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Yield and Species Composition of Binary Mixtures of Kura Clover with Kentucky Bluegrass, Orchardgrass, or Smooth Bromegrass

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ABSTRACT : Kura clover (*Trifolium ambiguum* M. Bieb.) is a rhizomatous perennial legume that has potential as a forage crop in the North-Central USA because of its excellent persistence under environmental extremes. Little information is available about defoliation effects on productivity of mixtures of kura clover with grasses typically grown in this region. Two field trials were conducted to evaluate the effects of defoliation management on yield and species composition of binary mixtures of 'Rhizo' kura clover with 'Comet' orchardgrass (*Dactylis glomerata* L.), 'Badger' smooth bromegrass (*Bromus inermis* Leyss.), 'Park' Kentucky bluegrass (*Poa pratensis* L.), and solo-seeded kura clover near Arlington, WI. Three harvest schedules (three, four, or five times annually) and two cutting heights (4 or 10 cm) were imposed. Infrequent defoliation and lower cutting height produced significantly greater total forage yield, 6.6, 5.8, and 5.2 Mg/ha in 3-, 4-, and 5-harvest systems, respectively; and 6.5 and 5.2 Mg/ha for the 4- and 10-cm cutting height, respectively. Averaged over 3 yr and two environments, mixtures had higher forage productions than solo kura clover (6.3, 5.7, and 6.0 Mg/ha for the Kentucky bluegrass, orchardgrass, and smooth bromegrass mixtures, respectively; compared to 5.2 Mg/ha for solo kura clover). The proportion of kura clover in mixtures increased from yr 1 to yr 2 and was constant from yr 2 to yr 3 (34, 58, and 57%, respectively). We conclude that kura clover has excellent potential as a long-term component of grass-legume mixtures regardless of the cutting height, harvest frequency or grass species, even though the proportion of kura clover in harvested forage was significantly greater with less frequent harvest and shorter cutting height of all mixtures. (**Key Words :** Kura Clover, Kentucky Bluegrass, Orchardgrass, Smooth Bromegrass)

INTRODUCTION

Maintaining productive grass-legume swards over a long period requires appropriate species and management practices. Orchardgrass, smooth bromegrass, and Kentucky bluegrass are commonly used in improved pastures or for hay in the North-Central USA. The primary legumes sown in pastures or for hay in this region are alfalfa (*Medicago sativa* L.), red clover (*Trifolium pratense* L.), white cover (*Trifolium repens* L.), and birdsfoot trefoil (*Lotus corniculatus* L.). A significant limitation of these legumes is lack of persistence (Forde et al., 1989; Matches, 1989). A primary goal in managing mixed swards is to keep legume populations high enough to maintain nitrogen self-sufficiency and high forage nutritive value (Zemenchik et al., 2001; Zemenchik et al., 2002).

Kura clover is a deep-rooted, rhizomatous perennial legume with potential as a forage crop because of its excellent persistence under environmental extremes. It has excellent winter hardiness, is adapted to a diversity of soil conditions, tolerates frequent defoliation, and tolerates drought (Spencer et al., 1975; Taylor and Meche, 1982; Speer and Allinson, 1985; Peterson et al., 1994). Kura clover is more tolerant of poor drainage than red clover or white clover and persists under drought by becoming dormant (Bryant, 1974; Speer and Allinson, 1985). Unique botanical characteristics of kura clover, associated with vegetative propagation by means of rhizomes, should increase persistence of kura clover over other legumes under grazing (Taylor and Meche, 1982). Kura clover has multi-branched roots that consistently exceed 60 cm in depth, and kura clover started from rhizome segments can spread laterally in excess of 1.2 m by early in the second season of growth (Speer and Allinson, 1985).

Until recently the use of kura clover had been limited by inadequate seed supplies, unavailability of appropriate rhizobia, and lack of seedling vigor (Speer and Allinson,

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Table 1. Mean date of harvests for the three harvest frequency±one standard error and grass growth stage at first harvest of each harvest schedule for 1991-1994

Harvest	Harvest schedule[1]		
	5×	4×	3×
	---------- Harvest date ----------		
First	May 19±0.9	May 25±1.0	June 3±1.1
Second	June 13±1.7	June 26±1.4	July 19±1.1
Third	July 11±1.5	July 31±1.8	August 31±1.8
Fourth	August 7±1.8	August 31±1.8	
Fifth	August 31±1.8		
Grass species	---------- Grass stage at first harvest[2] ----------		
Kentucky bluegrass	Early heading	Early anthesis	Late anthesis
Orchardgrass	Late boot	Early heading	Early anthesis
Smooth bromegrass	Late boot	Early heading	Early anthesis

[1] Harvested five times (5×), four times (4×) or three times (3×) per year.
[2] Mean grass maturity stage over all years. Kura clover was vegetative except for first harvest in the 3× management when some flowers were present.

1985; Townsend, 1985). Once established, however, kura clover produces forage yields that are comparable to those of other legumes such as red clover or white clover (Vartha and Clifford, 1978; Stewart and Daly, 1980). Sheaffer et al. (1992) reported that kura clover yields were similar to birdsfoot trefoil in the first 2 yr and greater after 3 yr when birdsfoot trefoil stands began to decline. Peterson et al. (1994) observed the total season production of kura clover grown in monoculture was not affected by cutting frequency from three to six harvests, and averaged 7.2 mg/ha in Minnesota. Pastures with high proportions of kura clover are bloat potent (Mouriño et al., 2003), thus there is reason to grow grasses with this legume. And cutting and drying for hay or silage is substantially improved by growing kura clover with taller grasses (Albrecht, unpublished observations).

Previous studies (Spencer et al., 1975; Taylor and Meche, 1982) have provided information regarding kura clover as a potential solution to lack of legume persistence under environmental and management extremes. Relatively little information is available, however, about the performance of mixtures of kura clover with cool-season grasses. Our objective was to determine the effect of defoliation frequency and cutting heights of kura clover-grass mixtures on forage yield and species composition.

MATERIALS AND METHODS

Two field studies were conducted on a Plano silt-loam soil (fine-silty, mixed, mesic, Typic Agriudoll) at the Arlington Agricultural Research Station near Madison, WI (43°18’N, 89º21’W). Experiment 1 was established in April 1990, and data were collected from 1991 through 1993. Experiment 2 was established in April 1991, and data were collected from 1992 through 1994. The same procedures were used in both experiments except for the randomization of treatments. Available soil P and K ranged from 23 to 34 mg/kg and 90 to 125 mg/kg, respectively, and soil pH and organic matter ranged from 6.5 to 7.0 and 28 to 34 g/kg, respectively, at both experimental sites. Nitrogen fertilizer was not applied to the plots.

Rhizo kura clover was sown in binary mixtures with Comet orchardgrass, Badger smooth bromegrass, and Park Kentucky bluegrass, and solo-seeded. Each grass species was sown in 1.5- by 6.1-m plots (10 rows spaced 0.15 m apart) at rates recommended for grass-legume mixtures in Wisconsin. Kentucky bluegrass was sown at 4.5 kg/ha, orchardgrass at 2.2 kg/ha and smooth bromegrass at 9.0 kg/ha. The entire experimental area was oversown with Rhizo kura clover, inoculated with appropriate rhizobia (LiphaTech, Inc., Milwaukee, WI), at 10.1 kg/ha. Poast (sethoxydim) was applied as needed to solo kura clover plots to suppress perennial grass encroachment from neighboring plots and annual grasses. During the establishment year, forage and weeds were harvested and removed from the experimental site twice.

Each experiment was conducted as a split plot arrangement of a randomized complete block design with four replications. Three harvest frequencies (three, 3×; four, 4×; and five, 5× times per year) and two cutting heights (4 and 10 cm) were randomly assigned to whole plots. Binary mixture types (kura clover-Kentucky bluegrass, KBG; kura clover-orchardgrass, OG; kura clover-smooth bromegrass, SB; or solo kura clover, Solo) were randomly assigned to subplots. Plots were harvested beginning mid-May through the end of August at approximately 42-, 32-, and 25-day intervals for three, four, and five harvests per year for 3 years, from 1991 for Exp. 1 and 1992 for Exp. 2 (Table 1). Harvest frequency and cutting height were assigned to whole plots to provide a practical means of mechanized plot harvesting and to improve precision for analysis among binary mixture types.

A sickle-bar mower was used to cut a swath 0.9×4.9 m, at a 4- or 10-cm stubble height, through the center of each

Table 2. Forage yield and species composition of binary mixtures of kura clover with Kentucky bluegrass, orchardgrass and smooth bromegrass, and solo kura clover subjected to three harvest frequency treatments and two cutting height treatments over a 3-year period

Treatment	Year 1				Year 2				Year 3				Three-year mean			
	Total	Kura	Grass	Weed	Total	Kura	Grass	Weed	Total	Kura	Grass	Weed	Total	Kura	Grass	Weed
	----- Mg/ha -----															
Harvest frequency[1]																
3×	5.82[a,2]	2.31[a]	3.30[a]	0.21[a]	6.70[a]	4.15[a]	2.33[a]	0.21[b]	7.16[a]	4.65[a]	2.11[a]	0.40[c]	6.56[a]	3.70[a]	2.58[a]	0.27[b]
4×	4.63[b]	2.16[a]	2.34[a]	0.18[a]	6.13[b]	4.11[a]	1.80[b]	0.22[ab]	6.62[b]	4.24[b]	1.83[b]	0.54[b]	5.79[b]	3.49[b]	1.99[b]	0.31[b]
5×	4.12[c]	1.92[b]	2.04[b]	0.17[a]	5.15[c]	3.38[b]	1.50[c]	0.28[a]	6.19[c]	3.81[c]	1.64[c]	0.74[a]	5.15[c]	3.04[c]	1.72[c]	0.39[a]
Cutting height [3]																
4 cm	6.06[a]	2.77[a]	3.04[a]	0.25[a]	6.33[a]	4.25[a]	1.76[b]	0.32[a]	6.99[a]	4.53[a]	1.70[b]	0.76[a]	6.46[a]	3.85[a]	2.17[a]	0.44[a]
10 cm	3.66[b]	1.47[b]	2.07[b]	0.12[b]	5.65[b]	3.51[b]	1.99[a]	0.16[b]	6.32[b]	3.93[b]	2.03[a]	0.36[b]	5.21[b]	2.97[b]	2.03[b]	0.21[b]

Values are means of two experiments.

[1] Refer to Table 1 for description of harvest frequency; values are averaged across cutting height and binary mixture type.

[2] Means within a column followed by the same letter, within main effect, are not significantly different at 0.05 level of probability using a Fisher's LSD test.

[3] Values are averaged across harvest frequency and binary mixture type.

subplot. A subsample for determining the proportion of kura clover, grass, and weeds was randomly taken from the cut forage in each plot. The proportion was determined by hand-separating the components and measuring the mass of each component after drying at 55°C. The remaining forage was subsequently collected and weighed, and 600-g samples were dried at 55°C to determine dry matter percentage. In 1993 and 1994 the sickle-bar mower was replaced with a rotary mower (0.54-m wide cut) with a collection basket. The subsample for determining the component-proportion was collected before harvest from three 0.09 m^2 quadrats that were randomly placed in each plot. Forage yields were obtained by weighing each basket from which 600-g samples were taken to determine dry matter percentage.

Analysis of variance was used to test statistical significance of environment (experiment), treatment effects, and interactions. Few experiments by treatment interactions were found and these were of no consequence because they resulted from small changes in magnitude of differences among treatments, and no appreciable changes in ranking of treatments occurred. Therefore, data from Exp. 1 and 2 were combined such that yr 1 includes 1991 data from Exp. 1 and 1992 data from Exp. 2, yr 2 includes 1992 data from Exp. 1 and 1993 data from Exp. 2, and yr 3 includes 1993 data from Exp. 1 and 1994 data from Exp. 2 for analysis of variance. Analyses of the data were conducted using the GLM -procedure of SAS (SAS 6.02, 1988). Years, harvest frequency, cutting height, and binary mixture were considered fixed variables in the analysis. Fisher's protected least significant difference (LSD) procedure was used to compare the treatment means.

RESULTS AND DISCUSSION

Total forage production differed from year to year depending on rainfall. The growing season precipitation (March through August) at Arlington in 1992 and 1993 was 400 and 828 mm, respectively. The normal growing season rainfall at Arlington is 487 mm based on a 30-yr average (1961 through 1990). Forage production was reduced when rainfall was below average in 1992. In contrast, greater forage production resulted when favorable moisture conditions were present in the other 3 yr. In 1993, when rainfall was about twice the long-term average, there was vigorous forage growth through the entire season.

Total forage production of the mixtures

All three binary mixtures had greater forage production than solo kura clover when yields were averaged over the 3 yr of the experiments (Table 2). Harvest frequency had a significant effect on total forage production and kura clover and grass yield (Table 2). Less frequent harvesting increased total, kura clover, and grass yields compared to more frequent harvesting, while the production with 4× was intermediate throughout the 3 years. This result is consistent with a previous study in which grass-legume mixtures (ladino clover with smooth bromegrass or orchardgrass) under a three-cut schedule produced higher yields than under a five-cut schedule (Wolf and Smith, 1963). Less frequent cutting also tended to limit weed appearance in all treatments.

Kura clover yields were higher when harvested to a height of 4-cm than the 10-cm during this study (Table 2). In contrast, grass yields with the 4-cm cutting height were significantly greater in year 1 (the year after establishment), however in years 2 and 3, grass yields were significantly greater with the 10-cm cutting height, averaged over all three harvest frequencies (Table 2). Except for year 1, these results agree with those reported by Bell and Ritchie (1989), who observed that white clover yield in mixtures with prairie grass (*Bromus willdenowii* Kunth), perennial ryegrass (*Lolium perenne* L.), and browntop (*Agrostis capillaris* L.) was greater at a 4-cm than an 8-cm cutting height for 3 years. Weed yield, mostly dandelion (*Taraxacum officinale* Weber), was significantly greater at

Table 3. Forage yield and species composition of binary mixtures of kura clover with Kentucky bluegrass (KBG), orchardgrass (OG) and smooth bromegrass (SB), and solo kura clover when subjected to three harvest frequency and two cutting heights over a 3-year period

Treatment[1]			Year 1				Year 2				Year 3			
BM	HF	CH	Total	Kura	Grass	Weed	Total	Kura	Grass	Weed	Total	Kura	Grass	Weed
KBG	3×	4 cm	7.90$^{a, 2}$	4.06^{a}	3.78^{a}	0.05^{a}	8.89^{a}	5.52^{a}	3.29^{a}	0.08^{ab}	8.51^{a}	5.38^{a}	2.91^{a}	0.22^{bc}
		10 cm	4.26^{c}	1.96^{c}	2.28^{b}	0.02^{a}	7.38^{bc}	3.87^{b}	3.48^{a}	0.04^{b}	7.40^{b}	4.48^{bc}	2.84^{a}	0.07^{d}
	4×	4 cm	5.71^{b}	3.36^{b}	2.29^{b}	0.06^{a}	7.64^{b}	5.08^{a}	2.46^{b}	0.11^{a}	7.20^{b}	4.95^{ab}	1.94^{c}	0.31^{ab}
		10 cm	3.46^{d}	2.00^{c}	1.43^{c}	0.03^{a}	6.69^{cd}	4.12^{b}	2.51^{b}	0.07^{ab}	6.74^{bc}	4.13^{cd}	2.47^{b}	0.15^{cd}
	5×	4 cm	4.84^{c}	2.82^{b}	1.97^{b}	0.05^{a}	5.68^{e}	3.62^{b}	2.00^{c}	0.06^{ab}	6.47^{cd}	3.86^{d}	2.22^{bc}	0.39^{a}
		10 cm	3.28^{d}	1.89^{c}	1.36^{c}	0.03^{a}	5.85^{de}	3.34^{b}	2.45^{b}	0.07^{ab}	6.07^{d}	3.52^{d}	2.38^{b}	0.17^{cd}
OG	3×	4 cm	7.39^{a}	1.63^{a}	5.74^{a}	0.02^{a}	6.59^{a}	4.23^{a}	2.28^{ab}	0.08^{b}	7.58^{a}	4.56^{a}	2.70^{bc}	0.33^{bc}
		10 cm	4.75^{c}	0.78^{bc}	3.98^{c}	0.00^{a}	5.46^{b}	2.57^{b}	2.84^{a}	0.05^{b}	6.73^{bcd}	2.67^{b}	3.97^{a}	0.09^{d}
	4×	4 cm	6.17^{b}	1.46^{a}	4.69^{b}	0.02^{a}	5.80^{ab}	3.78^{a}	1.84^{bc}	0.19^{ab}	7.00^{ab}	3.23^{b}	3.22^{b}	0.55^{b}
		10 cm	3.79^{d}	0.74^{c}	3.05^{d}	0.01^{a}	5.20^{bc}	2.88^{b}	2.20^{ab}	0.13^{b}	6.04^{d}	2.69^{b}	3.21^{b}	0.14^{cd}
	5×	4 cm	5.19^{c}	1.10^{b}	4.07^{c}	0.02^{a}	4.44^{c}	2.93^{b}	1.23^{c}	0.29^{a}	6.19^{cd}	3.07^{b}	2.30^{c}	0.82^{a}
		10 cm	3.69^{d}	0.93^{bc}	2.75^{d}	0.00^{a}	5.20^{bc}	3.05^{b}	2.06^{abc}	0.09^{b}	6.15^{cd}	3.22^{b}	2.70^{bc}	0.23^{cd}
SB	3×	4 cm	8.51^{a}	2.54^{a}	5.93^{a}	0.04^{ab}	7.62^{a}	4.15^{a}	3.38^{a}	0.08^{b}	7.41^{a}	4.94^{a}	1.85^{bc}	0.61^{bc}
		10 cm	5.56^{b}	0.89^{c}	4.65^{b}	0.02^{bc}	6.31^{b}	2.89^{b}	3.37^{a}	0.05^{b}	6.66^{b}	3.76^{bc}	2.63^{a}	0.27^{e}
	4×	4 cm	6.01^{b}	1.78^{b}	4.20^{b}	0.03^{b}	6.46^{b}	3.78^{a}	2.54^{bc}	0.15^{a}	6.90^{ab}	4.45^{ab}	1.71^{bc}	0.73^{b}
		10 cm	4.04^{c}	0.95^{c}	3.09^{cd}	0.00^{d}	5.90^{bc}	3.02^{b}	2.83^{b}	0.05^{b}	6.02^{bc}	3.44^{c}	2.13^{b}	0.45^{ce}
	5×	4 cm	5.43^{b}	1.56^{b}	3.82^{bc}	0.06^{a}	5.17^{cd}	2.84^{b}	2.14^{c}	0.19^{a}	6.31^{b}	3.76^{bc}	1.51^{c}	1.04^{a}
		10 cm	3.03^{d}	0.72^{c}	2.30^{d}	0.01^{cd}	5.14^{d}	2.97^{b}	2.10^{c}	0.07^{b}	5.83^{c}	3.29^{c}	2.02^{b}	0.52^{c}
Solo	3×	4 cm	5.60^{a}	4.59^{a}	-	1.00^{a}	6.77^{a}	5.85^{a}	-	0.92^{ab}	7.01^{a}	5.92^{a}	-	1.09^{b}
		10 cm	2.58^{c}	2.05^{c}	-	0.53^{bc}	4.52^{c}	4.15^{cd}	-	0.37^{c}	6.02^{b}	5.47^{ab}	-	0.56^{d}
	4×	4 cm	5.18^{ab}	4.33^{ab}	-	0.86^{ab}	6.03^{ab}	5.42^{ab}	-	0.61^{bc}	6.98^{a}	5.63^{ab}	-	1.35^{e}
		10 cm	2.71^{c}	2.32^{c}	-	0.39^{c}	5.28^{bc}	4.80^{bc}	-	0.48^{c}	6.09^{b}	5.42^{ab}	-	0.67^{cd}
	5×	4 cm	4.76^{b}	3.96^{b}	-	0.81^{ab}	4.86^{c}	3.84^{d}	-	1.02^{a}	6.37^{b}	4.66^{c}	-	1.72^{a}
		10 cm	2.73^{c}	2.36^{c}	-	0.37^{c}	4.86^{c}	4.45^{cd}	-	0.41^{c}	6.12^{b}	5.10^{bc}	-	1.00^{bc}
LSD (0.05)[3]			0.65	0.50	0.55	0.22	0.79	0.70	0.57	0.19	0.65	0.68	0.48	0.25

Values are means of two experiments.

[1] BM, HF, and CH are binary mixture type, harvest frequency, and cutting height, respectively.

[2] Means within column and BM type followed by the same letter are not significantly different within each binary mixture and solo kura clover at p = 0.05 based on Fisher's Protected LSD.

[3] LSD for making comparisons across the mixtures and solo kura clover.

the 4-cm CH over 3 years. In contrast, weed yield was not different among HF for the first year, even though weeds tended to encroach more aggressively over time with frequent cutting. The appearance of weeds seems to be more related to CH than to HF, especially in years 1 or 2. After the first year the KBG had the highest annual yield (Table 2). The SB had the highest yields in year 1, and the OG yielded the least except for the third year in which it was equal to the SB. Among the binary mixtures, kura clover yield was highest in the KBG, lowest in the OG, and intermediate in the SB through the entire experiment (Table 2).

Cutting regime effect on each binary mixture

Significant ($p<0.05$) HF×CH, and some CH×BM and HF×BM interactions were obtained (Table 2) but these were due primarily to changes in magnitude of difference and not to change in ranking. Simple effects are shown in Table 3 to illustrate the effect of HF and CH on each binary mixture type.

In the KBG, total forage production always decreased with increasing HF at each CH through the entire experiment (Table 3). In this mixture, clover yield was greater in 3× and 4× than in 5×, and grass yield was greater in 3× than with more frequent harvest, averaged over CH. Weed yield was always less than 5% of total forage yield and by year 3 was less in the 10- than 4-cm cutting height but was affected little by harvest frequency. Total forage yield was higher using a 4-cm CH, however the yield difference between the two CH became progressively smaller with time; from 2.48 Mg/ha (year 1), 0.76 Mg/ha (year 2) to 0.65 Mg/ha (year 3) averaged over HF. Kura clover yield over the 3 yr was similar to the total forage yield pattern, however, grass yield was higher in year 1 using a 4-cm CH, equal between CH in year 2, and greater in year 3 using the 10-cm CH. The highest forage production of the KBG was always obtained when harvested three times at the 4-cm cutting height.

Total forage production of the OG usually increased with reduced HF especially at the 4-cm CH (Table 3). However, while grass yield increased using a reduced HF, the clover yield was not affected by HF in the first 2 years but less frequent cutting in year 3 tended to produce more kura clover with the 4-cm CH. With the 4-cm CH, kura clover and orchardgrass yields were highest when totaled over the 3 years. Total forage production with the 4-cm CH

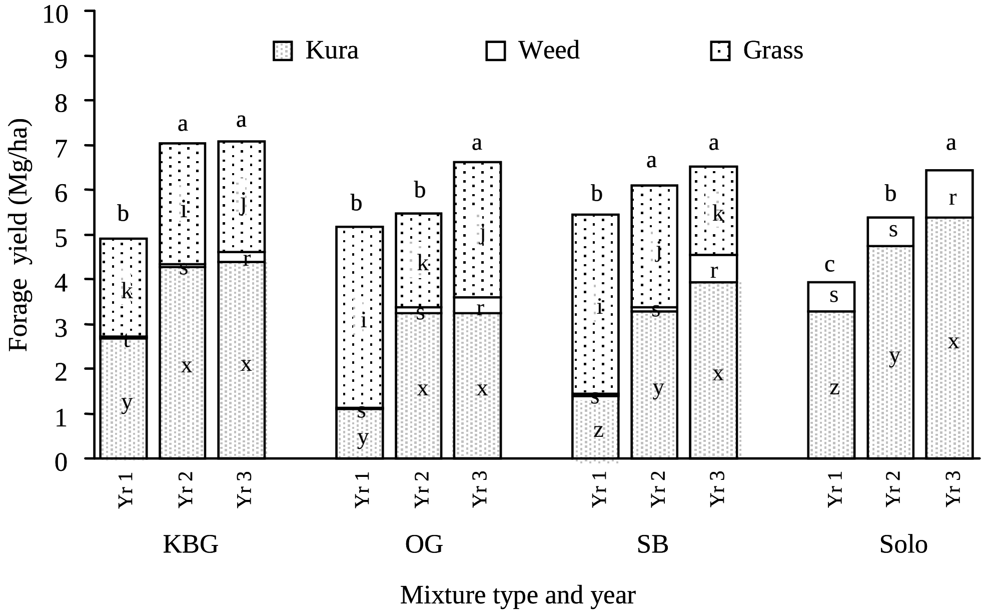

Figure 1. Forage yield and species composition of binary mixtures of kura clover with Kentucky bluegrass (KBG), orchardgrass (OG) and smooth bromegrass (SB), and solo kura clover over 3 years. Values are averaged across harvest frequency and cutting height. Total yield and species composition within the mixture and solo kura clover followed by the same letters are not significantly (p>0.05, Fisher's Protected LSD) different among the 3 years.

was higher in years 1 and 3, but not significantly different from the 10-cm CH in year 2. The total and clover yields were greatest with 3× at a 4-cm CH.

The total, kura clover, and grass yields in the SB were highest with 3× averaged over CH (Table 3). Clover yield was always significantly higher at the 4-cm CH with all HF over 3 years. Although the grass yield at the 4-cm CH was greater in year 1, it was equal to or lower than the 10-cm CH in years 2 and 3. This result is consistent with previous research on alfalfa grown in mixtures with several temperate grasses. Smith et al. (1973) concluded that the persistence of grass species in mixtures with alfalfa was greatly influenced by cutting treatment. They observed severe stand reduction of smooth bromegrass and timothy grown with alfalfa with a three-per-year HF and these grasses were nearly eliminated with a 4-cm CH. In our study, smooth bromegrass was not eliminated from mixtures with kura clover by short and frequent defoliation, but productivity was greatly reduced after 3 years. Three-year mean total forage production was greatest when smooth bromegrass-kura clover mixtures were harvested 3× at the 4-cm CH.

Harvest frequency did not affect forage production of solo kura clover with exceptions in year 2 and 3 when the production was significantly lower in 5× at the 4-cm CH (Table 3). These results are similar to those reported for kura clover production under varied defoliation frequencies over 2 years in St. Paul, Minnesota (Peterson et al., 1994). They observed no consistent differences in total season yields of kura clover as frequency increased from three to six defoliations per year. The clover yield was significantly greater with the 4-cm CH in years 1 and 2, but was not affected by CH in year 3. The forage production of solo kura clover was usually highest with 3× or 4× at the 4-cm CH.

Three-year mean total forage production of 8.43 Mg/ha and kura clover yield of 4.99 Mg/ha in the Kentucky bluegrass-kura clover mixture harvested three times at a 4-cm CH were greater than any other treatment combination tested. Next highest 3-year mean yields were in the SB with 3× at the 4-cm CH. The three-year mean total forage production of the KBG is similar to that (8.62 Mg/ha) of a smooth bromegrass-alfalfa mixture cut at an 8-cm stubble height two or three times annually in an adjacent field 10 years earlier (Casler and Drolsom, 1984).

Total forage production and species transition over 3 years

The total forage production of all mixtures and solo kura clover increased from year 1 to year 3 (Figure 1). Clover yields increased at the expense of the grass component in the mixtures. This was especially true for both the KBG and SB. However, in the second year of the OG the kura clover component stabilized and the increased total forage yield in year 3 was due to increase of the orchardgrass component. The proportion of weeds, mainly dandelions, became substantial in the mixtures and solo kura clover in year 3.

The proportion of kura clover in mixtures, averaged over HF and CH, with orchardgrass and smooth bromegrass

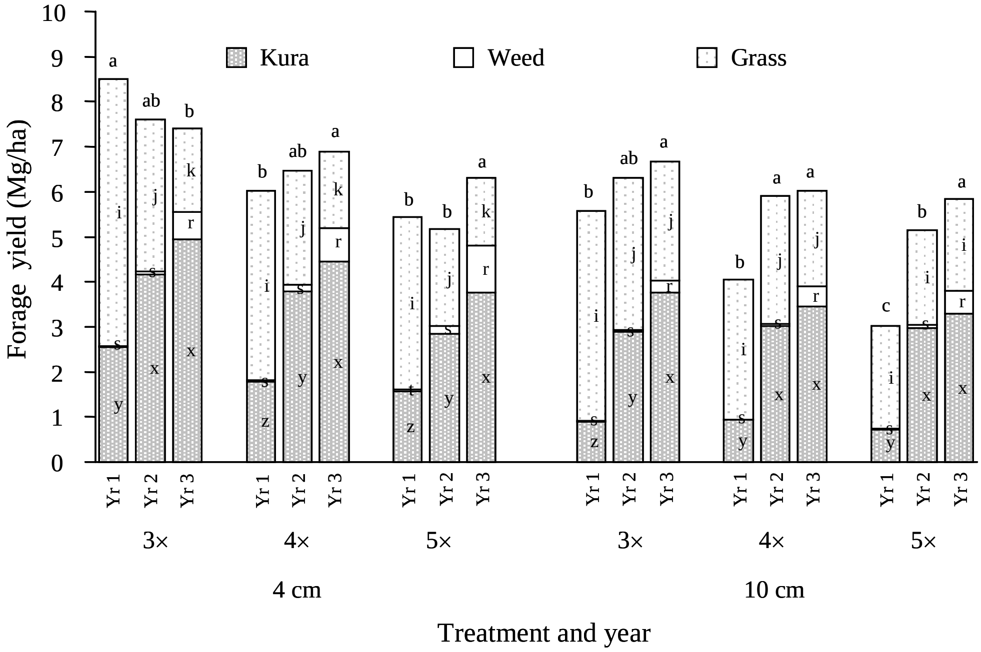

Figure 2. Forage yield and species composition of the smooth bromegrass/kura clover mixture using each cutting schedule (three-per-year, 3T; four-per-year, 4T; five-per-year, 5T) and cutting height (4- and 10-cm) over 3 years. Total yield and species composition within each cutting schedule/cutting height combination followed by the dame letters are not significantly (p>0.05, Fisher's Protected LSD) different among the 3 years.

in year 1 was fairly small; 21% in the OG and 26% in the SB (Figure 1). However, the proportions increased to 59% (year 2) and 49% (year 3) in the OG, and 54% (year 2) and 60% (year 3) in the SB. Kura clover proportions in mixture with Kentucky bluegrass did not change over the 3 years and were 54% in year 1, 61% in year 2 and 62% in year 3. These results are in stark contrast with previous work on white clover-tall fescue mixtures in which the white clover ratio decreased to less than 20% in the third year from more than 50% in the first two years (Gibson and Cope, 1985).

The pattern of total forage production and clover yield of the KBG and OG under each HF and CH was similar to that of the KBG and OG averaged over HF and CH. However, the pattern of total forage production and clover yield of SB under each HF and CH was different from those of the SB averaged over HF and CH because of some interaction of HF×CH (Figures 1 and 2). At the 4-cm CH, the total forage production pattern of the SB differed among HF over 3 years (Figure 2). When harvested three times annually, total forage production generally decreased, however harvesting four or five times resulted in increasing yields from year 1 to 3. Kura clover yields increased and smooth bromegrass decreased from year 1 to 3 in all three HF. The decrease in smooth bromegrass productivity is consistent with other studies where smooth bromegrass stands were thinned and reduced by cutting in the stem elongation and early heading stages in spring, especially when grown with alfalfa (Reynolds and Smith, 1962; Eastin et al., 1964; Smith et al., 1973). Smith et al. (1973) stated that when smooth bromegrass cut at this stage of development energy reserves for regrowth are low and new basal tiller growth has not been initiated. Consequently smooth bromegrass can not compete with the rapid regrowth of companion alfalfa. Since kura clover stems elongate only in the first crop and regrowth after defoliation is relatively slower than alfalfa, it is less competitive with smooth bromegrass regrowth. With the 10-cm CH, total forage production with all three HF increased from year 1 to 3. With the 10-cm CH, smooth bromegrass yields were greater in year 1 than in years 2 and 3 when mixtures were harvested three or four times per season but did not change with time when harvested five times per season. The clover yield consistently increased from year 1 to year 3 under all HF and CH treatments. Over 3 years the grass yields consistently decreased with the 4-cm CH with all three HF, however with the 10-cm CH, the yields remained relatively constant.

Seasonal distribution of forage yield

The general distribution pattern of seasonal forage production was similar for all three mixtures and solo kura clover and for all HF and CH treatments (Figures 3, 4 and 5). However, harvesting five times per season resulted in more uniform distribution of forage production than harvesting three or four times per season in all mixtures, especially with a 10-cm CH (Figure 5). Total mixture forage production was usually greatest at the first defoliation and least at the last defoliation in each HF. A large proportion of

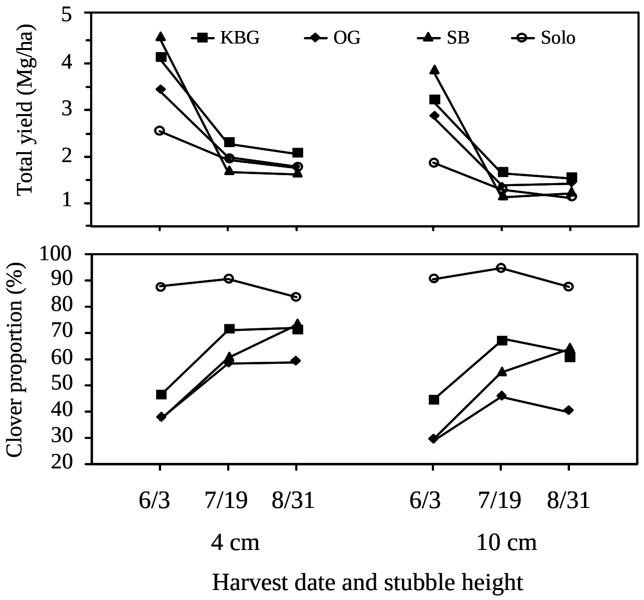

Figure 3. Total forage yield and kura clover proportion of binary mixtures of kura clover with Kentucky bluegrass (KBG), orchardgrass (OG) and smooth bromegrass (SB), and solo kura clover harvested three times per year at 4- and 10-cm cutting heights. Values are means of years 1, 2 and 3 for both experiments.

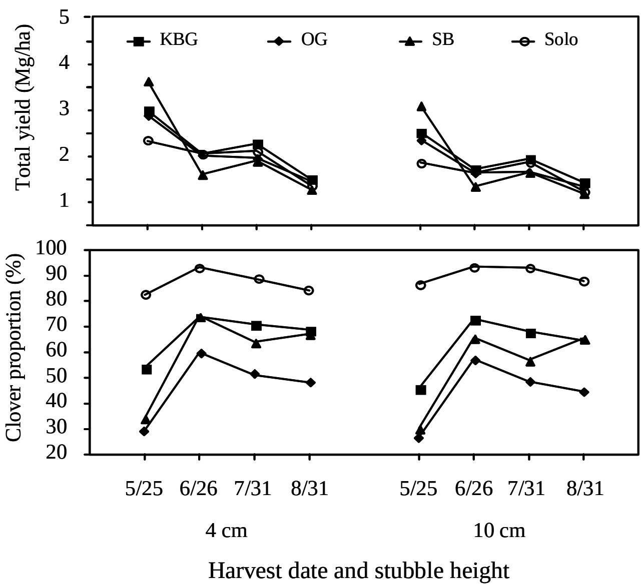

Figure 4. Total forage yield and kura clover proportion of binary mixtures of kura clover with Kentucky bluegrass (KBG), orchardgrass (OG) and smooth bromegrass (SB), and solo kura clover harvested four times per year at 4- and 10-cm cutting heights. Values are means of years 1, 2 and 3 for both experiments.

the first harvest forage of the mixtures consisted of the various grass species. The grass component usually decreased with subsequent harvest. The forage yield distribution of solo kura clover was more uniform across the growing season than were mixtures of clover and grass.

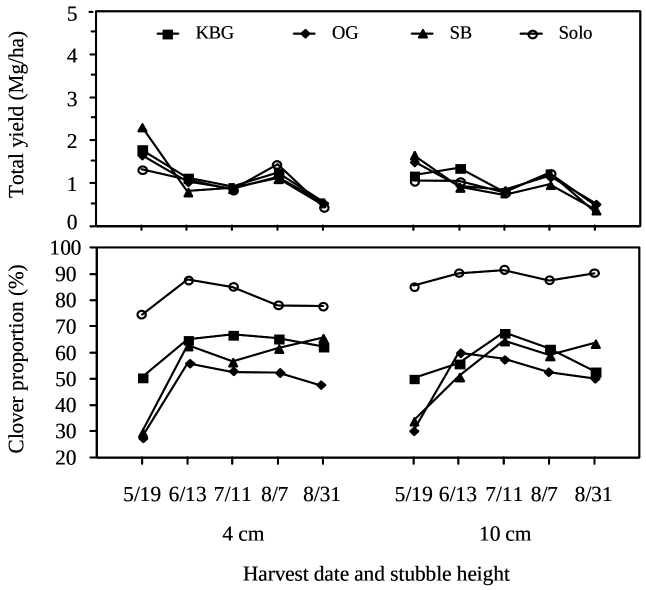

Figure 5. Total forage yield and kura clover proportion of binary mixtures of kura clover with Kentucky bluegrass (KBG), orchardgrass (OG) and smooth bromegrass (SB), and solo kura clover harvested five times per year at 4- and 10-cm cutting heights. Values are means of years 1, 2 and 3 for both experiments.

In 3×, average relative yields (% of total seasonal yield) for the mixtures were approximately 50% for the first defoliation and approximately 25% for both the second and third defoliation with both CH. In contrast, relative yields of solo kura clover were 42% for the first defoliation, 31% for the second defoliation and 27% for the third defoliation. This result is in agreement with previous research (Peterson et al., 1994), where kura clover forage yields generally decreased in sequential defoliations with three cuttings. The forage production of the SB was highest among all mixtures in the first defoliation and lowest in the second defoliation in all three HF with both CH (Figures 3, 4 and 5).

Kura clover yield in the SB tended to increase in the last harvest of the 3× in contrast to the leveling off or decrease of kura clover yield in other mixtures (Figure 3). This result shows that kura clover production increased during the summer slump of smooth bromegrass. After the first defoliation, the KBG generally yielded more than the other mixtures in all defoliation treatments. This high aftermath forage production was associated with greater kura clover yields in the KBG than in the other mixtures. The KBG resulted in more evenly distributed forage production through the growing season than other mixtures, especially with the 5× harvest frequency system.

Seasonal distribution, N-economy, persistence, forage yield and forage nutritional values are important factors to consider when legumes are grown with various species of grass. In the North-Central USA, persistence is a critical factor because legumes used in mixed grass-legume swards in this area lack long-term persistence. The data presented here demonstrate that kura clover will not likely be suppressed from defoliation over the range of management evaluated when grown in binary mixtures with three grasses commonly used in the region. In fact, kura clover became the dominant species in each binary mixture after the first year with a few exceptions (occurred on 3× with 10 cm cutting height due to the clover suppression). We conclude that kura clover has excellent potential as a long-term component of grass-legume mixtures regardless of the cutting height, harvest frequency or grass species, even though the proportion of kura clover in harvested forage was greater with less frequent harvest and shorter cutting height. Highest yields were obtained from kura clover/ Kentucky bluegrass mixtures, and the dense, compact structure of this sward could improve bite size and intake of grazing livestock on pasture. Clearly, kura clover dominated mixtures with Kentucky bluegrass and smooth bromegrass after 3 years, and this could result in bloat problems in pastures. Orchardgrass mixtures with kura clover will offer greater potential as a hay crop because of the taller stature of this mixture. Furthermore, the proportion of legume in this mixture seems to have stabilized after three years at a level that would be less likely to induce bloat in pastures.

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