

The Wisconsin Integrated Cropping Systems Trial Eighth Report - 1999 & 2000

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Prologue

This is the eighth technical report of the Wisconsin Integrated Cropping Systems Trial (WICST). In earlier reports, we discussed the objectives of the project, the results of the uniformity year (1989), and the first nine production years (1990 – 1998). In this report, we discuss the results of the 1999 & 2000 growing seasons. This is the eighth time all the phases of the six rotations have run concurrently, permitting us to again compare all the systems. By the end of the growing season in 2000, all the treatments of the Cropping Systems had completed at least two cycles of their respective rotations. Also included in this report are research results of satellite trials conducted both on-farm and adjacent to the WICST core trials.

Funding for the project continues to come primarily from the USDA-ARS pilot project on Integrated Farming Systems. Other grants important to the success of the project come from the Wisconsin Fertilizer Research Council, USDA-National Research Initiative, USDA-Sustainable Agriculture Research and Education Fund, as well as Hatch funds managed by the College of Agricultural and Life Sciences.

Summer 1999 & 2000

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We also acknowledge with many thanks, the contributions to this project of those who assisted the two superintendents in managing the crops and animals –Clint Clemens, Darwin Frye, and Sandy Trower at Arlington and at Lakeland, Jessica Leinberger, and Terry LeMehieu.

Introduction

In the fall of 1988, a group consisting of faculty from the College of Agricultural Life Sciences, agents from the Wisconsin Extension Service, agronomists from the Michael Fields Agricultural Institute, and farmers came together to design the Wisconsin Integrated Cropping Systems Trial (WICST). The overall objective of the trial was to compare alternative production strategies with the performance criteria of productivity, profitability, and environmental impact. Concomitant with this technical objective was the decision to develop the trial in a "Learning Center" environment, where all the members of the community could learn about agroecology and production agriculture.

From these discussions evolved a plan to work at two locations in southern Wisconsin. The Lakeland Agricultural Complex (LAC) is situated on the Walworth County Farm about 45 minutes west of Milwaukee, and the Arlington Research Station (ARS) is a University of Wisconsin agricultural research farm about 30 minutes north of Madison (see Figure 1). At both sites a 60-acre area was set aside and in 1989, a uniformity trial was held in order to facilitate the subsequent blocking of the core rotation experiment. The year 1990 was the first production year of the project.

The selection of cropping systems provoked a great deal of discussion within the group. Ultimately, a factorial array of rotations was selected. It was observed that within southern Wisconsin there were two principal types of farm enterprises: cash-grain and forage-based systems, each with its own production requirements. At the level of production strategy, our hypothesis stated that as systems became more complex, they would require less and less external inputs to remain productive. As a result, production strategies with a high, medium, and low level of complexity were designed. Put in an inverse fashion, systems that required a high, medium, and low level of purchased inputs were put into practice. The six rotations are schematically represented in Figure 2. Some of the anticipated differences between the rotations are outlined in Table i.

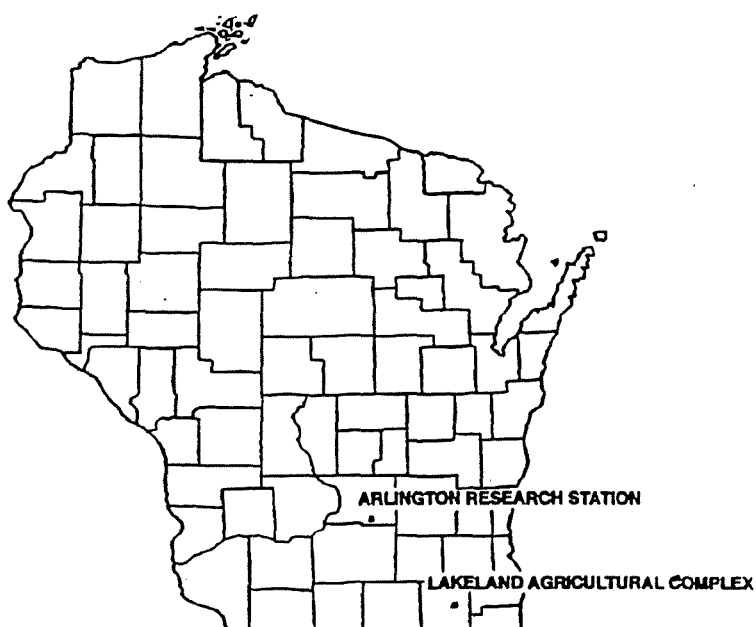
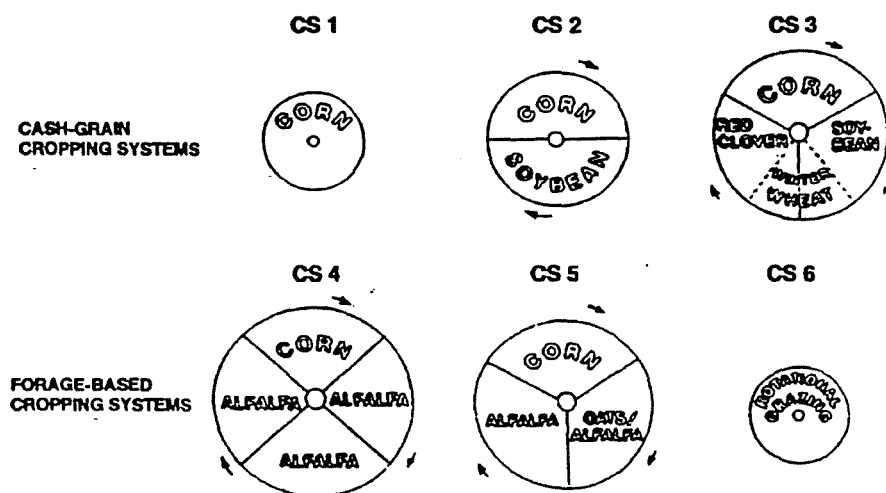


Figure 1. Outline of major Land Resource Area 95B and two sites of the Wisconsin Integrated Cropping Systems Trial.



*Area within the circle is proportional to the length of the rotation (1, 2, 3, or 4 years).

Figure 2. Schematic drawing of cropping systems in the Wisconsin Integrated Cropping Systems Trial.

Table i.. Productivity, Economic, and Environmental Comparisons Between Rotations. Wisconsin Integrated Cropping Systems Trial 1990.

Rotation	Predicted Yield/acre	Mean above ground productivity ¹ Lb/a/yr	Mean energy input ² Mcal/a/yr	Energy output/input ³ ratio	Variable costs ⁴ \$/a/yr	Chemical inputs			Erosion ⁵ t/a/yr
						N Fertilizer on corn lb/a	Herbicide AI/a	Insecticide AI/a	
R₁ Continuous Corn	150 bu	15,780	2369	6.0	140	150	Atrazine 2 lb Alachlor 2 lb	Counter 1.4 lb	4.1
R₂ Drilled Soybean Corn	55 bu 160 bu	12,510	1788	6.9	104	110	Bladex 2.5 lb Alachlor 2.5 lb Sencor 0.5 lb Treflan 1.5 lb	0	4.0
R₃ Row soybean Wheat Corn	40 bu 60 bu/2t straw 120 bu	10,010	763	12.6	50	0	0	0	2.9
R₄ Seeding alfalfa Hay I Hay II Corn	3t dm 5t dm 5t dm 160 bu	10,710	1188	13.7	110	10	Eptam 2.9 lb Bladex 2.0 lb Alachlor 2.5 lb	Lorsban 1.0 lb	1.9
R₅ Oats/alfalfa Hay I Corn	60 bu/2t dm 4t dm 120 bu	9,440	811	18.2	45	10	0	0	1.6
R₆ Rotational Grazing	4t dm	8,000	129	104.3	16	na	0	0	0.5

¹ Mean above ground productivity: dry matter biomass production per acre per year. Calculated based on the following harvest indices: Corn .45; soybean .35; wheat .42; oat .45.

² Mean energy input includes only seed, fertilizer, lime, pesticides, and fuel. Based on Pimentel, D. 1980 Handbook of Energy Utilization in Agriculture, CRS Press Inc.

³ Ratio of energy value of agricultural output to energy consumption

⁴ Variable costs include seed, fertilizer, pesticides, drying, fuel, and labor. Costs based on 1988 Wisconsin Crop Budgets. R. Klemme and L. Gillespie.

⁵ Erosion estimates were made using the USLE for a 4% slope, 200 feet long with a silt loam soil and contour planting.

MAIN SYSTEMS TRIAL 1999&2000

1a. Arlington Agricultural Research Station – 1999 Report

Dwight Mueller and Paul Bergum

Corn Phase

Treatment of all the corn plots was similar to 1998. Corn in CS1, CS2, and CS4 were all planted on April 30th at 32,000 seeds/A with a 105-day corn, Golden Harvest 2441. CS3 and CS5 were planted on May 13th at 34,500 seed/A with a 95-day corn, DeKalb 471. Deep nitrate soil tests were taken for the CS1 and CS2 plots. As a result of the tests, a pre-plant application of 80 lbs N/a was applied on CS1 plots and 60 lbs N/a on CS2 plots on April 27th. Legume and manure credits were taken in the other systems. The only other fertilizer used was a starter fertilizer (6-24-24) on CS1, CS2, and CS4.

1999 was a year when everything grew very well! Weed control worked out as planned in all the plots. Both chemical and mechanical weed control was done in a timely manner for effective control over the weeds. The weed seed bank continues to build up in the CS3 plots. As we stated last year, the CS3 plots were kept under control – but if an adverse year for weed control comes up in the near future – that weed bank is poised to take over.

Corn yields averaged 172 bu/a across all treatments, above average from the past years (Table 1a). Similar to past years, corn yields averaged lower for CS1 compared to the other treatments. This demonstrates the significant benefit to rotating corn with other crops.

Soybean Phases

Asgrow 2301 was planted at 250,000 seeds/A in 7" rows for the CS2, no-till rotation on May 13th. Asgrow 2247 was planted at 190,000 seeds/A in 30" rows for the CS3 rotation on May 12th. The CS2 soybeans were no tilled into high residue cover (approximately 75% cover) with a John Deere no-till drill. For CS2, a pre-plant treatment of 1 pt/A of Round up helped control early weeds. A second application of Round-up Ultra on the Round-up ready beans on 6/25 took care of the post-planting weeds. Weed control for the rest of the growing season was excellent in the CS2 rotation.

Mechanical weed control in the CS3 soybean plots could never keep up with the weed pressure this year. As we stated last year, the weed seed bank continues to build in the CS3 plots. The excellent growing conditions for spring germination meant that not only did the soybeans grow quickly, but so did the weeds! The in-row weeds continued to flourish all season, creating difficult harvest conditions and obviously lower yields. The weed seed bank in CS3 plots has reached such a high level that growing soybeans in this manner on these specific plots is almost impossible.

The reason mechanical weeding works in CS3 corn is because corn can handle heavier cultivating (cultivator travels at a higher speed in order to throw more dirt to cover the in-row

weeds) and the corn plant is generally taller than the weeds. Wide row soybean yields (CS3) averaged 31 bu/a compared to 59.2 bu/a for narrow row soybeans (CS2) (Table 1a).

Wheat/Red Clover Phase

Wheat (var, Glacier) had been planted on October 8th, 1998 following soybean harvest tillage at a seeding rate of 180 lbs/a. Red Clover was seeded on March 22nd at 12 lbs/a, with a John Deere no-till drill. The stand of red clover was excellent with over 2.5 tons DM at the end of the growing season. The wheat yield averaged 57 bu/a (Table 1a) and straw yields were modest at 0.62 tons DM/a.

Forage Phases

The new seedlings in CS4 and CS5 systems were planted with Wintergreen on March 23rd. CS4 was planted with a rate of 12lbs of alfalfa seed/a. CS5 had 12 lbs/a of alfalfa, 80 lbs/a of bay oats, plus 50 lbs/a of Trapper field peas to help with forage yield and quality and weed control. All the established plots were harvested 4 times during the season. The last cutting was made on November 1st. CS5 oats were taken off as silage on June 14th. Both CS4 and CS5 alfalfa stands established well and were harvested twice during the season. Low yields on the later cuttings resulted from the dry weather condition of late summer and fall (Fig. 1a). Relative feed value was similar to past years and was highest on CS4 and lowest on oats/peas/alfalfa phase of CS5 (Table 2a).

1b. Arlington Agricultural Research Station – 2000 Report

Dwight Mueller and Paul Bergum

A. Corn Phase:

Treatment of all the corn plots was similar to 1999. Corn in CS1, CS2, and CS4 were all planted on May 1st at 32,000 seeds/A with Cargill 4111. CS3 and CS5 were planted on May 15th at 34,500 seed/A with Cargill 4111. Deep nitrate soil tests were taken for the CS1 and CS2 plots. As a result of the tests, a side-dress application of anhydrous at 80 lbs N/a was applied on CS1 and CS2 plots on April 27th. Legume and manure credits were taken in the other systems. Starter fertilizer (6-24-24) was also used on CS1, CS2, and CS4. Due to heavy rainfall and expected nitrate leaching, pre-sidedress nitrate soil tests were taken on June 16th. As a result, another 160 lbs N/a was applied to CS1 and 120 lbs N/a was applied to CS2.

2000 was a normal year for crop growth and weed control. Weed control worked out as planned in all the plots. Both chemical and mechanical weed control was done in a timely manner for effective control over the weeds. The weed seed bank continues to build up in the CS3 plots. As we stated last year, the CS3 plots were kept under control – but if an adverse year for weed control comes up in the near future – that weed bank is poised to take over.

Corn yields averaged 162 bu/a across all treatments, slightly above average from the past years. Similar to past years, corn yields averaged lower for CS1 compared to the other treatments. This demonstrates the significant benefit to rotating corn with other crops.

B. Soybean Phases:

Asgrow 2301 was planted at 250,000 seeds/A in 7" rows for the CS2, no-till rotation on May 15th. Novartis 1990 was planted at 190,000 seeds/A in 30" rows for the CS3 rotation on May 15th. The CS2 soybeans were no tilled into high residue cover (approximately 75% cover) with a John Deere no-till drill. For CS2, a pre-plant treatment of 1 pt/A of Round up helped control early weeds. A second application of Round-up Ultra on the Round-up ready soybeans on June 23rd took care of the 31 post-planting weeds. Weed control for the rest of the growing season was excellent in the CS2 rotation.

Mechanical weed control in the CS3 soybean plots did an adequate job with the weed pressure this year. As we stated last year, the weed seed bank continues to build in the CS3 plots. The excellent growing condition for spring germination meant that not only did the soybeans grow quickly, but so did the weeds! The in-row weeds continued to flourish all season, creating difficult harvest conditions and obviously lower yields. The weed seed bank in CS3 plots has reached such a high level that growing soybeans in this manner on these specific plots is very difficult.

The reason mechanic weeding works in CS3 corn is because corn can handle heavier cultivating (cultivator travels at a higher speed in order to throw more dirt to cover the in-row weeds) and the corn plant is generally taller than the weeds. Wide row soybean yields (CS3) averaged 40.9 bu/a compared to 56.3 bu/a for narrow row soybeans (CS2).

C. Wheat/Red Clover Phase:

Wheat (var, Kaskaskia) was planted on October 8th following soybean harvest at a seeding rate of 180 lbs/a. Red Clover was seeded on March 8th at 15 lbs/a, with a John Deere no-till drill. The wheat yield averaged 41.7 bu/a.

D. Forage Phases:

The new seedlings in CS4 and CS5 systems were planted with DeKalb 124 on March 30th. CS4 was planted with a rate of 12lbs of alfalfa seed/A. CS5 had 12 lbs/a of alfalfa, 80 lbs/a of bay oats, plus 50 lbs/a of peas to help with forage yield and weed control. All the established plots were harvested 4 times during the season. The last cutting was made on September 9th. CS5 oats were taken off as silage on June 29th. Both CS4 and CS5 alfalfa stands established well and were harvested twice during the season. The weather affected all the crops this year. Over 21 inches of rain fell in late May and into early June (Fig. 1a). Quality of each phase of each system was similar to the long-term trial average (Table 2a).

2a. Lakeland Agricultural Complex- 1999 Agronomic Report

Jim Stute, John Hall, Dan Forsythe, and Lee Cunningham

Growing Season

Once again, weather extremes defined the growing season at the Lakeland Agricultural Complex. While growing season rainfall was above normal (Fig. 1b) it was not well distributed. Rainfall through June was well above normal (>150%) while often inadequate for the remainder of the season. This year it was an issue for both field operations and crop growth. Field activities began early in 1999 due to early snowmelt and good drying conditions. This included sowing of the oat/pea/forage mix in March. Early planted corn and soybean treatments were also planted near their target date while a prolonged wet period in May delayed planting of the later treatments by two weeks. During June we experienced several cycles of wet then dry stretches, allowing timely application of weed control measures. Harvest of oatlage was made difficult by this weather pattern.

Below normal rainfall in from late June onward depleted soil moisture reserves and eventually produced serious moisture stress in the field crops at times. Except for a rain event in late September, which delayed soybean harvest and wheat planting, dry soil conditions and unseasonably warm temperatures allowed timely completion of fall fieldwork. End of season well sampling was not possible because the water table was too low. Water depth measurements on the nearby Sludge Plots taken in November were similar to those taken at the end of the 1988 drought year (Art Peterson, personal communication).

Total growing degree day (GDD) accumulation was 110% of normal (Fig. 2b). Warm temperatures resulted in early crop maturity and low grain moistures at harvest.

The 1999 growing season also marked the initiation of changes to some of the systems at the Lakeland location. Please see related text elsewhere for a complete explanation.

Corn

Corn yields averaged 85% of normal and differences between systems were quite apparent in the corn phase (Table 1b). Weed control was effective in all treatments, so differences in yield were based on other things such as system, hybrid or possibly planting date. In general, greatest yields occurred in CS4 and 5 where corn followed forage with a manure application. This is in spite of both being planted in late May, and using only mechanical weed control methods (CS4 in transition to organic)

Soybean

The 1999 growing season was average for soybean yield (Table 1b). Yields in cropping system 2 were lower than average despite early planting. Hard rains before emergence caused soil crusting and reduced populations. White mold was not evident in CS2 as in years past. Presumably, dry weather, low humidity in July and later canopy development prevented initiation of the disease. Soybean in CS3 and 5 yielded greater than the long-term average for row beans, presumably because of good season-long weed control.

Wheat

Winter wheat yield was average (50 bu/a) in 1999. This appears to be variety related. In *UWEX* variety trials conducted at Janesville and Racine, Glacier only yielded 69% of the other varieties. Stands of frost-seeded red clover were good to excellent. This coupled with a timely rain (4+ inches) in September and a long fall resulted in a large amount of clover biomass. Straw yields were respectable at 1.17 tons DM/a.

Alfalfa

Forage production was good in 1999, mostly because of abundant rainfall early in the season. All regular hay cuttings were harvested in a timely fashion, while wet soil conditions delayed harvest of the oatlage. Dry weather limited regrowth after harvest of third crop and despite over 4 inches of rain in late September (Fig. 1b), there was insufficient material to mechanically harvest. Potato leafhoppers were detected in CS4 plots throughout the season, but at levels below the treatment threshold. Quality was highest in the established years of both phases and were comparable to the long-term trial average (Table 2b).

Pasture

Grazing was initiated in mid-April. Red clover was not frost seeded because stands were considered to be adequate. Seven heifers with an average beginning weight of 609 pounds grazed the pastures in rotation through late June when three were removed. The remained continued through late September. Specific information related to pasture and animal performance can be found in the grazing chapter.

2b. Lakeland Agricultural Complex- 2000 Agronomic Report

Jim Stute, John Hall, and Lee Cunningham

Growing Season

As in the past three years, weather extremes defined the growing season at the Lakeland Agricultural Complex. Growing season rainfall was 115% of the long-term average with early season (April through June) averaging 163% normal, resulting in frequent ponding in many of the plots (Fig. 1b). As in 1999, it was an issue for both field operations and crop growth. Field activities began early in 2000 due to early snow melt, little over-winter precipitation (including a dry fall in 1999) and good drying conditions. This included sowing of the oat/pea/forage mix in March. Early planted corn and soybean treatments were also planted near their target date while a prolonged wet period in May delayed planting of the later treatments by several weeks. A pounding rain shortly after late planting resulted in poor corn stands, resulting in the decision to replant. During June we experienced several cycles of wet then dry stretches, making all field operations difficult, as the soil would dry almost to the point of being workable, then it would rain again. Rainfall distribution in May and June is presented in Fig. 3.

Corn

Corn yields averaged 71% of normal and differences between systems were quite apparent in the corn phase (Fig. 4). With the exception of the change in rank between systems two and four, relative rankings compared to long-term trial means were the same, only magnitudes changed. Replanting dramatically reduced yields in systems three and five. Even though the shortest maturity hybrid available was used, it never reached physiological maturity. Of the early-planted systems, the no-till planted corn in CS2 fared the best, yielding 116% of its long-term trial average (Fig. 4). Although N rates in this and CS1 are routinely adjusted based on carry-over nitrate as detected by the pre-plant nitrate test, the full rate (120 and 160 lbs N/acre, respectively) was applied because of the amount of rainfall and frequent condition of standing water. Presumably the yield decline in CS14 was due to either slow mineralization of legume and manure N, early season losses caused by standing water, or a combination of the two. Over-time, quackgrass pressure in CS1 has built and may have contributed to reduced yield in 2000. Late harvest of corn prevented a planned post-harvest application of glyphosate, designed to reduce this problem.

Soybean

Soybean yield averaged 80% of the long-term trial average (Fig. 4). Of note is the difference between CS3 and 15. Although both systems used the same variety, planted the same time, using identical planting equipment and techniques, yield in system 15 was 15 bu/acre greater. This difference could be attributed to several factors. Soybean was only introduced to that system in 1999 and these plots have never been planted with soybean, which would result in lower levels of disease incidence. It could also be a systems effect with the yield enhancement attributed to manure use in the system, as has been reported by some farmers (J. Hall, personal communication).

Wheat

Winter wheat yield averaged 82% of the long-term trial average (Fig. 4). Stands appeared to survive the winter well, but suffered from the lack of moisture from planting through April. Stands of frost-seeded red clover were good to excellent. This coupled with a timely rain (nearly 5 inches) in September (see Fig. 1b) and a long fall resulted in a large amount of clover biomass.

Forage

Forage production was slightly above average in 2000 and all regular hay cuttings were harvested in a timely fashion. System differences were very noticeable in both newly seeded and established stands. The forage mix in CS15 with includes alfalfa, red clover and perennial ryegrass yielded much better than the pure alfalfa in CS14. Total forage production in CS15 was also greatly enhanced by large oat/pea mix yields. Potato leafhopper was not a problem in either system.

IGR

Grazing was initiated in early May. Red clover was not frost seeded because stands were considered to be adequate. For the first time only four animals were used, as opposed to the previous practice of starting with seven, then removing three when pastures entered the "summer slump" period and dry matter yield declined drastically. This created a situation of excess forage production, so some was harvested as hay, then fed back in September and October. The animals were also given 2 pound of concentrate mix per head per day. The four heifers with an average beginning weight of 529 pounds spent 170 days on pasture and gained an average of 1.42 lbs per day.

Table 1a. Yield Results for the Arlington Agric. Research Station- WICST (1994-2000).

<u>Corn</u>		1994	1995	1996	1997	1998	1999	2000
		Bu/a						
CS ₁	Continuous corn	178.1	143.1	131.5	128.6	196.2	170.4	161.6
CS ₂	Corn after soybeans	190.2	167.7	140.0	157.4	212.6	162.9	162.9
CS ₃	Corn after red clover	188.4	155.6	83.4	147.6	197.8	155.6	132.8
CS ₄	Corn after alfalfa	196.5	167.5	151.2	159.1	226.8	189.7	179.4
CS ₅	Corn after alfalfa	198.8	157.1	153.6	155.3	205.1	181.9	135.2
LSD (P<0.05)		12.6	11.6	16.0	10.0	12.3	14.7	24.5
<u>Soybean</u>		1994	1995	1996	1997	1998	1999	2000
		Bu/a						
CS ₂	Drilled soybeans	42.7 ¹	58.1	53.7	51.9	63.6	59.2	56.3
CS ₃	Wide-row soybeans	44.4	63.3	60.2	48.8	51.9	31.0	40.9
LSD (P<0.05)		NS	2.20	NS	NS	NS	3.4	4.5
<u>Wheat</u>		1994	1995	1996	1997	1998	1999	2000
		Bu/a						
CS ₃	Wheat	60.9	68.1	45.4	54.4	57.7	56.9	41.7
<u>Seeded Alfalfa</u>		1994	1995	1996	1997	1998	1999	2000
		tons DM/a						
CS ₄	Direct seeded	3.21	3.19	1.57	3.56	2.63	2.27	2.59
CS ₅	Oats/alfalfa ²	3.37	3.21	2.68	4.66	5.67	4.69	4.14
LSD (P<0.05)		NS	NS	0.90	NS	0.67	0.34	0.23
<u>Established Forage</u>		1994	1995	1996	1997	1998	1999	2000
		tons DM/a						
CS ₄	Hay I	4.56	4.02	4.16	5.08	4.30	4.56	5.44
CS ₅	Hay I	5.30	4.89	4.42	4.99	4.47	5.48	5.86
CS ₄	Hay II	3.68	2.24	3.77	4.50	4.13	4.06	5.31
LSD (P<0.05)		0.42	0.36	0.59	NS	NS	0.35	0.27
<u>Pasture</u>		1994	1995	1996	1997	1998	1999	2000
		tons DM/a						
CS ₆	Pasture ³	3.86	2.17	1.67	1.84	2.94	2.21	2.13

¹ Soybeans replanted 6/15 due to severe herbicide damage to soybeans and poor weed control.² Oats harvested as oatlage and one alfalfa harvest.³ Intensive rotational grazing of heifers, forage production based on calculations using animal energy requirements.

Table 1b. Yield Results for the Lakeland Agric. Complex – WICST (1994-2000).

<u>Corn</u>		1994	1995	1996	1997	1998	1999	2000
		bu/a						
CS ₁	Continuous corn	177.0	150.1	41.7	112.6	165.5	72.0	94.6
CS ₂	Corn after soybeans	184.4	149.7	40.1	153.8	172.2	106.1	152.7
CS ₃	Corn after red clover	187.0	130.9	44.8	133.5	129.0	89.5	31.8
CS ₁₄	Corn after alfalfa	211.3	154.4	64.3	160.0	172.2	132.7	100.3
CS ₁₅	Corn after alfalfa	198.3	143.7	57.4	151.4	92.7	128.4	57.6
LSD (P<0.05)		9.8	14.6	14.4	26.6	55.6	20.9	18.1
<u>Soybean</u>		1994	1995	1996	1997	1998	1999	2000
		bu/a						
CS ₂	Drilled soybeans	63.1	54.9	39.5	57.8	67.7	50.7	44.8
CS ₃	Wide-row soybeans	47.4	59.1	27.3	48.6	45.0	51.4	30.0
CS ₁₅	Wide-row soybeans	-	-	-	-	-	47.7	44.7
LSD (P<0.05)		2.3	2.9	6.6	NS	NS	NS	12.8
<u>Wheat</u>		1994	1995	1996	1997	1998	1999	2000
		bu/a						
CS ₃	Wheat	50.9	70.0	76.9 ¹	57.4	47.2	49.9	41.2
<u>Seeded Alfalfa</u>		1994	1995	1996	1997	1998	1999	2000
		tons DM/a						
CS ₄	Direct seeded	2.37 ²	1.24 ²	0.15 ³	1.45	3.12	-	1.01
CS ₅	Oats/alfalfa	3.49 ⁴	1.51 ^{2,4}	1.87 ⁵	2.32 ⁴	2.97 ⁴	-	-
CS ₁₅	Oat/pea/forage	-	-	-	-	-	2.97	4.65
LSD (P<0.05)		0.54	NS	0.50	NS	NS		1.14
<u>Established Forage</u>		1994	1995	1996	1997	1998	1999	2000
		tons DM/a						
CS ₁₄	Hay I	4.12 ²	4.47	4.26	1.30 ⁶	4.53	3.23	-
CS ₁₅	Hay I	3.82 ²	4.62	4.35	3.00	4.86	4.15	4.12
CS ₁₄	Hay II	4.05 ²	3.34	3.74	3.40	4.32	3.31	3.32
LSD (P<0.05)		NS	0.71	0.78	0.86	NS	0.72	0.82
<u>Pasture</u>		1994	1995	1996	1997	1998	1999	2000
		tons DM/a						
CS ₆	Pasture	4.08 ⁷	3.58 ⁷	0.96 ⁷	1.00 ⁸	1.36 ⁹	1.63	1.77

¹ Winter wheat did not survive the winter and was replaced by oats.² August cutting ruined by rain and chopped onto field.³ Only one harvest; 1 of 4 reps (3 reps had seedlings killed by wet soil conditions).⁴ Oats harvested as oatlage and one alfalfa harvest.⁵ Oats harvested as grain (grain and straw converted to tons of dry matter per acre).⁶ Reseeded - 96 seeding failed due to wet conditions.⁷ Intensive rotational grazing of heifers, forage production based on calculations using energy requirements.⁸ Estimated yield.⁹ Does not include growth from before July 3rd

Table 2. Weighted Relative feed values on WICST forage systems 1992-2000.

A. Arlington Agricultural Research Station										
	1992	1993	1994	1995	1996	1997	1998	1999	2000	92-00 avg
CS4										
Direct seed alfalfa	184	152	160	126	150	123	140	153	141	148
Haylage I	128	138	156	147	126	152	154	128	154	143
Haylage II	134	141	143	151	155	144	164	141	162	148
CS5										
O/a-Oatlage	124	missing ¹	103	116	103	116	96	95	95	106
O/a haylage	143	missing ¹	149	103	116	141	111	104	125	124
Haylage I	142	139	141	132	147	143	148	141	149	143
CS6										
Pasture	128	133	124	103	142	130	135	127	103	125
B. Lakeland Agricultural Complex										
	1992	1993	1994	1995	1996	1997	1998	1999	2000	92-00 avg
CS4										
Direct seeded alfalfa	148	missing ²	172	159	missing ²	159	137	missing ³	132	151
Haylage I	164	136	162	140	137	144	152	142	missing ³	147
Haylage II	164	153	170	155	131	152	138	139	142	149
CS5										
O/a-Oatl	missing ¹	95	90 ⁴	108	missing ¹	130	137	102	102	110
O/a haylage	missing ¹	130	171	missing ⁵	94	114	101	123	104	119
Haylage I	159	133	167	135	145	125	136	142	136	142
CS6										
Pasture	118	114	137	117	missing ⁶	missing ⁶	na ⁷	103	110	117

¹ missing data because oats harvested as grain not oatlage or haylage.

² missing value because 3 of 4 plots chopped back on to field - only have data for one plot.

³ no treatments at Lac due to system changes starting in 1999.

⁴ Assume 90 RFV for economic analysis--forage harvested in mid-August, oats were mature, forage rained on.

⁵ no second cut taken

⁶ no data collected due to reestablishment

⁷ not available (grazing did occur this year)

formula for weighted RFV = [(Y1*RFV1) + (Y2*RFV2) + (Y3*RFV3) + (Y4*RFV4)]/(Y1+Y2+Y3+Y4)

Table 3. Total nutrient composition of manure applied to CS4 and CS5 on WICST plots at Arlington (ARS) and Lakeland (LAC) 1990-2000.¹

Year	Arlington Agriculture Research Station				Lakeland Agricultural Complex			
	DM%	Total N	P2O5	K2O	DM%	Total N	P2O5	K2O
	lbs/ton				lbs/ton			
1990 ²	19.4	11.9	7.1	10.1	29.0	12.5	10.3	17.1
1991	17.0	13.2	7.4	12.9	27.2	12.7	10.9	16.7
1992 ²	17.0	10.7	7.5	16.0	24.7	15.5	7.2	35.0
1993 ³	-	-	-	-	27.3	13.5	10.4	19.8
1994	12.1	8.9	4.5	11.3	26.4	13.8	9.2	20.3
1995	15.6	10.6	5.8	10.4	35.2	13.0	13.0	25.6
1996 ⁴	15.3	9.8	7.2	9.8	21.5	12.8	5.1	16.7
1997	11.7	9.2	3.6	8.8	34.3	11.3	9.3	14.8
1998	14.3	10.3	3.7	9.9	36.8	34.9	7.9	17.6
1999	16.8	11.1	3.8	7.1	44.9	14.9	6.7	14.0
2000	13.2	11.6	3.1	6.8	47.4	14.8	13.2	17.4

¹ Manure applied previous fall before tillage unless otherwise noted

² Manure applied prior to spring planting at ARS in 1990 and at LAC in 1990 and 1992.

³ Missing or not sampled at ARS in 1993. The average value from 1992-1995 was used for the credit.

⁴ Rep 4 at LAC received manure with composition of 20.4% DM, 14.0 N, 9.2 P2O5, and 13.1 K2O

Table 4. Growing season rainfall (inches) at the Wisconsin Integrated Cropping Systems Trial sites.**A. Arlington Research Station ¹**

Month	2000	(*)	1999	(*)	1998	(*)	30-year avg 1961-1990
April	3.38	(0.54)	5.95	(3.11)	3.71	(0.87)	2.84
May	10.46	(7.33)	4.22	(1.09)	4.06	(0.93)	3.13
June	7.17	(3.37)	4.17	(0.37)	6.81	(3.01)	3.80
July	3.41	(-0.01)	3.43	(0.01)	2.13	(-1.29)	3.42
August	3.31	(-0.57)	2.53	(-1.35)	6.65	(2.77)	3.88
September	3.12	(-1.16)	1.41	(-2.87)	2.95	(-1.33)	4.28
October	0.73	(-1.65)	1.38	(-1.00)	3.38	(1.00)	2.38
Growing Season Total	31.58	(7.85)	23.09	(-0.64)	29.69	(5.96)	23.73
Yearly Total	39.21	(8.07)	31.30	(0.16)	36.75	(5.61)	31.14

(*) Deviation from 30-year average.

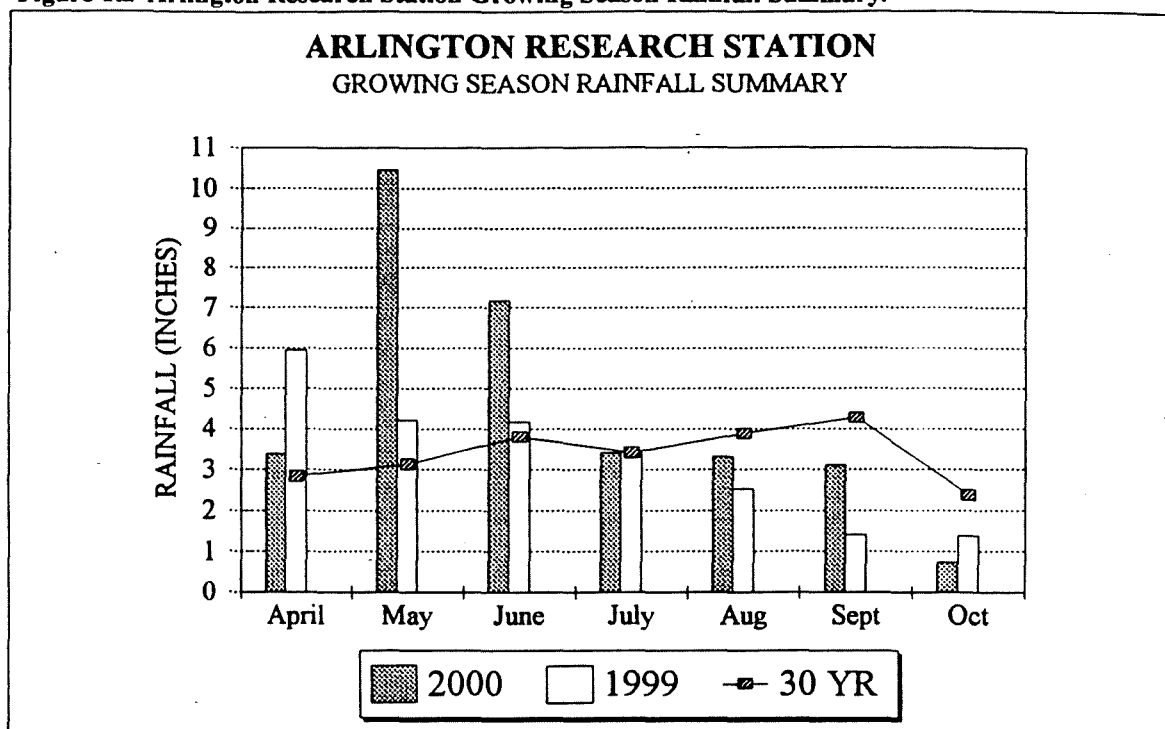
B. Lakeland Agricultural Complex ²

Month	2000	(*)	1999	(*)	1998	(*)	30-year avg 1961-1990
April	4.41	(0.75)	5.64	(1.98)	3.60	(-0.06)	3.66
May	10.59	(7.34)	5.15	(1.90)	4.61	(1.36)	3.25
June	4.14	(0.26)	8.79	(4.91)	6.76	(2.88)	3.88
July	2.69	(-1.61)	1.02	(-3.28)	1.65	(-2.65)	4.30
August	3.50	(-0.42)	2.42	(-1.50)	2.17	(-1.75)	3.92
September	4.70	(0.61)	4.23	(0.14)	2.66	(-1.43)	4.09
October	1.19	(-1.55)	0.98	(-1.76)	4.20	(1.46)	2.74
Growing Season Total	31.22	(5.38)	28.23	(2.39)	25.65	(-0.19)	25.84
Yearly Total	35.74	(-1.79)	36.32	(-1.21)	36.88	(-0.65)	37.53

(*) Deviation from 30-year average.

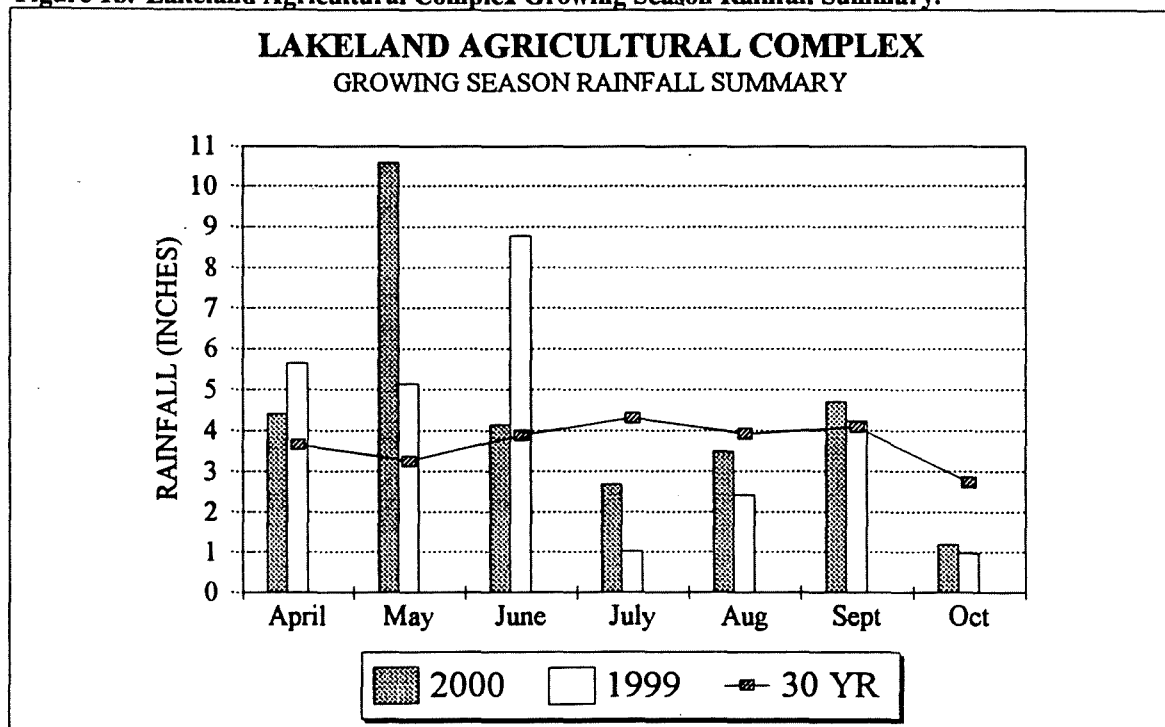
¹ Data from Arlington National Weather Service Cooperative Station.² Data from Lake Geneva National Weather Cooperative Station. (7 miles southeast of the Lakeland Ag Complex).

Figure 1a. Arlington Research Station Growing Season Rainfall Summary.



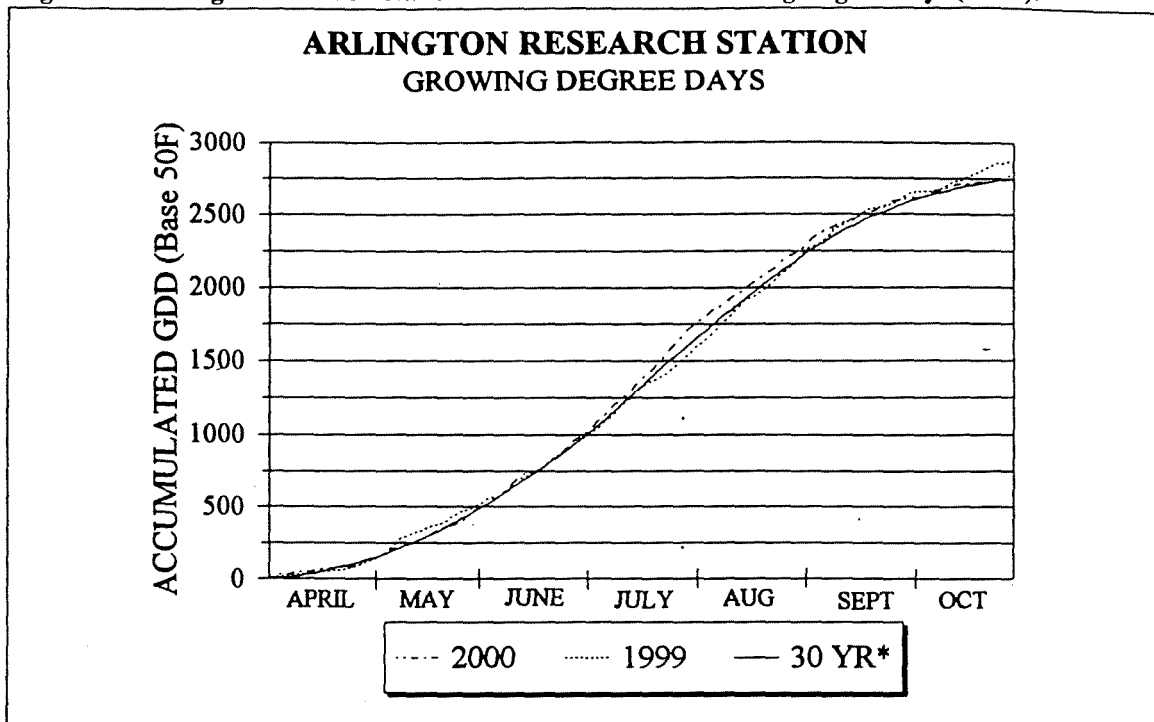
*30 YR DATA from 1961 - 1990

Figure 1b. Lakeland Agricultural Complex Growing Season Rainfall Summary.



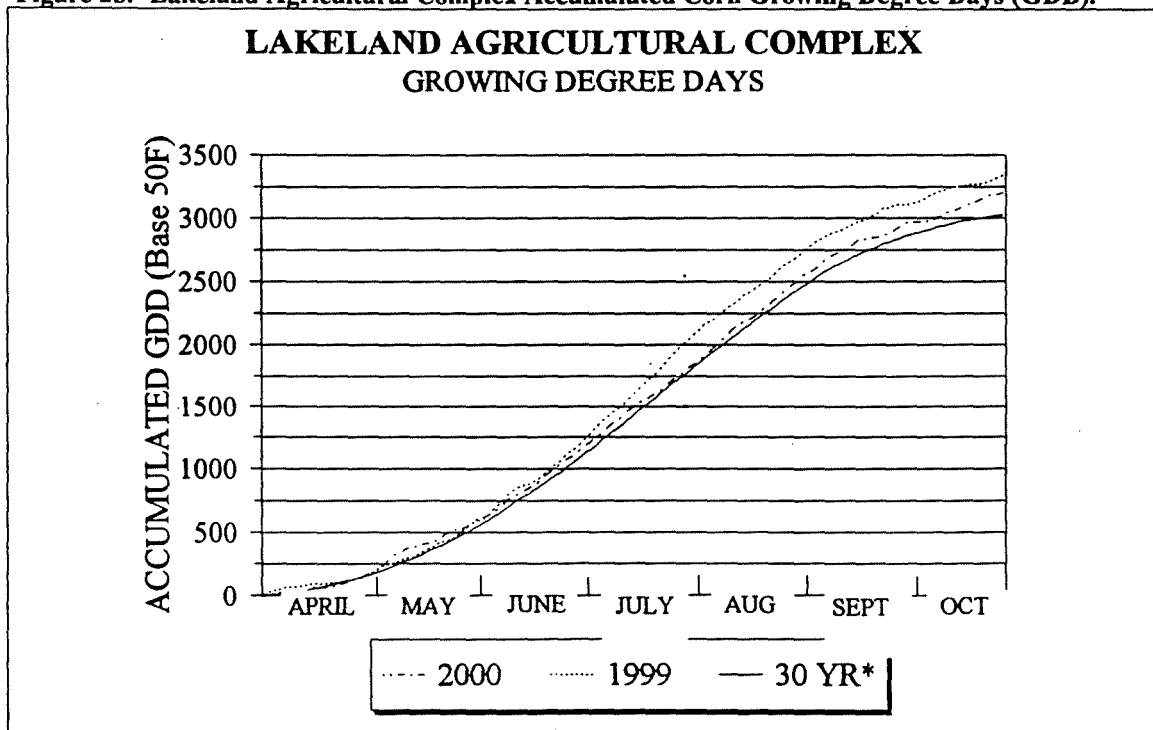
*30 YR DATA from 1961 - 1990

Figure 2a. Arlington Research Station Accumulated Corn Growing Degree Days (GDD).



*30 YR DATA from 1961 - 1990

Figure 2b. Lakeland Agricultural Complex Accumulated Corn Growing Degree Days (GDD).



*30 YR DATA from 1961 - 1990

Figure 3. Rainfall distribution during May and June 2000 at Elkhorn, WI

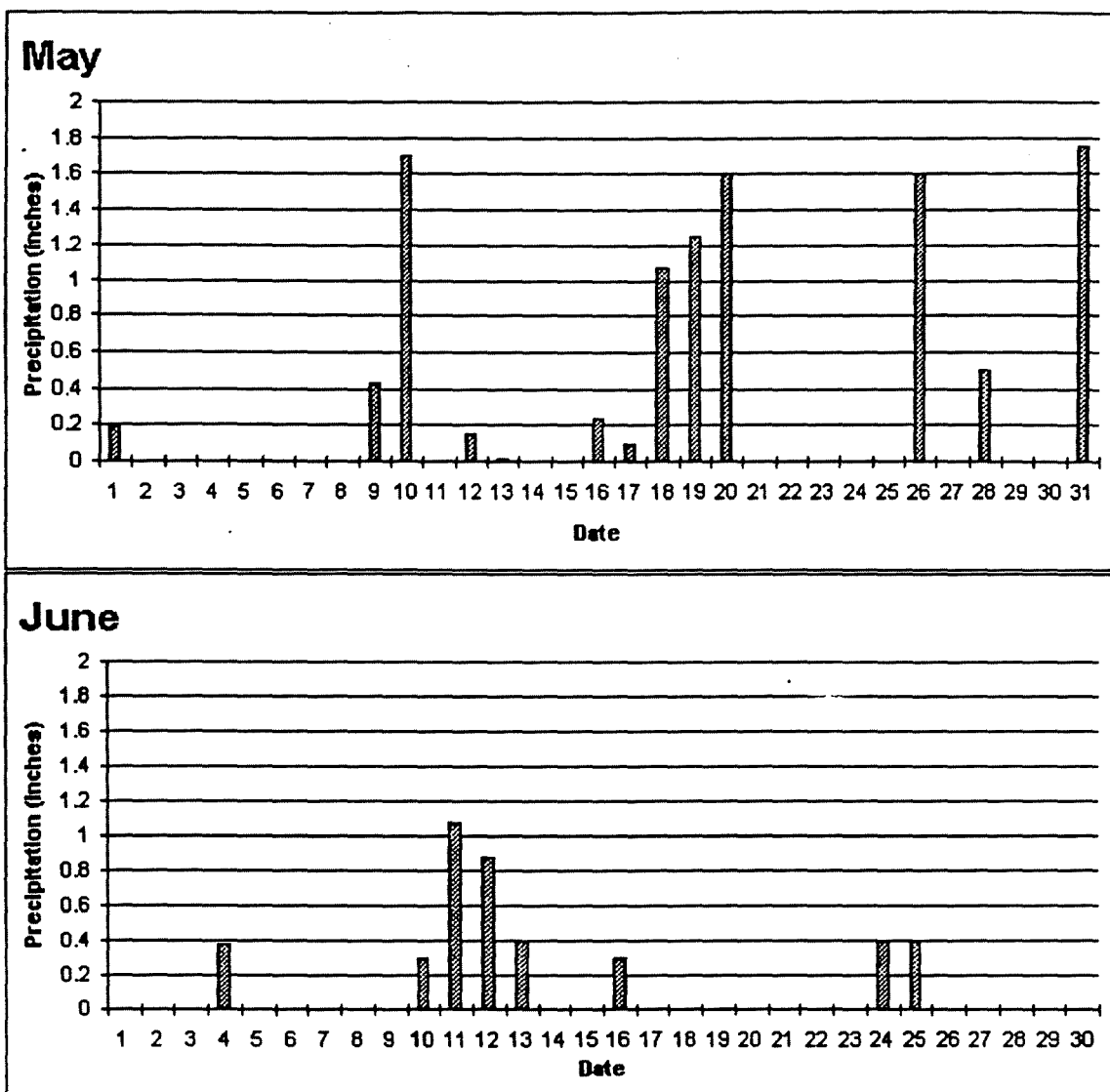
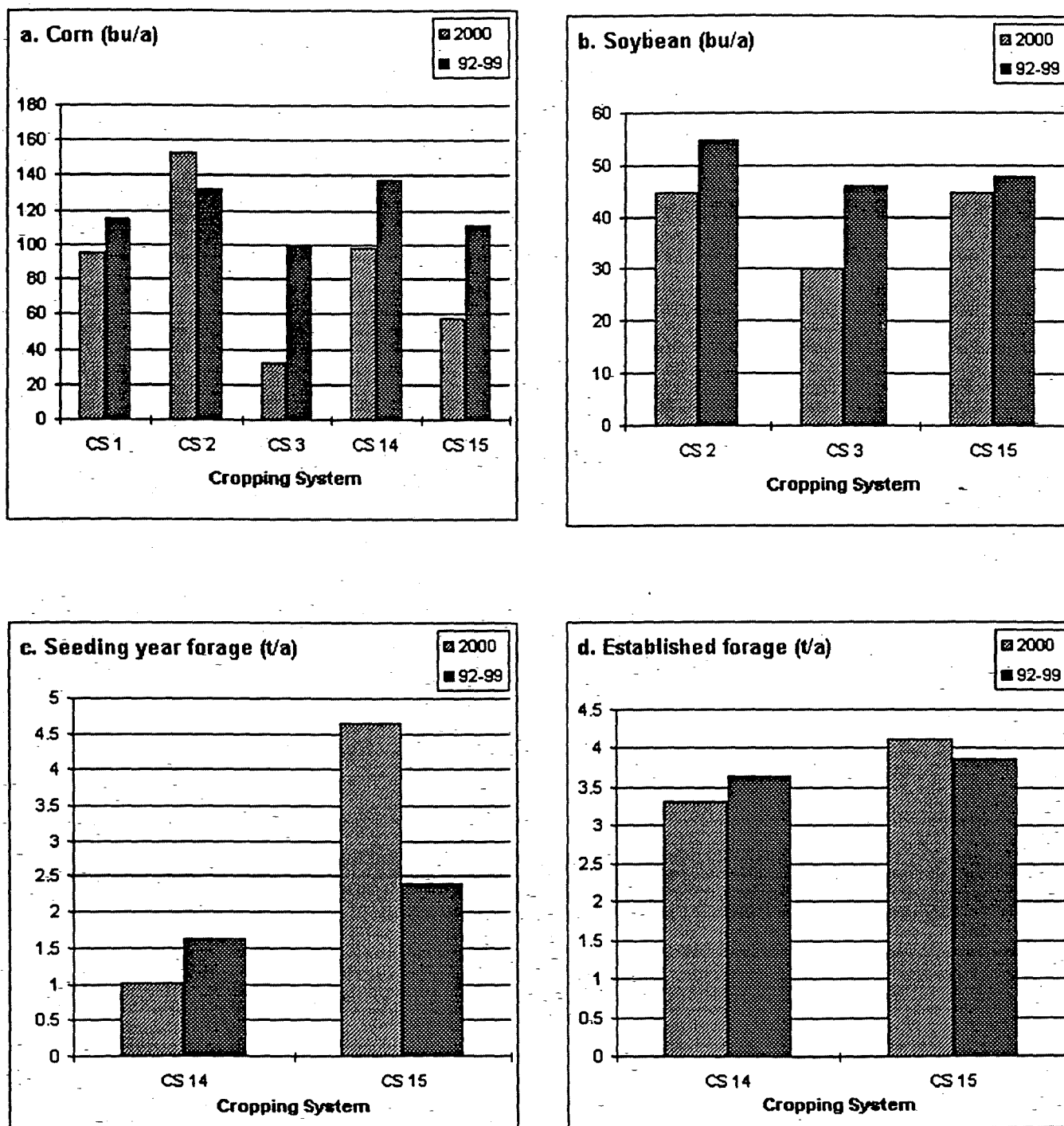


Figure 4. Individual crop yield by system in 2000 compared to the long-term trial mean at Lakeland



3a. Economic Analysis of the Wisconsin Integrated Cropping Systems Trial - 1992-2000

Don Schuster¹

Introduction

The 1999 and 2000 economic analysis for the Wisconsin Integrated Cropping Systems Trials (WICST) will be added to the previous years of data going back to 1992. It will again summarize results from the Lakeland Agricultural Complex (LAC) and Arlington Agricultural Research Station (ARS). It will compare the three cash grain cropping systems, CS1, CS2 and CS3, and the two forage based systems, CS4 and CS5. The pasture system CS6 remains an important biological check in the trial but the size of the plots makes economic analysis difficult.

Rainfall patterns in 1999 and 2000 affected planting calendar at both the LAC and ARS sites. However, the 2000 growing season proved to be particularly challenging for LAC where May plus June rainfall was over 200% of the long-term average.

Commodity prices in 1999 and 2000 were the lowest in the history of the trial. Average prices used in the analysis for 1999 were \$1.57 for corn at both sites, \$5.01 and \$4.32 for soybeans at ARS and LAC, respectively, and \$1.69 and \$2.25 for wheat at ARS and LAC, respectively. In 2000, the corn price climbed \$0.11/bu. Soybeans fell by \$0.68/bu at ARS but were \$0.01 higher at LAC. Winter wheat price increased by \$0.08/bu at ARS but lost \$0.39/bu at LAC.

Methods

The economic analysis is based on the concept of gross margins. This concept deducts the variable cost of production (seed, fertilizer, chemical, drying cost, fuel, and repairs) from the gross revenue generated per acre. This gross revenue is based on the actual yield, its quality (in the case of alfalfa), and price for the product when harvested. This gross margin figure equals the dollars available to cover the overhead costs of capital, land, labor and management. The way to interpret the adequacy of the gross margin figure is to estimate the amount of dollars needed per acre to cover those overhead costs. We would estimate that a cash grain farmer would need approximately \$35-\$40 per acre to cover labor and management, \$80 to \$140 for rent, and approximately \$40-\$60 to cover the depreciation and interest cost associated with machinery and drying facilities owned on the farm. This adds up to approximately \$200 to \$250 per acre to be covered by gross margins.

Loan deficiency payments (LDP's) were calculated for the first time in 1999. LDP's are payments that a farmer can receive from the USDA, when a floor price for a commodity is reached. LDP's have not been much of a factor throughout the trial but with two years of low commodity prices, it was decided to look at their effect to the gross margins.

¹ Outreach Specialist – Center for Integrated Agricultural Systems at the University of Wisconsin-Madison.

Results are reported separately for each site due to different soil type and environment. Cash grain systems are separated from forage systems due to different assumptions and scenarios such as land base which is set at 1200 acres for cash grain farms and 150 a for forage-based farms.

Results

Cash Grain Systems

1999. Gross margins for all three grain systems were below the trial average at each site (Figs. 2 and 3). Cropping system 2 had the highest gross margins this year at ARS with \$161/a. Cropping system 2 at ARS performed well above CS1 and CS3 consistently throughout the trial (Fig. 1) with long-term average of \$194/a. Likewise, in most years at LAC, CS2 performed the best of the three grain systems averaging \$164/a (Fig. 2). However, in 1999, CS3 had the highest gross margin at LAC due to above-average soybean and wheat yields and low inputs. Generally, gross margins have been lowest for CS1 over the course of the trial at both sites, which reflect high external inputs, and mediocre corn yields. At LAC the gross margin for CS1 has been negative three times since 1992, with poor corn yield related to corn rootworm infestations.

2000. Again, gross margins were highest for CS2 at both sites (Figs. 1 and 2). Yields were generally at or above average for corn at ARS, but CS3's soybean yield were below average due to very heavy weed pressure. In addition, wheat yields were low perhaps due to a late planting date. Corn yield on CS1 at ARS was respectable at 162 bu/acre, the fourth highest in trial history. However, higher seed, anhydrous ammonia and fuel cost brought CS1 gross margin down to \$73/acre, the lowest in trial history. The corn yields at LAC for all three grain systems were below average. For the first time, gross margins were negative for CS3 at LAC of -\$0.68/acre, well below the trial average of \$134/a, due to low soybean, wheat and corn yields². Poor corn yield, replanting cost, and high drying cost reduced profit on CS3.

LDP. To take full advantage of USDA programs, higher yields are given the most return. When including LDP's, only ARS's CS2 had gross margins high enough to cover overhead cost at \$213/a in 1999 and \$236/a in 2000. The lowest gross margins were at LAC in 1999 on CS1, which had a gross margin of -\$4/a even with the LDP. In the year 2000, wheat LDP's were the highest in history and most of the time, there was no LDP on wheat. The adding of the LDP's did not alter the outcome of the rankings for the cropping systems but it does move the gross margins closer to the trial average.

Forage Systems

Arlington. Over the period 1993-2000, the forage rotations have generated similar gross margins per acre, averaging \$230/acre (Fig. 3). However, in 2000, gross margins of CS4 were at a trial high of \$274/acre, \$40/acre higher than CS5, reflecting the higher forage

² Corn was harvested in November at 31.79 bu/acre and 49.6% moisture. The corn quality was very poor, had a black color and sour smell.

quality and better corn yield on CS4. Comparing the long-term gross margin of CS4 to CS5 showed only a small difference of \$6 per acre or \$900 per year on a 150-acre farm. This result is a bit surprising in that the established alfalfa sequence in CS5 is only one year and requires more frequent seeding. However, the 4-cut alfalfa management system being used for CS4 at both sites may have limited profits because of winterkill and the need to maintain a longer stand in CS4, including the use of pesticides and other chemicals.

Lakeland. The two forage systems at LAC have had similar gross margins (averaging \$154/a) throughout the course of the trial (CS4 = \$159/a and CS5 = \$149/a) with the exception of 2 years where CS4 had substantially higher gross margins than CS5 due to exceptional corn yields on CS4 in those years (Fig. 4). However CS5 has been modified by adding soybeans to the rotation for the first time in 1999. Lakeland's cropping system 4 and 5 are now in the second year of transition. Lakeland's CS4 has switched from a 4-year crop rotation to a 3 crop rotation (c-sb-w/rc with manure) and CS5 has gone from a 3-year crop rotation to a 4-year crop rotation (c-sb-o/a-a with manure). Because of the transition, comparison to previous years has little value at LAC. However, as can be seen in Figure 4, neither system had gross margins above the \$200/a break-even level over the past two years. Corn yields were also hurt by the wet condition at LAC resulting in 100 bu/acre in CS4 and 58 bu/acre in CS5, both well below the trial average.

Changes for WISCT 2000 Economic Analysis

The economic analysis for 2000 saw only two changes from the previous years and both dealt with corn moisture. In the past a cost of \$0.02/bu per moisture point was used in the calculations for drying corn. Because of the high cost of natural gas, this rate was increased to \$0.03/bu per moisture point.

Lastly, actual corn moisture was used for LAC. This was done because Janesville research plots didn't have a comparable variety as the one in LAC.

Future analysis should consider new assumptions that reflect current scenarios. For example, farm size would likely be increased for both grain and forage systems. Similarly, equipment sets may need adjustments or custom hiring should be considered as a management option.

Summary

Comparison of the cash grain systems shows CS2 to be the dominant systems in terms of highest gross margins followed CS3. Yet, only with the LDP, does CS2 reach the minimum level of \$200/acre to cover fixed costs.

As we have seen in the past, the forage systems had higher gross margins than the cash grain systems. In fact, the forage crops at ARS (CS4 and CS5) were the only cropping systems that did better than the \$200/acre needed to cover fixed cost in 1999 and 2000.

The more integrated systems, which include both grain and forage and manure, seem to be the most economically sound. The low input forage system, CS5, is very comparable

to the high input system (CS4) in terms of gross margins. It produces more variable forage quality in the seeding year, which can be allocated livestock with different nutritional needs. Environmentally conscious producers can use this CS5 system and may get the same results as their conventional counterparts.

Figure 1. Gross Margins – CS1, CS2 and CS3, Arlington Agricultural Research Station - 1992-00.

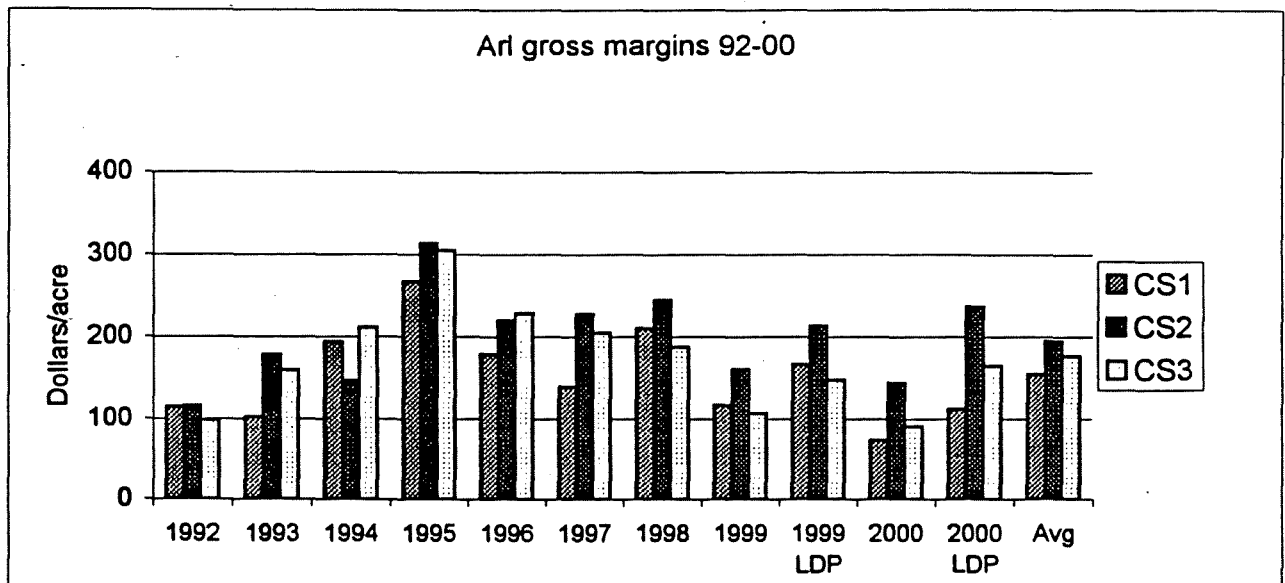


Figure 2. Gross Margins – CS1, CS2 and CS3, Lakeland Agricultural Complex - 1992-00

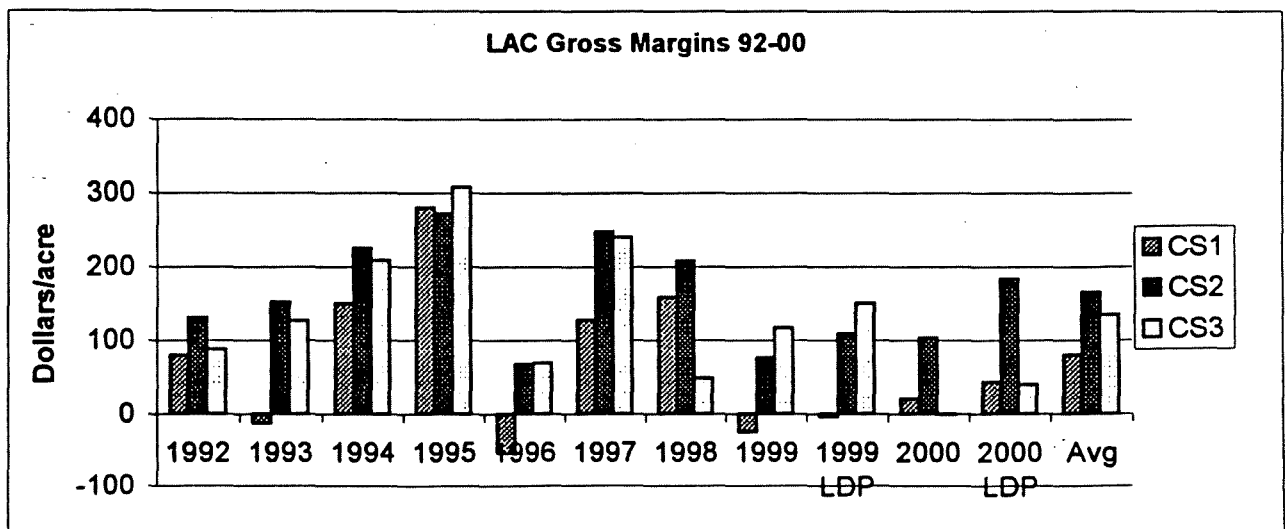


Figure 3. Gross Margins – CS4 and CS5, Arlington Agricultural Research Station 1993-2000.

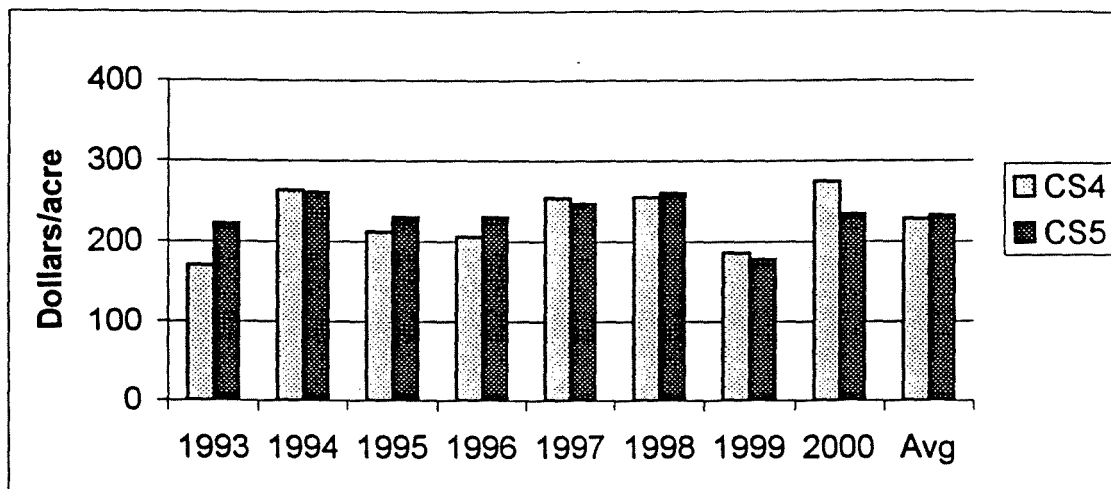
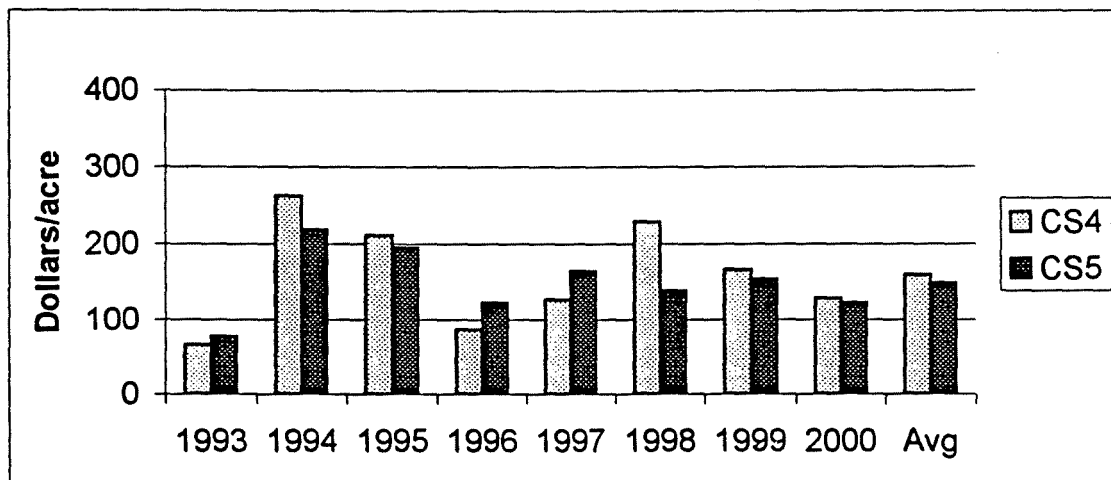


Figure 4. Gross Margins – CS4 and CS5, Lakeland Agricultural Complex 1993-2000.



3b. WICST Commodity Price Analysis

Don Schuster

One of the theories behind the Wisconsin Integrated Cropping Systems Trial is that having multiple crops for an individual farm will help spread out price risk. In mono-cropping systems, a producer is taking the chance that the one crop they grow will return the best profit for them.

In this paper, we exam the sensitivity of cropping systems 1, 2 and 3 with respect to corn, soybeans and winter wheat price correlation.

Commodity prices were taken from the harvest months, October for corn and soybeans and August for winter wheat. The prices for the corn and soybeans were obtained from the Wisconsin Agricultural Statistics Service. Nine regions divide the corn and soybean price, the southeast was used for Lakeland the south central was used for Arlington. The regional price data goes back to 1978.

Unfortunately, Wisconsin Agricultural Statistics Service doesn't keep regional data for winter wheat. As a result, the state average August cash price for winter wheat was used at both locations.

Results

The basis between Arlington and Lakeland shows a slight price advantage to Arlington in both corn and soybeans. The advantage for Arlington's corn was \$0.01518/bu from 1978-99 and \$.0025/bu for the trial years of 1992-99. Soybeans at Arlington averaged \$0.01664/bu from 1978-99 over Lakeland and by \$0.0275/bu over Lakeland during the trial period.

To examine the price sensitivity for the cropping systems, the Pearson correlation coefficient was used. The Pearson correlation coefficient is a measure of association, or covariation, between two variables, the coefficient (r) ranges between -1 and $+1$. The correlation coefficient would be $+1$ for the case of perfect positive correlation, and an r near zero would indicate little or no correlation.¹ The results are as follows:

	Arlington		Lakeland	
	1978-99	1992-99	1978-99	1992-99
Corn - soybeans	0.8100	0.9178	0.8491	0.9262
Corn - wheat	0.7931	0.8951	0.7906	0.9006
Soybeans - wheat	0.6491	0.8760	0.6777	0.8751

During the trial years of 1992 -99, the prices of the three commodities at both sites, are positively correlated. Arlington and Lakeland's corn and soybeans prices are highly correlated (0.92) while soybeans and wheat are the least positively correlated (0.87). This indicates that

¹ Econometrics Basic and Applied, Aaron C. Johnson, Jr., Marvin B. Johnson, Rueben C. Buse, 1987, p.90

these commodities did have some price variation over that time period, but not a significant amount.

However, over a 20-year period (1978–99) the correlation is somewhat weaker, but still not significantly different between the sites. The corn–soybeans correlation drops to 0.83 and corn–wheat combinations to 0.79. The soybean–wheat combination again, had the least amount of correlation of any of the combinations—only 0.66 for both sites.

Conclusion

In the short run, it does not appear that there is much price risk advantage in diversifying rotations. So from a price perspective, planting corn year in and year out should not affect the variation in the bottom-line all that much of any particular farmer.

In the long run, there seems to be enough of a difference that by diversifying, one could protect against some price risk. By adding wheat and soybeans to a corn rotation, a farmer a farm could spread the risk out in hopes of getting a good price for at least one of the commodities.

It should be pointed out that this is only looking at the commodity price, and not any production factors that could greatly affect the outcome of any particular operation and it is based on marketing month prices only.

3c. Labor Flow Analysis

Don Schuster and Rick Klemme²

The Wisconsin Integrated Cropping Systems Trial has examined profitability, nitrogen availability, weed seed bank changes, biodiversity and many other areas of interest for the past ten years. The economic findings have shown potential for each system to make a profit. Further findings have indicated that the diversified systems tend to be more environmental friendly.

However, there is a practical aspect to the comparison of these systems that has been neglected thus far. This paper examines the effectiveness of labor, that is, how it is distributed across the year for the systems. It is very important that a system be workable so that field operations can be completed on time. It does not matter how profitable or environmental friendly a system is if it has unreasonable labor requirements.

Procedure

For this analysis, the number of actual machinery passes for Arlington and Lakeland were used to determine whether all the operations in a system could be completed in a timely manner. (See table 4b.1) Average passes over the field were used for rotary hoeing and row cultivation for cropping system 3. At Arlington, the average rotary hoeing occurred 2.4 times per year for soybeans and 2.25 times for corn. At Lakeland, the average rotary hoeing occurred 2.1 times per year for soybeans and 1.75 times for corn. At Arlington, the average in row cultivation occurred 3.6 times per year for soybeans and 2.5 times for corn. At Lakeland, the average in row cultivation occurred 1.9 times per year for soybeans and 1.25 times for corn.

The amount of days available for each field operation was held constant across all systems. For example, each system had 48 days to get the corn planted. This is not saying that corn planted in the middle of June will perform as well as corn planted on May 1st, it's just saying that corn could be planted during that time frame. (See table 4b.2) All operations had the same number of available days and they covered the same time periods, except for soybean harvest. Because winter wheat is planted after soybean harvest in cropping system 3, the beans must be harvested earlier than in cropping system 2.

This number of days represents the maximum days available for each machinery operation. In a normal farming operation, weather, machinery breakdowns, personal agendas, etc. contribute to decreasing the total number of available days.

Results

The no-till cropping system two needed the least number of hours to perform all the farm operations--564 hours for a 1200-acre farm. This was followed by the continuous corn system

² Don Schuster, Outreach Specialist at the Center for Integrated Agricultural Systems, UW-Madison, Rick Klemme, Assoc. Dean, College of Ag. and Life Science, UW-Madison

Table 2: Operation Time Schedule

Machinery Operation	Earliest Date	Latest Date
Chisel Plow	10/10	11/15
Soil Finisher	4/15	6/10
Broadcast Seeding	3/15	4/15
Corn Planting	4/28	6/15
Soybean Planting	5/10	6/15
Rotary Hoeing	5/5	6/10
Cultivating	6/10	7/05
Harvesting – Combining Corn	10/1	11/15
Harvesting – Combining Soybeans	9/25	10/25*
Harvesting – Combining Wheat	7/20	8/30
Drill - Wheat	9/25	10/20
Stalk Chopper	10/1	11/15

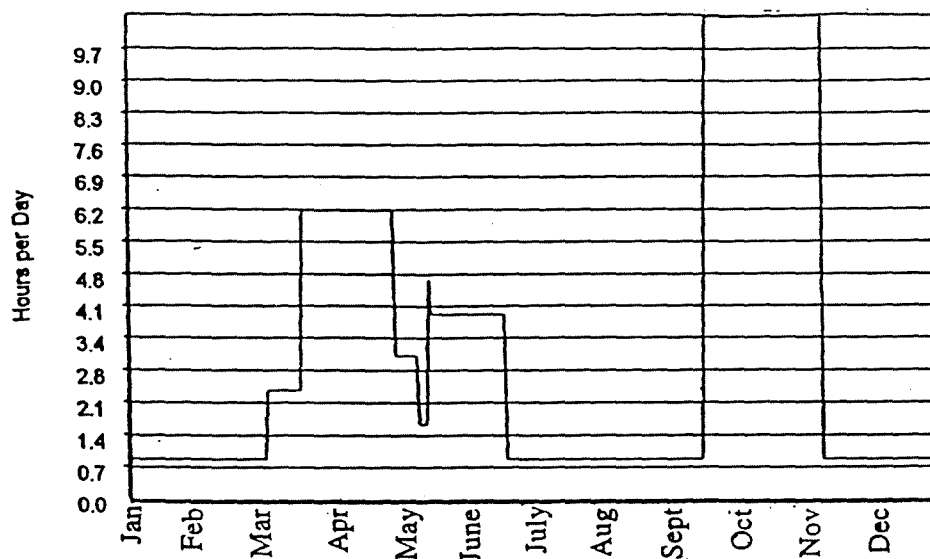
Harvesting soybeans on CS 3 needs to be completed by October 10th so that winter wheat can be planted in a timely fashion.

Labor Flow Analysis

Hours/day during a cropping season

Cropping System 1

Graph 1

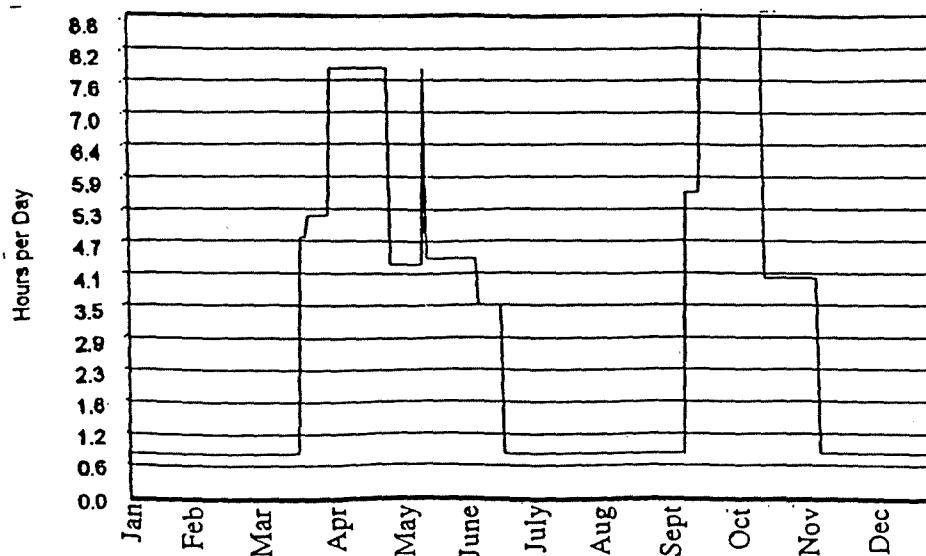


Labor Flow Analysis

Hours/day during a cropping season

Cropping System 2

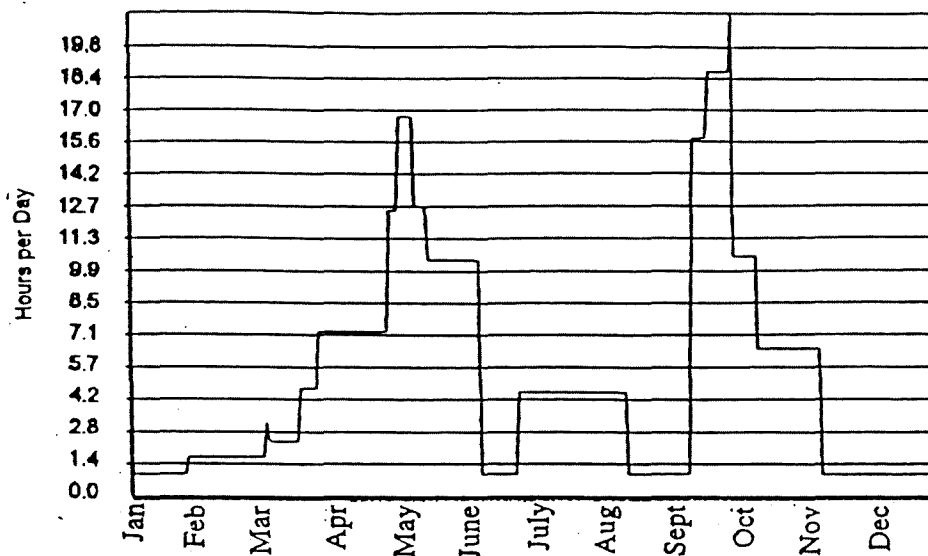
Graph 2



Labor Flow Analysis

Hours/day during a cropping season
Cropping System 3 at Arlington

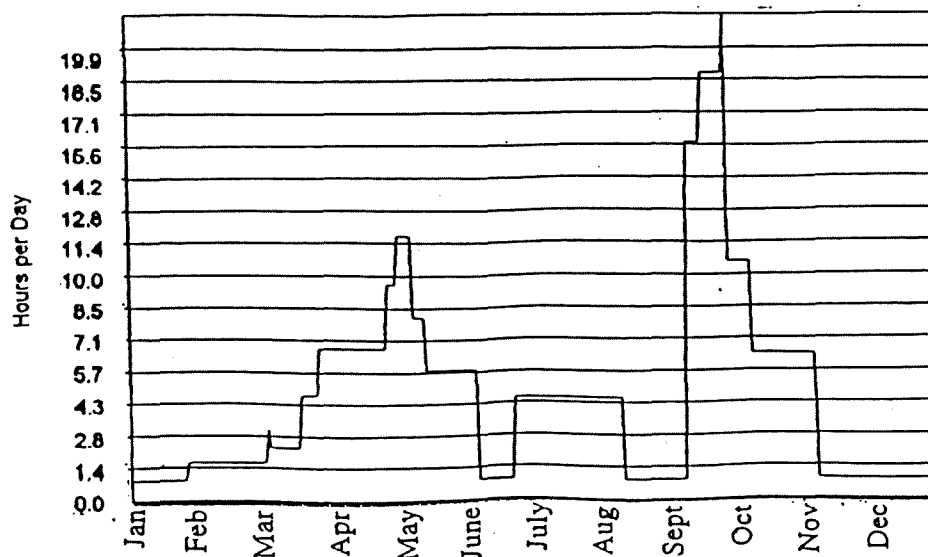
Graph 3



Labor Flow Analysis

Hours/day during a cropping season
Cropping System 3 at Lakeland

Graph 4



4. WICST Management-Intensive Rotational Grazing of Dairy Heifers

Janet Hedtcke¹ and Jim Stute²

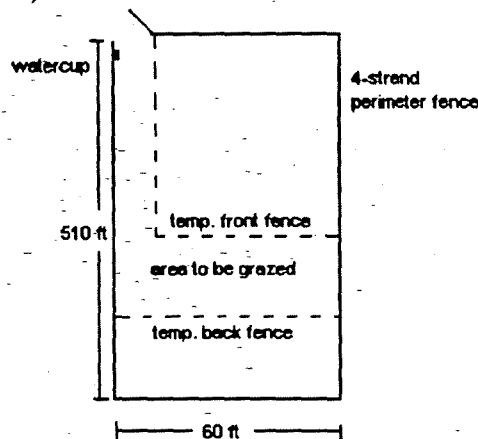
Introduction

Management-intensive rotational grazing (MIRG) is a low input form of dairy herd management that is increasing throughout the United States. In Wisconsin, about 23 percent of dairy farmers used MIRG last year, more than triple that since 1993 (Jackson-Smith and Powell, 1999). Of the three dairy forage systems represented in the Wisconsin Integrated Cropping Systems Trial (WICST), rotational grazing is the lowest input system which measures productivity in terms of animal performance and forage production. Long-term effects of animals on soil and vegetation are also being monitored.

Materials and Methods

Pastures were established at the Lakeland Agricultural Complex (LAC) and the Arlington Agricultural Research Station (ARS) in 1990. Fencing and water lanes for pastures at both locations were built during the spring of 1992. Fig. 1 shows an example of paddock layout at ARS which was 0.70 acres; layout was similar at LAC but paddock size was 300' x 120' or 0.83 acres. Initially, species included red clover, smooth brome grass and timothy; later, orchardgrass, perennial ryegrass and reed canarygrass were also included (see Table 1 for seeding dates and rates). At LAC, the forage was mechanically harvested until the spring of 1992 (see table 5 for yield) when grazing began. At ARS, severe winterkill of the grasses required reseeding in 1992 and grazing began in the spring of 1993. Red clover was seeded into the pastures on alternative years through 1995. Thereafter, red clover was seeded at a reduced rate when deemed necessary. Two of the paddocks at LAC (reps 1 and 4) were tilled and reseeded in August of 1996 to repair severe trampling damage which occurred during the early summer wet weather. The fall seeding of 1996 at LAC failed and there was no reseeding there until the fall of 1997.

Fig. 1 Pasture layout at Arlington (similar at LAC).



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² Agronomist, Michael Fields Agricultural Institute, East Troy, WI (262) 642-3303

Table 1. WICST rotational grazing seeding dates and rates.

Lakeland Agricultural Complex				Arlington Ag Research Station		
Year	Date	Species	(lb/acre)	Date	Species	(lb/acre)
1990	30-May	'Marathon' red clover	6.1	23-Apr	'Marathon' red clover	7.0
		'Badger' smooth brome grass	3.0		'Badger' smooth brome grass	8.0
		'Toro' timothy	3.5		'Toro' timothy	4.0
1992	-	-	-	30-Apr	Orchardgrass (early)	6.0
					'Badger' smooth brome grass	12.0
					'Toro' timothy	6.0
				31-Jul	Orchardgrass (early)	4.5
1993	07-Apr	'Arlington' red clover	20.0	09-Apr	'Arlington' red clover	12.0
1995	24-Mar	'Arlington' red clover	18.0	17-Mar	'Arlington' red clover	15.0
1996	09-Mar	'Arlington' red clover*	18.0	26-Apr	'Arlington' red clover	6.0
	22-Aug	'Arlington' red clover**	6.0			
		timothy	4.0			
		perennial ryegrass	3.0			
1997	21-Aug	reed canarygrass	8.0	05-Apr	'Arlington' red clover	6.0
		Orchardgrass (early)	3.0			
		'Arlington' red clover	8.0			
1998	30-Mar	'Arlington' red clover***	15.0	-	-	-
1999	-	-	-	-	-	-
2000	-	-	-	-	-	-

* Seeded with no-till drill; otherwise broadcast seeded except for drilling with 1990 establishment.

** reps 1 and 2

*** Heavy seeding due to poor pasture conditions

Results and discussion

Pasture Management

Arlington 1999. Grazing began May 4 in 1999. Continuing with the same management of the previous three years (put and take system), twelve dairy heifers flash grazed the paddocks the first week of the grazing season (See 6th Annual WICST Report for further details). We used the flash grazing practice to control some of the growth surge of the spring grass and avoid the need for mechanical harvest. No hay was mechanically harvested during the season. Beginning in mid-May, paddocks were subdivided with temporary electric wire into third or quarter sections and a back fence was put up to prevent animals from grazing new regrowth. An alleyway was set up in each paddock to allow animals access to water at all times. Approximately 1500 square feet of the paddock was used as this alleyway. Six heifers were removed on June 1 to accommodate pasture supply. Throughout the grazing season of 1999, the heifers were cycled through the four paddocks 5 times. Moisture was at or above the 30-year average through July (see Fig. 1a, page 14). However, it was extremely dry from late July to October which severely slowed the rate of pasture growth. Grazing ended on September 14, about 50 days short of our goal of 180 grazing days.

Lakeland 1999. Seven dairy heifers were put on pasture trial on April 28. Three

heifers were removed from the paddocks on June 30 to accommodate pasture growth. Since regrowth was slow, no back fence was set up; therefore, no alleyway was necessary. No hay was mechanically harvested during the season. Heifers were cycled through the paddocks five times during the season. Similar to ARS, dry weather in late summer reduced forage growth and grazing season ended September 23, for a total of 149 grazing days.

Arlington 2000. On April 21, paddocks were evaluated using a pasture condition score sheet compiled by Cosgrove et al. (1996). All plots were in the 'good' category. Late growth of legumes and low plant density reduced the score from the 'very good' category. After several discussions with researchers and dairymen practicing MIRC, we decided to change our stocking strategy slightly to improve the forage stands. Instead of stocking the pastures heavily in the early spring to control spring growth, we decided to keep the stocking rate constant over the season and harvest excess forage as hay. Grazing began on April 25th. Rainfall was average in April but heavy in May and June (see Fig. 1, page 14). Pasture growth was good all season. Hay was harvested from plot 207 in mid-May yielding 1.15 tons dm/a and from plot 302 in mid-June yielding 1.68 tons dm/a. It was not necessary to feed this hay back to these heifers in mid-summer. All plots but 207 was fertilized with 40 lb N/a in mid-June. The four heifers cycled through each paddock approximately six times during the season for a total of 162 grazing days.

Lakeland 2000. Similar to ARS, the stocking density of four heifers was held constant over the grazing season. Grazing began on May 2 and ended on October 13 for a total of 164 grazing days. Hay was harvested once in late June from plot 408 yielding 1.59 tons DM/a. No N fertilizer was applied. Although heavy rains in May and June (200% above long-term average) hampered field operations in other systems, grazing continued without problems. Grasses, especially reed canarygrass are extremely productive in wet conditions. Heifers cycled through the plots four times during the grazing season.

Animal Details

Arlington 1999. Eighteen dairy heifers were chosen for the study. All 18 animals were weighed on a shrunk-weight basis at the initiation of the grazing season. The control group, which would remain in confinement, weighed an average of 499 lbs. The trial group, which would be on pasture, weighed an average of 439 lbs.

Heifers were supplemented with four lbs of grain per head per day from May 4–June 23. After this time, the grass was essentially all vegetative, leafy material and grain supplement was decreased to two lbs per head per day for the remainder of the grazing season. In total, 364 lbs grain/animal was supplemented for the season.

Midseason weights were recorded on the six controls and the six animals remaining in the trial group (see Table 2). The six heifers that were taken off the trial early were weighed the day after they were removed from the trial (group A, Table 2). This group's minimal weight gain may be due to stress and poor adjustment to high fiber diet as well as poor forage quality during rapid grass maturity.

The remaining six heifers (group B, Table 2) adapted to the pasture system and the frequent movement with final gains of 1.82 lb/head/day. Confinement heifers gained an average of 2.08 lb/head/day. The range in gain was quite similar for both groups: 1.59 to 2.16 and 1.82 to 2.20 lb/head/day for pasture and confinement groups, respectively (data not shown). Final body weights of pastured heifers averaged 668 lbs/head, slightly below breeding size.

Lakeland 1999. Seven heifers were weighed before being put on pasture with an average initial weight of at 609 lbs. Supplement included barley grain at 2.5 lbs/hd/day from April 28 to June 30. Grain supplementation increased to 3.7 lbs/hd/day for the remainder of the season. A total of 475 lbs grain/animal was supplemented during the season. During the last week on pasture (September 19-23), heifers were given 40 lbs corn silage, 8 lb steer mix, and 35 lbs alfalfa hay to compensate for low forage availability.

Midseason weights averaged 735 lbs on June 30. Three heifers were removed from the trial at this time with an average daily gain of 1.41 lb/day/head (Table 2, LAC Group A). Final gains averaged 1.84 lb/day/head (Table 2, LAC Group B). Final body weights averaged 886 lbs/head, ideal size for breeding. No data was collected for the control group.

Arlington 2000. Ten heifers were selected for the study and initial weights were recorded on a shrunk-weight basis. Six of the ten heifers were controls and remained in confinement with initial average weight of 499 lbs. The initial average weight of the four heifers in the pastured group was 476 lbs. They were given the entire paddocks for the first ten days on the trial to control early forage growth. Thereafter, paddocks were divided into quarters and heifers were moved about every 2 to 3 days to new area.

Heifers were supplemented four lbs of corn grain per head per day for the first month; grain was later reduced to two lbs per head per day for the remainder of the grazing season. In total, 366 lbs grain/animal was supplemented for the season.

Midseason weights averaged 628 lbs for pastured heifers and 713 lbs for confinement heifers. At this time, heifers were dewormed and vaccinated if not already done. Heifers were removed from the trial on October 5 due to cold weather conditions. Average final weight was 759 lbs from the pastured heifers and 856 for confinement heifers. Average daily gain was 1.75 lbs/hd (ranging from 1.65 to 1.86 lbs/day) for pastured animals and 2.20 lb/hd (ranging from 1.89 to 2.27 lb/day).

Lakeland 2000. Initial average shrunk weight of the four heifers was 529 lbs. There was no data collected on a confinement group. Paddocks were quartered and heifers were given new sections every two days.

Heifers received two lbs corn grain per day per head for the entire season. Total grain

supplemented for the season was 328 lbs/hd.

No mid-season weights were measured. Final weight averaged 762 lbs/hd. Average daily gain averaged 1.42 lb/head (ranging from 1.13 to 1.77 lbs/hd). Cold temperatures and cold rains in October may have hindered animal productivity.

Table 2. Weight gain of pasture animals at Arlington Research Station (ARS) and Lakeland Agricultural Complex (LAC), WICST 1999 and 2000.

	Site / Group	No. animals	Avg. initial weight (lbs)	Avg. final weight (lbs)	# days	Wt. gain (lb/day)
1999	ARS A	6	450	456	29	0.21
	ARS B	6	428	668	133	1.82
	LAC A	3	602	725	63	1.95
	LAC B	4	613	886	148	1.83
2000	ARS A	4	476	759	162	1.75
	LAC A	4	529	762	164	1.42

Table 3 shows the current summary of animal performance at both ARS and LAC from 1992-2000. It is apparent that the grazing days has been well below the expected 180 days at both sites over the years. Grazing usually begins in late April but rarely extends beyond mid-September due to either lack of forage or cold weather conditions.

Table 3. Summary of animal weight gain for WICST rotational grazing for 1992-2000.

year	Lakeland Agricultural Complex			Arlington Ag Research Station		
	Total # of animals	# of days on pasture	weight gain lb/day	total # of animals	days on pasture	weight gain lb/day
1992	8	167	2.27	-	-	-
1993	4	75	1.65	8	137	1.76
	8	152	-			
1994	8	178	2.02	8	120	1.61
1995	8	154	1.91	8	60	0.78
1996	3	53	1.76	4	36	1.33
	*	56	1.49	3	48	1.18
				5	134**	1.80
1997	-	-	-	3	17	-1.47
				3	23	0.48
				6	125	1.75
1998	7	96	2.20	2	42	0.40
				2	47	1.30
				6	138	1.72
1999	4	63	1.41	6	29	0.21
	7	148	1.83	6	133	1.82
2000	4	164	1.42	4	162	1.75

* Animals at LAC were on pasture 86 and 122 days; only 53 and 56 of those days were on plots.

** Days on pasture include 6 days in confinement for mid-season shrink wts & deworming.

Forage Quantity and Quality

At ARS, four random areas of the paddock was sampled to ground level using a hand held electric grass shears and a 0.5m² quadrant. At LAC, one sample was clipped to grazing height (approximately 10" for reed canarygrass) with a quadrant and shears. The samples represented forage that would be immediately grazed by the heifers. Samples were dried and yields of dry matter per acre were calculated. Samples were sent to University of Wisconsin Soil and Plant Analysis Lab. Using NIRS, forage quality was estimated for crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF). Generally, fiber and protein levels were similar at each site for most of the season and at levels appropriate for this class of livestock.

1999. Throughout the growing seasons, weekly forage samples were collected at LAC and monthly samples were collected at ARS. Across sites and months, crude protein levels ranged from 13.0-21.0%; NDF levels ranged from 47.9-69.4%; and ADF levels ranged from 29.8-42.3% (Figs. 2-3). Relative feed values ranged from 108-161 at ARS and 76-123 at LAC (Fig. 4). Mid-season estimates of CP and ADF and NDF show high quality forage was available at ARS and marginal quality forage was available at LAC (Table 4). Differences in quality between the two sites was due to different plant management and diversity between sites. Several species made up the pasture at ARS while reed canarygrass was the main species present at Lakeland.

2000. Samples were collected weekly at ARS and monthly at LAC. Protein levels were lower than expected at both sites suggesting that red clover should be reseeded next year (Fig. 2) Typical of any cool-season grass pasture, our pastures started out with very high quality in late April/early May but declined until July when most grasses were finished heading out. Fiber levels increased to their highest levels in June but remained relatively constant over the remainder of the season (Fig. 3), when the pastures were mostly leafy, vegetative material. Crude protein levels ranged from 13.0 to 18.9 across sites, similar to 1999. Fiber levels were also in a similar range as 1999.

Fig. 2. Monthly crude protein levels at ARS and LAC, 1999-2000.

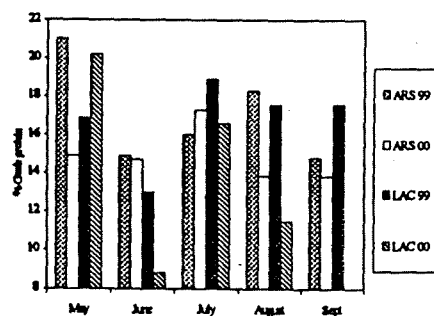


Fig. 3. Seasonal ADF and NDF in 1999 and 2000 at ARS and LAC.

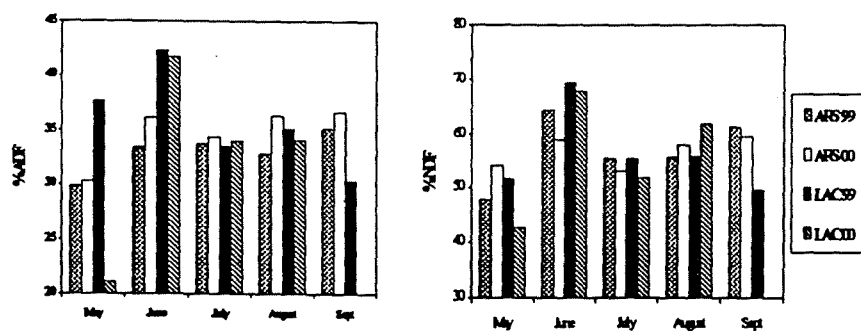
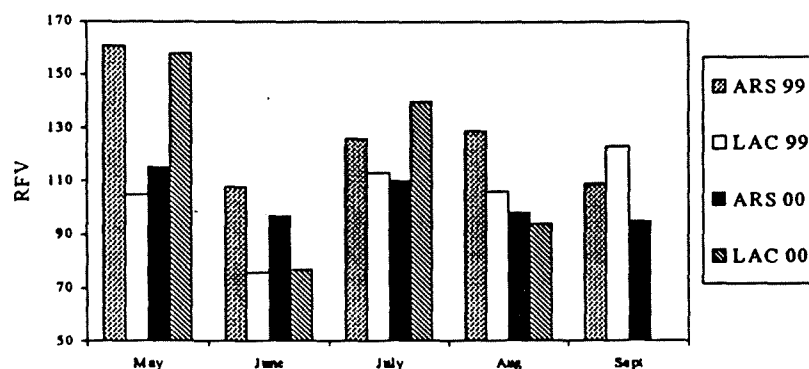


Table 4. Forage quality on WICST rotational grazing pastures for 2 periods each summer 1993-2000.						
	Lakeland Agricultural Complex			Arlington Research Station		
time period*	% ADF	% NDF	% CP	% ADF	% NDF	% CP
7/1/93	28.9	50.5	16.4	28.9	53.4	16.9
8/1/93	28.2	44.6	21.8	32.0	52.6	20.1
7/1/94	30.3	49.4	15.6	31.8	50.9	16.7
8/1/94	29.0	46.7	18.7	31.5	48.2	19.7
7/1/95	33.6	50.5	17.2	35.0	52.4	16.6
8/1/95	32.7	51.0	21.9	-	-	-
7/1/96	-	-	-	26.2	41.7	23.4
8/1/96	-	-	-	30.4	47.8	23.1
7/1/97	-	-	-	31.0	50.0	18.1
8/1/97	-	-	-	34.0	51.3	17.4
7/1/98	-	-	-	29.7	46.6	21.0
8/1/98	-	-	-	30.6	50.3	17.9
7/1/99	41.1	67.6	12.6	33.7	55.5	16.0
8/1/99	42.0	68.4	14.0	32.8	55.7	18.3
7/1/00	-	-	16.6	40.7	64.1	14.1
8/1/00	34.1	61.8	11.5	35.9	55.1	13.7

* Forage quality data is an average from the two closest sampling dates to the time period date.

Fig. 4. Monthly Relative Feed Values (RFV) at ARS and LAC, 1999-00.



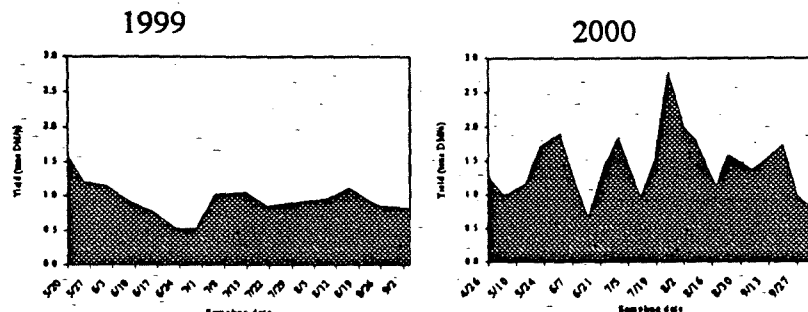
Seasonal forage availability is shown in Figs. 5a and 5b. Forage availability at ARS was measured indirectly each week by the use of a plate meter in which height and density of the forage was measured and quantity was predicted using a regression equation (EQ 1). In addition, samples were clipped once a month to ground level for forage quality evaluation and dry weights were

recorded which compared with the plate meter estimates. Each paddock was not sampled equally but each was measured throughout the season. As shown in Fig. 5a, approximately 1 ton DM/a was available to the animals at ARS in 1999. Between 1.5 and 2.0 ton DM/a was available in 2000 and possibly another harvest of hay could have been taken.

Forage availability at LAC was measured directly from the dry weight of the samples collected weekly in 1999. In Fig. 5b, over 2 ton DM/a was available for most of May and June at LAC. Early-season rapid forage growth can be controlled with mechanical defoliation or higher stocking rates. Lack of mechanical defoliation and understocking in the early months likely contributed to the reduced forage quality at LAC. No data was available on forage height/seasonal forage distribution for 2000 at LAC.

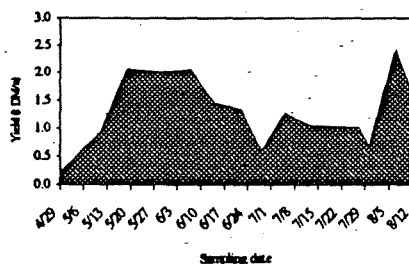
EQ1: $Y \text{ (tons DM/a)} = 0.004073 \times \text{forage ht in mm}^3$

Fig. 5a. Seasonal forage availability at Arlington



³ Equation from Undersander and Casler, 1999.

Fig. 5b. Seasonal pasture production at LAC, 1999



Although forage availability, determined by weekly measurements, is a useful estimate of pasture production, it is not what the animal actually consumes as dry matter intake (DMI). Actual pasture production is difficult to determine for grazing studies. We used animal energy consumption formulas, tables of feed composition, and animal nutrient requirements to estimate dry matter consumed by the grazing animals (Table 5). Daily net energy for maintenance (NE_M) and net energy for growth (NE_G) requirements for the animals were determined by the standard formulas from the 1989 NRC Publication on Nutrient Requirements for Dairy Cattle (shown below) using average weight of each animal during the grazing period and their average rate of gain.

$$NE_M \text{ (in Mcal/day)} = .086 * (LW)^{.75}$$

and

$$NE_G \text{ (in Mcal/day)} = .035 * (LW)^{.75} * (LWG/1000)^{1.119} + 1.0 * LWG/1000$$

where LW is live weight in kg and LWG is live weight gain in g/day.

Daily dry matter consumption was calculated using the following equation:

$$DMI \text{ (kg/d)} = (\text{daily } NE_M \text{ requirement} / NE_M \text{ per kg ration}) + (\text{daily } NE_G \text{ requirement} / NE_G \text{ per kg ration})$$

The pasture NE_M and NE_G (in Mcal/kg DM) used for ARS were an average of the following three values taken from the NRC feed energy tables:

- 1) $NE_M = 1.52$ and $NE_G = 0.93$ for avg. of early and medium bloom red clover
 - 2) $NE_M = 1.69$ and $NE_G = 1.08$ for young orchardgrass
 - 3) $NE_M = 1.48$ and $NE_G = 0.89$ for avg. of early and medium maturity bromegrass
- Avg $NE_M = 1.56$ and $NE_G = 0.97$ for grass/clover mix pasture**

Energy value of supplemented grain mix is

$$NE_M = 1.96 \text{ and } NE_G = 1.30$$

Pasture NE_M and NE_G (in Mcal/kg DM) values used for Lakeland were taken from the NRC feed energy tables and are shown below:

$$NE_M = 1.31 \text{ and } NE_G = 0.74 \text{ for reed canarygrass}$$

$$NE_M = 2.06 \text{ and } NE_G = 1.40 \text{ for grain supplement}$$

The actual NE_M and NE_G of the complete ration was calculated after determining the percent of daily dry matter intake from the grain. Forage consumption was then determined per animal per day by subtracting off the grain from the daily dry matter intake. Then, we multiplied the number of days the animals were on pasture by the daily dry matter consumed per animal. Total forage production per acre was determined by multiplying forage consumption per animal by the total number of animals on each paddock and adding any mechanically harvested forage. Table 5 shows resulting forage production using this method at both sites, as well as quality parameters from 1990 through 2000.

Table 5. Average Forage Quality, and Estimated Dry Matter Intake (DMI) Using Animal Energy Requirements for WICST Rotational Grazing System, 1990-2000*						
	Lakeland Agricultural Complex			Arlington Ag. Research Station		
	DMI	Quality**		DMI	Quality**	
year	t DM/acre	% CP	RFV	t DM/acre	% CP	RFV
1990	0.00	-	-	4.15	19	142
1991	3.39	15	105	4.70	17	113
1992	3.36	17	118	2.81	17	128
1993	2.54	18	114	2.18	20	133
1994	4.08	20	137	3.86	20	124
1995	3.58	19	117	2.17	16	103
1996	0.96	-	-	1.67	24	142
1997	-	-	-	1.84	19	130
1998	1.36***	-	-	2.94	19	135
1999	1.63	17	104	2.21	17	127
2000	1.77	14	110	2.13	15	103

* Grazing began in 1993 at ARS and in 1992 at LAC, harvested mechanically in previous years.

** Quality determined from hand cut samples during each season; does not include mechanically harvested forage when cattle were grazing.

*** Does not include growth before July 23.

Conclusion

Rotational grazing offers a low input system with very good forage quality and respectable animal performance. Close attention to forage growth and weather conditions is important to maintain high forage quality. Excess forage growth should be harvested as hay in May and June. Grain supplementation may not be necessary all year but it is a relatively inexpensive energy source that can improve the dry matter intake when needed. By managing both forage and animal needs, we can realize the potential of management-intensive rotational grazing as a viable alternative to conventional heifer rearing.

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5. WISCONSIN INTEGRATED CROPPING SYSTEM TRIAL: AN ANALYSIS OF THE CROP YIELDS

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1 May 2001

INTRODUCTION AND OBJECTIVES

The primary objective of this report is to determine the characteristic or average yields for the cropping systems in the Wisconsin Cropping Systems Trials and to ascertain which of the cropping systems, if any, produced the best yields. Clearly, crop yield is not the only factor to consider in designing cropping systems, but it is among the key items and it is the focus of this report. Other reports will examine many of the additional factors.

To determine if the cropping system yields are truly different or if their variations are simply due to chance or randomness, we used traditional analysis of variance techniques. Analysis of variance models divide the observed yields into two parts: 1) a static, or average, portion that is characteristic of known factors such as cropping system or site, and 2) a variable portion that is due to random error or uncontrollable factors, such as soil differences or weather. If the known portion is substantially larger than the variable portion, then we are comfortable in concluding the mean yields are characteristic of the cropping system and we say the known source (cropping system) is statistically significant. If however, the variability approaches or exceeds the effect of the known factors, then the known factors are indistinguishable from the random factors. With this simple idea, traditional statistical analyses provide powerful tools to find the best alternatives, in most cases, in spite of variability.

MATERIALS AND METHODS

General

The WICST study consists of six cropping systems, replicated four times, at two sites in southern Wisconsin. The cropping systems include

- CS1 Continuous corn with high external inputs
- CS2 Corn-soybean rotation with medium external inputs
- CS3 Corn-soybean-winter wheat(red clover) rotation with low external inputs
- CS4 Corn-alfalfa-alfalfa-alfalfa rotation with high external inputs
- CS5 Corn-oats(alfalfa)-alfalfa rotation with medium external inputs
- CS6 Rotational grazing with low external inputs.

Although CS5 is nominally a medium external input system, it is a low external input system relative to most conventional systems. The trials were established in 1989 with all plots planted to corn to improve the uniformity and allow baseline measurements to be taken. The crop rotations were initiated in 1990 using a staggered start to ensure consistent cycling of the rotations through the plots. The staggered start meant that in 1990 we initiated the first crop of each system (6 systems) and in 1991 we planted the second crop of each system on those plots and initiated the first crop on a new set of plots for the four systems with more than one crop. This continued until 1993 when we had all 14 phases of the 6 systems established. Cunningham et al. (1992) and Posner, Casler, and Baldock (1995) provide additional details on the design and conduct of the WICST project.

The model equation for a traditional statistical analysis of the WICST yield data is

$$Z_{ijkl} = \mu + S_i + Y_j + SY_{ij} + B_k(S) + YB_{jk}(S) + T_l + ST_{il} + YT_{jl} + SYT_{ijl} + \epsilon_{ijkl},$$

where

- Z_{ijkl} = observed yield for the ijkl th case,
- μ = overall mean yield
- S_i = site, i
- Y_j = year, j
- SY_{ij} = interaction of site i with year j
- $B_k(S)$ = block k nested within site
- $YB_{jk}(S)$ = interaction of year j with block k nested within site
- T_l = cropping system, l
- ST_{il} = interaction of site i with cropping system l
- YT_{jl} = interaction of year j with cropping system l
- SYT_{ijl} = interaction of site i with year j and cropping system l
- ϵ_{ijkl} = residual error
- $i = 1, \dots, s$
- $j = 1, \dots, y$
- $k = 1, \dots, b$
- $l = 1, \dots, c.$

There are three major complications with this model, which includes sites and years, and which is often called the full model. First, there are so many sources of variation to consider that the most important factors are obscured (Table M1). Second, there are too few degrees of freedom to adequately estimate some terms in the full model for some crops. And third, synthetic error terms must be calculated to test some of the factors including cropping systems in the traditional Methods of Moments analysis because there is a mixture of random effects (sites, blocks, and years) and fixed effects (cropping systems, Table M1). Some of the difficulties in the latter complication; e.g. determining expected mean squares and synthetic error terms, can be avoided with the newer Restricted Maximum Likelihood approach for mixed models. However, the two methods give essentially the same results in balanced cases such as this and the Restricted Maximum Likelihood algorithm does not converge properly in many cases (Lehman et al., 2000).

Collapsing sites and years into one factor called environment produces a more practical statistical model equation for this analysis:

$$Z_{ijk} = \mu + E_i + B_j(E) + T_k + ET_{jk} + \varepsilon_{ijk},$$

where

- Z_{ijk} = observed yield for the ijk th case,
- μ = overall mean yield
- E_i = environment, i
- B_j = block j nested within environment
- T_k = cropping system k
- ε_{ijk} = residual error
- i = 1, ..., e
- j = 1, ..., b
- k = 1, ..., c .

Note that the upper limit for i will vary with the crop because of the staggered start. Also, note that the number of cropping systems in the analysis, c , will vary from 1 to 5 (pasture yields were not comparable to the other crops so the maximum for k is 5). Table M2 outlines the analysis of variance (AOV) corresponding to this model. This reduced model summarizes the key sources of variation and circumvents the complications of the full model. On the other hand, we are still dealing with a mixed model. That is, factors involving blocks or environments are random factors, but cropping system is a fixed factor. As a consequence, the appropriate error for testing cropping systems in the traditional Method of Moments approach is the environment $\times$ cropping system interaction (not the bottom-line error, which is the pooled error within environments). As with the full model, the Restricted Maximum Likelihood technique often did not converge satisfactorily, so we did not use it in this report.

A note on the consequences of designating a factor in the analysis as fixed or random is in order. When a factor is designated as fixed, it means the levels in the trial are the only ones of interest for that trial and no attempt to generalize to other levels will be made. For example, cropping system is a fixed factor because the six systems are unique and we would not try to generalize the results from these systems to all cropping systems. When a factor is designated as random, it means the levels in the trial are only a sample of the

possible levels of interest. For instance, environments should be regarded as a random factor so that we can generalize the WICST results to similar, but not identical environments. That is, if we had declared environment to be a fixed factor, then only recommendations for the particular years and sites in this study could be made.

Designating a factor as fixed or random not only affects the kinds of conclusions that we can reach, but also how the tests of significance are conducted. If all the factors are regarded as fixed, then all the factors are test against the estimated plot-to-plot variability, i.e., bottom-line error term. However, if some of the factors are random then some of the interactions will be required to test for significance. In this study, for instance, the fixed factor cropping systems interacts with the random factor environment to produce the random term cropping system $\times$ environment term, which is used to test cropping systems

Although we rely primarily on the reduced model, we will briefly discuss the components of the environment factor, sites and years. By doing that, we hope to capitalize on the simplicity of the reduced model without overlooking some important sources of variation. Other possible approaches and models for the statistical analyses of the WICST yield data include a transition analysis (looking for trends due to converting from conventional to low input or due to changes in soil fertility etc) and a whole farm analysis, which are outlined in Posner, Casler, and Baldock (1995).

In addition to the AOV, which gives a preliminary test of the average effect of various sources of variation, we used linear comparisons and graphical techniques to provide a more detailed assessment of the factors influencing crop yields. We computed the AOV and linear comparisons in JMP 4.0 software (Lehman et al., 2000) to compute the analysis of variance (AOV) for the model equation and for linear comparisons. We used SYSTAT 9.0 (SPSS, 1999) and STATISTIX for Windows 7.0 (Analytical Software, 2000) for some of the graphical, residual, and correlation analyses.

Corn

Corn can be regarded as the key test crop in the WICST study because it occurs in five of the six cropping systems, which is more than any other crop. Due to the staggered start, the first year that CS1 through CS5 had corn was 1993. Using all the corn data for 1993 through 1998 provided 240 cases, consisting of 5 cropping systems $\times$ 2 sites $\times$ 4 replications $\times$ 6 years. Appendix B lists these 240 cases.

First we conducted the AOV for the 240 corn yields according to the reduced model described above. Then we compared the cropping systems with four orthogonal, linear comparisons (Table M3). Such linear contrasts are usually more meaningful and more powerful than pair wise comparisons. The linear comparisons shown in Table M3 are those suggested in the Choice of Systems section of Posner, Casler, and Baldock (1995). They fit closely, but not exactly, the themes of the treatment design discussed when the study was initiated (Cunningham et al., 1992; page 2). Cunningham et al. (1992) viewed the treatment design as a true factorial arrangement of enterprise types (cash grain versus dairy-forage) and levels of external inputs (low, medium, and high). However, Posner, Casler, and Baldock (1995) regarded the treatment design as a nested or hierarchical factorial because the external inputs were not identical for the corresponding levels in the cash grain and forage enterprises. Consistent with the latter, we made the comparisons of external input levels within enterprise type instead of across enterprise types (Contrasts 3

and 4 in Table M3). This does not preclude making the cash grain versus forage system comparison (Contrast 2 in Table M3), however, it must be remembered that the input levels are not the same within both groups.

Soybeans

Two of the cash cropping systems, CS2 and CS3, included soybeans. Since soybeans initiated the rotation in those systems, the first soybeans were planted in 1990. Consequently, we base this analysis on 144 observations: 9 years of soybean yields $\times$ 2 cropping systems $\times$ 4 replications per site $\times$ 2 sites (listed in Appendix B).

As with the corn data, we first conducted the reduced AOV (Table M2) for all 144 cases. With only two cropping systems containing soybeans, there was only one degree of freedom for cropping system in the AOV, hence only one comparison, which was equivalent to Comparison 3 in Table M3.

Winter Wheat

One cropping system, CS3, included winter wheat. It followed soybeans in the rotation, so the first wheat harvest was in 1991. The database should contain 64 wheat yields from the 8 years, 2 sites, and 4 replications per site, but the 1996 crop at LAC winterkilled and was replanted to oats. Also, both grain and straw yields were taken, except no straw yields were taken at LAC in 1992. Consequently, the database includes 60 wheat grain yields and 56 straw yields (listed in Appendix B). In order to balance the data sufficiently for analysis, we omitted all 8 cases for 1996 from the grain analysis. Similarly, we omitted all cases for both 1992 and 1996 from the straw analysis. We computed the AOV for grain and straw using only the first four terms (counting the overall mean) of the full model because there was only one cropping system.

Alfalfa

Two of the forage cropping systems, CS4 and CS5, included alfalfa. In CS4, alfalfa initiated the crop rotation and then was maintained for two more phases. Thus, the first CS4 alfalfa was direct seeded in 1990, which means 1992 was the first year that all three phases could be harvested. Alfalfa also began the crop sequence for CS5 in 1990 when it was seeded with a companion crop of oats and then maintained for one more phase. Consequently, the database contains 7 years $\times$ 3 phases $\times$ 4 replications per site $\times$ 2 sites, which equals 168 cases for CS4 plus 7 years $\times$ 2 phases $\times$ 4 replications per site $\times$ 2 sites, which equals 112 cases for CS5. Thus, there were a total of 280 alfalfa cases that had all phases.

However, there are two reasons not to use the full data set described above in one overall analysis. First, due to the unequal number of alfalfa phases, comparing the cropping systems on total or average alfalfa production would confound the difference between systems with the difference between phases. Consequently, the comparison between cropping systems should be made on corresponding phases; e.g., the establishment-year yields should be compared, then the first-year-after-establishment yields, etc. Second,

there is a built in correlation of error problem for perennial crops such as alfalfa. That is, the yield in the establishment year is likely correlated with the yield in the succeeding years for a given planting. One way to avoid under estimating or over estimating the error due to such correlations is to analyze each phase separately. Therefore, to avoid the problems of confounding and correlation, we analyzed each phase separately.

The establishment-year analysis compares the direct-seeding method in CS4 to the companion-seeding method in CS5. No alfalfa was harvested from the CS5 plots in 1992 and 1993 when the companion seeding of oats was harvested for grain. However, in 1994 through 1998 the alfalfa and oats were harvested together as oatlage, which usually allowed one additional cutting in the seeding year. Due to the mixture of species in CS5, we analyzed the relative feed value to measure the quality (see below) of the forage as well as the quantity. Unfortunately, all the seedings failed in 1996 in both systems. The result was a data set of establishment-year yields from 4 years (1994, 1995, 1997, and 1998) $\times$ 2 cropping systems $\times$ 4 replications $\times$ 2 sites for a total of 64 cases (see Appendix B). Because the spring seedings failed in 1996, summer seedings were made so there would be alfalfa for the next phase.

For the first year after establishment there were more observations. There were 7 years $\times$ 2 cropping systems $\times$ 4 replications $\times$ 2 sites for a total of 112 possible cases. There was one missing value (ARS plot 409 in 1995 was accidentally killed with a herbicide), which left 111 cases for analysis (see Appendix B).

After comparing the cropping systems on analogous phases of alfalfa, we conducted the analysis of the difference between phases within each of the cropping systems separately. The analysis over phases is especially likely to have a correlation of error problem, so we used both the univariate and multivariate (repeated measures) approaches. To get an appropriate data set for the repeated measures analysis of CS4, we began with each alfalfa plot as a row of data. After adding the identification columns (site, plot number, etc), we made a column of the establishment-year yields and added a column for each of the subsequent years of that stand. For CS4 this data set contained 5 years $\times$ 2 sites $\times$ 4 replications minus 12 cases with zero yields or other problems for a total of 28 cases. For CS5 it only contained 16 observations because only the alfalfa seeded in 1994 and 1997 provided complete data.

As mentioned above, quality is a vital consideration when comparing forages containing different species. It is also an important parameter in comparing different production systems using the same species, for example the different input and harvest schedules in CS4 and CS5. We used relative feed value (RFV) as the measure of forage quality. RFV is an index used to compare quality of forage to full bloom alfalfa. Neutral detergent fiber (NDF), which is used to determine dry matter intake [EQ 1], and acid detergent fiber (ADF), used to determine digestibility [EQ 2], are used to calculate RFV [EQ 3].

$$\text{EQ 1: Dry matter intake (DMI)} = 120 / \text{NDF}$$

$$\text{EQ 2: Digestible dry matter (DDM)} = 88.9 - (0.779 * \text{ADF})$$

$$\text{EQ 3: RFV} = (\text{DDM} * \text{DMI}) / 1.29$$

To determine RFV we took grab samples from several areas of the wagon load from each plot as it was taken to the scale for yield measurement on an 'as is' basis. The samples

were frozen immediately and later sent to the University of Wisconsin Soils and Plant Analysis Laboratory at Marshfield. The lab analyzed the samples for percent moisture, crude protein, fiber and RFV with NIRS. We report the overall RFV for a season on a weighted basis [EQ 4]. That is, the yield (Y, tons dm/a) of each cut was multiplied by the RFV for the cut and the total of those products was divided by the seasonal yield.

$$\text{EQ 4: Seasonal RFV} = \frac{((Y1 \cdot \text{RFV1}) + (Y2 \cdot \text{RFV2}) + (Y3 \cdot \text{RFV3}) + (Y4 \cdot \text{RFV4}))}{(Y1 + Y2 + Y3 + Y4)}$$

Table MM1. Outline of the analysis of variance for full model.

Source	df	Expected Mean-Square
Sites, S	s-1	$\sigma_e^2 + b\sigma_{SYC}^2 + by\sigma_{SC}^2 + c\sigma_B^2 + bc\sigma_{SY}^2 + byc\sigma_S^2$
Years, Y	y-1	$\sigma_e^2 + b\sigma_{SYC}^2 + bs\sigma_{YC}^2 + c\sigma_B^2 + bc\sigma_{SY}^2 + bsc\sigma_Y^2$
S × Y	(s-1)(y-1)	$\sigma_e^2 + c\sigma_B^2 + bc\sigma_{SY}^2$
Block(S,Y), B	(b-1)sy	$\sigma_e^2 + c\sigma_B^2$
Cropping System, C	c-1	$\sigma_e^2 + b\sigma_{SYC}^2 + by\sigma_{SC}^2 + bs\sigma_{YC}^2 + bys\sigma_C^2$
S × C	(s-1)(c-1)	$\sigma_e^2 + b\sigma_{SYC}^2 + by\sigma_{SC}^2$
Y × C	(y-1)(c-1)	$\sigma_e^2 + b\sigma_{SYC}^2 + bs\sigma_{YC}^2$
S × Y × C	(s-1)(y-1)(c-1)	$\sigma_e^2 + b\sigma_{SYC}^2$
Pooled error	sy(b-1)(c-1)	σ_e^2

Table MM2. Outline of the analysis of variance for reduced model.

Source	df	Expected Mean-Square
Environment, E	e-1	$\sigma_e^2 + b\sigma_{EC}^2 + c\sigma_B^2 + bc\sigma_E^2$
Block(E)	e(b-1)	$\sigma_e^2 + \quad + c\sigma_B^2$
Cropping System, C	c-1	$\sigma_e^2 + b\sigma_{EC}^2 + eb\sigma_t^2$
E × C	(e-1)(c-1)	$\sigma_e^2 + b\sigma_{EC}^2$
Pooled error	e(b-1)(c-1)	σ_e^2

Table MM3. Coefficients of the linear comparisons used in analyzing corn data.

Comparison: Group A versus Group B	Cropping System				
	1	2	3	4	5
Comparison 1: A: Continuous corn B: Corn in rotation	4	-1	-1	-1	-1
Comparison 2: A: Cash crop rotation B: Forage crop rotation	0	1	1	-1	-1
Comparison 3 - within cash grain systems: A: Medium external input (CS2) B: Low external input (CS3)	0	1	-1	0	0
Comparison 4 - within forage systems: A: High external input (CS4) B: Low external input (CS5)	0	0	0	1	-1

RESULTS AND DISCUSSION

Corn

Table C1 summarizes the analysis of variance for the 240 corn yields taken in 1993 through 1998. The difference among cropping systems was highly significant when tested against the environment $\times$ cropping system interaction. For the six-year period, the mean corn yields for the five cropping systems ranged from 130 to 162 bu/acre (Table C2). Appendix A provides the mean yields for each system-site-year combination.

The overall mean yield, of 144 bu/acre was amazingly close to the 142 bu/acre hypothesized in the planning phase of this study (Cunningham et al., 1992). However, the mean yields for the cropping systems were much closer together than expected (Table C2). The team had hypothesized that CS1 and CS2 yields would be more than those actually obtained. They also expected the lower input systems, CS3 and CS5, to have smaller corn yields than those that were achieved. Only CS4 produced corn yields close to the anticipated level.

Even though the differences in corn yields between cropping systems were less than expected, there were significant differences. In fact, all four linear comparisons were significant at the 10% level (Table C3). There was nearly a nine bushel/acre advantage for growing corn in rotation with other crops as opposed to growing corn continuously (Comparison 1, Table C3). Growing corn in a forage rotation yielded 12 bu/acre more than growing it in a cash grain rotation (Comparison 2). Also, using more external inputs in either a cash grain or leguminous forage rotation produced over 19 bu/acre more corn (Comparisons 3 and 4). Thus, if the sole basis for planning a cropping system was producing top corn yields, then a farmer would be wise to grow corn in a legume-forage based rotation with high levels of external inputs. However, there are many factors besides corn yield that need to be considered in designing a cropping system.

In addition to cropping systems, environment affected corn yields in this study. That is, the difference among the 12 environments was a highly significant (Table C1). The environment term has three components: 1) sites, 2) years, and 3) the site $\times$ year interaction, all of which were significant at the 10% level (Table C4). The ARS location produced higher yields than LAC by an average of 32 bu/acre. Although the difference between sites was large, the differences among years were even larger. Yearly yields ranged from 91 bu/acre in 1996 to 191 in 1994 (Fig. 1). The significant interaction between sites and years was a matter of degree, not a reversal of effects. That is, ARS out yielded LAC yields in four of the six years, but yields were nearly equal in the other two (Fig. 2).

Inspection of the residuals in this analysis revealed that there were two data points that were probably outliers because they were more than four standard deviations from the mean. When we repeated the analysis without those two cases, there was very little change in the results (data not shown). All of the same effects were significant with only slight changes in their probability levels. The mean-square-error was reduced by over 35% to 93, but it is not a major factor in this analysis. Further inspection of the residuals showed that they were reasonably homogeneous, but not quite normally distributed. Most of the nonnormality could be attributed to the probable outliers because the hypothesis of

normality could not be rejected when they were omitted. Even with the slight nonnormality introduced by the probable outliers, the results should be unaffected because of the robustness of the F and t tests (Cochran, 1947).

Nonhomogeneity and correlation of errors are more serious deviations from the assumptions. Visual inspection of the residuals illustrates homogeneity across yield levels (Fig 3) and cropping systems at ARS (Fig. 4). Fig. 5 shows the residuals were also homogeneous over cropping systems at LAC, except for the two outliers (large value in CS2 and small value in CS3). There often is a positive correlation of errors, which leads to underestimating the error in long-term studies because the same plots are used in multiple years (Cochran, 1947). It is not likely to be a problem in this analysis because a one-way AOV of the residuals by plot found that only 10% had residuals that were significantly above or below the mean. Furthermore, the environment $\times$ cropping system interaction, which is a mean over many plots was used to test cropping systems, not the mean square error. Nevertheless, the degree and effect of correlation of errors should be examined in more detail when a longitudinal analysis is done.

In addition to grain yield, corn grain moisture levels at harvest are an important consideration in cropping systems. More moisture at harvest means incurring more expensive drying, special storage conditions, or lower prices. Table C5 presents the AOV for grain moisture. It shows that the differences among cropping systems in grain moisture content at harvest were significant at the 10%, but the 5%, level. The only linear comparison that was significant estimated that the corn in the forage systems was 1.6 percentage points drier than the corn in the cash grain systems (Table C3). It is not clear what caused the corn in the forage systems to be drier, but it is not uncommon for conditions that lead to higher yield to lead to more rapid maturity. Corn in rotation did not differ from continuous corn in respect to grain moisture. The fact that the differences in moisture between the low versus the moderate-to-high external input cropping systems was not greater suggests that the strategy to use a shorter maturity hybrid in the low external input systems was successful (this strategy was followed in 8 of 12 site-year seasons). There were three extreme values in the plot of residuals; two were from the immature corn harvested at LAC in 1996 as a result of an extremely wet spring and early summer (Fig 6). Omitting these potential outliers would not change the conclusions.

Soybeans

Table B1 summarizes the analysis of variance for the 144 soybean yields taken in 1990 through 1998. The difference among cropping systems was significant at the 10% level but not the 5% when tested against the environment $\times$ cropping system interaction. The mean soybean yield for CS2 was 53 bu/acre compared to 49 for CS3 (Table B2). Appendix A provides the mean yields for each cropping system-site-year combination.

The overall mean yield, of 51 bu/acre was a little more than the 48 hypothesized in the planning phase of this study (Cunningham et al., 1992). Similar to the case for corn, the team had hypothesized that CS2 yields would be higher than those actually obtained and they also expected CS3 to have lower soybean yields than those that were achieved (Table B2). As a result, the mean yields for the cropping systems were much closer together than expected.

In addition to cropping systems, environment had a small, but significant effect on soybean yields in this study. That is, the difference among the 18 environments was a significant (Table B1). The environment term has three components: 1) sites, 2) years, and 3) the site $\times$ year interaction. The main effects were not significant. The mean difference between sites was only 1.2 bu/acre in favor of ARS and the range among years was relatively small also. The low occurred in 1992 with 41.7 bu/acre and the maximum was 58.8 in 1995. The significant site $\times$ year interaction was due to ARS producing higher yields than LAC in four years, similar yields in three, and lower yields in two (1992 and 1994). In four of the nine years of data, the site that had the higher yield with CS2 had the lower yield with CS3, which suggest that management practices interacted with the weather. For instance, the herbicide based weed control program in CS2 was likely favored by rainfall at key times and the mechanical weed control of CS3 was probably enhanced by dry weather at the time of hoeing or cultivation.

Similar to corn, the residuals in soybean AOV deviated significantly from a normal distribution. Most of the nonnormality was due to the four potential outliers (Fig. 7). When those values were omitted, then the null hypothesis of normality could not be rejected. Fig. 7 and plots of the residuals by cropping system and plot demonstrated that these data were reasonably homogeneous and that it was unlikely that the errors were correlated enough to affect the results. However, the latter assertion needs more study.

Winter Wheat

Table W1a and W1b summarize the analysis of variance for winter wheat grain and straw yields. Appendix A provides the mean yields for each cropping system-site-year combination. The mean grain yield, 48.9 bu/acre, was nearly 20% less than the 60 bushel/acre hypothesized in the planning phase of this study (Cunningham et al., 1992). It was also less than the 51.3 bu/acre that farmers in Columbia and Walworth Counties averaged in that same period. Straw yields, too, were lower than planned at the outset. Straw yields averaged 1.19 tons dry matter per acre (1.4 tons at 15% moisture, or approximately 55 bales per acre).

One reason yields undershot the targeted levels was that 1992 and 1993 were the two worst years for winter wheat in Wisconsin in the last twenty years (WAS, 1980,...,1999). Another reason for missing the planned yield level was that the team decided to favor the soybean phase over the winter wheat phase of this cropping system. That is, we chose to plant full-season or near full-season soybean varieties that usually do not reach harvestable maturity until late September, which forces the winter wheat planting into October. Since wheat yields decline approximately 0.5 bu/acre for each day planting is delayed after 1 September (based on Arlington data from Dr. Ed Oplinger) this strategy is one cause of the lower than anticipated wheat yields. The original plan called for broadcasting the winter wheat into the soybeans before harvest, so the trade-off between higher yielding, full-season-soybean varieties and timely wheat planting was not a problem. However, that planting method did not work well at these sites, which also contributed to some of the low yields in the 1991 through 1993 crops, so the planting method was switched to drilling in fall 1993. Making that switch and deciding to take advantage of the greater returns from soybeans has been successful as shown by the above county average soybean yields and near county average wheat yields since 1993.

Since wheat was grown in only one system, the question of how these cropping systems affect wheat yield is moot. Environment, however, did influence wheat yields. Site was significant for grain yield with ARS producing better grain yields than LAC (54.1 to 43.6 bu/acre). However, LAC had better straw yields (1.29 versus 1.09 tons dry matter/acre), but that difference was not significant. The difference among years was large and significant for both grain and straw. The range in grain yields between the high yield year (69.0 bu/acre in 1995) and low yield year (25.5 bu/acre in 1993) was over 40 bu/acre. For straw the range was nearly 1 ton dry matter/acre. The very large site $\times$ year interaction was the most significant of the environmental effects for both grain and straw; which resulted from substantial reversals of which site raised the most in a given year.

In contrast to corn and soybeans the wheat residuals did not show any potential outliers. They were also relatively homogeneous across predicted yield level (Fig. 8) and did not deviate significantly from normality. On the other hand, the straw yield residuals did not exactly fit a normal distribution even though there were no potential outliers (Fig. 9). The nonnormality for the straw residuals occurred because there were too many that fell near zero and too many in the extremes, which left too few cases in the shoulders of the distribution.

Alfalfa

Table A1 summarizes the analysis of variance for the 64 alfalfa yields and 48 RFV measurements taken from the seeding-phase of CS4 and CS5. Table A2 presents the analysis of variance for the first year of alfalfa after establishment for 1992-8. The means by cropping system and phase are given in Tables A3 and A4. Appendix A provides the mean yields for each cropping system-site-year combination.

There was a yield advantage for the companion seeding system in CS5 in the seeding year (Table A3), and the 0.8 tons dry matter/acre difference was statistically significant at the 10% level (Table A1 and A3). CS5 also produced more forage than CS4 in the first year after establishment, but the disparity was about half that in the seeding year (Table A3). Nevertheless, the difference was statistically significant at the 5% level due to the larger number of observations and smaller yield variability across environments (Table A2). The yields in the final year of alfalfa in CS4 were slightly less than they were in the first year after establishment (Table A3).

The team had hypothesized that the high external input system, CS4, would yield 1.3 t dm/acre more than CS5 when the yields of the two systems were averaged over the phases (Table A3). However, CS5 actually produced 0.5 t dm/acre more than CS4. The team accurately forecast the overall mean alfalfa yield within 6% of the actual, so how did we miss the relative yield of CS4 and CS5 by over 50%? In our opinion there are four reasons we missed the mark with our original hypotheses. One, we anticipated that the oat companion crop in CS5 would be harvested as grain so there would be at most one cutting of alfalfa in the seeding year (when the trials were in the planning stage, low input farmers expressed interest in oat grain as part of the ration for the herd and oats straw for bedding). Two, we overestimated the yield advantage of a four-cut compared to a three-cut system. Three, we failed to appreciate the difficulty of a four-cut system and consequently did not achieve the yield potential of a four-cut system. And four, the yields in the low-input system, CS5, have not yet fallen to their equilibrium level. The evidence on which we base our opinion follows.

First, it is widely known that an oat-alfalfa seeding harvested as oatlage will out yield direct-seeded alfalfa in the establishment year. Undersander et al. (1994) present a chart showing the estimated yield of the oat-alfalfa seeding to be 3.8 t dm/acre in the first year and the pure alfalfa seeding to be 3.4 t dm/acre. On the surface it that would seem to favor the oat companion crop seeding system used in CS5. However, the RFV of the pure alfalfa is usually far superior to that of the oatlage. Undersander et al. (1994) estimate the RFV of the sole-seeded alfalfa to be 137 and that of the oatlage to be 102. They also point out latter is acceptable feed for dry cows and heifers, but not for lactating dairy cows; while the former (the pure alfalfa) is acceptable for dairy cows for the last 200 days of their 300 day lactation. Thus, although both were a little low, the relative yields of CS4 and CS5 in the establishment year are consistent with current UW Extension standards for alfalfa management. Accordingly, the team's hypotheses would have been more in line with those standards, if we had known most of the oat-alfalfa companion crops would be harvested as oatlage.

Second, there is substantial evidence in the literature that a three-cut system produces more dry matter than a four-cut system. In research conducted in 1956-7 Smith and Rohweder (1977) showed an 18% yield advantage for three-cut versus four-cut systems. Advances in alfalfa production have narrowed, but not eliminated, the dry matter yield advantage of a three-cut system. Undersander et al. (1994) summarize information for the north central US that estimates the yield of a three cut system to be 4.5 t dm/acre compared to 4.3 for a four-cut system. Thus, based on the planned cutting schedules, it is not surprising that the three-cut system, CS5, out yielded the four-cut system, CS4.

Thirdly, we failed to reach the yield potential of the four-cut system. The 4.5 t dm/acre yield average for established alfalfa in a three-cut systems determined from charts in Undersander et al. (1994) is remarkable close to the 4.4 t dm/acre attained in CS5 (Table A3). However, the 4.3 t dm/acre average for established alfalfa in a four-cut system determined from those same charts is substantially more than the 3.9 and 3.6 t dm/acre attained in CS4 (Table A3). Thus, it appears the team did not take full account of the exacting requirements of a four-cut system. These requirements include: starter fertilizer in the establishment year, higher than normal potassium fertilization, bacterial wilt resist varieties, winter-hardy varieties, replenishment of carbohydrate reserves at least once a year (especially in the establishment year), and an early first harvest (generally before 25 May) (Smith and Rohweder, 1977; Tesar and Yager, 1985; Sheaffer et al. 1992; Undersander et al., 1994).

Management of CS4 fell short of these guidelines in at least three areas: starter fertilizer, maintaining a high level of potassium fertilization, and getting an early start to the cutting schedule. Beginning with the last item, the records show that the first cutting was made after 25 May at both sites in all but the last year 1998. When the first cutting is not made early enough, then the stand does not recover in time to allow four cuttings without depleting carbohydrate reserves in the critical fall period and jeopardizing yields in the following year. The team was able to get four-cuttings/year on CS4 less than 50% of the time, which is clear evidence that we needed to place more emphasis on getting the first harvest done before 25 May. The requirement for early cutting also applies to the establishment year. Undersander et al. (1994) recommend that sole-seeded alfalfa be cut approximately 60 days after planting regardless of growth stage. This standard was met in only 3 of 12 site-years checked and the interval was over 80 days in 4 cases. Consequently, much more attention to the cutting schedule was needed to make the four-cut system successful.

With so many of the harvests for CS4 made on the three-cut schedule one would expect higher yields as discussed in the previous paragraph. However, the fertilization program was not adequate to support the periodic four-cuttings in the established stands nor the periodic three-cuttings taken in the establishment year (as opposed to two taken in CS5). Appendix III of the most recent WICST report shows that the soil test K levels were below the Exceptionally High range in 11 (LAC) or 12 (ARS) of the 28 plot-year measurements (Alt et al, 1998). Furthermore, 8 (LAC) and 4 (ARS) of these tests were in the High range, which is just above the optimum. Kelling et al. (1998) recommend applying 25 to 50 lbs/acre of potash prior to seeding alfalfa for average production systems when the soil test K levels are in the range exhibited by over one-third of the tests reported. Thus, a high-input, high-production system should receive at least that much. Also, there is some research evidence that a little nitrogen helps get the alfalfa seeding off to a vigorous start (Undersander et al., 1994). Thus, in retrospect, we should have been applying some starter, especially K, to the alfalfa seeding in CS4 and topdressing the first year of established alfalfa in many cases.

Fourth and finally, the yields in CS5 are probably above their equilibrium level because the soil test K levels are still generally above the optimum and their equilibrium level. Thus, CS5 yields will likely fall when the soil test K level drop below the optimum. That will probably occur because forage crop systems that rely on manure for nutrients generally operate at a potassium deficit. WICST data summarized by Iragavarapu et al. (1996) for 1992 through 1995 confirm that generality for ARS, but not for LAC. They found that there was a net removal of 66 lbs K per acre per year in CS5 at ARS, but a net addition of 72 lbs K/acre per year at LAC. It was not clear if there was a greater tonnage of manure applied at LAC or if the K content was higher than average in this time frame. When the soil test K levels were checked, they were more consistent across sites and with the general K balance. At ARS the average soil test K in the top 24 inches of soil decreased from 133 ppm to 116 over seven years (Alt et al, 1998 Appendix V). At LAC, the decrease was from 138 to 123 ppm K. A more detailed discussion of the P and K balances and trends for all the cropping systems is planned for another report, but it is clear from this brief analysis that there was an overall decline in soil test K, which confirms the overall net deficit of K for CS5. Consequently, the soil test K levels will eventually decline to the point that they will limit yields in this system to the 3.5 to 4.0 t dm/acre level anticipated by the team in our original hypotheses.

Dry matter yield should not be the only focus in comparing alfalfa systems. The RFV and palatability of the forage are also important criteria. In fact, these quality factors are as much the reason for making more than three cuttings of alfalfa as the hope for higher dry matter yields. Consequently, it is necessary to examine the RFV along with the dry matter yield to truly characterize the forage productivity of these cropping systems.

In the establishment year, the RFV of the forage from CS4 was superior to that from CS5 by nearly 30 points, which was statistically significant (Tables A4 and A1). That difference reflects the greater feed value of pure alfalfa compared to the oat-alfalfa mix. In the first year of established alfalfa, the RFVs were virtually identical at 146 (CS4) and 142 (CS5). This small difference was not statistically significant (Table A2). Thus, the usual trade-off of yield versus quality existed and the decision on which one to favor would depend on the nutrient requirements of the animals to be fed.

In addition to cropping systems, environment affected alfalfa yields in this study. That is, the difference among the 8 environments for the seeding year and the 14 environments for

the first-year-after-establishment were significant (Tables A1 and A2). The environment term has three components: 1) sites, 2) years, and 3) the interaction between sites and years. In the case of alfalfa, the main effects of site and year were agronomically important, but there were not enough environments to obtain statistical significance. For the seeding year the yield advantage for ARS was 1.4 t dm/acre, and the difference between the best and worst years was 1.3 t dm/acre. The mean difference between sites for the first-year-after-seeding was nearly 0.8 t dm/acre in favor of ARS, and the range over years was similar, the minimum was 3.62 t dm/acre in 1997 and the maximum was 4.54 in 1998. Similarly, the seeding year site $\times$ year interaction was not significant, however, this interaction for the first-year-after-seeding was significant at the 10%, but not the 5%, level.

There weren't any outlier's in the establishment year yield residuals (Fig. 10) or the RFV residuals (Fig. 11). Also, the distributions of the yield residuals and the RFV residuals were consistent with the normal distribution according to the Shapiro-Wilk W-test (data not shown). There weren't any outlier's in the first-year-after-establishment yields (Fig. 12), but those residuals did not fit a normal distribution well because there were too few observations that fell in the shoulders of the bell-shaped curve (Shapiro-Wilk W-test and inspection of histogram, data not shown). On the other hand, there were four potential outliers in the RFV data for this phase (Fig. 13), but the null hypothesis of normality could not be rejected with the Shapiro-Wilk W-test (data not shown).

The team projected constant yields for the second and third alfalfa phases in CS4 (Table A2). However, a preliminary analysis showed that the third phase yielded less than the second phase. This univariate analysis was suspect because of the correlation of errors encountered due to taking repeated yields on the same seeding of alfalfa. When multivariate, repeated measures procedures were applied to the data, it was clear that the second phase was the highest yielding at ARS, but the second and third phases were essentially equal at LAC. Thus, the site $\times$ phase interaction was significant. This analysis was more powerful in comparing sites and found the difference between sites was significant.

We also applied the multivariate, repeated measures analysis to CS5. Similar to the results for CS4, this analysis found that site, phase, and site $\times$ phase differences were all significant. That means that ARS produced significantly higher yields than LAC, plus there was a significant linear increase in alfalfa yields from the seeding phase to the first-year-after-seeding, and that linear trend was not the same for ARS as it was for LAC. A plot of the data showed that the significant site effect and interaction were due to ARS yielding substantially more in the seeding year, but the same or slightly less in the first-year-after-seeding. Consequently, the slope of the line between the first and second alfalfa phase yields was relatively flat for ARS and quite steep for LAC.

CORRELATION OF CROP YIELDS

One often cited advantage of using several crops in a cropping system is that such a strategy spreads the yield risk over several different crops thus reducing the risk of low crop yields. In order for this strategy to be most effective the yields of the different crops in the cropping system should be negatively correlated (ideally -1). That is, when the yields of one crop are low, then the yields of another crop would be high and vice versa.

Conversely, if crop yields were positively correlated, then there would be little reduction of yield risk. The worst case would be a correlation coefficient of +1.

The WICST data provide an opportunity to examine the correlation of yields for several crops commonly used in cropping systems in the north central USA. The mean crop yields by environment (site-year combinations) are shown in Table CC1 and the pairwise Pearson (assumes normally distributed data) and Spearman Rank (nonparametric data) correlation statistics are shown in Table CC2. Yields of all three grain crops were positively correlated regardless of correlation procedure (Pearson or Spearman Rank). Thus, cropping systems composed of corn, soybeans, and wheat offer little protection from yield fluctuations. Alfalfa yields were not correlated with corn or soybean yields, but may be correlated with winter wheat yields. Nevertheless, the correlation coefficient estimate between alfalfa and each of the three grain crops was positive. Consequently, alfalfa fluctuations may be independent of the grain crops, but they would not likely have the counteracting yields that are desired to reduce yield risk substantially.

CONCLUSIONS

Based on the statistical analyses of the data from the WICST for 1990 through 1998, we conclude that

- 1) There was nearly a 9 bushel/acre advantage for growing corn in rotation with other crops (CS2, CS3, CS4, or CS5) as opposed to growing corn continuously (CS1).
- 2) Growing corn in a forage rotation (CS4 or CS5) yielded 12 bu/acre more than growing it in a cash grain rotation (CS2 or CS3).
- 3) Using moderate to high amounts of external inputs (CS2, and CS4) produced over 19 bu/acre more corn than using low amounts in either a cash grain or leguminous forage rotation (CS3 and CS5).
- 4) Although the corn yields for the low external input systems (CS3 and CS5) were less than those in the conventional systems (CS1, CS2, and CS4) the differences were not as great as originally hypothesized.
- 5) The corn grain in the forage systems was 1.6 percentage points drier than the corn in the cash grain systems, but there was no difference in moisture for corn in rotation versus continuous corn or for low external input systems versus moderate to high external input systems.
- 6) The mean soybean yield for the moderate external input system (CS2) was 4 bu/acre greater than that in the low external input system (CS3). This difference was smaller than originally hypothesized.
- 7) The mean winter wheat grain yield in the low external input system (CS3) was 48.9 bu/acre, which was only slightly less than the 51.3 bu/acre that farmers in Columbia and Walworth Counties averaged in that same period. Straw yields averaged 1.19 tons dry matter per acre.
- 8) In the alfalfa establishment year, the high external system (CS4) produced fewer tons of forage than the low external system (CS5, 2.6 versus 3.4 t dry matter/acre), but the quality was much better (RFV of 140 versus 111). Thus, the usual trade-off of yield versus quality existed and the decision on which one to use would depend on economics and the nutrient requirements of the animals to be fed.
- 9) In the first year of alfalfa after seeding, the high external system (CS4) produced fewer tons of forage than the low external system (CS5, 3.9 versus 4.4 t dry matter/acre), but the RFVs were virtually identical at 146 (CS4) and 142 (CS5).
- 10) In general the low external input systems produced less grain but more forage than the more conventional systems. Consequently, the choice of which system to use is not clearly defined by yields alone so other factors such as profitability, environmental hazards, and farm characteristics must also be considered.
- 11) Yields of all three grain crops were positively correlated; thus, cropping systems composed of corn, soybeans, and wheat offer little protection from yield fluctuations.
- 12) Alfalfa yield fluctuations were independent of changes in grain crop yields, but the correlation coefficients were positive. Consequently alfalfa would not likely have the counteracting effect on grain yields that is desired to substantially reduce their yield risk.

Figure 1. Variation in corn yields over years.

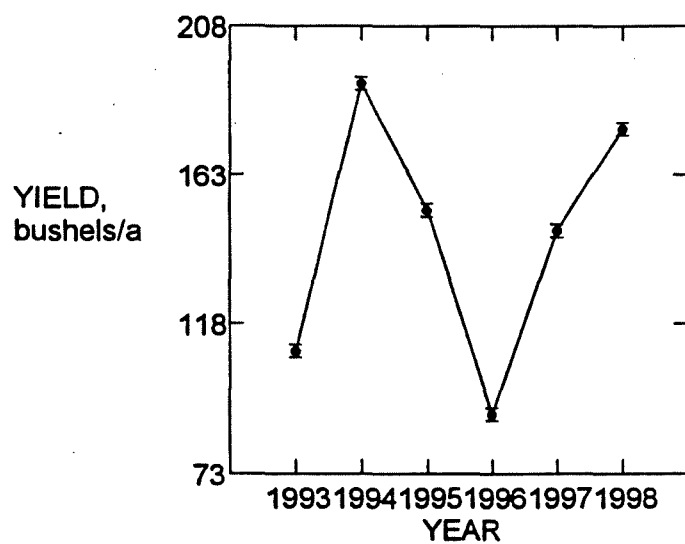


Fig. 2. Mean corn yields at ARL and LAC by year.

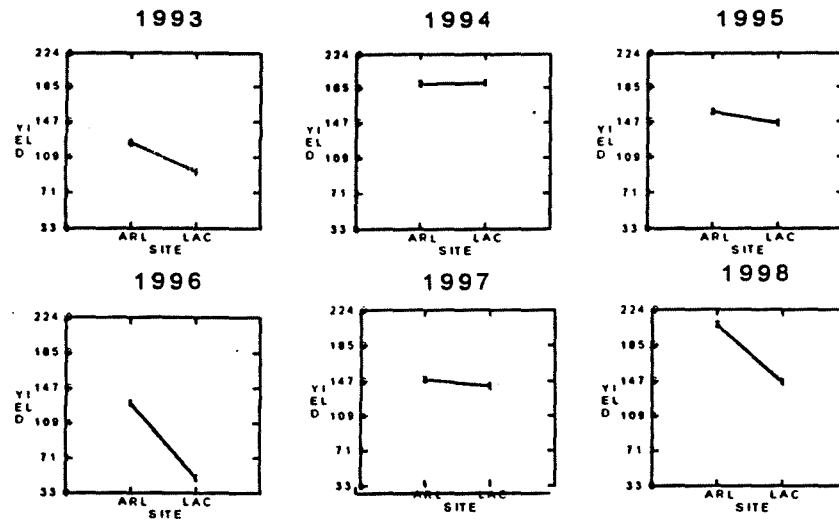
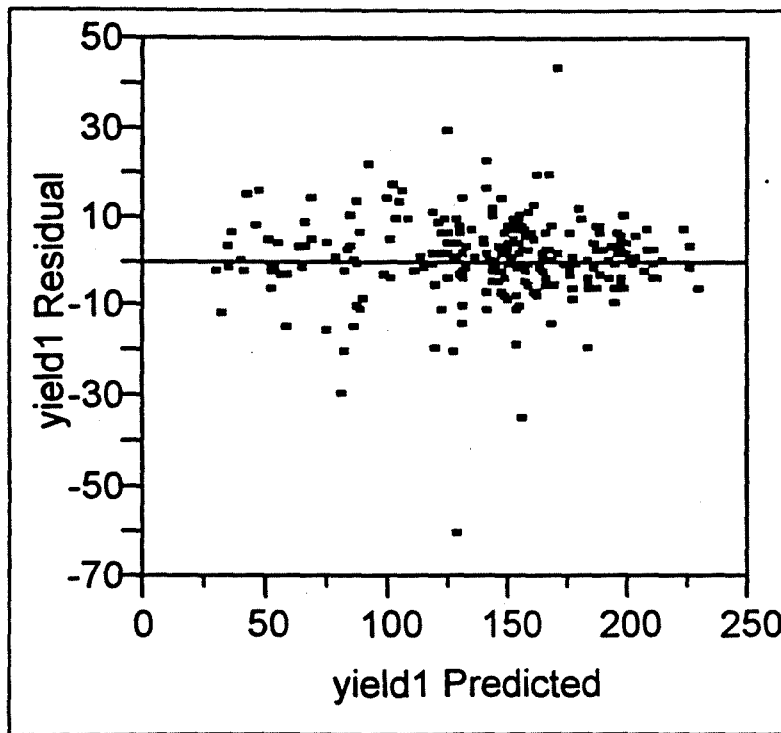


Fig 3. Residuals from corn yield analysis versus predicted yield.

Figure 4. Corn yield residual by cropping system: ARS.

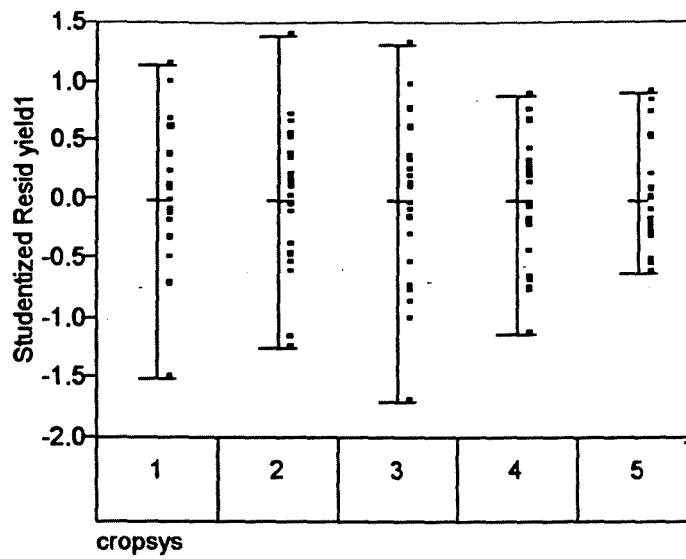


Fig. 5. Corn yield residuals by cropping system: LAC.

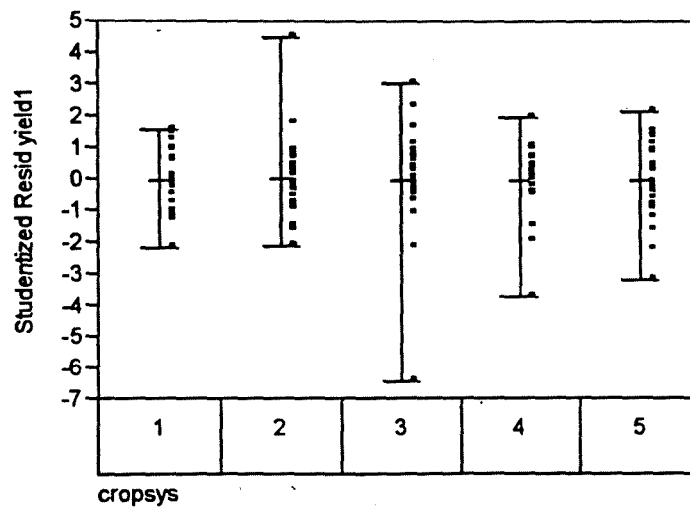


Fig. 6. Corn grain moisture residuals as a function of predicted values.

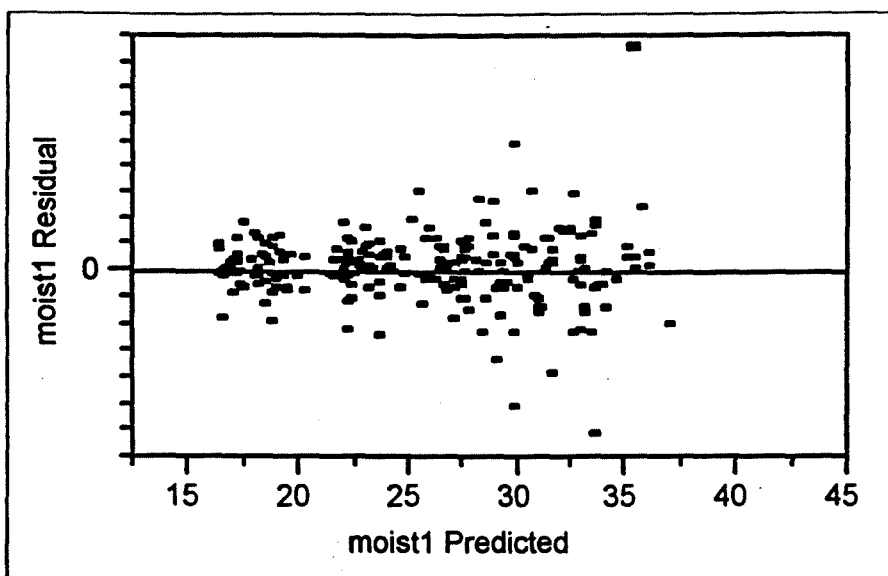
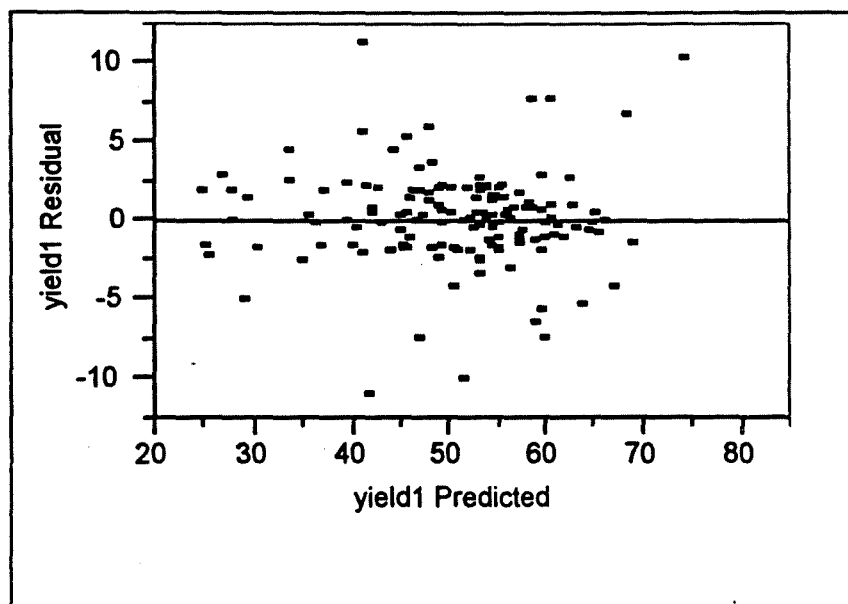


Fig. 7. Residuals from soybean analysis as a function of the predicted yields.

Table C1. Analysis of variance summary for corn yields 1993-1998.

Source	df	Mean-Square	F-ratio	Prob.†
Environment, E	11	37432.30	37.7	<0.01
Block(E)	36	231.52		
Cropping System, C	4	7035.14	7.71	<0.01
E × C	44	911.91	6.08	<0.01
Pooled error	144	149.96		

† Probability that an F-ratio as large or larger could occur by chance, percent.

Table C2. Mean corn yields and grain moisture by cropping system: 1993-1998.

Cropping System	Actual bu/acre†	Hypothesized bu/acre§	Actual Moisture, %†
1	137.4	150	25.7
2	149.9	160	26.6
3	130.2	120	25.9
4	161.8	160	24.5
5	142.7	120	24.7
Overall mean	144.4	142	25.5

† n=48 for each cropping system.

§ From Cuningham et al. (1992) Table 1.

Table C3. Linear comparisons of cropping system corn yields and moisture: 1993-1998.

Comparison: Group A versus Group B	Yield, bu./a. Mean A Mean B (P†)	Moisture, % Mean A Mean B (P†)
Comparison 1: A: Continuous corn B: Corn in rotation	137.4 146.2 (7.8)	25.7 25.4 (66.7)
Comparison 2: A: Cash crop rotation B: Forage crop rotation	139.2 151.4 (0.8)	26.2 24.6 (0.5)
Comparison 3 - within cash grain systems: A: Medium external input (CS2) B: Low external input (CS3)	149.9 130.2 (0.3)	26.6 25.9 (37.1)
Comparison 4 - within forage systems: A: High external input (CS4) B: Low external input (CS5)	161.8 142.7 (0.4)	24.5 24.7 (83.9)

† Probability that a difference in means as large or larger could occur by chance, percent.

Table C4. Partitioning of environment into site and year components for corn 1993-1998.

Source		Df	Mean-Square	F-ratio	Prob.†
Environment, E	11		37432.30		
Site, S		1	61759.8	5.66	6.41
Years, Y		5	59025.5	5.18	4.22
S x Y		5	10973.5	13.53	<0.01
Block(E)	48		231.52		

† Probability that an F-ratio as large or larger could occur by chance, percent.

Table C5. Analysis of variance summary for corn grain moisture 1993-1998.

Source	df	Mean-Square	F-ratio	Prob.†
Environment, E	11	601.251	32.65	<0.01
Block(E)	36	7.248		
Cropping System, C	4	34.942	2.47	5.85
E x C	44	14.155	4.74	<0.01
Pooled error	144	2.986		

† Probability that an F-ratio as large or larger could occur by chance, percent.

Table B1. Analysis of variance summary for soybean yields 1990-1998.

Source	df	Mean-Square	F-ratio	Prob.†
Environment, E	17	503.81	2.85	1.5%
Block(E)	54	36.11		
Cropping System, C	1	703.28	4.25	5.5%
E x C	17	165.50	6.70	<0.01%
Pooled error	54	24.71		

† Probability that an F-ratio as large or larger could occur by chance, percent.

Table B2. Mean soybean yields by cropping system: 1990-1998.

Cropping System	Actual bu/acre†	Hypothesized bu/acre§
2	53.2	55.0
3	48.8	40.0
Overall mean	51.0	47.5

† n=72 for each cropping system.

§ From Cuningham et al. (1992) Table 1.

Table B3. Partitioning of environment into site and year components for soybeans 1990-1998.

Source		Df	Mean-Square	F-ratio	Prob.†
Environment, E	17		503.93		
Site, S		1	52.32	0.05	87.0%
Years, Y		8	518.42	518.42	63.4%
S x Y		8	545.90	5.91	0.7%
Block(E)	54		36.12		

† Probability that an F-ratio as large or larger could occur by chance.

Table W1a. Analysis of variance summary for wheat grain yields 1991-5 plus 1997-98.

Source	df	Mean-Square	F-ratio	Prob.†
Sites, S	1	1525.10	5.18	6.32
Years, Y	6	1662.03	5.64	2.69
Y × S	6	294.45	9.05	<0.01
Pooled error	42	32.55		

† Probability that an F-ratio as large or larger could occur by chance, percent.

Table W1b. Analysis of variance: wheat straw yields in 1991 plus 1993-95 and 1997-98.

Source	df	Mean-Square	F-ratio	Prob.†
Sites, S	1	0.4795	1.34	29.9
Years, Y	5	1.7737	4.96	5.2
Y × S	5	0.3576	8.50	<0.01
Pooled error	36	0.04205		

† Probability that an F-ratio as large or larger could occur by chance, percent.

Table W2. Mean wheat yields 1991-1998.

Cropping System, cropfraction	Actual	Hypothesized§
3, grain, bu/a	48.9†	60.0
3, straw, t/a	1.19‡	2.0

† n=56, 1996 omitted due to missing data at LAC.

‡ n=48, 1992 and 1996 omitted due to missing data at LAC.

§ From Cuningham et al. (1992) Table 1.

Fig. 8. Residuals versus predicted values for wheat grain yields.

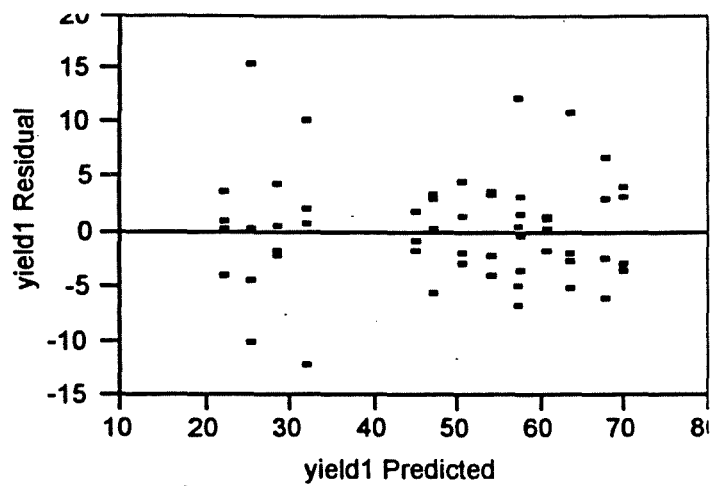


Fig. 9. Residuals versus predicted values for wheat straw yields.

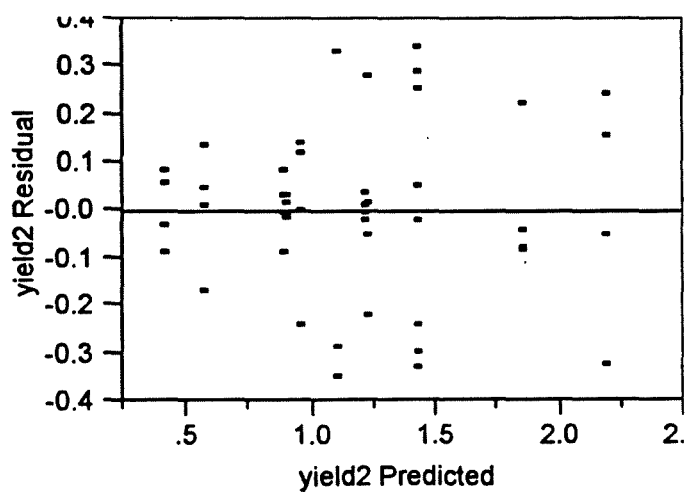


Table A1. Analysis of variance summary for seeding-year alfalfa yields 1994-5 and 1997-8.

Source	df	Yield, t dm/acre		RFV†	
		Mean-Square	Prob.†	Mean-Square	Prob.†
Environment, E	7	7.9607	5.2%	791.68	52.0%
Block(E)	24	0.2722		154.45	
Cropping System, C	1	9.3362	7.5%	10285.2	1.8%
E × C	7	2.1377	<0.01%	853.1	<0.8%
Pooled error	24	0.2210		189.58	

† Probability that an F-ratio as large or larger could occur by chance.

‡ No data for 1994.

Table A2. Analysis of variance for first-year-after-seeding alfalfa yields, 1992-1998.

Source	df	Yield, t dm/acre		RFV	
		Mean-Square	Prob.†	Mean-Square	Prob.†
Environment, E	13	4.5848	0.3%	742.10	4.9%
Block(E)	42	0.2821		67.65	
Cropping System, C	1	5.6966	1.5%	300.33	32.1%
E × C	13	0.7369	5.0%	283.11	0.2%
Pooled error	41	0.3750		89.46	

† Probability that an F-ratio as large or larger could occur by chance.

Table A3. Mean alfalfa yields by cropping system and phase.

Phase	Actual CS4 t dm/acre	Actual CS5 t dm/acre	Hypothesized CS4 t dm/acre§	Hypothesized CS5 t dm/acre§
2† (seeding)	2.60	3.36	3.0	2.0
3 (Hay I)	3.93#	4.39‡	5.0	4.0
4‡ (Hay II)	3.60		5.0	
Mean	3.34	3.88	4.33	3.0
Overall mean		3.56		3.8

† n=32.

‡ n=56.

n=55.

§ From Cuningham et al. (1992) Table 1.

Table A4. Mean alfalfa RFV by cropping system and phase.

Phase	RFV	
	CS4	CS5
2† (seeding)	140	111
3 (Hay I)	146#	142‡
4‡ (Hay II)	150	
Mean	145	127

† n=24.

‡ n=56.

n=55.

Fig. 10. Establishment year alfalfa yield residuals versus predicted yield.

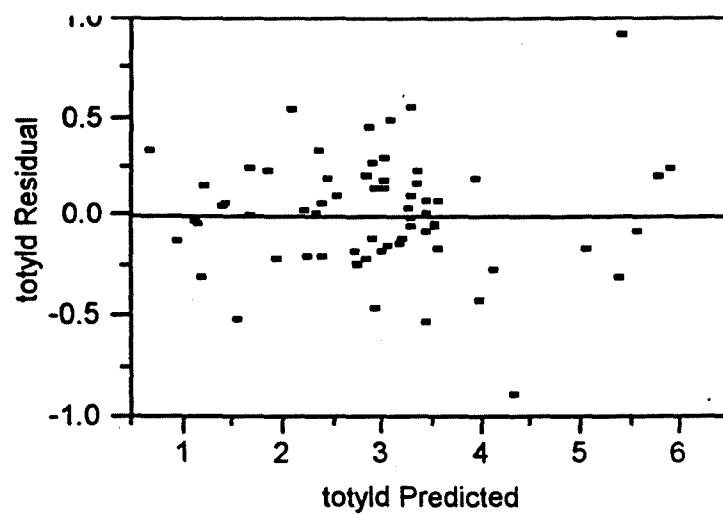


Fig 11. Establishment year alfalfa RFV residuals versus predicted RFV.

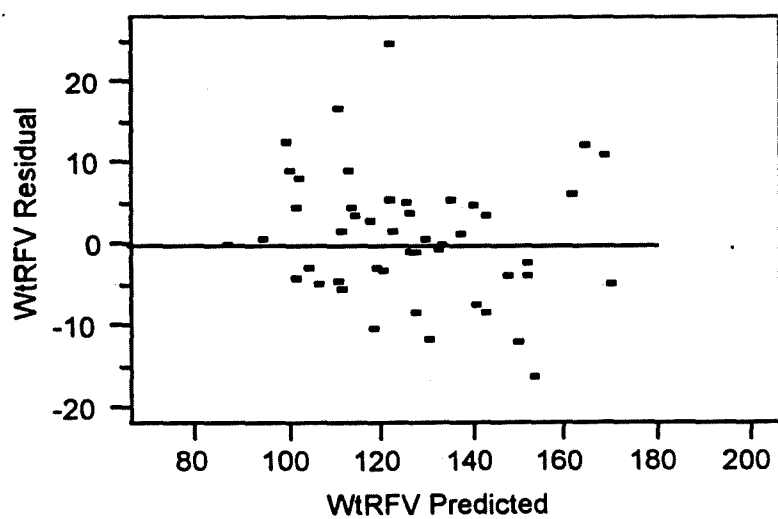


Fig. 12 First established year alfalfa yield residuals versus predicted values.

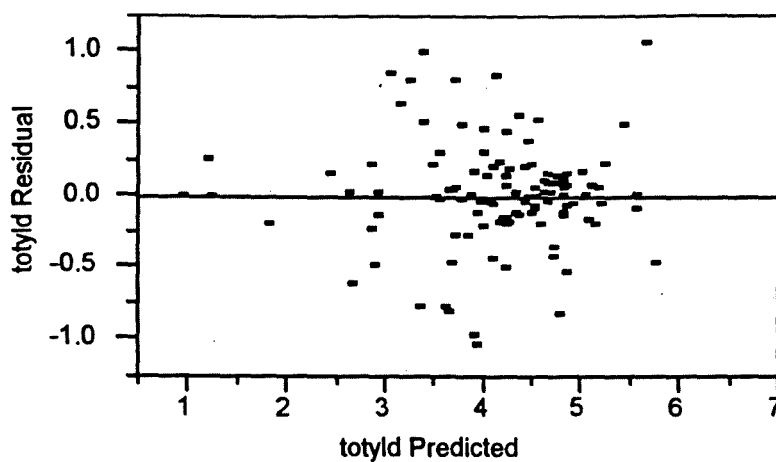


Fig. 13. First established year alfalfa RFV residuals versus predicted RFV

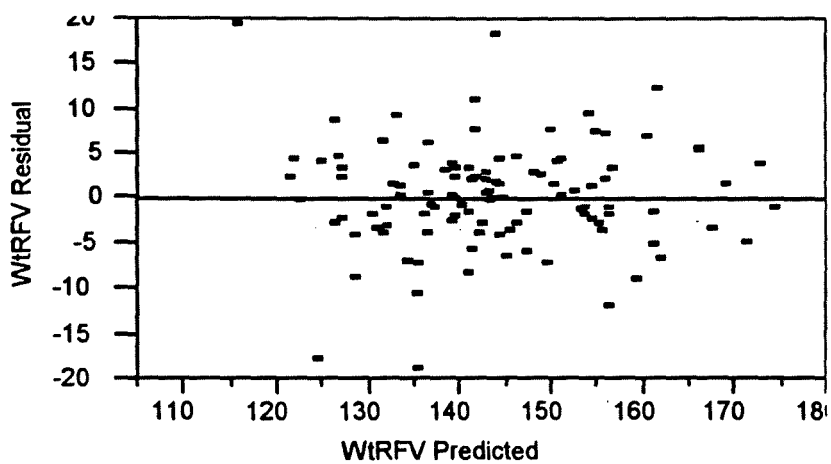


Table CC1. Crop yield data used in correlation analyses.

Site	Year	Corn	Soybean	Wheat	Alfalfa
ARS	1990		54.30		
ARS	1991		53.85	63.65	
ARS	1992		34.04	45.23	4.314
ARS	1993	125.0	53.04	28.63	4.408
ARS	1994	190.4	43.58	60.93	4.930
ARS	1995	158.2	60.68	68.07	4.519
ARS	1996	131.8	56.95	45.39	4.294
ARS	1997	149.6	50.38	54.35	5.035
ARS	1998	207.7	57.75	57.66	4.374
LAC	1990		53.70		
LAC	1991		54.83	32.05	
LAC	1992		49.39	25.68	3.594
LAC	1993	94.5	40.65	22.29	3.124
LAC	1994	191.6	55.23	50.86	3.973
LAC	1995	145.9	56.99	70.00	4.546
LAC	1996	49.6	33.37	0.00	4.307
LAC	1997	142.2	53.18	57.42	2.166
LAC	1998	146.3	56.36	47.17	4.696

Table CC2. Correlations between yields of WICST crops.

Crop pair	Pearson			Spearman	
	n	r	Prob., %	r	Prob., %
Alfalfa-corn	12	0.227	47.9	0.357	24.6
Alfalfa-soybeans	14	0.074	80.1	0.209	46.4
Alfalfa-wheat	14	0.207	47.7	0.495	7.2
Corn-soybeans	12	0.643	2.4	0.518	8.4
Corn-wheat	12	0.811	0.1	0.692	1.5
Soybeans-wheat	16	0.592	1.6	0.624	1.1

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APPENDIX A: MEAN CROP DATA BY SYSTEM, SITE, AND YEAR

Table AC1. Corn grain yields by cropping system, year, and site (n=4).

Site	year	CS1	CS2	CS3	CS4	CS5	Mean
bu/acre							
ARS	1993	123.7	129.8	87.1	165.1	119.1	125.0
ARS	1994	178.1	190.2	188.4	196.5	198.8	190.4
ARS	1995	143.1	167.7	155.6	167.5	157.1	158.2
ARS	1996	131.2	140.0	83.4	151.2	153.4	131.8
ARS	1997	128.6	157.4	147.6	159.0	155.3	149.6
ARS	1998	196.2	212.6	197.8	226.8	205.1	207.7
ARS	Mean	150.2	166.3	143.3	177.7	164.8	160.5
LAC	1993	99.7	101.2	77.7	113.3	80.6	94.5
LAC	1994	177.0	184.4	187.0	211.3	198.3	191.6
LAC	1995	150.9	149.7	130.9	154.4	143.7	145.9
LAC	1996	41.7	40.1	44.8	64.3	57.4	49.6
LAC	1997	112.6	153.8	133.5	160.0	151.4	142.2
LAC	1998	165.5	172.2	129.0	172.2	92.7	146.3
LAC	Mean	124.6	133.5	117.2	145.9	120.7	128.4
Both	Mean	137.4	149.9	130.2	161.8	142.7	144.4

Table AC2. Corn grain moisture by cropping system, year, and site (n=4).

Site	year	CS1	CS2	CS3	CS4	CS5	Mean
ARS	1993	29.23	33.70	33.70	27.65	29.95	30.85
ARS	1994	26.45	27.91	27.19	24.82	26.65	26.60
ARS	1995	24.71	22.23	22.20	23.17	22.06	22.87
ARS	1996	31.93	33.40	34.55	30.53	28.05	31.69
ARS	1997	30.98	31.38	29.38	31.48	29.13	30.47
ARS	1998	22.53	23.59	24.08	22.12	22.68	23.00
ARS	Mean	27.63	28.70	28.52	26.63	26.42	27.58
LAC	1993	26.25	21.85	26.40	23.45	25.33	24.66
LAC	1994	18.63	19.30	17.85	18.40	16.90	18.22
LAC	1995	17.00	17.23	17.25	17.13	16.60	17.04
LAC	1996	28.83	34.25	30.80	24.85	32.45	30.24
LAC	1997	32.73	35.40	29.15	32.20	26.83	31.26
LAC	1998	19.05	18.75	18.10	18.73	19.78	18.88
LAC	Mean	23.75	24.46	23.26	22.46	22.98	23.38
Both	Mean	25.69	26.58	25.89	24.54	24.70	25.48

Table AB1. Soybean grain yields by cropping system, year, and site (n=4).

	ARS			LAC			Mean			
Year	CS2	CS3		CS2	CS3		CS2	CS3		Mean
	bushesl/acre									
1990	56.47	52.13		52.94	54.46		54.71	53.29		54.00
1991	58.53	49.17		58.34	51.32		58.44	50.24		54.34
1992	30.07	38.02		46.88	51.89		38.47	44.96		41.71
1993	52.79	53.28		49.00	32.30		50.90	42.79		46.84
1994	42.74	44.42		63.09	47.37		52.91	45.89		49.40
1995	58.08	63.29		54.89	59.10		56.49	61.19		58.84
1996	53.71	60.18		39.46	27.28		46.59	43.73		45.16
1997	51.93	48.84		57.80	48.56		54.86	48.70		51.78
1998	63.61	51.89		67.70	45.01		65.66	48.45		57.05
Mean	51.99	51.25		54.46	46.36		53.22	48.80		51.01

Table AW1. Winter wheat grain and straw yields by year and site (n=4).

Year	ARS			LAC			Mean	
	Grain	Straw		Grain	Straw		Grain	Straw
	bushels/a	t dm/a		bushels/a	t dm/a		bushels/a	t dm/a
1991	63.65	0.90		32.05	0.42		47.85	0.66
1992†	45.23			25.68			35.46	0.33
1993	28.63	1.43		22.29	2.20		25.46	1.82
1994	60.93	1.43		50.86	1.86		55.89	1.65
1995	68.07	1.22		70.00	1.23		69.03	1.23
1996‡								
1997	54.35	0.96		57.42	1.11		55.88	1.04
1998	57.66	0.59		47.17	0.91		52.41	0.75
Mean	52.99	1.05		43.64	1.29		48.86	1.19

† No straw yield was available for LAC, so ARS straw yield was omitted also.

‡ Wheat failed at LAC, so ARS data was omitted also.

Table AA1. Alfalfa yields in the seeding year by cropping system, year, and site (n=4).

	ARS			LAC			Mean		
Year	CS4	CS5		CS4	CS5		CS4	CS5	Mean
	tons dry matter/acre								
1994	3.207	3.371		2.366	3.489		2.786	3.430	3.108
1995	3.184	3.216		1.242	1.512		2.213	2.364	2.289
1997	3.559	4.666		1.455	1.981		2.507	3.323	2.915
1998	2.629	5.672		3.122	2.967		2.876	4.320	3.598
Mean	3.145	4.231		2.046	2.487		2.595	3.359	2.977

Table AA2. Alfalfa RFV in the seeding year by cropping system, year, and site (n=4).

	ARS			LAC			Mean		
Year	CS4	CS5		CS4	CS5		CS4	CS5	Mean
	RFV								
1994									
1995	125.72	110.79		158.50	108.00		142.11	109.40	125.75
1997	122.75	127.97		158.99	124.55		140.87	126.26	133.56
1998	139.60	101.08		137.18	94.69		138.39	97.88	118.14
Mean	129.35	113.28		151.56	109.08		140.46	111.18	125.82

Table AA3. Alfalfa yields in the first year after seeding by cropping system, year, and site (n=4).

	ARS			LAC			Mean		
Year	CS4	CS5		CS4	CS5		CS4	CS5	Mean
	tons dry matter/acre								
1992	3.463	5.165		3.648	3.540		3.556	4.353	3.954
1993	4.164	4.653		2.874	3.375		3.519	4.014	3.766
1994	4.559	5.300		4.122	3.825		4.340	4.562	4.451
1995	4.021†	4.892		4.475	4.618		4.248	4.755	4.502
1996	4.162	4.427		4.263	4.351		4.213	4.389	4.301
1997	5.082	4.989		1.328	3.004		3.205	3.997	3.601
1998	4.301	4.446		4.534	4.859		4.417	4.653	4.535
Mean	4.250	4.839		3.606	3.939		3.928	4.389	4.159

† n=3.

Table AA4. Alfalfa RFV in the first year after seeding by cropping system, year, and site (n=4).

	ARS			LAC			Mean		
Year	CS4	CS5		CS4	CS5		CS4	CS5	Mean
	RFV								
1992	127.66	142.29		164.30	159.17		145.98	150.733	148.36
1993	138.76	139.39		135.64	132.51		137.20	135.9527	136.58
1994	155.53	141.25		161.61	166.59		158.57	153.9202	156.25
1995	147.40†	132.16		139.94	135.38		143.67	133.7692	138.72
1996	126.01	146.61		136.56	144.58		131.29	145.5984	138.44
1997	152.35	143.00		144.35	124.95		148.35	133.9755	141.16
1998	153.77	147.65		151.65	135.98		152.71	141.8155	147.26
Mean	143.07	141.76		147.72	142.74		145.40	142.2521	143.82

† n=3.

Table AA5. Alfalfa yield and RFV in the second year after seeding in CS4 by year, and site (n=4).

	ARS			LAC			Mean	
Year	Yield t dm/a	RFV		Yield t dm/a	RFV		Yield t dm/a	RFV
1992	3.988	134.36		3.567	163.79		3.778	149.07
1993	3.247	140.76		2.609	153.13		2.928	146.95
1994	3.679	143.18		4.047	169.52		3.863	156.35
1995	2.245	150.98		3.342	154.96		2.793	152.97
1996	3.775	154.95		3.526	130.76		3.651	142.86
1997	4.505	143.76		3.381	152.14		3.943	147.95
1998	4.128	164.04		4.316	138.24		4.222	151.14
Mean	3.652	147.43		3.541	151.79		3.597	149.61

6. 1992-2000 Energy use and Output/Input ratios for the Wisconsin Integrated Cropping Systems Trial

Johanna Oosterwyk and Joshua L. Posner

Introduction

The consumption of non-renewable energy in agriculture is an issue that waxes and wanes in the public interest. The sudden rise in oil prices in the early 1970's spawned a number of studies on the use of energy in agriculture (Pimentel, 1973; Heichel, 1973). Energy however, remained relatively cheap, and technologies requiring high-energy inputs continued to be popular. Then again, in 1990, farmers were concerned about the effect of the impending conflict in the Middle East on natural gas prices for drying corn during the wet fall of that year. The following winter, during Operation Desert Storm, fertilizer dealers were not quoting prices for anhydrous ammonia for delivery in the spring, but when prices didn't rise, interest in low energy alternatives again waned. Most recently, as fuel prices climbed to record heights in the summer of 2000, farmers were again asking the same questions that they have many times about the economic returns from high input systems.

Methods

Predicted energy use in the six rotations of the Wisconsin Integrated Cropping Systems Trial has been estimated by using published tables that quantify the energy required to produce agricultural inputs (Pimentel, 1980; Stout, 1984) and the Minnesota Farm Machinery Economic Estimates (1992) for fuel use estimates. Software called ABCS (Agricultural Budget Calculation Software) estimates fuel usage for specific field operations. Energy conversions for all fertilizer products (anhydrous ammonia, urea ammonium nitrate, starter, etc.) are based on the total amount of product applied. Some of the key conversions used to calculate energy consumption are summarized in Table 1.

In order to compare energy use in six cropping systems and their output/input ratios, the team addressed three theoretical issues:

- 1) Only the fuel cost in spreading manure were counted as an input in systems 4, 5 and 6. The energy content of the manure and the equivalent energy value of the nutrients in the manure were not considered as external inputs to the cropping system on a dairy farm.
- 2) The energetic value of each cropping system's output was calculated on a total energy basis, and not as metabolic energy for either cows or humans. In this way the numbers were standardized, regardless of end use of the agricultural product.
- 3) In order to simplify the calculations, human energy in terms of labor per system was not included as part of the inputs.

Results

Calculated energy use and output/input ratios for the past nine years are presented in Tables 2 and 3. Table 2 shows the variation in inputs between the specific phases of each cropping system, while Table 3 illustrates the differences in energy efficiency between whole systems.

Table 2 first compares the inputs and outputs of the corn phase of each cropping system. The first two cash grain systems (continuous corn and corn following soybean) are clearly higher in inputs than the other three systems, where the use of pesticides, fertilizers and, except in the case of CS3, drying costs are much higher. Due to the higher moisture of no-till corn at harvest, drying costs in CS2 account for a greater portion of the total inputs and decrease the efficiency of that system. Also, in CS4 and CS5, we harvest the corn as high moisture ear corn, avoiding drying costs, which can make up one-third to one-half of the total energy inputs in the years when corn is grown. Corn production also varied greatly by system so the energy represented by corn yields varied by the same measure. The forage-based systems consistently produce higher corn yields than the cash-grain systems, which increase the output/input ratio. The resulting output/input ratios vary from about 7 to 11 in the cash grain systems, while in the forage based systems, the corn phase is much more energy efficient and ratios range from 20 to 30.

The two soybean phases (CS2-drilled, no-till; CS3-row soybeans) have more similar input patterns. Though the no-till practices in CS2 kept fuel prices down and yields were also higher, increased herbicide use made the ratios fairly even between CS2 and CS3. However, compared to corn, growing a legume like soybeans with no nitrogen fertilizer requirement or energy for drying results in higher output/input ratios of around 13. In 1999, Lakeland added soybeans to the low-input forage rotation (CS15), which resulted in an output/input ratio near 20. This may be due to adding soybeans to a system that had not had soybeans and generating greater yields. Also, this system is organic unlike CS2.

In the forage systems (CS4, CS5, and CS6) the alfalfa phases are especially energy efficient. For instance, Hay I produces a ratio of around 40 since maximum production is usually achieved in this phase and the energy inputs of planting have been accounted for the previous year in the direct seeding phase. Rotational grazing (CS6) has the highest input/output ratio. Purchased inputs in this system are very low, and, unlike CS3, weed management and harvesting is done by the animals instead of machinery driven by diesel fuel.

While looking at the energy inputs and outputs by phase permits better understanding of the numbers, whole systems analyses are crucial if we want to understand the implications of energy use on Wisconsin farms. As can be seen in Table 3, the energy inputs in the cash grain systems were higher than the energy inputs in the forage rotations. By the same token, within enterprise types, increasing plant diversity resulted in decreasing energy inputs, and when we compare the energy value of the output to the inputs, we find again that increasing plant diversity resulted in increasing efficiency in energy use. In the cash grain crops, System 3, with its rotation of corn, soybean and wheat and red clover, consistently out-performed System 2 (corn-soybean), both of which proved to be more energy efficient than the continuous corn rotations in System 1. The same pattern was seen in the forage rotations. The pasture mix of timothy, brome grass, canary grass and red clover, was more energy efficient than the oats/alfalfa/corn rotations of System 5 and the alfalfa-corn rotation of System 4 (CS3>CS2>CS1; CS6>CS5>CS4).

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Table 1. Values used for Calculating Energy Use of WICST Crop Rotations

Primary Formula: $\text{lb/acre} * \text{Mcal/lb} = \text{Mcal/acre}$

ENERGY VALUES USED

INPUT	Mcal/lb	Fertilizer	Mcal/lb product	Pesticides	Mcal/lb a.i.
Seed				Herbicides	
Corn	11.275	82-0-0	4.473	Accent, Classic, Dimate, Harmony*, Pinnacle,	
Soybean	3.447	28-0-0	1.849	Poast, Pursuit, Ranger, RoundUp, Stinger	51.759
Wheat	1.365	6-24-24	0.9027	Ammonium Sulfate	1.09
Oats	1.867	4-10-10	0.4764	Atrazine, Extrazine	23.186
Red Clover	17.093	0-34-0	0.4636	Assure*, Lexone, Treflan	35.17
Alfalfa	28.009	0-0-60	0.4364	Banvel	34.55
Timothy	9.48	Manure	0.035836	Bladex, Cyanazine	24.376
Orchard Grass	9.839	46-0-0	2.99	Buctril, 2,4 - D	30.505
Hairy Vetch	19.75	9-23-23	1.082	Confidence, Dual, Lasso	32.71
Annual Rye	14.22	6-23-30	0.9327273	Crop Oil (same as diesel fuel)	43.145
Forage Peas	5.53	(P 24 CRC Pimentel)		Eptam, Surfactants, Fusilade, Preference, Reflex	45.414
Reed Canary	31.284			Insecticides	
brome grass	14.22*			Counter, Force	33.773
(P 32 CRC Pimentel)				Lorsban	27.941
				Pounce	35.805
				(P45-47 CRC Pimentel)	

Drying .756 Mcal/lb to remove 1 lb H₂O
 lb H₂O/bu - Table 6.8 Grain Drying, Handling and
 Storage Handbook (Midwest Plan, 1987)

Fuel
 diesel 43.145 Mcal/gal (P 15 CRC Pimentel)
 Fuel requirements for specific field operations
 are calculated in ABCS software using
 Minnesota Farm Machinery Economic Estimates (1992)

OUTPUT (lb/acre DM yield*Mcal/lb)

Crop	%fat	%prot	%carbo	Kcal/g	Mcal/lb
corn	4.3	10	84.1	4.42	2.006
soybean	18.8	42.8	32.9	5.54	2.517
wheat	1.8	13	83.1	4.31	1.958
wheat stra	1.8	3.6	86.8	3.93	1.785
oat	5.4	13.3	77.9	4.46	2.023
oat straw	2.2	4.4	85.6	3.97	1.801
oatlage bo	2.6	17.5	73.4	4.24	1.927
alf.late veg	3.8	20	67	4.24	1.923
alf early bl	3	18	69.4	4.15	1.882
Timothy la	2.8	17	73.1	4.22	1.917
formula** = % fat*9.45+%prot*5.65+%carbo*4.1					

Table 2A. 1992-2000¹ Arlington Research Station average energy inputs per system phase (Mcal/A).

	Yield		Seed	Fertilizer	Pesticide	Drying		Total Input	Total Output	Ratio
	bu/a	TDM/a				Costs	Fuel			
CORN										
CS1	153		224	804	105	877	327	2338	17194	7.4
CS2	164		224	757	85	1053	206	2327	18441	7.9
CS3	139		237	-	0	877	313	1428	15572	10.9
CS4	179		223	93	47	-	308	671	20154	30.1
CS5	163		241	-	0	-	354	596	18241	30.6
SOYBEAN										
CS2	52		313	-	56	-	198	567	7859	13.8
CS3	48		266	-	-	-	333	600	7246	12.1
WHEAT										
CS3	51	1.00	641	-	4	-	241	885	9563	10.8
ALFALFA										
CS4 DSA		2.78	399	-	100	-	373	872	10487	12.0
CS5 O/A	62 ³	4.05	646	-	-	-	326	972	14827	15.3
CS4 Hay 1		4.42	37	2	4	-	413	455	17004	37.3
CS5 Hay 1		5.00	22	-	13	-	402	437	18825	43.1
CS4 Hay 2		3.92	133	2	29	-	483	647	15096	23.3
PASTURE										
CS6 seed		4.15	271				322	593	17712	29.9
CS6 ⁵ Forage		2.85	100	100	-	-	113	313	11323	36.2

Table 2B. 1992-2000¹ Lakeland Agricultural Complex average energy inputs per system phase (Mcal/A)

	Yield		Seed	Fertilizer	Pesticide	Drying		Total Input	Total Output	Ratio
	bu/a	TDM/a				costs	Fuel			
CORN										
CS1	115		224	823	143	400	306	1896	12894	6.8
CS2	132		224	852	136	544	188	1943	14808	7.6
CS3	100		261	-	4	424	298	987	11199	11.3
CS4	139		223	213	66	-	290	792	15566	19.7
CS5	114		234	-	4	-	318	555	12780	23.0
SOYBEAN										
CS2	53		295	-	132	-	187	613	7960	13.0
CS3	44		272	-	2	-	305	579	8594	11.4
CS15	46		328	-	-	-	109	436	6977	16.0
WHEAT										
CS3 ²	46	1.33	559	-	-	-	193	752	8133	10.8
ALFALFA										
CS4 DSA ⁴		1.23	503	-	89	-	314	906	5297	5.8
CS5 O/A	54 ³	2.55	769	-	-	-	262	1031	9583	9.3
CS4 Hay 1		3.54	35	-	3	-	326	364	13626	37.4
CS5 Hay 1		4.13	-	-	11	-	352	364	15545	42.8
CS4 Hay 2		3.51	31	-	29	-	386	446	13504	30.3
PASTURE										
CS6 seed		0.96	362		39		278	680	4097	6.0
CS6 ⁵ Forage		2.71	156	24	-	-	90	270	11582	42.9

¹ All cash grain ratios are calculated from 1992 to 2000 except where otherwise noted. CS4 and CS5 ratios are calculated from 1993-2000 unless otherwise noted.

² Data from 1996 not included due to wheat seeding failure which was replanted to oats.

³ Oats (instead of oatlage) was harvested in 1993 at Arlington and in 1996 at LAC.

⁴ The direct-seeding phase was not included in field in 1999 due to system changes that year.

⁵ Energy ratios for CS6 are calculated from 1990-2000.

Table 3A. 1992-2000¹ Arlington Research Station average energy inputs per System (Mcal/A).

SYSTEM	Seed	Fertilizer	Pesticide	Drying Costs	Fuel	Total Input	Total Output	Average Ratio
cash grain								
CS1	224	804	105	877	327	2338	17194	7.4
CS2	269	379	71	527	202	1447	13150	9.1
CS3	381	0	1	292	296	971	10794	11.1
forage								
CS4	201	24	45	0	394	659	15682	23.8
CS5	303	0	4	0	361	668	17298	25.9
CS6 ⁴	100	100	0	0	113	313	11323	36.2

Table 3B. 1992-2000¹ Lakeland Agricultural Complex average energy inputs per System (Mcal/A).

SYSTEM	Seed	Fertilizer	Pesticide	Drying Costs	Fuel	Total Inputs	Total Output	Average Ratio
cash grain								
CS1	224	823	143	400	306	1896	12894	6.8
CS2	260	426	134	272	188	1278	11384	8.9
CS3 ²	364	0	1	141	265	773	8642	11.2
forage								
CS4 ³	198	53	47	0	329	627	11998	19.1
CS5	333	0	4	0	260	584	11221	19.2
CS6 ⁴	156	24	0	0	90	270	11582	42.9

¹ All cash grain ratios are calculated from 1992 to 2000 except where otherwise noted. CS4 and CS5 ratios are calculated from 1993-2000 unless otherwise noted.

² Data from 1996 not included due to wheat seeding failure which was replanted to oats.

³ The direct-seeding phase was not included in field in 1999 due to system changes starting that year.

⁴ Energy ratios for CS6 are calculated from 1990-2000.

7. Quantifying the Impact of Preferential Flow on Field-scale Chemical Transport Under Two Steady-state Conditions in Silt Loam Soil

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Introduction:

To ensure high food/fiber production from limited arable lands, fertilizers and pesticides play essential roles in modern agriculture. After extensive use, however, some of these agrichemicals have resulted in nonpoint groundwater contamination. The general public demands not only high-quality, low-cost food and fiber but also clean and pristine environments. Tremendous efforts have been focused on alleviating the undesirable trade-off between production of food/fiber and deterioration of water quality during the past three decades. Each year, federal (USDA/USGS/EPA) and state (DNR) agencies, private industries, and research institutes together spend hundreds of millions of dollars to monitor the potential adverse effects of agrichemicals on environments. Generally, there is substantial scatter and variability in the results - making scientific interpretation and policy development difficult. Groundwater and surface water contamination represents one of our nation's most significant, long-term problems.

Results from many lab experiments based on chemical transport in homogenized soil matrix demonstrated that soil should be an excellent filtering system. This is why many highly toxic chemicals have been approved by regulatory agencies for agricultural use. However, research results from field experiments indicate that chemicals can bypass the vast soil matrix and be transported to groundwater expeditiously (Helling and Gish, 1991; Flury, 1996). There have been many papers published during the last two decades to demonstrate that preferential flow was the major reason for non-point groundwater contamination by pesticides. Nevertheless, the scope and magnitude of preferential flow as well as its impact on and relevance to field-scale contaminant transport have not been quantified and resolved. This was mainly because the conventional sampling protocols approved by the US-EPA were not effective.

Both pesticides and the conventional sampling protocols were developed more than 50 years ago when preferential flow and its impact on contaminant transport were not understood at all. The conventional sampling protocols implicitly assume that contaminants move through the entire soil matrix. Therefore, samples are collected at random locations and results are averaged to determine the patterns of overall deep leaching. Because the hydraulically active preferential flow pathways generally occupied a very small fraction of the entire soil matrix, most randomly collected samples would not detect the transport through preferential pathways. A sample that happens to be near a preferential pathway will recover much more than those located away from a pathway (Ju et al., 1997). This partly explains the substantial scatter and variability in sampling results - making scientific interpretation and policy development difficult.

To accurately determine the mass flux of pesticide transport in an unsaturated soil, one must identify and sample the preferential pathways (Ju et al., 1997). However, there are no tools that can nondestructively and 3-D map and visualize these complex preferential flow paths. In a tile-drained field, regardless of how insidious/complex the preferential flow paths may be, some contaminants that reach shallow groundwater will drain out in the tiles as long as the water table is above the tile line. Sampling tile drain was the only alternative method to directly measure total mass flux of chemical leaching under large field-scale conditions. Nevertheless, Flury (1996) pointed out that using tile drain as a monitoring protocol has its intrinsic drawback. Unless tiles were closely spaced, some chemicals reaching the shallow watertable would inevitably be transported either vertically into regional groundwater or laterally (parallel to the tile) away from the field, when the chemicals were

applied to the entire field. Under both conditions, some chemicals reaching a shallow groundwater table would not drain out from tiles. This suggested that monitoring tile drain would underestimate the total mass flux. Furthermore, chemical breakthrough time and pattern collected from tile drain would reflect the convoluted chemical transport through both unsaturated and saturated zones. In order to use results from tile drain to predict contaminant transport in an unsaturated soil profile, one must deconvolute the chemical breakthrough time and pattern to extract information on the transport through the unsaturated zone. This has been an extremely difficult task complicated by the fact that a shallow groundwater table would fluctuate during a precipitation event.

Using multiple piezometers to monitor the fluctuation of shallow watertable during precipitation events in the Till Hydrology Farm of the Iowa State University, it was found that the watertable close to the tile line barely changed and always had the steepest gradient (Dr. Dan Jaynes, personal communication, 1997). This suggested that chemical transport occurred mostly in the unsaturated zone if a chemical was applied only to a narrow strip at soil surface close to the tile line. In other experiments independently conducted in the Till Hydrology Farm of the Iowa State University by Dr. Dan Jaynes and the Willsboro Farm of the Cornell University by Dr. Tammo Steenhuis, respectively, results showed that, after soil profile was healed, contaminant transport through preferential flow paths was not caused by the installation of the tiles.

Results from field experiments by Kung et al. (2000) demonstrated that applying chemicals at a narrow strip near the tile could quantify the impact of preferential flow paths on contaminant transport. Most importantly, they found that preferential flow paths of natural soils have a wide pore spectrum. Preferential flow paths with larger pores would become hydraulically active only when the profile becomes wetter during a precipitation event. This suggested that not all preferential flow paths are simultaneously active and the impact of preferential flow paths on contaminant transport is dictated by rain intensity and duration. Because the volumetric flow in a pore is proportional to the fourth power of the pore radius, in order to predict and prevent contaminant transport through preferential flow paths, it is important to comprehend when a preferential flow would become hydraulically active. *The soil pore size spectrum is one of the most fundamental soil properties.*

The small and large pores are formed very differently. The small matrix pores are always interconnected and generally self-similar. The spectrum of the small pores is a static property of a soil profile and measurement made at several locations can accurately represent the spectrum of the primary pores of an entire soil horizon with the same soil texture. The larger structural pores is much more complex and have very dynamic formation and destruction cycles. As a result, the size spectrum of large pores measured at several random locations can not be extrapolated to represent the spectrum of the entire soil profile. Nor can a measurement be extrapolated temporarily. For this reason, it is difficult to directly measure the field-scale size spectrum of the large structural pores, which constitute the preferential flow paths in finer soils.

No methodology has been ever developed to holistically measure the field-scale size spectrum of large secondary soil structural pores. The "hydraulic conductivity" has been traditionally used to describe the lumped effect of all the soil pores on water movement. From the 1960's, soil physicists have spent tremendous effort to directly measure soil hydraulic conductivity and use statistical approach to

estimate the 3-D nature of soil hydraulic conductivity. But, results show that, even the field-scale 3-D soil hydraulic conductivity is too complex to be measured by conventional instruments, which simply could not encompass the spatial and temporal scales of the secondary soil structural pores. The lack of methodology to non-destructively quantify the size spectrum of the large secondary soil structural pores has frustrated all efforts to correctly predict contaminant transport, let alone to prevent groundwater contamination by agrichemicals. As a result, agrichemicals have been increasingly criticized by environmentalists; many people have gradually become reluctant to acknowledge the essentialness of agrichemicals.

When a process was too complex to identify/measure all involved parameters, indirect method was often used to find relationship between input and outcome. For example, "Transfer Function" approach was developed in hydrology for watershed-scale storms hydrograph to predict flooding and later adopted to estimate contaminant transport in unsaturated soils (Jury, 1982). Furthermore, inverse algorithms have been developed and commonly used in many areas such as complex signal processing and artificial intelligence.

The objective of the study was to collect accurate chemical breakthrough patterns so that it would be possible to use these patterns to deconvolute and indirectly quantify the field-scale pore size spectrum of preferential flow paths under different rain intensities. Under transient infiltration condition like those of Kung et al (2000), soil matrix potential gradients could cause lateral water movement and solute transport among inter-connected pores. This made it difficult to use indirect method to estimate the soil pore spectrum by using accurately measured tracer breakthrough patterns. In order to measure soil pore spectrum relevant to field-scale contaminant transport, the complexity of lateral dispersion associated with transient flow must be first eliminated from the experimental procedure. In other words, tracer breakthrough pattern must be collected under steady state conditions under different infiltration rates.

Material and Methods:

Field experiments were conducted in summer of 1999 at the Walworth County Farm in Elkhorn, Wisconsin. The site is located within the Southern Wisconsin and Northern Illinois Drift Plain. The Lake Michigan and Green Bay glaciers retreated from this area about 10,000 years ago and tall grass prairie began to dominate from five to six thousand years ago (Curtis, 1959) until the arrival of European farmers. Then, the area has gone through an evolution of primarily continuous small grains, to dairy, to cash grain corn/soybean systems. Generally there is a silt loam surface horizon (0-35 cm, organic matter 3%), followed by a clay-loam or sandy clay-loam B-horizon (35-65 cm), and underlain by glacier well-mixed gravelly till. The average depth to compacted glacial till is between 80 and 130 cm. The soils in the site are classified as Pella silt loam soils. These prairie-derived silt loam soils covers the southeast of the Wisconsin into the northern Illinois and represent one of the most productive agricultural lands in this region.

A 160 m by 72 m field plot was selected. The field has around 1% to 3% slope and has been under no-till corn-soybean-wheat rotation for 12 years. Tiles with uniform 18-m spacing at around 1 to 1.2 m depth were installed in the field in early 1970's. Manhole at the down gradient of the field was installed in 1997. Flow rate of the tile drain was continuously recorded by using a submerged

pressure transducer (with resolution of 75 mV per 1 cm water head) to measure water height in a flume with a 15° V-shaped, sharp-edged notch.

The soybean was just emerged when the experiments started. A steady 4 mm h⁻¹ irrigation is applied to two 16 m by 30 m areas near the three central tile lines through two rows of solid-state sprinklers (Fig. 1). Each row of sprinklers had 3 nozzles. Between the two rows of solid-state sprinklers, there was a 3.5 m by 24 m shed in the center. The shed was 1.5 m high and made of aluminum frame and corrugated PVC wall/roof, which had about 90% light transparency. The long side of the shed was parallel to the tile line offset 0.3 m. There were 8 carefully calibrated nozzles inside the shed. These nozzles were oscillating inside the shed, similar to the design of Ghodrati et al (1990). However, the nozzles were 2.4 m apart and mounted on a trolley and oscillating along the long side of the shed. This design offered around 90% to 95% Christianson uniformity inside the shed under all climatic conditions, while that of the outside nozzles varied from 20% to 85% depending primarily on the wind conditions. The irrigation rate inside the shed was 3.1 mm h⁻¹. The shed was 15 m from the manhole. Water collected from the roof of the shed during natural precipitation events was diverted away from the field by gutters.

The tile flow was continuously monitored after irrigation started. After the tile reaches steady-state outflow, a pulse of conservative tracer, potassium bromide (2.35 kg Br), was applied from the nozzles inside the shed. During the tracer application, the irrigation rates at both inside and outside were maintained constant. No tracers were applied to outside. Water samples from tile drain were manually collected once every 2 minutes during the first 2 hours after tracer application. Then, water samples were collected once every 6 minutes during the next 10 hours. Water samples were collected once every 15 minutes for the next 12 hours and then decreased to every 30 minutes for the next 12 hours. Then, water samples were collected once every hour for the next 3 days and once every two hours for the next 10 days. Flow rate of the tile drain was continuously monitored.

The irrigation was terminated at 22 days after tracer application. The entire field was under free drain for a week. Then, four 10-cm diameter soil cores were collected inside the shed and soil samples from each core were collected every 7.5 cm to 75 cm depth. At this time, the soybean reached about 25 cm height. Mower was used to cut the soybean to about 10 cm height on a 5 m by 40 m strip along to the other side of the tile line beside the shed. The entire irrigation system was then moved laterally to the other side of the tile line such that the shed was again 0.3 m offset from the tile.

The experiment was repeated, except the irrigation intensity inside the shed was reduced to 0.89 mm h⁻¹, while that of the outside was maintained at 4 mm h⁻¹. After the tile drain reached steady state, a second pulse of conservative tracer, penta-fluorobenzoic acid (PFBA 1.02 kg) was applied from the nozzles inside the shed. Again, water samples were collected with identical frequency after tracer application. The experiment was terminated at 14 days after tracer application.

This experiments were design to collect the field-scale breakthrough patterns of conservative tracers so that the impact of preferential flow on chemical transport in an unsaturated soil profile could be quantified and compared under two different steady state infiltration rates. Tracers recovered from tile drain had traveled through unsaturated soil profile and saturated zone. Kung et al (2000) showed

that by applied tracer only to a narrow strip close to tile line would minimize the tracer travel time in the saturated zone. Nevertheless, as irrigation rate decreased during the second tracer experiment, the overall shape of water table between two adjacent tiles would drop. This could influence the tracer travel time in the saturated zone and make the comparison of breakthrough patterns of two tracers less meaningful. We minimized this error by maintaining the same outside irrigation intensity at 4 mm h^{-1} to assure that the overall shape of water table between two adjacent tiles was approximately the same during the two tracer experiments. On the other hands, the two tracers were applied to two sides of a tile line and traveled through different soil profiles. The main reason that we moved the shed was because, about a week after tracer application, a thin layer of algae started to grow on soil surface inside the shed. Nevertheless, because the tile was installed almost 30 years ago, it was plausible to assume that the soil on two sides of a tile line had identical physical properties. There was no surface ponding or runoff inside the shed through both experiments.

Results and Discussion:

Figure 2 shows that tile flow as a function of time after the first tracer application. The flow rate was extremely steady around 200 mL s^{-1} during the first 30 hours after tracer application. Although the irrigation intensity was maintained constant, the tile flow did have diurnal fluctuation because of the evaporation and transpiration. At the 35 h and 60 h after tracer application, there were heavy and short thunderstorms, which cause sharp increase of tile drain. After the second precipitation, the irrigation outside the shed was shut off because water started to pond on the soil surface outside the irrigation shed and surface runoff occurred. Nevertheless, because metal flashing was installed around the shed, there was no runoff into the shed.

After the precipitation, because it was difficult to decide when to turn the outside irrigation back on, the tile flow dropped to 130 mL s^{-1} . The irrigation outside the shed was again shut off at around 4.5 days after tracer application because of a forecasted local thunderstorm with high intensity. However, the storm never occurred. This event caused tile flow to drop and deviate from steady state flow. The generator failed at 7.5 days. This again caused tile flow to drop and deviate from steady state flow. After 10 days, the outside irrigation was accidentally shut down twice.

Although there is fluctuation in tile drain, Fig. 2 shows that bromide had distinct breakthrough pattern. Initial arrival was detected in tile drain only 16 minutes after its application. The saturated hydraulic conductivity of homogenized soil samples taken from the soil profile ranged from 3 to 20 mm h^{-1} . The irrigation inside the shed was very uniform and its intensity was less than the saturated conductivity of the soil. The quick initial breakthrough showed that bromide was leached down through preferential flow paths. In another tracer experiments, Kung et al. (2000, 2000a) applied a benzoic acid six hours after a steady-state irrigation with 3 mm h^{-1} intensity in the Clermont silt loam of the South East Purdue Agricultural Center of Purdue University in Butlerville, Indiana and the Rhinebeck variant loam of the Willsboro Research Farm of the Cornell University in Willsboro, NY, where tile drain was used as monitoring protocol. The results showed that the breakthrough of benzoic acid tracer in the tile occurred in 18 and 12 minutes after tracer application, respectively. Their sampling interval was every six minutes. It was rather surprising to find that the bromide breakthrough time in the Pella silt loam in southeastern Wisconsin was very similar to those in Indiana

and NY. The similar initial breakthrough time in three different sites indicated that the three sites have similar preferential flow pathways. This confirmed the hypothesis proposed by Kung et al. (2000a) that preferential flow pathways were not dictated by the soil textures and soil origins.

The bromide mass flux shown in Fig. 2 quickly increases two orders of magnitude within 6 hours after tracer application. The mass flux maintained essentially constant from 6 to 60 hours after tracer application. Afterward, bromide mass flux started to tail off gradually until 10 d after tracer application. The total bromide mass recovered from the tile was 85.1% of the total mass applied. The quick peaking and the high total mass recovered from tile again showed that most of the bromide was leached down through preferential flow paths.

In the second tracer experiment, the flow rate of tile drain fluctuated around 140 mL s^{-1} and again had slight diurnal because of the evaporation and transpiration (Fig. 3). There were 4 major natural precipitation events occurred from 90 to 300 h after tracer application and each event caused sharp increase of the tile flow hydrograph. This was beyond our control. Because the shutting off and turning on of the outside irrigation was better controlled during the second tracer experiment, the tile flow never dipped below the steady state rate of 140 mL s^{-1} .

Figure 3 shows that there is very low amount PFBA detected sporadically in tile drain from 10 minutes to 3 hours after application. Because the background PFBA concentration was essentially zero and the concentrations from samples collected during this period were well above the detection limit of 10 ug L^{-1} , we considered the breakthrough during this period was real. This early breakthrough suggested that preferential flow paths also participated in the transport of PFBA under a lower steady state infiltration rate of 0.89 mm h^{-1} . Theoretically, because the irrigation rate during the first tracer experiment was about 3 times higher than the second experiment, the bromide should have an earlier breakthrough time than PFBA. However, the PFBA arrived at only 10 minutes after application (vs. 16 minutes for bromide). This was mainly because the PFBA had a much lower detection limit of 10 ug/L as compared to 0.5 mg/L for bromide.

From 7 to 90 hours after tracer application, there was steady detection of very low amount PFBA. Although the PFBA breakthrough started earlier, the total PFBA mass recovered during the first 90 hours was only 0.16% of the total PFBA mass applied (vs. 66.6% for bromide during the same 90-hour period). This suggested that, although early breakthrough of PFBA indicated that the preferential flow paths participated under 0.89 mm h^{-1} infiltration rate, its impact on the total mass loss of a contaminant was negligible. This confirmed observation by Kung et al. (2000) that, when a soil profile became wetter during a prolonged precipitation event, more and more preferential flow pathways became hydraulically active.

It is around 90 hours after PFBA application when a main PFBA breakthrough starts to emerge (shown in Fig. 3). This main breakthrough curve peaked at around 240 h after tracer application. This slow peak was not observed in the Br breakthrough curve. This suggested that most of the PFBA was transported through soil matrix pores and the preferential flow pathways used to transport bromide during the first irrigation event were not hydraulically active during the second irrigation.

The total PFBA mass recovered from the tile during the entire sampling period was 16.8% of the total mass applied. Note that, however, when the irrigation was terminated, the breakthrough of PFBA is still gradually tailing off as shown in Fig. 3. As a result, the total PFBA mass leached out could not be accurately calculated. About twice amount of bromide mass was applied as compared to that of the PFBA. However, the mass flux of the PFBA at peak was about 16 times less than that of the bromide. The lower mass flux at peak and much broader breakthrough pattern together suggested that most of the PFBA had been transported through the soil matrix pores.

To confirm this assessment, the 1-D steady-state analytical solution of convection-dispersion equation by Jury et al (1991) was used to fit the PFBA mass breakthrough pattern. There are three parameters in the analytical solution, i.e., velocity V , apparent dispersion D , and the soil profile depth L . The V was derived from irrigation rate (0.89 mm h^{-1}) divided by the effective soil water content θ , which was 32% (measured from 4 soil core samples taken from the top 30 cm at the end of the experiment). The depth to tile drain was 0.95 m. The D was not measured during the experiment and was, therefore, adjusted to achieve the best fit.

The fitted analytical result is shown as a solid line in Fig. 3. It was found that when D was $5 \times 10^{-8} \text{ m}^2 \text{ s}^{-1}$ would achieve the best fit. This value was close to many lab measurements of D based on homogenized silt loam soils. The perfect fit between the measured breakthrough pattern and the analytical solution suggested that, under a steady state rate of 0.89 mm h^{-1} , vast majority of the tracer was transported in a field soil through the small matrix pores, which had little difference between homogenized lab condition and undisturbed field condition. Therefore, if the second tracer were reactive instead of conservative, it would have been most likely adsorbed and degraded and not reached the water table.

Summary and Conclusions:

Tile drain monitoring facility was used to examine chemical leaching patterns under two steady state infiltration conditions. Results from the first tracer breakthrough pattern showed that chemical arrival occurred within 16 minutes after tracer application and the peaking of breakthrough was very sharp. This demonstrated that preferential flow paths played significant role on contaminant transport in a field soil profile. This breakthrough pattern was ideal to be used in indirect method to assess the soil hydraulic properties.

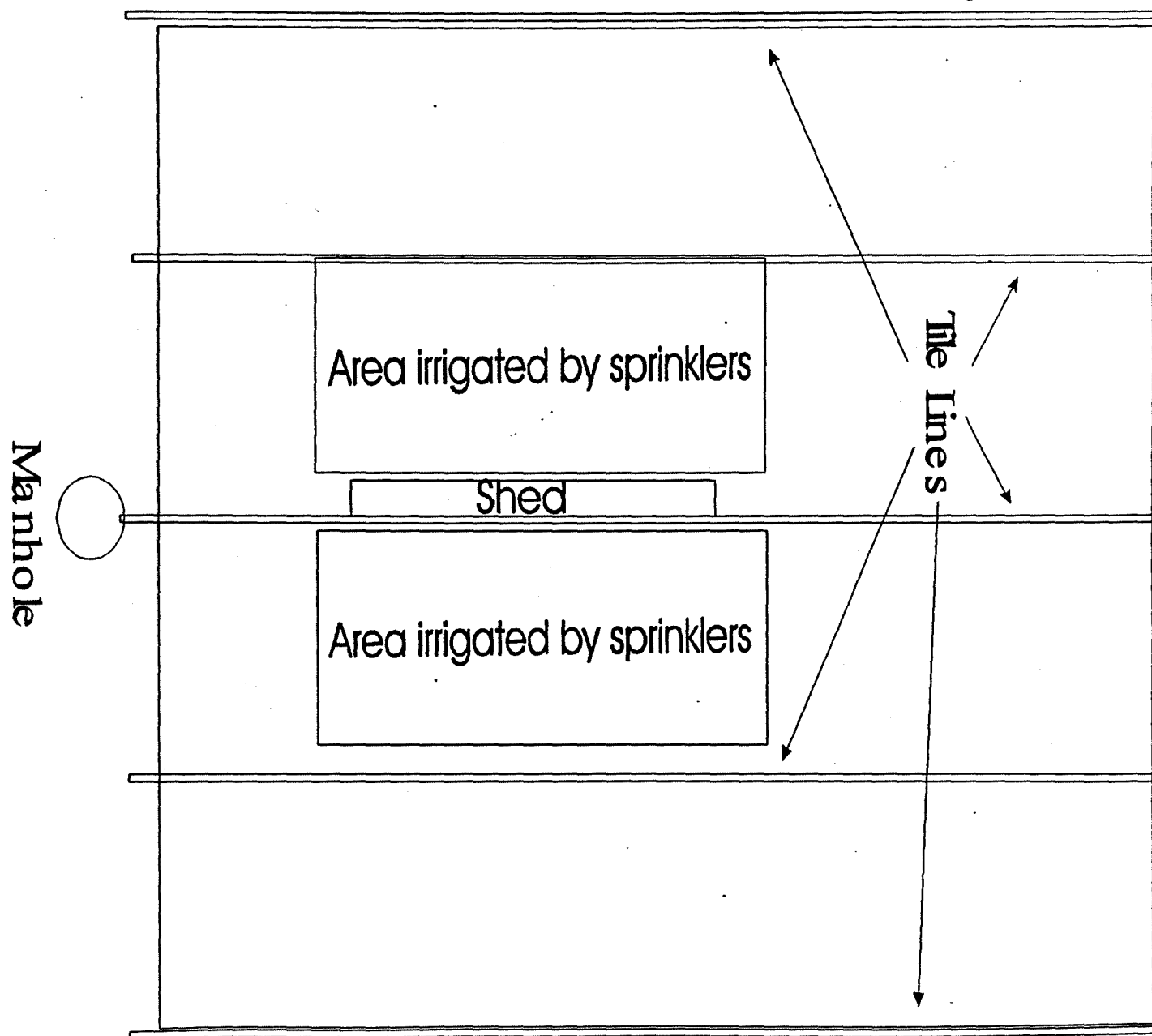
Results from the second tracer experiment showed that the main breakthrough did not occur until 90 hours after tracer application and the breakthrough reached peak slowly. This main breakthrough pattern coincided with an analytical solution based on 1-D convective-dispersive transport. This suggested that the spectrum of matrix pores under undisturbed field condition was similar to that of the homogenized soil. There was sporadic fast breakthrough. However, the total mass leached out before 90 hours was negligible. This indicated that the preferential flow paths were not hydraulically active and had little impact on the contaminant transport when the intensity of a precipitation event was below a certain value.

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Fig. 1



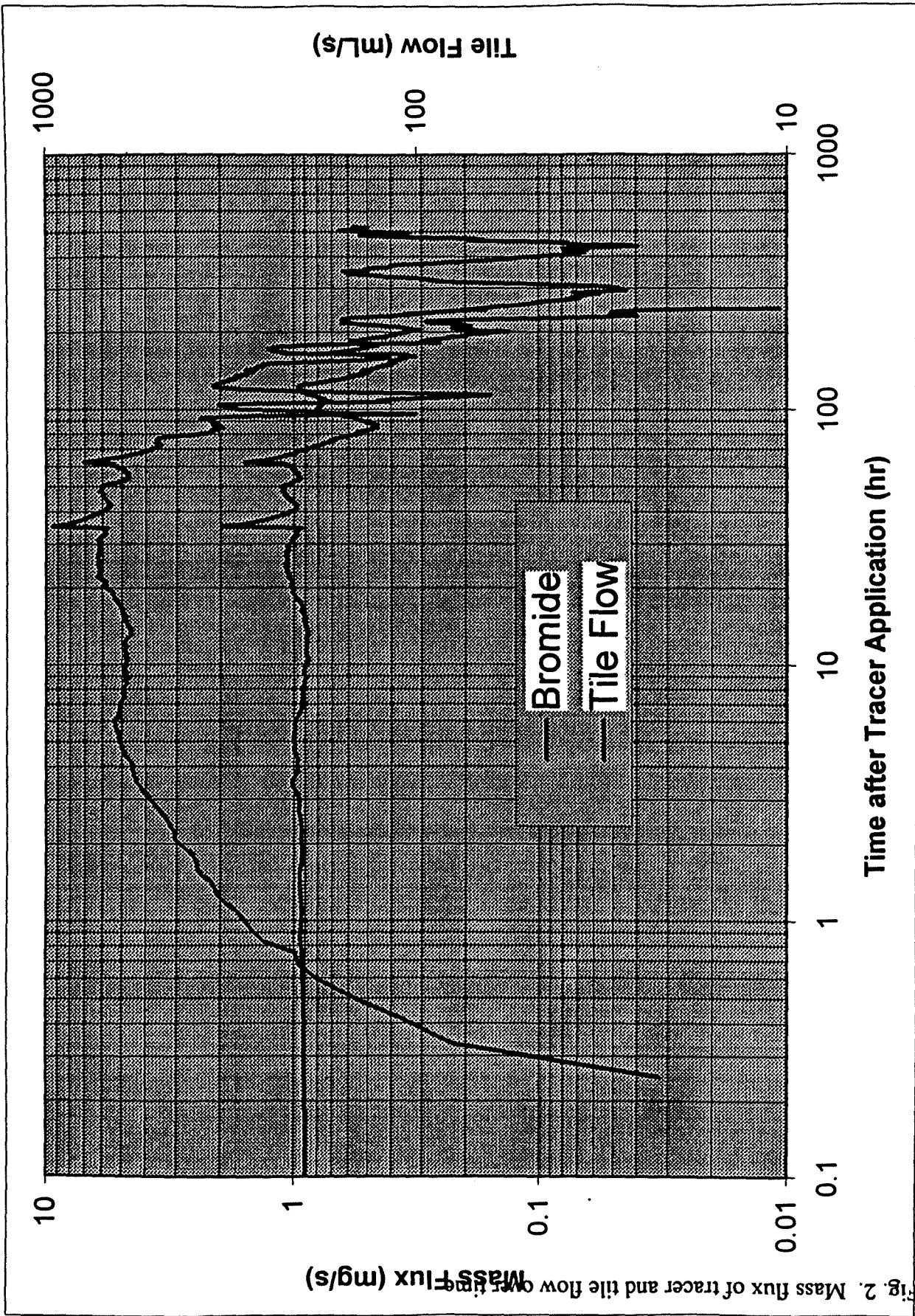
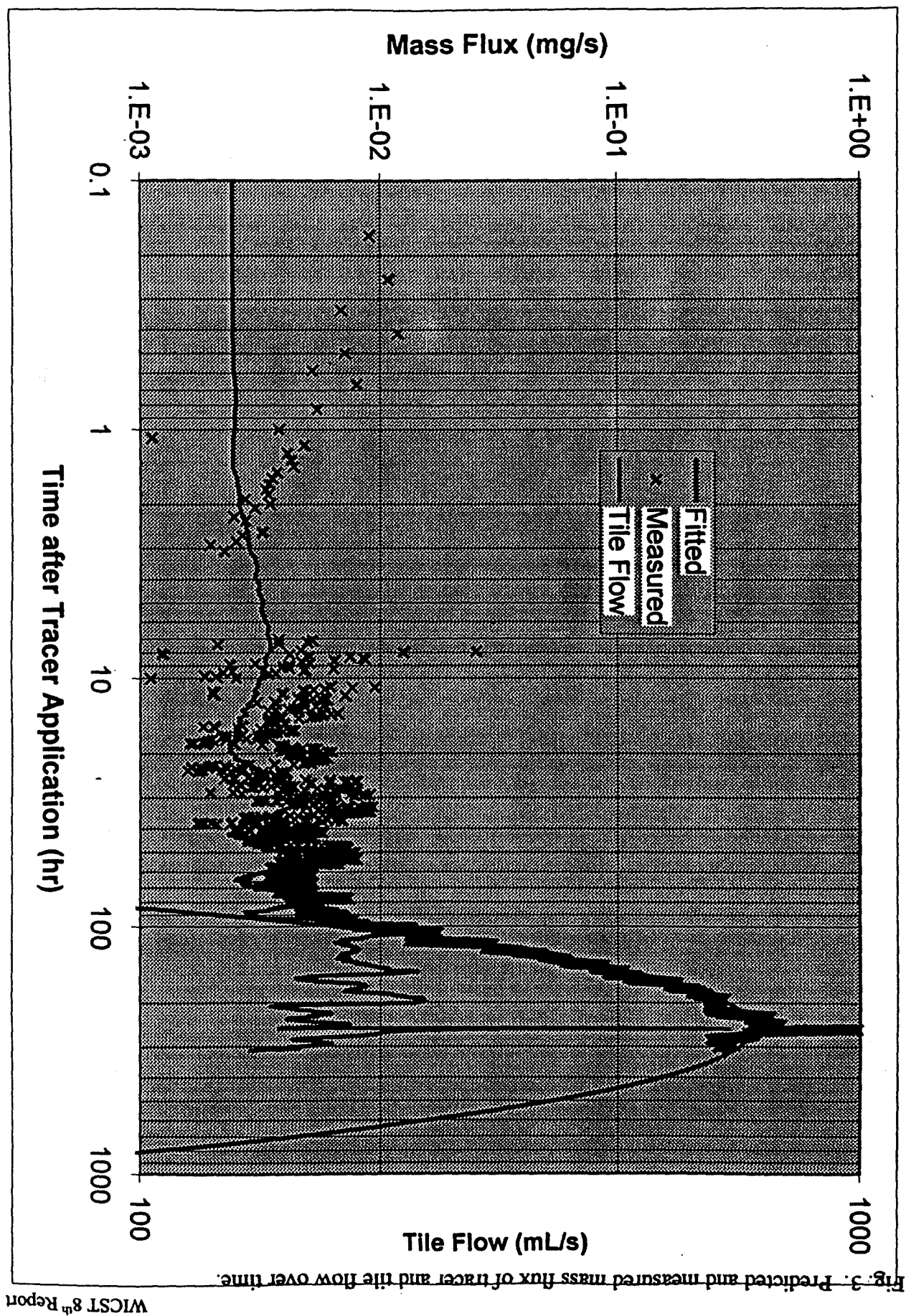


Fig. 2. Mass flux of tracer and tile flow over time



BIODIVERSITY PROJECTS

8. Earthworm Populations at the Wisconsin Integrated Cropping Systems Trial

Jon Simonsen¹, Martha Rosemeyer², and Joshua Posner³

Introduction

Many farmers, organic gardeners, and researchers have recognized earthworms as important organisms contributing to "healthy" soils (Romig et al. 1995). Earthworms are frequently associated with their ability to mix the soil (Cook and Linden 1996, Marinissen and Hillenaar 1997), increase rates of water infiltration (Bouche and Al-Addan 1997, Linden et al. 1991, Zachmann et al. 1987, Trojan and Linden 1994, 1998), improve soil aeration (Edwards and Lofty 1982), and build soil structure (Ketterings et al. 1997). They also have important roles in nutrient cycling (Blair et al. 1997, Subler et al. 1997, Bouche et al. 1997, Parmelee et al. 1998) and increasing the biological activity of the soil (Brown 1995, Doube and Brown 1998). Less positive functions of earthworms in agricultural soils include increased rates of nitrate and atrazine leaching (Tan et al. 1998, Sigua et al. 1995) and loss of residue cover (Gallagher and Wollenhaupt 1997).

In agricultural soils the earthworms are predominantly of European origin and are broadly classified into three functional groups (epigeic, endogeic, and anecic) according to their morphological attributes and ecological role in the soil (Bouche 1977). Epigeics are small pigmented earthworms that rarely burrow into the soil and live in the litter layer feeding on decaying organic matter. These species are common in forested areas but are rarely found in agricultural fields because of inadequate residue cover and surface moisture. The endogeic species are the most abundant earthworm in agricultural fields. Rarely found at the surface of the soil, these unpigmented earthworms are larger than the epigeics and continuously burrow horizontally through the soil searching for areas high in organic matter content. There is one species of anecic earthworm in Wisconsin, the well known nightcrawler (*Lumbricus terrestris*). This large pigmented species creates one or two permanent vertical burrows (up to eight feet deep) and feeds nocturnally by pulling vegetation from the soil surface into its burrow.

Research examining earthworms in agricultural soils has primarily focused on their response to a single input such as tillage or pesticide application but few studies investigate populations under field conditions that closely resemble those found on a farmer's field. Current research priorities include the need to study the effects of conventional and alternative agricultural systems on earthworm populations (Hendrix 1998). The experimental design of the WICST project provides an ideal setting to study the response of earthworm populations to field-scale, systems level management on both conventional and low chemical input cropping systems.

An initial screening took place at the beginning of the trial in 1990 and 1991 (Brown and

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Posner 1991) and work resumed in 1999 after the cropping systems had gone through at least two full rotations.

Materials and Methods

Soil cores were used to sample the endogeic earthworm populations. After extraction these cores were sorted through a ¼ inch sieve to ensure that all of the soil was thoroughly searched. The total number of earthworms was recorded and biomass was estimated by weighing the preserved specimens in the lab⁴. In April 1999 two soil cores were extracted from all plots⁵ at Arlington and Lakeland using a cylindrical coring device that measured 89.03 cm² X 25 cm (0.0022 m³). This was similar to the sampling procedure used by Brown and Posner nine years earlier. A number of pilot studies were also conducted during this period to determine the subsampling effort required and to see if earthworm numbers could be correlated with the field drainage (elevation) or proximity to the grass buffer edge between plots.

Soil sampling was repeated in June 1999 using a flat spade marked at 25 cm to excavate larger soil cores approximately 625 cm² X 25 cm (0.0156 m³). Again, two samples were extracted in each plot and sorted through a ¼ inch sieve at both Arlington and Lakeland. To determine if earthworm number could be correlated with the groundcover, vegetation, or incorporated crop residue, these parameters were visually estimated for each soil sample. To determine if earthworm numbers were correlated with soil organic matter content⁶ or soil moisture⁷ subsamples of the cores were taken from all plots at Arlington but only ½ of the plots (2 blocks) at Lakeland.

A third sampling effort followed in July 1999 to quantify the deeper burrowing *Lumbricus terrestris* (nightcrawler) which, because of their deep permanent burrows, are often missed by the soil cores. Nightcrawler activity was recorded by counting the number of active middens⁸ in a 1.0 m² quadrat. Twenty quadrats were taken in each plot at both sites.

Results and Discussion⁹

Earthworm Species Identification:

Earthworms were identified from the soil cores in terms of functional group on the basis of presence or absence of pigmentation. The core sampling rarely captured nightcrawler adults. Juvenile anecics were captured but these earthworms are polyhumic endogeics that feed on organic matter in the upper soil profile until they are large enough to create the vertical macropores (Sam James pers. comm.). Consequently in the data analysis the numbers from the soil cores are used to represent the number of the endogeics and the midden data are used to measure the number of anecic earthworms.

In 1991 Brown and Posner found that the predominant species were *Aporrectodea tuberculata* and *turgida* (endogeic) and *Lumbricus terrestris* (anecic). The earthworms collected in 1999 from the spring (April) and summer (June) soil cores were immediately preserved in 100% EtOH. However this did not preserve the diagnostic characteristics

⁴ Soil was not dissected from the digestive system.

⁵ WICST is designed as a randomized complete block experiment, one block was sampled each day.

⁶ Loss on ignition procedure – Soil and Forage Analysis Lab, UW Madison.

⁷ Gravimetric method

⁸ Middens are the small mounds of litter and casting material created by feeding activity at the soil surface above the burrows.

⁹ All significant results are reported at $\alpha \leq 0.05$.

needed for identification. In order to start a reference collection adults were collected from one day of sampling at Arlington and Goose Pond Sanctuary in late June. These specimens were preserved with a 10% formalin solution for 24 hours followed by 70% EtOH (Schwert 1990). Four species were identified¹⁰: *Lumbricus terrestris* (Linnaeus), the anecic nightcrawler, and *Aporrectodea tuberculata* (Eisen), an endogeic, were identified from the WICST plots. The endogeics, *A. tuberculata*, *Octolasion tyrtaeum* (Savigny), and *Eiseni rosea* (Savigny) were found at Goose Pond Sanctuary.

Pilot Studies:

Graphical analysis of sample size for the spring soil core data show that much of the variation in estimating the mean is removed when eight or more soil cores were extracted from a plot. Application of the sample size formula $n = ((z * \sigma) / d)^2$, where (z) = the $\alpha/2$ upper quantile of the normal distribution, (σ) = standard deviation of the measurement¹¹, and (d) = the error of margin from the true mean that is tolerated¹² (Yandell 1997), for the data indicate that an average of 21 subsamples are required per plot. Such a large sample size was not feasible and prompted the second sampling of the plots using a larger soil excavation and more hired help to maximize the sampling effort. A more detailed statistical analysis examining the effect of core size and subsampling effort will be done in 2000.

The graphical analysis of sample effort for the midden sampling indicated that most variation of the population mean estimate was reduced when 15 or more quadrats were taken per plot. Using the same sample size formula for the data indicated that an average of 11 quadrats were required per plot.

Somewhat surprisingly, there were no significant differences between the number of earthworms taken from the grassy edge vs. the center of a plot or the topographically high vs. low areas. Additionally no relationships were observed between the number of earthworms and the amount of incorporated crop residue, percent bare ground, percent litter, percent live vegetation, percent crop, percent weed, soil organic matter content, or percent soil moisture.

Total Earthworm Numbers:

Population levels were typical of agricultural systems (Edwards and Bohlen 1996) and the endogeics greatly outnumbered the anecics (Figures 1a & 1b)¹³. In 1991 numbers were higher on the better drained Arlington soils (279/m²) than the somewhat poorly drained Lakeland soils (197/ m²). In 1999 both Arlington and Lakeland had similar endogeic populations that ranged from 34 to 374 /m² (Figures 2a & 3a). Midden density ranged from 0 to 27 /m² (Figures 4a & 4b) but Lakeland had 56% less than Arlington (Figure 1b). The reduced nightcrawler activity at Lakeland is a consequence of the shallower soils and a heavy rain event that ponded the plots prior to the summer soil core (June) and midden sampling (July). When the fields began to dry many decomposed earthworms were observed at the surface of the soil.

As expected, earthworm numbers decreased in the summer (June) when compared

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¹¹ Estimated from the data.

¹² An acceptable difference (d) was set at 1 worm /soil core and (z) was set at 0.025.

¹³ Biomass data for nightcrawlers will be collected during the 2000 field season.

to the spring (April) sampling at both sites. The total population at Arlington decreased 17% but at Lakeland populations decreased significantly by 52%. As soil temperatures rise and the soil moisture levels decrease endogeic earthworms burrow deeper into the soil profile, and enter into a state of quiescence during which they curl themselves into a tight ball to reduce water loss, and reduce their metabolic rates until conditions become favorable (Edwards and Bohlen 1996). During the second soil core sampling both aestivating and active individuals were found in the soil cores at both sites. This indicates that some endogeic earthworms had already burrowed below 25 cm, entered into dormancy and were missed. Mechanical weed control in CS3 and CS5 may also be a factor reducing the populations. The greater decrease of earthworm numbers at Lakeland is a result of the heavy rain event that reduced the populations in all cropping systems.

Cash-Grain vs. Forage-Based Cropping Systems:

By the fall of 1991 (October) differences between treatments were beginning to become obvious with the forage systems having higher numbers of endogeic earthworms than the cash grain rotations. In 1999 we still expected to find higher earthworm populations in the forage-based systems because of the use of manure (Edwards and Loftly 1997) and the reduced tillage during the alfalfa phases of these rotations (Kladivko et al. 1997, Jordan et al. 1997, Clapperton et al. 1997) (Figures 2 & 3). During both soil sampling periods at Arlington the cash grain systems had 59% fewer earthworms than the forage-based systems. The cash-grain systems averaged 133.1 and 110.8 earthworms /m² during the spring core and summer excavation sampling respectively and the forage-based systems averaged 327.9 and 273.1 earthworms /m² during the same periods. Similar results were obtained at Lakeland which had 56% less earthworms in the cash grain systems during the spring sampling (186.2 and 422.9 earthworms /m² respectively)¹⁴. Nightcrawler activity at Arlington was also lower in the cash grain rotations where there were 28% less middens than in the two forage-based systems (CS4 and CS5)¹⁵.

Cash-Grain Cropping System Comparisons:

We expected the no till cropping system to have the highest number of earthworms because of minimal soil disturbance and CS1 to have the lowest because of yearly tillage and intensive chemical use. We anticipated that CS3 would fall in the middle because the intensive mechanical weed control will reduce populations but the wheat/ red clover phase may promote earthworm numbers (Edwards and Bohlen 1996).

In 1991 more endogeic earthworms were found in the lower chemical input system (CS3) than the higher chemical input continuous corn rotation (CS1). In 1999 during the spring sampling earthworm populations in CS2 and CS3 were similar at both sites (Figure 2a). CS1 had the significantly lowest number of earthworms at Arlington but at Lakeland the continuous corn system was similar to the other grain systems (Figure 2a). During the summer sampling at Arlington CS2 had the highest number of earthworms /m² followed by CS3 and CS1 all of which were significantly different

¹⁴ No comparisons could be made during the summer sampling at Lakeland because of the transitional cropping systems (CS4 and CS5).

¹⁵ Nightcrawler activity could not be estimated in the pasture because of the difficulty in delineating the middens with the dense vegetative cover and trampling by cattle. No comparisons could be made at Lakeland because neither the pasture or the two transitional cropping systems could be included in the analysis.

(Figure 3a). At Lakeland the same pattern was evident but there were no significant differences (Figure 3a) and it is likely that cropping system effects were masked by the large rain event. As noted earlier earthworm numbers decreased during the second sampling but not all systems decreased in the same way (Figures 2a & 3a). The mechanical weed control used in CS3 during the corn phase of the rotations can directly influence earthworm populations (Werner and Dindal 1989). Alternatively, in the no till system (CS2), where there is minimal soil disturbance, the endogeics are still present later in the season. This pattern was observed at Arlington where numbers decreased by 74 earthworms /m² in CS3 but did not change much in the continuous corn (-8.2 earthworms /m²) or no till systems (+15.2 earthworms /m²). The same pattern was not observed at Lakeland primarily as a result of the large rain event and all three cropping systems had similar declines in earthworms /m² (-139.7 (CS1), -93.2 (CS2), -104.7 (CS3) earthworms/ m²).

The response of active middens to cash-grain cropping systems were very similar at both sites even though Lakeland had lower midden numbers (Figure 4a). The no-till cropping system, CS2 had significantly higher numbers compared to CS1 and CS3 which were similar to each other¹⁶.

Forage-based Cropping System Comparisons:

In the forage-based cropping systems we expected the rotationally grazed pasture to have the highest earthworm population because there is no tillage, a well developed sod (Springett and Gray 1997), and addition of manure and urine by heifers throughout the growing season. Differences between CS4 and CS5 were more difficult to predict. CS5 promotes earthworm populations because it has low chemical inputs and a less intensive cutting schedule but reduces populations because it receives fall tillage and intensive mechanical weed control once every three years of the rotation. CS4 may reduce populations by using pesticides and an intensive cutting schedule that may lead to soil compaction but would promote earthworm populations because it gets tilled less intensively one out of every four years of the rotation. We hypothesized that CS5 would have lower earthworm populations than CS4 because of the intensive mechanical weed control every three years.

In 1991 there were no differences observed in the forage systems. In 1999 the rotationally grazed pasture did usually have higher populations than the other two systems but the difference was only significant during the spring soil core sampling at Lakeland where high numbers of earthworms were observed (674 /m²) (Figures 2b & 3b)¹⁷. There were no significant differences found when comparing CS4 and CS5 for any of the soil core sampling dates or the number of middens recorded in these systems.

When comparing endogeic earthworm populations in the spring vs. summer soil sampling at Arlington CS5, the low chemical input system with mechanical weed control, had the greatest decrease (-132 /m²) in the number of earthworms compared to CS4 (-28 /m²) and CS6 (-4 /m²) (Figures 2b & 3b).

Summary

These preliminary results suggest that primary tillage, mechanical weed control, and manure application have a large influence on the earthworm populations. Future

¹⁶ Middens were not counted in the spring so no seasonal patterns could be observed.

¹⁷ CS4 and CS5 at Lakeland are transitional cropping systems and not included in the summer analysis.

analyses will focus on the response of the earthworm functional groups within the context of cropping system phases to further tease apart their population dynamics in these cropping systems.

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Figure 1a and 1b. Total earthworm populations on the WICST plots (a) average # of endogeics (b) average # of anecics

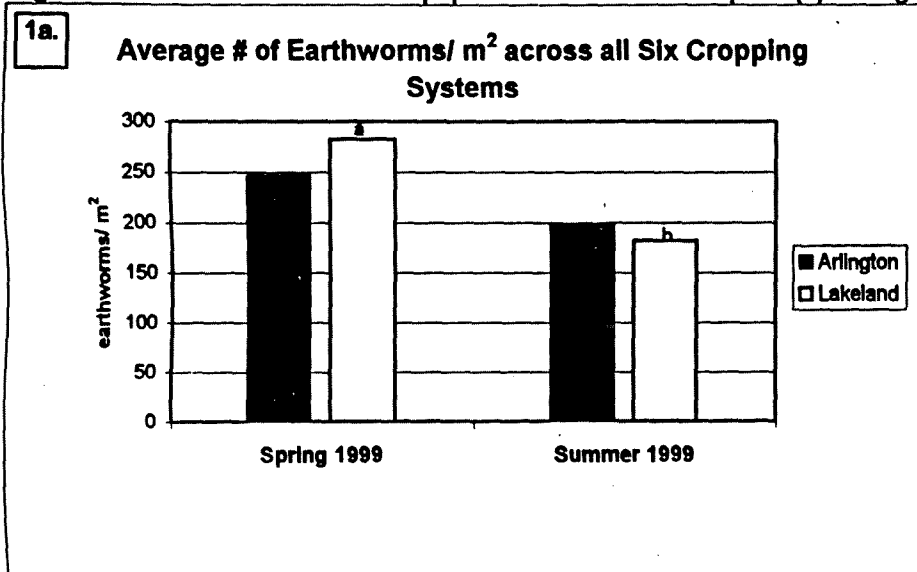
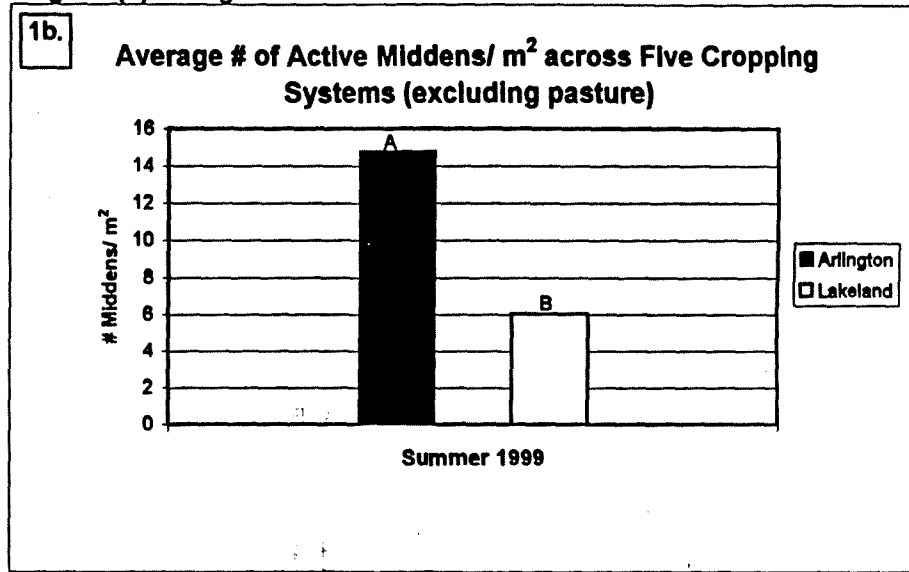


Figure 2a and 2b. Number of endogeic earthworms from the spring soil core sampling (a) cash-grain systems (b) forage-based systems.

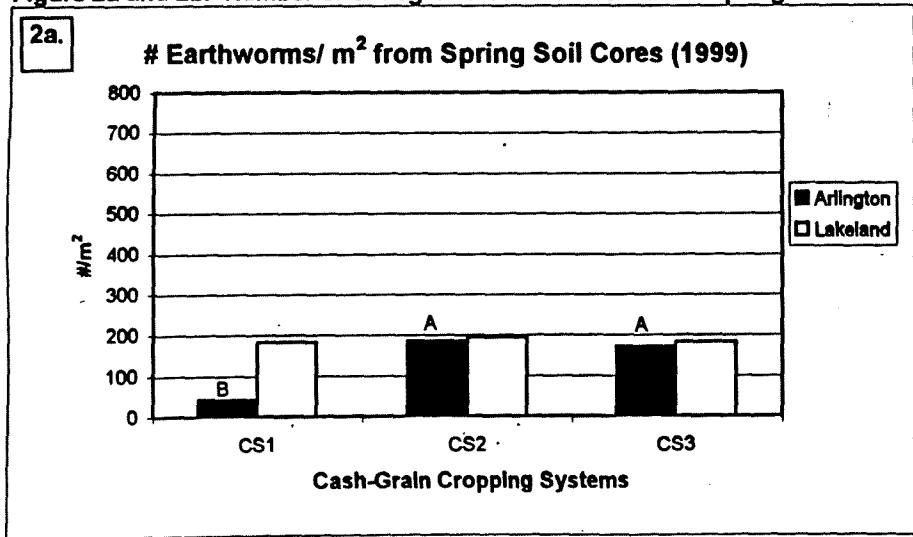
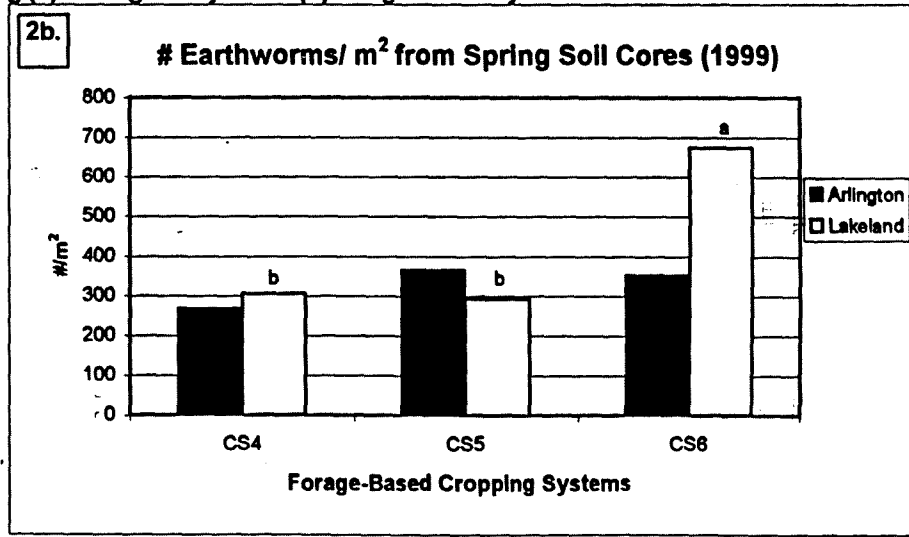


Figure 3a and 3b. Number of endogeic earthworms from the summer soil core sampling (a) cash-grain systems (b) forage-based systems.

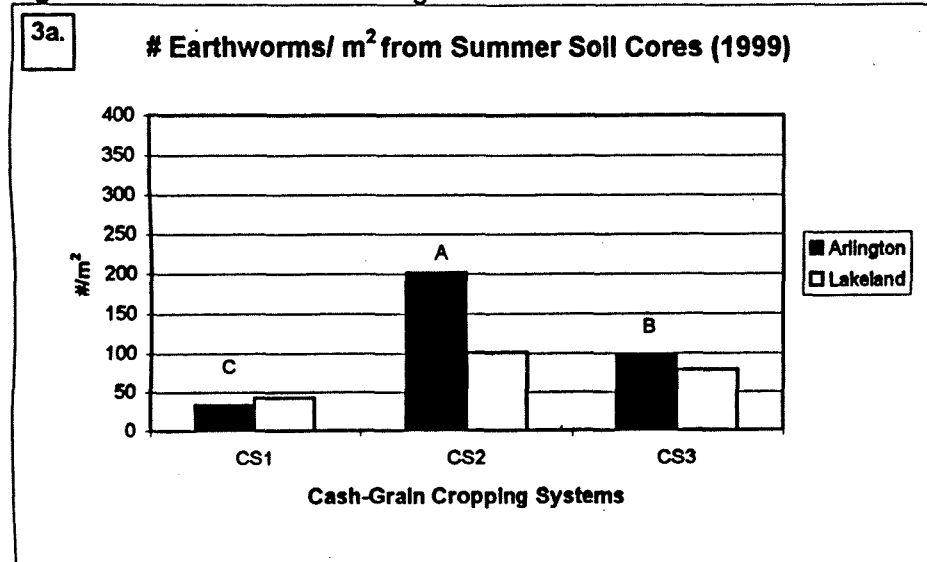
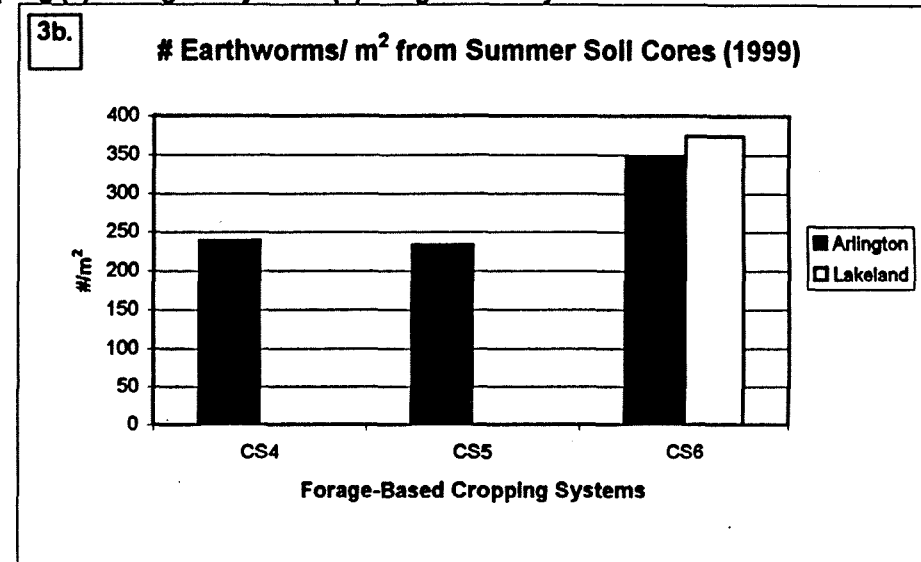
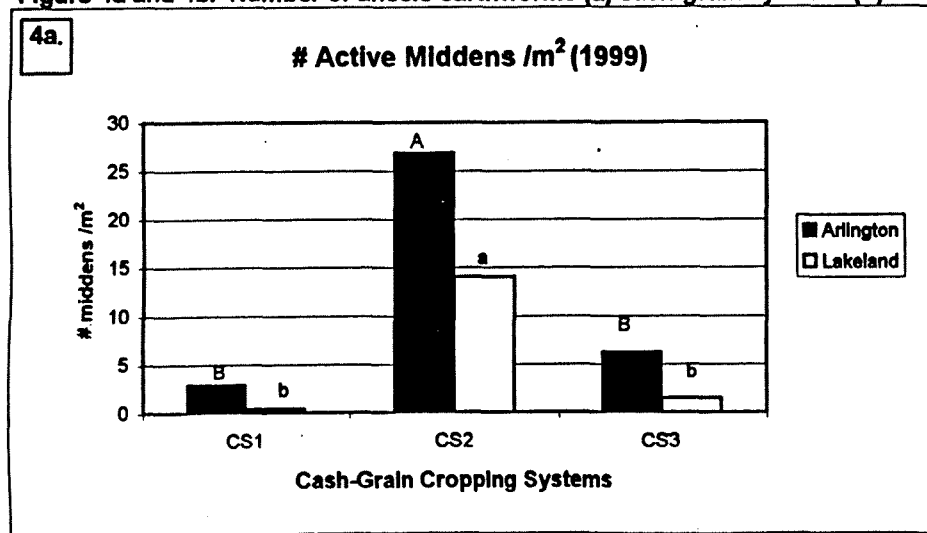
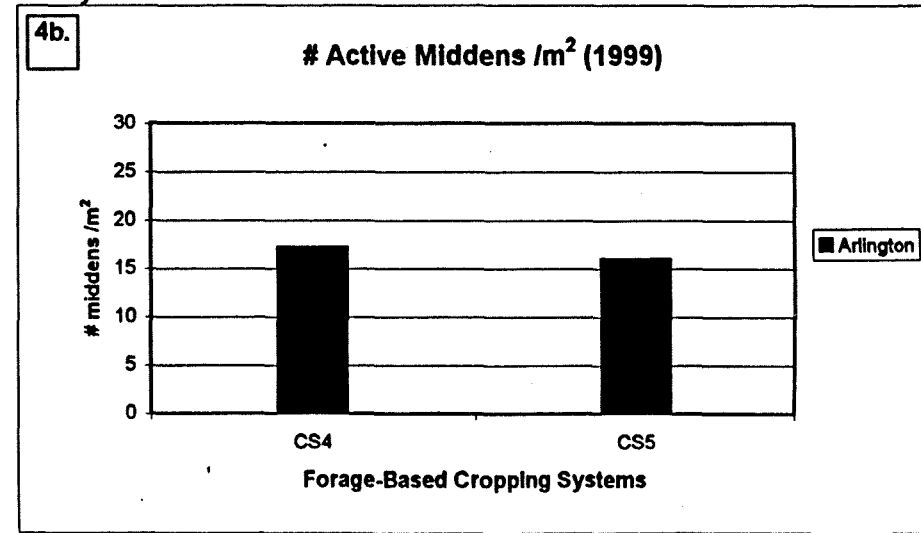


Figure 4a and 4b. Number of anecic earthworms (a) cash-grain systems (b) forage-based systems



9. Effects of Agricultural Cropping Systems on Soil Microbial Community Structure.

P.A. Selbach, A.S. Yuroff and W.J. Hickey

Microorganisms of the Bacteria (no nucleus), Eucaryotes (nucleus) and Archae (an ancient, anaerobic group) were sampled using molecular techniques so that unculturable microorganisms could also be assessed. The general structure of the microbial community changes with cropping system (CS3, CS5 and CS6) at Arlington in one soil sampling time in 1996 (check date?). The Eukaryotes dominated in relative abundance followed by bacteria and the Archae in all systems (see Figure 1). However, the Archae were significantly greater in the systems where manure was applied (CS5 and CS6), than in CS3. Many Archae are methanogens and may have been introduced with the manure. Eucaryotes were significantly greater in CS3 where residues of green manure crops were in decomposition.

10. General summary: WICST cropping system effects on Ground-dwelling Arthropods 1995-1997

E. Rebek, D. Young, D. Hogg, M. Rosemeyer and T. Lim

Arthropods were collected from pitfall traps (1995 and 1996), soil cores (1995, 1996 and 1997) and litterbags in CS1, CS3, CS5 and CS6 at the Lakeland and Arlington sites. (Litter bags will be discussed elsewhere.)

In soil cores from Arlington in 1997 there were a greater abundance of insects in CS1 and CS5 (Figure 1), although in Lakeland there was a greater abundance in the pasture than the other cropping systems. Species diversity was only significantly greater at Lakeland where CS3, CS5 and CS6 were greater than CS1 (Figure 2). In pitfall traps throughout the cropping season the relative abundance of insects in cropping systems change with a greater abundance in pasture later in the season.

Taken together an interesting pattern emerges-- it appears that Arlington was greater in abundance in CS1 and CS5, but with an equivalent number of taxa in all four systems. On the other hand in Lakeland the pasture had the greatest abundance of insects but its diversity was equivalent to that of CS3 and CS5.

When we examine functional groups further differences appear. Cropping systems had characteristically different functional groups of insects. Predators (spiders and harvestmen) found in pitfall traps were significantly greater in the pastures and forages in certain years or time in relation to the cutting cycle (Figures 3 and 4). Spiders respond to the structure of vegetation and litter layer (Rypstra et al. 1999). Consequently and the relative constancy of pasture structure may have contributed to this.

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SATELLITE TRIALS

11. Summer Seeded Cover Crops — 1996 through 1999

J. Posner¹, J.L. Hedtcke¹, S.G. Alt¹, J.K. Stute²

Introduction:

Leguminous cover crops are potentially important phases in rotations due to their beneficial effects on soil nutrients, organic matter accumulation and the prevention of erosion. These cover crops can be planted with or subsequently to a small grain which is harvested midway through the growing season. Although cover crops are cheaper to frost seed into winter wheat or companion seed with spring-seeded small grains, many farmers in the upper Midwest prefer seeding cover crops following small grain harvest. This is due to their concern that the cover crops can adversely affect straw quality. Frequently, clean small grain straw will add \$70-\$100/acre to the value of the crop (60 bu/a wheat; 100 bu/a oats). The recommended summer-seeded option however, is expensive (\$30/a seed costs) so it is necessary to look for other alternatives.

The second issue to be addressed in these trials dealt with the speed of re-establishing ground cover after the cover crop planting. NRCS officials were concerned that a new planting of cover crops would disturb the existing ground cover of the small grain residue (personal communication J. Pingry, 1996). As a result, in an effort to increase biologically fixed nitrogen in the rotation, one could inadvertently increase the potential for soil erosion in the late summer.

In order to address these two issues of summer seeded cover crop options and tillage methods for sequential seeding, a three-year study was initiated at Arlington in August, 1996. In 1996, 1997 and 1998 cover crop plots were planted and evaluated. In all 3 years, corn was planted over the previous year's cover crops to measure the yield effect of the plowdown green manure.

Materials and Methods:

All three of the annual plantings were done on the Stemke farm, on a prairie-derived plano silt-loam, located near the Arlington Research Station. Seven different cover crops and cover crop mixtures followed a small grain crop each year (Tables 1 and 2). A split-plot treatment design was used with tillage level as main plots (no-till and conventional till) and cover crop species as the subplots. The cover crops options were selected due to their estimated price, reported ability to rapidly fix nitrogen, and in the case of the mixtures, to see if we could combine lower price, adequate N-accumulation and rapid ground cover. The trial design was a randomized complete block with 4 repetitions and individual plots measured 50 feet long by 20 feet wide.

The small grain straw was bailed off prior to the cover crop planting. The no-till cover crop plots were directly seeded with a John Deere no-till drill. Conventional tillage in 1996 consisted of a single pass with the soil finisher; an implement with disks, 6-inch sweeps, and a leveling drag. In 1997 and 1998 a disk preceded the soil finisher. The cover crops were then seeded with the same no-till drill adjusted for proper seed placement. Biomass measurements on the cover crops were made in mid to late October once it was clear that a killing frost had taken place. To insure overwinter kill, a chisel plow or sweeps were used in mid-November in preparation for spring corn planting.

In the second year, a 95-day corn was planted (32,000 seeds/A) over the cover crop plots in mid-May after the field was disked and received one pass from the soil finisher (Table 3). Aside from starter fertilizer (100 # of 6:10:10) and a pre-emergence herbicide, the corn received no additional inputs. On the fallow treatment under each tillage regime (conventional till; no-till), a small fertilizer response trial was laid out and subplots received 0, 40, 80, 120, 160, and 200 lb N/a. Corn was hand-harvested in the fertilizer response plots (2 rows by 17 feet) and machine-harvested on the cover crop plots (4 rows by 50 feet). The response curve developed each year made it possible to estimate the Fertilizer Replacement Value (FRV) of each of the green manures.

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Percent ground cover from both small grain residue and live plants of the seven planted species, and the unplanted check was monitored each year at 0, 15, 30 and 45 days after planting (DAP). The line transect method was used to estimate percent ground cover by taking a 5m string with marks every 8 cm, and making 2 transects per plot (Lafien et al., 1981). The frequency of intersections between marks on the string and seeded crop and plant residue laying on the soil were recorded and converted to percent ground cover. Cover crop biomass was estimated by taking two 0.5m² samples in each plot in the fall just after a killing frost. The material was then separated into green manure, weed and volunteer grain fractions and dried in a forced air oven at 60°C for 72 hours. After the separate fractions were dried and weighed, they were ground and analyzed for total N content. Data were analyzed separately each year using ANOVA and means were separated with Fisher's LSD or Duncan's Multiple Range Test.

Results and Discussion:

Weather conditions:

Low late-summer rainfall in 1996 markedly affected cover crop growth (Table 4). August plus September total rainfall was only 3.69 inches, less than half of the long-term average (1961-1990, 8.16 in). As a result, this was a very good year to test the potential of sequential seeding under dry conditions. August and September rainfall of 1997 was also well below average (4.77 inches), but 3.2 inches occurred in August accompanying high soil moisture conditions from July rainfall. This assured good cover crop establishment. Late summer rainfall in 1998 was excellent for establishment and growth.

Evolution of Ground cover (Fig. 1a-c):

After small grain harvest and straw removal, it appears that there is about 35% of the ground was still covered by small grain residue. In the fallow plots, ground cover increases up to 80% over the next 15 days due to volunteer small grain regrowth and weed development- depending on year and moisture. The no-till planter causes little disturbance and by 15 days after planting, ground cover was above 80% in 1997 and 1998 but only 40% in the dry 1996 summer. This was our first summer with the no-till seeding and we think part of our problem was poor seed-to-soil contact. With conventional tillage, some disturbance takes place and groundcover dropped to 25% just after planting. However, by 30 days after planting, ground cover was equivalent to the fallow plots. The large-seeded options, like field pea, soybeans, hairy vetch and the combinations with rape, grew somewhat more quickly in August than the small-seeded species (e.g. berseem clover and annual medic) (1996 WICST Annual Report). This data from three summers of work indicates that no-till summer seeding of cover crops will result in a very rapid increase in ground cover after the small grain harvest. With conventional tillage, initially some small grain residue cover will be lost, but within 30 days the tilled plots were approximately equivalent to the undisturbed fallow plots.

Above Ground Biomass and Nitrogen Accumulation:

No-till planting was advantageous for speed of ground cover, as well as biomass and N accumulation. No-till treatment produced higher total biomass, as well as cover crop biomass than conventional tillage in 2 out of 3 years. However, cover crop biomass was only significantly greater in 1997 ($p < 0.1338$ -1996, 0.0139 -1997, and 0.1115 -1998) (Fig. 2). In 1996, conventional tillage had twice the volunteer small grain than no till ($P < 0.0166$) though there were no differences in the other two years. There were no differences between tillage treatments for total weed biomass. Higher cover crop yields with no till is likely due to less soil disturbance and therefore less soil moisture loss.

Nitrogen from the total above ground biomass was higher on the no till treatment 2 out of 3 years but was only statistically significant in 1997 (Fig. 3). Weeds were not included in the 1997 analysis since they represented less than 1.5% of the plot biomass. The cover crop portion of the biomass accumulated between 30 and 60 lb N/a. Generally speaking, the volunteer small grain accumulated between 10 and 25 lb N/a by the first killing frost across all species (Fig 3). Fallow plots accumulated higher N rates of 20 to 40 lb N/a from volunteer small grain.

There was a significant difference in biomass nitrogen among the planted cover crops, but no interaction with tillage system. As a result, the mean per species of the two tillage treatments is represented in Table 5. These numbers are total biomass N (cover crop + volunteer small grain + rape + weeds) and the final row (bars) represent the fallow plots where there was only volunteer small grain. The most productive cover crop options under our

conditions appears to be hairy vetch (the current recommendation), field peas, and soybeans. Somewhat cheaper but also less productive are the options including rape. The breakdown by biomass production and nitrogen for the two mixes is presented in Figure 4 a&b. In two out of three years, rape made up the largest proportion of the total biomass of the mixed seedings. Nitrogen levels ranged from 50 to 75 lb N/a for the two mixes with hairy vetch/rape mix being more productive of the pair in all 3 years.

Corn Yield:

There was no significant interaction between cover crop tillage treatment and subsequent corn yield. As can be seen in Table 6, corn following hairy vetch, berseem clover, and soybeans generally produced the highest yields. In order to calculate fertilizer replacement value (FRV), the regression curves in Figure 5 were drawn. They are based on the average response of the corn grown on the no-cover crop fallow plots with a range of fertilizer additions (0-200 lb N/a). Substituting actual corn yields from the green manure plots into the regressions permits estimating the FRV of the green manure itself. Good weather conditions during cover crop establishment in 1998 produced the most green manure and actually resulted in 1999 corn yields (another good year) above any of the fertilized treatments. Since the fertilizer rates did not go above 200# N/A, the green manures are given a forfeit FRV of 200 #N/A (Table 7). In the dry conditions of 1996 (1" of rain in 20 days following planting), poor cover crop establishment and thus less green manure production resulted in lower FRV ranging from 15 lb N/a for annual medic to 57 lb N/a for field peas. In 1997, cover crop establishment was good, but corn yields the following year were mediocre. In general, hairy vetch and berseem clover had the highest FRV over the 3-year trial.

Conclusions:

- No-till systems are as good or better than conventional (conservation) tillage when establishing cover crops. Ground cover, biomass and N accumulation all tend to be higher under no-till.
- Hairy vetch, field peas, and soybeans were the most productive cover crops with respect to legume biomass. Mixtures with rape can decrease the seed price but also result in lower N production.
- Berseem clover, although mediocre in biomass and N accumulation, produced the highest corn yields. In 2 out of 3 years, berseem clover had the highest FRV. Annual medic was not much better than fallow.
- Substantial N credits can be assumed (100 lb N/a) if green manures like berseem clover or hairy vetch were well established the year before. Small grain stubble and volunteer regrowth contain up to 25 lb N/a.

Footnote 1. In 1999, total N content of corn grain ranged from 1.20 to 1.30% for the cover crop species treatments. Total N increased from 1.30% on 0 lb N/a treatment and peaked at 1.47% on the 80 lb N/a treatment.

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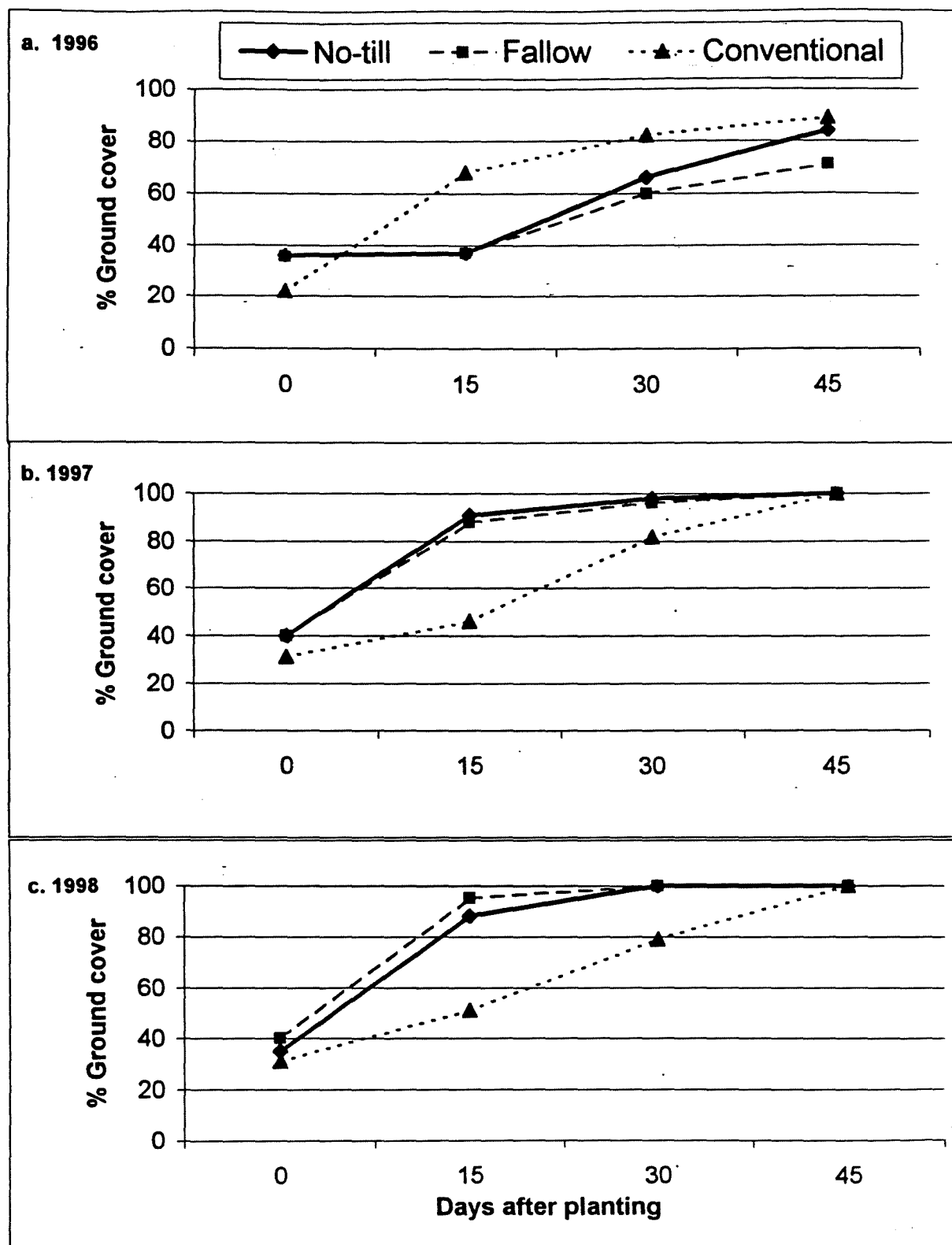


Fig 1. Evolution of ground cover with summer seeded cover crops (mean of 7 species and 4 replications).

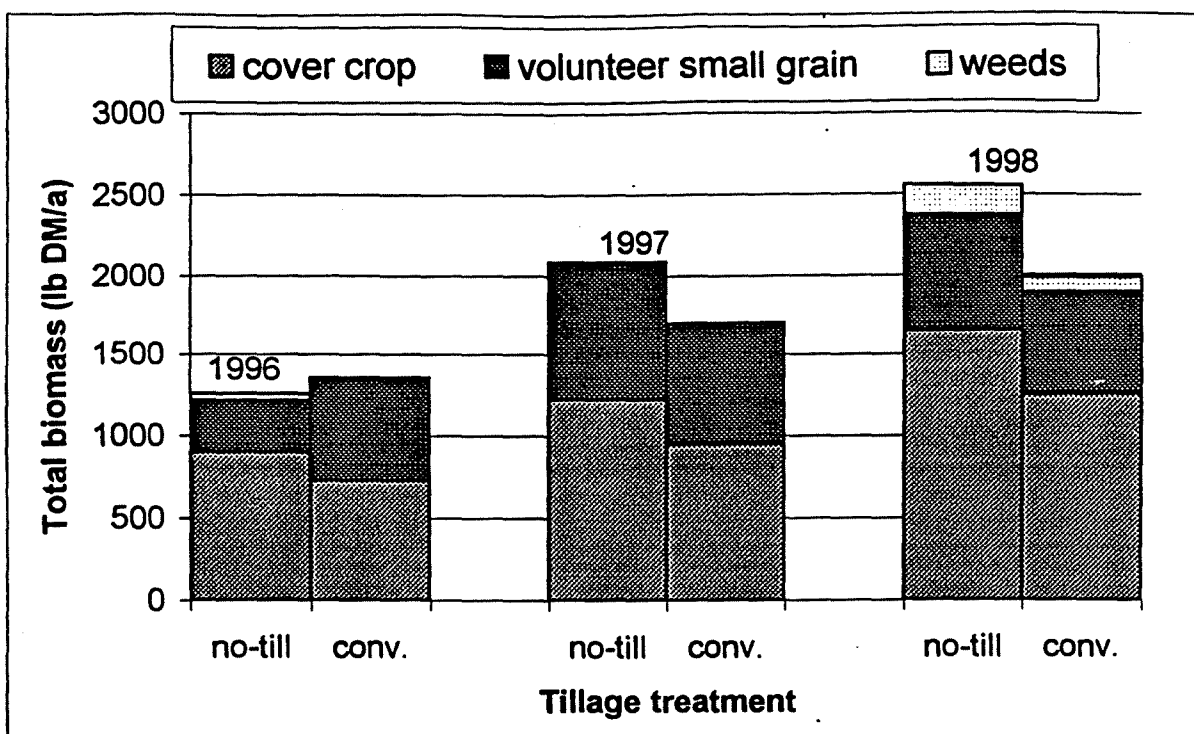


Fig. 2. Mean biomass (cover crop, small grain, weeds) at frost on no till and conventional tillage treatments in 1996, 1997, and 1998. (Weeds in 1997 were less than 1.5% of total and were not included). Means are averaged over 7 species and 4 replicates.

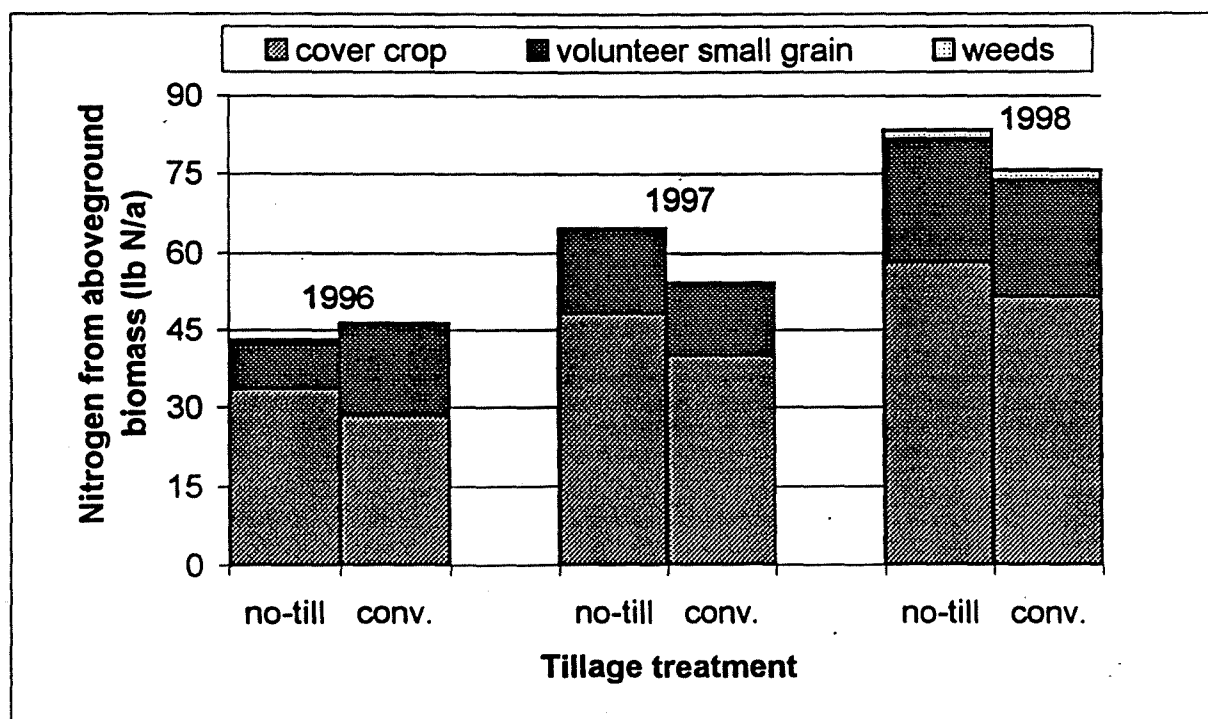


Fig. 3. Total N from aboveground biomass (cover crop, volunteer small grain and weeds) on no till or conventional tillage treatments at frost for 1996-1998. Means are averaged over 7 species and four replicates.

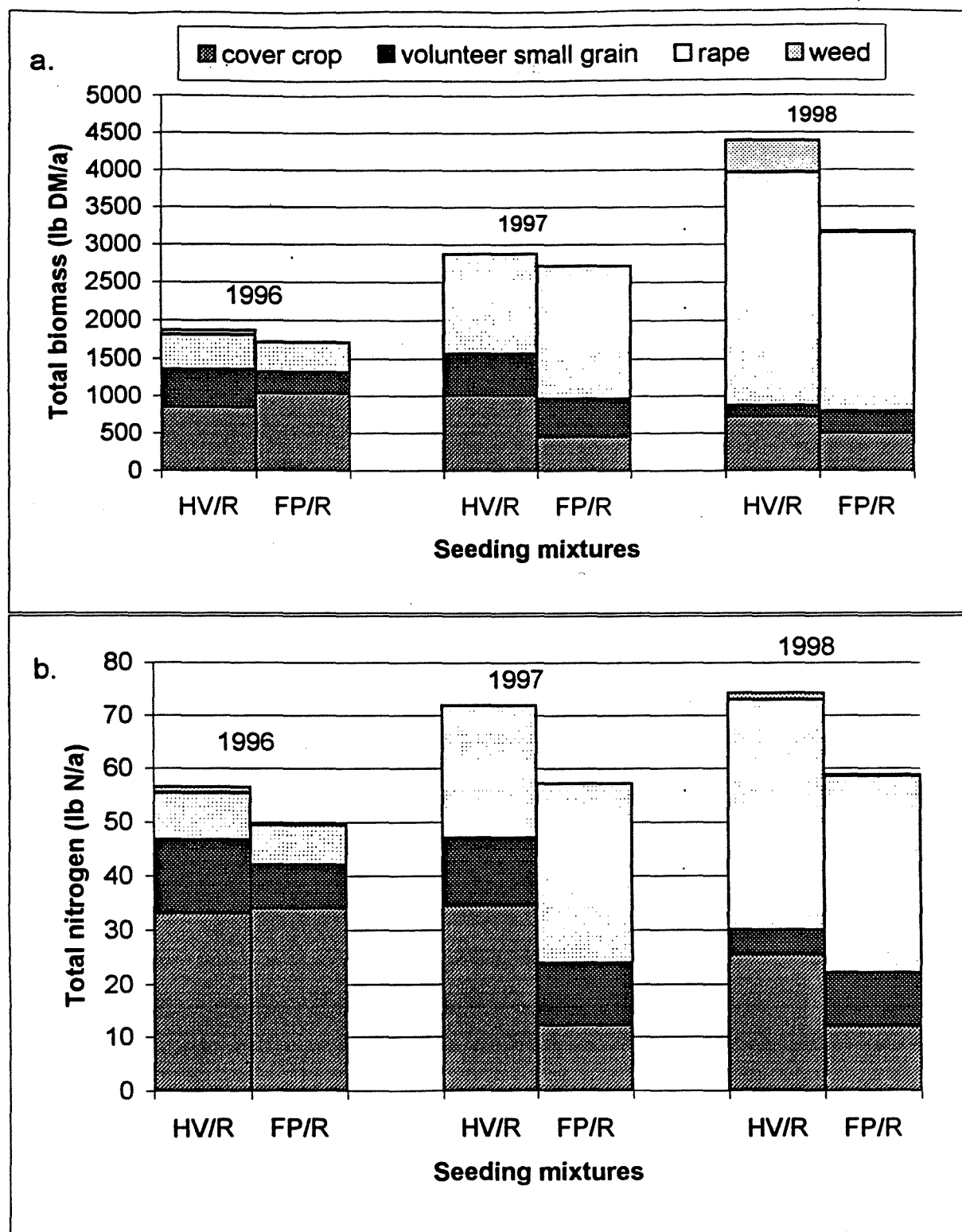


Fig. 4(a). Total biomass (lb DM/a) and (b) total N (lb N/a) of seeded mixtures (HV/R = hairy vetch/rape, and FP/R = field peas/rape) at frost in 1996, 1997, and 1998. Components include cover crop, volunteer small grain, rape, and weeds. Means are over 2 tillage treatments and 4 replicates.

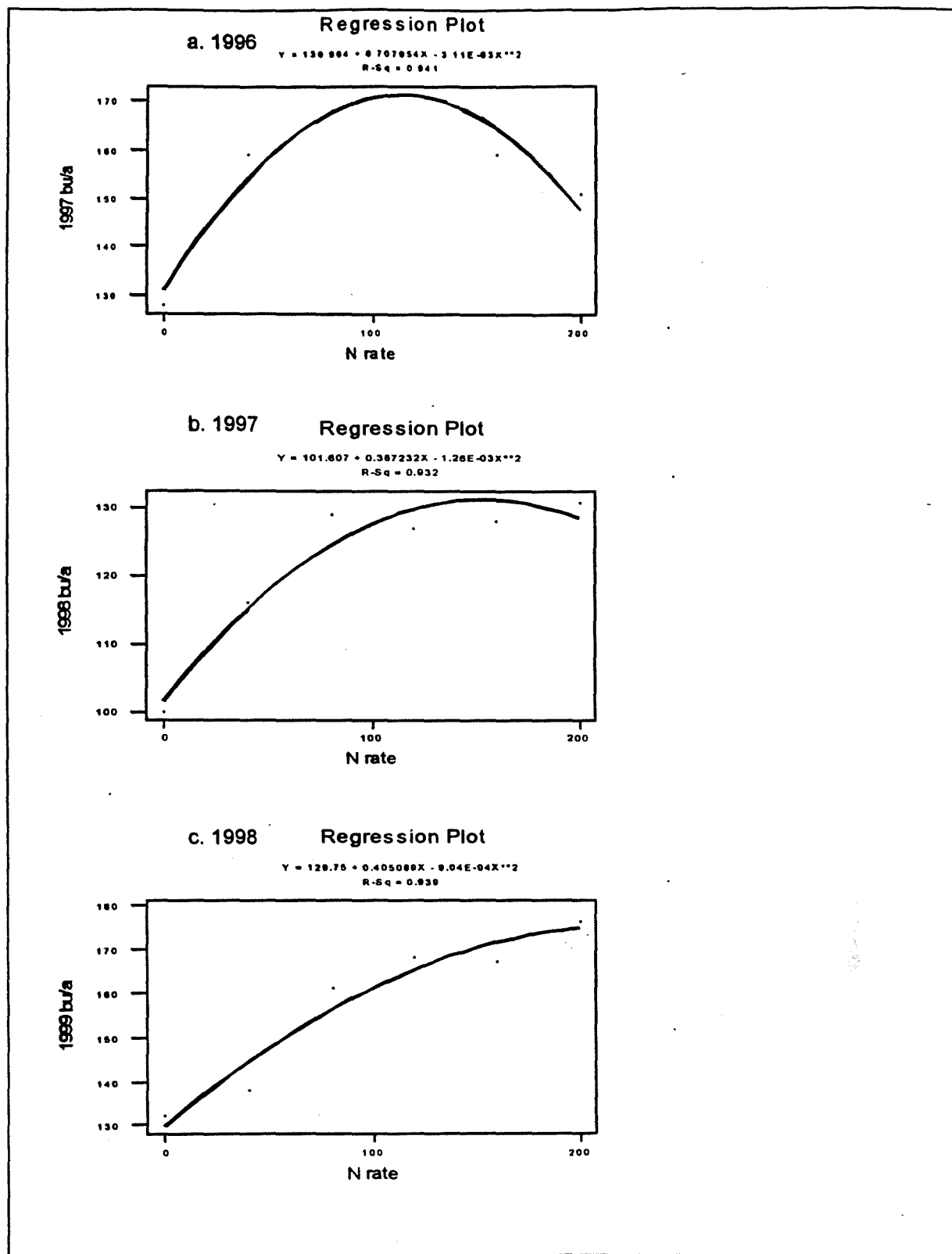


Fig. 5. Response curves of corn to added N following small grain and no cover crop in 1997, 1998, and 1999. Nitrogen was sidedressed at rates of 0, 40, 80, 120, 160, and 200 lb N/a.

Table 1. Small grain phase of summer seeded cover crops experiment, 1996-1998

Small Grain	genus and species	Variety	grain harvest	grain yield	cover crop
			date	bu/a	date of planting
Barley	<i>Hordeum vulgare</i>	Kewaunee	8/9/1996	77	8/12/1996
Rye	<i>Secale cereale</i>	Hancock	8/1/1997	74	8/8/1997
Wheat	<i>Triticum aestivum</i>	Kaskaskia	7/28/1998	60	8/13/1998

Table 2. Sequential seeding cover crop trial: Species planted, seed costs, and actual seeding rates, 1996-98.

Treatment	Scientific name	Projected	Actual seeding rate			Seed cost ²	
		seeding rate	1996	1997	1998	1996	1999
		-----lbs/a-----	-----lbs/a-----	-----lbs/a-----	-----lbs/a-----	-----dollars/a-----	-----dollars/a-----
1. Canadian Field Peas	<i>Pisum sativum</i> cu. <i>arvens</i>	120	113	106	98	24.00	19.20
2. Soybeans	<i>Glycine max</i>	120	99	105	120	34.80	34.80
3. Berseem Clover	<i>Trifolium alexandrinum</i>	12	21	13	21	12.60	22.32
4. Hairy Vetch	<i>Vicia villosa</i>	30	30	27	33	30.00	54.60
5. Medix Mix ¹	<i>Medicago spp.</i>	12	11	20	16.5	15.00	24.60
6. Hairy Vetch/Rape	<i>Vicia villosa/Brassica rapa</i>	22/3	26/5	30/5	22/8.2	26.00	42.08
7. Field Peas/Rape	<i>Pisum sativum</i> cu. <i>arvens</i>	90/3	71/5	71/5	82/5.4	21.00	17.34
8. Fallow check	-	-	-	-	-	-	-

¹ in 1996, mixture of Parragio barrel (7%), Borung Barrel (14%), Sava Snail (38%), and Santiago Burr (38%) medics.

In 1997 and 1998 it was 100% Sava Snail annual medic (\$1.90/lb).

² Cost of inoculum ranged from \$3.27 to 3.87 for a 50lb bag of seed.

Table 3. Corn phase of summer seeded cover crops experiment, 1997-99

Year	Variety	Date of Planting	Date of N sidedress ¹	Date of Harvest
1997	DeKalb 512	5/12/1997	6/12/1997	10/16/1997
1998	Gutwein 2400	5/11/1998	6/17/1998	10/23/1998
1999	Pioneer 35R57	5/1/1999	6/15/1999	10/14/1999

¹ Only fallow plots were fertilized (40, 80, 120, 160, 200 lb N/a) to compute fertilizer replacement values.

Table 4. Late summer rainfall at Arlington, WI, 1996-98 and 30-yr average.

Year	August	September	Total
-----inches-----			
1961-1990	3.88	4.28	8.16
1996 ¹	2.83	0.86	3.69
1997	3.20	1.57	4.77
1998	6.65	2.95	9.60

¹ Cover crops planted on August 12, 1996. August rainfall following planting was only 1.12 inches.

Table 5. Total lbs N/a from summer seeded cover crops at frost (aboveground portion only including volunteer small grain, rape and weeds). Means of 2 tillage treatments and 4 replicates.

Species	1996	1997	1998	3-yr mean¹
Field pea	91a ²	57d	96ab	81
Soybean	42cd	82ab	112a	79
Berseem clover	24e	61cd	69bc	51
Hairy vetch	64b	86a	111a	87
Annual Medic	23e	34e	64cd	40
Hairy vetch/rape	48c	72bc	73bc	64
Field pea/rape	36d	57d	59cd	51
Fallow	19e	27e	37d	28

¹ Not included in statistical analysis.

² Means within a column with same letter are not different at $p < 0.05$ separated using Duncan's Multiple Range Test.

Over the three year trial % N levels in the cover crops were the following:

Field pea- 3%; soybeans-3.4%; berseem clover-2.9%; hairy vetch-3.7%; annual medic-2.8%; rape-1.9%; barley-2.8; rye-2.3; and wheat-3.4%

Table 6. Mean corn yield following various cover crops, 1997-1999. Means over 2 tillage treatments and 4 replicates.

Species	1997	1998 ¹	1999 ²	3-yr mean ³
	bu/a			
Field peas	161	113 b	175 c	150
Soybeans	152	115 b	194 abc	154
Berseem clover	155	124 a	200 a	160
Hairy vetch	153	120 ab	196 ab	156
Annual Medic	141	112 b	188 abc	147
Hairy vetch/rape	157	115 ab	177 bc	150
Field peas/rape	149	99 c	185 abc	144
no cover crop check ³	128	100	132	120
LSD(0.05)	NS	9	20	-

¹ Means within a column with same letter are not different at $p < 0.05$ using Fisher's LSD.

² Means within a column with same letter are not different at $p < 0.08$ using Fisher's LSD.

³ Not included in statistical analysis

Table 7. Estimated fertilizer replacement value of green manure crops for corn.
Means of 2 tillage treatments and 4 replicates.

Species	1997	1998	1999	3-yr mean
Field peas	57	34	200	97
Soybeans	35	40	200	92
Berseem clover	42	78	200	107
Hairy vetch	38	60	200	99
Annual medic	15	30	200	82
Hairy Vetch/Rape	47	40	200	96
Field Peas/Rape	30	0	200	77

12. SARE Final Report: Using Small Grain Cover Crop Alternatives to Diversify Crop Rotations.

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AgControl, agricultural consultants
Extension agents (Manitowoc Co., Sauk Co.)
Cenex Cooperative
Local grain producers

I. ABSTRACT

Our goal of this project was to increase the sustainability of Midwestern farming systems through diversification of the predominant corn-soybean rotation. Our strategy has been to re-introduce the use of small grain and cover crops following soybeans and preceding corn. We aimed to maintain production while reducing agrochemical inputs leading to increased environmental benefits for society at large and economic benefits for farmers. The specific objectives of this project were to:

- 1.) Provide educational, technical and networking support to farmers interested in integrating small grain-cover crop combinations into their crop rotations;**
- 2.) Broaden the range of market opportunities and uses for small grains in the Upper Midwest; and**
- 3.) Evaluate and communicate the results and experiences of producers and buyers directly involved with this project to a wider audience of growers and other agriculture professionals.**

Objective 1. To meet our first objective, we built a unique outreach team of producers, university agronomists, extension agents, non-governmental organizations and the food-processing industry. To support farmers technically, a detailed handbook on small grain production was prepared and updated annually. Team personnel aided growers with record keeping and production advice. Complementing this manual was the fortnightly Small Grain Update Newsletter that was published between April and October each year. Production and economic data was collected and analyzed from 30 upper Midwest farms that had integrated small grains into their corn/soybean rotations. Agronomically, farmers were generally pleased with small grain yields and cover crop establishment. Corn yields following small grain and cover crop were comparable to the 2-crop rotation but with 63% less synthetic N. Many growers assessed their soil health and tilth as improved following the small grain and plow down green manure. In addition to better yields, participants in the Small Grains Initiative got better prices. They received, on average, 24% more in 1997, 35.2% more in 1998 and 12.8% more in 1999. Actual total income (not including cost of land or management) was \$108.86/a for oats, \$163.01/a for wheat and \$230.48/a for barley and quite similar to that of corn (\$174.42/a). With the small grains, nearly half the income came from the sale of straw.

Objective 2. Our second objective was met through efforts of the team to provide market contracts for production of high-quality food-grade grain for food-industry processors and grain handlers. Several marketing strategies have been developed for placing the small grains and beans from this 3-crop rotation in food markets, yielding a higher price (green labeling, soy sauce production, bread wheat). The team facilitated the formation of local cooperatives among small grain producers to provide the large quantities required by processors, e.g. Itochu (soybeans) and Quaker (oats).

Objective 3. To meet our third objective, results and experiences were disseminated via newsletters, field days, and conference presentations. Results were included in field days and grower meetings (23), conference presentations (12), and newsletters/updates (16) with mailing list of 600 people. Three winter meetings 1998, 1999 and 2000 facilitated direct interaction among the team members and among other producers while providing an opportunity to increase public interest in the diversification of crop rotations and subsequent economic and environmental benefits.

III. SMALL GRAINS INITIATIVE REPORT

Introduction

Wisconsin ranked #2 in the U.S.A. in wheat production in the mid-to late 1800's¹. Since then, there has been a steady decline in total acreage planted to wheat and other small grains. From 1964 to 1998 the area in small grains dropped by more than 70%.² On dairy farms, increased usage of corn silage and direct seeded alfalfa, alternative bedding options, and increased reliance on purchased feeds have lessened interest in small grains. Recently, because of government programs and low prices for small grains, small grains have nearly disappeared from farmers' cropping rotations. For the past few years however, researchers have tried to reintroduce small grains into cropping rotations to increase diversity and improve sustainability.

A. Objectives

Our goal has been to increase the sustainability of regional farming systems, through the introduction of small grain and cover crops to the corn-soybean rotation. Our project addresses, in particular, three of the Program Goals of the North Central Regional SARE which all enhance farming sustainability: 1) enhancing the environmental quality of intensive row crop rotations by including a small grain and cover crop; 2) enhancing the economic viability of individual farm operations by focusing on food-grade grain production; and 3) increasing crop and enterprise diversity on the farm with the inclusion of a third cropping phase for cash grain producers, or small grain feed for dairymen.

Specifically, we have three objectives of the Small Grains Initiative:

- 1.) Provide educational, technical and networking support to farmers interested in integrating small grain-cover crop combinations into their crop rotations;**
- 2.) Broaden the range of market opportunities and uses for small grains in the Upper Midwest; and,**
- 3.) Evaluate and communicate the results and experiences of producers and buyers directly involved with this project to a wider audience.**

B. Methods/Approach

In this project we primarily worked at three levels: 1) with 30 producers to test the potential of introducing small grains into the corn-soybean rotation; 2) with a subset of these producers to conduct additional on-farm trials; and, 3) with a total of approximately 300 producers who marketed their small grains through our program. We developed acreage contracts with the first group of 30 farmers to produce small grains on 20 acres (with at least 5 acres in a cover crop) and offered a small stipend, as a production incentive, to keep field records. We provided recommendations for the small grain/cover crop phase in our manual ("Farmer's Guide & Resource to Quality Small Grain Production") and offered help in securing cover crop seed. In addition the team monitored nitrogen levels for the subsequent corn crop (green manure biomass estimates,

¹ U.S.D.A Statistical Bulletin #158, 1955-56.

² Wisconsin Dept. Agric. Statistics, 1965 and 1999 publications.

pre-sidedress N soil tests and corn stalk nitrogen tests). By 1999, when some farmers had all three phases of the rotation in side-by-side comparisons, additional scouting for pests and diseases were undertaken. Field information was recorded in an easy-to-use, pocket-sized notebook. We held a number of satellite and super-imposed trials with the cooperating farmers or at local research stations.

- **On farm testing of cover crop options and their impact on subsequent corn yields.** Farmers either interseeded or sequentially seeded cover crops during the small grain phase. Cover crop biomass was measured in 1998 and 1999 and total pounds of nitrogen in the green manure were estimated.
- **Monitoring nitrogen levels and corn yields.** Growers were very concerned that adding a green manure to the small grain phase would require additional investment on their part, but might not have any economic return in the subsequent corn crop. As a result, a number of efforts were made to estimate the impact of these cover crops not only on corn yield but also on the soil and crop nitrogen status throughout the corn year using pre-sidedress nitrate tests, N-rate trials on corn following green manure, and end of season cornstalk tests (Blackmer and Mallarino, 1996).

C. Results

Small Grains

Yields. Producers on the Small Grains Initiative project consistently averaged higher small grain yield than the Wisconsin state averages (Table 1). In 1997 participants put 38% more oats into the bin than the Wisconsin state average, 23.8% for all crops in 1998 and 21.9% more for all crops in 1999. However, there was a wide range among producers. Producers with the highest yielding wheat were those who planted in late September versus earlier dates. This could be due to less aphid pressure in late September and therefore less viral transmission (Gaska, 1999). Pioneer and Terra varieties tending to have higher yields. There was no consistent pattern with planting date of oats and yield. Producers in the project generally had their oats planted by the first of April which is sufficiently early.

Small grain straw yields ranged from 0.56 to 3.25 tons dry matter/acre. Oat and wheat straw average yields were 1.16 and 1.62 tons dry matter/acre, respectively, across farms. Straw was sold in most cases.

Quality. Small grain quality was high with test weights for oats averaging 37 over 3 years. Test weights for wheat averaged 57 over 2 years. Barley made malt grade on the two farms where it was produced. Project participants received, on average, 24% higher prices in 1997, 35.2% higher in 1998 and 12.8% higher in 1999³ than the state average.

Cover crop biomass and nitrogen production.

Establishment. Cover crop establishment is dependent on both moisture and amount of small grain stubble. In 1998, yields of cover crop biomass were excellent ranging

³ Barley was omitted because there were only 2 participants that grew barley that year and they received 57% higher prices than the state average.

between 1790 and 1976 lbs DM/a (Table 2). In 1999, the initial cover crop stand was good. But when dry weather persisted, growth essentially stopped. We have seen good establishment so far in 2000, the better stands being planted just after straw harvest. Generally speaking, dry August weather appears to be more damaging to sequentially seeded cover crops (i.e. those planted after the small grain was harvested) than those that are frost seeded. Also, contrary to some producers' expectations, we found that good small grain yields did not adversely affect frost seeded red clover establishment. In fact, competition in the Spring resulted in very short early growth of the clover crop and it had almost no adverse effect on the quality of the small grain straw removed at harvest.

Yields

1998. Three species of legume cover crop, berseem clover, hairy vetch, and annual medic, were measured across two farms in 1998 (Table 2). All species were sequentially seeded after small grain harvest and established well. Average production ranged between 1716 and 1976 lb DM/a. Berseem clover produced the highest average of biomass but hairy vetch had the tightest range from 1063 to 2368 lb DM/a.

1999. Red clover (interseeded with small grain) produced the highest biomass (lb DM/a) and 15 out of 25 farmers chose to seed this species (Table 2). In 1999, an average of 2627 lb DM/a was produced across 12 sites. Three seedings were failures due to dry weather and one was accidentally sprayed. Other species sequentially seeded included hairy vetch, berseem clover and sweet clover. Hairy vetch and berseem clover produced approximate 1600 lb DM/a over 2 years and 11 sites.

Legume cover crops provided between 41 and 70 lb N/a measured by total N in aboveground biomass in 1998. Hairy vetch and berseem clover were planted both years and yield and total N were higher in 1998 due the better establishment and growing conditions (Table 2). Red clover was planted in both years but it was not measured in 1998 although stands were visually appraised as very good stands in 1998. More species were measured in 1999 with sweet clover providing very little N and red clover producing the most N. Hairy vetch and red clover produced up to 101 and 153 lb N/a, respectively in 1999.

Corn

Yields. Producers in our project consistently produced higher corn (and soybean) yields than the state average across rotations (Table 3). Where we had the two-phase (corn and soybean) and three-phase (corn, soybean, small grain + cover crop) rotations side by side, corn yields were quite similar while synthetic N inputs were reduced by 54% on the 3-crop rotation (Table 4). Most of the times that hairy vetch or red clover were used, pre-sidedress nitrate tests the subsequent year was above 15 ppm, resulting in significantly lower N recommendation for corn. End-of-season stalk nitrate test showed that additional N inputs on corn following green manure plow down always resulted in higher stalk nitrates but not improved corn yields (Table 5). On farms where multiple cover crops were compared with fallow, corn yields were highest following hairy vetch with 10 bu/a more than the fallow in 1999 (Table 6). Results were less striking in 2000 likely due to the dry fall of 1999 and therefore poor cover crop establishment (Table 6).

To measure N input from green manures, several farmers in our project compared different N rates on corn following cover crops. In one case, rates of 90 and 180 lbs N/a were applied where hairy vetch had been grown in the fall of 1999. Both rates resulted in the same corn yield of 153 bu/a. On another farm, 3 N rates (0, 30, and 60 lbs N/a) were applied to a fallow area and to an area that had berseem clover in the fall of 1999. On the cover crop treatment, corn yields were the same (170 bu/a) across all N rates. On the fallow area, corn yields increased by 51 bu/a (119 to 170 bu/a) by increasing N rate from 0 to 30 lbs/a but there was no further increase above the 30 lbs N/a rate. See Tables 5 and 7 for more N rate trials and yield comparisons.

On-station trials showed economic N inputs on corn following small grain and green manure (Table 7). Yield responses from 20 to 60 pounds of applied-inorganic N/acre, depending on location, increased net return, at current N and corn prices. Applying additional N, over 60 lb/acre, did not always increase yield, yet always reduced net income.

Plant counts. We found no statistical differences in number of plants/acre that followed either fallow or cover crop treatments across several farms. Similarly, we found no differences in number of plants/acre between 2 or 3-crop systems on a farm using repeated and randomized plots.

Surface residue. Spring ground cover by small grain residue averaged 33% over 1999 and 2000. Residue was not different between small grain alone or small grain with cover crop. Year 2000 data showed higher small grain residue (47%) than 1999 (23%). This was likely due to a dry fall of 1999 with little rainfall events. Measurements were taken in early June 2000 before heavy rain induced flooding.

Soybeans

In our study, soybean is the crop in the 3rd phase. Yields averaged 40 bu/a and ranged from 36 to 46 bu/a across farms. Soybean yield were consistently higher in the 3-crop system vs. the 2-crop system when tested on-farm (Table 8). Plant counts in the spring of 2000 were significantly higher ($p < 0.05$) on the 3-crop system vs. 2-crop system on both farms that had this comparison. Plant counts on 3-crop averaged 181,500 plants/acre while the 2-crop system averaged 161,610 plants/acre [LSD (0.05) = 6700]. White mold was very low ranging from almost non-existent in wide row soybeans (1.6% incidence) to slightly higher levels in narrow row beans (6.0% incidence). There were no differences in white mold incidence between 2-crop and 3-crop systems, where comparisons between systems were made between fields with the same spaced rows.

D. Economics from Small Grains Initiative⁴

Methods

Data books were sent to farmers and filled out with the aid of project personnel. Input costs, yields, prices received were requested and total expenses and net income were calculated (Tables 1 and 2). The data we collected from farmers was in 3 states, but

⁴ Don Schuster, Outreach Specialist at the Center for Integrated Agricultural Systems, UW-Madison.

predominately Wisconsin. Therefore, the prices received were compared to the Wisconsin state average along with the Wisconsin state average bushels per acre.

The following analysis assumes that machinery cost for growing small grains would be \$38 per acre and \$54 per acre for corn and soybeans, respectively. All other cost used are actual information that was received from the farmers. The equipment set data used to calculate this was taken from the 1999 Wisconsin Integrated Cropping Systems Trial, 7th Annual Report. No cost for land and management has been included.

Results

Program participants received higher prices than did farmers who were not involved with this program. The Wisconsin state average price of oats was \$1.19 from 1997-1999 and was \$1.92 for wheat from 1998-1999. Growers received for wheat and oats, on average, 24% more in 1997, 35% more in 1998 and 13% more in 1999 than state average (Table 1).⁵ Net income was consistently higher for the expanded rotation vs. the 2-crop corn-soybean rotation for both corn and soybean across 2 years (Table 2). Possible explanations for these higher prices and returns include organic premiums for some farmers in the study. Also, participants in our study may be more progressive, well-informed and knowledgeable enabling them to consistently produce high quality grain. Participants also on average fared better than the state average when it came to total yield per acre. In 1997, oat yields were 38% higher than the state average, and all crops were 25.5 and 18.5% higher than the state average in 1998 and 1999, respectively (Table 1). Expenses were 40% lower in the small grain phase than the corn phase. Reduced N inputs in corn following wheat and green manure ranged from \$6.84/a to \$31.00/a savings compared to corn following soybean (Table 5). Actual total income was \$108.86/a for oats, \$163.01/a for wheat and \$230.48/a for barley, quite similar to that of corn (\$174.42/a). With the small grains, nearly half the income came from the sale of straw. Generally, by adding a small grain and cover crop to the corn/soybean rotation, farmers were able to reduce synthetic N inputs in the corn phase by 13%, as well as, overall reduction in agrochemicals for the system. Therefore, the system should be more economically and environmentally attractive to farmers.

E. Marketing⁶

Introduction

Broadening small grains market opportunities in the upper Midwest has proven more complicated than merely providing growers with food-grade grain contracts. Food processors and grain handlers, while initially supportive of this effort, present almost insurmountable barriers to a revival of regional small grain production. However, persistent market research, negotiations with Asian markets and coordination with growers and grain buyers, has achieved a modest measure of success during this project. They illustrate the need for new strategies and new approaches to the marketing of small grains.

⁵ Wisconsin Dept. of Agricultural Statistics, 1999 publication.

⁶ Prepared by Ron Doetch, Sharon International Grain and Tony Ends; Michael Fields Agricultural Institute.

Pooling oats in volume (for dispersal in lot sizes of 7 rail cars per month), for instance, could not surmount logistical problems of critical grain storage space shortages this past July in the Upper Midwest. Agreements to accept semi-truck loads of grain, while easily attainable, required bottom line contracts for production quantities higher than the scale of this project. The 50 scattered growers in 20-acre trials associated with this project proved unable to meet this volume. Fluctuating prices for corn and soybeans (from record highs to 10- and 50-year lows) the past 5 years also influenced feed prices early on, circumventing trial delivery to food grade markets.

Foreign Competition remains strong:

Foreign production in competition with upper Midwestern growers remains strong. Canada's spring wheat plantings in 1996 exceeded 24.6 million acres, and barley acreage the same year was just short of 13 million acres. Spring wheat and barley are among the top three crops grown in Canada. About 40 percent of Canada's oats, another of its important cash grains, were exported in the 1998-99 growing season. Most of this grain went to the U.S. premium horse feeds and milling oat markets (rolled oats or its components).

Pooling and strong collective production capacity still drive Canadian exports. Together, the Saskatchewan Wheat Pool and its wholly-owned subsidiary Can-Oat operate 470 line elevators in Canada with more than 80,000 farm members. They dominate the grain trade and have in less than 15 years become the largest industrial supplier of oat products in the world. Can-Oat Milling added a second processing facility in 1997 at Saskatoon, Saskatchewan, to its first modern plant constructed in 1991 at Portage la Prairie. These two facilities process more than 250,000 metric tons of raw oats every year into both intermediate and finished food products. Daily processing of oat ingredients exceeds one million pounds. About 95 percent of this production is exported – much of it to the United States, and Can-Oat has avowed that it will maintain a leading presence as a supplier to industrial cereal and baked goods manufacturers in this hemisphere.

Facing the Canadian small grains production capacity, the Quaker Oats Company has now allied with Cargill, Inc., the largest grain handler in the world, with a strong presence in Canada. Under its arrangement with Cargill, Quaker has been sourcing oats in Canada at volumes of 25-rail car lot sizes to meet its 50-million bushel annual demand for oats. The 99-year-old cereal maker enjoyed \$5 billion in net sales in 1999 across all food categories, and it has a 10 percent share of the \$7.6 billion U.S. cold cereal market. Quaker initially agreed to purchase semi-load lots of oats from growers who would collaborate with the USDA SARE Small Grains Initiative. However, it wanted a minimum contract of 750,000 bushels of food-grade quality oats. Growers in the initiative have met Quaker's food-grade standards (13 percent moisture, 36-pound test weight, etc.). Yet logistics, freight and volume requirements have conspired against successful transactions.

Ultimately, the depth and strength of Canadian oat production, pooling efforts and organization have continued to depress oat prices – and domestic food-grade oat production – in the United States. Projected U.S. corn harvests for 2000 (73.1 million

acres of corn, up from 70.5 million in 1999) and soybeans (73.5 million acres, up from 72.5 million) reflect continued national commitment to the two-crop rotation. For growers' efforts, USDA price forecasts in July 2000 showed farmers will get an average of \$1.70/bu for corn, 10 cents below last year's prices, and \$4.40/bu for soybeans, down 25 cents below 1999.

Growers in this initiative showed they can grow quality oats, wheat and barley that meet grain-purchasing specifications for a variety of uses. Delivering volume in heavily consolidated markets still poses a terrific challenge. Growers cannot source sufficient quantities of small grains for individual buyers and processors in the United States. Major members of the brewing industry. For example, seek a minimum of 25-rail car lots of grain. Seminole Feeds, based in Ocala, Fla., has in recent years sought a high-quality, 600,000-bushel oat supply or pool of suppliers for an expanding recreational horse feed market along the eastern seaboard.

New Midwest Initiatives: Consolidated Grain & Barge (CGB) Enterprises, Inc.

Our Small Grains Initiative, however, demonstrated that even with meager resources and a small grower base, volumes of small grains for targeted markets can be achieved in the upper Midwest. In advance of the 1999 wheat harvest, our *Small Grains Update* newsletter, which grew from 150 to more than 600 circulation during the project, announced an "on-farm buyer's call" arrangement with CGB Enterprises. Staff also described this polling arrangement in a press release and feature story distributed ahead of a field tour in July 1999. Consolidated Grain & Barge Enterprises, Inc. offered to pay a \$0.10/bushel premium. The bid was made to growers who agreed to load their grain together in bulk within a certain time period. The offer for one barge-load lot of wheat sought 50,000 bushels of grain. The wheat was to be collected at one of CGB Enterprises' northern Illinois facilities. By the end of the harvest, CGB Enterprises actually bought 12 barge loads of wheat from Upper Midwestern farmers, approximately 600,000 bushels.

Switching to hard red winter wheat:

Feed-grade soft winter wheat purchased from farmers in this program cannot tap higher premium markets in the upper Midwest. Spring wheat varieties planted in the upper Midwest were often developed through western wheat breeding programs in arid climates and alkaline soils. Trials here show very low yields. With assistance from the Small Grains Initiative, two northern Illinois farmers began late last year growing high-protein, hard red winter wheat. The 'Patriot' variety of wheat, grown for seed, targets the bread milling market. Millers indicate they will purchase this wheat according to specifications at \$0.50 to \$1/bushel over soft winter wheat. Production harvested in July 2000 provided 7,500 seed units for planting this fall.

A consultant to the Small Grains Initiative worked for several years to procure this milling quality wheat variety for SARE effort producers. Negotiations in Canada for a hard red variety were finally successful last year, with acquisition of 'Patriot' variety seed from C&M Seeds in Palmerston, Ontario. C&M Seeds has 419 Canadian growers producing 18,892 acres of milling wheat, which provides them \$20 to \$50 more profit per

acre. The Patriot variety was developed in southern Ontario at about the same latitude as Milwaukee, Wis. This new hard red wheat has an extremely hard kernel and other characteristics millers seek. It also boasts straw strength essential to hard reds grown in high nitrogen ground such as is found in cash grain rich areas. Trials have demonstrated excellent winter survival, early maturity, mildew resistance and protein premiums.

Yields at the two trial sites in Illinois, despite above average moisture through late spring and early summer, were 65 bu/acre and 80 bu/acre. One grower had more fertilizer present in his seed trial and thus more lodging and not as good of quality. The other achieved 63-lb. test weight. Samples were provided to local flour millers toward establishing "Identity Preserved" wheat production contracts. These contracts were made available to Midwestern growers for additional wheat seed plantings in September 2000 and for greatly expanded stocks in 2001. A cluster of central Wisconsin growers in the initiative this year planted about 4,000 acres in a 1.4 relative maturity bean. This allowed early bean harvest and fall planting of the 'Patriot' wheat seed grown in the northern Illinois trial planting. It will also ensure better yield potential and reduced over-wintering problems for the hard red wheat, as opposed to plantings following the 2 and 2.4 maturity beans typical of this region.

Amber Milling recently completed a plant in Kenosha with a 21,000 cwt. (2.1 million pounds) of primary finished productive capacity per day. The plant has a 950,000-bushel storage facility as well. Amber Milling is a subsidiary of Harvest States Milling, which recently merged with CENEX and Land O' Lakes. It is a contract buyer for food-grade grains, producing Semolina, Durum flour and bakery flour, ranging from 12 to 14.2 percent protein. With connections to Canadian Pacific and Union Pacific railroads, Amber's Kenosha plant purchases wheat in 104-car lots. Under the present strategy, growers in the Small Grains Initiative will be able to balloon stocks of the hard red winter wheat following the July 2001 harvest. They will then target Amber Milling's new hard wheat bakery flour products – bread, rolls, etc. – with locally sourced, high-protein grain.

Working with Kikkoman:

Kikkoman Foods Inc. has operated a plant in Walworth Wisconsin since 1972 making soy sauce, teriyaki sauce and related products. The best-selling, most widely recognized maker of naturally brewed soy sauce built a second \$40 million plant in Folsom, California 2 years ago. These facilities produce more than 20 million gallons of soy sauce each year for distribution through 10 centers around the United States. Kikkoman responded favorably to a proposal from this initiative to source a quality wheat variety in the Midwest. While its Walworth facility has long stood in America's most fertile soybean and wheat-producing region, it has been railing its grains from outside the area. For wheat, which the Walworth plant uses in quantities of a rail car per week, this has meant a reliance on dark northern spring wheat varieties grown in the Dakotas. This wheat presently is not identity preserved and is supplied by Cargill. It is dark in color for the manufacture of soy sauces.

Kikkoman's requires a wheat with 13 to 15 percent protein, similar moisture features and zero vomatoxin presence. If state line growers enrolled in the Small Grains Initiative can

meet such requirements, they can deliver single truck lots to the Walworth facility. The plant lacks storage capacity and has been operating under a "just-in-time" sourcing system for the 500,000 bushels of wheat it purchases in any given year. For wheat growers in northern Illinois and southern or central Wisconsin, this situation presents a truck buyer advantage. The freight spread over western suppliers is about 40 cents/bushel, and the premium for food-grade quality wheat Kikkoman's needs for its products could bring 50 cents to \$1/bushel.

Promoting food quality of the three-phase rotation:

This effort follows a marketing strategy of establishing premiums for corn, soybeans and small grains, grown together in a wider rotation. Targeted are superior output characteristics – less incidence of disease, toxins, pests, for instance – across the production. The effort has been discussing merits of this approach with Japanese and domestic concerns. Quality Traders, which produces specialty grains in the United States for distribution in Japan and elsewhere, has led this promotional effort. It is funding a study in Elkhorn, Wisconsin to document the quality characteristics of corn and beans grown in the wider rotation. Reduced damage and yield from white mold in soybeans is targeted in this research. QTI has also underwritten the Patriot seed effort with a buy-back agreement. Buyers willing to purchase corn and beans at premium prices from this wider rotation represent minimum lot sizes of 30,000 acres. Asahi Breweries, Ltd., of Japan, is interested in corn from the wider rotations.

Some individual producers have independently sought out specialty markets, tapping the new trend toward niche marketing. They demonstrate that what growers do in marketing their small grains is as important as what they do in the field to get good yields. The Small Grains Initiative has maintained an advisory and referral service through its consultant at Sharon International Grain in Walworth County, Wisconsin on the state line. This program has sampled, tested and advised more than 200 growers on quality and quantity specifications targeting specific organic and conventional markets. Efforts were made to link growers with the closest available market based on lot sizes and farm locations. Many shipments of oats in this referral program went to millers sourcing grains through St. Ansgar, Iowa. The consultant in this project has been challenging growers to add value to their small grains, to increase their storage capacity and physical ability to preserve identity, and to adapt their timing of sales to the tailored needs of individual market clients.

The Small Grains Initiative has also uncovered strong grower interest in the concept of developing a farmer-owned enterprise for small grains. In winter producer meetings for the initiative, 28 growers (almost all of those present) filled out two-page surveys of support for this approach. Marketing and business studies would have to document the feasibility of such an undertaking, and significant investment and public grant or loan support would also be essential. The retail dollar value of breakfast cereals, snack and pet foods in the United States, however, is more than \$40 billion annually, with cereals marking steady growth through the 1990s and representing more than one-fourth of that sum.

Related experiences:

A farmer-owned, value-added marketing strategy could stimulate economic incentives for farmers to widen the conventional corn-soybean rotation to include small grains and cover crops. It would make this possible by mapping out business, marketing, product and processing plans for stronger returns derived from their own value-added manufacturing. About 75 "new generation" cooperatives, such as the Dakota Pasta Growers Co-op in Carrington, North Dakota and the Minnesota Corn Processors Cooperative, have sprung up since 1990. These cooperatives focus more on value-added products, market (rather than supply-driven) orientation, aggressive strategies and up-front farmer investments than have traditional cooperatives. They respond to strong needs in the farm community for local level, multi-state involvement.

Three custom processors expressed interest in a small grains cooperative of farmers and providing services to them for manufacturing specialty foods and products, which the group would then market. A cooperative small grains business could target the growing interest in green label, organic, locally-grown and/or eco-label foods. Models for such farmer-owned enterprises are receiving public support. Iowa has appropriated \$25 million in interest-free loans for grower-owned ventures as stimulus to enterprises, such as a large bakery that will buy certified organic wheat from Iowa farmers. It also offers 5 percent stock ownership to farmers and non-recourse loans for stock purchase. Another farm group in North Dakota has attracted 250 oat growers to a project called Oat Technologies. The group plans to undertake an equity drive to build a \$40 million processing plant within the year. The plant will make lethicin, sterols, antioxidants, oils, defatted soluble fiber, proteins and starches from oats. The group forecasts annual revenues of \$25 million and hopes to pay farmers up to \$2.20/bushel. The cooperative estimates it will need 51,700 tones of oats per year; it is targeting nutraceuticals, cosmetics and industrial niche markets. Representatives visited Prairie Oat Growers Assoc. in Winnipeg in December 1999, to attract Canadian growers to the cooperative. Illinois growers who have participated in the small grains project are trying to organize a group marketing effort. The farmers are making application with Boone County Soil and Water Conservation District and members of the Northern Illinois Organic Growers Association for grant assistance to undertake joint marketing of feeds produced in expanded rotations.

Conclusions:

Disappearance of local businesses and infrastructure for handling, transporting and processing small grains over the past 40 years is still making return to production difficult for individual growers. Long-distance trucking fees eat into returns and diminish premiums. Freight-car volumes prohibit small-scale production and discourage experimentation. As transportation costs generally rise with fuel costs and depletion of energy resources, even large processors will soon be persuaded to patronize growers closer to home.

In 20 to 30 presentations with farmers and farm groups around the region each year of the past 3 and in talks at scores of field days, collaborators have addressed these marketing strategies in the overall effort to widen rotations with small grains and cover crops. Barriers cited in the grant application to SARE – foreign transportation, pooling, volume

and marketing power – at the start of this effort are just as real today as they were 3 years ago. Competitive markets for domestic production of small grains do exist, that some foreign strengths can be matched and that prospects for individual and collective enterprise are just as real as the challenges. American farmers have shown they can produce high quality, food-grade small grains for milling and malting. Their limitations relate to meeting required lot sizes, coordinated handling and shipping capabilities, which mega markets typically require today. American farmers have shown they can out-innovate research, with some exceptions due to the lack of variety research and breeding programs that do not address premium and added-value markets in the Upper Midwest.

If the sustainable agricultural community is to help Upper Midwest growers make a significant share of domestic small grains production as fluid as corn and soybeans, it will require minimally the three dominant features of our marketing effort: 1) Strong grower involvement, networking and communication; 2) outside, public assistance and commitment to making these approaches for both domestic and foreign markets work and to providing resources necessary to help farmers make them happen; 3) concerted, cooperative work with Asian markets that recognize and reward agronomic and ecological advantages of quality grains from wider rotations.

Growers on a broad basis are not accustomed to aggressively marketing their grains, and they are not organized to do so collectively. They need the seasoned experience of parties who have worked in the private grain industry. Multiple delivery and collection points, obviously, must be established to help overcome lot size and transportation barriers. On-farm and collective storage capacity with strong sensitivity to the timing and delivery requirements of specialized markets need to become commonplace. And the importance of this mode of delivery and customer service needs to become widely understood and accepted. A complex situation that has evolved over the past 40 years of decline in U.S. small grains production, thus, defies simple solutions.

F. Impact And Potential Contributions

The Small Grains Initiative, as we call it, is a win-win system in production, environment, and economics. Diversifying the rotation has resulted in maintaining production outcomes while minimizing inputs, aiding in economic and environmental viability. Reduction in insecticide positively impacts wildlife. Reduction in synthetic nitrogen fertilizer prevents ground and surface water pollution. Reduced use of synthetic N also improves soil health due to less soil acidification, and by using cover crops, the soil is protected from erosion.

Substantial savings in synthetic N inputs were accomplished in our study with the use of legume cover crops. Synthetic N inputs were reduced by 63% on corn in the 3-crop rotation compared to the 2-crop rotation (Table 5). However, in the duration of this study, the price per unit of N was fairly inexpensive compared to the cost of legume seed. This is a difficult hurdle to get farmers to justify spending more on cover crops when synthetic N is comparatively less expensive. However, N prices have already jumped 25% over one year from 1999 to 2000. In the year 2001, synthetic N prices are forecasted to increase twofold as natural gas price increases (Jim Witthaus, mimeo,

2000). At higher synthetic N prices, it makes economic and environmental sense to use biological N sources.

Energy saving from reduced synthetic N production is also a major benefit to a more diverse/lower input system. As fuel prices climbed to record heights in the summer of 2000, there was renewed concern about the economic returns from high input systems. Energy costs to produce synthetic N fertilizer are extremely high with energy values of 8250 kcal per pound of N. Continuing to rely so heavily on fossil fuels to produce synthetic N is costly and will result in loss of this non-renewable resource. Within enterprise types, increasing plant diversity will result in decreasing energy inputs as shown on the Wisconsin Integrated Cropping System trial from 1993-1999. Our systems research over this time period has shown energy output to input ratios to be 8.0 for the corn/soybean rotation and 11.8 for corn/soybean/wheat-red clover system. Policy changes and mandatory regulation will likely be necessary to reduce synthetic N use as is already happening in Europe.

G. Farmer Adoption, Impact, Involvement

In addition to the 30 cooperating farmers we estimate that over 3000 farmers either participated in our field days, received our Manual, were inscribed to receive our Small Grains Update, or participated in our marketing program. We estimate that more than 300 farmers will continue to market their small grains with our program. From private conversations with our cooperating farmers, most will continue to use small grains in their cash grain rotations. Others will join the program as marketing channels improve and more people appreciate cover crops for their high N credit, soil cover effect, and impact on soil structure.

H. Involvement Of Other Audiences

The Small Grains Initiative has presented its findings to several groups through our outreach efforts (Table 11). For example, we caught the interest of food safety-conscious consumers at the Food For Thought Festival. Restaurateurs have expressed interest in obtaining organically grown soybeans. Agency personnel from Boone County Soil and Water Conservation District, Natural Resource Conservation Service, and Northern Illinois Organic Growers Association have attended our field days and participated in our conferences. The USDA Dairy Forage Research Center has provided us with on-station research trials involving small grain and cover crops. Crop consultants (Agstat, Soil Solutions, AgControl) have also assisted us by spreading the results to their clientele.

I. Areas Needing Further Study

An educational effort is necessary to help growers focus on small grain production as they currently do with corn and soybeans. The techniques and varieties are available for good production in the humid upper Midwest. What is still missing is the "culture" of quality small grain production. Simultaneously with developing this tradition must come increased options for marketing. Both the issues of finding niche markets (local sourcing of oats, green labeling, performance market for horses) and volume must be addressed.

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Table 1. Small Grains Initiative small grain data from cooperators in a 3 state region from 1997-1999.

Grain	year	Yield		Selling Price			Expenses ¹			Total Direct	
		avg	WI avg	grain	WI avg	straw	Seed	Fertilizer	Chemical	Expenses	Net Income
Oats		-----bu/a-----		-----\$/bu-----		---\$/a---	-----\$/a-----			-----\$/a-----	
(n=22)	1997	101	63	1.92	1.46	-	14.75	8.69	2.99	74.41	131.96
(n=14)	1998	83	61	1.45	0.95	80.65	15.08	15.22	2.45	71.21	64.89
(n=7)	1999	85	62	1.54	1.15	56.71	10.19	6.82	0.39	53.72	129.72
Wheat											
(n=12)	1998	70	55	2.56	2.10	84.41	20.44	16.96	3.12	101.05	134.76
(n=15)	1999	76	60	2.00	1.73	69.68	22.96	23.62	9.09	94.35	191.25
Barley											
(n=2)	1999	80	52	2.82	1.15	100.5	13.58	12.50	5.81	69.95	230.48

¹ Total expenses include grain seed, grain hauling, chemical and application, fertilizer and application, fuel (no machinery depreciation or land rental).

Table 2. Cover crop biomass and N in SGI fields, 1998 and 1999.

	1998 cover crop species ¹			1999 cover crop species ¹				
	BC	HV	AM	RC	BC	SC	HV	Fallow ²
Biomass (lb DM/a)	1976	1716	1790	2627	1473	68	1232	2737
Biomass range (lb DM/a)	485 to 3466	1063 to 2368	235 to 3344	324 to 4839	595 to 3014	-	269 to 2135	2378 to 3206
Total N (lb N/a) ³	49	70	41	96	30	6	57	26
N range (lb N/a)	23 to 75	58 to 82	13 to 68	13 to 153	16 to 44	-	13 to 101	21 to 30
Establish. success (%)	100	100	100	75	100	100	100	100
Total # sites	2	2	2	16	3	1	4	2
# sites measured	2	2	2	12	3	1	4	2

¹ RC=red clover, BC=berseem clover, HV=hairy vetch, AM=annual medic, SC=sweetclover
there was red clover both years but none sampled in 1998.

² This consists of regrowth and volunteer oats.

³ Total N was measured as in aboveground biomass.

Table 3. Small Grains Initiative corn and soybean data from cooperators in a 3 state region from 1999-2000.

Grain	rotation	Yield			Selling Price		Expenses ¹			Total Direct	
		avg	range	WI avg	grain	WI avg	Seed	Fertilizer	Chemical	Expenses	Net Income
Corn		-----bu/a-----			-----\$/bu-----		-----\$/a-----			-----\$/a-----	
1999	2-crop ² (n=5)	178	157-193	143	1.78	1.70	34.02	39.85	38.87	173.33	170.15
	3-crop ³ (n=16)	172	128-207	143	1.94	1.70	33.92	28.43	28.69	182.70	178.68
2000	2-crop ² (n=1)	163	n/a	132	2.10	1.83	28.00	47.29	29.33	187.16	178.69
	3-crop ³ (n=8)	160	117-192	132	2.09	1.83	35.78	32.08	32.11	206.38	152.55
Soybean											
1999	2-crop ² (n=5)	50	35-57	46	5.09	4.60	26.77	5.75	27.96	114.66	178.09
	3-crop ² (n=3)	48	46-53	46	8.26 ⁴	4.60	24.52	17.98	14.63	119.85	300.64 ⁴
2000	2-crop ² (n=4)	39	36-44	40	4.78	4.54	19.59	0.00	28.92	109.05	105.55
	3-crop ³ (n=6)	41	39-46	40	4.75	4.54	20.75	1.67	27.48	112.72	109.67

¹ Total expenses include grain seed, cover crop seed (~\$30/a), grain hauling, chemical and application, fertilizer and application, fuel (no machinery depreciation or land rental).

² 2-crop is corn and soybean in rotation.

³ 3-crop is corn, soybean, small grain/legume cover crop in rotation.

⁴ One organic farmer in this group with organic premium. Net income excluding organic farmer is \$154.33/acre

Table 4. Corn yields in a 2-crop and a 3-crop rotation on the Small Grains Initiative 1999.

Farm	Type of site	2-crop rotation ¹		3-crop rotation ²		Amount saved	
		Yield	N input	Yield	N input	N input ³	Energy ⁴
		-----bu/a-----	-----lb N/a-----	-----bu/a-----	-----lb N/a-----	---\$/a---	---Mcal/a---
Viney	farm	177	147	182	60	17.40	718
Doherty	farm	188	160	187	100	9.42	495
Harris	farm	200	165	210	60	11.55	866
Arlington	on-station	163	80	156	0	8.80	660
Lakeland	on-station	106	124	90	0	31.00	1023
Forsythe	on-station	174	96	128	60	6.84	297
Polson	farm	82	120	85	0	21.48	990
Gaska	farm	157	180	156	135	7.07	371
Jewell ⁶	farm	163	150	166	150	0.00	0
Average		157	136	151	63	\$13.00	602

¹ 2-crop rotation = corn-soybean

² 3-crop rotation = corn-soybean-small grain + legume cover crop

³ Generally, N fertilizer was anhydrous ammonia (82-0-0) at \$0.11/lb N or urea ammonium nitrate (28-0-0) at \$0.19/lb N.

⁴ 8.25 Mcal of energy per lb N

⁵ Cost of cover crop seed ranged from \$22.75/a to \$27.75/a

⁶ Corn yields at this farm are from the 2000 growing season.

Table 5. End-of-season cornstalk nitrate test with corresponding corn yield 1999.

Farm	Added synthetic N	stalk nitrate	Corn yield
	lb N/a	ppm N	bu/a
Gaska	90	556	146.2
	180	1958	165.4
Harris	60	6649	194.7
	120	6660	190.9
Ripp	100	2556	174.7
	150	5962	173.0
Doherty	0	5257	187.0
	60	6936	192.2
Viney	0	1630	182.3
	60	1769	175.7
Jensen	0	3734	183.0
	60	4467	181.4

Categories for corn grain production:

Low < 250 ppm

Marginal 250 to 700 ppm

Optimal 700 to 2000 ppm

Excessive > 2000 ppm

Table 6. Corn yield following small grain+cover crops in 1999 and 2000 on 5 WI farms.¹

Year	Farm	Cover crop treatment			
		annual medic	hairy vetch	berseem clover	fallow
1999	Gaska	156.3	172.6	172.5	133.2
	Harris	207.3	219.5	202.9	199.0
	Ripp	173.0	178.9	170.5	176.3
	Jensen	-	183.0	-	188.5
	Kaufman	-	167.0	-	172.0
	Average	178.9	184.2	182.0	173.8
2000	Harris	-	-	170.0	154.0
	Ripp	-	109.0	-	124.0
	Jensen	-	161.5	-	160.4

¹ Synthetic N was added to the plots as recommended by pre-sidedress nitrate tests.

Table 7. Corn yield and additional economic response of 1999 corn to supplemental nitrogen fertilizer on plots where small grains and green manures were planted in the previous year.

A.) Corn yield following 1998 red clover green manure at Elkhorn, WI.(Forsythe)

N Rate (lb N/a)	Corn Yield (bu/a)	Increase in yield compared to:		Additional Cost*	Additional Return**
		0 rate (bu/a)	Previous rate (bu/a)		
0	108.6	-	-	0.00	0.00
20	120.9	12.2	12.2	10.76	11.76
40	121.5	12.9	0.7	15.52	-14.31
60	128.3	19.6	6.7	20.28	-7.88
80	111.0	2.4	-17.2	25.04	-56.76
100	117.6	9.0	6.6	29.80	-17.71
120	122.2	13.5	4.6	34.56	-26.15
160	124.6	16.0	2.4	44.08	-39.61

* N price \$.238/lb N and application cost of \$.60/a

** Additional return = additional yield @ \$1.84/bu less additional fertilizer cost for each increase in N rate. This method excludes additional costs associated with additional yield such as drying.

B.) Corn yield following a 1998 hairy vetch green manure at Belvidere, IL (BCSWCD)

N Rate* (lb N/a)	Corn Yield (bu/a)	Increase in yield compared to:		Additional Cost**	Additional Return***
		0 rate (bu/a)	Previous rate (bu/a)		
0	170.2	-	-	0.00	0.00
30	177.2	7.0	7.0	12.50	0.66
60	183.8	13.6	6.6	20.00	-7.59
90	185.7	15.5	1.9	27.50	-23.93

* All treatments received 27 lb N acre as a preplant application of DAP

* N price \$.25/lb N and application cost of \$.50/a

*** Additional return = additional yield @ \$1.84/bu less additional fertilizer cost for each increase in N rate. This method excludes additional costs associated with additional yield such as drying.

C.) Corn yield following a 1998 red clover green manure at Lancaster, WI (Wood).

N Rate (lb N/a)	Corn Yield (bu/a)	Increase in yield compared to:		Additional Cost*	Additional Return**
		0 rate (bu/a)	Previous rate (bu/a)		
0	177.6	-	-	\$0.00	\$0.00
30	176.6	-1.0	-1.0	\$13.14	-\$14.98
60	193.6	16.1	17.1	\$20.28	\$11.12
90	194.7	17.1	1.1	\$27.42	-\$25.44
120	195.5	18.0	0.8	\$34.56	-\$33.02
150	207.1	29.6	11.6	\$41.70	-\$20.41

* N price \$.238/lb N and application cost of \$.60/a

** Additional return = additional yield @ \$1.84/bu less additional fertilizer cost for each increase in N rate. This method excludes additional costs associated with additional yield such as drying.

Table 8. Soybean yields from a 2-crop and a 3-crop rotation in the Small Grains Initiative 2000.

Farm	Type of site	2-crop rotation ¹	3-crop rotation ²
		bu/a	
Viney	farm	36.0	40.6
Doherty	farm	40.2	40.2
Harris	farm	44.0	46.0
Arlington	on-station	56.3	40.9
Lakeland	on-station	44.8	30.0
Gaska	farm	37.5	39.0

¹ 2-crop rotation = corn-soybean² 3-crop rotation = corn-soybean-small grain + legume cover crop

13. Oats date of planting study 1997-1998

J.L. Hedtcke, J.L. Posner, J.K. Stute

Introduction

In the 1990's, oat yields averaged between 60 and 75 bu/a in the upper Midwest¹ and were grown mainly for supplemental feed and straw for livestock. However, on farm research has shown that when oats are well managed, 100 bu/acre yields of high quality oats are common (see "A Farmer's Guide to Quality Oat Production and Resource Guide", Doetch and Kane, 1998).

In addition to variety selection and harvesting technique, a key to the production of high quality, high yielding oats is early planting. Typically, planting date for oats in Wisconsin is April 10-25. Studies from Iowa State University indicate a yield loss of 10% per week if planted after April 16 and 15% per week during the first two weeks of May (Hansen, 1992). The risk for lodging also increases with later planting dates as well as the pressure from lambsquarter (*Chenopodium album*), giant ragweed (*Ambrosia trifida*), foxtail (*Setaria spp.*), and others (Wright, 1993). Early planting of oats can also reduce the impact of such diseases as crown rust and yellow dwarf virus (Munkvold, 1998).

Unfortunately, the number of days in the Midwest available for drilling oats in the early spring is limited. Until the frost layer leaves the ground, surface soils are either frozen solid (early March) or too wet to plant (late March, April). Exceptions exist however, in the early morning in late March and early April, when the surface soil has the strength to hold farm equipment because it is just thawing, after temporarily re-freezing during the night.

The goal of this project was to study alternative methods of planting oats in the late winter/early spring to insure the potential for high yields. To insert oats into the corn soybean rotation, three factors were analyzed in this project: 1) fall land preparation following soybean; 2) date of planting in March; and, 3) oat planting method.

Materials And Methods

Plots were established in early 1997 and 1998 for the spring seeded small grain and the previous fall for the winter wheat check at the Arlington Agricultural Research Station (ARS). At the Lakeland Agricultural Complex the trial was only conducted for one year (1997). Plots were 10' by 50' at Arlington and 15' by 200' at Elkhorn. Experimental design was a randomized complete block with four replicates. Soil type at ARS was a well-drained silt loam while soil type at LAC was a somewhat poorly drained silt loam.

Treatments are displayed in Table 1. Oat variety was Dane and wheat variety was Glacier (ARS) or Merrimac (LAC).

- Wheat (treatment 1) was used as an economic check to compare the best oat treatment to the "common wisdom" best option which is to use the longer fall window to plant small grains;

¹ USDA National Agricultural Statistics Service, 1996

- Treatments 2 and 3 were broadcast seedings on frozen ground (March 5th target date), but the fall preparation was different. With treatment 2 there was a fall disking after the soybean harvest and in treatment 3 there was not. Oat seed is not a particularly good shape to be worked into the ground by the natural freezing and thawing of the surface soil (like red clover) so it was hypothesized that a worked seedbed might result in a better catch;
- Treatments 4 (disking) and 5 (no fall tillage) were similar to treatments 2 and 3 but planted three weeks later (March 25th target date) during the active freeze-thaw period prior to the frost completely leaving the soil;
- Treatments 6 and 7 were similar to treatments 4 and 5 except that the former was planted using a no-till drill while treatments 4 and 5 were planted using the broadcast method; and
- Treatment 8 was the conventional check and the grain was planted in mid-April using a conventional drill.

Sites were analyzed separately using PROC GLM (SAS 1995) due to unequal year numbers. Linear contrasts were used to separate treatment differences. Yields are reported on lbs/acre basis to equilibrate across the different small grains used in the study.

Results

Lakeland, 1997. Oat yields were excellent in 1997 and treatments 6, 7 and 8 were all above 100 bu/a. Winter wheat yields were 55.6 bu/a. Treatments 6 and 7, using a no-till drill during the freeze/thaw cycle, were as productive as the conventionally drilled treatment 8, which is planted in mid-April on thawed, ground (Table 1). The least productive treatments were 2, 3, 4, and 5 in which seed was broadcast on frozen or partially frozen ground. The no-till drill planting was more effective, most likely due to the uniform seed placement in the soil.

Fall tillage after soybean harvest did not affect oat yields in any of the contrasts at $p < 0.05$. However, treatment 6 which was disked in the fall, yielded 371 lb/a higher than treatment 7, which has no fall tillage ($p < 0.1116$). Looking at the linear contrasts between planting methods, drilled treatment 7 yielded 31.9% higher than broadcast treatment 5 due to better soil-seed contact from the no-till drill ($p < 0.0001$). Similarly, yields were 37.5% higher on drilled treatment 6 than broadcast treatment 4 ($p < 0.0001$).

Arlington.

1997: Oat yields were modest in 1997 (58 to 80 bu/a) and wheat yields were very poor (30.3 bu/a) due to the very dry fall. Fall-planted wheat, treatment 1, was significantly lower than the conventionally planted oat treatment 8 ($p < 0.0298$). Yields on all other treatments were not statistically different from one another.

1998: Yields in 1998 were similar to those in 1997 with the exception that wheat yields were significantly better (57.6 bu/a) and conventionally drilled oats were over run with weeds and only yielded 46 bu/a. An early spring in 1998 was favorable for early planting and treatments 3 and 4 (March 5 and 25th) yielded significantly higher than the

conventional treatment 8 which was planted on April 15th ($p < 0.05$). Fall tillage was effective in increasing yields on treatment 4 vs. 5 ($p < 0.0279$) possibly by improving ground conditions for broadcast seeding. Similar to results at LAC, planting with a no-till drill during freeze/thaw cycle resulted in higher yields (29%) than planting with the broadcast method ($p < 0.1405$). The fall planted wheat yielded significantly higher than all other treatments ($p < 0.0004$) likely as a result of the head start it got during the warm weather in February and March.

Summary

Early spring planting of oats can be a challenge in southern Wisconsin due to the late thaw. Yet early planting can reduce the impact of weeds and disease. We found that using a no-till drill to place the seed down in the soil resulted in higher yields than broadcast seeding and allowed planting during the freeze/thaw cycles. Generally, it was not beneficial to till the ground in the fall prior to planting oats. Planting with close attention to spring weather patterns will provide the most optimal yields.

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Table 1. Treatments and yields for the oat date of planting experiment in 1997 and 1998 at Arlington (ARL97 and ARL98) and 1997 at Lakeland (LAC97).

Treatment	Fall Tillage	Ground conditions	Seeding rate Bu/A	Target Planting date	Planting method	Yield (lb/a)		
						ARL97	ARL98	LAC97 ¹
1 wheat	none	warm	2.5-3.0	25-Sept/10-Oct	no-till drill	1694 b ²	3056 a	3348 b
2 oats	disking	frozen	4.0	5-Mar	broadcast	2222 ab	2049 bc	2444 c
3 oats	none	frozen	4.0	5-Mar	broadcast	2184 ab	2327 b	2564 c
4 oats	disking	freeze-thaw	4.0	25-Mar	broadcast	1882 ab	2295 b	2428 c
5 oats	none	freeze-thaw	4.0	25-Mar	broadcast	1936 ab	1587 cd	2391 c
6 oats	disking	freeze-thaw	4.0	25-Mar	no-till drill	2157 ab	2052 bc	3884 a
7 oats	none	freeze-thaw	4.0	25-Mar	no-till drill	2177 ab	2046 bc	3513 ab
8 oats	none	optimal	2.5	15-Apr	convent drill	2563 a	1227 ³ d	3689 ab
LSD (0.05)						776	635	465

¹ Barley was planted in treatments 2 and 3 at LAC

² Means with different letters in same column are significantly different at p<0.05.

³ Yield figure from hand sampling method. Weed pressure prevented mechanical harvest.

14. Yields and Profits of a Low-External-Input Cropping System Compared to a Moderately-Low-External-Input Cropping System.

Jon Baldock and Josh Posner

24 Apr 2001

INTRODUCTION

External crop inputs (such as fertilizer and pesticides) are a key factor in profitability as well as a major factor in the pollution potential of a cropping system. One of the original justifications for the WICST was to furnish reliable data for the debate between the high-external-input advocates (nozzle heads) and the low-external-input advocates (granola heads). However, there are many more options for input levels than those two extremes and the intermediate alternatives are often more viable and thus more interesting. Much of the discussion about the intermediate options centers on how to set the level of inputs low enough to keep input costs down and avoid pollution problems without severely reducing crop yield and income.

For example, the WICST data taken on the main plots in the first ten years could be interpreted as showing that the inputs in the low external input systems are too low. That is, corn in the moderate input level system, CS2, out-yielded corn in the low input system CS3 in 14 of 16 site-years by an average of 23 bu/acre. Also, the high input forage system, CS4, produced more corn than the relatively low external input forage system, CS5, in 12 of 14 site-years by an average of 17 bu/acre. Thus, even if corn prices are low, say \$2.00/bushel, the low-external-input systems grossed \$34 to \$46/acre less than the higher-external-input systems.

On the other hand, the WISCT data from the primary experiment also show the merits of minimizing external inputs. That is, the low-external-input systems (CS3 and CS5) reduced costs sufficiently that their gross margins were almost as good as the higher yielding systems. They also had lower soil nitrate levels in the fall and use less pesticide.

Ideally, we would like to avoid the lower productivity of the low-external-input systems, but we would like to retain their low cost and low environmental risk features. This ideal begs the question "Is there a set of slightly greater external inputs than used in CS3 and CS5 that would capture the yield advantages of CS2 and CS4 while maintaining the low expense and low pollution hazard benefits of CS3 and CS5?" To help answer this question the WISCT has compared a moderately low-external-input approach (dubbed "ChemLite") based on the Corn-Soybean-Wheat(red clover) cropping system of CS3 to CS3 itself at the Arlington site.

Possible Inputs for ChemLite

Opinions vary on what inputs are most important to convert a very low-input system such as CS3 to a ChemLite system. However, for corn there are three commonly recommended inputs. One, add sufficient starter fertilizer to help P and K uptake in cold, wet springs (usually 10 to 20 lb/a of N, P₂O₅, and K₂O). Two, fertilize with 40 to 60 lbs N/a to fill in most of the difference between the legume N credit for the red clover cover crop (60 to 120 lbs N/a) and the Best Management

Practice recommendation of 160 lbs N/acre on the Arlington soils. And three, apply grass and broadleaf herbicides at less than the full-labeled rate. There are several options for using reduced herbicide rates. The herbicide could be applied either as a preemergence application in a band over the row that covered approximately 50% of the area at the full labeled rate or at a reduced rate. Another alternative is to broadcast the herbicide at a reduced rate. With the addition of one or more herbicides, the number of mechanical weed control passes are generally reduced to one cultivation plus one rotary hoeing if conditions require it. Usually the combination of herbicide and mechanical weeding provide more consistent weed control than either alone. For example, using a preemergent herbicide controls weeds when it is too wet to rotary hoe. However, sometimes it is too dry for herbicides to work, but those are the best conditions for rotary hoeing.

For soybeans, only one additional input is needed to convert CS3 to a ChemLite System and that is a reduced-rate-herbicide program. The same herbicide application options discussed above for corn apply to soybeans. For wheat, there are four possible additional inputs to transform CS3 into a ChemLite System: 1) a broadleaf herbicide to control winter annual weeds, 2) a fungicide, 3) some starter fertilizer applied at planting, and 4) a small amount of N applied in the spring to carry the crop needs until the soil is warm enough to release N from the previous soybean crop. The first two options have the highest success rate and could be based on scouting or other integrated pest management techniques.

MATERIALS AND METHODS

Cunningham et al. (1992) and Posner, Casler, and Baldock (1995) describe the design and conduct of the main WICST cropping systems, so those details will not be repeated here. The ChemLite versus CS3 comparison was started at Arlington in 1995 on the east end of Blocks 1 and 2. The Corn-Soybean-Wheat(red clover cover crop) sequence used from Cropping System 3 (CS3) was used in the ChemLite System so the effect of slightly increased input levels could be compared to CS3 itself. The actual inputs used in the comparison of the ChemLite System to CS3 are shown in Table 1.

The data from 1995 through 1999 were available for this analysis. Thus, the data set included 5 years $\times$ 2 cropping systems $\times$ 2 replications $\times$ 3 crops for a total of 60 cases (see listing in Appendix A). In 1995 the ChemLite soybean and wheat data were apparently recorded as a mean over the two replications instead of as two separate plots. Also, one replication of CS3 soybeans was missing in 1999. These three missing values caused some complications in the analyses, but are unlikely to have caused any changes in the results.

Although the ChemLite crops were not randomly interspersed with the CS3 crops, the plots used for ChemLite were adjacent to the main trial and deemed homogeneous enough to apply statistical tests. I used only Blocks 1 and 2 from the main trial in the analyses because those were the blocks

$$T_i + Y T_{ji} + \epsilon_{ji},$$

that were adjacent to the ChemLite plots and that achieved the balance needed for the statistical tests (2 reps for each system). The model equation shown below provides the basis for the analysis of variance.

$$Z_{jkl} = \mu + Y_j + B_k + YB_{jk} +$$

where

Z_{jkl} = observed yield for the jkl th case,

μ = overall mean yield

Y_j = year, j

B_k = block k

YB_{jk} = interaction of year j with block k

T_l = cropping system, l

YT_{jl} = interaction of year j with cropping system l

ϵ_{jkl} = residual error

j = 1, ..., y

k = 1, ..., b

l = 1, ..., c.

Table MM1 outlines the analysis of variance that corresponds to this model. Because there were too few sites and years to have a good sampling of environments, we regarded years as a fixed factor, not a random factor, which made the bottom line the appropriate error for testing the significance of both the Year $\times$ Cropping System interaction and Cropping System (see the Expected Mean Squares in Table MM1). We calculated the analyses of variance in JMP 4.0 (Lehman, 2000). Because there was some nonhomogeneity, we also analyzed these data with the sign test using STATISTIX7 (Analytical Software, 2000).

Table MM1. Outline of the analysis of variance.

Source	df	Expected Mean-Square
Years, Y	y-1	$\sigma_e^2 + c\sigma_{YB}^2 + bc\sigma_{\Sigma Y}^2$
Block, B	b-1	$\sigma_e^2 + y\sigma_B^2$
Y $\times$ B	(b-1)(y-1)	$\sigma_e^2 + c\sigma_{YB}^2$
Cropping System, C	c-1	$\sigma_e^2 + by\sigma_C^2$
Y $\times$ C	(y-1)(c-1)	$\sigma_e^2 + b\sigma_{YC}^2$
Pooled error	y(b-1)(c-1)	σ_e^2

RESULTS AND DISCUSSION

Crop Yields

Table 2 shows the analysis of variance for the crop yields in the two systems. Observe that there are a number of significant effects in spite of the low number of degrees of freedom for error. Table 3 presents the yearly mean crop yields and the mean crop yields averaged over years for both systems. This table shows that the ChemLite system out yielded CS3 in winter wheat grain every year and for the other commodities in four of five years.

The largest difference in mean yields and the highest level of significant differences occurred in corn. These results are consistent with one of the primary reasons the ChemLite system was studied, that is, low CS3 corn yields in some years. Eighty percent of the 19-bu/acre advantage for the ChemLite system occurred in 1996, which was a cool, wet spring. Even though these conditions only happened once in the ChemLite comparison, they should not be regarded a rare event because similar conditions with similarly low CS3 corn yields occurred in 1992 and 1993 in the main WICST trial. It is not clear which input was most responsible for the improved yield in ChemLite or if more than one of the three added inputs contributed. In years other than 1996, the CS3 corn yields were close to, or even slightly above those in the ChemLite system. As a result the Year $\times$ System interaction was highly significant. In some cases, a significant interaction means that the difference between the systems was so variable over years that a recommendation cannot be made. However, in this case, the results favor the ChemLite system four out of five years with a large advantage in one of five years. Thus based on corn yields, the ChemLite system is clearly recommended over the CS3 system.

The ChemLite system also produced an average of 4 bu/acre more soybeans than the CS3 system. Because herbicide use was the main additional input, it probably was the main cause of the difference, but residual effects of the starter fertilizer applied to corn may have also contributed to the increased yield. The Year $\times$ System interaction was not significant, which was due at least in part to the consistent advantage of the ChemLite system (the low number of degrees of freedom for error was also likely a contributing factor). Thus, although the advantage is not as dramatic as for corn, the ChemLite system is recommended over the CS3 system based on soybean yields.

The ChemLite wheat grain yields were greater than those for CS3 in all 5 years, but the difference between systems was not quite significant (Table 2). That is not too surprising because the ChemLite and CS3 inputs levels for wheat were virtually the same (Table 1) and there were only 4 df for error (Table 2). However, the small advantage for ChemLite in straw yield was significant (Table 2). Because the wheat was managed the same, the ChemLite advantage in straw yield (Table 3) was likely due to residual effects of fertilizer or weed control from the other phases. Thus, the differences in wheat yields would probably have been greater and significant for both grain and straw, if small amounts of those inputs had been applied directly to the wheat.

Yield variability and the associated risk can be an important factor apart from mean yields. In this time period, which was characterized by generally good growing conditions and high yield in four of the five years, the ChemLite system had less variability in corn yields than the Low External

Input System. The range in ChemLite corn yields was 53 bu/acre (standard deviation of 21.0 bu/acre), but for CS3 corn yields it was 119 bu/acre (standard deviation of 41.8 bu/acre). This difference is significant at the 5% level. The small number of years is probably not a factor that exaggerates the variability of CS3 because the one poor yield in five years for the CS3 in the ChemLite study is actually a lower percentage than CS3 experienced in the main WICST study (three poor years in eight).

The differences in variability were small for soybeans and wheat. The range in ChemLite soybean yields was 22.2 bu/acre versus 20.6 for CS3 (standard deviations 8.59 v. 11.0). The range in ChemLite wheat grain yields was 29.7 bu/acre compared to 21.1 for CS3 (standard deviations of 9.36 v. 8.15). The range in ChemLite wheat straw yields was 1.02 t/a compared to 0.93 for CS3 (standard deviations of 0.43 v. 0.37).

If we view this study as a comparison of two systems using the same three crops over five years, then there are fifteen chances for CS3 to out yield ChemLite and vice versa. This formulation allows use of the sign test, which has the advantage of not depending on assuming the errors are from the normal distribution or homogeneous. The sign test indicates the ChemLite yields were greater than the CS3 yields in 13 of the 15 chances if the grain yields were used for wheat, which was significant at the 1% level. If the straw yields were used for wheat, then ChemLite produced more than CS3 in 12 of the 15 crop-years, which was significant at the 2% level.

Thus, even though the ChemLite inputs were not applied every year or to every crop, the ChemLite systems out yielded CS3 for corn, soybeans, and wheat straw. The yield advantage for ChemLite would likely have been greater, if small amounts of fertilizer and herbicides had been used more consistently across all three crops. Also, the differences in yields in favor of ChemLite may increase as the soil P and K levels in CS3 decrease. That is because the CS3 soil P and K levels began at a very high level and although they are decreasing (Alt et al., 1998 Appendix III-A), they are still above the optimum for these crops (Kelling et al., 1998).

Economic Analysis

The ChemLite system out yielded CS3 for corn, soybeans, and wheat straw. Therefore, there is a set of modest inputs that can produce higher yields, which answers one of the questions that this study tried to answer. However, the question remains "Are those yields high enough to pay for the inputs, so that profitability is improved?"

We used a modified version of the Crop Rotation Options Program (CROP; Baldock et al., 1998) to analyze the latter question. The main modification consisted of bypassing CROP's formula for cropping district average yields and agronomic factors, so that the actual yields obtained in this study could be used. The economic analysis compared two 1000-acre cash crop operations: one running ChemLite, the other CS3. The machinery compliments for the two farms are shown in Table 4. Note that the only difference in equipment is that the ChemLite farm has a sprayer. The major input prices and commodity prices used in the comparison are shown in Table 5. The crop prices were set at the loan rate because harvest-time market prices have been below the loan rate for several years, but most farmers could easily obtain the loan price using the government loan

program itself or the loan deficiency payment option. The N price is typical of the price that existed during the conduct of the trial. However, N prices have increased sharply in the last several months, so a sensitivity analysis for N prices will be discussed below. Similarly, some of the WICST team members believe the CS3 is an organic system and that the commodity prices should reflect an organic crop premium, so a sensitivity analysis for those premiums will also be discussed. Finally, the cost of fertilizers, herbicides, and mechanic weed control for the two systems are shown in Table 6. Unfortunately, the inputs were not as consistent as desired, so in many cases the average or the most common level was used.

Table 7 summarizes the income, expenses and net return for the two systems. With the standard price scenario the ChemLite Farm realized a pretax profit of \$34092 and the CS3 Farm realized \$20043. That is a 70% improvement in net return for a modest set of inputs. In other words, the ChemLite Farm's income increased \$3.10 for every dollar invested in additional inputs. If the herbicides and fertilizer had really been applied more consistently in the ChemLite system and the mechanical weed control passes reduced as discussed in the introduction, then ChemLite may have performed even better.

Recently, some people have been forecasting the demise of any system that applies N from external sources because fertilizer N prices have increased by 25 to 200%. We ran a sensitivity analysis to examine how the price of N affects the net return on the ChemLite Farm (the CS3 farm does not use any N, so the price of N has no bearing on its net return). Obviously, as the N price increases, the net return decreases, assuming everything else stays the same (Table 8). However, it would take a drastic increase in N price to reduce the ChemLite net return to the level of CS3. In fact, the N price would have to increase nearly 6-fold, to near \$1.38/lb N, before the ChemLite income would be as low as CS3.

What if the CS3 Farm was able to obtain an organic premium for its grain? To answer that question, we examined how large such a premium would have to be across all three grains before the CS3 net return was as large as for ChemLite (Table 9). The answer is that the CS3 Farm would have to get a little better than a 6% premium to be as profitable as ChemLite. That is, instead of \$1.80/bu, \$2.47/bu, and \$5.18/bu for corn, wheat, and soybeans; the CS3 farm would have to get more than \$1.91/bu, \$2.62/bu, and \$5.49/bu. At these low price levels those premiums equate to 11¢/bu on corn, 15¢/bu on wheat, and 31¢/bu on soybeans. An exercise for another time would be to determine how much premium the CS3 Farm would need on one or two crops to be as profitable as the ChemLite Farm.

CONCLUSIONS

The ChemLite system out yielded CS3 for corn, soybeans, and wheat straw. There was no significant difference between the systems for wheat grain yield, but ChemLite had higher grain yields than CS3 in all five years. Therefore, there is a set of modest inputs that can produce higher crop yields. Were the ChemLite yields sufficiently more than the CS3 yields to pay for the additional inputs? An economic analysis showed that they were. In fact, the net return to labor, management, and capital for a 1000 acre ChemLite Farm was over \$14,000 more than for the same size CS3 Farm (\$34100/year versus \$20000/year). In other words, income was increased \$3.10 for every dollar invested in additional inputs. Sensitivity analyses showed that fertilizer N prices would have to increase nearly 6-fold to reduce the ChemLite return to the level of the CS3 Farm. A similar analysis for the effect of organic premiums on CS3 demonstrated that the premium would have to be over 6% for all three grains in order for the CS3 Farm net return to reach the level of the ChemLite Farm.

Table 1. Additional inputs for ChemLite System.

Year	Corn	Soybeans	Wheat
1995	Starter: 6-24-24 at 100 lb/a N: 82-0-0 at 73 lb/a Herbicide†: Accent 1/3 oz/a Buctril 0.5 pt/a Rotary hoe: 3 times Cultivate: 2 times	Starter: none N: none Herbicide†: Basagran 0.5-pt/a Resource 2.0 oz/a Crop Oil .5 qt/a 28% N 0.25 gal/a Rotary hoe: 3 times Cultivate: 2 times	Starter: none N: none Herbicide: none
1996	Starter: 6-24-24 at 100 lb/a N: 82-0-0 at 50 lb/a Herbicide†: Accent 0.22 oz/a Buctril 0.25 pt/a NIS 0.1 qt/a Rotary hoe: 3 times Cultivate: 3 times	Starter: none N: none Herbicide: none Rotary hoe: 3 times Cultivate: 4 times	Starter: none N: none Herbicide: none
1997	Starter: 6-24-24 at 100 lb/a N: 82-0-0 at 50 lb/a Herbicide†: Accent 1/3 oz/a Buctril 0.5 pt/a Rotary hoe: 3 times Cultivate: 7 times	Starter: none N: none Herbicide†: Poast Plus 0.75 pt/a Crop Oil 0.25 qt/a Rotary hoe: 3 times Cultivate: 8 times	Starter: none N: none Herbicide: none
1998	Starter: 6-24-24 at 100 lb/a N: 82-0-0 at 50 lb/a Herbicide: none Rotary hoe: 2 times Cultivate: 1 times	Starter: none N: none Herbicide: none Rotary hoe: 2 times Cultivate: 3 times	Starter: none N: none Herbicide: none
1999	Starter: 6-24-24 at 100 lb/a N: 82-0-0 at 50 lb/a Herbicide: none Rotary hoe: 1 time Cultivate: 2 times	Starter: none N: none Herbicide: none Rotary hoe: 1 time Cultivate: 3 times	Starter: none N: none Herbicide: none

† The rates shown are the amount per total acre. The applications were made in a 15-inch band on 30-inch rows, thus the rate in the band itself was twice that shown.

Table 2. Analysis of variance for crop yields.

Source	df	Corn MS	Soybean MS	Wheat, Grain MS	Wheat, Straw MS
Year, Y	4	3640.32**	238.64*	193.79*	0.6534**
Block, B	1	540.34*	7.43ns	29.027*	0.0000ns
Y × B	4	65.92	24.94	24.251	0.0013
System, S	1	1857.55**	175.89#	16.741ns	0.0295**
Y × S	4	1032.25**	73.58ns	2.070ns	0.0128ns
Error	5	33.16	22.15†	4.692†	0.00128†

† Soybean MSError has 3 df, Wheat grain and straw MErrors have 4 df.

**, *, # Significant at the 1%, 5%, and 10% level respectively.

Table 3. Mean crop yields†.

Year	Crop	ChemLite	CS3
1995	Corn, bu/a	147	149
1996	Corn, bu/a	150	74
1997	Corn, bu/a	159	147
1998	Corn, bu/a	200	193
1999	Corn, bu/a	160	155
Mean	Corn, bu/a	163	144
1995	Soybean, bu/a	68.3‡	63.4
1996	Soybean, bu/a	60.2	60.1
1997	Soybean, bu/a	46.1	48.6
1998	Soybean, bu/a	62.5	47.2
1999	Soybean, bu/a	49.8	32.5‡
Mean	Soybean, bu/a	56.2	52.3
1995	Wheat grain, bu/a	76.9‡	68.1
1996	Wheat grain, bu/a	47.2	47.0
1997	Wheat grain, bu/a	51.9	51.0
1998	Wheat grain, bu/a	59.2	55.4
1999	Wheat grain, bu/a	59.8	56.9
Mean	Wheat grain, bu/a	57.0	55.7
1995	Wheat straw, t/a	1.50‡	1.23
1996	Wheat straw, t/a	1.68	1.53
1997	Wheat straw, t/a	0.99	1.09
1998	Wheat straw, t/a	0.73	0.67
1999	Wheat straw, t/a	0.66	0.60
Mean	Wheat straw, t/a	1.07	1.02

† n=2 for year means, unless noted otherwise.

‡ n=1.

Table 4. Equipment compliment for the 1000-acre cash crop farms.

Equipment item	Size	ChemLite Farm, no.	CS3 Farm, no.
Tractors over 200 hp, hp	225	1	1
Tractors under 200 hp, hp	98	2	2
Combine	medium	1	1
Disk-chisel plow, ft	15	1	1
Field cultivator, ft	25	1	1
Standard planter, ft	15	1	1
Grain drill, ft	15	1	1
Cultivator, ft	15	1	1
Trailer sprayer, boom width, ft	60	1	none
Gravity boxes, bu	250	4	4
Soybean head, ft	15	1	1
Corn head, rows	6	1	1

Table 5. Input and commodity prices used in the economic analysis.

Item	Price
Diesel fuel, \$/gallon	1.60
LP, \$/gal	0.90
N, \$/lb	0.23
P2O5, \$/lb	0.17
K2O, \$/lb	0.123
Corn, \$/bu No. 2 corn	1.80
Soft red winter wheat, \$/bu	2.47
Soybeans, \$/bu	5.18
Straw, \$/ton	70.00

Table 6. Cost of fertilizer, herbicides, and mechanical weed control for the two farms.

Item	ChemLite Farm				CS3 Farm		
	Corn	Beans	Wheat		Corn	Beans	Wheat
	-----\$/acre-----						
Herbicides†	7.62	5.03	0		0.00	0.00	0
Rotary hoe‡	4.00	4.00	0		4.00	4.00	0
Cultivate	10.00	15.00	0		15.00	20.00	0
Spray	1.00	1.00	0		0.00	0.00	0
Spread fertilizer	0.25	0.00	0		0.00	0.00	0

† \$2/acre per hoeing (includes only variable costs).

‡ \$5/acre per cultivation (includes only variable costs).

Table 7. Net return to labor , management, and capital on a 1000 acre farm.

Category		ChemLite Farm, \$	CS3 Farm, \$
Gross income			
	Corn	97799	86399
	Soybeans	97038	90304
	Wheat, grain	46930	45859
	Wheat, straw	31940	30440
Expenses			
	Variable (wo fertilizer)	91298	88069
	Fertilizer	2829	0
	Fixed equipment costs	45488	44890
	Land rent	100000	100000
Total income		273707	253002
Total expenses		239615	232959
Net return		34092	20043

Table 8. Effect of increasing price of N on net return for ChemLite farm.

N price, \$/lb N	Net return, \$
0.23	34092
0.29	33383
0.35	32676
0.46	31261
0.69	28432
0.92	25603
1.15	22774
1.38	19945
1.84	14288
2.30	8630

Table 9. Effect of organic premiums on net return for CS3 farm.

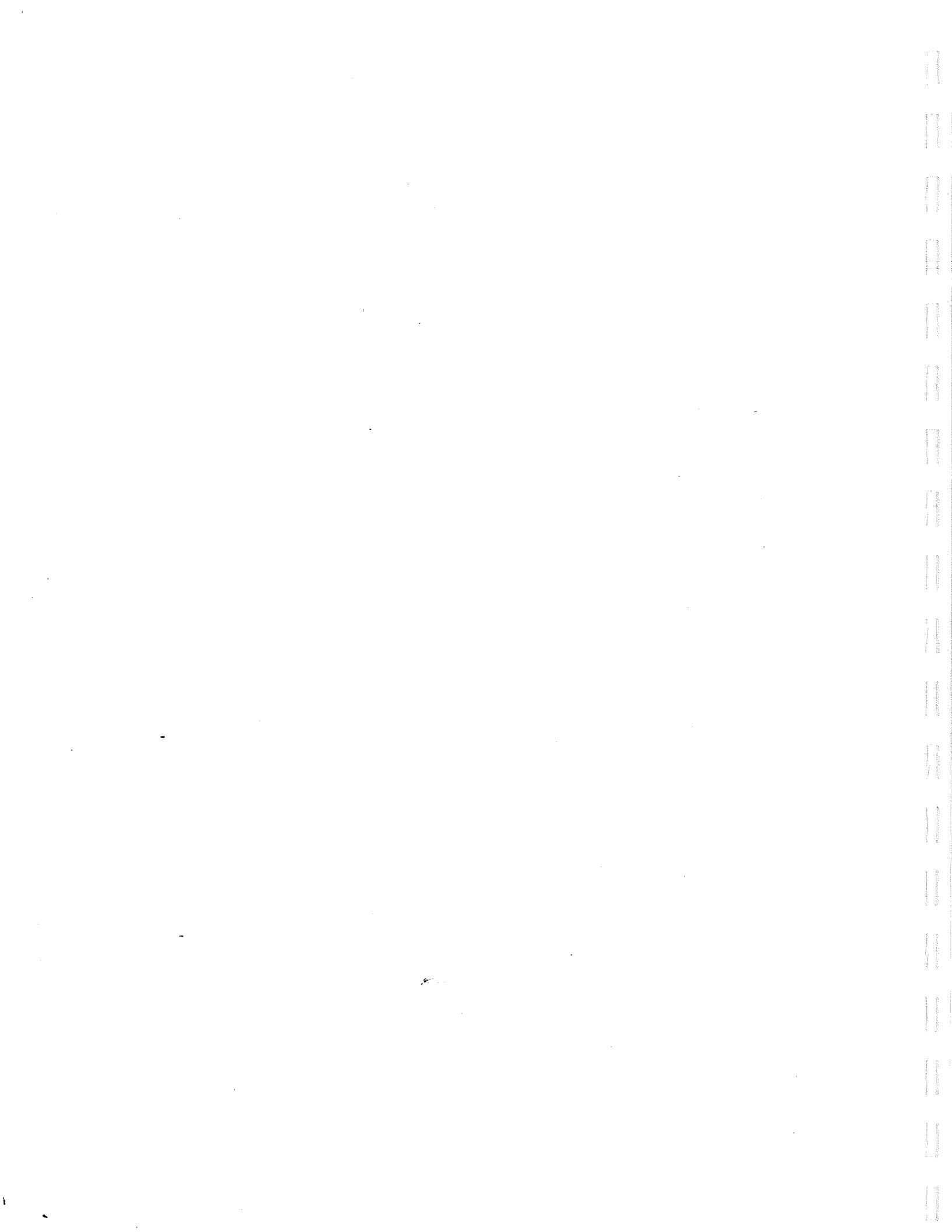
Premium, %	Net return, \$
0	20043
2	24495
4	28946
6	33397
8	37848
10	42300

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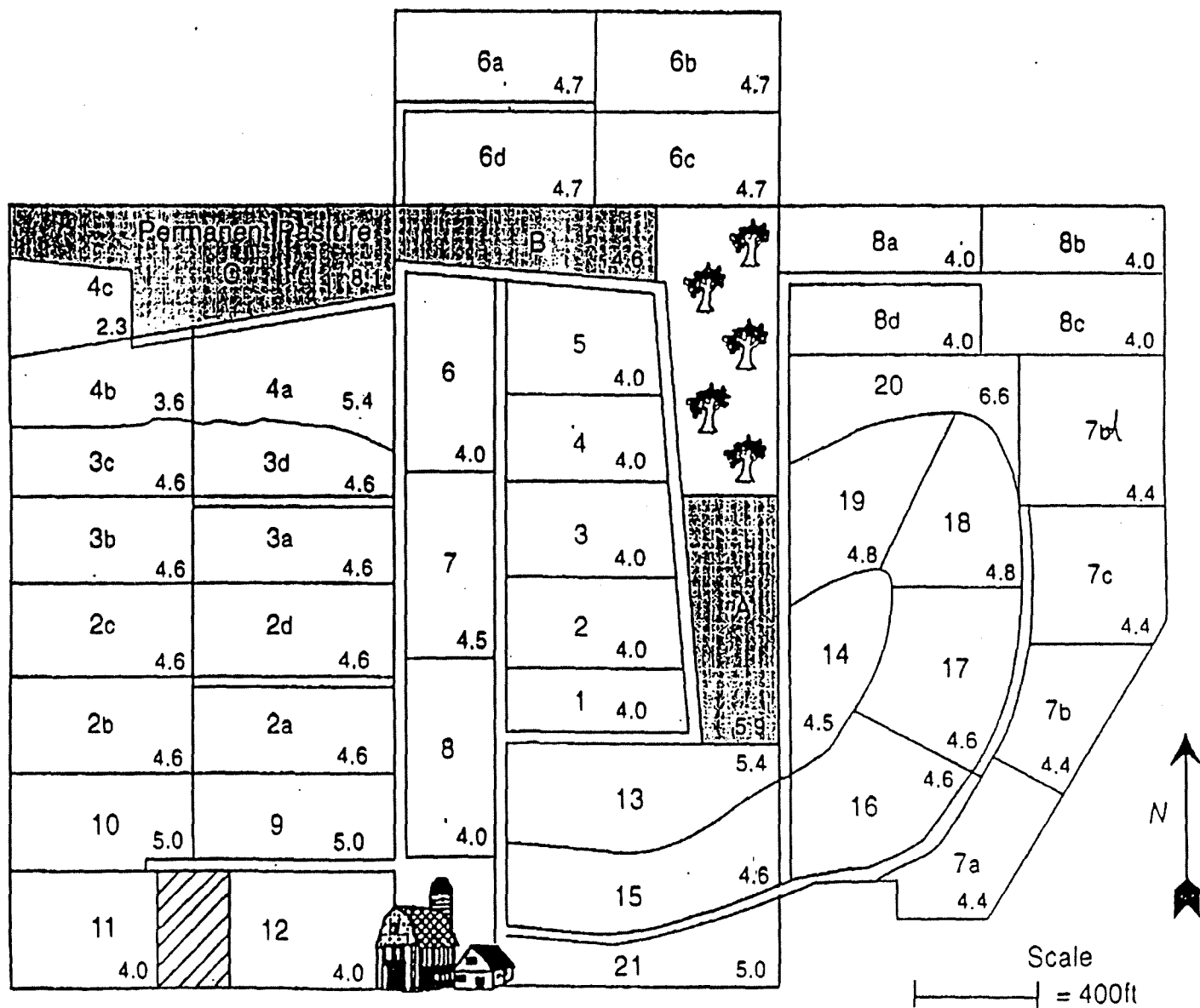


Figure 1. Krusenbaum Farm field map.

KRUSENBAUM PROJECT**15. Evaluation of Potassium Fertilization for Improved Forage Yield and Quality**J.K. Stute¹, A.L. Payne¹, J.L. Posner², and S.G. Alt²**Introduction**

Forage yield in the intensive, rotationally grazed (IGR) system used on the Krusenbaum Farm has been lower than expected, even several years after the transition from a conventional dairy system. Periodic soil sampling has indicated the farm has low levels of soil test potassium (STK) under the University of Wisconsin soil analysis/fertility recommendation system. Available potassium can be a limiting factor in forage yield and quality. It seems logical that adding supplemental K would serve to increase forage yield. At the same time, routine forage analysis has indicated tissue K levels are in the normal range. If available potassium were limiting, traditional wisdom suggests tissue K would fall in the low range. That is not the case here creating a puzzle which when coupled with high costs of organic K sources, led to the investigation of supplemental K in an organically managed, IGR system.

Materials and Methods

The effect of added potassium on forage yield, quality, and STK was studied from 1997 to 1999 on a Miami silt loam soil, found on this farm near East Troy, WI. Four sets of side by side one-acre strips were superimposed over established paddocks. Potassium in the form of K₂SO₄ (supplied by Midwest BioAg) was broadcast applied at a rate of 400 lb/a in April of 1997 and reapplied in April of 1998. This rate was based on estimated annual crop removal. Soil samples (10 per plot, to a 6 inch depth) were taken prior to application in both years, and again in April and November 1999, a year in which no K was applied., and analyzed for STK. Throughout the study, forage samples were taken prior to grazing to estimate dry matter yields and K content. Forage quality analysis was conducted by the NIR method. Tissue K level was determined by using wet chemistry methods. Data were subject to analysis of variance procedures to determine significant main effects. Years were analyzed separately because of an uneven number of sampled harvests. Changes in STK were estimated using spring sample results to prevent confounding caused by seasonal variation in STK.

Results**Yield**

Addition of K did not significantly increase total forage yield in either year, or total over the course of the study. Only once did a significant difference exist for an individual cutting/grazing, the third harvest in 1998, an increase of 535 lb/acre.

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Tissue K and K Removal

Addition of K produced a significant increase in tissue K in 2 of 7 harvests, third crop in 1997 and first in 1998. The increase was not great enough however to increase total K removal by harvest for either of these harvests. Total season as well as overall K removal was also uninfluenced by addition of supplemental K (Table 1)

STK

Addition of K resulted in a significant increase in STK from the first application, measured in spring 1998 (Table 1). The combination of reapplication of K in 1998, with residual from the 1997 applications did not produce a similar effect on STK measured in spring 1999.

Table 1. Effect of supplemental potassium on soil test potassium (STK)

Treatment	1997		1998		1999 STK		Change in		
	Initial	Crop	Initial	Crop			STK measured in Spring		
	STK	Removal	STK	Removal	Spring	Fall	1997-1998	1998-1999	1997-1999
	ppm	lb/a	ppm	lb/a	ppm		ppm		
Treated	79	202	86	179	93	76	8	5	14
Untreated	84	146	78	162	69	73	-6	-9	-15
F test	ns	ns	*	ns	ns	ns	Ns	ns	ns
cv (%)	26.3	33.4	4.1	7.0	19.2	13.1			

*, significant at the 5% level of probability; ns, not significant.

Discussion

Yields and K concentration were not significantly affected overall (data not shown) so it would appear that additional K was unnecessary for yield optimization within this production environment (N status, pH etc.). Although crop yield was unaffected, data in Table 1 shows that crop removal (and hence uptake) was greater where K was applied, especially in 1997. The lack of a significant treatment effect may be do to variability as suggested by the coefficient of variation, compared to 1998. Without a corresponding increase in yield, this additional uptake could be considered luxury in nature.

As was expected, STK levels increased with the supplemental potassium, and decreased without additional K. However, in the end the change was not significant at the 0.05% level of probability. Its interesting to note that by the end of the 1999 growing season, 20 months and two cropping seasons after the last K application, STK levels were nearly identical (Table 1). Though soils may test low in potassium, adding K does not always increase yields. Fixed K, undetected by soil tests, or that from subsoil may naturally provide more plant available K than we believe. We will continue to monitor STK to determine long-term trends.

16. Effect of Aeration on Yield and Quality of Pasture Forage at the Krusenbaum Farm.

Janet Hedtcke and Altfrid Krusenbaum

Introduction

Forage yield has been lower than expected on the intensively managed pasture at the Krusenbaum farm in recent years. One hypothesis was that heavy stocking rates have resulted in surface soil compaction adversely affecting forage yield and through reduced legume growth-forage quality as well. It was decided to see if mechanical aeration of the surface soil would have an effect on production and quality.

Materials and Methods

Soil type is a Miami silt loam. Paddocks 1-5 (about 4 acres each) located just northeast of the barn, essentially the center of the farm, were used for this study. In the fall of 1996, the entire area was worked over with the Aerway soil builder. The aerator penetrated approximately 6 inches into the soil. Four strips (20 x 500 ft) were laid out across the five paddocks in December of 1997. The experimental design was a randomized complete block design with 10 replicates: Each paddock had two replicates. The treated strips were aerated with a 10-ft Aerway and the other strips were controls. The entire area was reseeded with red clover and the Aerway was driven across the indicated strips on April 24, 1998. The Aerway strips were treated again on October 5, 1998, May 5, 1999, and again on April 24, 2000. Red clover was also reseeded to the entire area at time of aeration in 1999.

All forage samples were collected just before harvest or grazing. In 1998, sampling occurred just once in the late spring (May 30th) and no yield measurements were taken. No sampling took place in 1999. In 2000, forage sampling occurred four times over the season (May 24, July 5, August 15, and October 4). Not all paddocks were available for sampling at each time period. Two samples were collected from each treatment per replicate in each paddock with a 0.5m² quadrant and hand shears. Samples were dried and weighed to estimate yield. Samples were ground through a Wiley mill to 1mm size and then sent to the UW Soils and Plant Analysis Lab in Marshfield for quality and mineral analysis. Crude protein, fiber (neutral and acid detergent fiber, NDF, ADF) and relative feed value (RFV) were estimated using NIRS. Minerals including P, K, Ca, and Mg were measured with wet chemistry techniques.

Results and Discussion

1998. Aeration improved most all quality factors that year (Table 1) probably by improving the red clover catch from the late April seeding. Crude protein (CP) increased by 3 percentage points to 16% of the dry matter (DM). Fiber, NDF and ADF, were 8 and 5 percentage points lower with aeration, thus improving RFV nearly 21 points. Lactating dairy cows require forage with RFV of 125 or higher. Although aeration improved RFV by over 20 points in the reseeding year, one would still like to see it another 10 points higher for lactating dairy cows. Of the macro minerals, Ca and K were both increased with aeration, however, P and Mg were unchanged.

2000. Aeration did not result in improved yields or quality factors at any time during the grazing season (Table 1). Typical of any pasture, first harvest had the highest yields with over 2 tons DM/a across paddocks. Forage yields in July and August were only about half that of the May harvest. Hand in hand with high yield is lower quality. Forage quality improved at each harvest with very high quality forage available in late summer and early fall.

Summary

It appears that annual surface aeration did not result in an improved sod. In a reseeding year, the Aerway may have had a positive effect on red clover establishment. Levels of minerals were already in the adequate/sufficient range for grass and alfalfa before aeration, thus it is not surprising that there were no differences in the mineral content of the forage.

Table 1. Yield and quality estimates of forage, aerated or not, for 1998, 2000. Means averaged over 10 replicates, and 2 subsamples.

Date	Treatment	Yield	Quality component							
			CP	ADF ¹	NDF ²	RFV ³	Ca	Mg	P	K
		--lb DM/a--	--%							
May 30, 1998	Aerated	missing	16.0	33.8	50.6	116	0.96	0.29	2.53	0.29
	Non-aerated	missing	13.0	38.2	58.5	95	0.71	0.28	2.52	0.23
May 24, 2000	Aerated	4032b ⁴	16.5	35.3	56.3	102	0.46	0.22	0.38	2.66
May 24, 2000	Non-aerated	4833a	15.8	36.2	57.0	100	0.59	0.23	0.38	2.44
July 5, 2000	Aerated	1778	18.7	31.2	48.1	128	0.64	0.30	0.43	2.59
July 5, 2000	Non-aerated	1901	18.0	32.2	49.4	122	0.67	0.32	0.43	2.48
August 15, 2000	Aerated	1842	20.6	31.5	47.2	128	0.79	0.34	0.44	2.52
August 15, 2000	Non-aerated	1625	21.1	30.3	44.9	136	0.86	0.36	0.46	2.33
October 10, 2000	Aerated	missing	22.0	26.5	41.7	154	1.02	0.36	0.37	2.35
October 10, 2000	Non-aerated	missing	22.4	26.8	41.3	158	0.96	0.34	0.36	2.52

¹ ADF= acid detergent fiber, is the portion of the total fiber that is relatively indigestible.

² NDF = neutral detergent fiber represents the total fiber portion of a feed.

³ RFV = relative feed value, an index used to compare forage quality relative to full bloom alfalfa.

⁴ Treatment means on this date are statistically different at $p < 0.07$.

17. Effect of Additional Manure on Yield and Quality of Pasture Forage at the Krusenbaum Farm.

Janet Hedtcke and Altfred Krusenbaum

Introduction

Forage yield has been lower than expected on the intensively managed pasture at the Krusenbaum farm in recent years. One hypothesis is that nitrogen is lacking in the system due to modest legume stands. Additionally, manure buildup from the parlor and barnyard needed to be distributed. An experiment was initiated to measure the effect of manure, in addition to that from grazing, on the yield and quality of the pasture forage.

Materials and Methods

Soil type is Miami silt loam. Paddocks 10 and 11 (about 5 acres each) located in the southwest corner of the farm were used for this study. Baseline soil samples were collected from both paddocks in the summer of 1997 to compare their fertility (Table 1).

Manure from the parlor and barnyard was spread on paddock 10 throughout the season in 1997, 1998 and in May 1999. Manure was collected at three different time points in 1997 (July 23, September 24, November 6) and once in 1998 (April 28) to determine variability in nutrients, especially moisture throughout the year. Manure was analyzed for dry matter, total N, P and K (Table 2). Paddock 10 received 11, 17, and 5 loads of manure in 1997, 1998, and 1999, respectively. Manure in the summer tended to be dryer and higher in N, P, and K. Therefore, the amount of manure applied is reported on a dry matter basis. Approximately 12.5 tons of dry manure was added per acre over the 3-yr time period. Paddock 11 was the control, which receive no additional manure besides that from grazing.

Four random forage samples were collected from each treatment with a 0.5m² quadrant and hand shears at three dates during the 2000 season (May 24, July 5, and October 4). We have yield data for the first two grazing dates and quality data for all dates. Samples were dried and weighed to estimate yield. Samples were ground through a Wiley mill to 1mm size and then sent to the UW Soils and Plant Analysis Lab in Marshfield for quality and mineral analysis. Crude protein, fiber (neutral and acid detergent fiber, NDF, ADF) and relative feed value (RFV) were estimated using NIRS. Minerals including P, K, Ca, and Mg were measured with wet chemistry techniques.

Results and Discussion

Soil from both paddocks was quite similar except for STK, which was high in paddock 10 before the treatments were applied (Table 1). Both paddocks were excessively high in P. Organic matter and pH were at appropriate levels for forages. Analysis of the manure showed dry matter to range from 19.6 to 54.4%, with summer manure being drier and spring and fall manure being more wet due to outside storage and seasonal rainfall patterns.

Generally, forage yield and quality are quite good on the Krusenbaum farm. Paddocks produced nearly a ton of dry matter at each sampling. Protein levels are at or above the requirement for high producing dairy cows. Fiber levels are representative of vegetative grass/legume mixtures. Forage in paddock 10 responded to the manure in the first cut only. Forage yield was nearly 30% higher under the manured treatment (Table 3). However, there was no carryover to the second cut. There was no consistent pattern across the quality constituents. Crude protein levels were slightly higher on the manured treatment in May and July. First-cut fiber levels were higher on the manured treatment which reduced the relative feed value. High soil STP lead to high forage P well above that required by lactating dairy cows. Potassium levels were higher on the manured treatment, especially in May, and Ca and Mg were reduced with additional manure. High potassium levels and low Mg levels can be related to metabolic disorders such as grass tetany and milk fever, especially in the early spring when grass is lush and the weather is cool.

Summary

As with the aerator work, we must conclude that concentrating manure on a paddock, at least two years later (summer 1998 to spring 2000) had relatively little impact on production. However, it appears that the paddock did "green up" more quickly than the control. The high soil P is a problem on dairy farms and concentrating manure on certain paddocks will not help with that problem. A result of the high STP values is high P in the forage. Forage from the manured treatment (paddock 10) should be harvested as hay in early spring to avoid potential metabolic disorders in the herd due to high potassium levels. Soil tests should be taken soon to determine the impact of added manure on soil P and K.

Table 1. Baseline soil analysis (July 1997) from paddock 10 and 11 prior to manuring.

	pH	OM%	P ppm	K ppm
Paddock 10	6.7	3.1	104	142
Paddock 11	6.7	3.2	90	93

Table 2. Analysis of manure from parlor and barnyard in 1997 & 1998 spread on paddock 10 (5 acres).

Season	DM%	tons/load	of loads	N	P	K	N	P	K
				lbs/ton manure ('as is')			lbs added/acre ('as is')		
Spring	19.6	8.5	15	9.8	2.1	6.1	250	54	156
Summer	54.4	5.0	4	29.4	10.7	53.5	118	43	214
Fall	30.9	7.0	7	14.8	6.9	22.5	145	68	221
Winter	20.9	8.0	7	11.7	2.5	9.8	131	28	110

Table 3. Yield and quality of forage sampled in 2000 from paddocks 10 (manured) and 11 (control).

Grazing period	Treatment	Yield	CP	ADF ¹	NDF ²	RFV ³	P	K	Ca	Mg
		-lb Dm/a-					%			
05/24/00	manured	2509	21.8	24.8	45.6	143	0.44	3.31	0.36	0.23
05/24/00	control	1829	19.6	23.1	38.0	175	0.41	2.44	0.60	0.29
07/05/00	manured	1861	19.3	30.8	49.6	122	0.41	2.89	0.56	0.33
07/05/00	control	1830	16.8	31.9	52.2	114	0.47	2.55	0.52	0.28
10/04/00	manured	missing	22.6	23.7	41.0	161	0.45	2.62	0.71	0.31
10/04/00	control	missing	24.4	22.2	35.2	194	0.41	2.20	1.14	0.42

¹ ADF= acid detergent fiber, is the portion of the total fiber that is relatively indigestible.

² NDF = neutral detergent fiber represents the total fiber portion of a feed.

³ RFV = relative feed value, an index used to compare forage quality relative to full bloom alfalfa.

18. Krusenbaum Dairy Herd Health and Production Report – 1999

Ken Nordlund, DVM, Clinical Professor

School of Veterinary Medicine, University of Wisconsin-Madison

The primary production and health trends in the Krusenbaum dairy herd for calendar year 1999 is summarized in this report. The information comes from Dairy Herd Improvement records from Wisconsin AgSource and upon field investigation reports from the UW School of Veterinary Medicine.

1. Herd populations (*Figure 1*)

Herd numbers started at 100 cows in January, reached a high of 123 in June and declined to 115 in December. There are more mature cows and fewer first lactation cows in the herd in 1999 compared to 1998. Theoretically, this should result in slightly increased milk production.

2. Production

a. Milk

Rolling herd average (average annual milk production per cow averaged over the past 12-months) has been very stable over the past 12 months, beginning the year at 17,292 and finishing the year at 16,712. (*Figure 2*)

Mature equivalent milk (ME305) shows a similar modest decline through 1998 ending at 18,200 lbs. Of interest is the pronounced increase in ME305 milk during the months of April and May, with dramatic drops in June and July. (*Figure 2*)

Milk per cow per day reached a high of 77 lbs per cow in April, higher than the prior year. Management Level Milk (standardized for days-in-milk and components) shows that the poorest months are June-August. (*Figure 3*)

b. Bulk milk

Figure 4 shows herd milk sold on test dates is very similar to 1997. The maximum milk sold per day is slightly lower than 1997, but appears to be more sustained than in 1997.

c. Milk components (*Figure 5*)

At 3.9%, milk fat % was higher in 1999 than the 3.6% average from 1998. However, milk fat % did reach very low points of 3.2% in June, 3.3% in July, and 3.0% in August, suggestive of abnormal rumen fermentation.

d. Clinical diagnosis of subacute rumen acidosis

Diagnostic work on ruminal acidosis was repeated again in late June 1999 by the School of Veterinary Medicine. Rumenocentesis samples from 11 cows showed pH values of less than 5.50 in 5 cows, which indicates that subacute ruminal acidosis is a problem in the herd. The values are improved from 1998, but remain a problem.

Ruminal acidosis is caused by rations that are low in fiber and relatively high in starch. It is my opinion that the relatively low sward density of the pastures results in less forage consumption

than expected. Grass is also a less effective buffer than alfalfa. The continued problems with subacute acidosis explain much of the problems of low milk production and low milk fat% in June through August. The solution to this problem will be found in either improvements of pasture sward density, increased supplementation of the ration with alfalfa or other byproduct feeds, or a combination of both.

3. Mastitis

The herd continued to produce high quality milk in 1999. The average SCC over the year was 209,000. The fact that the logarithmic linear scores stay relatively stable throughout the year, while the SCC increases dramatically to 350,000 during the summer months of June, July, and August suggests that the increased SCC in those months is due to infection of a very small number of cows. (*Figure 6*)

Figure 7 shows that first lactation cows enter the herd with an average linear score of about 2.4 and remain quite stable, and older cows enter their lactations at about 2.4 and increase slightly as the lactation progresses. Overall, some improvement could be made in the entering scores of the first lactation cows as we have a goal of 2.0 at this point.

4. Reproduction

Herd reproductive performance continued to be excellent in 1999. The herd reported 85 pregnant cows at the end of December with an average of 1.6 services per conception. This is considered excellent (*Figure 8*). Average days to first breeding were 78, which reflects a very active heat detection effort (*Figure 9*).

Overall management of the dry periods is also excellent, with an average dry period length of 59 days and very few cows with unduly short or long dry periods (*Figure 10*). The management of dry periods is better in the winter of 1998-99 than in the prior year.

5. Genetics (*Figure 11*)

Changes in semen selection policy of several years ago have started to show in the cowherd. Genetic merit of the sires of the second lactation and older cows averages 104 PTA\$, compared to an average of 130 for the top 20% of herds in the industry. Sires of first lactation cows average 163 PTA\$ compared to industry standards of 167\$, a minor difference. However, sires currently in use have an average PTA\$ of 143, whereas leading herds are now using sires with an average PTA\$ of 216.

Scientific studies show that the daughters of superior AI bulls perform better whether in conventional dairy management systems or in grazing systems. The genetic index of Net Merit \$ includes a longevity component, along with SCC and protein production. I would strongly encourage the use of the NM\$ index for semen selection in this operation.

6. Replacement Rearing (*Figure 12*)

Average age at first calving meets the industry goal of 24 months.

7. Culling (*Figure 13*)

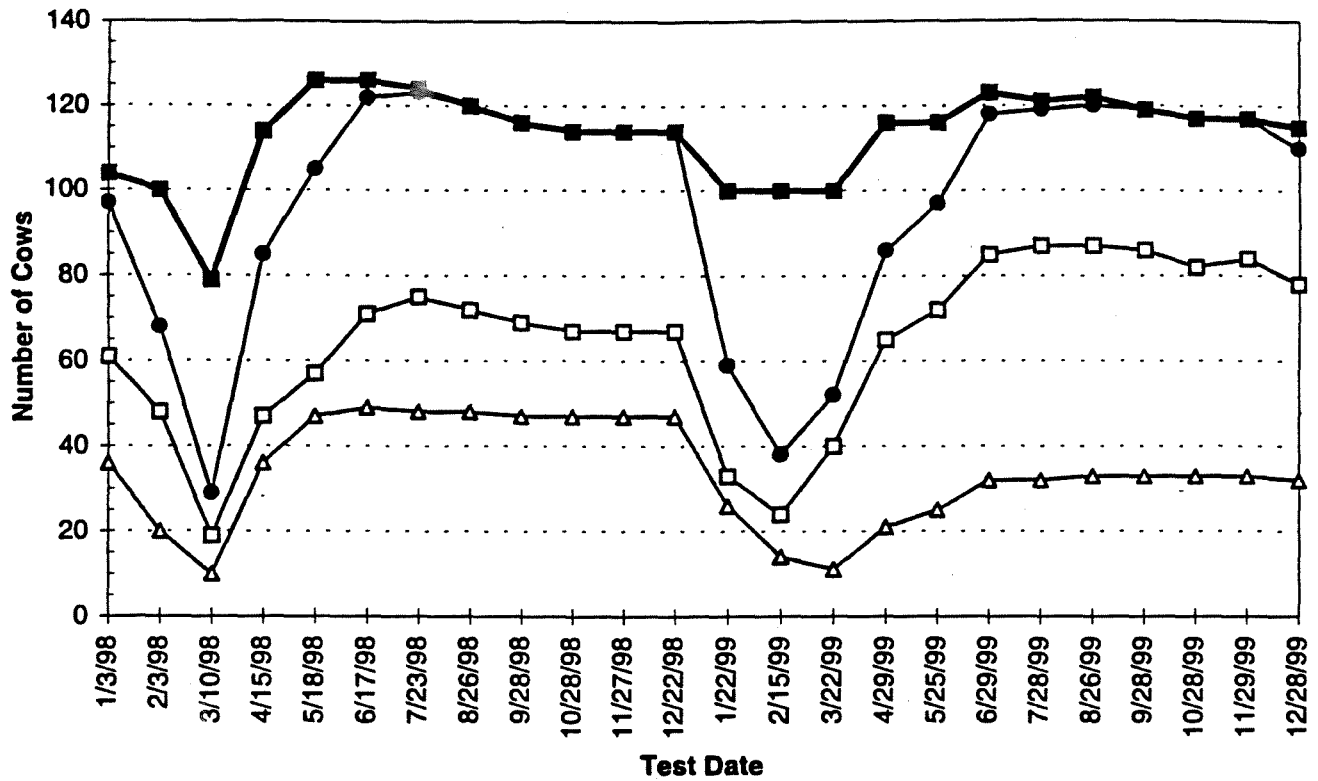
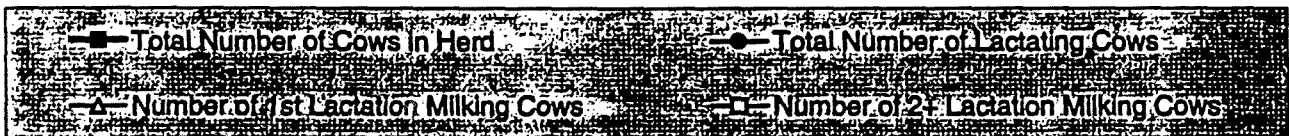
Annual turnover rate was 32 %, less than the industry average of 37%. In addition, a majority of the cows sold left as “dairy” replacements at a higher value than cows culled to the slaughter markets. Overall, this represents excellent control of culling.

Summary

In general, herd performance in 1999 has stabilized and is very much the same as 1998. Overall, reproductive performance, replacement rearing and culling management is excellent, mastitis management is very good, and genetics and nutrition management needs improvement.

Krusenbaum 35650824 (12/28/99) Herd

Milking Herd Populations



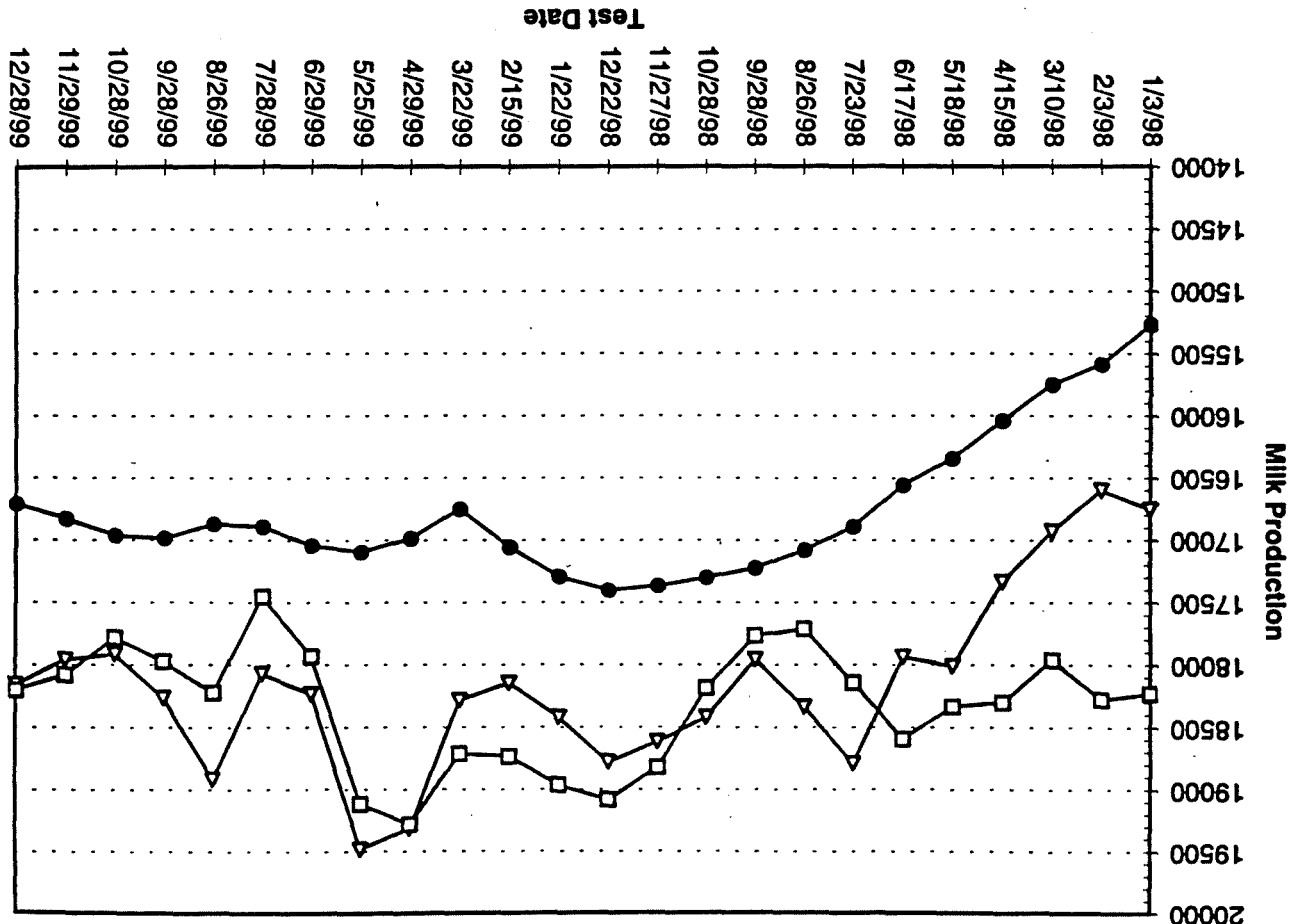
Percent 1st Lactation Cows in milking herd on last test = 29.1

Percent Dry Cows on last test = 4.3

Number of tests in last 12 months = 12

Krusenbaum 35650824 (12/28/99) Herd

Rolling Herd Average, Heifer and Cow ME's



Rolling Herd Average, Heifer and Cow ME's

Figure 3

krusenw010600.xls Milk

12 Month Average Milk/Cow/Day = 52
12 Month Average Mgmt Level Milk = 53.8

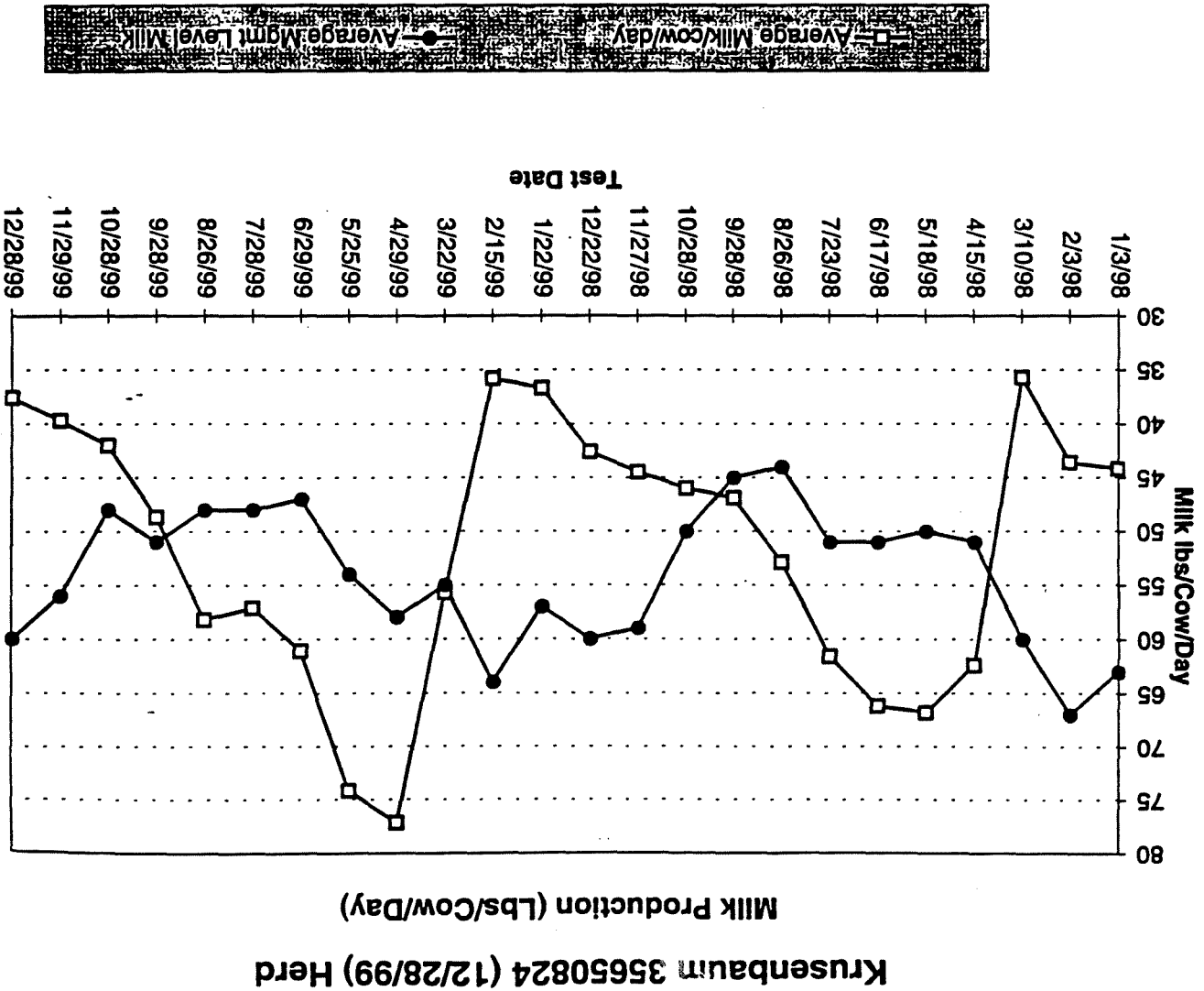


Figure 4

krusenw010600.xls Tank

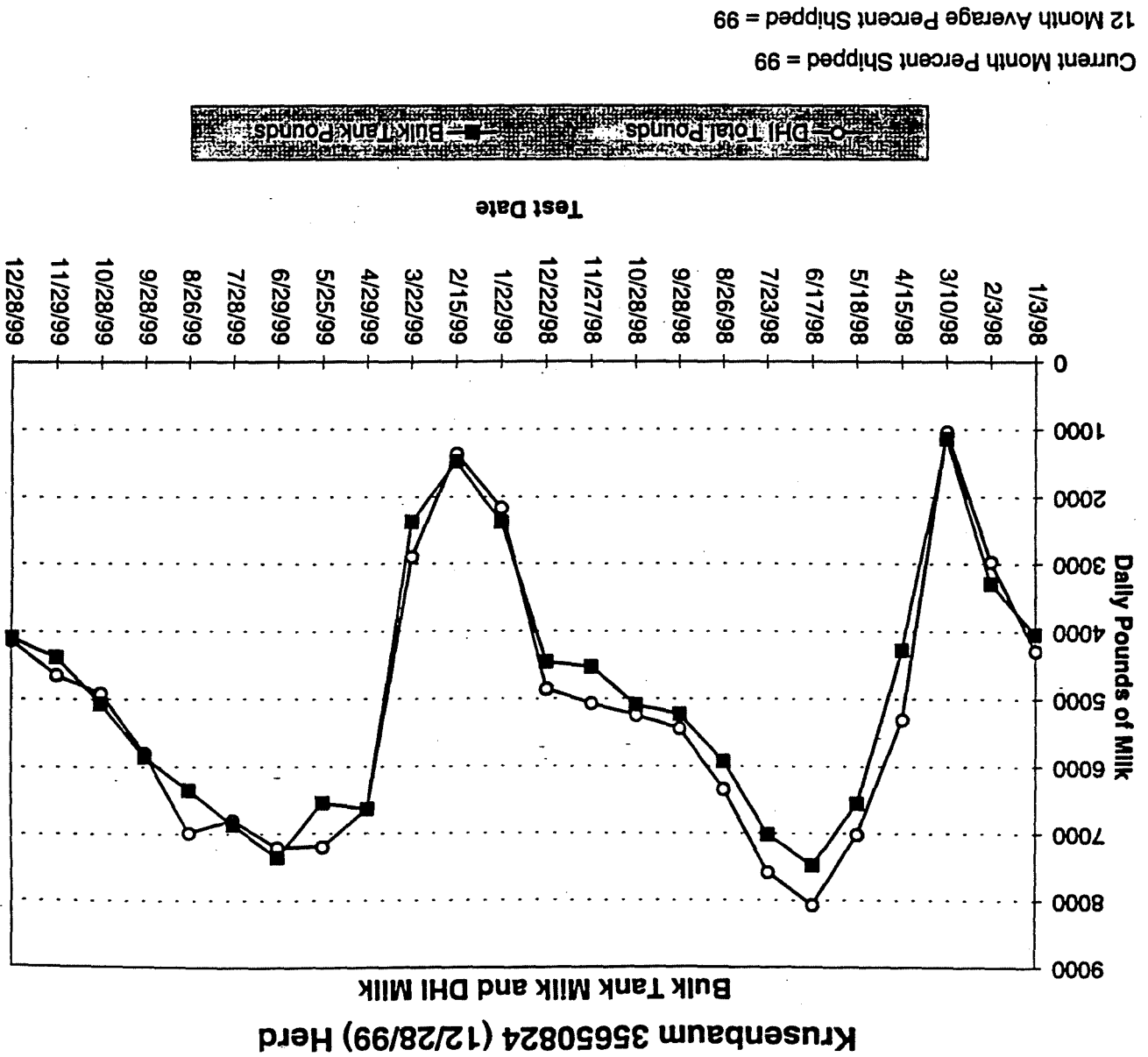
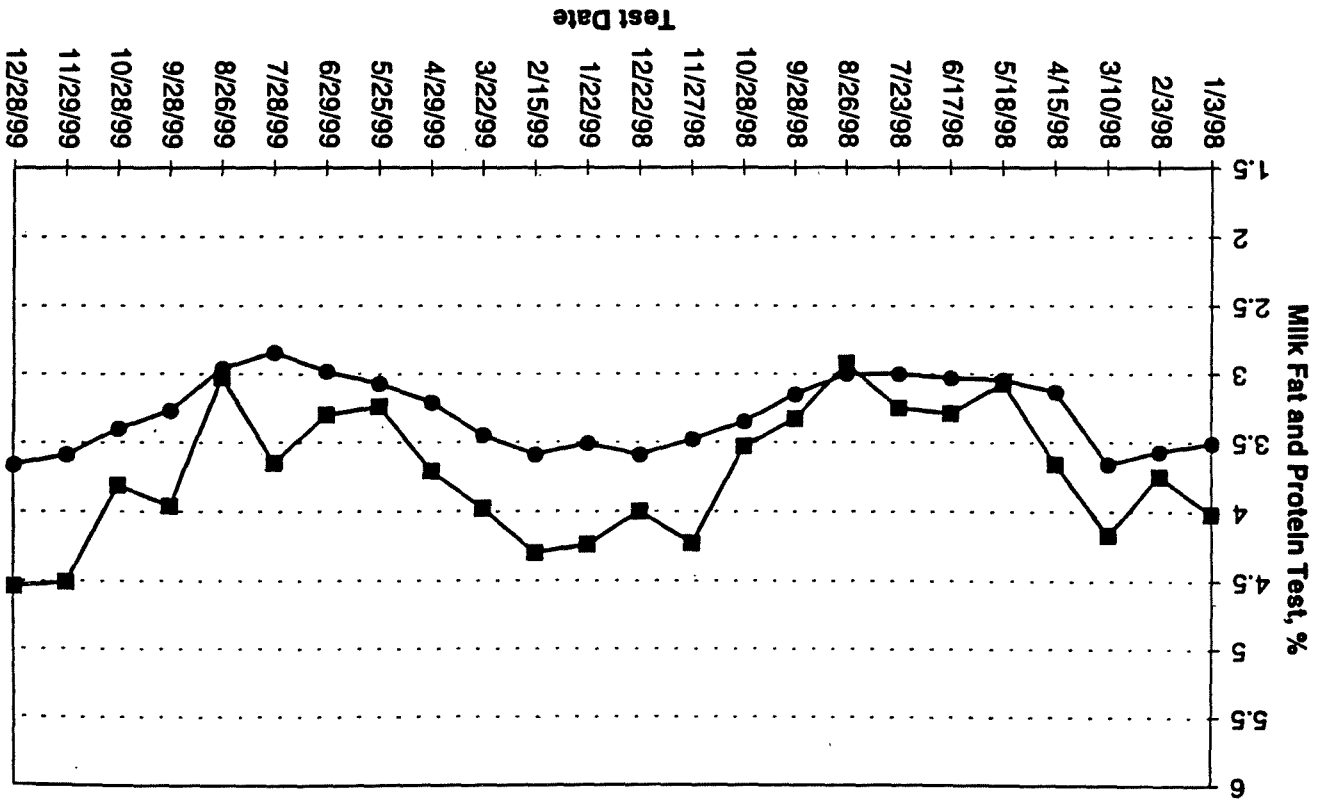


Figure 5

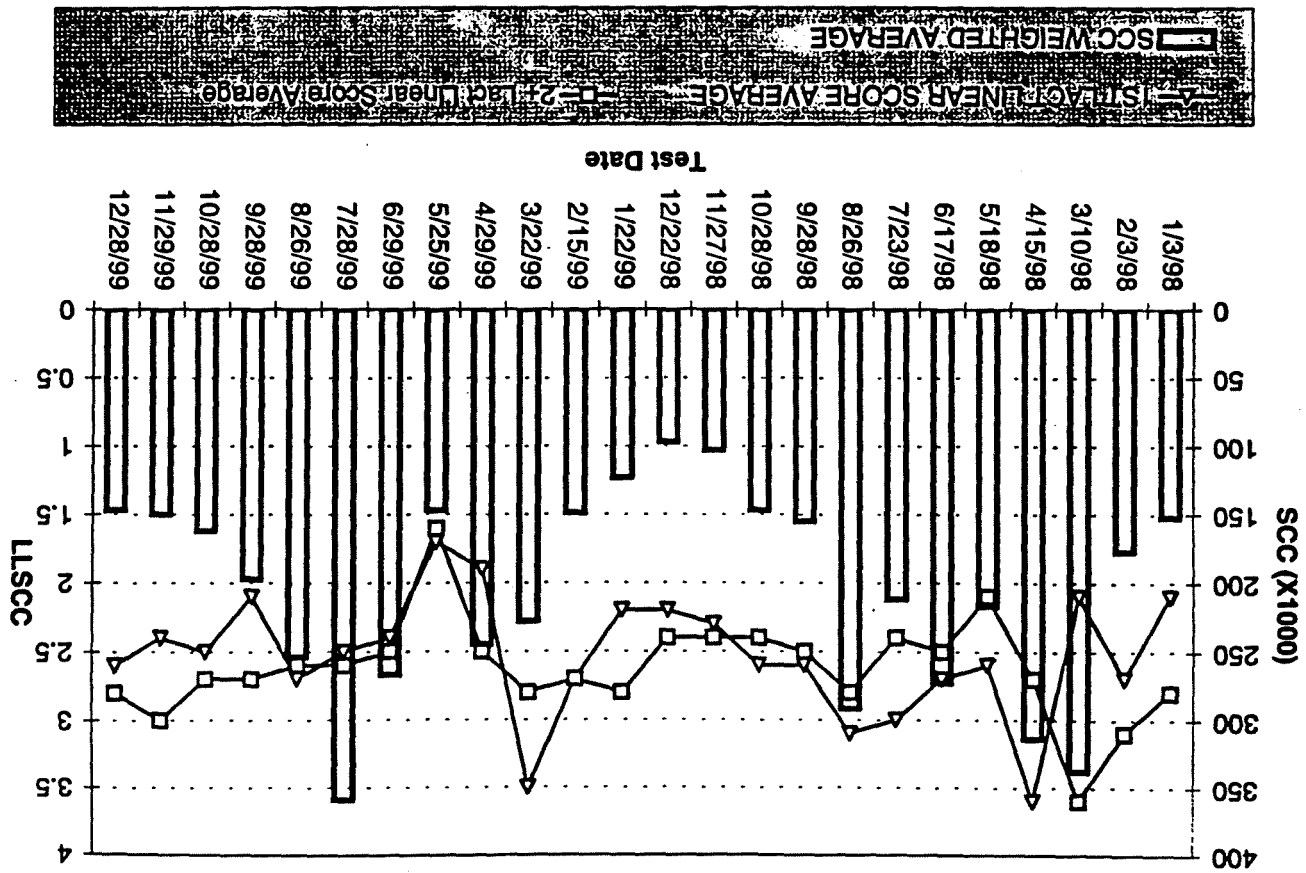
krusenwng010600.xls %Fat



Krusenbaum 35650824 (12/28/99) Herd
Milk Fat and Protein Tests

Krusenbaum 35650824 (12/28/99) Herd

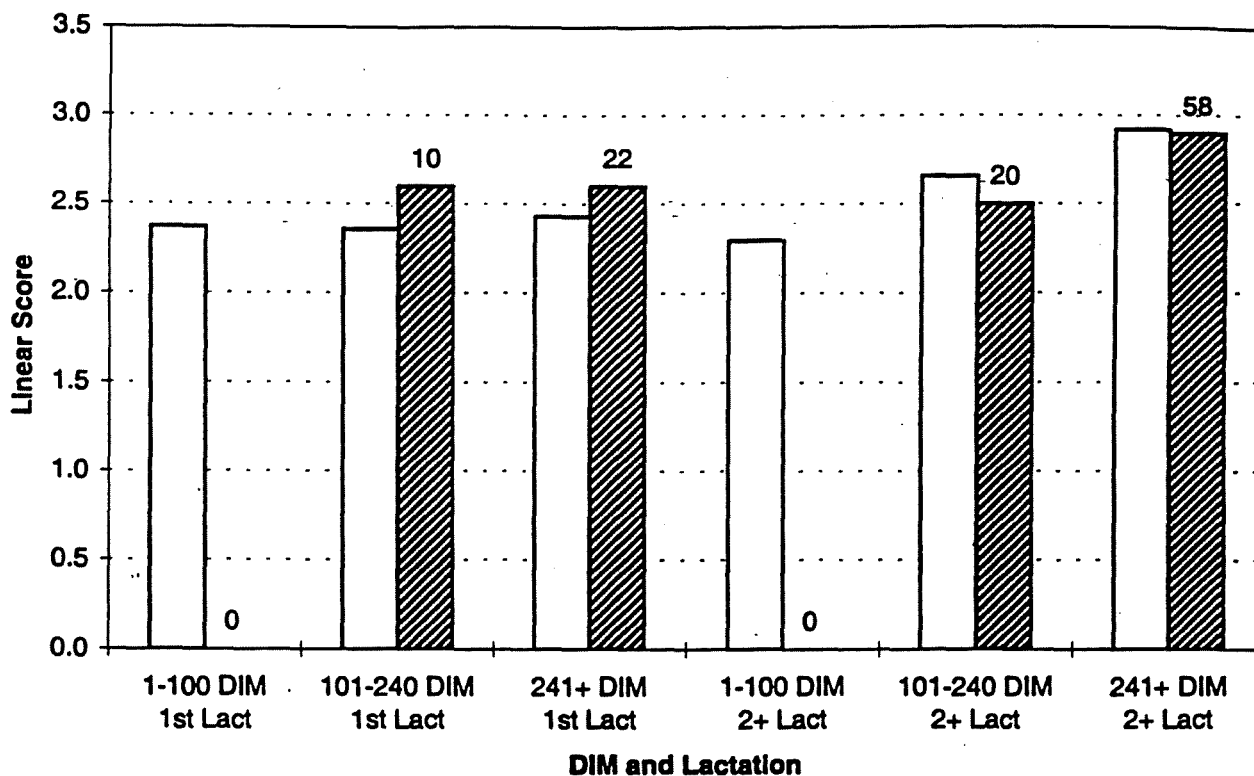
Subclinical Mastitis Data



Average 1ST LACT Linear Score (last 12 months) = 2.4
 Average 2+ LACT Linear Score (last 12 months) = 2.6
 Average Weighted SCC (last 12 months) = 209.1

Krusenbaum 35650824 (12/28/99) Herd

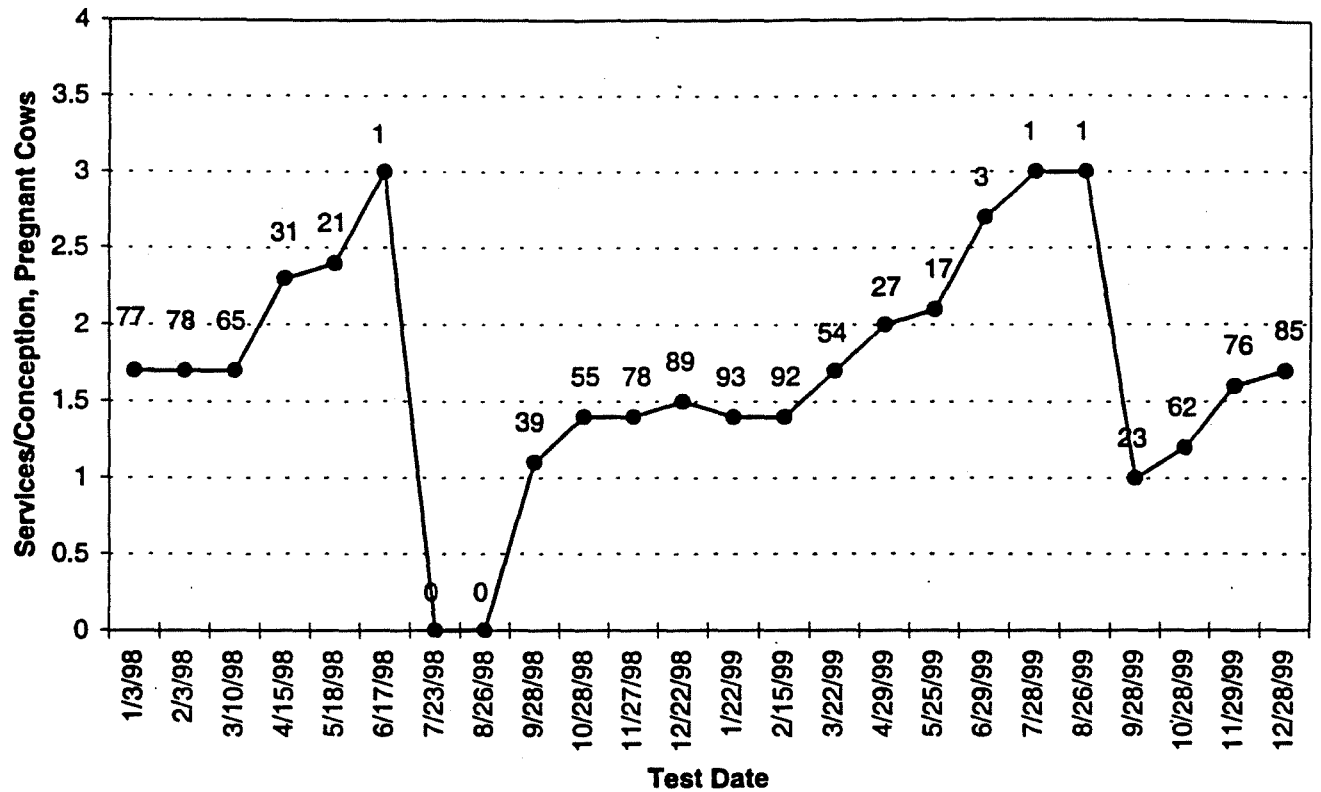
Average Linear Score by DIM



Number above the bar indicates the cows in the group
 Average 1ST LACT Linear Score (last 12 months) = 2.4
 Average 2+ LACT Linear Score (last 12 months) = 2.6

Krusenbaum 35650824 (12/28/99) Herd

Reported Services per Conception, Pregnant Cows



Services/Conception, Pregnant Cows

Number Indicates Pregnant Cow Count

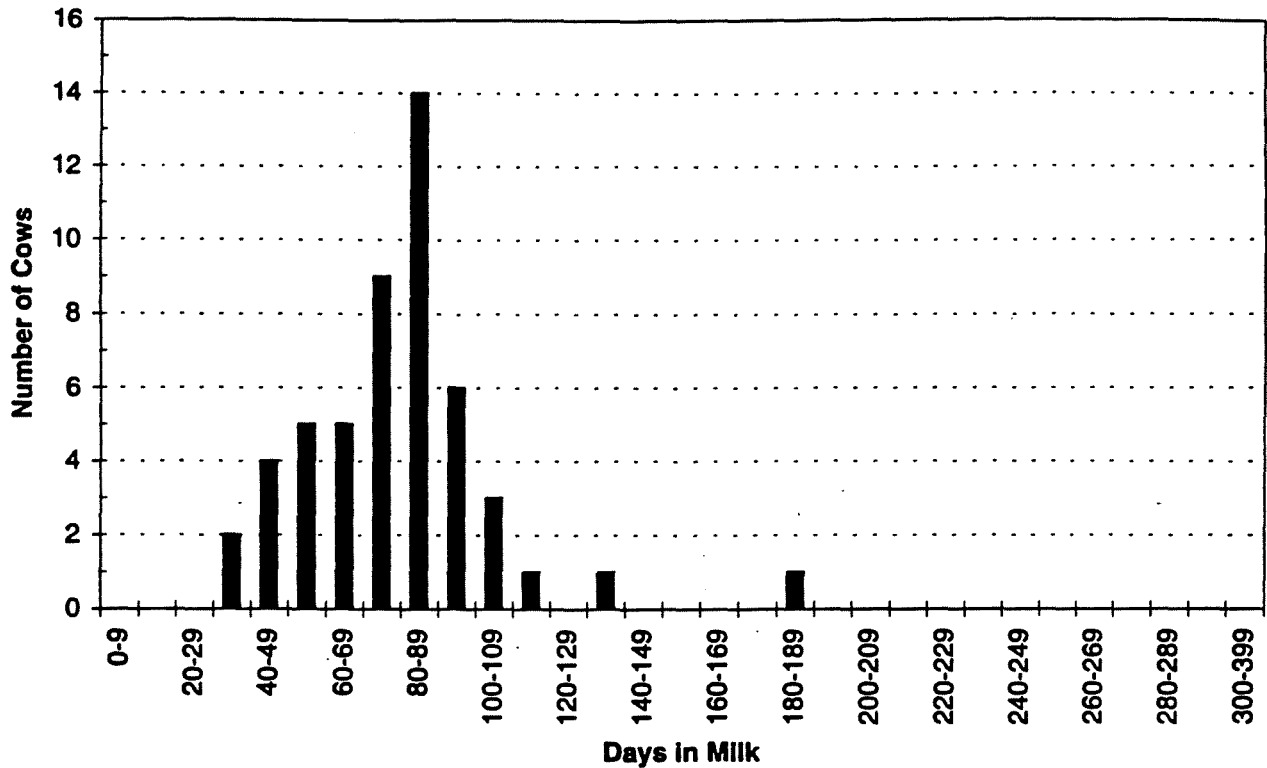
#DIV/0!

All breedings must be reported in order for this chart to be valid.

Cows with a breeding date and no subsequent information are assumed pregnant after 90 days in DHI calculations.

Krusenbaum 35650824 (12/28/99) Cow

Days in Milk at First Breeding*, All Cows Bred



Average Days to 1st Breeding = 78

Median Days to 1st Breeding = 80

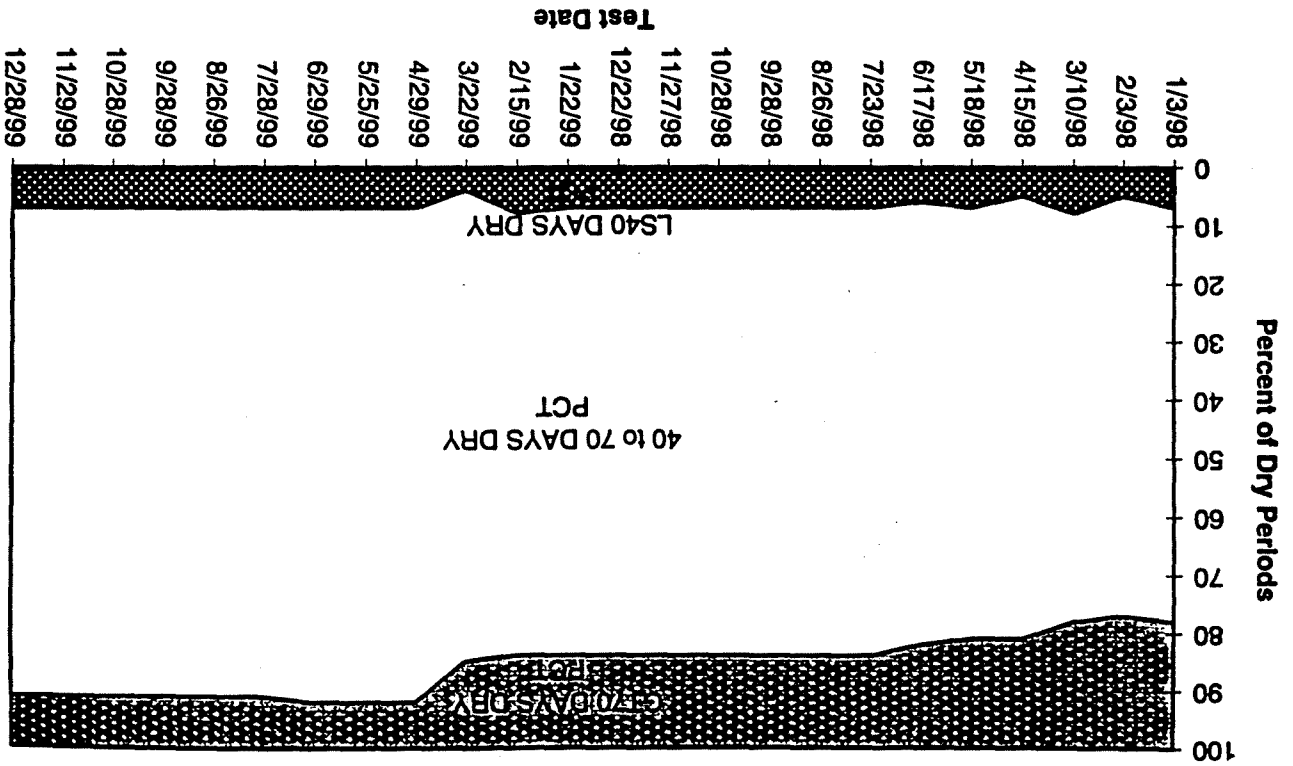
Selection Criteria:

Dim>=1

* All breedings must be reported in order for this chart to be valid

Krusenbaum 35650824 (12/28/99) Herd

Days Dry Distribution



Average Days Dry (Current Test) = 59
Average Days Dry (last 12 months) = 59

LS40 DAYS DRY PCT 40 to 70 DAYS DRY PCT LS40 DAYS DRY PCT

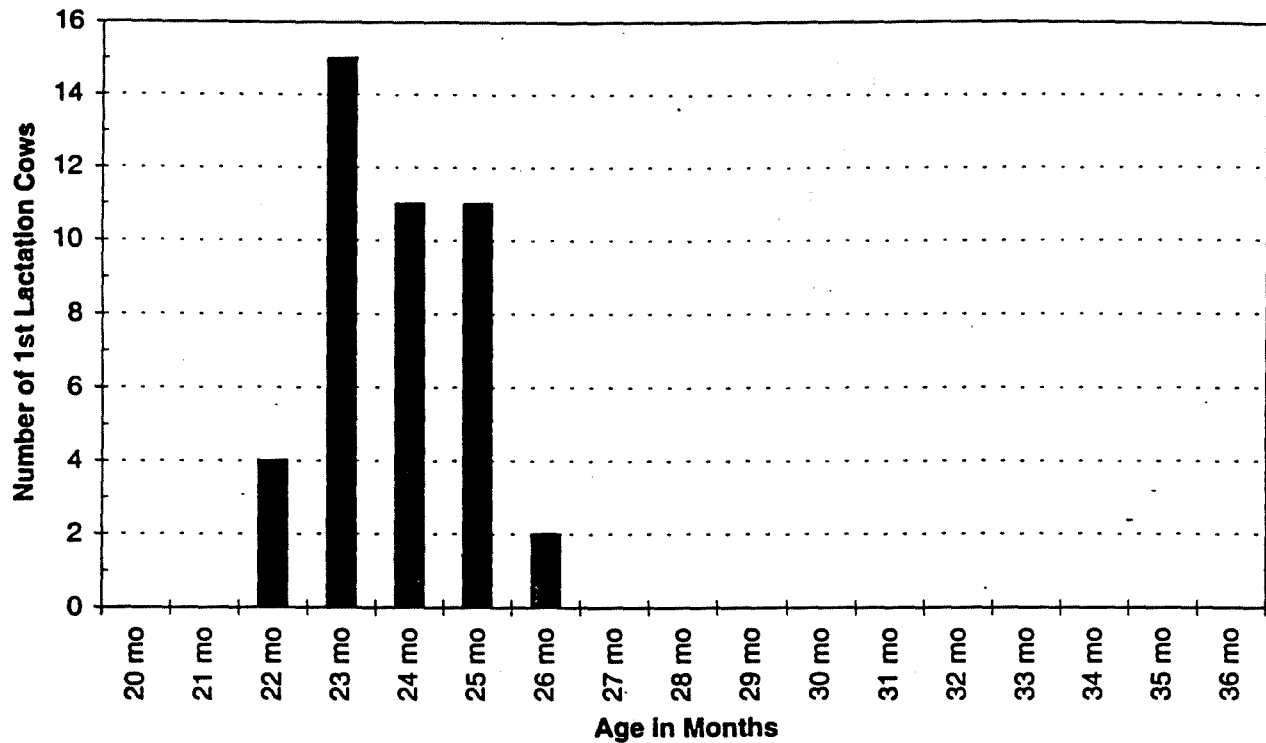
PTA\$ Trends



krusenwgo10600.xls NM\$-h

Krusenbaum 35650824 (12/28/99) Cow

Age at First Calving Distribution



Average Calving Age in Months = 24

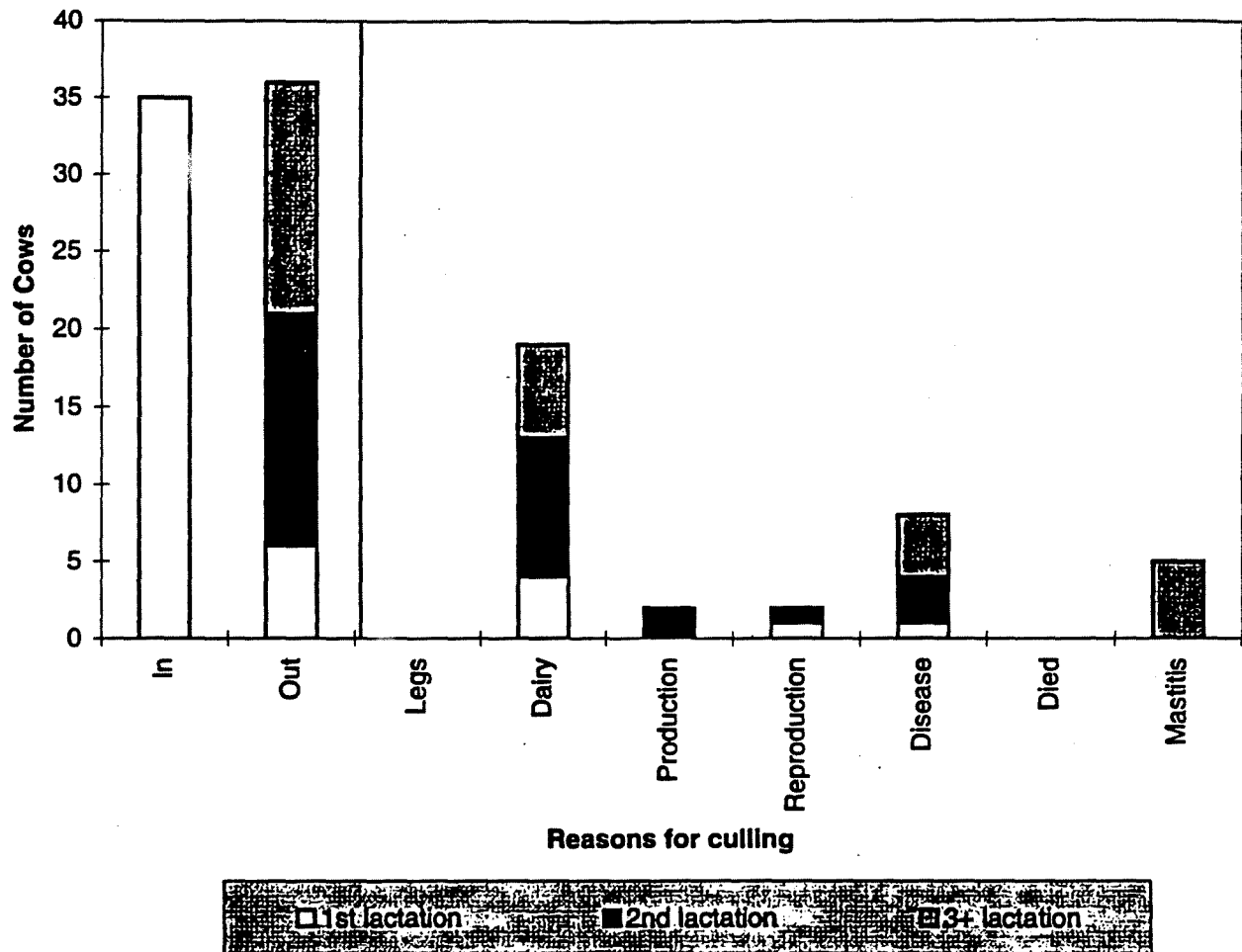
Median Calving Age in Months = 23

Selection Criteria:

Lactation=1

Krusenbaum 35650824 (12/28/99) Herd

Turnover Summary (Last 12 Months)



Average Number of Animals in herd (last 12 months) = 114

Turnover Rate (last 12 months) = 32

Number of tests in last 12 months = 12

TEST DATE	1/22/99	2/15/99	3/22/99	4/29/99	5/25/99	6/29/99	7/26/99	8/26/99	9/26/99	10/26/99	11/29/99	12/28/99
COW CNT	100	100	100	116	116	123	121	122	119	117	117	115
TEST DAY MILKING COW CNT	59	36	52	66	97	116	119	120	119	117	117	110
1ST 305 ME MILK LBS CNT	47	44	31	32	32	32	32	33	34	33	33	33
GT1 305 ME MILK LBS CNT	67	57	67	83	86	89	91	89	89	86	84	84
RHA MILK LBS	17292	17057	16748	16984	17095	17040	16690	16670	16966	16961	16829	16712
1ST 305 ME MILK LBS	18423	18150	18285	19318	19486	18235	18072	18920	18266	17915	17950	18156
GT1 305 ME MILK LBS	18968	18738	18715	19285	19121	17930	17455	18224	17973	17780	18061	18202
AVG MILK LBS MILKING COWS	36.7	35.8	55.7	77.2	74.2	61.1	57.1	56.2	48.7	42	39.7	37.8
MGMT LEVEL MILK LBS AVERAGE	57	64	55	58	54	47	48	48	51	48	56	60
TEST DAY AVERAGE FAT PERCENT	4.24	4.3	3.96	3.71	3.24	3.3	3.65	3.03	3.96	3.81	4.51	4.54
TEST DAY AVERAGE PRO PERCENT	3.51	3.50	3.45	3.21	3.07	2.96	2.84	2.96	3.27	3.4	3.50	3.66
1ST PEAK MILK LBS	64	64	61	64	67	66	67	67	66	67	67	67
GT1 PEAK MILK LBS	85	84	80	83	84	82	83	83	83	83	83	83
1ST LACT LINEAR SCORE AVERAGE	2.2	2.7	3.5	1.9	1.7	2.4	2.5	2.7	2.1	2.5	2.4	2.6
GT1 LACT LINEAR SCORE AVERAGE	2.8	2.7	2.8	2.5	1.6	2.5	2.6	2.6	2.7	2.7	3	2.8
SCC WEIGHTED AVERAGE	123	149	228	245	147	267	359	254	197	162	150	147
12MO LS2 DIST PCT	65	66	66	67	68	68	68	68	68	68	67	66
12MO LS3 DIST PCT	14	14	14	14	13	13	13	13	13	13	13	13
12MO LS4 DIST PCT	10	9	8	8	9	9	9	9	9	9	10	11
12MO LS5 DIST PCT	11	11	12	11	10	10	10	10	10	9	10	10
TEST DAY LACT DIM AVG	284	288	117	38	57	80	107	135	168	196	230	259
SVC PTA USDA DOL AMT	169	178	162	0	199	0	0	0	212	169	143	143
1ST PTA USDA DOL AMT	157	158	175	167	168	170	170	166	166	166	163	163
GT1 PTA USDA DOL AMT	88	86	91	103	107	110	109	106	106	106	104	104
DAYS DRY AVG	60	59	62	58	58	58	59	59	59	59	59	59
LS40 DAYS DRY PCT	7	8	4	7	7	7	7	7	7	7	7	7
GT70 DAYS DRY PCT	16	16	15	8	8	8	9	9	9	9	9	9
YR TEST CNT	12	12	12	12	12	12	12	12	12	12	12	12
1ST ERLY LACT LINEAR SCORE AVG	0	0	4	1.9	1.7	2.8	2.7	3.3	1.3	0.9	0.8	0
1ST MIDL LACT LINEAR SCORE AVG	3.9	0	0	0	0	1.1	2.4	2.5	2.1	2.5	2.6	2.6
1ST LATE LACT LINEAR SCORE AVG	2.1	2.7	2.6	0	0	0	0	0	0	0	2.4	2.6
GT1 ERLY LACT LINEAR SCORE AVG	0	1.8	2.8	2.5	1.5	2.1	3.3	2.8	3	0	0	0
GT1 MIDL LACT LINEAR SCORE AVG	2.7	6.9	0	0	5.8	3	2.3	2.6	2.7	2.7	2.7	2.5
GT1 LATE LACT LINEAR SCORE AVG	2.9	2.5	2.7	0	0	0	0	0	0	3.5	3.2	2.9
TEST DAY MILKING COW CNT	59	36	52	66	97	116	119	120	119	117	117	110
AVG MILK LBS MILKING COWS	36.7	35.8	55.7	77.2	74.2	61.1	57.1	56.2	48.7	42	39.7	37.8
BULK TANK PCT	91	92	122	100	110	96	99	110	99	97	106	101
PREG COW CNT	93	92	54	27	17	3	1	1	23	62	76	85
PREG NUM SERV AVG	1.4	1.4	1.7	2	2.1	2.7	3	3	1	1.2	1.6	1.7
1ST MIDL LACT PCT LAST MILK	93	0	0	0	0	79	93	105	83	88	95	129
GT1 MIDL LACT PCT LAST MILK	90	94	0	0	83	92	91	102	85	88	93	93
LV1 1ST LACT COW CNT	8	3	1	13	16	14	14	16	20	12	17	15
LV2 1ST LACT COW CNT	11	4	5	6	5	7	7	3	4	10	8	7
LV3 1ST LACT COW CNT	4	6	1	1	3	5	4	6	3	4	2	3
LV4 1ST LACT COW CNT	2	1	1	1	1	4	3	4	2	5	5	3
LV5 1ST LACT COW CNT	0	0	2	0	0	2	4	4	4	2	1	4
LV1 GT1 LACT COW CNT	12	9	13	35	50	45	49	42	37	30	26	26
LV2 GT1 LACT COW CNT	10	8	14	9	8	10	5	13	18	20	20	20
LV3 GT1 LACT COW CNT	3	4	3	4	2	10	10	12	10	16	12	15
LV4 GT1 LACT COW CNT	4	0	5	8	8	7	7	6	13	10	18	11
LV5 GT1 LACT COW CNT	4	3	5	9	4	14	16	14	8	8	8	6
1ST ERLY LACT COW CNT	0	0	5	21	25	25	13	8	1	1	1	0
1ST MIDL LACT COW CNT	1	0	0	0	0	7	19	25	32	32	16	10
1ST LATE LACT COW CNT	25	14	6	0	0	0	0	0	0	0	16	22
GT1 ERLY LACT COW CNT	0	1	30	65	71	51	28	16	3	0	0	0
GT1 MIDL LACT COW CNT	8	1	0	0	1	34	59	71	83	81	40	20
GT1 LATE LACT COW CNT	25	22	10	0	0	0	0	0	0	1	44	58
1ST LACT IN COW CNT	0	0	7	16	3	7	0	1	1	0	0	0
2ND LACT IN COW CNT	0	0	0	0	0	0	0	0	0	0	0	0
GT2 LACT IN COW CNT	0	0	0	0	0	0	0	0	0	0	0	0
1ST LACT OUT COW CNT	3	0	1	0	1	0	0	0	1	0	0	0
2ND LACT OUT COW CNT	5	0	4	0	1	0	1	0	1	1	0	2
GT2 LACT OUT COW CNT	6	0	2	0	1	0	1	0	2	1	0	2
1ST OUT FEET LEGS CNT	0	0	0	0	0	0	0	0	0	0	0	0
2ND OUT FEET LEGS CNT	0	0	0	0	0	0	0	0	0	0	0	0
GT2 OUT FEET LEGS CNT	0	0	0	0	0	0	0	0	0	0	0	0
1ST OUT DAIRY CNT	3	0	0	0	0	0	0	0	1	0	0	0
2ND OUT DAIRY CNT	5	0	3	0	0	0	0	0	1	0	0	0
GT2 OUT DAIRY CNT	5	0	0	0	0	0	0	0	1	0	0	0
1ST OUT LOW PROD CNT	0	0	0	0	0	0	0	0	0	0	0	0
2ND OUT LOW PROD CNT	0	0	0	0	0	0	1	0	0	0	0	1
GT2 OUT LOW PROD CNT	0	0	0	0	0	0	0	0	0	0	0	0
1ST OUT REPRO CNT	0	0	1	0	0	0	0	0	0	0	0	0
2ND OUT REPRO CNT	0	0	0	0	0	0	0	0	0	0	0	1
GT2 OUT REPRO CNT	0	0	0	0	0	0	0	0	0	0	0	0
1ST OUT DISEASE CNT	0	0	0	0	1	0	0	0	0	0	0	0
2ND OUT DISEASE CNT	0	0	1	0	1	0	0	0	0	1	0	0
GT2 OUT DISEASE CNT	1	0	2	0	1	0	0	0	0	0	0	0
1ST OUT DIED CNT	0	0	0	0	0	0	0	0	0	0	0	0
2ND OUT DIED CNT	0	0	0	0	0	0	0	0	0	0	0	0
GT2 OUT DIED CNT	0	0	0	0	0	0	0	0	0	0	0	0
1ST OUT MASTITIS CNT	0	0	0	0	0	0	0	0	0	0	0	0
2ND OUT MASTITIS CNT	0	0	0	0	0	0	0	0	0	0	0	0
GT2 OUT MASTITIS CNT	0	0	0	0	0	0	1	0	1	1	0	2

19. KRUSENBAUM MACHINERY ANALYSIS, 1999

Ronald T. Schuler^{1/}

During 1999, new machinery acquired were bale processor and bale hauler. A new lease on a 105 horsepower tractor was obtained, adding to the previous inventory of two tractors. The hours of tractor use increased over 50 percent. Some of the additional hours were attributed earlier supplemental feeding in the fall resulting in an estimated 100 hours of more use. Another cause was believed to be due to the electronic tachometers on the new tractor versus the mechanical tachometers on the two older tractors that are not as accurate. The machinery inventory throughout the project started in 1990 is shown in Table 1.

Table 1. Current machinery inventory on the Krusenbaum Farm, 1999.

Machine	Age	Size	Purchase Price	
			Actual	New (MN)
<u>Power units</u>				
JD 2630	22	65 hp	8,900	21,400
Case 970	23	86 hp	6,000	26,900
Case 1175		122 hp	11,000	55,200 (sold)
ATV				
Case MX (leased)	0	105 hp	\$12,942/year	
<u>Tillage</u>				
Moldboard plow		5-18's	2,350	9,000 (sold)
Tandem disk		18 ft	1,625	10,700 (sold)
Field cult.		18 ft	825	4,700 (sold)
Rotary hoe	11	15 ft	1,500	3,500 (not used)
Row cult.		4-38	2,650	5,400 (sold)
Guidance system			2,000	N/A (sold)
Cultimulcher		12 ft	1,500	N/A (sold)
Aerway	3	10 ft	4,800	N/A
<u>Planting Equip.</u>				
Grain Drill		12 ft	4,500	13,200 (sold)
Planter		4-38	4,000	9,100 (sold)
<u>Harvesting</u>				
Haybine		9 ft	3,500	33,500 (sold)
Mower-conditioner	3	9 ft	11,150	14,320 (New)
Baler (Sm. Rect.)		9 ft	3,900	9,300 (sold)
Rake	10	9 ft	1,550	3,300
Baler (Round)	5	9 ft	21,600	17,000
Bale Wrapper	5	N/A	13,000	13,900
Bale Processor	0	N/A	7,500	N/A
Bale Hauler	0	N/A	5,500	N/A
Bale Feeder	4	N/A	5,500	N/A
Manure Spreader	3	N/A	12,250	11,558

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The primary machines remaining in 1999 are mower-conditioner, hay rake, round baler, bale wrapper, bale processor, bale hauler, manure spreader and a rolling cultivator. For the duration of this ten year study many changes have taken place in the machinery inventory, Table 1. Since the beginning of the machinery analysis in 1990 eleven machines and one tractor were sold and not replaced while the self-propelled mower conditioner was replaced with a pull-type machine. Except for the tractors and hay rake, the machinery is less than five years old.

Machinery Use:

Machinery use, shown in Table 2, in 1999 was down slightly when compared to 1998. The machine receiving substantial use in 1999 were mower-conditioner, rake, baler, bale wrapper, bale processor and bale hauler. The last two were purchased in 1999.

Table 2. Annual use(Acres/year) of machines compared to Minnesota data.

Machine	Minnesota	1990	Krusenbaum					1994	1995	1996	1997	1998	1999
			1991	1992	1993								
<u>Tillage</u>													
Chisel Plow							150	sold			-		
Moldboard Plow	349	20	45	19	0			sold					
Tandem Disk	824	165	325	173	203		166	sold					
Field Cultivator	1047	112	91	107	0		sold						
Rotary Hoe	434	211	217	296	154		27	0	N/A				
Row Cultivator	465	238	217	164	128		37	sold					
Cultimulcher	N/A				59		0	18					
Aerway	N/A									68	180	320	180
<u>Planting</u>													
Grain Drill	382	44	43	32	70		55	18	sold				
Planter	275	112	109	98	64		27	sold					
<u>Harvesting</u>													
Haybine	436	242	245	96	144		228	170	Replaced				
Mower-Conditioner									300(1)	278	450	300	
Baler(Rect.)	756	199	213	40	121		0	0	Sold				
Rake	698	156	193	66	265		79	170	100	150	260(4)	150	
Baler(Round)	603						237	170	220	550(2)	450	340(5)	
Bale Wrapper	303							170	130	300(3)	310	200	
Bale Processor	150*											170	
Bale Hauler	150*											N/A	
Manure Spreader	100*										N/A	N/A	N/A

* Numbers refer to the Minnesota data which is expressed in hours per year.

(1) About 30 percent of these acres were custom work but a neighbor did 100 acres of mowing for Krusenbaum's.

(2) About 60 percent of these acres were custom work.

(3) About 40 percent of these acres were custom work.

(4) About 10 percent of these acres were custom work.

(5) About 15 percent of these acres were custom work.

Tractor use in 1999 was 1514 hours which was an increase of 544 hours over the 1998 use, over 50 percent increase. An estimated additional 100 hours of tractor use was needed for the additional supplemental feeding in fall. Normally supplemental feeding had started in October, but in 1999, this feeding started in August. A second potential cause may be the hauling of the 750 tons of corn silage and 6220 bushels of snaplage that was purchased. Another cause for increased hours was the new tractor which had an electronic tachometer which recorded time whenever the ignition switch was turned on. It is believed the mechanical tachometers on the two older tractors indicated tractor hours only when the engine speed was at or near the full operating speed.

Table 3. Annual Use(hours/year) for tractors compared to Minnesota data.

Tractor model	Minnesota	Krusenbaum									
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
JD 2630	400	350	400	360	370	422	420	532	420	550	309
Case 970	400	160	250	240	220	337	240	178*	300	420	240
Case 1175	450	210	220	180	227	131	sold				
Case MX120(Lease)											965
Tractor totals		720	870	780	817	890	660	710	720	970	1514
ATV				300	235	390	400	300	260	225	250
Golf cart											120

*Case tractor was not available for two months but a neighbor's tractor was used.

Machinery Cost Comparisons:

Machinery costs were computed annual using machinery costs spreadsheet described in Estimating Agricultural Field Machine Costs, Tables 4 and 5. The spreadsheet results are compared to the Minnesota Farm Machinery Economic Cost Estimate and the Wisconsin Custom Rate Guide. The spreadsheet uses data specific to the machine using information such as purchase price, age and annual use. The Minnesota data is based on a new purchase price obtained from machinery dealers and a standard annual use based a standard for annual use. Frequently this published annual use is rather high compared to actual farm use. The Wisconsin Guide is based on a survey of Wisconsin custom operators.

The costs for each of the machines in 1999 were very similar to published data except for the manure spreader that was used to haul only ninety loads. An additional forty loads were spread with a rented spreader.

For the two owned tractors, the hourly costs were much lower than the Minnesota data, Table 5. This is due to low purchase price which leads to very low fixed costs in comparison to the Minnesota data. The leased tractor costs are less than the Minnesota data primarily because of the high usage, 965 hour versus 450 for the Minnesota data. The ATV and golf cart costs were not analyzed because data are not available for fuel consumption, repairs and depreciation. In addition, ATV's and golf carts are not reported in the Minnesota data or the Wisconsin Custom Rate Guide.

Table 4. Estimated annual cost (\$/acre) 1990 through 1999 compared to Minnesota data and Wisconsin rental survey.

Krusenbaum												
Machine	Minn	WI Rent	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
<u>Tillage</u>												
Mold. Plow	13.43	13.60	27.04	17.02	29.86	----	----	----	----	----	----	----
Tan. Disk	6.34	9.60	3.38	2.78	3.31	3.31	3.74	----	----	----	----	----
Field Cult.	3.18	7.90	2.79	3.16	3.19	----	----	----	----	----	----	----
Rotary Hoe	1.51	5.55	2.84	2.89	2.63	3.46	11.56	----	----	----	----	----
Row Cult.	3.41	6.50	6.20	6.46	7.00	7.86	15.86	----	----	----	----	----
with Guid.	N/A	N/A	6.58	6.96	7.87	9.33	24.48	----	----	----	----	----
Cultimulcher	N/A	9.25					13.43	----	----	----	----	----
Aerway	1.44	N/A							9.83	6.05	5.25	6.45
<u>Planting</u>												
Grain Drill	7.59	10.10	20.79	21.85	26.38	16.46	21.63	54.80	----	----	----	----
Planter	7.99	11.20	11.19	11.82	12.04	16.25	32.32	----	----	----	----	----
<u>Harvesting</u>												
Haybine(SP)	11.20	8.95	4.69	4.86	7.52	6.30	5.50	6.38	----	----	----	----
Mower-Cond.	7.09	8.95							8.78	7.66	6.89	8.25
Baler(Rect.)	9.26	12.40	7.83	7.99	12.04	10.77	8.56	----	----	----	----	----
Rake	6.26	4.20	5.63	5.58	7.27	5.60	8.29	10.25	8.07	5.97	5.84	6.27
Baler(Round)	15.99	13.70						10.65	14.53	10.87	11.89	13.40
Bale Wrap.	17.39	6.35/bale						8.63	12.10	7.09	6.91	8.97
Bale Proc.	N/A	N/A										11.11
Bale Hauler	N/A	N/A										
Manure Sp.(1)	31.51	34.40								75.30	54.47	79.95

(1) Cost per hour.

Table 5. Estimated annual cost(\$/hour) for tractors compared to Minnesota data and Wisconsin rental survey.

Tractor model	Minn	WI Rent	1990	Krusenbaum		1993	1994	1995	1996	1997	1998	1999
				1991	1992							
JD 2630	10.43	17.80	8.21	8.95	9.01	9.23	9.23	8.73	8.41	8.72	8.66	10.0
Case 970	12.47	17.80	7.42	6.60	7.19	6.88	6.36	6.67	7.73	6.38	6.02	7.5
Case 1175		23.20	9.37	9.40	11.92	10.10	15.07	sold	-----	-----	-----	-----
CASE MX120	20.09											13.7 ^a

Summing up 1999 machinery activities, the costs appear to be normal, but the tractor use increased dramatically with somewhat less machinery use. The increased tractor use was attributed to additional supplemental feeding, additional corn silage and snaplage hauling and difference in tachometer operation on old and new tractors.

References:

Lazarus, W. 2000. Minnesota Farm machinery Economic Cost Estimates for 2000. Minnesota Extension Service.

Schuler, R. T. and G. G. Frank. 1991. Estimation Agricultural Field Machine Costs. University of Wisconsin-Extension, Fact Sheet A3510.

Wisconsin Custom Rate Guide. 1998. University of Wisconsin-Extension. Fact Sheet A3656.

20. Krusenbaum Financial Report - 1999

Gary Frank and Altfried Krusenbaum

Introduction

The Krusenbaum farm continues to prosper. They have accumulated substantial assets over the past ten years (1990-1999). They also have debts in excess of \$200,000 and a growing net worth. They have employed numerous conventional conservation and soil saving techniques and other holistic practices plus some other less-than conventional practices over those 10 years, most of them profitability.

In 1999, they used futures contracts as a price risk management tool. Also, they constructed an extensive lane system in their pastures. Because the majority of this expenditure was cost-shared, it was entered into their financial records as a net value. Therefore, their cost-basis assets show only the addition moneys they invested above the amount cost-shared. In 1999, this asset's fair market value was set equal to its cost basis value.

Incomes

The income and expenses for 1999 are shown in Figure 1 (the Farm Earnings report). The total milk income was \$191,630, \$273,013, and \$251,752 in 1997, 1998 and 1999 respectively and milk income per cow was \$2,017, \$2,184, and \$2,208. Total accrual adjusted farm income was \$248,424, \$354,604, and \$309,578 in 1997, 1998 and 1999 respectively.

Expenses

The total accrual adjusted farm expense was \$202,637, \$256,975, and \$237,335 in 1997, 1998, and 1999 respectively. The amount of interest paid has approximately \$153, \$146 and \$137 per cow. This is well below the goal of \$300 (or less) per cow. However, the farm is paying rental expenses of \$191, \$284, and \$295 per cow in 1997, 1998, and 1999 respectively. This is somewhat higher than the average rental costs plus property tax payments of \$190 to \$210 per cow on other farms in the same period.

In 1997, veterinary fees and medicine expenses dropped to \$66 per cow; in 1998, \$42 per cow; and in 1999, \$61 per cow. These are the three years in this farm's 10-year history where veterinary and medicine costs have been below \$100 per cow. The goal of \$50 per cow, set when this farm was started, now appears to be achievable.

Feed purchases are becoming a smaller and smaller part of the total cash expenditures. In 1997, cash farm expenses were \$172,471 and \$62,471 of that was purchased feed. In 1998, cash farm expenses were \$200,292 and \$50,993 of that was purchased feed. In 1999, cash farm expenses were \$196,050 and only \$34,301 of that was purchased feed! Purchased feed per cow was \$658, \$408, and \$301 in 1997, 1998, and 1999 respectively.

Figure 1

<i>Farm Earnings</i>			
KRUSENBAUM FARM			
January 1999 through December 1999			
Income			Percent of Total Income
Sales of Livestock, Produce, Grains and Other Products Raised	\$256,222.72		82.77%
Distributions Received from Cooperatives	\$2,881.49		0.93%
Agricultural Program Payments	\$12,227.78		3.95%
Custom Hire (Machine Work) Income	\$1,664.00		0.54%
Other Income, Including Gasoline/Fuel Tax Credit or Refund	\$5,862.56		1.89%
Sales of Raised or Purchased BLS Owned < 2 Years	\$27,294.05		8.82%
Sales of Other Farm Assets Owned >= 1 Year-Sold At A Gain	\$200.00		0.06%
Income	\$306,352.60		98.96%
Expense			
Breeding Fees	\$6,164.87		1.99%
Chemicals	\$1,294.80		0.42%
Custom Hire (Machine Work)	\$12,740.76		4.12%
Employee Benefit Program	\$82.51		0.03%
Feed Purchase	\$34,300.71		11.08%
Freight and Trucking	\$1,192.28		0.39%
Gasoline, Fuel, and Oil	\$3,174.81		1.03%
Farm Insurance	\$2,250.00		0.73%
Other Interest	\$15,609.59		5.04%
Labor Hired	\$16,471.70		5.32%
Rent/Lease Equipment	\$12,942.14		4.18%
Rent/Lease Other	\$20,680.00		6.68%
Repairs and Maintenance	\$25,058.50		8.09%
Seeds and Plants Purchased	\$3,919.00		1.27%
Storage and Warehousing	\$1,500.00		0.48%
Supplies Purchased	\$16,364.86		5.29%
Taxes	\$1,535.48		0.50%
Utilities	\$4,624.51		1.49%
Veterinary Fees and Medicine	\$7,004.77		2.26%
Other Expenses	\$9,138.81		2.95%
Expense	\$196,050.10		63.33%
Change in Feed Inventories	(\$9,975.00)		-3.22%
Change in Raised Livestock	\$13,200.00		4.26%
Change in Accounts Receivable	\$0.00		0.00%
TOTAL INCOME	\$309,577.60		100.00%
Depreciation Claimed	\$41,284.67		13.34%
TOTAL EXPENSE	\$237,334.77		76.66%
Net Farm Income	\$72,242.83		23.34%

Supplies purchased per cow were \$159, \$124, and \$144 in the each of the last three years.

The majority of the depreciation claimed in 1997 and 1998 was due to the swing parlor and related equipment. The cost of the swing parlor is being recovered (depreciated) over ten years; therefore depreciation claimed was approximately \$30,000 in 1997 and \$57,000 in 1998. The

depreciation claimed in 1999 was over \$41,000.

Net Worth

The Net Worth decreased in 1996 due to the difference between the construction cost of the swing parlor and the fair market value of the swing parlor once it was constructed. The Net Worth increased \$21,237 in 1997, \$79,880 in 1998 and \$48,196 in 1999. Of this \$149,313, \$86,914 was Retained Earning. Try accomplishing that with an ordinary job over a three-year period. The current Debt to Asset Ratio is 57 percent. This is higher than the goal of 40 percent or less, however they are renters and do not have the land asset to reduce their ratio.

The Krusenbaums' Rate of Return on Assets (ROROA) in 1997, 1998 and 1999 respectively was 9.84, 22.37 and 13.80 percent on a fair market value (FMV) basis with appreciation. The ROROA was 6.42, 14.88, and 10.39 percent on a cost basis without appreciation. The Wisconsin average ROROA, without appreciation, was 5.42, 8.73, and 7.50 percent in those same years.

Figure 2

<i>Cost of Producing Milk</i>	
KRUSENBAUM FARM	
January 1999 through December 1999	
Total Farm Income	\$309,577.60
Average Milk Price	\$13.86
CWT EQs of Milk Produced	22,336.05
Total Allocated Costs	\$237,334.77
Total Interest Paid	\$15,609.59
Wages and Benefits Paid	\$18,089.69
Depreciation Claimed	\$41,284.67
Total Basic Costs	\$162,350.82
Basic Cost per CWT EQ	\$7.27
Total Margin	\$147,226.78
Costs per CWT EQ of Milk	
Cost of Resale Items or Basis	\$0.00
Car and Truck Expenses	\$0.00
Chemicals	\$0.06
Custom Hire (machine work)	\$0.57
Feed Purchased	\$1.54
Fertilizers and Lime	\$0.00
Freight and Trucking	\$0.05
Gasoline, Fuel and Oil	\$0.14
Insurance (other than health)	\$0.10
Rent or Lease (Equipment)	\$0.58
Rent or Lease (Other)	\$0.93
Repairs and Maintenance	\$1.12
Seeds and Plants Purchased	\$0.18
Supplies Purchased	\$0.73
Taxes	\$0.00
Utilities	\$0.21
Veterinary, Breeding, and Medicine	\$0.59
Other Expenses	\$0.48
Basic Costs	\$7.27
Mortgage Interest	\$0.00
Other Interest	\$0.70
Employee Benefit Programs	\$0.07
Labor Hired	\$0.74
Depreciation	\$1.85
Other Costs	\$3.36
Total Cost	\$10.63

The Asset Turnover Ratio was 63, 75, and 64 percent in 1997, 1998, and 1999 respectively. This is much higher than the Wisconsin average of 44 percent, however they are renters and do not have the land asset to reduce their ratio.

Cost of Production (Figure 2)

The Basic Cost per Hundredweight Equivalent (CWT EQ) of producing milk was \$8.30 in 1997, \$7.48 in 1998 and \$7.27 in 1999, a very impressive trend. The Basic Cost per CWT EQ in Wisconsin was \$7.86, \$8.23, and \$7.41 in those years. The Total Allocated Cost per CWT EQ on the Krusenbaum farm in 1997 was \$11.74, \$11.83 in 1998 and \$10.63 in 1999 versus \$11.80, \$12.42, and \$1.76 on Wisconsin farms. Total Allocated Costs does not include a charge for the unpaid

labor and management provided by the owner-operator and the operator's family or a return to the owner-operator's equity capital. These vary from farm to farm but generally add about \$2.50 to the Cost of Production per CWT EQ.

Milk Sales Trend

In 1997 the Krusenbaums converted to modified seasonal calving. This caused them to produce more milk per cow in January, February, and March; and lead to a more than 15 percent increase in production per cow. The pounds of milk sold per cow in 1997 was approximately 14,500. Milk sales per cow slipped somewhat in 1998 to approximately 14,250 pounds. This was largely due to the purchase of 24 heifers and an increase in herd size. The milk sold per cow increased to 15,300 pounds in 1999.

Summary

When comparing this farm to your farm or other farms, Basic Costs per CWT EQ is the best measure. This value neutralizes the effects on expenses caused by the ratio of "paid to unpaid labor" and the "debt load of the farm".

Net Farm Income From Operations (NFIFO) is the return to the Krusenbaum family's unpaid labor, management, and equity capital. The NFIFO in 1997 was \$45,788 or \$416 per cow. This compares to the Wisconsin average of about \$440 per cow in 1997. The NFIFO in 1998 was \$97,630 or \$781 per cow versus the Wisconsin average of \$716. The NFIFO on the Krusenbaum farm was \$634 per cow in 1999 versus \$658 on a sample of Wisconsin dairy farms.

OUTREACH

21. WICST EDUCATIONAL OUTREACH 1999 and 2000

Dwight Mueller, Jim Stute and Janet Hedtcke

As in previous years we used the WICST trials as an excellent visual tool to demonstrate and discuss issues of sustainability such as crop rotation, environmental stewardship, economic sustainability, and bio-diversity. In addition to field tours, we have disseminated the WICST research to local and regional events and scientific meetings. Nearly 5000 people either participated in our field days or received WICST information through meetings and conferences in 1999 and 2000. Table 1 summarizes the outreach and educational activities for WICST in 1999 and 2000.

On-station. Several groups of students visited the WICST plots for hands-on learning throughout the growing seasons of 1999 and 2000. These included 4th and 6th grade elementary students, DeForest 8th grade middle school students, East Troy high school students, UW (Madison) and University of Illinois (Chicago) students. For example, WICST helped sponsor the annual Science field day for 250 DeForest 8th graders in early autumn. This was an interactive hands-on field day enjoyed by all. Students moved among five different stops, which included presentations and activities on soil profile descriptions, groundwater and soil water movement, rainfall simulation and soil erosion, soil bio-diversity and crop production and nitrogen. Each student had to collect data, which was later used for future discussion, quizzes and exams in the classroom. A similar event was also held in September at Lakeland with 160 students from suburban Chicago land.

Other activities included Prairies Jubilee Field Day and several Agronomy Field Days. Once again WICST helped sponsor Prairies Jubilee Field Day with the Madison Audubon Society, which attracted an audience of over 500 people. Displays were set up describing WICST, and research it supports. Presentations were given at the Agronomy Field day on economic and environmental aspects of the systems. Field tours were given several times a year to several groups including extension agents, local farmers, and foreign visitors, from Australia and Africa.

Local/Regional. WICST participated in the Food For Thought Festival in downtown Madison in both years. We set up a display to inform the audience about agricultural practices and effects on soils and water and food quality. Presentations were also given at the ASA, CSSA, SSSA meetings in Minneapolis and at the Upper Midwest Organic Farming Conference in LaCrosse.

WICST efforts were also presented at several conferences and symposiums on nutrient management, and soil and water quality across the U.S. In particular, the WICST experiment was presented at meetings concerning the hypoxia issue in the Gulf of Mexico. In addition, WICST data was presented to state and federal agencies such as USDA-ARS and DATCP.

Table 1. Educational and Outreach Activity Listing for WICST

	EVENT	LOCATION	DATE	ATTENDANCE
1999	National ARS Meeting	Beltsville, MD	January	40
	WICST Winter Meeting	Madison, WI	January 27	35
	WI Soybean Marketing Brd.	Madison, WI	February	20
	Midwest Sustainable Agric. Working Group	East Troy, WI	February	30
	Upper Midwest Organic Farming Conference	LaCrosse, WI	March	40
	USDA-ARS Laboratory	Morris, MN	March	30
	Mukwonago Rotary Club	Mukwonago, WI	April	30
	AgFacts w/ Jeanie Geurink	WI Public Radio	May 26	Statewide broadcast
	Hypoxia Task Force Mtg.	Memphis, TN	June	40
	Elementary School Students	Arlington, WI	June 8	300
	Mississippi River Basis Alliance Annual Conf.	St Louis, MO	July	300
	WI Crop Improvement Assoc. Tour	Lakeland, Elkhorn, WI	July	20
	UW Soil Science Summer School Class	Arlington, WI	July 13	50
	Farming System Effects on Soil and Water Quality: A Long-term View	Arlington, WI	July 30	100
	Summer Institute of African Agricultural Research	Arlington, WI	July 23	50
	U.S. Joint Commission on Agriculture Conference	Milwaukee, WI	September	60
	Agronomy Field Day	Arlington, WI	September 16	200
	Food for Thought Festival	Madison, WI	September 26	100
	MFAI open house - WICST tours	Lakeland, Elkhorn, WI	October	30
	Middle Sch. Students (Science Field Day)	Arlington, WI	October 5 & 6	250
	Prairie Jubilee	Arlington, WI	October 10	500
	UW Short Course	Arlington, WI	October 14	50
	Small Farm Conference and Trade Show	Indianapolis, IN	November	80
	ARS Integrated Agric. Systems Program Development Conference	Denver, CO	December	100
	Total			2455

Table 1 (continued). Educational and Outreach Activity Listing for WICST

2000	EVENT	LOCATION	DATE	ATTENDANCE
	Rock River Partnership Mtg	Jefferson, WI	January	60
	Practical Farmers of Iowa	Ames, IA	February	40
	Field Day			
	WICST Winter Meeting	Madison, WI	February 23	28
	DATCP Public Hearing on	East Troy, WI	March	30
	Nutrient Management			
	Gulf of Mexico Symposium	Mobile, AL	April	40
	WICST Field Tour	Lakeland, Elkhorn, WI	May 3	25
	USDA Symposium for	Chicago, IL	May	30
	Limited Resource Producers			
	Workshop			
	Practical Farmers of Iowa	Ames, IA	June	40
	WICST Field Tour for	Lakeland, Elkhorn, WI	June	40
	Australian farmers			
	Soil Quality Symposium	Sharon, WI	June 21	30
	Farm Progress Days	Eden	July 10-13	100
	Midwest Sustainable Agric.	East Troy, WI	August	30
	Working Group			
	Practical Farmers of Iowa	Ames, IA	August	25
	Field Day			
	East Troy Chamber of	East Troy, WI	August	20
	Commerce Meeting			
	Food for Thought Festival	Madison, WI	September 9	200
	Mississippi River Basin	Memphis, TN	September	30
	Conference			
	Upper Mississippi River	Sinsinawa, IA	September	100
	Conference			
	USDA-ARS-DFRC	Madison, WI	September	40
	Stakeholders Meeting			
	WICST Field Day	Arlington, WI	September 20	20
	WICST Field Day	Lakeland, Elkhorn, WI	September 22	40
	Middle Sch. Students	Arlington, WI	September 27 & 28	250
	(Science Field Day)			
	Prairies Jubilee	Arlington, WI	October 8	500
	ASA, CSSA, SSSA	Minneapolis, MN	November 5-9	400
	UW Soils Class	Madison, WI	December 5	15
	Nitrate Reduction Strategy	Ames, IA	December	50
	Session Meetings			
	AgFacts w/Jeanie Geurink	WI Public Radio	December 18	Statewide broadcast
	WICST Winter Meeting	Madison, WI	February, 9	35
	Upper Midwest Organic	LaCrosse, WI	March 16, 2001	35
	Farming Conference			
Total				2253

NEW RESEARCH

22. Establishing prairie on nutrient rich soils

Catherine Simonsen¹, Evelyn Howell², Joshua Posner³, Martha Rosemeyer⁴

Primary Audience: Extension Agents, NRCS, private landowners, restoration ecologists.

Project Summary:

With this project we plan to establish native Wisconsin prairie plant species on the nutrient rich agricultural soils of the WICST plots. We will investigate how different planting mixes respond to intense weed competition, and whether this affects long-term success and/or ecological functioning. The WICST plots offer a unique opportunity to incorporate some of the ecosystem parameters from the cropping diversity to the native species diversity.

We will use two planting mixes of native WI prairie species; high diversity (6 grasses, 23 forbs, 7 functional groups), and low diversity (3 grasses, 3 forbs, 3 functional groups). Continuous corn will be planted and used as a link to the WICST trials. Some questions this project will attempt to examine include:

1. Does initial planting diversity/guild composition affect prairie seedling survival in the first years of establishment?
2. Does initial planting diversity/guild composition affect weedy competitors?
3. Is there a significant difference in community composition between the diversity treatments?
4. Is there a significant difference between the diversity treatments regarding ecological parameters? (C-sequestration, POM, macro fauna, etc.)?
5. Is there a significant difference between prairie and cropping system control regarding these parameters?

Materials and Methods:

The experimental design is a randomized complete block with 3 replicates. Three treatments consist of continuous corn,

Give us a table with the list of species (common and botanical name) and seeding rates.

Mention the options of planting in the early spring or late fall (theoretical advantages of each)

Land preparation and seeding methods

Establishment of permanent monitoring stations, random stations, what measurements you are taking

Preliminary Results:

1999:

In the spring and summer of 1999, the corn and the two prairie treatments were planted at Arlington Research Station. Corn was planted on April 30 and managed according to CS1

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protocol. The prairie treatments were planted June 4, 1999. After soil preparation with a culti-packer, the prairie plots (2132 m²) were hand-broadcast seeded. Four permanent 1-m² quadrats were also established in each treatment and three soil samples were taken at each for weed seedbank, fertility, and nitrate measurements. These quadrats were excluded from the hand broadcast planting by a plastic cover and later hand planted with the precise number of seeds counted and representing the rates on the field. Due to heavy rains in the spring at Lakeland (over 5 inches in May), planting was postponed to spring 2000.

As expected, the prairie plots at Arlington were quickly overcome by weed invasion, most notably lamb's quarter, pigweed, and crabgrass. By July the pigweed and lamb's quarters were nearing 4 feet tall and out of concern for the emerging native seedlings the plots were mowed with a brush hog to a height of about 8 inches. However, there were several species emerging such as, black-eyed susan, saw-toothed sunflower, butterfly weed and big bluestem, but the numbers were alarmingly low. Also initiated in 1999 was research on weed seed banks and seed germination trials.

2000:

Heavy spring rains again delayed planting at the more poorly drained Lakeland site and seeding was postponed to the fall. May and June rainfall at Lakeland was over 200% of the long-term average. Unfortunately, seeding did not take place in the fall at Lakeland.

At Arlington, many of the native species have germinated by the second year (Table 1) and we are currently monitoring the plots by way of the four permanent m² quadrats in each replicate as well as 20 stratified random ¼ m² quadrats in each replicate.

Start Date: Spring 1999

End Date: Spring 2001

Table 1. Established prairie species at the Arlington Agriculture Research Station, 2000.

BOTANICAL NAME	COMMON NAME	Low diversity	High diversity	Seeding rates per acre (low/high)
<i>Andropogon gerardii</i>	BIG BLUESTEM	X	X	0.5 lbs
<i>Sorghastrum nutans</i>	CANADA WILD RYE	X	X	0.5 lbs
<i>Elymus canadensis</i>	INDIAN GRASS		X	2 lbs
<i>Allium cernuum</i>	WILD ONION		X	0.5 oz
<i>Asclepias tuberosa</i>	BUTTERFLY WEED		X	0.5 oz
<i>Aster novae-angliae</i>	NEW ENGLAND ASTER		X	0.25oz
<i>Astragalus canadensis</i>	MILKVETCH		X	0.5 oz
<i>Baptisia leucantha</i>	WHITE WILD INDIGO		X	0.5 oz
<i>Coreopsis palmata</i>	PRAIRIE TICKSEED		X	0.5 oz
<i>Desmodium canadense</i>	TICK TREFOIL	X	X	0.25/0.5 oz
<i>Eryngium yuccifolium</i>	RATTLESNAKE MASTER		X	0.5 oz
<i>Galium boreale</i>	NORTHERN BEDSTRAW		X	0.25 oz
<i>Geum triflorum</i>	PRAIRIE SMOKE		X	0.25 oz
<i>Helianthus grosseserratus</i>	SAWTOOTH SUNFLOWER		X	0.25 oz
<i>Helianthus laetiflorus</i>	SHOWY SUNFLOWER		X	0.25 oz
<i>Lespedeza capitata</i>	ROUND-HEADED BUSH CLOVER	X	X	0.5 oz
<i>Monarda fistulosa</i>	WILD BERGAMOT		X	0.25 oz
<i>Potentilla arguta</i>	PRAIRIE CINQUEFOIL		X	0.05 oz
<i>Ratibida pinnata</i>	YELLOW CONEFLOWER	X	X	0.5 oz
<i>Rosa carolina</i>	WILD ROSE		X	1 oz
<i>Rudbeckia hirta</i>	BLACK-EYED SUSAN	X	X	0.5/0.25 oz
<i>Silphium integrifolium</i>	ROSINWEED		X	0.5 oz
<i>Solidago rigida</i>	STIFF GOLDENROD		X	0.5 oz
<i>Tradescantia ohioensis</i>	COMMON SPIDERWORT		X	0.25 oz
<i>Viola pedatifida</i>	PRAIRIE VIOLET		X	0.5 oz

23. Coupling of H and N cycles in several common agroecosystems of Midwestern United States

M. Avila and P. Barak

ABSTRACT

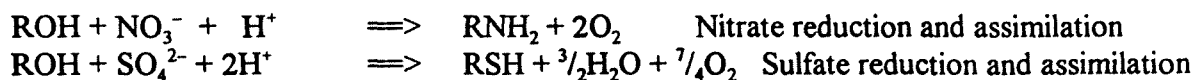
Excess nitrogen inputs produce soil acidification as a result of coupling of nitrogen and proton biogeochemical cycles and increased nitrate leaching causes increased cation leaching. Crops interact with soils by extracting cations and anions, excreting acidity or alkalinity, and storing alkalinity as organic anions. The Wisconsin Integrated Cropping Systems Trial at Arlington (WI) Research Station has sampled soils and plants under standard rotations and nutrient inputs since 1989. Archived samples from this trial are being used to study the coupling of nitrogen and proton cycles under real farm conditions and to evaluate acidification and alteration of soil chemical properties in common agroecosystems. Leaching of cations, potential acidification due to excessive nitrogen inputs, and crop-induced acidification are under evaluation as indicators of how agriculture impacts long term soil quality.

INTRODUCTION

The laws of conservation of mass and energy imply also the conservation of charge in any physical or biological system. In agroecosystems, redox reactions of nitrogen and sulfur cycling through plant and soils produce or consume protons at various stages of the cycles, indicating the coupling of these cycles with the proton cycle. Electroneutrality is forced on the system in terms of 1) total cation and anion uptake at the plant/soil interface, 2) internal cation/anion balance by synthesis of organic anions upon reduction and assimilation of nitrate and sulfate, and 3) counterion leaching upon enhanced nitrate leaching.

Cation-anion uptake balance in crops:

Mineral cations are used in their cationic form while some anions (NO_3^- and SO_4^{2-}) are normally reduced to form organic compounds. Reduction processes require protons, which the plant supplies by producing and deprotonating organic acids.



In those cases where absorption of one type of charge exceeds the other, the plant equalizes charge by excreting acidity or organic anions, thus leading to acidification or alkalization of the rhizosphere. What is excreted is mainly controlled by the form of nitrogen, (NH_4^+ or NO_3^-) on which the plants feed.

Leaching of nitrification products:

Electroneutrality requires equivalent amounts of positive and negative charge to leach simultaneously from the system. Therefore, the greater the amount of NO_3^- leached from the soil, the greater the amount of Ca^{2+} , Mg^{2+} , K^+ and Na^+ leached.

When H^+ is generated by crop uptake of cations or by nitrification process, it displaces cations from the exchange complex. The displaced cations are then prone to leaching with anions such as NO_3^- and SO_4^{2-} . This results in the loss of mineral cations (mainly Ca^{2+} , Mg^{2+} , K^+ and Na^+) from the soil by leaching while H^+ accumulates in the exchange complex.

Leaching of NO_3^- constitutes the uncoupling of H and N cycles in agroecosystems and is the point in the cycle at which H^+ flux becomes irreversible.

PRELIMINARY RESULTS

Nitrate-N accounts for ~90% of the total anions taken up by the plant and the proportion N:P:S is approximately the same for the different plant tissues analyzed. In contrast, the proportion Ca:Mg:K varies according to the tissue, with particularly low calcium content in the grain.

Anion uptake in corn (cropping system 1, WICS Trials) indicates that mineral anion uptake exceeds cation uptake by about $110 \text{ cmol}_e \text{ kg}^{-1}$ (Figure 1), thus requiring an equivalent amount of alkalinity to be excreted into the soil.

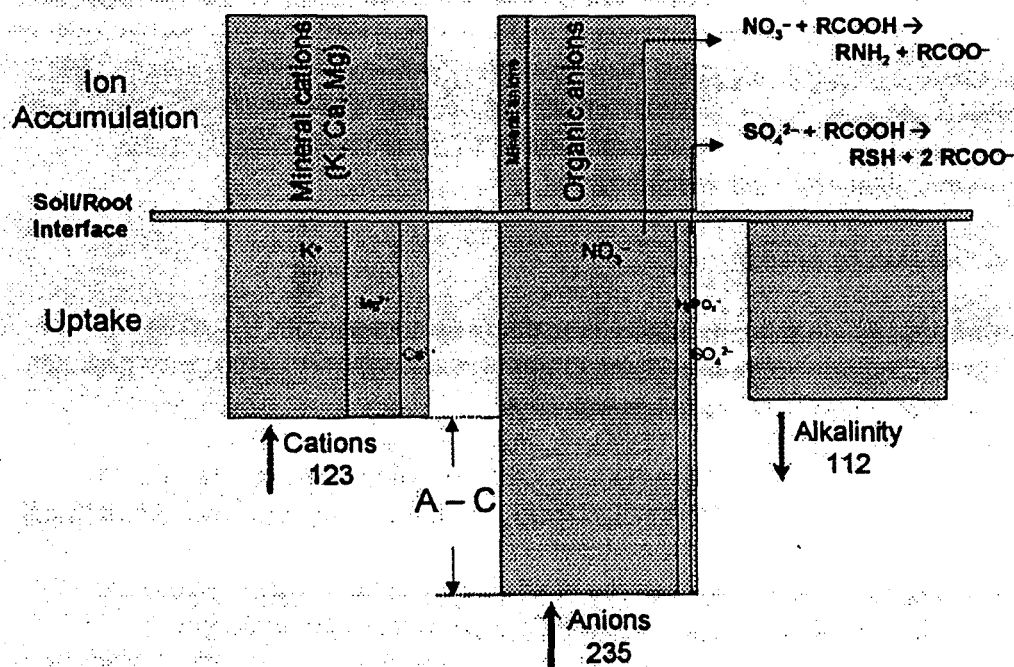


Figure 1. Uptake and accumulation of cations and anions in corn ($\text{cmol}_e \text{ kg}^{-1}$ tissue) based on elemental analysis of above ground biomass (Barak and Avila, 2000).

Elemental analysis indicates that grain harvest has a significant impact on the amount of acidification produced by N inputs. The grain removes ~60% of the total acidity of the system, which is equivalent to almost 60% recovery of total available N (~80% nominal fertilizer efficiency). Mineralization of the stover should not contribute to soil acidification because the stover is essentially acid base neutral (Table 1). Although this particular system seems very efficient at cycling N from soil to plant even this system has the potential for leaching ~5 kmol $\text{NO}_3^- \text{ ha}^{-1} \text{ yr}^{-1}$, which requires ~270 kg $\text{ha}^{-1} \text{ yr}^{-1}$ of agricultural lime to neutralize the resulting acidity.

Table 1. Acid/base balance for continuous corn; cropping system 1, WISCS Trial.

Source	Potential alkalinity (organic anions)	Potential acidity (org-N + org-S)	Net
<hr/>			
	<hr/> kmol _c ha ⁻¹ <hr/>		
Total above ground material	5.38	13.20	7.82
Grain (harvested biomass)	0.53	8.41	7.88
Stover	4.85	4.79	0.04
Fertilizer (134 kg N ha ⁻¹ as NH_4NO_3 ; 1997)	—	9.60	9.60
Mineralization (~45 kg ha ⁻¹ yr ⁻¹)	?	3.20	3.20
Atmospheric Deposition (~7 kg ha ⁻¹ yr ⁻¹ ; Wisconsin DNR, 1995)		0.50	0.50
Potential acidity of the system (N inputs – harvest removal)		5.42	5.42
CaCO_3 (kg ha ⁻¹ required for neutralization of acidity)			270

This type of analysis is under way for other cropping systems at the WICST Trials and changes in mineral properties are being analyzed in order to evaluate the long-term fate of soil properties in acidified agricultural soils.

24. The Effects of Organic Manures, Grazing, and Biodynamic Growth Regulators on an Alternative Cropping System.

Walter Goldstein and Rick Klemme

Summary. The rotation of maize-soybean-winter wheat + red clover has potential as an alternative to maize-soybean systems. It should be profitable, will significantly reduce the use of agrochemicals, and offer increased management options for medium and small farms. However, questions remain concerning the stability of maize yields with this expanded rotation. Based on previous research we think that: 1) the positive effects of rotation and manure are due to improvements in the efficiencies of rooting systems; 2) the crop yields from the system depend on the soil having adequate supplies of biologically active organic matter; 3) combining the system with manure or compost inputs or grazing regulators will lead to improved yields and greater profitability; and 4) using biodynamic growth regulators will increase rooting, the production of active organic matter, and the stability of yields. To test these ideas, we will explore linkages between the use of crop rotations, compost, manure, grazing, and biodynamic regulators on the one hand and the formation of active organic matter, the dynamics and efficiency of root activity, mycorrhizal infection, and the nutrient uptake and yield of maize on the other. The study will involve three field experiments on two sites. Two experiments will compare alternative systems to commonly utilized, conventionally managed systems. One experiment will introduce grazing by cattle. Miniplot studies will clarify ideas on the mode of action of compost in increasing active organic matter. The results of our research will feed into ongoing implementation projects and will also be used to test an organic matter budget that is designed to help farmers plan sustainable options. The project addresses the economic viability of family farms, their long-term productivity, and the enhancement of the natural resource base. It is expected to enhance sustainability and to provide a model for wider application of manure.

25. Integrating Livestock Production and Conservation in the Restoration of Oak Savannas

M. Rosemeyer and J. Harrington

Oak savanna, though once the most dominant habitat type in southern Wisconsin, is now considered one of the most threatened habitats in the world. Most of degraded (brushy and overgrown) oak savanna is on private land, necessitating a novel approach for conservation. Cattle are currently being introduced into degraded oak savannas for two purposes: removal of brush and tax assessment purposes¹. Clearing degraded oak savannas to restore the original vegetative structure is an important first step in conserving these ecosystems and providing habitat for many rare or dwindling grassland species. However, the impact to the herbaceous layer is not known. Although this has the potential to be a win-win situation, with more producers grazing in forested ecosystems for tax purposes, it also has the potential for environmental harm, if producers do not have a clear set of management guidelines. This on-farm project will determine the feasibility of rotational grazing with two stocking densities to restore degraded oak savannas. It is an opportunity to develop a management system that would be beneficial to livestock producers, who by grazing degraded oak savanna could add to their available pasture base, reduce their tax burden and be equally valuable in the restoration of an important natural resource in Wisconsin. The proposed on-farm participative approach will facilitate farmer education and adoption.

Objective: The restoration of oak savanna habitat using rotational grazing with Scottish Highland cattle in comparison with burning.

Collaborators: Wisconsin Department of Natural Resources, USDA-Natural Resources and Conservation Service, UW-Agronomy, UW-Landscape Architecture, UW-Extension, Landowners, UW-Wildlife Ecology, Luther College

Treatments: burning, two levels of grazing intensity, burning and grazing, and control (no burning or grazing).

Repetitions: 5 blocks, 1 acre paddock size.

Sites: Yellowstone Lake Recreation Area
Rathbun farm
Niemann Farm

Parameters to be measured: Shrubs, trees, herbaceous layer, soil and litter characteristics, vegetation architecture, forage quality, animal performance, insects (ground beetles, spiders), small mammals.

WI Dept. Revenue. 2000. Agricultural Assessment Guide for Wisconsin Property Owners. Prop 061 (R. 12-99).

Questions to be addressed:

- (1) Can grazing increase reduce shrub and sapling growth within degraded savannas and if so what grazing management regime is necessary for this?
- (2) How does grazing intensity alter the herbaceous composition and structure?
- (3) How does grazing at different intensities impact light penetration and soil properties such as pH, soil organic matter, available potassium and phosphorus, bulk density?
- (4) How do individual applications of grazing or fire compare with interacting applications of grazing and fire in terms of vegetative, soil and light responses?
- (5) How do grazing and burning of degraded oak savanna compare in forage production and quality and the resulting cattle performance?
- (6) How do burning and grazing at two intensities affect ground beetle and small mammal populations/community structure?

Expected results: WIN-WIN SITUATION?

- Evaluate effectiveness of Highland cattle in restoring oak savanna structure.
- Learn how to manage cattle so that brush can be cleared with a minimum impact to desired herbaceous species.
- Insects and small mammals will be immediately impacted by burning and may be impacted by moderate grazing treatment and more severely impacted by high grazing.
- Utility of ground beetle populations to monitor disturbance.
- Livestock producers may increase productivity of enterprises.

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Appendix I-A. 1999 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION

Corn rotations					
CROP-99 Rotation Treatment #	CORN CS1 1	CORN CS2 3	CORN CS3 6	CORN CS4 9	CORN CS5 12
Plot #'s	109, 204, 306, 412	101, 214, 303, 401	102, 212, 313, 407	105, 203, 308, 406	103, 213, 314, 410
Primary Tillage	Chisel plow 10/29/98	No-till	Chisel plow w/sweeps 11/17/98	Chisel plow 11/17/98	Chisel plow 11/17/98
Secondary Tillage	Field digger 4/27/99	None	Field digger 5/13/99	Field digger 4/24/99	Field digger 4/27/99, 5/13/99
Planting Date	4/30/99	04/30/99	5/13/99	4/30/99	5/13/99
Variety	Gold.Harv.2441	Gold.Harv.2441	Dekalb 471	Gold.Harv.2441	Dekalb 471
Rate	32,000 seeds/a	32,000 seeds/a	34,500 seeds/a	32,000 seeds/a	34,500 seeds/a
Starter Fertilizer	100 lb product 6-24-24	None	None	100 lb product 6-24-24	None
Nitrogen Fertilizer	80 lb N/a 82-0-0 4/27/99 preplant	80 lb N/a ¹ 82-0-0 04/27/99 preplt	None	None	None
Manure	None	None	None	20 ton/a 10/28/98	15 ton/a 10/28/98
Pesticides	4/30/99 Counter (5 lb/a) <u>Pre-emergence</u> 5/3/99 Dual II (2 pt/a) <u>Post-emergence:</u> 6/3 Accent (2/3 oz/a) 6/5 Buctril (1 pt/a)	<u>Pre-emergence</u> 5/3/99 Dual II (2 pt/a) <u>Post-emergence:</u> 5/13 Roundup Ultra (1 pt/a) 06/05 Buctl (1pt/a) 06/10-Stinger (plots #303 & 401)	None	<u>Post-emergence:</u> 06/03-Buctril (1 pt/a) 06/03-Accent (0.67 oz/a)	None
Rotary Hoe	5/25/99	None	05/25/99	None	5/25/99
Cultivation	6/8/99, 6/19/99	None	6/8/99, 6/19/99	6/9/99, 6/19/99	6/8/99, 6/19/99
Harvest	10/28/99	10/28/99	10/28/99	10/28/99	10/28/99
Yield	170.4 bu/a	162.9 bu/a	155.6 bu/a	189.7 bu/a	181.9 bu/a
Fall Practices	Chop stalks 11/10/99 Chisel plow 11/16/99	None	Chisel plow 11/16/99	Chop stalks 11/10/99 Manure 20 t/a 11/15/99 Chisel plow 11/16/99	Chop stalks 11/10/99 Manure 15 t/a 11/15/99 Chisel plow 11/16/99
Crop 2000	Corn	Soybean	Soybean	D.S. Alfalfa	Oats/Alfalfa

¹ CS2 corn did not need all 80 lb N/a but that was the lowest setting on the fertilizer spreader

Appendix I-A. 1999 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION

Soybean and Wheat Rotations			
CROP-99 Rotation Treatment #	NR Soybean CS2 2	WR Soybean/Wheat CS3 5	Wheat/Red Clover CS3 4
Plot #'s	108, 206, 310, 408	106, 202, 307, 411	104, 201, 301, 402
Primary Tillage	No-till	Chisel plow 10/29/98	Soil digger 10/11/98 Double disk drill 10/12/98
Secondary Tillage	None	Field digger 4/30/99, 5/12/99	None
Planting Date	5/13/99	SB: 5/12/99 WW: 10/08/99	Red clover: 3/22/99 WW: 10/12/98
Variety Rate	Asgrow 2301 250,000 seeds/a	Asgrow 2247 190,000 seeds/a Glacier 3 bu/a	Arlington red clover: 12 lb/a Glacier wheat: 130 lb/a
Fertilizer	None	None	None
Pesticides	<u>Pre-plant</u> 05/3/99 Roundup-Ultra (1 pt/a) <u>Post-emergence</u> Roundup-Ultra (date?) (2 pt/a)	None	None
Rotary Hoe	None	5/25/99	None
Cultivation	None	6/19/99, 6/28/99, 7/6/99	None
Harvest	10/7/99	10/7/99	Grain: 7/14/99 Straw: 7/20/99
Yield	59.2 bu/a	31.0 bu/a ¹	Grain: 56.9 bu/a Straw: 0.62 t DM/a
Fall Practices	None	Field digger 10/7/99 Plant wheat 10/8/99	Chisel plow w/sweeps 11/19/99
Crop 2000	Corn	Wheat / Red Clover	Corn

¹ Low yields related to very heavy weed pressure.

Appendix I-A. 1999 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION

Forage rotations						
CROP-99 Rotation Treatment #	D.S. Alfalfa CS4 8	Estab. Alfalfa I CS4 7	Estab. Alfalfa II CS4 10	Oats/Alfalfa CS5 11	Estab. Alfalfa I CS5 13	Pasture CS6 14
Plot #'s	113, 210, 311, 414	111, 209, 305, 409	107, 205, 309, 404	110, 208, 304, 413	114, 211, 312, 403	112, 207, 302, 405
Primary Tillage	Chisel plow 10/29/98	None	None	Chisel plow 10/29/98	None	None
Secondary Tillage	3/24/99 Field digger	None	None	3/24/99 Field digger	None	None
Planting Date Variety	3/24/99 Wintergreen	4/15/98 Wintergreen	4/17/97 Innovator	3/24/99 Bay Oats Trapper peas Wintergreen 2.5 bu/a, 50 lb/a 12 lb/a	4/15/98 Wintergreen alf, oats, trapper peas Alf -11 lb/a Oats - 50 lb/a Peas - 50 lb/a	None
Rate	12 lb/a	15 lb/a	15 lb/a			
Fertilizer	None	None	None	None	None	None
Manure	20 ton/a 10/28/98	None	None	15 ton/a 10/28/98	None	Grazing
Pesticides	<u>Post-emerge:</u> 5/15/99, 5/21/99 Pursuit (1.08 oz/a) 7/13/99 Dimetholate (1 pt/a)	6/26/99 Pounce (4 oz/a) 7/13/99 Dimetholate (1 pt/a)	6/25/99 Pounce (4 oz/a) 7/13/99 Dimeth (1 pt/a) 10/26/99 Roundup (1 pt/a)	None	None	None
Harvest	7/2/99 8/5/99 9/3/99	6/5/99 7/2/99 8/5/99 10/22/99	6/5/99 7/2/99 8/5/99 11/1/99	<u>Oatlage:</u> 06/15/99 <u>Haylage:</u> 8/19/99	6/5/99 7/16/99 9/22/99	Rotational Grazing
Yield	2.27 t DM/a	4.56 t DM/a	4.06 t DM/a	Oatlage: 2.61 Haylage: 2.09 t DM/a	5.48 tDM/a	1.8 lb/hd/dy 2.21 t DM/a
Fall Practices	None	None	Manure 20 t/a 11/15/99 Chisel plow 11/17/99	None	Manure 15 t/a 11/15/99 Chisel plow w/sweeps 11/19/99	None
Crop 2000	Alf I	Alf II	Corn	Alf I	Corn	Pasture

Appendix I-A. 1999 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION**Satellite plots – Chemlite of Cropping System 3**

CROP-99	Corn	WR Soybean/Wheat	Wheat/Red Clover
Rotation	CS3	CS3	CS3
Treatment #	6	5	4
Primary Tillage	Chisel plow w/sweeps 11/17/98	Chisel plow 10/28/98	Soil digger 10/11/98 Double disk drill 10/12/98
Secondary Tillage	5/13/99 Field digger	4/30/99, 5/12/99 Field digger	None
Planting Date	5/13/99	SB: 05/12/99 WW: 10/08/99	Red clover: 3/22/99 WW: 10/12/98
Variety	Dekalb 471	Asgrow 2247	Arlington red clover: 12 lb/a
Rate	34,500 seeds/a	190,000 seeds/a Glacier 3 bu/a	Glacier wheat: 130 lb/a
Fertilizer	None	None	None
Pesticides	None	None	None
Rotary Hoe	05/25/99	5/25/99	None
Cultivation	6/8/99, 6/19/99	6/19/99, 6/28/99, 7/6/99	None
Harvest	10/28/99	10/7/99	7/14/99
Yield	160.0 bu/a	49.8 bu/a	Grain: 59.8 bu/a straw: 0.66 t DM/a
Fall Practices	Chisel plow 11/16/99	Field digger 10/7/99 Plant wheat 10/8/99	Chisel plow w/sweeps 11/19/99
Crop 2000	Soybean	Wheat / Red Clover	Corn

Appendix I-B. 2000 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION

Corn rotations					
CROP-00 Rotation Treatment #	CORN CS1 1	CORN CS2 2	CORN CS3 4	CORN CS4 10	CORN CS5 13
Plot #'s	109, 204, 306, 412	108, 206, 310, 408	104, 201, 301, 402	107, 205, 309, 404	114, 211, 312, 403
Primary Tillage	Chisel plow 11/16/99	No-till	Chisel plow w/sweeps 11/16/99	Chisel plow 11/16/99	Chisel plow 11/16/99
Secondary Tillage	Field digger 4/27/00	None	Field digger 4/27/00, 5/15/00	Field digger 4/27/00	Field digger 4/27/00, 5/10/00
Planting Date	05/01/00	5/1/00	5/15/00	5/1/00	5/15/00
Variety	Cargill 4111	Cargill 4111	Cargill 4111	Cargill 4111	Cargill 4111
Rate	32,000 seeds/a	32,000 seeds/a	34,500 seeds/a	32,000 seeds/a	34,500 seeds/a
Starter Fertilizer	100 lb product 9-23-30	100 lb product 9-23-30	None	100 lb product 9-23-30	None
Nitrogen Fertilizer	80 lb N/a 82-0-0 4/25/00 preplant 160 lb N/a 82-0-0 6/22/00 sidedress	80 lb N/a ¹ 82-0-0 04/25/00 preplant 120 lb N/a 82-0-0 6/22/00 sidedress	None	None	None
Manure	None	None	None	20 ton/a 11/15/99	15 ton/a 11/15/99
Pesticides	5/1/00 Force (5 lb/a) <u>Pre-emergence</u> 5/4/00 Dual II (2 pt/a)	<u>Pre-emergence</u> 5/4/00 Dual II (2 pt/a)	None	<u>Pre-emergence:</u> 5/4/00 Dual II (2 pt/a)	None
Rotary Hoe	5/23/00	None	5/23/00, 5/26/00	None	5/23/00, 5/26/00
Cultivation	6/19/00	None	6/19/00, 6/30/00	6/30/00	6/19/00, 6/30/00
Harvest	10/25/00	10/25/00	10/25/00	10/25/00	10/25/00
Yield	161.6 bu/a	162.9 bu/a	132.8 bu/a	179.4 bu/a	135.2 bu/a
Fall Practices	Chop stalks 11/09/00 Chisel plow 11/10/00	None	None	Chop stalks 11/9/00 Manure 20 t/a 11/10/00 Chisel plow 11/11/00	Chop stalks 11/9/00 Manure 15 t/a 11/10/00 Chisel plow 11/11/00
Crop 2001	Corn	Soybean	Soybean	D.S. Alfalfa	Oats/Alfalfa

¹ CS2 corn did not need all 80 lb N/a but that was the lowest setting on the fertilizer spreader

Appendix I-B. 2000 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION**Soybean and Wheat Rotations**

CROP-00 Rotation Treatment #	NR Soybean CS2 3	WR Soybean/Wheat CS3 6	Wheat/Red Clover CS3 5
Plot #'s	101, 214, 303, 401	102, 112, 313, 407	106, 202, 307, 411
Primary Tillage	No-till	Chisel plow 11/16/99	Field digger 10/7/99
Secondary Tillage	None	Field digger 4/27/00, 5/10/00	None
Planting Date	5/15/00	SB: 5/15/00 WW: 10/11/00	Red clover: 3/8/00 WW: 10/8/99
Variety Rate	Asgrow 2301 250,000 seeds/a	Novartis 1990 190,000 seeds/a Kaskaskia 3 bu/a	Arlington red clover: 15 lb/a Glacier wheat: 130 lb/a
Fertilizer	None	None	None
Pesticides	5/4/00 Roundup-Ultra (1 pt/a)	None	None
Rotary Hoe	None	5/23/00, 5/26/00	None
Cultivation	None	6/19/00, 6/30/00, 7/14/00	None
Harvest	10/10/00	10/10/00	Grain: 7/19/00 Straw: 7/25/00
Yield	56.3 bu/a	40.9 bu/a ¹	Grain: 41.7 bu/a Straw: 0.83 t DM/a
Fall Practices	None	Plant wheat 10/11/00	Chisel plow w/sweeps 10/11/00
Crop 2001	Corn	Wheat / Red Clover	Corn

¹ Low yields related to very heavy weed pressure.

Appendix I-B. 2000 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION

Forage rotations						
CROP-00 Rotation Treatment #	D.S. Alfalfa CS4 9	Estab. Alfalfa I CS4 8	Estab. Alfalfa II CS4 7	Oats/Alfalfa CS5 12	Estab. Alfalfa I CS5 11	Pasture CS6 14
Plot #'s	105, 203, 308, 406	113, 210, 311, 414	111, 209, 305, 409	103, 213, 314, 410	110, 208, 304, 413	112, 207, 302, 405
Primary Tillage	Chisel plow 11/16/99	None	None	Chisel plow 11/16/99	None	None
Secondary Tillage	Field digger, soil finisher 3/30/00	None	None	Field digger, soil finisher 3/30/00	None	None
Planting Date Variety	3/30/00 Dekalb 124	3/24/99 Wintergreen	4/15/98 Wintergreen	3/30/00 Dekalb 124 Bay Oats Trapper peas	3/24/99 Wintergreen, oats, trapper peas	None
Rate	12 lb/a	12 lb/a	15 lb/a	12 lb/a 2.5 bu/a 50 lb/a	Alf - 12 lb/a Oats - 80 lb/a Peas - 50 lb/a	None
Fertilizer	None	None	None	None	None	40 lb N/a all but plot 207 6/15/00
Manure	20 ton/a 11/15/99	None	None	15 ton/a 11/15/99	None	Grazing
Pesticides	5/15/00, Pursuit (1.08 oz/a) 5/15/00, Amm. Sulf. (2.5 lb/a) Activat. (1 t/a)	None	None	None	None	None
Harvest	7/11/00 8/22/00	5/23/00 6/30/00 8/1/00 9/6/00	5/23/00 6/30/00 8/1/00 9/6/00	Oatlage: 6/29/00 Haylage: 8/30/00	5/23/00 6/30/00 8/1/00 9/6/00	Hay 5/16/00 6/16/00
Yield	2.59 t DM/a	5.44 t DM/a	5.31 t DM/a	Oatlage: 2.75 Haylage: 1.40 t DM/a	5.86 t DM/a	1.75 lb/hd/dy 2.13 t DM/a
Fall Practices	None	None	Manure 20 t/a 11/10/00 Chisel plow w/sweeps 11/11/00	None	Manure 15 t/a 11/10/00 Chisel plow w/sweeps 11/12/00	None
Crop 2001	Alf I	Alf II	Corn	Alf I	Corn	Pasture

Appendix I-B. 2000 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION**Satellite plots – Chemlite of Cropping System 3**

CROP-00	Corn	WR Soybean/Wheat	Wheat/Red Clover
Rotation	CS3	CS3	CS3
Treatment #	4	6	5
Primary Tillage	Chisel plow w/sweeps 11/16/99	Chisel plow 11/16/99	Field digger 10/7/99
Secondary Tillage	Field digger 4/27/00, 5/10/00	Field digger 4/27/00, 5/10/00	None
Planting Date	5/15/00	SB: 5/1500 WW: 10/11/00	Red clover: 3/8/00 WW: 10/8/99
Variety	Cargill 4111	Novartis 1990	Arlington red clover: 15 lb/a
Rate	34,500 seeds/a	190,000 seeds/a Kaskaskia 180 lb/a	Glacier wheat: 130 lb/a
Fertilizer	80 lb N/a 82-0-0 - 4/25/00 100 lb/a Starter 9-23-30 5/15/00	None	None
Pesticides	None	None	Poast 1.5 pt/a 6/15/00
Rotary Hoe	5/23/00, 5/26/00	5/23/00, 5/26/00	None
Cultivation	6/19/00, 6/30/00	6/19/00, 6/30/00, 7/14/00	None
Harvest	10/25/00	10/10/00	7/19/00
Yield	154.5 bu/a	51.6 bu/a	Grain: 52.3 bu/a Straw: 0.75 t DM/a
Fall Practices	Chopped stalks 11/9/00 Chisel plow 11/10/00	Planted wheat 10/11/00	Chisel plow w/sweeps 11/11/00
Crop 2001	Soybean	Wheat / Red Clover	Corn

Appendix II-A. 1999 WICST INPUT/OUTPUT DATA - LAKELAND AGRICULTURAL COMPLEX

Corn Rotations					
CROP-99 Rotation Treatment #	CORN CS1 1	CORN CS2 3	CORN CS3 6	CORN CS4 9	CORN CS5 12
Plot #'s	101, 210, 303, 401	113, 206, 311, 410	111, 208, 306, 407	110, 212, 302, 414	105, 207, 309, 412
Primary Tillage	Chisel plow 11/16/98	No-till	Chisel plow with sweeps 11/16/98	Chisel plow 11/23/98	Chisel plow 11/23/98
Secondary Tillage	Field cultivator 5/3/99	None	Field cultivator 5/4/99, 5/26/99	Field cultivator 5/4/99, 5/26/99	Field cultivator 5/4/99, 5/26/99
Planting Date	5/4/99	5/4/99	5/27/99	5/27/99	5/27/99
Variety	Gold. Harv 2441	Gold. Harv 2441	DeKalb 471	DeKalb 471	DeKalb 471
Rate	32,000 seeds/a	32,000 seeds/a	34,500 seeds/a	34,500 seeds/a	34,500 seeds/a
Starter Fertilizer	100 lb product 9-23-30	250 lb product ¹ 9-23-30	None	None	None
Nitrogen Fertilizer	115 lb N 28-0-0 sidedress	101 lb N 28-0-0 sidedress	None	None	None
Manure	None	None	None	20 ton/a 11/16/98	15 ton/a 11/16/98
Pesticides	<u>Banded at planting</u> 5/4/99 Aztec (7.3 lb/a) <u>Pre-emerg broadcast</u> 5/14/99 Dual II (2 pt/a)	<u>Pre-emerg broadcast</u> 5/14/99 Roundup Ult (2 pt/a) NIS (1% v/v) Amm. Sulf. (3 lb/a) Dual II (2 pt/a)	None	None	None
Rotary Hoe	None	None	6/6/99	6/6/99	6/6/99
Cultivation	6/21/99	None	6/26/99 7/1/99	6/26/99 7/1/99	6/26/99 7/1/99
Harvest	10/6/99	10/6/99	10/6/99	10/6/99	10/6/99
Yield	72.0 bu/a ²	106.1 bu/a	89.5 bu/a	132.7 bu/a	128.4 bu/a
Fall Practices	Chisel plow 11/17/99	None	Chisel plow 11/17/99	Manure 20 T/a 11/12/99 Chisel plow 11/17/99	Chisel plow 11/17/99
Crop-2000	Corn	Soybean	Soybean	Soybean	Soybean

¹ Starter fertilizer added provide P and K to corn and subsequent soybean phase.² Low yields due to heavy rootworm infestation.

Appendix II-A. 1999 WICST INPUT/OUTPUT DATA - LAKELAND AGRICULTURAL COMPLEX

Soybean and Wheat Rotations				
CROP-99 Rotation Treatment #	NR Soybean CS2 2	WR Soybean/Wheat CS3 5	Wheat/Red Clover CS3 4	WR Soybean CS15 21
Plot #'s	108, 203, 304, 409	107, 205, 307, 406	109, 204, 308, 404	106, 211, 312, 413
Primary Tillage	No-till	Chisel plow 11/16/98	Mulchmaster 9/29/98	Chisel plow 11/23/98
Secondary Tillage	None	Field cultivator 5/4/99, 5/27/99	None	Field cultivator 5/4/99, 5/27/99
Planting Date	5/7/99	SB: 5/28/99 WW: 10/8/99	WW: 9/29/98 Red clover: 3/22/99	5/28/99
Variety Rate	Asgrow 2301 230,000 seeds/a	SB: Asgrow 2247 225,000 seeds/a WW: Glacier 180 lb/a	Glacier WW: 125 lb/a Arlington RC 18 lb/a	Iowa 2017 225,000 seeds/a
Fertilizer	None	None	None	None
Pesticides	<u>5/4/99 Pre-plant</u> Roundup Ultra (1 pt/a) NIS (1% v/v) Am Sulp. (3 lb/a) <u>6/21/99 Post-emerg</u> Roundup Ultra (2 pt/a) [surfact: NIS (1% v/v) Am. Sulp (3 lb/a)]	None	None	None
Rotary Hoe	None	6/6/99	None	6/6/99
Cultivation	None	6/26/99, 7/1/99	None	6/26/99, 7/1/99
Harvest	10/7/99	10/8/99	7/9/99	10/7/99
Yield	50.7 bu/a	51.4	Grain: 49.9 bu/a Straw: 1.17 t DM/a	47.7 bu/a
Fall Practices	None	Field cultivator 10/7/99 Plant wheat 10/8/99	Chisel plow w/sweeps 11/16/99	15 T/a manure 11/11/99 Chisel plow 11/17/99
Crop 2000	Corn	Wheat/Red Clover	Corn	O/P/F

Appendix II-A. 1999 WICST INPUT/OUTPUT DATA - LAKELAND AGRICULTURAL COMPLEX

Forage Rotations					
CROP-99 Rotation Treatment #	Established Alfalfa I CS4 7	Established Alfalfa II CS4 10	Oats/Pea/ Forage CS15 18	Established Alfalfa I CS5 13	Pasture CS6 14
Plot #'s	103, 202, 310, 411	112, 214, 301, 403	102, 209, 305, 402	114, 201, 313, 405	104, 213, 314, 408
Primary Tillage	---	---	Chisel plow 11/23/98	---	---
Secondary Tillage	---	---	Field cultivator 3/24/99	---	---
Planting Date Variety	4/13/98 Innovator +Z	4/27/97 Innovator +Z	3/29/99 50:50 oat/pea mix, Forage mix	4/13/98 Commercial mix with trapper peas	None
Rate	18 lb/a	18.5 lb/a	Oat/Pea 160 lb/a Forage 18 lb/a	150 lb/a mix 18 lb/a forage	---
Fertilizer	None	None	None	None	Grazing
Manure	None	None	None	None	None
Pesticides	None	None	None	None	None
Harvest	5/28/99 7/8/99 9/2/99	5/26/99 7/8/99 9/2/99	Oatlage: 6/18/99 Haylage: 9/2/99	5/28/99 7/8/99 9/2/99	Rotational Grazing
Yield	3.23 t DM/a	3.31 t DM/a	Oatlage: 1.19 Haylage: 1.78 t DM/a	4.15 t DM/a	1.83 lb/hd/dy 1.63 t DM/a
Fall Practices	None	20 T/a manure 11/9/99 Chisel plow 11/16/99	None	15 T/a manure 11/10/99 Chisel plow w/sweeps 11/16/99	None
Crop 2000	Alf II	Corn	Alf I	Corn	Pasture

Appendix II-B. 2000 WICST INPUT/OUTPUT DATA - LAKELAND AGRICULTURAL COMPLEX

Corn Rotations					
CROP-00 Rotation Treatment #	CORN CS1 1	CORN CS2 2	CORN ¹ CS3 4	CORN CS14 10	CORN ¹ CS15 13
Plot #'s	101, 210, 303, 401	108, 203, 304, 409	109, 204, 308, 404	112, 214, 301, 406	114, 201, 313, 405
Primary Tillage	Chisel plow 11/17/99	No-till	Chisel plow with sweeps 11/16/99	Chisel plow 11/16/99	Chisel plow 11/17/99
Secondary Tillage	Soil finisher (2 passes) 5/2/00	None	Soil finisher (1 pass) 5/2/00, 5/24/00 (6/23/00 2 pass) ¹	Soil finisher (2 passes) 5/2/00	Soil finisher (1 pass) 5/2/00 (6/23/00 2 pass) ¹
Planting Date	5/5/00	5/5/00	6/23/00 (replant)	5/5/00	6/23/00 (replant)
Variety	Cargill 4111	Cargill 4111	Kaltenburg 2609	Cargill 4111	Kaltenburg 2609
Rate	31,000 seeds/a	31,000 seeds/a	33,900 seeds/a	31,000 seeds/a	33,900 seeds/a
Starter Fertilizer	100 lb product 9-23-30	250 lb product ² 9-23-30	None	250 lb product 9-23-30	None
Nitrogen Fertilizer	160 lb N 28-0-0 sidedress	120 lb N 28-0-0 sidedress	None	None	None
Manure	None	None	None	20 ton/a 11/9/99	15 ton/a 11/10/99
Pesticides	<u>Banded at planting</u> 5/5/00 Counter CR (6 oz/a) <u>Broadcast</u> 6/23/00 Accent Gold (2.9 oz/a) Crop oil (1% v/v) AMS (3 lb/a)	<u>Pre-emerg bdcst</u> 4/28/00 Roundup Ult (1 pt/a) AMS (3 lb/a) <u>Broadcast</u> 5/25/00 Banvel (1 pt/a) 6/23/00 Accent Gold (2.9 oz/a) AMS (3 lb/a) COC (1% v/v)	None	<u>Broadcast</u> 6/23/00 Accent Gold (2.9 oz/a) AMS (3 lb/a) COC (1%v/v)	None
Rotary Hoe	None	None	6/8/00, ¹ 6/27/00, 7/2/00	None	6/8/00, ¹ 6/27/00, 7/2/00
Cultivation	7/19/00	None	7/19/00, 7/28/00	None	7/19/00, 7/28/00
Harvest	11/2/00	11/2/00	11/2/00	11/2/00	11/2/00
Yield	94.6 bu/a	152.7 bu/a	31.8 bu/a	100.3 bu/a	57.6 bu/a
Fall Practices	Chisel plow 11/10/00	None	Chisel plow 11/10/00	Manure 20 T/a 11/9/00 Chisel plow 11/10/00	Chisel plow 11/10/00
Crop-2001	Corn	Soybean	Soybean	Soybean	Soybean

¹ Due to wet field conditions and poor stands, all plots were retilled and replanted with shorter day corn variety.

² Starter fertilizer added provide P and K to corn and subsequent soybean phase.

Appendix II-B. 2000 WICST INPUT/OUTPUT DATA - LAKELAND AGRICULTURAL COMPLEX**Soybean and Wheat Rotations**

CROP-00 Rotation Treatment #	NR Soybean CS2 3	WR Soybean/Wheat CS3 6	Wheat/Red Clover CS3 5	WR Soybean CS15 22
Plot #'s	113, 206, 311, 410	111, 208, 306, 407	107, 205, 307, 406	105, 207, 309, 412
Primary Tillage	No-till	Chisel plow 11/17/99	Field cultivator 10/7/00	Chisel plow 11/17/99
Secondary Tillage	None	Soil finisher (1 pass) 5/4/00, 5/24/00	None	Soil finisher 5/4/00, 5/24/00
Planting Date	5/3/00	Soybean: 5/26/00 Wheat: 10/19/00	WW: 10/8/99 Red clover: 3/16/00	5/26/00
Variety Rate	Asgrow 2301 258,814 seeds/a	SB: Novartis 1990 225,000 seeds/a WW: Kaskaskia 180 lb/a	Glacier WW: 180 lb/a Arlington RC: 18 lb/a	Novartis 1990 225,000 seeds/a
Fertilizer	None	None	None	None
Pesticides	<u>Pre-plant</u> 4/28/00 Roundup Ultra (1 pt/a) AMS (3 lb/a) <u>Post-emerg</u> 6/23/00 Roundup Ultra (2 pt/a) AMS (3 lb/a)	None	None	None
Rotary Hoe	None	6/8/00	None	6/8/00
Cultivation	None	6/22/00, 7/10/00, 7/14/00	None	6/22/00, 7/10/00, 7/14/00 ¹
Harvest	10/17/00	10/17/00	7/21/00	10/17/00
Yield	44.8 bu/a	30.0 bu/a	Grain: 41.2 bu/a Straw: 0.84 t DM/a	44.7 bu/a
Fall Practices	None	Field cultivator 10/18/00 Planted wheat 10/19/00	None	20 T/a manure 11/9/00 Chisel plow 11/10/00
Crop 2001	Corn	Wheat/Red Clover	Corn	O/P/F

¹ Plot 105 was only plot cultivated on 7/14/00

Appendix II-B. 2000 WICST INPUT/OUTPUT DATA - LAKELAND AGRICULTURAL COMPLEX

Forage Rotations					
CROP-00 Rotation Treatment #	D.S. Alfalfa CS4 19	Established Alfalfa II CS4 10	Oats/Pea/ Forage CS15 18	Established Alfalfa I CS15 18	Pasture CS6 14
Plot #'s	110, 212, 302, 414	103, 202, 310, 411	106, 211, 312, 413	102, 209, 305, 402	104, 213, 314, 408
Primary Tillage	Chisel plow 11/17/99	None	Chisel plow 11/17/99	None	None
Secondary Tillage	Soil finisher (2 passes) 5/2/00	None	Field cultivator (2 passes) 3/30/00	None	None
Planting Date Variety	5/3/00 NK 919	4/13/98 Innovator +Z	3/31/00 40:60 oat/pea mix Alf - 8 lb/a RC - 6 lb/a Per. Ryeg - 2 lb/a	3/29/99 50:50 oat/pea mix Alf - 8 lb/a RC - 8 lb/a Per. Ryeg. 2 lb/a	None
Rate	18 lb/a	18 lb/a	Oat/pea 150 lb/a Forage 16 lb/a	oat/pea 160 lb/a Forage 18 lb/a	
Fertilizer	None	None	None	None	Grazing
Manure	20 tons/a 11/12/99	None	15 tons/a 11/11/99	None	None
Pesticides	Pursuit 3 oz/a Broadcast 6/23/00	None	None	None	None
Harvest	7/17/00 (clipped) ¹ 9/5/00	5/26/00 7/18/00 9/6/00	Oatlage: 6/19/00 Haylage: 9/5/00	5/24/00 7/17/00 9/5/00	MIRG plus hay plot 408 6/18/00
Yield	1.01 t DM/a	3.32 t DM/a	Oatlage: 2.41 Haylage: 2.34 t DM/a	4.12 t DM/a	1.42 lb/hd/day 1.77 t DM/a
Fall Practices	None	15 T/a manure 11/10/00 Chisel plow 11/10/00	None	20 T/a manure 11/10/99 None	None
Crop 2001	Alf I	Corn	Alf I	Corn	Pasture

¹ First cutting was clipped and left on ground due to poor quality and heavy weed contamination.

Appendix IIIa. WICST Phosphorus and Potassium Annual Routine Soil Test Results (0-6") 1992-2000. Arlington Research Station.¹

Cropping System		CROP								PHOSPHORUS (ppm)									POTASSIUM (ppm)									
YR System	92	93	94	95	96	97	98	99	00	92	93	94	95	96	97	98	99	00	92	93	94	95	96	97	98	99	00	
CS1-1	C	C	C	C	C	C	C	C	C	93	84	91	88	91	83	82	80	76	219	295	228	241	257	254	229	217	203	
CS2-2	C	Sb	C	Sb	C	Sb	C	Sb	C	79	65	68	67	66	61	59	75	69	239	229	183	182	214	178	184	197	169	
CS2-3	Sb	C	Sb	C	Sb	C	Sb	C	Sb	89	78	89	72	83	72	75	62	53	198	264	214	208	230	224	212	164	128	
CS3-4	Sb	W/r	C	Sb	W/r	C	Sb	W/r	C	69	64	68	65	66	55	55	46	43	189	251	182	175	209	166	180	124	104	
CS3-5	C	Sb	W/r	C	Sb	W/r	C	Sb	W/r	---	57	63	52	57	56	47	67	49	---	226	171	164	191	172	150	174	145	
CS3-6	W/r	C	Sb	W/r	C	Sb	W/r	C	Sb	---	53	57	49	49	48	45	52	51	---	201	142	149	155	136	131	149	130	
CS4-7	A	C	A	A	A	C	A	A	A	94	85	99	84	90	90	90	81	80	175	216	171	157	180	212	200	168	116	
CS4-8	A	A	C	A	A	A	C	A	A	105	81	92	93	94	81	91	93	81	203	170	154	184	189	153	166	179	128	
CS4-9	A	A	A	C	A	A	A	C	A	---	62	65	74	91	72	66	79	78	---	170	128	160	228	143	115	134	133	
CS4-10	f	A	A	A	C	A	A	A	C	77	71	72	67	77	76	63	66	74	189	224	155	153	196	205	141	133	137	
CS5-11	C	O/a	A	C	O/a	A	C	O/a	A	103	88	93	91	96	82	90	81	75	198	236	172	185	201	153	154	135	95	
CS5-12	A	C	O/a	A	C	O/a	A	C	O/a	72	67	72	64	72	66	59	68	60	181	210	144	127	143	128	98	110	87	
CS5-13	O/a	A	C	O/a	A	C	O/a	A	C	---	73	83	78	76	71	66	68	71	---	211	173	180	174	153	153	130	120	
CS6-14	P	P	P	P	P	P	P	P	P	---	82	84	75	74	73	64	68	64	---	186	157	176	208	210	180	202	148	

* original overall fertility average (top 6 inches of soil profile): P-89 ppm, K-238 ppm.

f = filler corn (grown before initiation of each rotation)

¹ Samples collected after crop harvest prior to manure application and tillage. The samples are a composite of 6 sets of 3 soil cores (¾") taken to a depth of 6 inches. For row crops, the 3 soil cores are taken in-row, between-row, and one mid-way between the first two. For non-row crops, the 3 soil cores are taken 8" apart.

Appendix IIIb. WICST Phosphorus and Potassium Annual Routine Soil Test Results (0-6") 1992-2000 Lakeland Agricultural Complex.¹

Cropping System	CROP									PHOSPHORUS (ppm)										POTASSIUM (ppm)									
YR-Tmt	92	93	94	95	96	97	98	99	00	92	93	94	95	96	97	98	99	00	92	93	94	95	96	97	98	99	00		
CS1-1	C	C	C	C	C	C	C	C	C	58	52	95	49	61	54	53	49	52	205	185	219	177	191	165	177	147	150		
CS2-2	C	Sb	C	Sb	C	Sb	C	Sb	C	52	47	64	39	41	43	37	43	47	186	158	177	137	132	132	133	153	137		
CS2-3	Sb	C	Sb	C	Sb	C	Sb	C	Sb	53	43	71	47	51	46	40	39	34	204	196	188	183	177	160	153	116	111		
CS3-4	Sb	W/r	C	Sb	W/r	C	Sb	W/r	C	46	39	56	39	43	35	37	32	39	173	181	161	154	155	150	157	128	126		
CS3-5	C	Sb	W/r	C	Sb	W/r	C	Sb	W/r	---	36	49	30	36	36	31	38	37	---	173	147	136	149	149	147	126	133		
CS3-6	W/r	C	Sb	W/r	C	Sb	W/r	C	Sb	---	39	46	37	37	34	34	31	33	---	179	152	156	152	141	142	117	127		
CS4-7	A	C	A	A	A	C	A	A	A	57	51	50	62	67	85	64	70	60	121	145	150	159	163	183	143	128	104		
CS4-8	A	A	C	A	A	A	C	OPF	A	52	52	43	77	74	62	73	72	71	171	165	150	256	206	150	190	201	168		
CS4-9	A	A	A	C	A	A	A	C	A	---	36	69	54	70	60	51	58	56	---	181	180	192	271	202	181	164	152		
CS4-10	f	A	A	A	C	A	A	A	C	59	62	52	62	89	75	80	76	88	181	203	150	152	220	184	184	138	195		
CS5-11	C	O/a	A	C	O/a	A	C	Sb	OPF	41	52	47	55	68	56	64	59	61	161	205	142	164	200	160	201	167	132		
CS5-12	A	C	O/a	A	C	O/a	A	C	Sb	55	48	45	53	72	73	68	70	72	159	181	130	151	188	178	143	130	131		
CS5-13	O/a	A	C	O/a	A	C	O/a	A	C	---	46	50	64	59	75	64	66	75	---	200	139	195	176	193	189	143	168		
CS6-14	P	P	P	P	P	P	P	P	P	---	41	46	42	61	60	54	61	54	---	166	132	177	240	228	230	205	195		

* original overall fertility average (top 6 inches of soil profile): P-59 ppm, K-182 ppm.

f= filler corn (grown before initiation of each rotation)

¹ Samples collected after crop harvest prior to manure application and tillage. The samples are a composite of 6 sets of 3 soil cores (¾") taken to a depth of 6 inches. For row crops, the 3 soil cores are taken in-row, between-row, and one mid-way between the first two. For non-row crops, the 3 soil cores are taken 8" apart.

Appendix IVa. WICST Phosphorus Soil Depth Test Results (0-6", 6-12", 12-24", 24-36") Arlington Research Station¹

Phosphorus									
Depth		0 – 6"		6 – 12"		12 – 24"		24 – 36"	
	Year	Initial Year	7th year	Initial Year	7th year	Initial year	7th year	Initial Year	7th year
Cropping System	Tri	----- ppm -----		----- ppm -----		----- ppm -----		----- ppm -----	
CS1 C	1	105	91	65	43	59	29	85	49***
CS2 C-Sb	2	88	48	47	35	50	10	73	ns
CS2	3	98	66	43	30	24	28	51	42***
CS3 C-Sb-W/Rc	4	57	45	38	21	16	23	39	42
CS3	5	105	66	59	34	20	20	43	ns
CS3	6	69	48	24	35	22	7	47	ns
CS4 C-A-A-A	7	115	90	46	47	35	31	57	ns
CS4	8	93	45	39	34	32	8	52	ns
CS4	9	66	66	44	38	21	25	45	52
CS4	10	77	66	34	40	51	52	86	75
CS5 C-O/A-A	11	53	96	20	44	8	28	5	ns
CS5	12	70	77	27	36	22	16	47	ns
CS5	13	84	66	42	34	21	29	36	41
CS6 Rot Grazing	14	114	74	56	52	74	43	96	75***

¹ Sampling done in the 7th year after the initiation of each treatment.

** Samples taken in the year prior to the treatment start year – 1989: treatments 1, 3, 5, 7, 11, 14; 1990 trts 2, 6, 8, 12; 1991: trts 4, 9, 13; and 1992: trt 10

*** 3rd foot sampled in 2000, not 7th year after start of rotation

ns Samples for 24" – 36" not taken.

Appendix IVb. WICST Phosphorus Soil Depth Test Results (0-6", 6-12", 12-24", 24-36") Lakeland Agricultural Complex¹

Phosphorus									
Depth		0 – 6"		6 – 12"		12 – 24"		24 – 36"	
Year		Initial Year	7th year	Initial Year	7th year	Initial year	7th year	Initial Year	7th year
Cropping System	Trt	----- ppm -----		----- ppm -----		----- ppm -----		----- ppm -----	
CS1 Cont. Corn	1	66	61	39	31	13	15	8	ns
CS2 C-Sb	2	65	73	43	46	14	50	12	ns
CS2	3	59	41	24	14	9	7	6	ns
CS3 C-Sb-W/Rc	4	49	34	24	30	33	14	24	6
CS3	5	64	43	30	23	10	18	4	ns
CS3	6	54	58	26	29	11	21	14	ns
CS4 C-A-A-A	7	76	67	39	21	10	7	8	ns
CS4	8	59	73	31	40	11	27	13	ns
CS4	9	37	51	32	48	26	19	25	6
CS4	10	59	71	46	23	9	10	8	ns
CS5 C-O/A-A	11	53	68	20	22	8	8	5	ns
CS5	12	68	79	32	35	8	24	7	ns
CS5	13	54	64	34	73	12	31	5	17
CS6 Rot Grazing	14	63	61	31	27	7	12	3	ns

¹ Sampling done in the 7th year after the initiation of each treatment.

** Samples taken in the year prior to the treatment start year – 1989: treatments 1, 3, 5, 7, 11, 14; 1990 trts 2, 6, 8, 12; 1991: trts 4, 9, 13; and 1992: trt 10.

ns Samples for 24" – 36" not taken.

Appendix Va. WICST Potassium Soil Depth Test Results (0-6", 6-12", 12-24", 24-36") Arlington Research Station¹

Potassium									
Cropping System	Depth	0 - 6"		6 - 12"		12 - 24"		24 - 36"	
	Year	Initial Year	7th year	Initial Year	7th year	Initial year	7th year	Initial Year	7th year
	Trt	----- ppm -----		----- ppm -----		----- ppm -----		----- ppm -----	
CS1 C	1	257	257	143	100	125	74	135	88***
CS2 C-Sb	2	283	144	126	130	125	124	123	ns
CS2	3	199	214	121	91	134	83	155	98***
CS3 C-Sb-W/Rc	4	195	135	124	91	86	121	98	123
CS3	5	236	209	133	95	126	80	156	ns
CS3	6	200	129	78	95	88	108	100	ns
CS4 C-A-A-A	7	277	180	123	81	126	80	131	ns
CS4	8	256	124	126	121	86	106	119	ns
CS4	9	214	115	103	79	85	95	101	133
CS4	10	189	133	96	91	109	101	111	124
CS5 C-O/A-A	11	163	201	113	86	120	80	115	ns
CS5	12	211	176	83	98	85	113	113	ns
CS5	13	293	153	123	89	98	99	95	114
CS6 Rot Grazing	14	266	208	143	101	154	86	135	88***

¹ Sampling done in the 7th year after the initiation of each treatment.

** Samples taken in the year prior to the treatment start year - 1989: treatments 1, 3, 5, 7, 11, 14; 1990 trts 2, 6, 8, 12; 1991: trts 4, 9, 13; and 1992: trt 10.

*** 3rd foot sampled in 2000, not 7th year after start of rotation

ns Samples for 24" - 36" not taken.

Appendix Vb. WICST Potassium Soil Depth Test Results (0-6", 6-12", 12-24", 24-36") Lakeland Agricultural Complex¹

Potassium									
Cropping System	Depth	0 – 6"		6 – 12"		12 – 24"		24 – 36"	
	Year	Initial Year	7th year	Initial Year	7th year	Initial year	7th year	Initial Year	7th year
	Trt	----- ppm -----		----- ppm -----		----- ppm -----		----- ppm -----	
CS1 C	1	196	191	134	105	126	114	124	ns
CS2 C-Sb	2	193	203	125	128	119	141	129	ns
CS2	3	178	132	118	86	126	103	115	ns
CS3 C-Sb-W/Rc	4	183	142	98	121	104	68	91	85
CS3	5	195	155	131	101	131	104	120	ns
CS3	6	153	177	100	106	108	105	111	ns
CS4 C-A-A-A	7	216	163	148	88	1436	95	128	ns
CS4	8	179	173	93	110	103	109	103	ns
CS4	9	149	181	85	120	96	195	91	74
CS4	10	181	124	135	88	124	108	133	ns
CS5 C-O/A-A	11	163	200	113	101	120	106	115	ns
CS5	12	213	140	106	86	108	104	104	ns
CS5	13	171	189	118	184	158	81	119	104
CS6 Rot Grazing	14	181	240	118	121	120	120	114	ns

¹ Sampling done in the 7th year after the initiation of each treatment.

** Samples taken in the year prior to the treatment start year – 1989: treatments 1, 3, 5, 7, 11, 14; 1990 trts 2, 6, 8, 12; 1991: trts 4, 9, 13; and 1992: trt 10.

ns Samples for 24" – 36" not taken.

Appendix VIa. WICST Corn and Soybean Populations, 1992 – 2000.

A. Arlington Agricultural Research Station

<u>Year</u>	<u>1992</u>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>1996</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>
	-----plants/acre-----								
^{1/} Corn									
CS1	27,750	30,850	26,950	29,250	30,100	30,150	28,000	29,400	30,500
CS2	28,650	30,800	27,300	30,200	30,000	31,850	27,417	28,550	29,413
CS3	24,700	20,800	28,050	28,100	26,950	30,900	26,083	26,050	22,800
CS4	-----	32,300	26,000	27,850	30,300	30,100	29,000	29,775	28,700
CS5	-----	27,500	28,000	28,300	26,950	34,000	28,083	28,100	25,350
^{2/} Soybean									
CS2	118,547	179,823	187,488	153,406	170,625	270,531	249,897	178,825	238,244
CS3	70,350	135,250	151,091	199,542	105,583	141,200	n.a.	64,300	54,479

Plant counts taken after cultivation or before harvest.

	^{1/} Corn		^{2/} Soybean	
	CS1, CS2, CS4	CS3, CS5	CS2	CS3
1992	32,100 seeds/a	32,100 seeds/a	235,000 seeds/a	156,000 seeds/a
1993	32,500 seeds/a	32,500 seeds/a	235,000 seeds/a	156,000 seeds/a
1994	31,500 seeds/a	34,000 seeds/a	235,000 seeds/a	175,000 seeds/a
1995	31,500 seeds/a	34,000 seeds/a	235,000 seeds/a	200,000 seeds/a
1996	31,500 seeds/a	34,000 seeds/a	235,000 seeds/a	175,000 seeds/a
1997	CS1 – 30,150 seeds/a CS2 – 31,500 seeds/a CS4 – 32,000 seeds/a	34,000 seeds/a	250,000 seeds/a (rep 4 double planted)	190,000 seeds/a
1998	32,000 seeds/a	34,500 seeds/a	250,000 seeds/a	190,000 seeds/a n.a. = unable to get stand count
1999, 2000	32,000 seeds/a	34,500 seeds/a	250,000 seeds/a	190,000 seeds/a

Appendix VIIb. WICST Corn and Soybean Populations, 1992 – 2000.

B. Lakeland Agricultural Complex

<u>Year</u>	<u>1992</u>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>1996</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>
¹ /Corn									
CS1	29,050	30,150	28,200	28,200	27,600	26,333	32,000	28,417	24,750
CS2	24,500	29,900	27,900	28,900	26,350	28,750	31,000	28,333	16,833
CS3	24,250	21,100	30,350	28,200	26,850	24,250	25,000	27,667	18,500
CS4	-----	31,250	30,050	29,250	26,400	29,000	28,000	26,417	26,000
CS5	-----	21,400	30,850	28,850	25,850	25,750	28,000	28,333	19,333
² /Soybean									
CS2	97,000	139,228	143,278	176,879	236,209	298,501	145,353	63,250	119,229
CS3	122,952	86,950	113,050	118,500	80,458	n.a.	167,500	133,584	140,360
CS15	-	-	-	-	-	-	-	105,512	131,164

Plant counts taken after cultivation or before harvest.

	¹ /Corn		² /Soybean	
	CS1, CS2, CS4 (CS14)	CS3, CS5 (CS15)	CS2	CS3, CS15
1992	32,000 seeds/a	32,000 seeds/a	196,000 seeds/a	156,000 seeds/a
1993	32,000 seeds/a	32,000 seeds/a	199,500 seeds/a	156,000 seeds/a
1994	32,000 seeds/a	35,000 seeds/a	230,000 seeds/a	175,000 seeds/a
1995	31,200 seeds/a	33,800 seeds/a	230,000 seeds/a	151,000 seeds/a
1996	31,500 seeds/a	34,000 seeds/a	235,000 seeds/a	175,000 seeds/a
1997	32,000 seeds/a	34,000 seeds/a	250,000 seeds/a (rep 4 double planted)	225,000 seeds/a
1998	32,000 seeds/a	34,000 seeds/a	230,000 seeds/a	n.a.= unable to get stand counts 225,000 seeds/a
1999	CS1, CS2 - 32,000 seeds/a CS4 - 34,500 seeds/a	34,500 seeds/a	230,000 seeds/a	225,000 seeds/a
2000	31,000 seeds/a	33,900 seeds/a	250,000 seeds/a	225,000 seeds/a

Appendix VIIa. WICST Fall Legume Nitrogen for Crop Preceding Corn Phase 1991-2000.

A. Arlington Agricultural Research Station

Year	Crop Syst.	Crop	Foliage		Roots		Total
			DM lb/a	N %	DM lb/a	N %	N lb/a
1991	3	Red Clover	1852	3.24	2604	2.63	128
1992	3	Red Clover	2102	2.89	1816	2.72	110
1992	4	Alfalfa	2697	2.03	1767	2.27	95
1992	5	Alfalfa	2090	3.42	3352	2.29	148
1993	3	Red Clover	2811	2.81	1314	3.18	119
1993 ^{1/}	4	Alfalfa	1866	2.91	1233	3.36	94
1993 ^{1/}	5	Alfalfa	1613	4.05	1443	2.18	97
1994 ^{2/}	3	Hairy Vetch	4325	3.29	134	3.24	146
1994 ^{1/}	4	Alfalfa	2242	1.75	1233	1.67	60
1994	5	Alfalfa	500	3.41	2327	2.04	64
1995	3	Red Clover	2460	2.89	947	3.09	100
1995 ^{3/}	4	Alfalfa	163	3.18	1235	2.51	36
1995 ^{3/}	5	Alfalfa	308	3.59	2345	2.32	66
1996 ^{4/}	3	Red Clover	3213	3.01	1836	2.75	147
1997 ^{5/}	3	Hairy Vetch	1343	4.66	767	2.75	84
1998 ^{6/}	3	Red Clover	3229	2.36	1229	2.75	109
1998 ^{6/}	4	Alfalfa	1283	3.83	2582	2.75	107
1998 ^{6/}	5	Alfalfa	1635	3.50	2328	2.75	121
1999	3	Red Clover	5354	4.00	2253	2.27	265
1999	4	Alfalfa	889	3.05	3026	2.16	92
1999	5	Alfalfa	1104	3.44	3069	2.34	109
2000	3	Red Clover	5974	2.53	1414	2.53	188
2000	4	Alfalfa	1180	4.47	2774	1.90	106
2000	5	Alfalfa	1260	3.98	2780	1.89	103

^{1/} Spring seeded with red clover in 1993 because of severe winterkill to alfalfa.

^{2/} 1994 - CS3 - Hairy vetch planted after wheat harvest because of thin stand of red clover, CS4 - 8/30 harvest, 10/10 Roundup application, CS5 - 9/30 harvest.

^{3/} CS4 - 9/5 harvest, 10/12 Roundup, CS5 - 9/14 harvest at ARS, 8/26 harvest and 10/10 Roundup for both CS4 and CS5 at LAC.

^{4/} Frozen soil prevented root harvest in 1996. Previous data was used to estimate root biomass as 75 % of herbage and root nitrogen as 2.75%.

^{5/} Root biomass estimated at 75% of herbage and root nitrogen as 2.75%.

^{6/} Root nitrogen estimated as 2.75%. CS4 - last Alfalfa harvest 09/04/98, Roundup applied 10/26/98; CS5 - last Alfalfa harvest 09/30/98, Roundup applied 10/26/98.

Appendix VIIb. WICST Fall Legume Nitrogen for Crop Preceding Corn Phase 1991-2000.

B. Lakeland Agricultural Complex

Year	Rotation	Crop	Foliage		Roots		Total
			DM lb/a	N %	DM lb/a	N %	N lb/a
1991 ^{1/}	3	Red Clover	669	3.12	916	2.63	45
1992	3	Red Clover	3316	2.52	2984	2.58	161
1992	4	Alfalfa	977	4.25	2731	1.87	93
1992	5	Alfalfa	1018	4.24	2627	1.91	93
1993	3	Red Clover	2687	3.24	1224	2.90	123
1993 ^{2/}	4	Alfalfa	2043	3.46	1251	2.74	104
1993 ^{2/}	5	Alfalfa	2127	3.18	1222	2.72	101
1994	3	Red Clover	1240	3.03	1182	2.52	67
1994 ^{2/}	4	Alfalfa	895	2.32	2251	2.08	68
1994	5	Alfalfa	713	3.13	1495	2.24	56
1995	3	Red Clover	2646	2.77	939	3.21	97
1995 ^{3/}	4	Alfalfa	423	3.64	1884	2.49	62
1995 ^{3/}	5	Alfalfa	896	3.36	1527	2.71	71
1996 ^{4/}	3	Red Clover	1501	2.91	858	2.75	67
1997		No data available					
1998		No data available					
1999	3	Red Clover	4131	2.25	2874	2.43	161
1999	4	Alfalfa	892	3.23	2536	2.06	82
1999	5	Alfalfa	1351	2.68	2243	2.35	89
2000	3	Red Clover	4527	1.90	659	2.38	114
2000	14	Alfalfa	1044	3.60	1915	1.82	101
2000	15	Alfalfa	710	3.38	1099	2.01	65

^{1/} Root N was not analyzed, used same % root N as at Arlington.

^{2/} Spring seeded with red clover in 1993 because of severe winterkill to alfalfa.

^{3/} CS4 - 9/5 harvest, 10/12 Roundup, CS5 - 9/14 harvest at ARS, 8/26 harvest and 10/10 Roundup for both CS4 and CS5 at LAC.

^{4/} Frozen soil prevented root harvest in 1996. Previous data was used to estimate root biomass as 75 % of herbage and root nitrogen as 2.75%.

Appendix VIIIa. WICST Nitrogen Additions as Purchased Fertilizers and Cattle Manure¹ 1991-2000.

Crop System	CROP										ARLINGTON AGRICULTURAL RESEARCH STATION									
											lb N/a									
Yr	91	92	93	94	95	96	97	98	99	00	91	92	93	94	95	96	97	98	99	00
CS1	C	C	C	C	C	C	C	C	C	C	126	141	166	124	106	99	126	151	86	89
CS2	C	Sb	C	Sb	C	Sb	C	Sb	C	Sb	96	0	126	0	126	0	126	0	80	0
CS2	Sb	C	Sb	C	Sb	C	Sb	C	Sb	C	0	126	0	126	0	126	0	126	0	89
CS3	W/Rc	C	Sb	W/Rc	C	Sb	W/Rc	C	Sb	W/Rc	0	0	0	0	0	0	0	0	0	0
CS3	Sb	W/Rc	C	Sb	W/Rc	C	Sb	W/Rc	C	Sb	0	0	0	0	0	0	0	0	0	0
CS3	C	Sb	W/Rc	C	Sb	W/Rc	C	Sb	W/Rc	C	---	0	0	0	0	0	0	0	0	0
CS4	A	A	C	A	A	A	C	A	A	A	0	0	203	179	0	0	191	205	0	0
CS4	A	A	A	C	A	A	A	C	A	A	265	0	0	185	211	0	0	211	222	0
CS4	f	A	A	A	C	A	A	A	C	A	---	215	0	0	217	196	0	0	228	232
CS4	f	f	A	A	A	C	A	A	A	C	---	---	197	0	0	202	185	0	0	232
CS5	A	C	O/a	A	C	O/a	A	C	O/a	A	0	161	148	0	158	147	0	154	166	0
CS5	O/a	A	C	O/a	A	C	O/a	A	C	O/a	199	0	148	134	0	147	139	0	166	173
CS5	f	O/a	A	C	O/a	A	C	O/a	A	C	---	161	0	134	158	0	139	154	0	173
CS6 ²	P	P	P	P	P	P	P	P	P	P	132	107	82	68	44	97	110	132	94	104

* f Filler corn; C Corn; Sb Soybean; W/Rc Winter wheat followed by frost-seeded Red Clover; A Alfalfa; O/a Alfalfa w/Oats nurse crop; P Pasture.

¹ Manured prior to corn planting and legume establishment in the harvested forage systems (20 t/a in CS4, 15 t/a in CS5). Nitrogen from green manure (alfalfa sod, red clover) plowdown is not included.

² Calculation of N input on pasture based on estimated forage intake, N% of plants, 75% N excretion rate for stocking density and # of grazing days in season. Nitrogen from 10 t/a manure application (1990 - 1992).

Appendix VIIIb. WICST Nitrogen Additions as Purchased Fertilizers and Cattle Manure¹ 1991-2000.

Crop System	CROP										LAKELAND AGRICULTURAL COMPLEX									
											lb N/a									
YR	91	92	93	94	95	96	97	98	99	00	91	92	93	94	95	96	97	98	99	00
CS1	C	C	C	C	C	C	C	C	C	C	104	142	157	76	108	116	74	149	124	169
CS2	C	Sb	C	Sb	C	Sb	C	Sb	C	Sb	109	0	123	0	128	0	129	0	138	0
CS2	Sb	C	Sb	C	Sb	C	Sb	C	Sb	C	0	124	0	111	0	126	0	103	0	143
CS3	W/Rc	C	Sb	W/Rc	C	Sb	W/Rc	C	Sb	W/Rc	0	0	0	0	0	0	0	0	0	0
CS3	Sb	W/Rc	C	Sb	W/Rc	C	Sb	W/Rc	C	Sb	0	0	0	0	0	0	0	0	0	0
CS3	C	Sb	W/Rc	C	Sb	W/Rc	C	Sb	W/Rc	C	---	0	0	0	0	0	0	0	0	0
CS4	A	A	C	A	A	A	C	A	A	A	0	0	266	275	0	0	235	697 ²	0	0
CS4	A	A	A	C	A	A	A	C	O/P/F	A	255	0	0	259	211	0	0	706 ²	298	0
CS4	f	A	A	A	C	A	A	A	C	A	---	255	0	0	269	266	0	0	298	297
CS4	f	f	A	A	A	C	A	A	A	C	---	---	259	0	0	272	226	0	0	297
CS5	A	C	O/a	A	C	O/a	A	C	Sb	O/P/F	0	192	201	0	194	199	0	523 ²	224	223
CS5	O/a	A	C	O/a	A	C	O/a	A	C	Sb	191	0	201	207	0	199	170	0	224	0
CS5	f	O/a	A	C	O/a	A	C	O/a	A	C	---	192	0	207	194	0	170	523 ²	0	223
CS6 ³	P	P	P	P	P	P	P	P	P	P	127	99	117	112	94	44	0	543	70	48

* f Filler corn; C Corn; Sb Soybean; W/Rc Winter wheat followed by frost-seeded Red Clover; A Alfalfa; O/a Alfalfa w/Oats nurse crop; P Pasture.

¹ Manured prior to corn planting and legume establishment in the harvested forage systems (20 t/a in CS4, 15 t/a in CS5). Nitrogen from green manure (alfalfa sod, red clover) plowdown is not included.

² Manure samples for LAC were very high in % dry matter in 1998 and thus a higher N concentration was put on the plots.

³ Calculation of N input on pasture based on estimated forage intake, N% of plants, 75% N excretion rate for stocking density and # of grazing days in season. Nitrogen from 10 t/a manure application (1990 - 1992).

Appendix IXa. Fall Nitrates in the top 3-ft of soil at the Arlington Research Station in 1991-2000.

ARLINGTON AGRICULTURAL RESEARCH STATION												
Year:			91	92	93	94	95	96	97	98	99	2000
Columbia County			lb/ 3 ft-acre									
Corn:	CS1	Continuous Corn	48	97	102	154	179	164	115	148	87	130
	CS2	Corn after Soybeans	41	105	105	166	141	170	128	100	77	107
	CS3	Corn after Red Clover	-- ¹	67	83	100	145	45	129	112	83	61
	CS4	Corn after Alfalfa	--	--	142	164	184	94	229	121	153	189
	CS5	Corn after Alfalfa	--	101	118	150	202	82	180	145	173	121
Soybean:	CS2	Narrow-row Soybeans	42	74	100	71	145	73	143	100	94	81
	CS3	Wide-row Soybeans	25	66	89	83	140	76	127	98	71	68
Wheat:	CS3	Wheat / Red Clover	26	48	65	48	85	38	90	76	51	57
Alfalfa:	CS4	Direct-seeded Alfalfa	32	61	80	77	117	59	114	100	75	69
	CS	Alfalfa Hay I	27	49	55	46	117	62	112	111	74	65
	CS4	Alfalfa Hay II	--	60	69	46	105	61	141	92	69	98
	CS5	Alfalfa with Oats	--	--	103	67	101	65	97	81	62	65
	CS5	Alfalfa Hay	--	--	84	67	107	51	116	72	63	70
Pasture:	CS6	Rotational Grazing	--	--	91	58	98	90	100	88	62	60
Check:			26	28	-	72	108	31	209	158	50	38

¹ staggered start - soil nitrates not tested until after first season in the rotation.

Estimation equations for 3rd foot nitrate levels:

1993 - 3ft samples taken for CS1, CS2, CS4 corn, CS3 soybean, CS5 oats/alfalfa, CS6 pasture;

2ft samples taken for remaining treatments; 3rd foot estimated using regression of 1990-1993 data

using the following formulas: ARS $Y = 2.81 + 0.754 * 2^d \text{ ft}$ $n = 103$ $r^2 = 0.70$

1994, 1995, 1996 - 3ft samples taken for reps 1 & 4, 2ft for reps 2 & 3. Third foot estimated using regressions of data from reps 1 & 4 using the following formulas:

1994 ARS $Y = 6.72 + 0.383 * 2^d \text{ ft}$ $n = 28$ $r^2 = 0.63$

1995 ARS $Y = 9.67 + 0.593 * 2^d \text{ ft}$ $n = 28$ $r^2 = 0.62$

1996 ARS $Y = 3.32 + 0.153 * 2^d \text{ ft}$ $n = 24$ $r^2 = 0.60$

1997 - Used the following regression equation for third foot samples.¹

1997 ARS $Y = 9.07 + 0.709 * 2^d \text{ ft}$ $n = 1943$ $r^2 = 0.71$

1998-2000 - 3rd foot samples collected for all plots.

¹ Source: Ehrhardt, P.D. and L.G. Bundy. 1995. Predicting Nitrate-N in the two- to three-foot soil depth from nitrate measurements on shallower samples. J. Prod. Agric. Vol. 8, no. 3.

Appendix IXb. Fall Nitrates in the top 3-ft of soil at the Lakeland Agricultural Complex: 1991-2000.

LAKELAND AGRICULTURAL COMPLEX												
Year:			91	92	93	94	95	96	97	98	99	2000
Walworth County			lb/3 ft-acre									
Corn:	CS1	Continuous Corn	132	86	134	126	135	160	146	83	116	101
	CS2	Corn after Soybeans	125	78	57	80	146	80	107	73	92	87
	CS3	Corn after Red Clover	-- ¹	62	59	117	130	71	130	87	109	136
	CS4	Corn after Alfalfa	--	--	122	207	209	130	209	137	131	118
	CS5	Corn after Alfalfa	--	81	79	178	160	102	218	109	144	155
Soybean:	CS2	Narrow-row Soybeans	76	86	98	69	120	68	167	103	109	69
	CS3	Wide-row Soybeans	34	63	69	97	125	70	137	75	101	78
	CS15	Wide-row Soybeans	-	-	-	-	-	-	-	-	128	91
Wheat:	CS3	Wheat / Red Clover	49	45	56	61	100	46	106	90	86	63
Alfalfa:	CS4	Direct-seeded Alfalfa	67	41	78	97	118	134	142	89	-	57
	CS4	Alfalfa Hay I	71	54	71	86	122	76	140	103	95	-
	CS4	Alfalfa Hay II	--	63	59	93	128	75	152	87	96	62
	CS5	Alfalfa with Oats	--	--	53	75	131	63	141	85	--	-
	CS5	Alfalfa Hay	--	--	78	79	143	76	108	83	97	-
	CS15	Oat/pea/forage mix	-	-	-	-	-	-	-	-	112	-
Pasture:	CS6	Rotational Grazing	--	--	66	111	125	103	218	146	99	69
Check:			35	29	-	78	79	40	-	72	41	76

¹ staggered start - soil nitrates not tested until after first season in the rotation.

Estimation equations for 3rd foot nitrate levels:

1993 - 3ft samples taken for CS1, CS2, CS4 corn, CS3 soybean, CS5 oats/alfalfa, CS6 pasture;

2ft samples taken for remaining treatments; 3rd foot estimated using regression of 1990-1993 data

using the following formulas: LAC $Y = 0.066 + 0.830 \cdot 2^d \text{ ft}$ $n = 106$ $r^2 = 0.77$

1994, 1995, 1996 - 3ft samples taken for reps 1 & 4, 2ft for reps 2 & 3. Third foot estimated using regressions of data from reps 1 & 4 using the following formulas:

1994 LAC $Y = 6.08 + 0.378 \cdot 2^d \text{ ft}$ $n = 28$ $r^2 = 0.71$

1995 LAC $Y = 8.49 + 0.635 \cdot 2^d \text{ ft}$ $n = 28$ $r^2 = 0.72$

1996 LAC $Y = 2.93 + 0.467 \cdot 2^d \text{ ft}$ $n = 28$ $r^2 = 0.61$

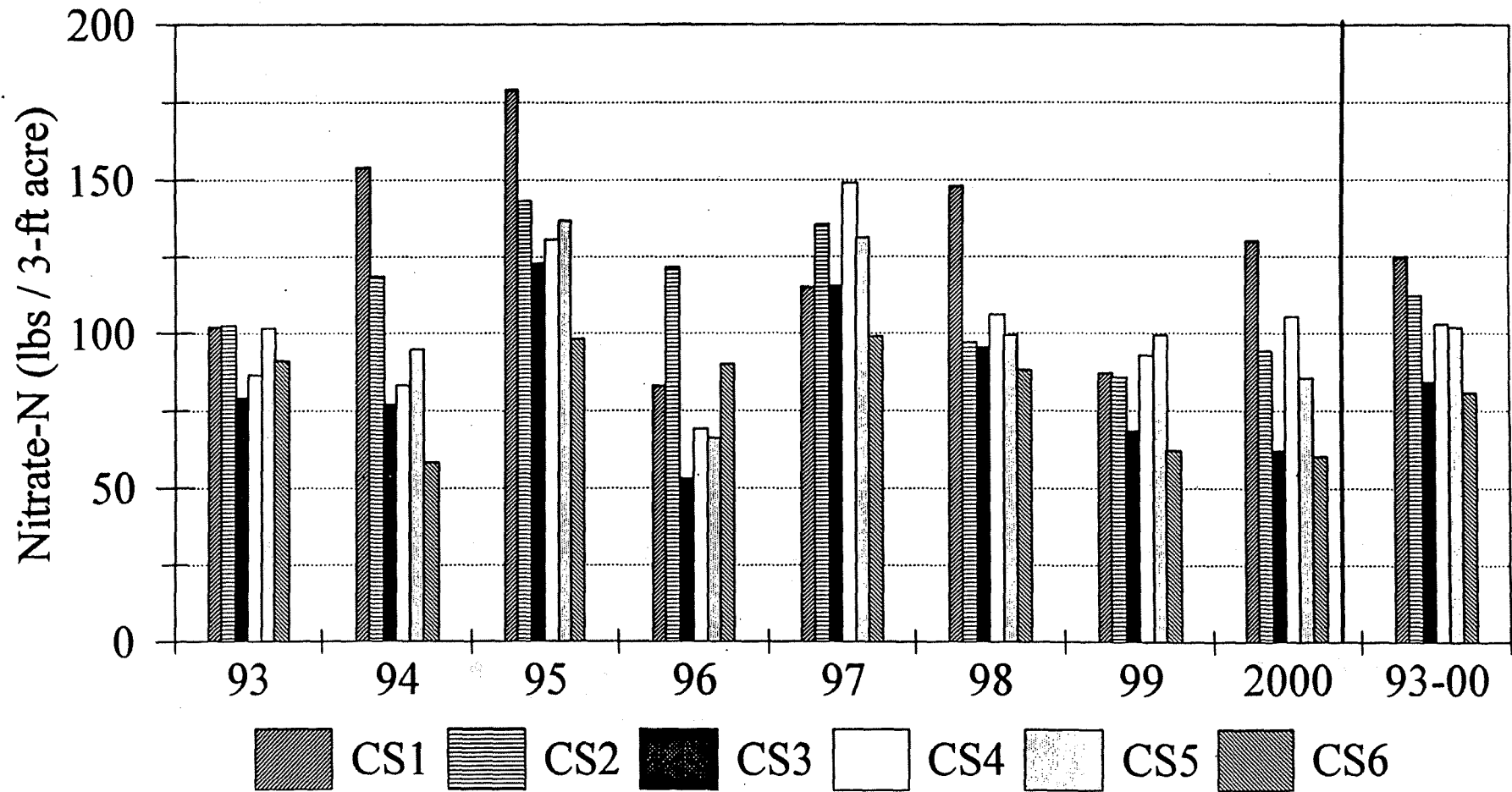
1997-99 - Used the following regression equation for third foot samples.¹

1997-1999 LAC $Y = 9.07 + 0.709 \cdot 2^d \text{ ft}$ $n = 1943$ $r^2 = 0.71$

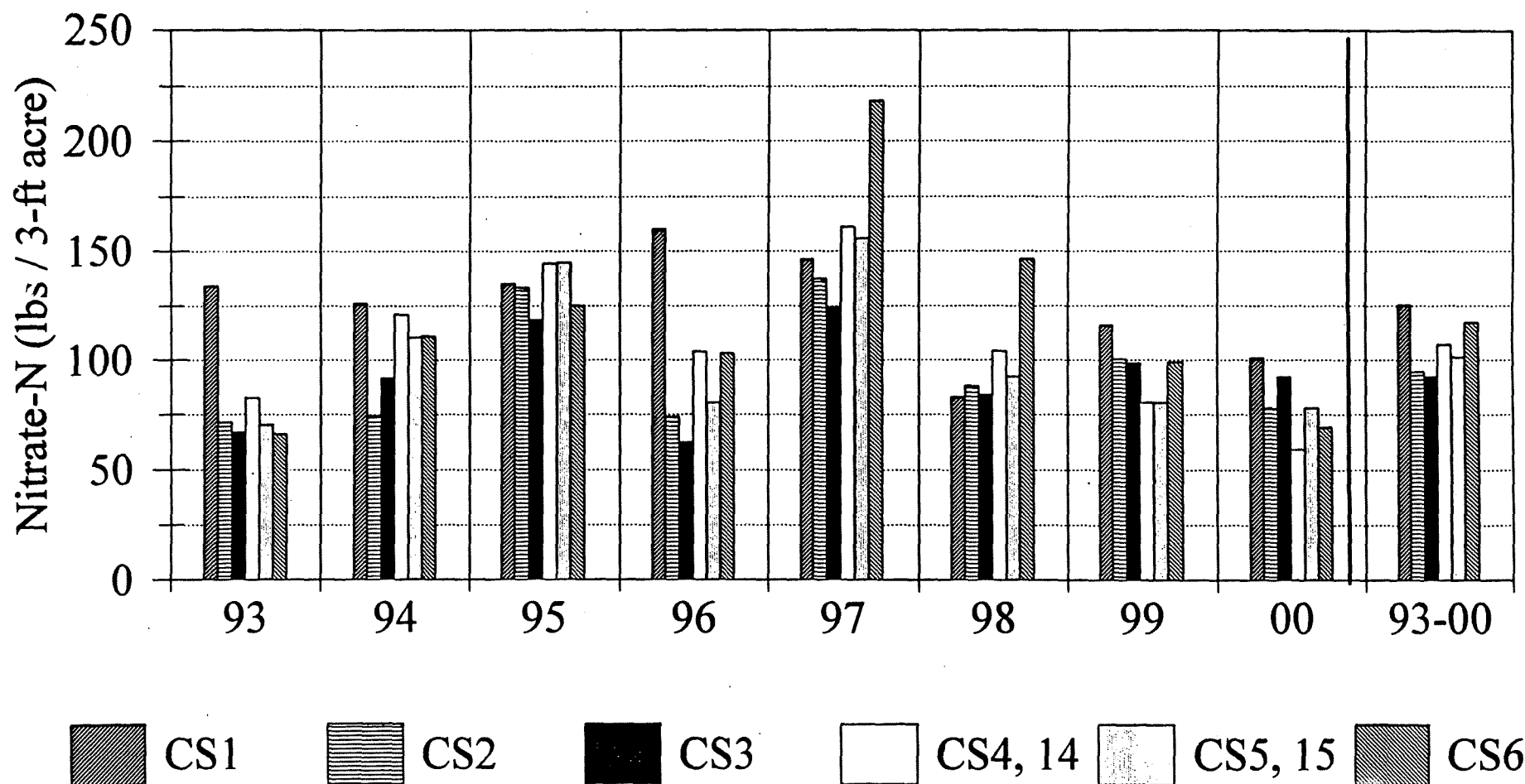
2000 - 3rd foot samples collected for all plots.

¹ Source: Ehrhardt, P.D. and L.G. Bundy. 1995. Predicting Nitrate-N in the two- to three-foot soil depth from nitrate measurements on shallower samples. J. Prod. Agric. Vol. 8, no. 3.

Appendix Xa. Nitrate-N levels at ARS
0 to 3 feet



Appendix Xb. Nitrate-N levels at LAC
0 - 3 feet



APPENDIX XL Potentially leachable fall nitrate in the 0 – 2 foot soil depth at ARS and LAC (1993 – 2000) with contrasts.

Environment: Location:	Env1 LAC93	Env2 AR93	Env3 AR94	Env4 LAC94	Env5 LAC95	Env6 AR95	Env7 AR96	Env8 LAC96	Env9 ARS97	Env10 LAC97	Env11 ARS98	Env12 LAC98	Env13 ARS99	Env14* LAC99	Env15 ARS00	Env16* LAC00	Avg**
NO ₃ -N (lb/2 ft-A)																	
CS1. Corn	115.6	80.9	132.5	105.5	97.0	137.2	73.9	142.7	88.9	115.2	118.7	60.8	67.1	63.3	98.1	80.4	98.6
CS2. Soybean	72.8	85.5	65.5	82.5	90.9	109.1	61.1	56.5	111.0	126.9	75.8	75.6	71.9	57.1	67.9	58.3	79.3
CS2. Corn	50.1	94.3	141.0	66.5	105.3	105.0	159.1	70.7	98.9	78.2	74.2	52.3	61.1	44.8	81.8	73.2	84.8
CS3. Sb/w	77.3	74.5	57.5	56.5	94.7	108.3	64.6	60.2	99.2	102.9	74.9	53.8	53.3	52.0	54.9	63.0	71.7
CS3. Wht	47.0	52.7	39.0	52.0	76.4	66.4	32.2	39.2	68.1	79.3	56.1	67.0	38.3	40.3	48.6	53.8	53.5
CS3. Corn	49.8	71.2	86.0	101.5	100.4	114.2	40.2	62.8	100.2	99.8	88.2	63.9	68.2	58.4	52.9	114.0	79.5
CS4. Alf	66.9	67.3	64.5	85.0	91.2	91.3	51.8	117.5	88.1	110.7	78.5	66.4	56.6	62.6	55.5	48.8	75.2
CS4. Alf1	55.3	45.4	35.5	74.0	96.3	92.6	54.2	67.8	86.7	105.8	86.5	78.2	56.3	48.4	53.2	-	69.1
CS4. Alf2	49.8	58.3	38.5	78.2	100.8	83.1	54.3	67.5	110.9	115.4	70.2	66.8	50.9	49.5	82.0	52.6	70.6
CS4. Corn	106.1	121.7	137.2	182.5	155.9	146.9	85.9	114.7	185.9	171.0	97.0	104.0	121.1	75.7	144.9	106.2	128.5
CS5. O/a	44.4	93.5	54.5	68.0	105.6	76.8	60.4	55.5	75.1	109.2	63.4	66.3	46.4	74.3	53.4	66.6	69.6
CS5. Alf1	69.9	71.4	55.5	68.0	112.8	84.5	45.1	67.5	89.3	79.1	54.6	63.6	47.0	49.9	59.7	57.4	67.2
CS5. Corn	67.7	99.0	126.5	155.0	124.4	156.1	73.2	87.5	143.8	170.4	119.0	85.3	139.6	84.8	100.2	127.4	116.2
CS6. Past.	54.2	79.7	48.7	97.7	100.7	76.2	82.9	93.9	76.0	175.4	72.7	74.1	47.7	52.7	50.9	62.6	77.9
System																	
CS1	115.6	80.9	132.5	105.5	97.0	137.2	73.9	142.7	88.9	115.2	118.7	60.8	67.1	63.3	98.1	80.4	98.6
CS2	61.4	89.9	103.2	74.5	98.1	107.0	110.1	63.6	105.0	102.6	75.0	64.0	66.5	51.0	74.9	67.8	82.2
CS3	58.0	66.1	60.8	70.0	90.5	96.3	45.7	54.1	89.2	94.0	73.1	61.6	53.3	50.2	52.1	76.9	68.2
CS4	69.5	73.2	68.9	104.9	111.0	103.5	61.5	91.9	117.9	125.7	83.1	78.9	71.2	59.1	83.9	69.2	85.8
CS5	60.7	88.0	78.8	99.6	114.3	108.4	60.9	70.2	102.7	119.6	79.0	71.7	77.7	69.7	71.1	81.9***	84.6
CS6	54.2	79.7	48.7	97.7	100.7	76.2	82.9	93.9	76.0	175.4	72.7	74.1	47.7	52.7	50.9	62.6	77.9
Pr>F																	
Grain vs. Forage	0.4412	0.5410	0.0002	0.0023	0.0024	0.2125	0.2081	0.0783	0.0355	0.0006	0.8407	0.0008	0.0221	0.0046	0.0542	0.8180	0.0120
CC vs other Corn	0.0002	0.5995	0.0001	0.0327	0.7438	0.0003	0.8538	0.0001	0.5780	0.2689	0.0002	0.8201	0.3537	0.0545	0.0001	0.3346	0.0001
CS2 vs CS3	0.7379	0.0066	0.0001	0.7244	0.3909	0.1675	0.0001	0.3994	0.1144	0.5213	0.8313	0.7019	0.0897	0.8905	0.0012	0.1050	0.0019
Pst vs other Forag	0.3375	0.9848	0.0043	0.7372	0.2599	0.0032	0.0976	0.3926	0.0037	0.0017	0.4196	0.8168	0.0053	0.0921	0.0008	0.0863	0.7377
Hi vs low inp For	0.3027	0.0391	0.0938	0.6487	0.6631	0.7339	0.7774	0.0257	0.0712	0.5806	0.5944	0.1795	0.3149	0.0235	0.0235	0.0305	0.6274
C vs Sb in CS2	0.1564	0.4967	0.0001	0.4201	0.2951	0.7309	0.0001	0.4177	0.4291	0.0223	0.9094	0.0204	0.3624	0.1487	0.1733	0.1598	0.5677
C vs oth in CS3	0.3694	0.4979	0.0002	0.0084	0.2139	0.0126	0.5908	0.3882	0.2144	0.6263	0.0681	0.6752	0.0338	0.0985	0.8954	0.0001	0.0172
Sb vs Wht CS3	0.0611	0.0971	0.0908	0.8199	0.1853	0.0011	0.0715	0.2330	0.0467	0.2559	0.1861	0.1804	0.2087	0.1686	0.5339	0.3858	0.0073
C vs alf in CS4	0.0005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0286	0.0378	0.0001	0.0009	0.1110	0.0001	0.0001	0.0023	0.0001	0.0011	0.0001
DS vs est CS4	0.2979	0.1721	0.0050	0.6047	0.5353	0.7382	0.8722	0.0020	0.4195	0.9955	0.9902	0.4694	0.7683	-	0.1719	0.7194	0.2224
Alf1 vs alf2 CS4	0.7280	0.3207	0.7801	0.8297	0.7420	0.4271	0.9955	0.9863	0.1181	0.6416	0.2503	0.2442	0.6460	0.9024	0.0067	-	0.9145
C vs other CS5	0.0807	0.4594	0.0003	0.0739	0.2754	0.0005	0.9720	0.1508	0.0001	0.0001	0.0001	0.0195	0.0001	0.0033	0.0001	0.0001	0.0001
O/a vs alf CS5	0.1126	0.0928	0.9258	0.6849	0.5987	0.5431	0.4517	0.4929	0.3541	0.1494	0.5324	0.7809	0.9563	-	0.5372	-	0.7703
CS1 vs rest	0.0002	0.7627	0.0001	0.3041	0.4702	0.0002	0.5566	0.0001	0.2265	0.8927	0.0003	0.1757	0.9004	0.3664	0.0004	0.3998	0.0008
P vs non CC	0.4463	0.8498	0.0018	0.5892	0.7014	0.0041	0.1718	0.0982	0.0137	0.0002	0.5957	0.5917	0.0274	0.3813	0.0089	0.1195	0.5835
Cash vs For (nocc)	0.3364	0.4700	0.3019	0.0006	0.0017	0.4423	0.1410	0.0014	0.0152	0.0043	0.2038	0.0019	0.0030	0.0005	0.0002	0.3632	0.0002
C(cash) vs C(for)	0.7806	0.0164	0.5219	0.0001	0.0002	0.0008	0.0049	0.6503	0.0001	0.0001	0.2494	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001
Seeded vs est(alf)	0.7926	0.0112	0.0227	0.5801	0.5791	0.7317	0.6996	0.0992	0.1590	0.4604	0.9546	0.6119	0.9896	-	0.1133	-	0.3319

* Treatment changes occurred this year in CS4 replacing dsu with oat/pea/forage mix and in CS5 replacing oats/alfalfa with soybeans.

** Contrast average from 1993-1999 due to difficulties in data analysis in 2000 with system changes at LAC

*** Soybean phase of system was 76.2 lb NO₃-N/2 ft-A

Appendix XII. Nitrate + Nitrite-N Concentration in Groundwater at the Lakeland Agricultural Complex 1991-1998¹.

Field ID#	Trt #	Water collection dates							
		12/10/91	12/09/92	11/23/93	11/23/94	04/23/96	04/09/97	11/13/97	11/16/98
----- ppm -----									
101	1	41.5	39.7	29.2	21.3	39.0	27.3	21.8	20.6
210	1	48.5	44.2	42.0	27.1	21.2	22.1	16.8	16.5
303	1	21.3	36.4	28.5	18.0	23.5	21.6	20.9	20.8
Mean		37.1	40.3	33.2	22.1	27.9	23.6	19.8	19.3
CS 1	C. Corn	C	C	C	C	C	C	C	C
108	2	60.5	47.8	45.6	49.8	15.5	12.3	12.7	10.3
203	2	14.0	20.0	18.7	19.1	13.2	8.9	9.9	6.7
304	2	20.1	20.1	16.4	14.8	14.0	8.5	10.5	7.2
Mean		31.5	29.3	26.9	27.9	14.2	9.9	11.0	8.1
CS 2	Sb-C	Sb	C	Sb	C	Sb	C	Sb	C
111	6	43.8	18.4	14.5	---	8.3	16.6	11.5	13.1
208	6	28.6	38.4	21.3	16.3	15.3	6.7	6.3	6.7
306	6	42.3	23.8	23.1	19.1	10.6	9.7	7.2	6.5
Mean		38.2	26.9	19.6	17.7	11.4	11.0	8.3	8.8
CS 3	Sb-W/r-C	Sb	W/rc	C	Sb	W/rc	C	Sb	W/rc
102	8	15.1	4.8	2.9	10.3	6.9	7.6	11.6	12.1
209	8	6.8	14.4	20.1	25.3	10.9	17.6	20.7	11.5
305	8	10.3	5.7	9.0	14.3	9.1	11.0	15.9	16.2
Mean		10.7	8.3	10.7	16.6	9.0	12.0	16.0	13.3
CS 4	A-A-A-C	A	A	A	C	A	A	A	C
105	12	15.4	10.8	10.4	14.8	6.9	4.5	8.7	5.1
207	12	49.7	38.7	26.1	28.1	12.3	10.7	13.2	8.6
309	12	7.3	8.3	13.3	14.7	9.1	13.0	11.0	4.2
Mean		24.1	19.3	16.6	19.2	9.4	9.4	11.0	6.0
CS 5	O/A-A-C	O/A	A	C	O/A	A	C	O/A	A
104	14	21.3	21.4	18.4	21.1	10.7	10.7	8.7	7.7
213	14	2.2	2.8	3.3	2.2	2.9	2.0	2.6	4.7
314	14	63.2	30.0	16.1	---	13.7	7.0	10.4	17.1
Mean		28.9	18.1	12.6	11.7	9.1	6.5	7.2	9.8
CS 6	Rotational Grazing	*	RG	RG	RG	RG	RG	RG	RG
ls ²		31.1	2.1	2.3	2.8	0.9	Empty	0.1	
ls ³		6.9	10.6	ND	4.2	6.8	Empty	---	

* Red Clover/Grass removed as hay 1991, grazed 1992 - 1998

¹ Check wells were too low to be sampled in fall of 1999 or spring of 2000 due to dry conditions.

² Check well #1 - 13 feet deep

³ Check well #2 - 28 feet deep

ND = no detection

Appendix XIII. List of Publications.**1990****Abstracts:**

POSNER, J.L., M.D. CASLER, K. MCSWEENEY, and D.J. SAVORY. 1990. Conducting "real world" agronomic research on-station. Planning the Wisconsin Cropping Systems Trial. Invited paper at the American Society of Agronomy Annual Meetings. Oct. 21-26, San Antonio, TX. Abstracts p. 29.

SAVORY, D.J., K. MCSWEENEY, AND J.L. POSNER. 1990. The use of a Geographic Information System for mapping and analysis of agronomic data layers. American Society of Agronomy Annual Meetings. Oct. 21-26, San Antonio, TX. Abstracts p. 279.

STUTE, J.K. and J.L. POSNER. 1990. Legume cover crops as an internal source of nitrogen in cash grain systems. American Society of Agronomy Annual Meetings. Oct. 21-26, San Antonio, TX. Abstracts p. 282.

Proceedings:

DOLL, J., R. DOERSCH, R. PROOST, and T. MULDER. 1990. Weed management with reduced herbicide use and reduced tillage. Proc. Of Conf. On "Progress in Wisconsin Sustainable Agriculture." Held at six locations in the state.

DOLL, J., R. DOERSCH, W. PAULSON, and T. MULDER. 1990. Effectiveness of substituting cultivation for herbicides. Proceedings of the 1990 Fertilizer, Agrilime and Pest Management Conference. Jan 16-18, 1990. Vol. 29:244-252.

1991**Abstracts:**

IRAGAVARAPU, T.K., J.L. POSNER, and G.D. BUBENZER. 1991. Using bromide to study water movement through a prairie derived silt-loam soil in Wisconsin. American Society of Agronomy Meetings, Oct 27 – Nov 01, Denver, CO. Agronomy Abstracts p. 333.

MULDER, T. and J. DOLL. 1991. Best management practices for corn weed control. American Society of Agronomy Meetings, Oct 27 – Nov 01, Denver, CO. Agronomy Abstracts p. 155.

Extension Bulletins:

STUTE, J.K. and J.L. POSNER. 1991. Cover crops as an internal source of nitrogen in cash grain production. Sustainable Agriculture Project Papers. Wisconsin Department of Agriculture, Trade, and Consumer Protection. ARM-PUB 53-42.

PORTER, P.A. 1991. Soil biological health: What do farmers think? NPM Field Notes 2:3. Center for Integrated Agricultural Systems, Univ. of Wisconsin, Madison, WI.

Proceedings:

DOLL, J. and T. MULDER. 1991. Reduced herbicide rates – The Wisconsin experience. Proc. Crop Protection and Production Conference. Iowa State University. Dec 03-04. Pp. 35-38.

MULDER, T. and J. DOLL. 1991. Best management practices for corn weed control. NCWSS Proceedings. 46:13.

Appendix XIII. List of Publications (cont'd)

STEVENSON, G.W. and J.L. POSNER. 1991. Multidisciplinary, radially-organized teams: A model and strategy for addressing challenges to agricultural research in the 1990's. Paper presented at the Conference on Innovative Policies for Agricultural Research. Nov. 21-22, Boston, MA.

Thesis:

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Thesis:

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Teaching module:

- CUNNINGHAM, L. 1992. Soils, crops, agriculture, and me: An agricultural awareness unit for fifth graders. Unpublished documents available from the University of Wisconsin-Extension, Elkhorn, WI.

1993**Abstracts:**

- BALDOCK, J.O. and J.L. POSNER. 1993. Cropping systems for improved manure management. American Society of Agronomy meetings. Cincinnati, OH. Nov. 7-12. Agronomy Abstracts p. 144.
- IRAGAVARAPU, T.K., J.L. POSNER and G.D. BUBENZER. 1993. Study of water and solute movement through soil under natural field conditions. In abstracts of Agricultural Research to Protect Water Quality. Soil and Water Conservation Society meeting held at the Radisson Hotel, Minneapolis, MN. Feb. 21-24. p. 36.
- IRAGAVARAPU, T.K., J.L. POSNER and L. BUNDY. 1993. Soil nitrate levels under three cash grain rotations in southern Wisconsin. In abstracts of Agricultural Research to Protect Water Quality. Soil and Water Conservation Society meeting held at the Radisson Hotel, Minneapolis, MN. Feb. 21-24. p. 36.
- MALLORY, E.B. and J.L. POSNER. 1993. Adding a cover crop to cash grain rotations in southern Wisconsin. American Society of Agronomy meetings. Cincinnati, OH. Nov. 7-12. Agronomy Abstracts p. 140.
- STUTE, J.K. and J.L. POSNER. 1993. Legume cover crops as an N source for corn in an oat-corn rotation. American Society of Agronomy meetings. Cincinnati, OH. Nov. 7-12. Agronomy Abstracts p. 288.

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IRAGAVARAPU, T.K. 1993. Monitoring the environmental impacts of alternative cropping systems: studies on water movement, fall soil nitrate levels, and phosphorous and potassium nutrient budgets. Ph.D. Thesis. Agronomy Dept. University of Wisconsin-Madison.

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GARLYND, M.J. D.E. ROMIG, and R.F. HARRIS. 1994. Characterization of soil health and soil quality of selected sites in Wisconsin. American Society of Agronomy Meeting, Seattle, WA., Nov. 13-18. Agronomy Abstracts. p.288.

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- GARLYND, M.J., A.V. KURAKOV, D.E. ROMIG, and R.F. HARRIS. 1994. Descriptive and analytical characterization of soil quality/health. *In: J.W. Doran et al. (Eds.) Defining Soil Quality for a Sustainable Environment. Soil Sci. Soc. Amer. Special Pub. 35:159-168.*
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- GARLYND, M.J., D.E. ROMIG, and R.F. HARRIS. 1995. Effect of cropping systems shift from continuous corn on descriptive and analytical indicators of soil quality. American Society of Agronomy Meeting, St. Louis, MO. Oct. 29 – Nov. 3, 1995. *Agronomy Abstracts. p.58.*
- POSNER, J.L., M.D. CASLER, and J.O. BALDOCK. 1995. The Wisconsin Integrated Cropping Systems Trial: Combining agroecology with production agronomy. Invited presentation. American Society of Agronomy Meeting, St. Louis, MO. Oct. 29 – Nov. 3, 1995. *Agronomy Abstracts. p.50.*
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POSNER, J.L., M.D. CASLER, and J.O. BALDOCK. 1995. The Wisconsin integrated cropping systems trial: Combining agroecology with production agronomy. *Am. J. of Alt. Agric.* 10:3:98-107.

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HICKEY, W., A. MacGUIDWIN, D. HOGG, and D. YOUNG. 06/27/95. "It's not just dirt." Wisconsin Teacher Enhancement Program.

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BALDOCK, J.O., J.L. POSNER, and D.R. FISHER. 1996. CROP: A whole farm planning tool. American Society of Agronomy, Indianapolis, IN. Nov. 3-8, 1996. *Agronomy Abstracts.* p.65.

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HARRIS, R.F. 01/19/96. Soil quality: From pictorial images to assessment and management plans. Invited paper to the Ohio Soil and Water Conservation meeting. Columbus, OH.

ROUSE, D., J. DOLL, R. KLEMME, J.K. STUTE, and J.L. POSNER. 07/11/96. Annual Agronomy Field Day. Arlington, WI.

REBECK, E., A. YUROFF, and V. GOLWITZER. 08/28/96. Presentation to DeForest Middle Schools.

BALDOCK, J.O., and D.R. FISHER. 09/17/96. CROP SPREADSHEET. New Approaches to Rural Nonpoint Source Pollution: What makes them work. Sept. 16-18, 1996. La Crosse, WI.

1997**Abstracts:**

MacGUIDWIN, A.E. 1997. The response of soil nematode communities to agricultural inputs. Soil Ecology Society. May 27-30, 1997. Manhattan, KS.

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BALDOCK, J.O., J.L. POSNER, and D.B. HOGG. 1997. Soil biodiversity in Wisconsin agroecosystems. Soil Ecology Society. May 27-30, 1997. Manhattan, KS.

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KARLEN, D.L., MAUSBACH, M.J., DORAN, J.W., CLINE, R.G., HARRIS, R.F., SCHUMAN, G.E. 1997. Soil quality: a concept, definition, and framework for evaluation. Soil Sci. Soc. Am. J. Madison, Wis. Soil Science Society of America. Jan/Feb 1997. v. 61 (1) p.4-10.

1998**Theses:**

REBEK, E. J. 1998. Cropping system effects on the diversity and abundance of Collembola in Southern Wisconsin. M.S. Thesis, Entomology Dept., University of Wisconsin-Madison.

FISHER, D.R. 1998. Whole farm nutrient budgeting: Estimating nutrient balance and identifying strategies for improvement. M.S. Thesis, Agronomy Dept., University of Wisconsin-Madison.

Bulletins:

STUTE, J.K. 1998. Including a small grain in the corn-soybean rotation: production economics of small grains. Michael Fields Agricultural Institute Bulletin #5. 4 pages.

STUTE, J.K. 1998. Using hairy vetch residue for nitrogen and weed suppression. Michael Fields Agricultural Institute Bulletin #6. 2 pages.

Publications:

IRAGAVARAPU, T.K., J.L. POSNER, and G.D. BUBENZER. 1998. The effect of various crops on bromide leaching to shallow groundwater under natural rainfall conditions. J. Soil and Water Conserv. 53(2):146-151.

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POSNER, J.L., G.G. FRANK, K.V. NORDLUND, and R.T. SCHULER. 1998. Constant goal, changing tactics: A Wisconsin dairy farm start-up. *Am. J. Alt. Ag.* 13(2):50-60.

1999**Thesis:**

GOLLWITZER, V. 1999. Molecular analysis of ammonia-oxidizing bacteria in Wisconsin agricultural soils. M.S. Thesis, Soil Science Dept., University of Wisconsin-Madison.

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DOETCH, R.G., D. KANE, J.K. STUTE, J.L. POSNER, AND T. ENDS. 1999. Farmers Guide & Resource to Quality Small Grains Production. Michael Fields Agricultural Institute.

DOETCH, R.G., AND T. ENDS. 1997-99. Small Grains Update: Striving for the production, handling, and processing of small grains. Fortnightly newsletter. Michael Fields Agricultural Institute, East Troy, WI.

KLEMME, R. 1999. Cropping Systems trial provides unique analysis. CIAS Research Brief #43. UW-CALS.

KLEMME, R., AND D. SCHUSTER. 1999. Diversity pays off on cash grain farms. CIAS Research Brief #44. UW-CALS.

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REBEK, E.J., D.K. YOUNG, AND D.B. HOGG. 1999. A list of Wisconsin springtails with new records and annotations (Hexapoda: Parainsecta: Collembola). *Great Lakes Ent.* 32(1): 51-62.

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GOLDSTEIN, W. 2000. The dynamics of root growth under different management systems. *Amer. J. of Alternative Agriculture*.

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MACGUIDWIN, A., M. ROSEMEYER, AND T. LIM. 2000 in preparation. The diversity of nematode communities of four established low and high input Midwestern cropping systems over three years. To: *Applied Soil Ecology*.

SELBACH, P.A., A.S. YUROFF and W.J. HICKEY. 2000 submitted. Effects of agricultural cropping systems on solid microbial community structure: Phylogenetic probe analysis. To *Soil Biology and Biochemistry*;

Appendix XIII. List of Publications (cont'd)

Posters:

AVILA-SEGURA, M. ET AL. 2000. Coupling of H and C cycles in several common agroecosystems of Midwestern United States. ASA, CSSA, SSSA Annual Meeting. Minneapolis, MN. November 5-9, 2000.

SIMONSEN, J., ET AL. 2000. Earthworm populations and functional group dynamics in conventional and alternative cropping systems. ASA, CSSA, SSSA Annual Meeting. Minneapolis, MN. November 5-9, 2000.

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