Educating Growers About Living Mulch Systems for Grain Crop Production

Final Research Report
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Executive Summary

Incorporation of perennial legumes into row cropping systems, in combination with reduced tillage, may help growers with soil erosion control and reduce production inputs, such as N. Reducing erosion is particularly important in the Driftless Area in northeast Iowa where current crop production practices have been identified as a contributor to the decline in surface water quality. Our overall objective was to demonstrate that corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] can be grown in a kura clover (*Trifolium ambiguum* M. Bieb.) living mulch system while maintaining yields of the current row-crop production systems. Specific objectives were with a Kura clover living mulch system to i) determine corn response to N fertilization rate, and ii) determine the effect of soybean seeding rate on grain yield. The experimental design was a randomized complete block in a split-plot arrangement with three replications. Main plots were strips of kura clover and strips of prior-year corn or soybean. In 2004, kura clover was planted at six locations and allowed to established without planting row crops in 2004 or 2005. In 2006, corn was planted at three locations and soybean at the other three locations. Corn and soybean was then rotated and planted where soybean and corn was planted in 2006, respectively. The corn and soybean were no-till planted into the kura clover and either previous corn or soybean stubble strips (without kura clover). Sub-plots at the corn locations were N rates of 0, 40, 80, 120, 160, and 200 lb N acre^{-1}. At the soybean locations the sub-plots were seeding rates of 150,000, 200,000, 250,000, and 300,000 seeds/acre.

When corn was grown with a kura clover living mulch system little additional plant available N was supplied, and not at adequate levels to solely support a growing corn crop. The effect of the living kura clover system on soil NO_3-N concentrations throughout the growing season was minimal, and most times soil NO_3-N concentrations in the soil profile were not different compared to the no kura clover, corn-soybean rotation system. The kura clover living mulch system was also not effective in reducing residual post-harvest profile soil NO_3. This, along with similar NO_3-N concentrations in the spring before planting, indicated that the living mulch system utilized in this project would not be effective in reducing potential for NO_3 to leach from the soil system.

Both corn and soybean yield was reduced in the kura clover living mulch system when not properly suppressed with herbicide applications and/or livestock grazing pressure. Careful management strategies need to be implemented to ensure kura clover competition is reduced. Increased seeding rate for soybean did not improve the yield as a means to overcome some of the competition early in the growing season. Proper timing of kura clover suppression and corn planting is essential to implementing row crops into the living mulch.

This project was the first large on-farm demonstration project in Iowa using kura clover as a living mulch integrated into the corn and soybean production system. Averaged across all locations where the corn and soybean yields could be determined, no corn or soybean yield differences were observed with and without kura clover. The yields and success of the row-crop production, however, were very variable from location to location depending upon the amount of kura clover competition during seedling establishment and early vegetative growth. Timely suppression to minimize competition of the kura clover is a key for success of this system.

Background

Iowa ranks first in the USA in corn and soybean production, with these two crops accounting for more than $5 billion of the state's cash income each year. Corn and soybean production is therefore very important for Iowa and the United States. Alfalfa-corn-soybean rotations occupy approximately 2 million acres of Iowa cropland, primarily in northeast Iowa (Dr. Steve Barnhart, person communication).

The current alfalfa-corn-soybean rotation evolved as a means to meet feed requirements of livestock, as a cheap way to meet N requirements for corn production, and as a means to conserve soil on sloping landscapes. Conservation tillage systems (i.e., those in which there is at least 30% ground cover by crop residue) in these rotations lower the risk for soil erosion, particularly during crop establishment; yet, as recently only 30% of Iowa cropped acres were established using such systems. Crop residue and living plants reduce soil erosion in the rotation by intercepting rainfall and limiting sediment detachment, surface sealing, and sediment transport in runoff. According to the USDA statistic service (NASS), 47% of USA cropland is losing topsoil in excess of its soil loss tolerance level (3 tons/acre/year). Extending the soil-conserving characteristics of established perennial forages through a crop rotation with soybean and corn would greatly improve soil conservation, reduce NO_3 leaching and reduce P runoff losses.

Living mulches are plants that are intercropped in combination with row crops. The mulch can decrease erosion, suppress weeds, reduce insect pests, and in the case of legumes supply N to the row crop. Kura clover is a relatively new forage legume in North America. It has an excellent forage yield and is persistent under a wide range of soil and climatic environments. Kura clover is a long-lived, perennial, rhizomatous legume that tolerates frequent defoliation in monoculture or in binary mixture with grass that is suitable for hay or pasture production. Kura clover is adapted to cold winters and very persistent. Kura clover persistence is associated with its large rhizome system that has large numbers of buds at various depths in the soil. Kura clover's ability to survive longer than alfalfa may outweigh its lower forage yield, which is about 80% of a good alfalfa crop (Dr. Kenneth A. Albrecht, personal communication). A research project was initiated in Wisconsin in 1996 to evaluate kura clover as a living mulch with corn production. Results were very promising, indicating that corn could be produced with no yield reduction in this type of system (if the kura clover was adequately suppressed with herbicides). Also, this research illustrated that kura clover will recover to full production for pasture, silage, or hay the following season (Pedersen, 1999; Zemenchik et al., 2000). This post-emergent suppression of kura clover was accomplished using low rates of glyphosate (N-(phosphonomethyl)glycine) and using glyphosate resistant corn hybrids.

Although there are many management questions to be investigated, it would be highly advantageous for kura clover-living mulch systems to be largely N self-sufficient, result in year-round groundcover, leave less opportunity for weed invasion, require less tillage, and reduce soil erosion compared to conventional systems. The living mulch cropping system should be applicable anywhere alfalfa-corn-soybean rotations are now used and especially where slope and soil erosion is a problem, such as in the unglaciated portion of the Upper-Mississippi Valley.

Part 1. Corn Response to Nitrogen Fertilization

Introduction

Corn production systems that incorporate legumes into cropping rotations can enhance yields and help supply crop available N. Traditionally, these legumes are managed and rotated for crop production, with soybean and alfalfa common examples in Iowa. There are many species of legumes that can be grown in rotation with corn, and some can be useful as living mulches. Benefits of legumes, especially forage legumes, include improved soil structure, nutrient cycling, and N supply to the grain crop (Singer and Pedersen, 2005). Greater crop N supply is well documented in corn when alfalfa was previously grown. The Iowa State University recommendation for N fertilizer application to corn following established alfalfa is 0-30 lb N acre^{-1}, compared to 150-200 lb N acre^{-1} for continuous corn (Blackmer et al., 1997). Recent experiments in Wisconsin have indicated that kura clover can perform well as a living mulch for corn production. It has been proposed that corn in this system requires little to no N fertilization, and causes no reduction in corn grain yield (Zemenchik et al., 2000; Affeldt et al., 2004). A reported range of calculated N fertilizer replacement values for kura clover inter-cropped with Kentucky bluegrass was between 200-250 lb N acre^{-1} (Zemenchik et al., 2001).

The objectives of this work were to determine if adequate N can be supplied to corn solely from a kura clover living mulch system and to compare N fertilizer response with corn following soybean without the living mulch.

Materials and Methods

Sites were located on six producer fields in northeast Iowa in 2006 and 2007, with three sites planted to corn each year. The experimental design was a randomized complete block in a split plot arrangement with three replications. Main plots were strips of established kura clover and strips of prior-year soybean (in a corn-soybean rotation with no kura clover). Strips were approximately 60 ft wide by 480 ft long. Sub-plots (6 rows by 50 ft length) with N rates of 0, 40, 80, 120, 160, and 200 lb N acre^{-1} were located in each strip. Kura clover (Endura cv.) was planted at 7.5 lb seeds acre^{-1} in late April of 2004, and maintained solely as kura clover with no inter-cropping in 2004 and 2005. The kura clover living mulch was managed by mowing the kura clover in June, July, and August during 2004 and 2005. Sites 5 and 6 were grazed by cattle (*Bos Taurus*) in the fall prior to corn planting in 2007.

Soil samples from the 0-6 inch depth were collected in the spring prior to planting from each kura clover and no kura clover main plot in 2004 and the N rate plot areas in the no kura clover system in 2006 and 2007. Samples were analyzed for routine soil tests; pH, soil test P (STP), soil test K (STK), and organic matter (Tables 1 and 2). Kura clover stand and growth was documented by collecting aboveground biomass (main kura clover plots) in the fall of 2004 and spring and fall of 2005-2007 (Table 3).

Corn was planted with no tillage planter (MaxEmerge, John Deere, Moline, IL) mounted with a coulter and residue wheels in the established kura clover using a living mulch system and into the soybean residue from the prior-year soybean crop. The corn hybrid planted at all sites in 2006 and 2007 was Golden Harvest H-8124GT at 30,000 seeds acre^{-1}. Corn was planted on May 23 in 2006, and May 1 in 2007. Calcium ammonium nitrate (2006) and ammonium nitrate (2007) were applied broadcast in the N rate N rate plots shortly after corn planting. Triple superphosphate and potassium chloride fertilizers were applied prior to corn planting at 60 lb P_2O_5 and K_2O acre^{-1}. Corn plant populations in the N rate plots were adjusted for uniformity. Corn was suppressed twice with glyphosate using 1 lb a.i. per acre per application. To the first application of glyphosate 0.4 lb a.i. per acre of dicamba (3,6-Dichloro-*o*-anisic acid) was added.

Soil samples were collected in the early spring (April) prior to corn planting (0-12 and 12-24 inch depths), late spring (early June) when corn was 6-12 inches tall (0-12 and 12-24 inch depth), and fall (October) after corn harvest (0-12, 12-24, and 24-36 inch depths) in the N rate plots. The zero N rate plots were sampled in April and the 0, 80, and 160 lb N acre^{-1} N rates were sampled in late spring and fall. Samples were analyzed for NO_3-N.

In-season N stress monitoring of corn plants was completed in late June and early July (approximate corn growth stage V10-V13). Chlorophyll readings were collected from corn leaves on 20 plants (upper most leaf with collar fully visible) from each N rate plot using a Minolta SPAD-502 chlorophyll meter. The SPAD meter in essence measures leaf greenness which reflects chlorophyll content and N status (Sawyer et al., 2006). The meter transmits light through the leaf, and calculates the ratio of measured visible (650 nm wavelength) and infrared (940 nm wavelength) light. Readings were converted to relative sensor values by normalizing the reading to the highest applied N rate (dividing SPAD reading by the reading from the 200 lb N acre^{-1} rate).

Corn grain was hand harvested from the middle two rows (25 ft length) of each N rate plot. Grain yield was then calculated and adjusted to 15.5% moisture. Data was analyzed using PROC MIXED in SAS (SAS Institute, 2003).

Results and Discussion

Table 4 gives soil NO_3-N concentrations measured at different times throughout the growing season. With sampling in April prior to corn planting, soil NO_3-N concentrations varied between years, and in all cases were low. In 2006, there was a significant system effect, and system by depth interaction. In the kura clover system, soil NO_3-N concentrations in the top 24-inch depths were statistically less than in soybean residue. In 2007, there were few differences between kura clover and no kura clover, except for a significant system by depth interaction at site 5 where the soil NO_3-N concentration was higher in the kura clover system at the 0-12 inch depth. The soil NO_3-N concentrations in early June were nearly identical for both systems, and did not differ statistically. Soil NO_3-N concentrations in the 80 and 160 N rates were elevated compared to the zero rate, indicating significant fertilizer N in the soil for plant N uptake in both the kura clover and no kura clover systems. The concentration in the 0-12 inch depth with the 160 lb N acre^{-1} rate was above the 25 mg kg^{-1} critical test level (Blackmer et al., 1997) at all sites. With the 80 lb N acre^{-1} rate, the concentrations were generally below the critical level. There was some movement of applied N below the top 12 inch depth as indicated by NO_3-N concentrations greater than with the zero rate at all sites, especially with the high N rate. Fall post-harvest profile NO_3-N concentrations with the kura clover and no kura clover systems were different in 2006 and 2007 (Table 4). There were statistically significant system, system by depth, and system by N rate effects in 2 of the 3 sites in 2006. The kura clover system at those 2 sites had higher soil NO_3-N concentrations across N rates and soil depths. This was likely due to the drastically reduced corn stands and yields which reduced N uptake through the season. In 2007, there were no differences between kura clover and no kura clover systems, except for a small system by N rate effect at site 5. The lack of differences between systems in 2007 were likely due to good corn growth and production in both systems and may also have been due to a residual rotation effect from 2006. In 2006, soybeans were planted into the kura clover to study soybean response when planted into a kura clover living mulch system.

Minolta SPAD-502 chlorophyll meter readings and calculated relative values across systems and N rates are given in Table 5. The SPAD readings were not collected at sites 2 and 3 from the kura clover system in 2006 due to erratic corn stands and low plant populations. The lower suppression and greater competition from the kura clover at 2006 sites compared to 2007 sites is apparent by the larger spring and fall kura clover biomass in 2006 (Table 3). The SPAD readings and relative values in 2006 indicate each site (no kura clover system) was responsive to applied fertilizer N, as indicated by SPAD readings that increased with increasing N rate and relative values much less than the 0.97 optimal value (Sawyer et al., 2006) with zero and low N application rates. The kura clover system at site 1 had a statistically significant difference for N rate, but SPAD values were higher in the zero N rate compared to the 120 and 160 lb N acre^{-1} rates, so the N status appeared adequate with no applied N. At site 4 in 2007, SPAD values across N rates in both systems were highly variable, and no significant N rate or system effects were evident. Sites 5 and 6 were responsive to N rate in both systems. The SPAD readings were statistically greater in the kura clover system compared to the no kura clover with no N applied, indicating that the kura clover living mulch supplied some plant available N to corn by late June.

Table 6 gives the corn grain yield response to applied N, economic optimum N rate (EONR), and yield return for each lb of N applied in the kura clover and no kura clover systems. Corn grain yield was not collected at sites 2 and 3 in 2006 from the kura clover system due to erratic and low plant stand. At site 1 in 2006, the kura clover system EONR was aero lb N acre^{-1}, meaning no fertilizer N application was needed to optimize return. However, corn grain yields were much lower compared to the no kura clover system at that site (due to delayed corn growth and cover crop competition in the kura clover system). Economic optimum N rates in the no kura clover system were variable in 2006 but within expectations for corn following soybean, ranging from 81 to 141 lb N acre^{-1}. In 2007, yields were high for both systems at all sites. The average economic yield was 217 bu acre^{-1} for the kura clover vs. 202 bu acre^{-1} in the no kura clover system (Table 6). In 2007 corn in the kura clover system required a greater average fertilizer N application rate than the no kura clover system as demonstrated by a higher EONR (135 lb N acre^{-1} vs. 124 lb N acre^{-1}). Most of that difference was due to N response at site 5. The no kura clover system in 2007 had a typical agronomic rate response for corn following soybean (124 lb N acre^{-1}). Analysis of corn yield increase to the EONR in 2007 for the kura clover and no kura clover systems indicated a similar average N response per unit of yield (1.83 vs. 1.76 bu lb^{-1} N applied).

Part 1 - Conclusions.

When corn is grown with a kura clover living mulch system little additional plant available N is being supplied, and certainly not at adequate levels to solely support a growing corn crop. In a good production year, the EONR was slightly higher with the kura clover living mulch system than only soybean as a previous crop. When competition from the kura clover was adequately suppressed, corn showed less stand variability, more normal growth and rate of growth development, and in-season plant N status comparable to corn in a no kura clover system. Compared to a no kura clover system, the EONR for corn grown in a kura clover system was lower at two sites (1 and 4) and was greater at two sites (5 and 6).

The effect of the living kura clover system on soil NO_3-N concentrations throughout the growing season was minimal, and most times soil NO_3-N concentrations in the soil profile were not different compared to the no kura clover, corn-soybean rotation system. The kura clover living mulch system was also not effective in reducing residual post-harvest profile soil NO_3. This, along with similar NO_3-N concentrations in the spring before planting, indicates the living mulch system utilized in this project would not be effective in reducing potential for NO_3 to leach from the soil system.

Corn grain production can be reduced by a kura clover living mulch system when not properly suppressed with herbicide applications and/or livestock grazing pressure. Careful management strategies need to be implemented to ensure kura clover competition is reduced. Proper timing of kura clover suppression and corn planting is essential to implementing row crops into the living mulch. In this project, corn plant stand and emerging corn seedlings required more time to develop than in a soybean residue only system due to living mulch competition and wet-cool springtime soils. Kura clover growth was reduced and suppression more successful at site 6, where the soil was a well drained, sandy loam with low organic matter. The corn yields at site 6 were also the highest of any site, suggesting a living mulch system may be more successful on light textured soils.

Table 1. Soils and routine soil test results at six northeast Iowa field locations at initiation of the project in 2004.

Sites		Soils	pH	STP	STK	OM
				mg kg^{-1}		%
2004						
1	Mason City	Clyde silty clay loam	6.7	20	177	6.9
2	Plainfield S	Waukegan, Kenyon, Lawler loams	7.1	31	228	2.9
3	Plainfield N	Kenyon loam	6.7	44	246	4.0
4	Floyd	Clyde silty clay loam, Floyd loam	6.2	39	180	7.1
5	Grundy	Muscatine, Tama, Dinsdale silty clay loams	7.2	41	166	3.9
6	Butler	Dickinson, Olin fine sandy loam	6.4	22	172	2.9

Soil test results are a composite from each replication of kura clover and no kura clover systems at the 0-6 inch depth.
Soil test P (STP) and soil test K (STK) determined with the Mehlich-3 test.

Table 2. Soils and routine soil test results in the N rate plot areas in 2006 and 2007, prior to corn planting in kura clover and no kura clover systems.

Sites		Soils	pH	STP	STK	OM
				mg kg^{-1}		%
2006						
1	Mason City	Clyde silty clay loam	7.1	15	173	6.0
2	Plainfield S	Waukegan, Kenyon, Lawler loams	7.2	23	264	3.7
3	Plainfield N	Kenyon loam	6.4	19	238	3.6
2007						
4	Floyd	Clyde silty clay loam, Floyd loam	6.5	22	103	6.8
5	Grundy	Muscatine, Tama, Dinsdale silty clay loams	7.1	41	152	4.3
6	Butler	Dickinson, Olin fine sandy loam	5.9	8	148	1.7

Soil samples were collected from the no-kura clover N rate plot areas in the spring prior to corn planting, 0-6 inch depth.

Soil test P (STP) and soil test K (STK) determined with the Mehlich-3 test.

Table 3. Estimated kura clover biomass, 2004-2007.

	Year						
	2004	2005		2006		2007	
Sites	Fall	Spring	Fall	Spring	Fall	Spring	Fall
	- lb acre^{-1} -						
1	629	1744	2584	1840	934_c	597_c	602_s
2	647	1621	2306	1886	504_c	381_c	357_s
3	781	2030	2678	1909	310_c	393_c	296_s
4	537	2177	3307	1956	1134_s	--	1305_c
5	246	2297	1211	2235	2171_s	--	1203_c
6	534	1698	1071	1072	298_s	--	428_c

c Indicates corn residue present at the time of kura clover biomass estimation.
s Indicates soybean residue present at the time of kura clover biomass estimation.
Biomass in lb acre^{-1} reported on a dry weight basis.

Table 4. Soil NO_3-N concentrations in early spring, late spring, and fall in the kura clover and no kura clover systems, 2006 and 2007.

			Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
Timing	Depth	N rate	Kura	No Kura	Kura	No Kura	Kura	No Kura	Kura	No Kura	Kura	No Kura	Kura	No Kura
	inch	lb acre^{-1}	mg kg^{-1}											
April	0-12	0	2	2	2	4	2	3	5	3	5	3	1	1
	12-24	0	1	4	1	4	1	3	4	3	3	4	2	2
			p>F											
		system	0.063		0.013		0.035		0.173		0.893		0.475	
		system*depth	0.001		0.101		0.007		0.229		0.039		0.900	
			mg kg^{-1}											
June	0-12	0	3	2	3	4	6	3	10	5	3	4	3	5
		80	15	16	18	17	22	17	24	35	13	12	17	18
		160	35	30	31	35	28	29	50	41	44	37	32	34
	12-24	0	1	2	1	5	2	4	3	3	1	3	2	6
		80	1	4	6	9	7	7	6	5	7	7	4	5
		160	2	4	12	14	9	10	5	5	10	11	6	9
			p>F											
		system	0.812		0.344		0.672		0.717		0.835		0.427	
		system*depth	0.152		0.334		0.097		0.802		0.317		0.941	
		system*N rate	0.657		0.823		0.293		0.127		0.821		0.941	
		system*depth*N rate	0.573		0.254		0.447		0.059		0.548		0.990	

Table 4 continued.

Timing	Depth	N rate	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
			Kura	No Kura	Kura	No Kura	Kura	No Kura	Kura	No Kura	Kura	No Kura	Kura	No Kura
	inch	lb acre^{-1}	mg kg^{-1}											
Oct.	0-12	0	2	0	0	0	3	0	5	5	3	4	2	1
		80	1	0	0	0	1	0	7	4	3	2	3	2
		160	13	5	0	0	3	0	5	5	3	1	3	2
	12-24	0	0	0	0	0	1	0	4	3	1	2	2	1
		80	0	0	0	0	1	0	6	4	2	1	3	2
		160	11	0	3	0	10	0	9	7	2	1	3	2
	24-36	0	0	0	0	0	1	0	2	2	1	1	2	1
		80	0	0	0	0	1	0	4	2	1	0	3	1
		160	0	0	4	0	12	0	8	6	1	1	4	2
			p>F											
		system	0.037		0.173		0.034		0.466		0.625		0.143	
		system*depth	0.003		0.096		0.112		0.705		0.703		0.200	
		system*N rate	0.001		0.053		0.0003		0.610		0.090		0.894	
		system*depth*N rate	0.003		0.064		0.001		0.557		0.431		0.390	

Sites 1, 2, and 3 were in 2006 and sites 4, 5, and 6 were in 2007.
System is either kura clover living mulch or no kura clover.

Table 5. In-season N stress measured at the V10-13 growth stages (uppermost corn leaf with collar fully visible) with a Minolta SPAD-502 meter at six N fertilizer rates in kura clover and no kura clover systems, 2006 and 2007.

		Kura		No Kura	
Site	N Rate	SPAD Reading	Relative Value	SPAD Reading	Relative Value
	lb N acre^{-1}				
1 Mason City	0	55.7	0.97	41.2	0.68
	40	57.5	1.01	52.8	0.88
	80	60.3	1.05	57.3	0.95
	120	55.2	0.97	61.0	1.02
	160	55.3	0.97	60.2	1.00
	200	57.2	1.00	60.2	1.00
		- - - - - - - - - - - *p>F* - - - - - - - - - - -			
	N rate	0.050		<0.001	
	system	0.059			
	system*N rate	<0.001			
2 Plainfield S	0	--	--	39.3	0.77
	40	--	--	49.8	0.97
	80	--	--	52.1	1.02
	120	--	--	51.6	1.01
	160	--	--	51.3	1.00
	200	--	--	51.1	1.00
		- - - - - - - - - - - *p>F* - - - - - - - - - - -			
	N rate	--		<0.001	
	system	--			
	system*N rate	--			
3 Plainfield N	0	--	--	37.2	0.73
	40	--	--	47.7	0.94
	80	--	--	51.8	1.02
	120	--	--	52.0	1.02
	160	--	--	50.0	0.98
	200	--	--	50.9	1.00
		- - - - - - - - - - - *p>F* - - - - - - - - - - -			
	N rate	--		<0.001	
	system	--			
	system*N rate	--			

Table 5 continued.

Site		N Rate	Kura SPAD Reading	Kura Relative Value	No Kura SPAD Reading	No Kura Relative Value
		lb N acre^{-1}				
4	Floyd	0	52.5	0.96	55.4	0.98
		40	46.9	0.85	53.3	0.95
		80	57.4	1.05	56.5	1.00
		120	56.7	1.03	49.7	0.88
		160	49.1	0.89	47.9	0.85
		200	54.9	1.00	56.4	1.00
			- - - - - - - - - - - *p>F* - - - - - - - - - - -			
		N rate	0.158		0.275	
		system	0.867			
		system*N rate	0.372			
5	Grundy	0	41.7	0.83	36.0	0.60
		40	44.6	0.89	47.8	0.79
		80	52.0	1.04	54.5	0.90
		120	50.4	1.01	59.9	0.99
		160	52.4	1.05	60.7	1.00
		200	50.0	1.00	60.4	1.00
			- - - - - - - - - - - *p>F* - - - - - - - - - - -			
		N rate	<0.001		<0.001	
		system	<0.001			
		system*N rate	<0.001			
6	Butler	0	40.2	0.68	33.4	0.60
		40	49.3	0.83	45.8	0.83
		80	58.3	0.98	54.4	0.98
		120	60.0	1.01	55.1	0.99
		160	61.2	1.03	50.7	0.91
		200	59.5	1.00	55.5	1.00
			- - - - - - - - - - - *p>F* - - - - - - - - - - -			
		N rate	<0.001		0.001	
		system	<0.001			
		system*N rate	0.671			

Sites 1, 2, and 3 were in 2006 and sites 4, 5, and 6 were in 2007.
Mason City site was measured at the VT (kura) and R3 (no kura) corn growth stages.
Relative value = reading relative to reading with the 200 lb N acre^{-1} rate.
System is either kura clover living mulch or no kura clover.
Statistical analysis is for SPAD readings.

Table 6. Corn grain yield response to applied fertilizer N in the kura clover and no kura clover systems, 2006 and 2007.

		Kura				No Kura			
Site	N Rate	Grain Yield	Yield at EONR	EONR	Return to Applied N	Grain Yield	Yield at EONR	EONR	Return to Applied N
	lb acre^{-1}	- - - bu acre^{-1} - - -		lb N acre^{-1}	bu lb^{-1} N	- - - bu acre^{-1} - - -		lb N acre^{-1}	bu lb^{-1} N
2006									
1 Mason City	0	121	121	0	--	101	186	81	2.3
	40	135				163			
	80	126				185			
	120	142				188			
	160	135				187			
	200	125				185			
2 Plainfield S	0	--	--	--	--	96	174	101	1.7
	40	--				142			
	80	--				169			
	120	--				173			
	160	--				173			
	200	--				175			
3 Plainfield N	0	--	--	--	--	96	172	141	1.2
	40	--				128			
	80	--				159			
	120	--				164			
	160	--				175			
	200	--				172			

Table 6 continued.

Site		N Rate	Kura Grain Yield	Kura Yield at EONR	Kura EONR	Kura Return to Applied N	No Kura Grain Yield	No Kura Yield at EONR	No Kura EONR	No Kura Return to Applied N
			- - - bu acre^{-1} - - -		lb N acre^{-1}	bu lb^{-1} N	- - - bu acre^{-1} - - -		lb N acre^{-1}	bu lb^{-1} N
<u>2007</u>										
4	Floyd	0	144	206	76	2.7	84	194	82	2.4
		40	189				164			
		80	214				188			
		120	190				178			
		160	175				205			
		200	216				203			
5	Grundy	0	122	208	200	1.0	99	228	174	1.3
		40	138				148			
		80	166				189			
		120	188				209			
		160	198				227			
		200	207				228			
6	Butler	0	93	238	129	1.8	65	184	116	1.6
		40	162				129			
		80	222				172			
		120	225				175			
		160	246				194			
		200	237				184			
	Average Across Sites		2006	121	0	-		177	108	1.73
			2007	217	135	1.83		202	124	1.76

EONR = economic optimum N rate, calculated from the regression fit to N rate response, 0.10 N:corn ($/lb:$/bu) price ratio.
Yield return to applied N = yield at the EONR divided by the EONR.

Part 2. Soybean Response to Seeding Rate

Introduction

Soybean is recognized to be a less favorable crop on erosion prone landscapes because of minimal soil residue carrying over through the winter. Grass and legume living mulch systems developed for soybean have produced mixed results. Spring sown rye (*Secale cereale*) living mulch significantly reduced soybean yields in 2 of 3 environments in Wisconsin (Ateh and Doll, 1996). Ocumpaugh et al. (1981) demonstrated that soybean could be established into tall fescue (*Festuca arundinacea* Schreb.) that had been suppressed with Paraquat (dicamba 1,1'-dimethyl-4,4'-bipyridinium dichloride), resulting in production of 3000 to 4500 lb acre^{-1} of soybean forage. Although there was not a direct comparison to conventionally produced soybean, these forage yields were substantially lower than the 7,000 lbs/acre obtained in Wisconsin (Hintz et al., 1992).

Little information exists in the literature on growing soybean in a living mulch. Soybean biomass accumulation is relatively slow prior to flowering (Pedersen and Lauer, 2004), and soybean could be more sensitive to abnormal environmental conditions when produced with no-tillage in a living mulch than in conventional tillage production systems. The effect of growing soybean in a kura clover living mulch system has not been published, although preliminary data from Wisconsin indicate a yield loss of up to 45% when grown with kura clover living mulch (unpublished data, Pedersen et al.). Kura clover has already been demonstrated as having remarkable potential as a living mulch for corn production (Zemenchik et al., 2000; Affeldt et al., 2004). However, the yield loss found in the preliminary studies from Wisconsin indicated that early season competition can be even more detrimental to soybean and an adjustment in agronomic management may be needed. Our objective was therefore to determine the effect of seeding rate on soybean grain yield grown in an established stand of kura clover that was suppressed with herbicides.

Materials and Methods

The soybean variety (Pioneer 92M30; Pioneer Hi-Bred, Johnston, IA) was planted no-tillage in the established kura clover living mulch system and into corn residue as described above in Part 1. The experimental design was a randomized complete block in a split-split plot arrangement with three replications. Main plots were strips of kura clover and strips of prior-year corn or soybean, sub-plots were seeding rates of 150,000, 200,000, 250,000, and 300,000 seeds acre^{-1} and sub-sub plots were with and without a fungicide seed treatment (Apron Maxx XL, Syngenta Crop Protection, Greensboro, NC). Kura clover biomass samples were collected at planting and again at harvest to determine kura clover dry matter in a random area of approximately 2 ft^2. In 2006, soybean was planted at sites 4, 5, and 6 but yield data was only collected at sites 4 and 6 because of establishment issues at site 5. In 2007, yield was harvest at all soybean sites (1, 2, and 3).

Seed yield was determined by harvesting the center with an Almaco plot combine (Almaco, Nevada, IA) and adjusted to moisture content of 13%. A subsample was collected from each plot to determine seed mass based on a sample weight of 300 seeds. Data collected during all years included: grain yield, grain moisture, plant height and lodging, and grain oil and protein. Lodging was based on a 1 (erect) to 5 (flat) scale. Grain oil and protein were determined at the Iowa State University Grain Quality Laboratory using near-infrared analysis.

Data were analyzed using Proc Mixed in SAS (SAS Institute, 2003). Individual analysis by year and location using the restricted maximum likelihood method for variance component estimation indicated that error variances were heterogeneous. Year and location was therefore analyzed separately with block treated as a random effect treatment was considered fixed. Homogenous error variances were observed for the seed treatment data and data was pooled. Mean comparisons were made using Fisher's protected LSD test ($P \leq 0.05$).

Results

Averaged across locations, no significant yield differences were observed between the kura clover and the traditional no-tillage system (Table 7). However, large variability existed among locations (Table 8-12). Soybean yields appear highly correlated to the amount of kura clover competition (Table 3). Averaged across locations, no differences were observed between the kura clover and the traditional corn-soybean no-tillage system for either final plant population, height, lodging, grain moisture, seed mass, or oil and protein content in the seed (Table 3).

There was no treatment (kura clover or traditional corn-soybean no-tillage system) by seeding rate interaction for grain yield indicating that an increased seeding rate cannot help overcoming some of the early season kura clover competition. Treatment by seeding rate interactions, however, were observed for final plant population, seed mass, oil and protein content.

Seeding rate, however, influenced many variables as we would expect. Final plant population, height and lodging increased as seeding rate increased. Oil content decreased and protein content increased as plant population increased. No effects were observed from plant population on grain moisture, yield, and seed mass which was expected since the final stand was above 100,000 plants per acre, which is an adequate population to maximize yield as soybean will compensate for open spaces by allocating more dry matter to branches.

Conclusion

Soybean grain yield will be reduced, and may even have crop failure, with planting into a kura clover living mulch system when the kura clover is not suppressed adequately. Despite the average yield across locations not being significantly different with or without the kura clover living mulch (likely due to large location to location and within location variability), large yield decreases were observed at some locations because of various competitive effects from the kura clover. Careful management strategies need to be implemented to ensure kura clover competition is reduced sufficiently to avoid poor early season seedling establishment and growth. Proper timing of kura clover suppression and soybean planting is essential to implementing soybean into the living mulch. Use of an increased soybean seeding rate, as proposed in this project, will not overcome excessive kura clover competition or eliminate soybean yield loss when that situation occurs.

Table 7. Soybean agronomic response in a kura clover living mulch system across the five environments in Iowa (2006-2007).

Treatment	Seeding rate	Final plant population	Height	Lodging	Grain moisture	Yield	Seed mass	Oil	Protein
		plants acre^{-1}	in.	1-5†	%	bu acre^{-1}	g 100 seed^{-1}	%	%
No kura		208,666	33.3	1.3	12.1	47.2	16.2	18.2	36.8
Kura		180,058	29.8	1.2	12.1	39.7	15.9	18.1	36.6
	150,000	147,510	31.0	1.1	12.2	43.4	16.0	18.2	36.5
	200,000	176,658	31.1	1.2	12.1	42.5	16.1	18.1	36.6
	250,000	212,216	31.4	1.2	12.1	43.8	16.1	18.0	36.9
	300,000	241,064	32.7	1.4	11.9	44.1	15.9	18.1	36.8
No kura	150,000	152,684	32.9	1.1	12.1	48.3	16.2	18.3	36.6
No kura	200,000	182,341	33.1	1.2	12.1	45.3	16.0	18.2	36.7
No kura	250,000	239,456	33.5	1.3	12.1	48.0	16.2	18.0	37.1
No kura	300,000	260,183	33.9	1.5	12.1	47.3	16.3	18.1	37.1
Kura	150,000	142,337	29.1	1.1	12.4	38.4	15.8	18.1	36.4
Kura	200,000	170,974	29.0	1.2	12.2	39.6	16.3	18.1	36.6
Kura	250,000	184,976	29.3	1.2	12.0	39.7	15.9	18.0	36.7
Kura	300,000	221,946	31.6	1.3	11.7	40.9	15.5	18.1	36.6
p>F									
Treatment (T)		0.12	0.14	0.47	0.99	0.20	0.54	0.68	0.43
Plant Population (P)		0.001	0.02	0.001	0.21	0.46	0.32	0.007	0.004
T X P		0.004	0.41	0.91	0.12	0.19	0.001	0.46	0.14
LSD 5%									
Treatment (T)		NS‡	NS	NS	NS	NS	NS	NS	NS
Plant Population (P)		14,113	1.2	0.1	NS	NS	NS	0.1	0.2
T X P		19,612	NS	NS	NS	NS	0.4	NS	NS

† Lodging score: the range extends from 1 = erect to 5 = flat
‡NS = no significant differences

Table 8. Soybean agronomic response in a kura clover living mulch system at Floyd (site 4) in 2006.

Treatment	Seeding rate	Final plant population	Height	Lodging	Grain moisture	Yield	Seed mass	Oil	Protein
		plants $acre^{-1}$	in.	1-5†	%	bu $acre^{-1}$	g 100 $seed^{-1}$	%	%
No kura		191,406	33.4	1.2	15.8	47.4	15.9	18.7	34.7
Kura		113,692	23.3	1.0	15.2	22.9	14.8	18.5	34.4
	150,000	111,732	27.6	1.0	16.0	36.6	15.4	18.6	34.6
	200,000	126,797	26.9	1.1	16.0	32.6	15.4	18.6	34.5
	250,000	181,198	27.6	1.2	15.3	34.4	15.4	18.5	34.7
	300,000	190,467	31.3	1.2	14.8	36.9	15.2	18.7	34.3
No kura	150,000	132,086	31.5	1.0	15.9	52.4	16.0	18.8	34.7
No kura	200,000	144,015	32.5	1.3	15.9	41.9	15.8	18.8	34.5
No kura	250,000	259,548	34.5	1.3	15.8	48.9	15.9	18.6	35.1
No kura	300,000	229,974	35.2	1.3	15.8	46.5	15.7	18.8	34.7
Kura	150,000	91,379	23.7	1.0	16.1	20.9	14.8	18.4	34.6
Kura	200,000	109,580	21.3	1.0	16.1	23.3	15.0	18.5	34.6
Kura	250,000	102,848	20.7	1.0	14.9	19.9	14.9	18.4	34.4
Kura	300,000	150,961	27.4	1.0	13.9	27.4	14.6	18.6	34.0
p>F									
Treatment (T)		<0.0001	<0.0001	0.0011	0.04	<.0001	0.0029	0.52	0.41
Plant Population (P)		<0.0001	0.0004	0.22	0.01	0.22	0.20	0.30	0.14
T X P		0.0011	0.01	0.22	0.04	0.01	0.47	0.43	0.06
LSD 5%									
Treatment (T)		24,388	1.4	0.1	0.6	3.2	0.4	NS	NS
Plant Population (P)		34,086	2.0	NS‡	0.8	NS	NS	0.1	NS
T X P		45,448	2.7	NS	1.1	5.9	NS	NS	NS

† Lodging score: the range extends from 1 = erect to 5 = flat
‡NS = no significant differences

Table 9. Soybean agronomic response in a kura clover living mulch system at Butler (site 6) in 2006.

Treatment	Seeding rate	Final plant population	Height	Lodging	Grain moisture	Yield	Seed mass	Oil	Protein
		plants acre^{-1}	in.	1-5†	%	bu acre^{-1}	g 100 seed^{-1}	%	%
No kura		242,112	34.7	1.4	16.3	45.0	16.2	19.3	35.0
Kura		202,386	26.7	1.1	16.7	33.5	16.2	19.3	34.2
	150,000	188,481	28.8	1.2	16.2	42.4	16.2	19.3	34.4
	200,000	216,731	30.7	1.2	16.4	37.7	16.2	19.2	34.7
	250,000	233,284	32.1	1.4	16.6	39.5	16.2	19.3	34.8
	300,000	250,499	31.3	1.3	16.7	37.2	16.2	19.3	34.6
No kura	150,000	189,364	36.3	1.3	16.0	47.5	16.2	19.4	34.7
No kura	200,000	234,388	34.8	1.3	16.3	42.9	16.2	19.3	34.5
No kura	250,000	257,782	35.3	1.5	16.4	44.7	16.2	19.2	35.5
No kura	300,000	286,915	32.3	1.5	16.5	44.6	16.2	19.1	35.3
Kura	150,000	187,598	21.3	1.0	16.5	37.3	16.2	19.3	34.1
Kura	200,000	199,075	26.5	1.0	16.6	32.5	16.2	19.1	34.9
Kura	250,000	208,786	28.8	1.3	16.9	34.3	16.2	19.4	34.1
Kura	300,000	214,083	30.2	1.0	16.9	29.7	16.2	19.5	33.8
p>F									
Treatment (T)		0.17	0.05	0.42	0.10	0.05	0.002	0.52	0.0049
Plant Population (P)		0.01	0.39	0.26	0.02	0.16	0.42	0.59	0.75
T X P		0.27	0.02	0.71	0.87	0.74	0.06	0.01	0.03
LSD 5%									
Treatment (T)		NS†	8.0	NS	NS	11.4	0.6	NS	0.5
Plant Population (P)		36,247	NS	NS	0.3	NS	NS	NS	NS
T X P		NS	NS	NS	NS	NS	NS	0.3	1.1

† Lodging score: the range extends from 1 = erect to 5 = flat

‡NS = no significant differences

Table 10. Soybean agronomic response in a kura clover living mulch system at Mason City (site 1) in 2007.

Treatment	Seeding rate	Final plant population	Height	Lodging	Grain moisture	Yield	Seed mass	Oil	Protein
		plants acre^{-1}	in.	1-5†	%	bu acre^{-1}	g 100 seed^{-1}	%	%
No kura		216,842	33.2	1.0	9.9	53.3	17.4	17.3	38.1
Kura		221,587	33.6	1.1	9.4	49.8	16.8	17.8	37.6
	150,000	167,735	33.5	1.0	9.6	48.1	17.4	17.6	37.7
	200,000	201,503	32.4	1.3	9.4	51.5	16.9	17.6	37.6
	250,000	237,257	33.0	1.0	9.7	54.1	17.2	17.4	37.9
	300,000	270,362	34.7	1.0	9.8	52.6	17.0	17.5	38.1
No kura	150,000	165,087	32.5	1.0	9.9	53.4	17.8	17.4	37.8
No kura	200,000	201,723	32.8	1.0	9.6	54.7	16.6	17.1	37.9
No kura	250,000	231,739	32.3	1.0	10.1	54.0	17.8	17.1	38.2
No kura	300,000	268,817	35.2	1.0	10.1	51.1	17.4	17.4	38.5
Kura	150,000	170,383	34.5	1.0	9.4	42.7	17.0	17.8	37.6
Kura	200,000	201,282	32.0	1.5	9.2	48.2	17.2	18.1	37.2
Kura	250,000	242,774	33.7	1.0	9.4	54.2	16.6	17.6	37.7
Kura	300,000	271,907	34.2	1.0	9.4	54.1	16.5	17.7	37.8
p>F									
Treatment (T)		0.11	0.86	0.23	0.13	0.03	0.36	0.07	0.34
Plant Population (P)		<.0001	0.29	0.0036	0.09	0.05	0.36	0.05	0.01
T X P		0.58	0.49	0.0036	0.68	0.01	0.03	0.01	0.30
LSD 5%									
Treatment (T)		NS†	NS	NS	NS	3.1	NS	NS	NS
Plant Population (P)		8,397	NS	0.2	NS	4.3	NS	0.2	0.3
T X P		NS	NS	0.3	NS	6.0	1.5	0.6	NS

† Lodging score: the range extends from 1 = erect to 5 = flat
‡NS = no significant differences

Table 11. Soybean agronomic response in a kura clover living mulch system at Plainfield N (site 3) in 2007.

Treatment	Seeding rate	Final plant population	Height	Lodging	Grain moisture	Yield	Seed mass	Oil	Protein
		plants acre^{-1}	in.	1-5†	%	bu acre^{-1}	g 100 seed^{-1}	%	%
No kura		194,778	30.8	1.1	8.8	46.0	16.1	17.9	37.9
Kura		186,252	32.3	1.0	9.0	48.2	17.1	17.1	38.8
	150,000	130,919	31.5	1.1	9.0	43.5	16.6	17.8	37.9
	200,000	180,094	31.6	1.1	8.9	46.6	17.0	17.5	38.4
	250,000	196,794	31.5	1.0	8.9	49.4	16.5	17.4	38.6
	300,000	254,251	31.5	1.1	8.9	49.1	16.2	17.4	38.5
No kura	150,000	138,334	31.0	1.0	8.8	39.8	16.0	18.1	37.5
No kura	200,000	180,977	30.3	1.2	8.8	46.1	16.5	17.9	38.0
No kura	250,000	201,135	30.7	1.0	8.7	49.3	15.5	17.9	37.9
No kura	300,000	258,665	31.2	1.2	8.8	48.9	16.3	17.7	38.1
Kura	150,000	123,504	32.0	1.2	9.1	47.2	17.2	17.4	38.3
Kura	200,000	179,212	32.8	1.0	8.9	47.0	17.6	17.1	38.7
Kura	250,000	192,454	32.3	1.0	9.0	49.5	17.5	16.9	39.3
Kura	300,000	249,837	31.8	1.0	9.0	49.3	16.2	17.1	38.9
p>F									
Treatment (T)		0.23	0.41	0.55	0.20	0.45	0.0003	0.01	0.06
Plant Population (P)		<.0001	0.99	0.77	0.16	0.01	0.24	0.0028	0.02
T X P		0.93	0.85	0.27	0.62	0.11	0.04	0.48	0.46
LSD 5%									
Treatment (T)		NS†	NS	NS	NS	NS	0.5	0.4	NS
Plant Population (P)		20,184	NS	NS	NS	3.5	NS	0.2	0.5
T X P		NS	NS	NS	NS	NS	1.1	0.5	NS

† Lodging score: the range extends from 1 = erect to 5 = flat

‡NS = no significant differences

Table 12. Soybean agronomic response in a kura clover living mulch system at Plainfield S (site 2) in 2007.

Treatment	Seeding rate	Final plant population	Height	Lodging	Grain moisture	Yield	Seed mass	Oil	Protein
		plants acre^{-1}	in.	1-5†	%	bu acre^{-1}	g 100 seed^{-1}	%	%
No kura		198,282	34.6	1.6	9.5	44.7	15.3	17.7	38.5
Kura		178,393	33.3	1.7	10.2	44.4	15.5	17.7	37.8
	150,000	133,894	33.8	1.1	9.9	44.0	15.4	17.9	37.5
	200,000	167,850	34.6	1.4	9.8	46.0	15.6	17.8	37.9
	250,000	202,994	33.4	1.6	10.0	43.0	15.2	17.5	38.3
	300,000	248,611	34.1	2.5	9.7	45.2	15.4	17.5	38.9
No kura	150,000	141,103	34.3	1.2	9.6	44.7	15.4	17.9	38.0
No kura	200,000	170,511	36.2	1.3	9.5	45.0	15.2	17.8	38.4
No kura	250,000	208,940	33.7	1.5	9.6	42.0	15.1	17.4	38.7
No kura	300,000	272,573	34.3	2.3	9.4	46.9	15.3	17.6	39.0
Kura	150,000	126,684	33.2	1.0	10.2	43.2	15.3	17.9	37.1
Kura	200,000	165,190	33.0	1.5	10.2	47.1	16.0	17.8	37.4
Kura	250,000	197,049	33.2	1.7	10.3	43.9	15.2	17.6	37.9
Kura	300,000	224,650	33.8	2.7	10.0	43.5	15.5	17.4	38.7
p>F									
Treatment (T)		0.02	0.34	0.48	0.23	0.89	0.31	0.94	0.09
Plant Population (P)		<.0001	0.80	<.0001	0.06	0.23	0.36	0.001	<.0001
T X P		0.25	0.68	0.78	0.93	0.26	0.27	0.51	0.56
LSD 5%									
Treatment (T)		15,911	NS	NS	NS	NS	NS	NS	NS
Plant Population (P)		22,756	NS	0.5	NS	NS	NS	0.2	0.5
T X P		NS†	NS	NS	NS	NS	NS	NS	NS

† Lodging score: the range extends from 1 = erect to 5 = flat

‡NS = no significant differences

Educational Outreach

The project gave us a great opportunity to talk to growers and extension personnel about cover crops and living mulch system. Similar presentations and workshop were conducted during this project.

2004.

- On July 23, 2004, I spoke at the Floyd County Fair where one of our locations were located. Around 30 people were in attendance.

2005.

- A kura living mulch workshop was held at North Iowa Area Community College in Mason City on January 26, 2005. We had 38 participants at the meeting, but also 20 students from the college. Prior to lunch we focused on biology and the forage quality of kura clover. After lunch, we talked about grazing of kura clover, erosion trends in Iowa, and how this living mulch system can fit into our production. Last, we covered the importance of a living mulch system on insect communities in our agroecosystem. The presenters at the meeting were Dr. Ken Albrecht from University of Wisconsin-Madison, Dr. Ken Moore from Iowa State University, Dr. Rick Cruse from Iowa State University, Dr. Matt Oneal from Iowa State University, and Dr. Jeremy Singer from Iowa State University/United States Department of Agriculture Soil Tilth Lab. We received a lot of nice feedback. Nine of the 38 participants came from Minnesota which means that we have initiated something that other people from outside Iowa also feel is important to be demonstrated. The presentations are available at www.soybeanmanagement.info

- A presentation was given on the project at the "2005 Agriculture and the Environment Conference" in Ames where 216 participants was registered.

- Two extension publications were written with Dr. Jeremy Singer from the USDA Soil Tilth Laboratory.

  Singer, J., T. Kaspar, and **P. Pedersen.** 2005. Small grain cover crops for corn and soybean. Publ. PM1999. Iowa State University Extension. 4 pp.

  Singer, J., and **P. Pedersen.** 2005. Legume living mulches in corn and soybean. Publ. PM2006. Iowa State University Extension. 4 pp.

- A section was added on the soybean research and extension webpage on the kura clover project (see www.soybeanmanagement.info).

- I was invited to give a presentation at the 2005 Minnesota Water and Annual Water Resources Joint Conference, Oct. 25-26, 2005, in Minneapolis. Approximately 90 participants were attending my presentation.

- A field day was held at NIACC on August 28, 2006 where 21 people attended and viewed the study site. It was a nice gathering and we got some useful feedback from the growers and some of the other participants at the field day.

<u>2006.</u>

- We had a field day at NIACC on August 28, 2006 where 21 people showed up to look at our plots. It was a nice gathering and we got some useful feedback from the growers.

<u>2007.</u>

- On March 8, 2007 we hosted another kura living mulch workshop in Ames with a total of 19 people attending. Dr. Ken Albrecht from the University of Wisconsin came down and gave two talks. In addition, Palle Pedersen, Daniel Barker, Jeremy Singer, and Matt Oneal gave presentations. The presentations are be available at www.soybeanmanagement.info

- A presentation was giving at the national ASA meeting in New Orleans presenting some of the results from the project.

Figure. 1. Field day at the kura clove site at North Iowa Area Community College near Mason City on August 28, 2006.

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