The Potential of Kura Clover as a Forage Crop: The Minnesota Experience

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Kura clover (*Trifolium ambiguum* Bieb.) has been a major topic of research emphasis at the University of Minnesota for the past two decades. The exceptional winterhardiness and persistence demonstrated in some of our first experiments with the species (Sheaffer and Marten, 1991) were the primary impetus prompting the ensuing efforts to: 1) characterize its growth and development, 2) determine its adaptation and management, and 3) attempt to overcome the limitations to its use. Aside from Minnesota's efforts, researchers in Wisconsin, Kentucky, New Zealand, and Australia have been among the most notable contributors to our understanding of Kura clover; their efforts and discoveries have been essential to bringing us ever closer to widespread use of Kura clover in grazing systems. Our objective with this paper is to summarize the Minnesota effort and experience with Kura clover, with emphasis on its characteristics, establishment, and management.

Kura clover is a relatively low growing, spreading perennial legume. It is also called Caucasian, Pellett's, or honey clover. Its primary use in agriculture will likely be as a grazing crop because of its prostrate growth habit and forage that is very leafy and high in moisture content, but the first growth in the spring can also readily be harvested for hay or silage. Because of its excellent persistence and spreading growth habit, Kura clover has great potential for soil cover and erosion control in agricultural and nonagricultural areas.

Kura Clover Yield and Persistence Compared to Other Legumes

'Rhizo' kura clover and several other legumes were seeded at Rosemount, MN in 1984 and subjected to 2-, 3-, and 4-cut harvest schedules in 1985 and 1986 (Sheaffer and Marten, 1991). Initial stands of Kura clover were poorer than the other legumes, but by spring 1987 Kura clover had 95% stands, greater than any other legume. Kura clover demonstrated a slow rate of establishment, having among the lowest yields of all legumes the year after seeding (Table 1). Its yield equaled that of alfalfa, however, by June 1987. The pattern of growth and development noted in this experiment prompted Dr. Gordon Marten to coin the expression, "Kura clover sleeps in the first year, creeps in the second year, and leaps in the third year".

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Table 1. Influence of cutting schedules on forage yield and final stands of perennial legumes at Rosemount, MN.

Cuts/year	Legume	Forage Yield 1985	1986	June 1987	3-yr Total	Stands, May 1987
		---------- Tons DM per acre ----------				---- % ----
2-cut	Alfalfa	4.6	4.9	2.0	11.5	53
	Alsike clover	2.1	2.1	0	4.2	5
	Red clover	3.8	4.8	0	8.6	10
	Birdsfoot trefoil	4.5	4.6	0.8	9.9	30
	Kura clover	2.8	3.3	1.7	7.8	95
	LSD(0.05)	0.4	0.5	0.8		14
3-cut	Alfalfa	6.2	5.2	2.0	13.4	54
	Alsike clover	2.2	0.6	0	2.8	10
	Red clover	3.4	4.4	0	7.8	11
	Birdsfoot trefoil	4.1	4.1	1.6	9.8	29
	Kura clover	2.8	4.1	1.8	8.7	95
	LSD(0.05)	0.2	0.4	0.4		18
4-cut	Alfalfa	5.5	4.9	1.6	12.0	38
	Alsike clover	1.6	0.7	0	2.3	5
	Red clover	2.8	3.7	0	6.5	9
	Birdsfoot trefoil	3.4	4.0	0.1	7.5	9
	Kura clover	2.1	4.1	1.5	7.7	91
	LSD(0.05)	0.3	0.4	0.4		16

'DK 120' alfalfa, 'common' alsike clover, 'Arlington' red clover, 'Norcen' birdsfoot trefoil, 'Rhizo' kura clover

Source: Sheaffer and Marten, 1991. Can. J. Plant Sci. 71:1169-1172.

Kura Clover and Kura Clover-Birdsfoot Trefoil Mixtures Grazed by Lambs

Kura clover, birdsfoot trefoil, and a Kura clover-birdsfoot trefoil mixture were seeded in spring 1985 and grazed by lambs at a high herbage allowance from 1986 to 1989 at St. Paul, MN (Sheaffer et al., 1992). Initial composition of the monocultures was >95%. The mixture was 10% Kura clover and 90% birdsfoot trefoil. By 1989, the kura clover monoculture and mixture were both nearly 100% Kura clover, while the birdsfoot trefoil monoculture had declined to 20% trefoil and 80% broadleaf weeds. Average daily gains were similar and high among treatments, averaging 0.44 lb/day. Lamb days per acre and gain per acre were similar initially (Table 2). However, by the fourth year after establishment, treatments with Kura clover had double the grazing days and gains per acre of those of the birdsfoot trefoil monoculture. When kura clover was greater than 20% of the mixture, seeding with birdsfoot trefoil was ineffective at reducing bloat.

Table 2. Average forage dry matter available and total season lamb days per acre for kura clover, birdsfoot trefoil, and a binary mixture of the two legumes seeded in 1985 and rotationally grazed by lambs at high forage allowance from 1986 through 1989 at St. Paul, MN.

	1986		1987		1988		1989	
	DM T/ac	Lamb days/ac	DM t/ac	Lamb days/ac	DM t/ac	Lamb days/ac	DM t/ac	Lamb days/ac
Birdsfoot trefoil	1.8	1532	1.8	1868	1.6	1350	0.5	1009
Kura clover	1.4	1426	1.3	1750	1.5	1580	1.3	2099
BFT-KC Mixture	1.8	1571	1.7	1936	1.3	1724	1.3	2057
LSD(0.05)		NS		81		NS		226

Source: Sheaffer et al., 1992. Agron. J. 84:176-180.

Table 3. Forage quality of birdsfoot trefoil and kura clover grazed by lambs for 4 years at St. Paul, MN.

Trait	Kura clover	Birdsfoot trefoil
	---------- % ----------	
Leafiness	97	81
Crude protein	25	22
Digestibility	83	72
Neutral detergent fiber	31	33

Source: Sheaffer et al., 1992. Agron. J. 84:176-180.

Kura Clover's Responses to Defoliation Management

In 1990, cutting frequency treatments ranging from three to six cuttings per year to a 3-inch stubble height were initiated on a 5-year-old stand of Rhizo Kura clover at St. Paul, MN, and continued for 3 years (Peterson et al., 1994a). Total season yield averaged 3.8 tons DM/acre and was unaffected by clipping frequency until the third year, when five and six cuttings per season produced 80 and 70% as much forage, respectively, as either three or four cuttings. However, first cutting yield the following spring was unaffected by cutting frequency the previous year(s). This limited negative response to frequent clipping contrasts dramatically with the responses of non-rhizomatous perennial legumes like alfalfa and birdsfoot trefoil.

A grazing trial with sheep was initiated that same year; treatments included continuous stocking and three rotational stocking regimes allowing 14 or 28 days of rest between grazing periods. There were two grazing treatments with a 28-d rest period that varied in duration; one was terminated in early September, the other in early October. In the second and third years of the trial, rotational stocking with 14-d rest periods reduced forage production by only 22% compared to rotational stocking with 28-d rest periods. Fall grazing reduced spring yields only after the first year of grazing treatments, and had no affect on spring or total season yields the following two years. Kura clover yield in early October was low, probably due to dormancy, suggesting limited forage production potential in fall.

These experiments revealed that height of defoliation has an impact on kura clover productivity. In the sheep grazing trial, sheep were allowed to remove herbage essentially to ground level, leaving no residual leaf area. Thus, average total season yields declined from almost 7 tons DM/acre in year one to just over 4 tons DM/acre in year three. With a 3-inch stubble in the clipping trial, residual leaves were often present, particularly for the more frequently harvested plots, enabling Kura clover to utilize current photosynthate to provide energy for regrowth. Yields were highest in spring, then decreased steadily through summer into fall, particularly under frequent defoliation. Kura clover thus exhibits phenotypic plasticity in response to time of year and extent of defoliation, thereby maintaining its persistence under grazing.

Below-ground mass of Kura clover to a 6-inch depth averaged almost 3 tons DM/acre and was comprised of 25% crown, 45% rhizome, and 30% root (Peterson et al., 1994b). TNCs in all below-ground plant parts followed a common pattern of TNC being lowest in June and increasing linearly to a maximum in the fall. In contrast to grazing to ground level, clipping treatments to a 3-inch stubble had little impact on below-ground morphology and TNC concentrations. Below-ground fractions frequently increased in mass in the fall. There was evidence that Kura clover may reduce aboveground growth under frequent, close defoliation to maintain adequate below-ground TNC concentrations for stand survival. Persistence was excellent under all treatments.

Averaged over experiments, treatments, and years, Kura clover forage had CP, NDF, ADF, ADL, and IVDDM concentrations of 25, 30, 27, 3, and 87 %, respectively. Crude protein and IVDDM concentrations increased and NDF, ADF, and ADL concentrations decreased as frequency of defoliation increased in both experiments, but these changes were relatively small, because of the leafiness of forage in all defoliation treatments.

Seeding Year Growth and Development of Kura Clover

Field experiments were conducted on a sandy loam soil at Becker, MN, and a silt loam at St. Paul, MN, to study herbage and root biomass accumulation and seedling development of Kura clover following spring and summer planting (Genrich et al., 1998). Spring-seeded Kura clover had rhizome development 9 weeks after planting. Some spring-seeded plants had rhizomes which were 8 inches long with leaves by the end of October. Pink nodules were observed 2 months after spring planting and 6 weeks after summer planting. By October of the seeding year, spring-planted Kura clover had average herbage yields of 1488 lb DM/acre and below-ground mass of 2432 lb DM/ac, with about 10% of the below-ground mass as rhizomes (Table 4). Endura had greater whole plant and herbage yields than Rhizo, but similar root yields. This experiment demonstrated the significant partitioning of dry matter to roots, and suggested that increased seedling vigor might be obtained by selecting for increased herbage accumulation.

Table 4. Total plant herbage root and rhizome DM yield from an October harvest of spring-seeded Kura clover on a high fertility silt loam soil and a sandy loam soil at Becker, MN. Root biomass includes roots, crowns, and rhizomes in 0-15 cm of the soil.

Sites/Entry	Whole Plant	Herbage	Root	Rhizome†
	----------lb/acre----------			
St. Paul				
Endura	4659	2088	2571	353
Rhizo	3698	1085	2612	289
LSD (0.05)	187	106	NS	45
Becker				
Endura	3875	1526	2348	212
Rhizo	3469	1259	2209	185
LSD (0.05)	295	116	NS	8

† Rhizomes were included as a fraction of the root yield.
Source: Genrich et al., 1998. Crop Sci. 38:735-741.

Nitrogen Fixation by Kura Clover

The nitrogen fixation capability of Kura clover was compared to that of birdsfoot trefoil in 2- and 3-year old stands at Becker and Rosemount, MN (Seguin et al., 2000). Both species produced the greatest amount of forage, total N, and fixed N yields at the first of four harvests each year. The percentage of N derived from fixation for Kura clover was stable across harvests and environments, averaging 57% (Table 5). This contrasted with that of birdsfoot trefoil, which varied during the season, peaking at the end of each season. The total N and fixed N yields of Kura clover were greater than those of birdsfoot trefoil at one of two locations. Overall, Kura clover fixed about 140 lb N/ac/yr compared to an average of 130 lb N/ac/yr fixed by birdsfoot trefoil.

Table 5. Yearly total forage, N, and fixed N yields, and the percentage of N derived from fixation for Kura clover and birdsfoot trefoil in their first and second production years after seeding at two Minnesota locations.

Location	Species	Forage Yield	N Yield	Fixed N	% of N Fixed
		Ton DM/acre	---------- lb/ac ----------		----- % -----
Becker/	Birdsfoot trefoil	3.3	191	117	61
Loamy sand	Kura clover	4.0	246	141	57
	Sign.	NS	**	*	NS
Rosemount/	Birdsfoot trefoil	3.8	223	144	64
Silt loam	Kura clover	3.9	237	135	57
	Sign.	NS	NS	NS	NS

*, ** Significant at the 0.05 and 0.01 levels, respectively.
Source: Seguin et al., 2000. Agron. J. 92:1216-1220.

Compatibility of Kura Clover with Grasses Under Grazing

Mixtures of 'Endura' kura clover with each of four grass species were evaluated under four years of rotational stocking by sheep at St. Paul and by goats at Grand Rapids (Peterson et al., 2001). Plots were established in 1993 and grazed from 1994 through 1997. Kura clover percentages in mixtures increased from 23% during 1994 to 58% during 1997. Yield rankings varied, but mixtures of Kura clover with reed canarygrass were most consistently among the highest yielding mixtures (Table 6). Timothy and Kentucky bluegrass did not compete adequately to be considered viable grass options. Orchardgrass generally maintained a favorable balance with kura clover, but its yield potential in combination with kura clover was inconsistent at St. Paul.

Table 6. Total season yield and season average Kura clover percentage in mixtures of Kura clover and grasses seeded in 1993 and grazed from 1994 through 1997 at St. Paul and Grand Rapids, MN.

		Total Season Yield				% Kura clover	
Site	Mixture	1994	1995	1996	1997	1994	1997
		---------- tons DM/acre ----------				----- % -----	
St. Paul	KC + Timothy	2.6	2.9	1.5	2.7	22	89
	KC + Reed canarygrass	2.7	3.5	2.1	3.5	12	52
	KC + Kentucky bluegrass	1.4	3.1	1.5	3.7	33	75
	KC + Orchardgrass	2.6	1.6	1.4	3.8	14	53
	KC alone	1.5	2.5	1.8	3.2	67	93
	LSD (0.05)	0.4	0.8	0.5	0.8	8	17
Grand Rapids	KC + Timothy	2.4	3.3	3.1	3.6	32	67
	KC + Reed canarygrass	1.8	3.7	2.9	4.1	51	54
	KC + Kentucky bluegrass	1.5	4.2	3.2	4.1	56	71
	KC + Orchardgrass	2.2	4.3	3.2	3.5	34	27
	LSD (0.05)	NS	0.8	NS	0.6	14	17

Source: Peterson et al., 2001. Proc. AFGC Conf. Springdale, Arkansas.

Rhizobial Inoculation and Nitrogen Fertilization Effects on Kura Clover

The effects of rhizobial inoculation and N fertilization on kura clover growth and N fixation in the seeding year were evaluated in three environments in Minnesota (Seguin et al., 2001). N fertilization during the seeding year increased both seeding year and post-seeding year forage yield in all locations, but the response to N fertilizer was greater on a loamy sand with low organic matter and available N than on a silt loam with high soil organic matter (Table 8). Rhizobial inoculation did not consistently improve seeding year forage yield but increased post-seeding year yield (Table 7). N fixation in the seeding year was small, ranging from only 8 to 22 lb N/ac. The commercial inoculant used was ineffective in establishing adequate nodulation in the seeding year, indicating the need to identify more effective rhizobia for Kura clover.

Table 7. Influence of Rhizobial inoculation and soil type/fertility on forage yield of Kura clover in the seeding year and spring of the post-seeding year at 3 locations in Minnesota.

		Soil Type		
Year	Treatment	Sandy Loam 1.8% O.M.	Sandy Loam 1.6% O.M.	Silt Loam 5.3% O.M.
		---------- lb DM/acre ----------		
Seeding Year	Not Inoculated	450	1286	4700
	Inoculated	998	1682	4637
	P-value	†	*	NS
Spring of Post-Seeding Year	Not Inoculated	297	1250	4272
	Inoculated	1950	1808	5076
	P-value	*	NS	*

† Significant at 0.10 level
Source: Seguin et al., 2001. Agron. J. 93:1262-1268.

Table 8. Influence of N fertilization at seeding and soil type/fertility on forage yield of Kura clover in the seeding year and spring of the post-seeding year.

		Soil Type		
Year	N Level (lb/ac)	Sandy Loam 1.8% O.M.	Sandy Loam 1.6% O.M.	Silt Loam 5.3% O.M.
		---------- lb DM/acre ----------		
Seeding Year	0	512	727	4004
	100	934	1342	5126
	LSD (0.05)	†	†	†
Spring of Post-Seeding Year	0	958	1058	5045
	100	1290	1695	4769
	LSD (0.05)	NS	*	NS

† Significant at 0.10 level
Source: Seguin et al., 2001. Agron. J. 93:1262-1268.

Current commercial rhizobial inoculant for Kura clover may have limited benefits in the seeding year. However, N fertilization more consistently increased Kura clover seeding year herbage DM accumulation, suggesting that Kura clover growth was often N limited in the seeding year. Benefits of seeding year N fertilization were sustained in the post-seeding year. Nodulation response to inoculation appeared more than 7 weeks after seeding, and it took over 3 months before more than 10 nodules per plant were obtained, confirming that nodulation of Kura clover is a very slow process. In other species, nodulation is typically observed 2 to 3 weeks after inoculation. This slow rate of nodulation may be responsible for Kura clover's poor seeding year response to inoculation.

A follow-up study compared the genetic diversity of rhizobia from 9 diverse North American environments with that of rhizobia from a single Russian environment at the center of origin of Kura clover (Seguin, 2000). While the genetic diversity within the North American

populations proved to be extremely limited, the Russian isolates were distinct with significant genetic diversity. This study confirmed that Kura clover is highly specific for rhizobia.

Kura Clover Establishment Methods

Alternative methods for Kura clover establishment in tilled seedbeds were evaluated at Rosemount, MN (Seguin et al., 1999). Methods included an oat companion crop harvested for forage, a birdsfoot trefoil companion crop seeded with or without Treflan, and solo-seeding with or without Treflan. Kura clover forage yield in the seeding and post-seeding years was maximized when solo-seeded with Treflan, but results varied (Table 9). Kura clover seeding year yields were characteristically low regardless of establishment method. The oat companion crop increased total weed-free forage yield in the seeding year, but reduced Kura clover yields in the seeding and post-seeding years by 45% compared with solo-seeding with a herbicide. Using birdsfoot trefoil as a companion crop produced similar or lower Kura clover yields as solo-seeding with Treflan in seeding and post-seeding years, but similar or greater total forage yields.

Table 9. Influence of establishment methods in tilled seedbeds on seeding and post-seeding year Kura clover and total weed-free forage yields at Rosemount, MN (averaged over three experiments).

	Kura clover yield		Total weed-free forage yield	
	Seeding Year	Post-Seeding Yr	Seeding Year	Post-Seeding Yr
	---------- lb DM/acre ----------			
Oat companion crop	72	2062	3262	2062
BFT with Treflan	69	1989	408	5666
BFT w/o Treflan	78	1276	189	4704
KC Solo with Treflan	169	2735	169	2735
KC Solo w/o Treflan	91	2323	91	2323

Source: Seguin et al., 1999. J. Prod. Agric. 12:483-487.

A field experiment was conducted at Morris, MN to evaluate the effects of sod suppression, planting method, and legume species on establishment of legumes including Kura clover into existing cool-season grass pastures (Cuomo et al., 2001). When 0.75 qt/ac Roundup was used to suppress the grass pasture at seeding, legumes stands averaged 38% compared to only 3% where no suppression was used (Table 10). Planting methods including no-till drilling, broadcasting, broadcasting followed by harrowing, and broadcasting followed by light disking produced similar legume stands. Stand establishment was greatest for alfalfa, intermediate for red clover, and poorest for birdsfoot trefoil and Kura clover. However, given Kura clover's ability to spread and increased in mixed stands, these levels of establishment are likely adequate.

Table 10. Influence of legume species and Roundup sod suppression on percent stand of inter-seeded legumes at Morris, MN, averaged over two experiments and two sampling dates (4 and 12 months after spring establishment).

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

Source: Cuomo et al., 2001. Agron. J. 93:458-462.

Increasing Kura Clover Seedling Vigor via Plant Breeding

Low seedling vigor presents a challenge to Kura clover establishment. Since Kura clover seedlings partition a significant portion of their resources to below ground growth, seedling vigor might be improved by increasing dry matter allocation to the shoot. Thus, a study was initiated to determine the potential of recurrent phenotypic selection in the greenhouse for reduced root/shoot ratio to increase seedling vigor (DeHaan et al., 2001). Three cycles of divergent selection for root/shoot ratio and a control selection for large plant biomass were performed from a parent population of from several germplasm sources. Three cycles of selection for low root/shoot ratio or large plant biomass increased shoot yield in the field 42 d after planting by 35% (Table 11). Selection for high root/shoot ratio did not affect seedling size in the field. Seed size was correlated with shoot and root growth, but not as highly correlated as greenhouse shoot weight, so gains are likely to be gained more rapidly by direct phenotypic selection for shoot growth. This experiment documented the potential of phenotypic greenhouse selection for seedling size as a means of increasing seedling vigor in Kura clover.

Table 11. Population means for seedling traits of Kura clover in a field evaluation of the parents and progeny populations from the three cycles of greenhouse selection for high root/shoot ratio, low root/shoot ratio, and large total plant biomass.

Kura Clover Population	Ratio	Root	Shoot	Total
		---------- grams ----------		
Parents	0.44	0.48	1.13	1.60
High Root/Shoot ratio (C_3)	0.45	0.53	1.23	1.75
Low Root/Shoot ratio (C_3)	0.37	0.54	1.53	2.07
Large Total Plant weight (C_3)	0.41	0.59	1.51	2.10
LSD(0.05)	0.04	0.08	0.19	0.26

Source: DeHaan et al., 2001. Crop Sci. 41:1034-1041.

Summary/Concluding Points

Kura clover has proven to be a very winter hardy species in Minnesota. Its extensive root-rhizome complex provides for excellent persistence. It has survived extreme winter conditions in Minnesota and Wisconsin and persisted for over 15 years while all other legumes including alfalfa and birdsfoot trefoil have died. Kura clover can tolerate frequent and close defoliation, utilizing residual leaf area, phenotypic plasticity, and high below-ground mass to maintain adequate TNC levels in its root-rhizome complex to ensure persistence. Its forage is leafy and consistently high in quality, conferring high animal performance. Its potential to induce bloat necessitates planting in mixtures; reed canarygrass has proven to be a compatible grass.

Although kura clover is very persistent once established, establishing kura clover is more challenging than for most other forage legumes. It has less seedling vigor than white clover and birdsfoot trefoil. However, time and financial resources spent in establishing long-term stands of kura clover should be considered an investment that will provide returns for years to come. It has been said: "Kura clover sleeps in the first year, creeps in the second year, and leaps in the third year". Because of its lack of seedling vigor, it is essential to minimize competition with weeds or companion crops at establishment. Kura clover nodulates slowly with currently available rhizobial inoculum, and is thus N-deficient during the seeding year; N fertilizer improved Kura clover seedling growth in monoculture. Once established, however, Kura clover fixed 140 lb N/ac/year. We have documented the potential to increase Kura clover seedling vigor by selecting for seedling size. Continued efforts to improve Kura clover establishment success in pastures is warranted given its proven long-term persistence and yield and consistently high quality.

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