agron. J.* 97:131–136 (2005).

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Abbreviations: CP, crude protein; IVTD, in vitro true digestibility; NDF, neutral detergent fiber.

clover in late summer have potential to increase autumn or spring production of high quality forage.

MATERIALS AND METHODS

The study was conducted from 1998 to 2000 at the University of Wisconsin Agricultural Research Stations in Lancaster (42°50' N lat; 90°47' W long) on Rozetta silt loam soils (fine-silty, mixed mesic, typic Hapludalfs) with pH 6.6 and 2.6% organic matter; and in Arlington (43°18' N lat, 89°21' W long) on Plano silt loam soils (fine-silty, mixed mesic, typic Argiudolls) with pH 6.6 and 3.7% organic matter.

Four small grain species—oat ('Dane' and 'Belle'), barley ('Kewanee'), winter wheat ('Cardinal'), winter rye ('Spooners')—and two Italian ryegrasses ('Jumbo' and 'Jeanne') were grown in monoculture and in binary mixture with 'Endura' kura clover. A randomized complete block design with a split plot arrangement with four replicates was used. Kura clover had been established a minimum of 3 yr before initiating the experiments. Before sowing small grains and ryegrass, portions of the kura clover sward were treated with clopyralid (3,6-dichloro-2-pyridinylcarboxylic acid) (0.094 kg a.e. ha⁻¹) plus glyphosate [*N*-(phosphonomethyl)glycine] (2.64 kg a.i. ha⁻¹) to eliminate kura clover and thus create sites for small grain and ryegrass monocultures. Other areas used for intercropping were not treated with herbicides. The whole plots measured 72 m² and were randomly assigned as intercrop vs. monoculture grass. Within each whole plot, 9.0-m² subplots were established with grass types. New sites were used for the experiments each year.

Small grains were sown at 100 kg ha⁻¹ and ryegrass at 17 kg ha⁻¹ with a Tye Pasture Pleaser no-till drill (Tye Mfg., Lockney, TX) in August (21–26) each year. Soil P and K levels were maintained as recommended for alfalfa production at each site (Kelling et al., 1991) and no N fertilizer was applied. Autumn harvest the year of grass establishment was in late October, near the first killing frost; the first spring harvest was in mid-May, when winter rye was at the early boot stage (Z43, Zadoks et al., 1974). Treatments in which grass survived after these two harvests were cut four more times during the summer for experiments planted in 1999 and 2000. These treatments were cut every 30 to 35 d, with final harvest taken in October, to measure forage yield but not forage quality.

At harvests in autumn and spring, maturity ratings were made for small grains (Zadoks et al., 1974) and ryegrass. Samples for botanical composition were taken in two 0.09 m² quadrats per plot by hand clipping and these were hand-separated into components of kura clover, small grain, or ryegrass. Kura clover and grasses were oven-dried at 60°C to estimate the kura clover and grass proportions on a dry matter basis. Botanical composition was also used to explain chemical differences among treatments.

Forage yields at each harvest were obtained by cutting a 4.63-m² swath at a 8-cm stubble height through the center of each plot using a flail mower. A 500-g subsample was taken from each plot harvested, and dried in a forced-air oven at 60°C to determine forage dry matter to calculate dry matter yield. Dried subsamples were ground in a laboratory mill to pass a 1.0-mm screen before forage chemical analysis.

Total N was determined by rapid combustion (850°C) conversion of all N combustion products to N₂ and subsequent measurement by thermoconductivity cell (LECO Model FP-528; LECO Corp., St. Joseph, MI). Crude protein (CP) concentration was estimated by multiplying total N by 6.25. Neutral detergent fiber was determined by the method of Robertson and Van Soest (1981) as modified by Hintz et al. (1996) to include sodium sulfite during refluxing. In vitro true digestibility (IVTD) was determined by a modification of the procedure

described by Goering and Van Soest (1970). Modifications were reduction of sample size to 250 mg and use of 50 mL test tubes as incubation vessels. Forage nutritive value was analyzed only for fall and spring harvests.

Total season precipitation was normal or above normal, based on the 30-yr mean, at both locations for the years of this research. However, precipitation from August to October 1999 was about half of the 30-yr mean at both locations. As a result, experiments at both locations lacked sufficient plant growth for an autumn harvest. Thus, fall 1999 harvest data were not included in the analysis of variance.

Analysis of variance for DM yield, CP, NDF, and IVTD was performed using the Mixed procedure of SAS (SAS Inst., 2001). Kura clover presence (grass monoculture or intercrop), grass type, and the kura clover × grass interaction were considered fixed effects. Environment (the interaction of year × location) and replication were considered random effects. If there were significant differences among treatments, mean separations were made with LSMEANS comparisons (SAS Inst., 2001) at $\alpha = 0.05$ with PDIF option. Dry matter yield analysis was divided into dry matter yield in the fall, dry matter yield in the spring, and total dry matter yield for those treatments that were harvested more than two times.

RESULTS AND DISCUSSION

Maturity at Harvest

There were differences in maturity among grass species at each harvest (Table 1). During autumn, spring oat and barley were more mature than winter wheat and rye and Italian ryegrass. Within species, maturity was similar for grasses in both monoculture and mixtures. At the spring harvest, however, winter rye was in the boot stage and winter wheat and ryegrass were at stem elongation, with no differences between monoculture and mixture (Table 1). These differences in maturity at harvest may explain some of the observed differences in forage quality in both mixture and monoculture. Greater maturity increased the proportion of grasses in mixtures as well as increasing fiber and decreasing CP.

Autumn Yield and Botanical Composition

Binary mixtures of oat or barley with kura clover had similar forage yield as monoculture kura clover in autumn (Table 2). Although yields of binary mixtures of winter small grains and ryegrass with kura clover were not different from monoculture kura clover or from binary mixtures of oat or barley with kura clover ($P > 0.05$), these mixtures yielded less than their respective grass monoculture. Averaged over all treatments,

Table 1. Growth stages of the small grains and ryegrass at October and May harvests according to the Zadoks scale. Values are means of four environments (autumn) or six environments (spring).

Cultivar/species	Autumn	Spring
Dane oat	stem elongation†	
Belle oat	stem elongation	
Kewanee barley	stem elongation	
Cardinal winter wheat	tillering	stem elongation
Spooners winter rye	tillering	early boot
Ryegrass	tillering	stem elongation

† Based on Zadoks et al. (1974).

kura clover yield in mixtures was 38% lower than monoculture kura clover. The difference in yield between monoculture and mixture grass yield was even more significant, with average grass yield in mixtures only 13% of that obtained in monoculture.

Although kura clover was harvested just before the grasses were sown in August, seedling grasses were competing with a well established rhizomatous clover. In addition, wheat, rye, and ryegrass are winter-tolerant species. These species accumulate fructans in the basal aboveground tissues in response to low temperatures, with slow changes in maturity during this transition period (Suzuki, 1993). In a short-day, low-temperature environment winter-type small grains yielded less than spring-type small grains.

Grown in monoculture, Dane and Belle oat had higher forage yield than barley, winter wheat, and ryegrass ($P < 0.05$). Oat and barley forage yields were comparable to those reported by Maloney et al. (1999), who also harvested these species during autumn in Wisconsin. Monoculture ryegrass yielded, on average, 1.3 Mg ha⁻¹, which was 1.0 Mg ha⁻¹ less than monoculture oat. Cardinal winter wheat and Spooner winter rye forage yields were not different ($P > 0.05$) and similar to those reported by Maloney et al. (1999). All monoculture grasses yielded more forage than monoculture kura clover and binary mixtures.

Although all grasses were successfully established in autumn in each of the six environments, late summer dry periods can delay germination and limit autumn productivity. In 1999, at both locations, none of the grasses intercropped with kura clover or grown in monoculture produced harvestable growth because of very dry conditions from August through October. This risk, combined with our results showing no yield improvement over monoculture kura clover, suggests that the practice has no application in the northern USA.

Spring Yield and Botanical Composition

Contrary to results from the autumn harvest, monoculture kura clover yielded less in spring than all binary mixtures, although the only significant differences were with kura clover–winter wheat or winter rye binary mixtures ($P < 0.05$) (Table 2). On average, intercropping winter grains or ryegrass with kura clover increased

yield by 56% compared with monoculture kura clover. Yield of kura clover–winter rye mixtures was similar to clover–winter wheat, but greater than the ryegrass mixtures ($P < 0.05$). Kura clover contributed 1.7 and 1.6 Mg ha⁻¹ to the yield of mixtures with winter grains and ryegrass, respectively. These clover yields were greater than or equal to those of monoculture kura clover. In contrast, comparing the contribution of grass forage yields in the mixture with those obtained in monoculture showed that average grass yield in mixture was 0.8 Mg ha⁻¹, 72% lower than monoculture, with greater impact in ryegrass than in winter cereals. Consequently, the yield increase in mixtures compared to monoculture kura clover was primarily the result of grass production added to a stable clover yield.

Within monoculture treatments, winter rye yielded more forage than winter wheat and ryegrass. Winter wheat and winter rye forage yields were about 46% lower than those reported by Maloney et al. (1999) and Edmisten et al. (1998a). In this study, winter wheat and winter rye were harvested at earlier maturity than in the two earlier experiments. During spring, biomass production of winter grains and ryegrass was greater than oat, barley, or ryegrass during autumn. In spring, winter grains and ryegrasses initiated growth earlier than kura clover, resulting in relatively better grass performance in mixtures compared with autumn.

Although yield of the first harvest in spring was enhanced by sowing winter small grains into kura clover the previous autumn, kura clover yields in the second harvest were depressed by about 0.8 Mg ha⁻¹ compared with monoculture clover (data not shown). The total season yields were similar for kura clover monoculture and binary mixtures of kura clover with winter wheat and winter rye, but greater production was shifted to early spring by the addition of the winter grains (Table 3). Sowing oat into kura clover in autumn had no impact on kura clover production the following season (data not shown). Total kura clover forage yields in monoculture or in binary mixture were higher than those reported by Zemenchik et al. (2001), Peterson et al. (1994), and Sheaffer and Marten (1991), who assessed kura clover under different cutting schedules.

Table 2. Forage yield of kura clover, ryegrass, and small grain monocultures and grass–legume binary mixtures. Values are means of four environments (autumn) and six environments (spring).

Cultivar/species	Autumn			Spring		
	Monoculture grass	Mixture or clover alone	Grass in mixture	Monoculture grass	Mixture or clover alone	Grass in mixture
	Mg ha ⁻¹		%	Mg ha ⁻¹		%
Dane oat	2.4a†	0.9a	47			
Belle oat	2.0ab	0.7a	38			
Kewanee barley	1.9bc	0.8a	38			
Cardinal winter wheat	0.9de	0.7a	22	3.1b	2.6ab	37
Spooner winter rye	0.8e	0.6a	11	4.3a	3.0a	42
Jeanne ryegrass	1.4d	0.6a	16	2.0c	2.0bc	25
Jumbo ryegrass	1.3d	0.6a	17	2.0c	2.1bc	23
Endura kura clover		0.8a			1.6c	
SE‡	0.3		0.5			

† Means followed by different letters within a column are significantly different at $P < 0.05$ using LSMEAN comparisons (SAS Inst., 2001).

‡ SE is for comparison of treatment means between monoculture and mixture within cultivars.

Table 3. Forage yield accumulated from kura clover, ryegrass, and small grains monocultures and grass-legume binary mixtures the season after autumn sowing of grasses into kura clover. Values are means of four environments.

Cultivar/species	Monoculture grass	Mixture or clover alone
	Mg ha ⁻¹	
Cardinal winter wheat	6.3b†	10.8ab
Spooner winter rye	6.2b	10.7ab
Jeanne ryegrass	10.8a	11.6a
Jumbo ryegrass	11.5a	11.4a
Endura kura clover		10.0b
SE‡	0.68	

† Means followed by different letters within a column are significantly different at $P < 0.05$ using LSMEAN comparisons (SAS Inst., 2001). Values represent the yield total over five harvests.

‡ SE is for comparison of treatments means between monoculture and mixture within cultivars.

Autumn Forage Quality

Crude protein concentration of monoculture kura clover was similar to binary mixtures of kura clover with winter small grains, barley, or ryegrass, but greater than mixtures containing oat in autumn ($P < 0.05$) (Table 4). Binary mixtures containing oat had lower CP than mixtures containing winter small grains and ryegrass because of higher grass proportion in the mixture compared with the proportion of winter small grains and ryegrass (Table 2). Moreover, oat and barley were more mature than the winter cereals and ryegrass at harvest (Table 1), which could also contribute to the lower CP level in mixtures. Crude protein concentrations of monoculture oat and barley support this explanation. The CP concentrations of oat and barley averaged 50 g kg⁻¹ DM lower than those of winter small grains and ryegrass. Thus, mixtures of kura clover with oat or barley had lower CP than mixtures with winter cereals and ryegrass because of the lower CP in the grass plant and high proportion in the mixture. Similar reasoning could be used to explain the CP variation between winter rye vs. winter wheat or ryegrass mixtures with kura clover. Winter rye made up 11% of the mixture while winter wheat and ryegrass were 22 and 17%, respectively. Plant maturity (tillering) was the same in the three species (Table 1). Monoculture winter rye had a higher CP concentration than ryegrass. Thus, a high CP concentration resulted when winter rye and kura clover were in mixture. Sulc et al. (1993) also reported that ryegrass maturity and its proportion in the mixture affected CP

concentration of ryegrass-alfalfa mixtures. These results agree with other studies that report greater CP concentrations in annual grass-legume mixtures compared with monoculture grasses (Chapko et al., 1991; Thompson and Stout, 1997). Crude protein concentrations of monoculture small grains were similar to those reported by Edmisten et al. (1998b) and Maloney et al. (1999), while monoculture kura clover had similar CP as that reported by Zemenchik et al. (2002) and Peterson et al. (1994).

Monoculture kura clover had similar NDF concentration as binary mixtures of kura clover with winter rye or ryegrass ($P > 0.05$), but lower than mixtures with winter wheat, oat or barley ($P < 0.05$) (Table 4). Maturity at harvest and proportion of grass in the mixture affected NDF values. For example, monoculture oat and barley had higher NDF concentrations than winter cereals and ryegrass. In binary mixtures with kura clover, oat and barley were in higher proportion than winter cereals and ryegrass (Table 2). As a result, binary mixtures of kura clover with oat or barley had higher NDF concentrations than mixtures containing winter cereals or ryegrass. Sulc et al. (1993) reported that in ryegrass-alfalfa mixtures, NDF concentration decreased as alfalfa proportion increased. Neutral detergent fiber concentrations of small grains were lower than those reported by Edmisten et al. (1998b) and Maloney et al. (1999), while NDF of monoculture kura clover was lower than that reported by Peterson et al. (1994), Sheaffer and Marten (1991), and Zemenchik et al. (2002).

Monoculture kura clover had similar IVTD as all binary mixtures except the barley-kura clover mixture, which was slightly less digestible ($P < 0.05$) (Table 4). Because differences in IVTD between the grasses and kura clover were relatively small, and IVTD of all species was high, species proportions in mixtures had little effect on IVTD of mixtures. Although oat made up 42% of the mixture with kura clover and was more mature than the other grass species, oat-kura clover mixtures had similar IVTD as binary mixtures of kura clover with winter small grains or ryegrass. In vitro true digestibility of kura clover, grasses, and mixtures was always >868 g kg⁻¹ DM in autumn-harvested forage.

Table 4. Crude protein (CP), neutral detergent fiber (NDF), and in vitro true digestibility (IVTD) of small grains and ryegrass monocultures and kura clover in monoculture or binary mixtures harvested in autumn. Values are means of four environments.

Cultivar/species	Monoculture grass			Mixture or clover alone		
	CP	NDF	IVTD	CP	NDF	IVTD
	g kg ⁻¹					
Dane oat	172e†	456ab	874c	223d	317a	915ab
Belle oat	193d	430cb	903b	245c	296ab	925a
Kewanee barley	213c	472a	880c	249bc	315ab	903b
Cardinal winter wheat	253a	413c	900d	267ab	278c	914ab
Spooner winter rye	258a	353d	932a	272a	259cd	923a
Jeanne ryegrass	233b	361d	928a	267ab	260cd	920a
Jumbo ryegrass	228bc	356d	934a	269a	262cd	916ab
Endura kura clover				267ab	248d	924a
SE‡	15.4	21.1	8.9			

† Means followed by different letters within a column are significantly different at $P < 0.05$ using LSMEAN comparisons (SAS Inst., 2001).

‡ SE is for comparison of treatment means between monoculture and mixture within cultivars.

Table 5. Crude protein (CP), neutral detergent fiber (NDF), and in vitro true digestibility (IVTD) of small grains and ryegrass monoculture and kura clover in monoculture or binary mixtures harvested in spring. Values are means over five environments.

Cultivar/species	Monoculture grass			Mixture or clover alone		
	CP	NDF	IVTD	CP	NDF	IVTD
	g kg ⁻¹					
Cardinal winter wheat	173a†	445b	891b	265c	301b	922b
Spooner winter rye	143b	527a	868c	248d	328a	913b
Jeanne ryegrass	173a	377c	909a	280b	254c	926ab
Jumbo ryegrass	175a	372c	918a	283b	250c	932a
Endura kura clover				300a	222d	933a
SE‡	4.8	17.8	8.5			

† Means followed by different letters within a column are significantly different at $P < 0.05$ using LSMEAN comparisons (SAS Inst., 2001).

‡ SE is for comparison of treatment means between monoculture and mixture within cultivars.

Spring Forage Quality

In spring, all binary mixtures had lower CP concentration than monoculture kura clover (Table 5). Crude protein of binary mixtures ranged from 17 to 52 g kg⁻¹ DM lower than monoculture kura clover. The proportion and maturity of grasses affected these CP differences in the mixtures. Specifically, binary mixture of winter rye with kura clover had lower CP than all other mixtures. Mixtures were harvested when winter rye was at the boot stage while winter wheat and ryegrass were at stem elongation. In addition, winter rye made up 42% of the mixture dry matter, while winter wheat and ryegrass were 37 and 24%, respectively. Therefore, when winter rye was grown in mixture with kura clover, the maturity and proportion of grass reduced the final CP concentration of the mixture, compared with those of winter wheat and ryegrass in mixture with kura clover.

Binary mixtures of kura clover with winter rye had higher NDF concentrations than binary mixtures with winter wheat or ryegrass (Table 5), and NDF of all binary mixtures was higher than monoculture kura clover ($P < 0.05$). Averaged over the binary mixtures, NDF was 72 g kg⁻¹ DM higher than in monoculture kura clover. Grass proportion in the mixture and maturity at harvest had an effect on the final NDF of grass-kura clover mixtures. For example, winter rye composed 42% of mixtures and NDF concentration of monoculture winter rye was 527 g kg⁻¹. The concentration of NDF in monoculture winter wheat was 445 g kg⁻¹, binary mixtures with kura clover contained 37% winter wheat, and mixture NDF was 301 g kg⁻¹.

Spring forage produced from kura clover, winter grains, ryegrass, and binary mixtures of kura clover with these grasses was highly digestible, always >870 g kg⁻¹ (Table 5). Winter rye and winter wheat were less digestible than ryegrass or kura clover. Likewise, mixtures containing these two winter grains were less digestible than monoculture kura clover. The improvement in digestibility of binary mixtures compared with winter wheat or ryegrass grown in monoculture was small. Greater differences may have been observed if an incubation period of <48 h been used in the in vitro digestibility assay.

CONCLUSIONS

Small grains and ryegrass were successfully established in autumn into living kura clover without the

use of herbicides or N fertilizer. None of the grasses evaluated in this research offered opportunity to increase fall forage production. Oat was the most productive grass in binary mixture with kura clover in autumn. However, oat competition with kura clover resulted in mixture yields equal to monoculture kura clover. Binary mixtures of kura clover with winter wheat or winter rye yielded more than monoculture kura clover in spring, offering an opportunity to improve early season forage production. Although Italian ryegrass does not routinely persist through Wisconsin winters, it survived in this research and increased total yield over the entire season. Based on the current research and knowledge of performance of these grasses in other situations in the northern USA, winter rye or winter wheat can be sown into kura clover in autumn to produce high quality forage early the following spring. This would shift the production window for high quality forage about 2 wk before the normal harvest season for alfalfa, and even earlier if the sward is grazed.

ACKNOWLEDGMENTS

F.E. Contreras-Govea was supported by the Consejo Nacional de Ciencia y Tecnología (CONACYT) and Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), Mexico. The authors thank Ed Bures for technical assistance.

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