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Forage Quality Management of Kura Clover in Binary Mixtures with Kentucky Bluegrass, Orchardgrass, or Smooth Bromegrass

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ABSTRACT : Kura clover (*Trifolium ambiguum* M. Bieb.) is a potentially useful perennial legume because of its excellent nutritive value and persistence under environmental extremes. However, information about forage quality of kura clover - grass mixtures adapted to the North-Central USA is limited. Objectives of this research were to determine forage nutritional value of kura clover-grass mixtures under different harvest frequency and cutting height regimes. 'Rhizo' kura clover was grown alone and in binary mixtures with 'Park' Kentucky bluegrass (*Poa pratensis* L.), 'Comet' orchardgrass (*Dactylis glomerata* L.), and 'Badger' smooth bromegrass (*Bromus inermis* Leyss.) at the Arlington Agricultural Research Station located near Madison, WI. Three harvest frequencies (3×, 4×, or 5× annually) and two cutting heights (4- or 10-cm) were imposed on each binary mixture and on kura clover grown alone. Higher nutritive value was observed in the binary mixtures with more frequent harvest and lower cutting height. Averaged over 3 years and all harvest frequency and cutting height treatments, the nutritive value of the Kentucky bluegrass and smooth bromegrass mixtures was superior to that of the orchardgrass mixture (410 g kg^{-1} NDF and 194 g kg^{-1} CP in the Kentucky bluegrass mixture; 405 g kg^{-1} NDF and 188 g kg^{-1} CP in the smooth bromegrass mixture; 435 g kg^{-1} NDF and 175 g kg^{-1} CP in the orchardgrass mixture). All of the mixtures and harvest management systems evaluated in this study produced forage with quality equivalent to "grade one" alfalfa hay and suitable for high-producing livestock, even though the highest quality was observed in the Kentucky bluegrass mixture with 5× harvesting at the shorter cutting height. (**Key Words :** Forage Quality, Kura Clover, Mixtures)

INTRODUCTION

Kura clover (*Trifolium ambiguum* M. Bieb.) is a nutritious legume due to its leafiness. It has a nutritive value similar to ladino clover (*Trifolium repens* L.) and lower acid detergent fiber (ADF) and lignin concentrations than alfalfa (*Medicago sativa* L.) forage (Allinson et al., 1985). Speer and Allinson (1984) reported that kura clover forage had higher Ca concentrations than alfalfa, and the concentrations of P, Mg, and K appeared to be adequate for ruminants. Sheaffer and Marten (1991) reported that kura clover herbage had greater *in vitro* digestible dry matter (IVDDM) concentration and similar crude protein (CP) concentration to birdsfoot trefoil (*Lotus corniculatus* L.). They also observed that lambs grazing kura clover and birdsfoot trefoil had similar average daily gains. In kura clover-grass (orchardgrass, smooth bromegrass, and intermediate wheatgrass) mixtures, the yield, CP, and IVDDM concentrations were higher than those of the monoculture grasses (Sleugh et al., 2000). Sheaffer et al. (1992) reported that kura clover persistence and forage production following 3 years of grazing with high herbage allowance were superior to those of birdsfoot trefoil. Peterson et al. (1994) reported that the herbage quality of kura clover generally increased with more frequent cutting treatments ranging from three to six defoliations per year.

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). In a cow-calf grazing system in North Carolina, calves gained 0.18 kg day^{-1} more on tall fescue (*Festuca arundinacea* Schreb.)-ladino clover pastures than on grass alone (Burns et al., 1973). The results of Petritz et al. (1980) showed that calf gains were greater on tall fescue-legume pastures (0.83 kg day^{-1}) than tall fescue pastures fertilized with 112 kg ha^{-1} N yr^{-1} (0.54 kg day^{-1}). The nutritive value of kura-grass mixtures is substantially better than monoculture grasses (Zemenchik et al., 2002) and increasing the proportion of clover in

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mixtures has significantly improved steer live weight gains on pasture (Mourino et al., 2003).

Forage quality of grass-legume mixtures can be greatly affected by forage species and maturity. Legumes have contributed to improved forage quality of mixtures. White clover has lower concentrations of cellulose, hemicellulose and lignin, and higher total N, organic acids and minerals than grasses (Frame and Newbould, 1986). The voluntary intake of white clover was typically 20% greater than grasses due to the rapid degradation of organic matter in the rumen (Thomson, 1984). Forage maturity and morphology can be manipulated through management by altering defoliation frequency and height. Forage quality generally declines with maturity as nutrients are translocated from aging tissue to areas of meristematic activity, overall cell-wall mass increases, and sites of lignification increase in certain plant parts (Akin et al., 1983). However, kura clover forage nutritive value changes little with maturity (Perterson et al., 1994; Contreras-Govea et al., 2006).

Information on the forage nutritive value of kura clover-grass mixtures under different management conditions over years is limited. This information is necessary for assessing the potential of kura clover in binary mixtures with grasses. The objective of this study was to determine the effects of harvest frequency and cutting height on forage nutritive value of kura clover in binary mixture with selected cool-season grasses.

MATERIALS AND METHODS

Two field studies were established in close proximity to one another to obtain information on the nutritive value of binary mixtures of 'Rhizo' kura clover with ‘Comet’ orchardgrass (*Dactylis glomerata* L.), ‘Badger’ smooth bromegrass (*Bromus inermis* Leyss.), or ‘Park’ Kentucky bluegrass (*Poa pratensis* L.). The research was conducted on a Plano silt-loam soil (fine-silty, mixed, mesic, Typic Agriudoll) at the Arlington Agricultural Research Station located near Madison, WI (43°18’N, 89°21’W). Two experiment sites were prepared in 1991 and 1992. The first one was established in April 1990, and data were collected from 1991 through 1993. The other was established in April 1991, and data were collected from 1992 through 1994 providing replication in time. Both experiments were identical except for randomization of treatment combinations. Establishment, treatments, experimental design, statistical analysis, and climatological and fertility conditions for the experiment are described in detail by Kim and Albrecht (2008).

Three harvest frequency schedules (3×, 4×, or 5× per year) and two cutting heights (4- or 10-cm) were imposed on each binary mixture over a 3-year period. The binary mixtures included kura clover-Kentucky bluegrass (KBG), kura clover-orchardgrass (OG), kura clover-smooth bromegrass (SB), and kura clover alone. Each experiment was conducted as a split plot arrangement of a randomized complete block design with four replications. Harvest frequency and cutting height treatments were assigned to whole plots, and binary mixtures were randomly assigned to subplots.

Forage samples of about 600 g were collected randomly from each plot for determining forage nutritive value of herbage in each treatment. After drying at 55°C, samples were ground in a mill to pass through a 1-mm screen, and subjected to laboratory tests of forage nutritive value. The ground material was analyzed for crude protein using a semi-micro Kjeldahl procedure to determine total N concentration (Bremner and Breitenbeck, 1983), with the salicylic acid modification described by Bremner (1965) for recovery of nitrate that may have accumulated in the grasses. Crude protein concentration was calculated by multiplying total N by 6.25. Neutral detergent fiber and ADF were determined by the sequential analysis method of Robertson and Van Soest (1981). This method was modified by reducing sample size to 0.5 g and treating the samples with 0.1 ml of *a*-amylase (Sigma Chemical Co., St. Louis, MO number A-5426) during refluxing in the neutral detergent solution and again during sample filtration (Hintz et al., 1996). Fiber and protein values are expressed as a proportion of total dry matter.

Analyses of the data were conducted using the GLM-procedure of SAS (SAS 6.02). Years, harvest frequency, cutting height, and binary mixture were considered fixed variables in the analysis. Main effect means are discussed along with the presence of interactions. Since significant interactions among main effects occurred for some measurements, the simple effects are also presented in tables. All tests of significance were made at the 0.05 level of probability. Treatment means of significant main effects and interactions were compared using Fisher’s protected least significant difference at $a = 0.05$.

RESULTS AND DISCUSSION

Environmental conditions varied greatly during the course of this study, especially with regard to the amount and distribution of rainfall during the growing season. Grass growth was observed to be especially responsive to soil moisture conditions. Dry conditions prevailed during the spring and early summer at Arlington in 1992, resulting in limited clover and grass growth. In contrast, there was abundant rainfall during the growing season in 1993, which produced vigorous clover and grass growth (Kim and Albrecht, 2008). Data from Exp. 1 (1991 to 93) and Exp. 2 (1992 to 94) were combined for purposes of brevity and clarity. Few significant ($p<0.05$) environment x treatment

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

Harvest	Cutting schedule *		
	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	Growth stage at first harvest**		
Kentucky bluegrass	Early heading	Early anthesis	Late anthesis
Orchardgrass	Late boot	Early heading	Early anthesis
Smooth bromegrass	Late boot	Early heading	Early anthesis

* Harvested five times (5×), four times (4×) or three times (3×) per year.
** Mean maturity stage over all years.

interactions were observed, and these resulted primarily from changes in magnitude of difference among treatments rather than changes in ranking of treatments.

Harvest frequency

Harvest frequency had a significant effect on grass maturity at first harvest (Table 1) and on forage quality throughout the entire experiment. Forage harvested less frequently tended to have higher NDF and ADF concentrations and lower CP concentration (Table 2). Greater plant maturity and stem elongation at first harvest, and longer periods of forage regrowth associated with lower harvest frequency resulted in higher NDF and ADF concentrations, and lower CP concentration. As plants

Table 2. Effect of harvest frequency, cutting height and binary mixture type on neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein (CP) concentration[1]

Treatment	Year 1			Year 2			Year 3			Three-year mean		
	NDF	ADF	CP	NDF	ADF	CP	NDF	ADF	CP	NDF	ADF	CP
Harvest frequency (HF)[2]	g kg^{-1} dry wt.											
3×	478[a, 3]	289[a]	147[c]	394[a]	258[a]	188[c]	372[a]	248[a]	200[c]	415[a]	265[a]	179[c]
4×	440[b]	267[b]	178[b]	360[b]	235[b]	212[b]	346[b]	229[b]	211[b]	382[b]	244[b]	200[b]
5×	416[c]	251[c]	192[a]	338[c]	217[c]	222[a]	319[c]	208[c]	226[a]	358[c]	226[c]	213[a]
Cutting height (CH)[4]												
4 cm	437[b]	265[b]	173[a]	356[b]	234[b]	208[a]	333[b]	223[b]	212[a]	375[b]	241[b]	198[a]
10 cm	452[a]	272[a]	172[a]	372[a]	239[a]	207[a]	358[a]	234[a]	213[a]	394[a]	249[a]	197[a]
Binary mixture (BM)[5]												
KBG	440[c]	266[c]	182[b]	402[a]	252[a]	194[b]	387[b]	242[b]	204[c]	410[b]	254[b]	194[b]
OG	514[a]	295[a]	136[d]	396[a]	252[a]	198[b]	396[a]	249[a]	192[d]	435[a]	265[a]	175[d]
SB	476[b]	276[b]	152[c]	397[a]	248[a]	199[b]	342[c]	227[c]	214[b]	405[b]	249[c]	188[c]
Kura alone	348[d]	238[d]	219[a]	260[b]	199[b]	238[a]	258[d]	196[d]	240[a]	289[c]	211[d]	232[a]
Interaction												
HF×CH	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
HF×BM	*	*	NS	*	*	NS	*	*	*	*	NS	*
CH×BM	NS	NS	NS	*	*	*	*	*	*	*	*	*
HF×CH×BM	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

* Significant difference at the 0.05 probability levels.
[1] The values for harvest frequency, cutting height and binary mixture were averaged across all other treatments and are means of two experiments.
[2] Harvest frequency (three-per-year, 3×; four-per-year, 4×; five-per-year, 5×). Values are averaged across cutting height and binary mixture.
[3] 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.
§ LSD for making comparisons within each treatment and within a column.
[4] Values are averaged across cutting schedule and binary mixture type.
[5] Binary mixtures of kura clover with Kentucky bluegrass (KBG), orchardgrass (OG) and smooth bromegrass (SB), and kura clover alone. Values are averaged across cutting schedule and cutting height.

mature, nutritive value declines in most forage species due to increasing lignification and proportions of cell walls. Ugherughe (1986) observed that decline of forage quality with maturity was primarily related to a decrease in the leaf-to-stem ratio. Both lignin and hemicellulose-lignin concentrations in several cool-season grasses increased more in stems than in leaves with maturity (Morrison, 1980). In the grass component of the mixtures, maturity ranged from anthesis to late anthesis at the first defoliation of 3× in early June to late boot-early heading at the first defoliation of 5× in mid-May (Table 1).

The harvest frequency x cutting height interaction was not significant ($p<0.05$) for NDF, ADF, or CP concentration (Table 2) throughout the entire experiment. That is, forage nutritive value was higher with frequent defoliation regardless of cutting height when the main effect of binary mixtures was averaged. However, significant interactions ($p<0.05$) usually occurred for harvest frequency×binary mixture and cutting height×binary mixture combinations. These results indicate that forage quality of mixtures responds differently to harvest frequency or cutting height treatments. Cutting schedule effects on each binary mixture are discussed in more detail later.

Cutting height

Significant differences ($p<0.05$) in NDF and ADF concentrations over 3 years were detected between the 4- and 10-cm cutting heights, however, there were no differences in CP concentration (Table 2). Lower NDF and ADF concentrations were observed at the 4-cm cutting height in the three binary mixtures. However, cutting height did not significantly affect the difference in NDF and ADF concentrations in the kura clover alone. These results were associated with differences in the kura clover - grass ratio in the three binary mixtures, with grass being of lower proportion at the 4-cm cutting height (Kim and Albrecht, 2008).

Binary mixture differences

Forage nutritive value of kura clover alone was better than that of the three binary mixtures over 3 years when averaged across all harvest frequencies and cutting heights (Table 2). Forage nutritive was similar for the KBG and SB binary mixtures. The OG mixture had the lowest forage nutritive value over 3 years which was undoubtedly due to a larger grass component than that of the KBG and SB binary mixtures (Kim and Albrecht, 2008). In Virginia, sheep continuously grazing Kentucky bluegrass-white clover pasture supported higher average daily gains (over 0.23 kg d^{-1}) than sheep grazing orchardgrass-ladino clover pastures (0.19 kg d^{-1}) (Carter et al., 1963). The harvest frequency× binary mixture and cutting height×binary mixture interactions were significant ($p<0.05$) for NDF, ADF and CP concentrations throughout the entire experiment (Table 2). However, changes in ranking were infrequent, and actual value gaps were minimal when ranking changes did occur.

Harvest frequency, cutting height, and binary mixture interactions

No significant harvest frequency×cutting height interactions were evident in the mixtures (Table 2). Less frequent harvesting resulted in lower forage quality regardless of cutting height. However, significant harvest frequency×binary mixture and cutting height×binary mixture interactions were usually observed because harvest frequency and cutting height treatments produced somewhat different results for each binary mixture.

In the KBG mixture, 3-year mean forage quality was lower with less frequent harvest at each CH (Table 3). No significant difference in forage quality was observed between 4- and 10-cm cutting heights in year 1; however, in year 2 and again in year 3 both NDF and ADF were lower when the binary mixtures were cut at 4-cm, while CP was higher. Forage nutritive value in this mixture was usually highest under 5× at the 4-cm cutting height.

In the OG mixture, more frequent harvest resulted in better three-year mean forage nutritive value at each CH (Table 3). Neutral detergent fiber and ADF concentrations were lower using the shorter cutting height, but CP concentration was not affected by cutting height in years 1 and 2. The highest forage quality in this mixture was obtained with 4× at the shorter cutting height and 5× at both cutting heights. These harvest frequency-cutting height combinations resulted in greater proportions of kura clover in the mixtures which seemed to be caused by orchardgrass winter damage under frequent harvest and short cutting height in year 2 (Kim and Albrecht, 2008).

In the SB mixture, 3-year mean NDF and ADF concentrations were lowest with more frequent harvesting and the shorter cutting height at each CH (Table 3). Cutting height had no effect on CP concentration at each HF treatment, but CP concentration was lower with less frequent defoliation. Highest forage quality was observed in this mixture using 5× at both cutting heights, which was due to the suppression of the grass and dominance by the legume (Kim and Albrecht, 2008).

When kura clover was grown without grass (kura clover alone), 3-year mean forage nutritive values were higher at each CH when harvested more frequently (Table 3). These results concur with previous data that NDF, ADF, and ADL concentrations of kura clover decreased as defoliation frequency increased (Peterson et al., 1994). Cutting height did not significantly alter NDF and ADF concentrations over the 3 years, however, CP concentration was higher when kura clover was cut at 10-cm (Table 3). A shorter cutting height would result in a greater proportion of petiole

Table 3. Effect of each harvest frequency (HF) and cutting height (CH) on binary mixtures of kura clover with Kentucky bluegrass (KBG), orchardgrass (OG) and smooth bromegrass (SB), and kura clover alone on neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein (CP) concentration over a 3-year period[1]

Binary mixture	Harvest frequeny	Cutting height	Year 1			Year 2			Year 3			Three-year mean		
			NDF	ADF	CP	NDF	ADF	CP	NDF	ADF	CP	NDF	ADF	CP
			g kg^{-1} dry wt.											
KBG	3×	4 cm	468^{a,2}	285^{a}	159^{c}	425^{b}	272^{b}	178^{c}	406^{a}	262^{a}	195^{cd}	433^{b}	273^{b}	177^{d}
		10 cm	470^{a}	288^{a}	160^{c}	458^{a}	282^{a}	167^{d}	420^{a}	266^{a}	190^{d}	449^{a}	279^{a}	172^{d}
	4×	4 cm	443^{ab}	265^{b}	186^{b}	378^{cd}	241^{d}	205^{b}	372^{c}	236^{c}	207^{bc}	398^{c}	247^{d}	199^{bc}
		10 cm	445^{a}	270^{b}	193^{ab}	393^{c}	250^{c}	201^{b}	389^{b}	244^{b}	200^{c}	409^{c}	255^{c}	198^{c}
	5×	4 cm	400^{c}	239^{c}	198^{ab}	371^{d}	233^{d}	215^{a}	352^{d}	211^{d}	221^{a}	375^{d}	228^{f}	211^{a}
		10 cm	416^{bc}	251^{c}	201^{a}	390^{cd}	235^{d}	199^{b}	382^{bc}	234^{c}	212^{b}	396^{c}	240^{e}	204^{b}
OG	3×	4 cm	536^{b}	315^{a}	115^{d}	405^{bc}	272^{a}	188^{cd}	395^{bc}	259^{b}	186^{b}	445^{b}	282^{ab}	163^{c}
		10 cm	563^{a}	306^{ab}	110^{d}	445^{a}	277^{a}	178^{d}	465^{a}	287^{a}	170^{c}	490^{a}	290^{a}	153^{d}
	4×	4 cm	488^{c}	284^{b}	143^{bc}	375^{cd}	241^{b}	202^{abc}	388^{bc}	244^{c}	189^{b}	417^{c}	256^{c}	178^{b}
		10 cm	521^{b}	302^{ab}	136^{c}	415^{ab}	260^{a}	193^{bcd}	419^{b}	258^{b}	186^{b}	452^{b}	273^{b}	172^{b}
	5×	4 cm	490^{c}	279^{b}	150^{ab}	358^{cd}	229^{b}	218^{a}	333^{d}	211^{d}	214^{a}	394^{d}	240^{d}	194^{a}
		10 cm	487^{c}	281^{b}	160^{a}	378^{bcd}	231^{b}	210^{ab}	375^{c}	234^{c}	208^{a}	413^{c}	249^{cd}	192^{a}
SB	3×	4 cm	499^{ab}	294^{a}	129^{c}	420^{ab}	263^{a}	179^{c}	355^{b}	242^{b}	202^{c}	424^{b}	267^{b}	170^{c}
		10 cm	537^{a}	308^{a}	122^{c}	439^{a}	265^{a}	178^{c}	389^{a}	251^{a}	198^{c}	455^{a}	275^{a}	166^{c}
	4×	4 cm	434^{d}	258^{b}	160^{b}	393^{c}	242^{c}	203^{b}	326^{c}	221^{d}	212^{b}	384de	240^{d}	191^{b}
		10 cm	452^{cd}	267^{b}	153^{b}	414^{bc}	256^{b}	203^{b}	357^{b}	232^{c}	215^{b}	408^{bc}	252^{c}	191^{b}
	5×	4 cm	452^{cd}	259^{b}	176^{a}	357^{d}	219^{d}	216^{a}	294^{d}	200^{e}	227^{a}	368^{e}	226^{e}	206^{a}
		10 cm	483^{bc}	274^{b}	173^{a}	361^{d}	223^{d}	218^{a}	332^{c}	215^{d}	228^{a}	392^{cd}	237^{d}	206^{a}
Kura alone	3×	4 cm	361^{a}	249^{ab}	195^{c}	282^{a}	220^{a}	215^{e}	278^{a}	213^{a}	218^{d}	307^{a}	227^{a}	209^{e}
		10 cm	390^{a}	266^{a}	190^{c}	275^{a}	213^{a}	224de	269^{b}	208^{a}	243^{b}	311^{a}	229^{a}	219^{d}
	4×	4 cm	375^{a}	248^{ab}	232^{ab}	253^{bc}	195^{b}	234^{cd}	255^{c}	195^{b}	232^{c}	295^{a}	213^{b}	233^{c}
		10 cm	363^{a}	241^{b}	225^{b}	258^{b}	196^{b}	251^{b}	261c	199^{b}	246^{b}	294^{a}	212^{b}	241^{b}
	5×	4 cm	299^{b}	210^{c}	232^{ab}	250^{bc}	186^{c}	241^{bc}	242^{d}	180^{c}	243^{b}	264^{b}	192^{c}	239^{bc}
		10 cm	299^{b}	213^{c}	243^{a}	241^{c}	184^{c}	263^{a}	243^{d}	183^{c}	256^{a}	261^{b}	193^{c}	254^{a}
	LSD (0.05)[3]		40	21	12	25	10	12	21	9	9	17	8	6

[1] Values are means of two experiments.
[2] Means within column followed by the same letter are not significantly different within each binary mixture and solo at p = 0.05 (Fisher's Protected LSD).
[3] LSD for making comparisons across the mixtures and kura clover alone.

in the harvested forage. Akin and Robinson (1982) observed little difference in fiber concentration between the lamina and petiole of arrowleaf clover (*Trifolium vesiculosum* Savi) and crimson clover (*Trifolium incarnatum* L.), however Nelson and Moser (1994) noted that CP concentration is usually higher in the lamina than in the petiole of forage legumes. Harvesting kura clover five times annually at either 4- or 10-cm resulted in higher forage quality than harvesting three or four times.

In all kura clover-grass mixtures, NDF and ADF concentrations decreased and CP concentration increased between the first year and the third year with all harvest frequencies regardless of cutting height. This change was more evident in the OG and SB mixtures than the KBG mixture. Similar trends were observed for the kura clover alone except that essentially no differences were observed between the second and third year. Greater forage quality was closely related to greater kura clover proportion in mixtures over time (Kim and Albrecht, 2008). In kura clover alone, the higher fiber concentrations in year 1 were associated with annual grassy weed contamination which was not present in years 2 and 3 (Kim and Albrecht, 2008).

Seasonal pattern of forage nutritive value

The NDF and ADF concentrations in each binary mixture under 5× were the most uniform across the growing season, however CP concentration tended to increase with each subsequent defoliation (Figure 1). Forage nutritive value under 3× at both cutting heights in each binary mixture was quite low at the first harvest and increased with

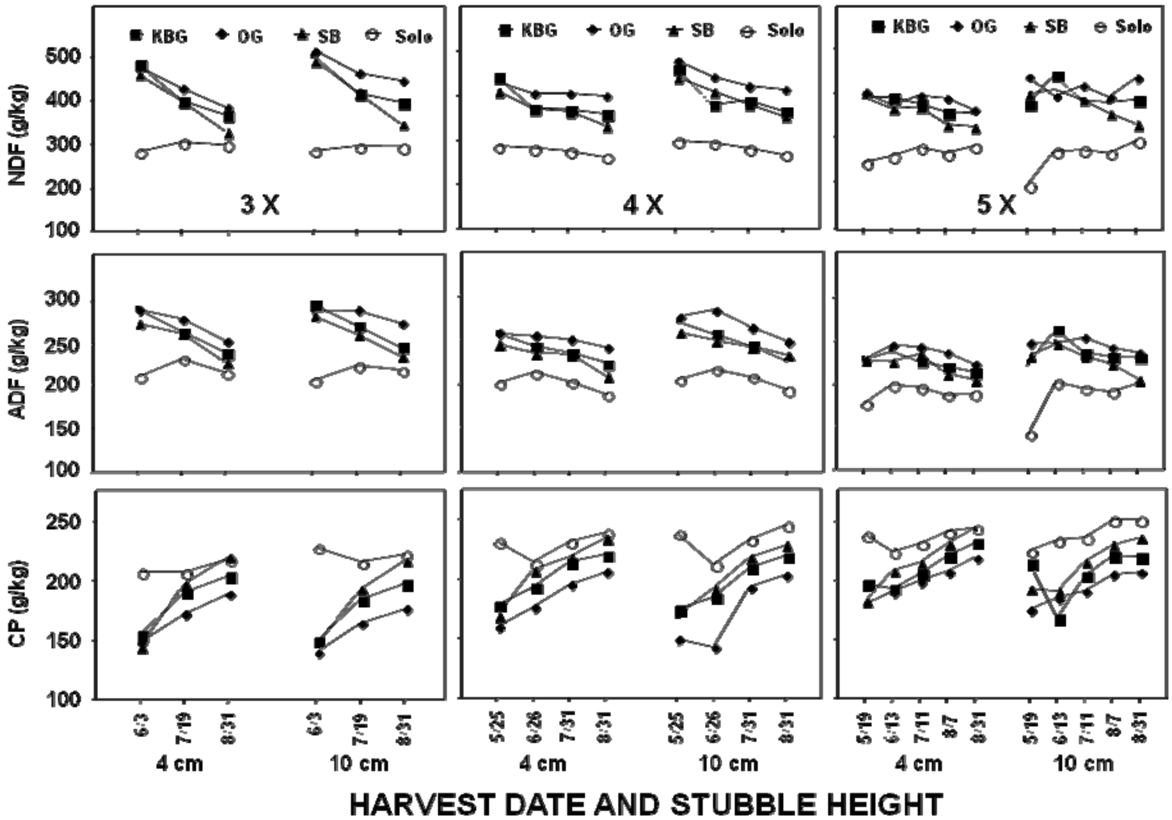

Figure 1. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein (CP) concentrations of binary mixtures of kura clover with Kentucky bluegrass (KBG), orchardgrass (OG) and smooth bromegrass (SB), and kura clover alone harvested three times (3×), four times (4×), and five times (5×) per year at 4- and 10-cm cutting heights. Values are means of years 1, 2 and 3 over two experiments.

subsequent harvest. However, kura clover alone had relatively constant forage nutritive value at each of the three harvests. The lower forage quality in 3× compared to 4× or 5× was associated with a larger proportion of grasses and especially grass stems in the first harvest (Kim and Albrecht, 2008; Table 1).

Forage quality of the SB binary mixture under 3× and 4× improved with subsequent defoliation more than the KBG and OG mixtures. This improvement resulted from greater smooth bromegrass yield reduction in the later part of the growing season compared to KBG and OG binary mixtures (Kim and Albrecht, 2008). Forage quality in the OG mixture was lower at each defoliation than the two other mixtures. In the OG mixture at the 10-cm cutting height and 4× harvest frequency, CP concentration at the second defoliation was low compared with later harvests. This seems to be related to mineralization of organic matter in the soil. The first harvest grass yield was high and likely depleted soil N to a level that caused N deficiency in the second harvest (Kim and Albrecht, 2008). Furthermore, some reproductive tillers that were too short for removal at a 10-cm cutting height developed and were harvested in the second harvest. In the KBG mixture at the 10-cm cutting height under 5×, forage quality at the second defoliation was quite low. This situation was due to the grass portion being relatively larger and more mature because of continued stem production in the second growth at the higher cutting height (Kim and Albrecht, 2008).

Harvest frequency and cutting height significantly affected nutritive value in binary mixtures of kura clover with three grasses commonly grown in the north central USA. Higher nutritive value was associated with greater harvest frequency and shorter cutting heights, two management factors that affected the proportion and/or maturity of grass in mixtures. After year 1 (year 1 was the year after establishment) the forage nutritive value of all mixtures approached that of grade one alfalfa hay (Rohweder et al., 1981) and should have been sufficient for high-producing livestock such as dairy animals, growing steers or lambs.

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