

# **The Wisconsin Integrated Cropping Systems Trial Seventh Annual Report**

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## Prologue

This is the seventh 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 seven production years (1990 – 1996). In this report, we discuss the results of the seventh and eighth years of field trials (1997 and 1998). This is the fifth (1997) and sixth (1998) 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 1998, all the treatments except 9 and 10 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 1997 and 1998

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| Walter Goldstein | Michael Fields Agricultural Institute                   |
| Rhonda Graef     | UW-Agronomy Department                                  |
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| John Hall        | Michael Fields Agricultural Institute                   |
| Dwight Mueller   | Superintendent, Arlington Agricultural Research Station |
| Josh Posner      | UW-Agronomy Department                                  |
| Janet Riesterer  | UW-Agronomy Department                                  |
| Martha Rosemeyer | UW-Agronomy Department                                  |
| Jim Stute        | Michael Fields Agricultural Institute                   |

We also acknowledge with many thanks, the contributions to this project of those who assisted the two superintendents in managing the crops and animals – Paul Bergum, Clint Clemens, Bob Elderbrook, 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 1.

Figure 1. Outline of major Land Resources Area 95B & two Wisconsin Integrated Cropping Systems Trial sites.

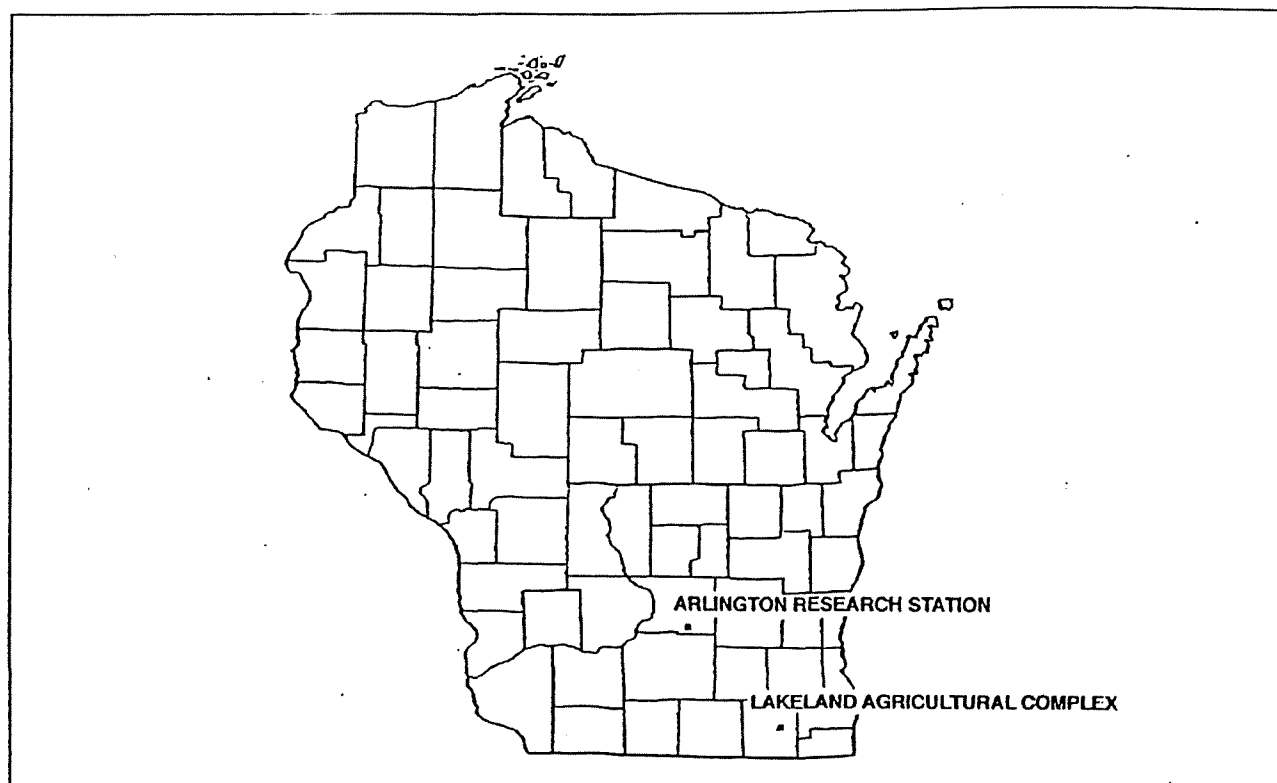


Figure 2. Schematic drawing of cropping systems in the Wisconsin Integrated Cropping Systems Trial.

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

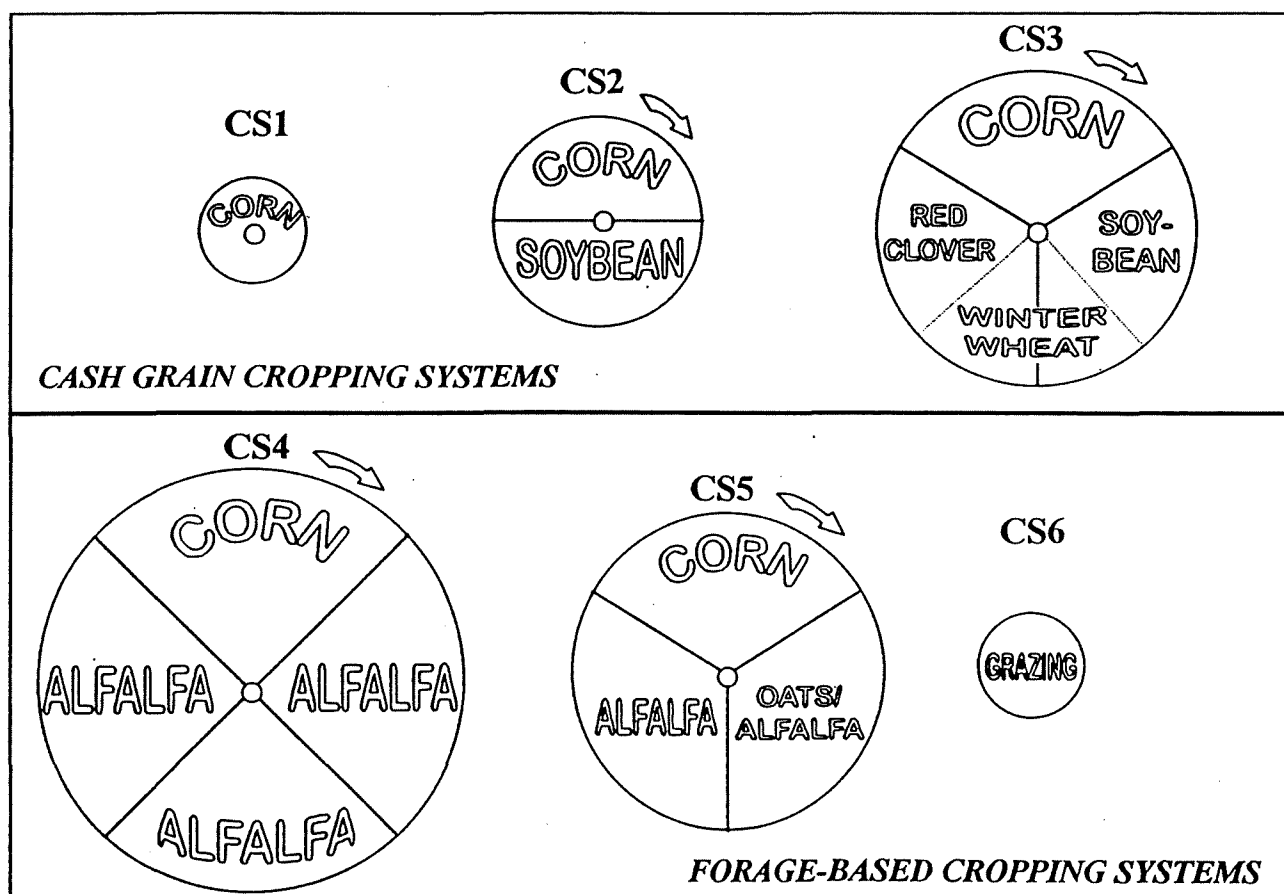


**Table 1. Productivity, Economic, and Environmental Comparisons Between Rotations. Wisconsin Integrated Cropping Systems Trial 1990.**

| Rotation                                                           | Predicted Yield/acre              | Mean above ground productivity <sup>1</sup><br>Lb/a/yr | Mean energy input <sup>2</sup><br>Mcal/a/yr | Energy output/input <sup>3</sup><br>ratio | Variable costs <sup>4</sup><br>\$/a/yr | Chemical inputs              |                                                                     |                     | Erosion <sup>5</sup><br>t/a/yr |
|--------------------------------------------------------------------|-----------------------------------|--------------------------------------------------------|---------------------------------------------|-------------------------------------------|----------------------------------------|------------------------------|---------------------------------------------------------------------|---------------------|--------------------------------|
|                                                                    |                                   |                                                        |                                             |                                           |                                        | N Fertilizer on corn<br>lb/a | Herbicide<br>AI/a                                                   | Insecticide<br>AI/a |                                |
| <b>R<sub>1</sub></b><br>Continuous Corn                            | 150 bu                            | 15,780                                                 | 2369                                        | 6.0                                       | 140                                    | 150                          | Atrazine 2 lb<br>Alachlor 2 lb                                      | Counter 1.4 lb      | 4.1                            |
| <b>R<sub>2</sub></b><br>Drilled Soybean Corn                       | 55 bu<br>160 bu                   | 12,510                                                 | 1788                                        | 6.9                                       | 104                                    | 110                          | Bladex 2.5 lb<br>Alachlor 2.5 lb<br>Sencor 0.5 lb<br>Treflan 1.5 lb | 0                   | 4.0                            |
| <b>R<sub>3</sub></b><br>Row soybean<br>Wheat<br>Corn               | 40 bu<br>60 bu/2t straw<br>120 bu | 10,010                                                 | 763                                         | 12.6                                      | 50                                     | 0                            | 0                                                                   | 0                   | 2.9                            |
| <b>R<sub>4</sub></b><br>Seeding alfalfa<br>Hay I<br>Hay II<br>Corn | 3t dm<br>5t dm<br>5t dm<br>160 bu | 10,710                                                 | 1188                                        | 13.7                                      | 110                                    | 10                           | Eptam 2.9 lb<br>Bladex 2.0 lb<br>Alachlor 2.5 lb                    | Lorsban 1.0 lb      | 1.9                            |
| <b>R<sub>5</sub></b><br>Oats/alfalfa<br>Hay I<br>Corn              | 60 bu/2t dm<br>4t dm<br>120 bu    | 9,440                                                  | 811                                         | 18.2                                      | 45                                     | 10                           | 0                                                                   | 0                   | 1.6                            |
| <b>R<sub>6</sub></b><br>Rotational Grazing                         | 4t dm                             | 8,000                                                  | 129                                         | 104.3                                     | 16                                     | na                           | 0                                                                   | 0                   | 0.5                            |

<sup>1</sup> 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.

<sup>2</sup> 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.

<sup>3</sup> Ratio of energy value of agricultural output to energy consumption

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

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



**THE MAIN SYSTEMS TRIAL – 1997 and 1998****1a. 1997 Agronomic Report - Arlington Agricultural Research Station**Paul Bergum and Dwight Mueller<sup>1</sup>**Corn Phases**

Treatment of all the corn plots was similar to 1996. In systems CS1, CS2, and CS4 corn was planted on April 25<sup>th</sup> at 31,500 seeds/A with a 105-day corn, Golden Harvest 2441. Systems CS3 and CS5 were planted on May 14<sup>th</sup> at 34,000 seeds/A with a 95-day corn, Dekalb 471. Deep nitrate soil tests were taken for the CS1 plots. As a result of the tests, a side-dress application of 120 lb N/a was applied on plots 204, 306 and 412 (CS1) on July 3<sup>rd</sup>. Legume and manure credits were taken in the other systems and only CS2 received additional N (120 lb N/a).

Weed control in treatments CS2 and CS4 continued to be very good. Slow germination of the corn, increasing weed pressure, and gophers caused the CS1 plots to have lower plant population. But by the end of the season, a large number of the remaining plants had produced a second ear of corn per stalk, making a respectable yield for the season. Mechanical weeding was done intensively on CS3 and CS5 plots (CS3 corn was rotary hoed three times and cultivated seven times; CS5 corn was rotary hoed once and cultivated seven times). The weed seed bank in those plots had increased greatly because of the problems in 1996. Also, we utilized a new type of no-till cultivator that made cultivating the crop easy and was very effective in controlling weeds. In-row weeds continue to be a problem in the mechanical weeding system.

Spot and border spraying was done to control perennial grasses and thistles in most of the corn plots.

Corn yields averaged 150 bu/a across all treatments. Similar to past years, corn yields averaged 15 to 20 percent lower for CS1 compared to the other treatments. This demonstrates the significant benefit to rotating corn with other crops. Corn yields on CS5 were higher in 1997 than in 1996, reflecting the improved weed control.

**Soybean Phases**

Asgrow 1900 was planted at 250,000 seeds/A in 7" rows for CS2, a no-till rotation. Kaltenberg 241 was planted at 190,000 seeds/A in 30" rows for CS3 rotations. Both plantings were performed on May 15<sup>th</sup>. 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. Weed control for the rest of the growing season was excellent in the CS2 rotation. Mechanical weed control in CS3 was very good until late in the season when some velvetleaf and annual grasses broke through the canopy. Wide row soybean yields (CS3) averaged 49 bu/A compared to 52 bu/A for narrow row soybeans (CS2).

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### **Wheat/Red Clover Phase**

Wheat (var. Glacier) was planted on October 06, 1996 following the soybean harvest and light tillage at a seeding rate of 150 lb/A. Moderate winterkill occurred and spring wheat was over-seeded on April 17, at 100 lb/A. Red Clover was seeded on February 24 at 15 lb/A with a Brillion Seeder. A very poor stand established and Hairy Vetch was planted on August 27 at 25 lb/A. The wheat yield averaged 54 bu/A.

### **Forage Phases**

The new seedings in CS4 and CS5 systems were planted with Innovator+Z on April 17 at a rate of 15 lb/A for CS4 and CS5. Bay oats were planted in CS5 at 50 lb/A, plus 2 lb of perennial ryegrass. The established plots were harvested four times during the season. A cold spring and a dry fall made for some inconsistent yields. The last cutting was made on October 01. CS5 oats were taken off as silage on June 24. Both CS4 and CS5 alfalfa stands established well and were harvested twice during the season.

## **1b. 1998 Agronomic Report - Arlington Agricultural Research Station**

Paul Bergum and Dwight Mueller <sup>1</sup>

### **Corn Phases**

Treatment of all the corn plots was similar to 1997. Corn in CS1, CS2, and CS4 were all planted on April 25<sup>th</sup> at 32,000 seeds/A with a 105-day corn, Golden Harvest 2441. CS3 and CS5 were planted on May 15<sup>th</sup> 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 side-dress application of 145 lb N/A was applied on plots 109, 204, 306 and 412 on June 1<sup>st</sup>. Legume and manure credits were taken in the other systems and only CS2 system received additional N (95 lb N/A).

1998 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. This year those 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 207 bu/A across all treatments, well above past years (+30%). 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 10<sup>th</sup>. NK23-12 was planted at 190,000 seeds/A in 30" rows for the CS3 rotation on May 15<sup>th</sup>. 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. Weed control for the rest of the growing season was excellent in the CS2 rotation. (Sprayer problems caused some weed escapes in plot 303). Mechanical weed control in CS3 was very good until late in the season when some velvetleaf and annual grasses broke through the canopy. Wide row soybean yields (CS3) averaged 52 bu/A compared to 64 bu/A for narrow row soybeans (CS2).

### **Wheat/Red Clover Phase**

Wheat (var, Glacier) was planted on October 2, 1997 following soybean harvest and light tillage at a seeding rate of 150 lb/A. Red Clover was seeded on April 7<sup>th</sup> at 15 lb/A, with a John Deere no-till drill. The wheat yield averaged 57 bu/A.

### **Forage Phases**

The new seedlings in CS4 and CS5 systems were planted with Wintergreen on April 15<sup>th</sup>. CS4 was planted with a rate of 15 lb of alfalfa seed/A. CS5 had 11 lb/A of alfalfa, 50 lb/A of bay oats, plus 50 lb/A of peas to help with forage yield and weed control. All the established plots were harvested four times during the season. The last cutting was made on September 30<sup>th</sup>. CS5 oats were taken off as silage on June 23<sup>rd</sup>. Both CS4 and CS5 alfalfa stands established well and were harvested twice during the season.

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## 2a. 1997 Agronomic Report - Lakeland Agricultural Complex

Jim Stute<sup>1</sup>, John Hall<sup>2</sup>, Dan Forsythe<sup>3</sup>, and Lee Cunningham<sup>3</sup>

### Growing Season

Field activities began early in 1997 due to early snowmelt and dry soil conditions. Dry conditions permitted timely field tillage and planting operations in April and May, but a pronounced lake effect caused by easterly winds slowed soil warming and early plant growth. Soil temperatures were essentially unchanged from late April to Late May. Growing degree day (GDD) accumulation during this period was 75 % of normal, and without unseasonably warm temperatures in September and October, it is doubtful either corn or soybean would have made it to physiological maturity. Total season GDD accumulation finished 97% of normal at 3028 (Figure 4).

Growing season rainfall was nearly six inches below normal (Table 1\_B). With the exception of a wet period in June, most of the season was dry, and moisture stress evident in both the growing crops and their yield

### Corn

Differences between systems were quite apparent in the corn phase, especially under conditions of moisture stress. Corn in CS1, CS2 and CS4 was planted on the same day and emerged together 23 days later despite systems differences in tillage. At the time of emergence, soil temperatures were 50 to 52° F, the same as at planting, which presumably masked any systems differences. From emergence onward, development of corn in CS1 and CS2 lagged behind CS4, a difference reflected in final grain yield (Table 2\_b). Corn in CS1 exhibited severe goosenecking, consistent with rootworm damage, and also lodged to a high degree making harvest difficult. Corn in CS3 and CS5 was planted on the same day and also emerged at the same time. Relative to CS5, corn in CS3 was paler and also developed more slowly. Grass weeds were also more prevalent in CS3, as indicated by visual observation.

Moisture stress during the growing season was most evident in CS1 and CS3, intermediate in CS5, and least in CS2 and CS4.

### Soybean

The 1997 growing season was well suited for soybean growth. Late season foxtail was a problem for CS3, while white mold was evident in CS2, although not to the extent experienced in years past.

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### **Wheat**

Winter wheat performed well in 1997. Winter injury appeared to be minimal despite being established by aerial seeding onto ground with pronounced cultivator ridges. Both grain and straw yields reflect this. Stands of frost seeded red clover were good to excellent.

### **Alfalfa**

Forage production was difficult in 1997. Limited moisture and cool temperatures reduced yields of established hay in both CS4 and CS5. Potato leafhopper infestation was also a problem in CS4, requiring use of insecticide in late July. Sweeping of established CS5 forage stands, which include not only alfalfa but also red clover and perennial ryegrass, showed considerably lower (and well under treatment thresholds) leafhopper numbers than pure alfalfa in CS4.

Alfalfa stands established in 1996 CS4 were re-established with apparent success in 1997. Plot 413 however contained a lot of quackgrass.

### **Pasture**

Pasture plots were also reseeded in 1997 because the previous year's efforts failed. Weeds in the pasture plots were grazed in mid-summer, then killed with Roundup-ultra. Manure was applied, and the plots were reseeded with reed canary and orchard grass once soil moisture was sufficient and good stands were obtained. Winter-annual weeds were killed in late fall with an application of 2,4-D.

## **2b. 1998 Agronomic Report - Lakeland Agricultural Complex**

Jim Stute<sup>1</sup>, John Hall<sup>2</sup>, Dan Forsythe<sup>3</sup>, and Lee Cunningham<sup>3</sup>

### **Growing Season**

Once again, weather extremes defined the growing season at the Lakeland Agricultural Complex. While growing season rainfall was nearly normal (Table 1B and Figure 2), it was not well distributed. Rainfall through June was well above normal, while often inadequate for the remainder of the season. This was more of an issue for field operations than crop growth. Field activities began late in 1998 due to wet soil conditions and rainfall in June prevented timely weed control in many systems and delayed forage harvest. Normal rainfall in August coupled with soil reserves prevented serious moisture stress in the field crops. However, late season forage yield was reduced by a lack of moisture. Dry soil conditions and unseasonably warm temperatures allowed completion of fall fieldwork.

Excessive rainfall amounts were often the result of violent thunderstorms. Storms in May, July, and August were accompanied by high winds (including a microburst in August) which caused extensive damage to the Lakeland Complex, and created severe lodging of corn. Crops less than three feet in height were not damaged.

Total growing degree day (GDD) accumulation was 3474, 115% of normal. Warm temperatures resulted in early crop maturity and low grain moistures at harvest.

### **Corn**

Corn yields ranged from excellent to poor, and differences between systems were quite apparent in the corn phase. Weed control methods in systems one, two and four were effective, while those in systems three and five were not, primarily due to weather. Mild over-winter conditions did little to damage the sod undercut the previous fall and plants began growing vigorously in spring. Wet weather delayed tillage which, when finally completed, produced a very cloddy and non-uniform seedbed, making rotary hoeing ineffective. Excessive rainfall prevented cultivation, and ultimately a post-emergence rescue herbicide treatment was made. Wet soil conditions also delayed this application and weed competition severely depressed yield. Lodging caused by high winds appeared to be consistent across systems.

### **Soybean**

The 1998 growing season was well suited for soybean growth. Late season foxtail was a problem for CS3 caused by weather delays of cultivation. A little white mold was evident in CS2, although not to the extent experienced in years past, despite excellent canopy. Presumably, dry weather and low humidity in July prevented initiation of the disease.

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### **Wheat**

Winter wheat yield was average in 1998. Both grain and straw yields reflect this. Stands of frost seeded red clover were good to excellent.

### **Alfalfa**

Although often difficult, forage production was good in 1998, mostly because of abundant rainfall early in the season. First crop hay was harvested in a timely fashion, while wet soil conditions delayed harvest of both second crop, and the newly seeded forages. Wet soil also prevented application of herbicide to CS4 direct seeded alfalfa. This combined with harvest delays allowed weed growth and poor quality of the resulting forage. Third crop was harvested in a timely fashion in all systems. Yield of the fourth crop was limited in plots that were to rotate into corn in 1999 because of dry conditions. In fact, there was insufficient material to mechanically harvest in CS5. Unlike previous years, potato leafhopper infestation was not a problem.

### **Pasture**

Grazing was initiated in mid-July, following last years reseeding of the pastures. Red clover was frost seeded in March, and the paddocks clipped in early June to prevent weeds from going to seed and to promote uniform regrowth prior to grazing. Seven heifers with an average beginning weight of 472 pounds grazed the pastures in rotation until October 27.

Table 1. Growing season rainfall (inches) at the Wisconsin Integrated Cropping Systems Trial sites.

**A. Arlington Research Station <sup>1</sup>**

| Month                               | 1998  | (*)     | 1997  | (*)     | 1996  | (*)     | 30-year avg<br>1961-1990 |
|-------------------------------------|-------|---------|-------|---------|-------|---------|--------------------------|
| April                               | 3.71  | ( 0.87) | 0.65  | (-2.19) | 2.64  | (-0.20) | 2.84                     |
| May                                 | 4.06  | ( 0.93) | 3.30  | ( 0.17) | 3.20  | ( 0.07) | 3.13                     |
| June                                | 6.81  | ( 3.01) | 4.86  | ( 1.06) | 7.76  | ( 3.96) | 3.80                     |
| July                                | 2.13  | (-1.29) | 6.00  | ( 2.58) | 2.42  | (-1.00) | 3.42                     |
| August                              | 6.65  | ( 2.77) | 3.20  | (-0.68) | 2.83  | (-1.05) | 3.88                     |
| September                           | 2.95  | (-1.33) | 1.57  | (-2.71) | 0.86  | (-3.42) | 4.28                     |
| October                             | 3.38  | ( 1.00) | 1.32  | (-1.06) | 3.29  | ( 0.91) | 2.38                     |
| <b>Growing<br/>Season<br/>Total</b> | 29.69 | ( 5.96) | 20.90 | (-2.83) | 23.00 | (-0.73) | 23.73                    |
| <b>Yearly<br/>Total</b>             | 36.75 | ( 5.61) | 28.33 | (-2.81) | 27.99 | (-3.15) | 31.14                    |

(\*) Deviation from 30-year average.

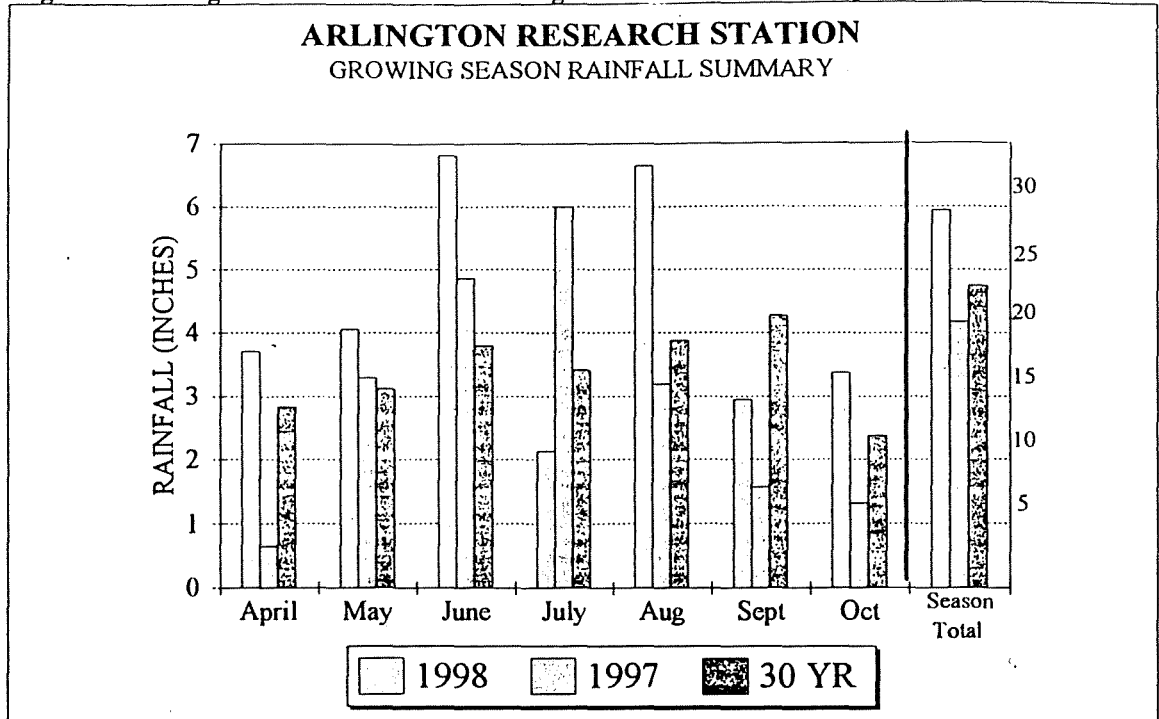
**B. Lakeland Agricultural Complex <sup>2</sup>**

| Month                               | 1998  | (*)     | 1997  | (*)     | 1996  | (*)     | 30-year avg<br>1961-1990 |
|-------------------------------------|-------|---------|-------|---------|-------|---------|--------------------------|
| April                               | 3.60  | (-0.06) | 2.64  | (-1.02) | 2.58  | (-1.08) | 3.66                     |
| May                                 | 4.61  | ( 1.36) | 3.15  | (-0.10) | 5.69  | ( 2.44) | 3.25                     |
| June                                | 6.76  | ( 2.88) | 5.36  | ( 1.48) | 6.61  | ( 2.73) | 3.88                     |
| July                                | 1.65  | (-2.65) | 3.20  | (-1.10) | 3.24  | (-1.06) | 4.30                     |
| August                              | 2.17  | (-1.75) | 2.03  | (-1.89) | 1.93  | (-1.99) | 3.92                     |
| September                           | 2.66  | (-1.43) | 4.25  | ( 0.16) | 1.57  | (-2.52) | 4.09                     |
| October                             | 4.20  | ( 1.46) | 1.82  | (-0.92) | 2.56  | (-0.18) | 2.74                     |
| <b>Growing<br/>Season<br/>Total</b> | 25.65 | (-0.19) | 22.45 | (-3.39) | 24.18 | (-1.66) | 25.84                    |
| <b>Yearly<br/>Total</b>             | 36.88 | (-0.65) | 28.86 | (-8.67) | 30.60 | (-6.93) | 37.53                    |

(\*) Deviation from 30-year average.

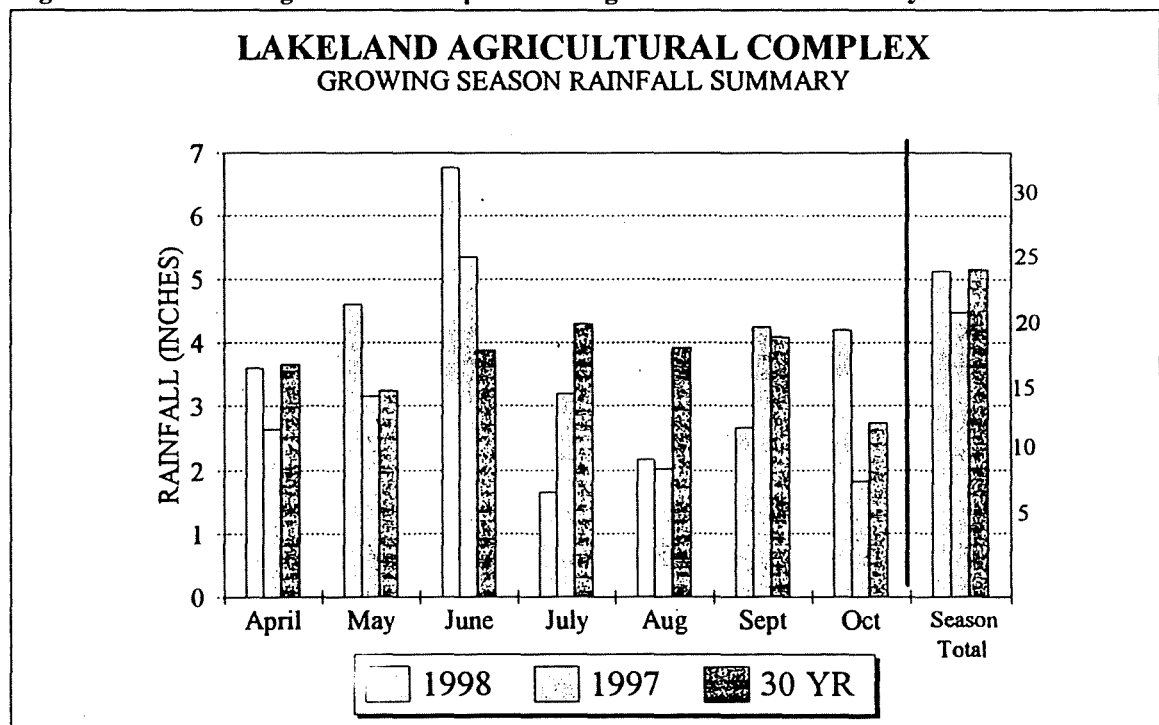
<sup>1</sup> Data from Arlington National Weather Service Cooperative Station.<sup>2</sup> Data from Lake Geneva National Weather Cooperative Station. (7 miles southeast of the Lakeland Ag Complex).

Figure 1. Arlington Research Station Growing Season Rainfall Summary.

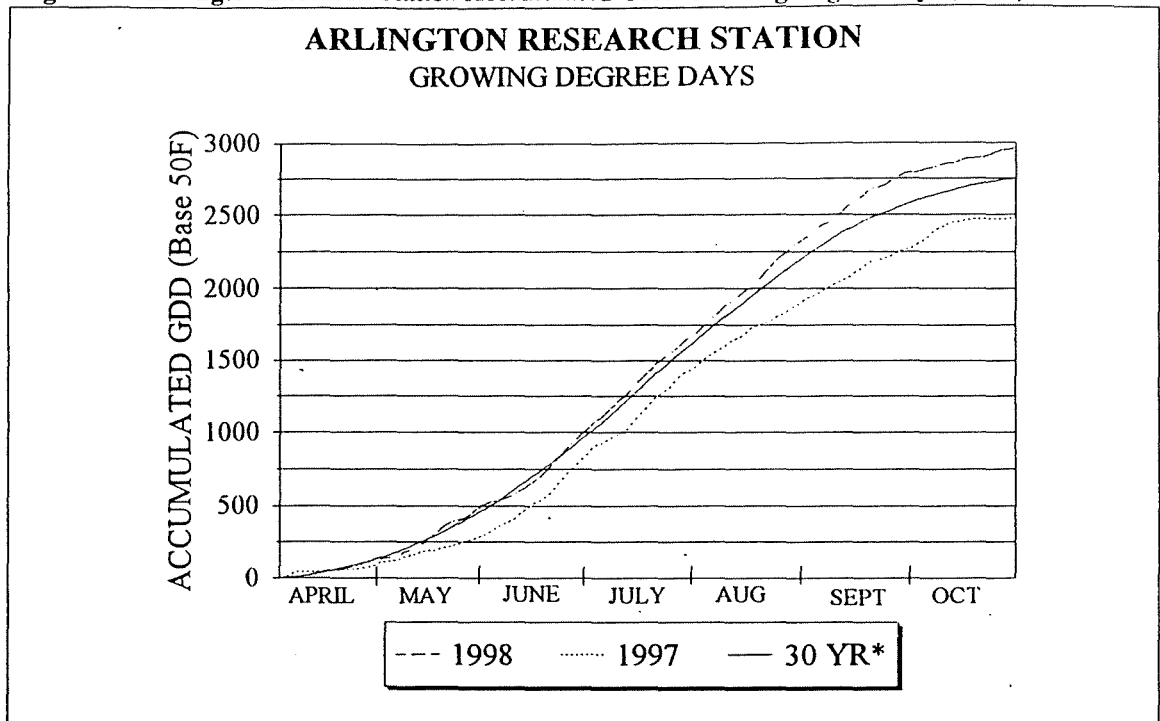


\*30 YR DATA from 1961 - 1990

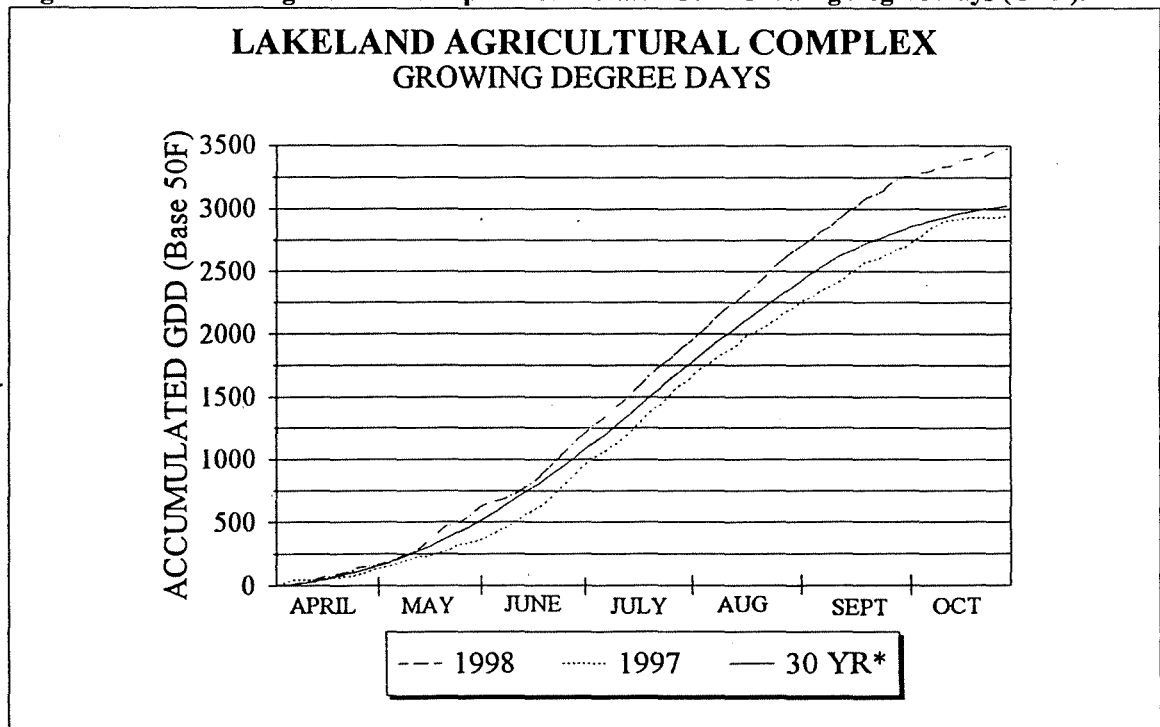
Figure 2. Lakeland Agricultural Complex Growing Season Rainfall Summary.



\*30 YR DATA from 1961 - 1990

**Figure 3. Arlington Research Station Accumulated Corn Growing Degree Days (GDD).**

\*30 YR DATA from 1961 - 1990

**Figure 4. Lakeland Agricultural Complex Accumulated Corn Growing Degree Days (GDD).**

\*30 YR DATA from 1961 - 1990

Table 2a. Yield Results for the Arlington Agricultural Research Station – WICST (1994 - 1998).

| <u>Corn</u>                                 | <u>1994</u>         | <u>1995</u>     | <u>1996</u>     | <u>1997</u>     | <u>1998</u>     |
|---------------------------------------------|---------------------|-----------------|-----------------|-----------------|-----------------|
|                                             | Bushels/acre        |                 |                 |                 |                 |
| CS <sub>1</sub> - Continuous corn           | 178.1               | 143.1           | 131.5           | 128.6           | 196.2           |
| CS <sub>2</sub> - Corn after soybean        | 190.2               | 167.7           | 140.0           | 157.4           | 212.6           |
| CS <sub>3</sub> - Corn after red clover     | 188.4               | 155.6           | 83.5            | 147.6           | 197.8           |
| CS <sub>4</sub> - Corn after alfalfa        | 196.5               | 167.5           | 151.2           | 159.1           | 226.8           |
| CS <sub>5</sub> - Corn after alfalfa        | 198.8               | 157.1           | 153.6           | 155.3           | 205.1           |
| LSD (P<0.05)                                | 12.6                | 11.6            | 16.0            | 10.0            | 12.3            |
| <br><u>Soybean</u>                          | <br><u>1994</u>     | <br><u>1995</u> | <br><u>1996</u> | <br><u>1997</u> | <br><u>1998</u> |
|                                             | Bushels/acre        |                 |                 |                 |                 |
| CS <sub>2</sub> - Drilled soybean           | 42.7 <sup>1</sup>   | 58.1            | 53.7            | 51.9            | 63.6            |
| CS <sub>3</sub> - Row soybean               | 44.4                | 63.3            | 60.2            | 48.8            | 51.9            |
| LSD (P<0.05)                                | NS                  | 2.2             | NS              | NS              | NS              |
| <br><u>Wheat</u>                            | <br><u>1994</u>     | <br><u>1995</u> | <br><u>1996</u> | <br><u>1997</u> | <br><u>1998</u> |
|                                             | Bushels/acre        |                 |                 |                 |                 |
| CS <sub>3</sub> - Wheat                     | 60.9                | 67.8            | 45.4            | 54.4            | 57.7            |
| <br><u>Seeded Alfalfa</u>                   | <br><u>1994</u>     | <br><u>1995</u> | <br><u>1996</u> | <br><u>1997</u> | <br><u>1998</u> |
|                                             | Ton dry matter/acre |                 |                 |                 |                 |
| CS <sub>4</sub> - Direct seeded             | 3.21                | 3.19            | 1.57            | 3.56            | 2.63            |
| CS <sub>5</sub> - Oats/alfalfa <sup>2</sup> | 3.37                | 3.21            | 2.68            | 4.66            | 5.67            |
| LSD (P<0.05)                                | NS                  | NS              | 0.90            | NS              | 0.67            |
| <br><u>Established Forage</u>               | <br><u>1994</u>     | <br><u>1995</u> | <br><u>1996</u> | <br><u>1997</u> | <br><u>1998</u> |
|                                             | Ton dry matter/acre |                 |                 |                 |                 |
| CS <sub>4</sub> - Hay I                     | 4.56                | 4.02            | 4.16            | 5.08            | 4.30            |
| CS <sub>5</sub> - Hay I                     | 5.30                | 4.89            | 4.42            | 4.99            | 4.47            |
| CS <sub>4</sub> - Hay II                    | 3.68                | 2.24            | 3.77            | 4.50            | 4.13            |
| LSD (P<0.05)                                | 0.42                | 0.36            | 0.59            | NS              | NS              |
| <br><u>Pasture</u>                          | <br><u>1994</u>     | <br><u>1995</u> | <br><u>1996</u> | <br><u>1997</u> | <br><u>1998</u> |
|                                             | Ton dry matter/acre |                 |                 |                 |                 |
| CS <sub>6</sub> - Pasture <sup>3</sup>      | 3.86                | 2.17            | 1.67            | 1.84            | 2.94            |

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

Table 2b. Yield Results for the Lakeland Agricultural Complex— WICST (1994 - 1998).

| <u>Corn</u>                             | <u>1994</u>         | <u>1995</u>         | <u>1996</u>       | <u>1997</u>       | <u>1998</u>       |
|-----------------------------------------|---------------------|---------------------|-------------------|-------------------|-------------------|
|                                         | Bushels/acre        |                     |                   |                   |                   |
| CS <sub>1</sub> - Continuous corn       | 177.0               | 150.1               | 41.7              | 112.6             | 165.5             |
| CS <sub>2</sub> - Corn after soybean    | 184.4               | 149.7               | 40.1              | 153.8             | 172.2             |
| CS <sub>3</sub> - Corn after red clover | 187.0               | 130.9               | 44.8              | 133.5             | 129.0             |
| CS <sub>4</sub> - Corn after alfalfa    | 211.3               | 154.4               | 64.3              | 160.0             | 172.2             |
| CS <sub>5</sub> - Corn after alfalfa    | 198.3               | 143.7               | 57.4              | 151.4             | 92.7              |
| LSD (P<0.05)                            | 9.8                 | 14.6                | 14.4              | 26.6              | 55.6              |
| <u>Soybean</u>                          | <u>1994</u>         | <u>1995</u>         | <u>1996</u>       | <u>1997</u>       | <u>1998</u>       |
|                                         | Bushels/acre        |                     |                   |                   |                   |
| CS <sub>2</sub> - Drilled soybean       | 63.1                | 54.9                | 39.5              | 57.8              | 67.7              |
| CS <sub>3</sub> - Row soybean           | 47.4                | 59.1                | 27.3              | 48.6              | 45.0              |
| LSD (P<0.05)                            | 2.3                 | 2.9                 | 6.6               | NS                | NS                |
| <u>Wheat</u>                            | <u>1994</u>         | <u>1995</u>         | <u>1996</u>       | <u>1997</u>       | <u>1998</u>       |
|                                         | Bushels/acre        |                     |                   |                   |                   |
| CS <sub>3</sub> - Wheat                 | 50.9                | 70.0                | 76.9 <sup>5</sup> | 57.4              | 47.2              |
| <u>Seeded Alfalfa</u>                   | <u>1994</u>         | <u>1995</u>         | <u>1996</u>       | <u>1997</u>       | <u>1998</u>       |
|                                         | Ton dry matter/acre |                     |                   |                   |                   |
| CS <sub>4</sub> - Direct seeded         | 2.37 <sup>1</sup>   | 1.24 <sup>1</sup>   | 0.15 <sup>6</sup> | 1.45              | 3.12              |
| CS <sub>5</sub> - Oats/alfalfa          | 3.49 <sup>3</sup>   | 1.51 <sup>1,3</sup> | 1.87 <sup>2</sup> | 2.32 <sup>3</sup> | 2.97 <sup>3</sup> |
| LSD (P<0.05)                            | 0.54                | NS                  | 0.50              | NS                | NS                |
| <u>Established Forage</u>               | <u>1994</u>         | <u>1995</u>         | <u>1996</u>       | <u>1997</u>       | <u>1998</u>       |
|                                         | Ton dry matter/acre |                     |                   |                   |                   |
| CS <sub>4</sub> - Hay I                 | 4.12 <sup>1</sup>   | 4.47                | 4.26              | 1.3 <sup>7</sup>  | 4.53              |
| CS <sub>5</sub> - Hay I                 | 3.82 <sup>1</sup>   | 4.62                | 4.35              | 3.0               | 4.86              |
| CS <sub>4</sub> - Hay II                | 4.05 <sup>1</sup>   | 3.34                | 3.74              | 3.4               | 4.32              |
| LSD (P<0.05)                            | NS                  | 0.71                | 0.78              | 0.86              | NS                |
| <u>Pasture</u>                          | <u>1994</u>         | <u>1995</u>         | <u>1996</u>       | <u>1997</u>       | <u>1998</u>       |
|                                         | Ton dry matter/acre |                     |                   |                   |                   |
| CS <sub>6</sub> - Pasture               | 4.08 <sup>4</sup>   | 3.58 <sup>4</sup>   | 0.96 <sup>4</sup> | 1.0 <sup>8</sup>  | 1.36 <sup>9</sup> |

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



### 3. Weed Seed Bank Changes: 1990 to 1998

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Crop management systems influence various aspects of the soil, not the least of which are weeds. The rotation, tillage system, intensity of herbicide use, and integration (or lack thereof) of herbicides with other control practices will certainly affect the weed seed bank. While this principle is well recognized, seed bank data to track the long-term effects of specific crop and weed management systems in Wisconsin are found only in the WICST trial.

The range of purchased input levels is very high to almost none across three cash grain and three livestock-based production systems. Weed management in the continuous corn system (CS1) uses conventional rates of herbicides and cultivation as needed. In the corn-soybean rotation (CS2), reduced herbicide rates are used in corn followed by cultivation, but in soybeans conventional herbicide rates are used because the crop is planted in narrow rows that do not permit row cultivation. This system uses a no-tillage strategy and in 1998 glyphosate-resistant soybean varieties were planted to address the increase in perennial weeds like Canada thistle, quackgrass, and common milkweed. The corn-soybean-wheat/red clover rotation (CS3) typically uses primary and secondary tillage, delayed planting, two or three rotary hoeings, and cultivation in corn and wide-row soybeans for weed control. No herbicides are used in any phase of this rotation.

The forage-based systems include a similar range of inputs. The high input system (CS4) uses herbicides and solo seeded alfalfa in the establishment year and insects are treated if thresholds are reached. After two full hay production years, the alfalfa is killed with fall-applied glyphosate, fall chisel plowing is done, and corn is planted for one year. In the corn phase, conventional herbicide rates and cultivation are used to control the weeds. In the moderate input forage system (CS5), alfalfa is seeded with oats and this mixture is harvested as oatlage. After one full hay production year, the alfalfa is fall chisel plowed (using sweeps), and corn is planted for one year. No herbicides or other purchased inputs are used in the corn year so weeds are managed with delayed planting, rotary hoeing and cultivation as needed. The lowest input system (CS6) is a permanent pasture managed with intensive rotational grazing by dairy heifers. We monitor the weed seed bank at both trial locations.

#### Weed Monitoring Methods

The weed seed bank is monitored annually by counting weed seedlings that germinate in soil collected from selected plots early in the spring. Currently we take four subsamples of soil per plot, each consisting of eight 0.75-inch diameter cores taken to a 6-inch depth (approximately 1.0 to 1.3 lb of soil per subsample). The soil is mixed with an equal weight of silica sand, placed in 8- by 12-inch plastic trays (giving a 0.75- to 1-inch soil depth) in the greenhouse, and automatically subirrigated daily. Weed seedlings are counted and identified as they emerge through three germination cycles from May to September and the number of seedlings per square foot is

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calculated. The sampling strategy is to sample all plots that have been in corn the previous year because this is a common crop in 13 of the 14 cropping sequences. The permanent pasture is sampled every fourth year. Additional plots were sampled through 1996 to more closely follow seed bank changes following the red clover cover crop and forages in these systems. Weed seed banks are grouped into relative population categories as follows:

| Relative Seriousness | Weed Seed Bank (seeds/ft <sup>2</sup> ) | Weed Biomass (lb dry wt/a) |
|----------------------|-----------------------------------------|----------------------------|
| Low                  | <400                                    | < 50                       |
| Moderate             | 401-800                                 | 51-100                     |
| High                 | 801-1200                                | 101-200                    |
| Severe               | >1200                                   | >200                       |

The weed biomass present in the corn and soybean plots has been measured annually from 1992 to 1997 by cutting all weeds taller than 4 inches in nine 5- by 5-ft randomly selected areas when corn is approximately 36 inches tall (typically early to mid July). Weeds are oven-dried and weighed and pounds of weeds per acre and the percentage of grasses and broadleaves are calculated. The relative seriousness of weed biomass is categorized in the above table.

### Weed Seed Bank Results

Data is collected for individual species but these data have not been thoroughly analyzed to see if species shifts have occurred. Field and data observations do not suggest, however, that shifts have occurred. The data presented in Tables 1 and 2 include the common broadleaves of common lambsquarters, pigweed species, velvetleaf, eastern black nightshade, common ragweed, smartweed species, and shepherd's purse. The common grasses are yellow, green, and giant foxtail; barnyardgrass; fall panicum and large crabgrass.

#### Cash grain-based cropping systems

Weed populations in continuous corn vary between sites and years, but the overall trend is **that seed banks are low and holding steady** at both locations in this input intensive system. The exception was the LAC site in 1998 where seed populations increase to the high end of the moderate level. This follows a relatively high weed biomass for this system at the LAC in 1997. Broadleaf species predominate at both locations. However, the LAC site has averaged 28% grass weed seeds (Tables 1 and 2).

The seed bank populations in the corn-soybean cropping system (CS2) have **been low to moderate** with some fluctuation from year to year. The higher than expected numbers at ARS in 1994 and LAC in 1995 correspond to relatively high weed biomass the previous year. This system has been completely no-till since 1994. To date there is no clear pattern in the relative importance of broadleaf and grassy weeds.

The weed management strategy in the soybean-wheat/red clover/corn system (CS3) of rotating a vigorously growing cool season crop sequence (wheat/red clover) with timely mechanical weeding in the two warm season crops (corn and soybeans) has seen the weed seed population drop in the 1996 measurements and rise to generally moderate levels in 1997 and 1998. This is directly related to the poor annual weed control in the corn phase of this system in 1996 and 1997 (see biomass data for treatment 6 in 1996 and treatment 4 in 1997 in Table 3). Seed numbers have been also high to severe in other years and phases of this system.

It appears that we are generally through the "transition phase" of this system as 1) the mechanical weeding skills and timings of rotary hoeing and cultivation have improved and 2) we are getting better stands of corn and soybeans. The beneficial effects of wheat and red clover with weeds during the "sod" phase of this system are not clearly evident, especially in the corn that follows the red clover. No clear trend is evident in the relative importance of grassy and broadleaf species in this system, but in general, grasses have remained steady or increased.

**It is intriguing to note that we consistently succeed in mechanical weeding soybeans in this system and struggle to succeed in corn.** This negates the argument that untimely rains prevented opportune weeding. Part of the weed pressure in the corn phase is due to annual grasses going to seed in the red clover after wheat harvest. Another aid to better weed suppression in the wide-row soybeans versus corn at the same row spacing is the excellent soybean stand we are achieving. The rotary hoeings kill the early emerging grasses and then crop competition stays ahead of later emerging flushes. Corn appears to be less competitive in this regard.

#### Forage-based cropping systems

Weed seed populations following corn treated with herbicide in the **high input alfalfa-corn system (CS4) are relatively low** at both sites though soil samples are taken in the spring after manure has been applied in the fall. Broadleaf weeds predominate in most of the sampling times at both sites. This system shows the speed with which weed seed populations can fluctuate in the soil. Seed populations are usually in the low category but have spiked to moderate and high levels on occasion.

Weed seed populations in the rapid turn around **oats-alfalfa-corn system (CS5) have generally been in the moderate level but since 1996 are usually in the low category.** Improved rotary hoeing, cultivating skills, and harvesting the oats as oatlage have helped suppress weed populations at both sites. Broadleaves have always predominated in ARS but the proportion of grasses increased after 1995. Species composition varies greatly between phases of this system at the LAC but since 1996 broadleaf weeds comprise 66 to 94% of the total seed bank population.

The continuous pasture system (CS6) has low to moderate weed seed densities at both sites and the populations are essentially the same as when the trial started in 1990. This is not surprising because annual weeds have little opportunity to become established and to produce seed in this system for two reasons. First, the permanent cover of forage species dominates the landscape so that weeds that need either light, tillage, or open space to germinate do not receive

the proper environmental conditions. Secondly, the frequent grazing intensity results in very close grazing of plants that are young, tender, and readily consumed by the heifers so that any weeds that did germinate would probably be eaten.

In summary, the weed seed bank populations in the high- and moderate-input cash grain systems (CS1 and CS2) are relatively low to moderate and broadleaves generally comprise more than 70% of the population. Populations in the mechanically weeded cash grain system (CS3) are generally steady or increasing, due perhaps to seed bank increases in the red clover. Grasses are becoming the dominant weed type in most phases of this system, especially at LAC. In the high input livestock-based system (CS4), seed bank populations vary by phase of the system and site, but are generally low. Broadleaf species predominate at both sites. In the organic crop-livestock systems (CS5), seed bank populations are generally low. Unlike the organic cash grain system (CS3), broadleaf species predominate in the organic forage system.

Table 4 summarizes the weed seed bank data by grouping the results over the initial (1990-92), mid (1993-95) and later years (1996-98) of the trials for both locations. In the cash grain systems, weed seed densities have increased in CS1, are held steady in CS2, and increased considerably and then decreased for CS3. In the forage-based systems, weed seed populations have decreased for all systems when we compare the early and later year periods. **This reemphasizes the fact that successful mechanical weed management is more easily attained in forage-based systems than in cash grain systems (CS3 vs. CS5) and that a well managed forage-based system prevents weed seed bank increases.**

Part of the improved weed management over time is due to the famed "learning curve" required to master the techniques of mechanically weeding in the absence of herbicide use and part is due to the rotation effect that should be present at this stage of the trials. Because the human element is similar across all systems, it appears that the forage-based systems offer more advantages to managing annual weeds mechanically than cash-grain based systems. The percentage of broadleaf weeds in the seed bank differs between locations, with more at ARS than at LAC (Table 5). This difference has narrowed over time, especially for the forage systems (CS4 and CS5) where the LAC has more broadleaf weeds than the ARS.

### Weed Biomass Results

Weed biomass has been low in the continuous corn system (CS1) and in the low to moderate categories in the corn-soybean system (CS2) except in 1992 when it reached high levels at both locations for treatment 3 (Table 3). Wide variations between predominance of broadleaves and grasses have occurred at both sites, often from one year to the next. However, because the weed biomass is often less than 20 lb/acre in these systems, caution must be used in giving much significance to these rapid changes in percentage composition of escaping weeds.

In the low-input cash grain system (CS3), weed biomass has reached high and severe levels most often at Arlington, especially in corn. Very dramatic differences sometimes occur. Note the severe level of weeds (299 lb/acre) in corn (treatment 6) in the system at Arlington in 1996 and treatment 4 (237 lb/a) in 1997. Soybeans (treatment 5) in the same system planted the same day and mechanically weeded at the same times averaged only 17 lb/acre of weeds and 34 lb/acre in

1997. To what extent this difference is due to previous crop and how much to differences in the seed bank (or to other factors or a combination of many factors) is subject to debate. Given the rainy conditions of 1996 at the time most mechanical weedings needed to be performed, the success of weeding the soybeans is remarkable; the severe level of grass weed pressure in the corn is easier to explain. Cool early season conditions in 1997 reduced corn vigor, especially at ARS, allowing escaping and later emerging weeds less competition than under more favorable weather.

The weed biomass in corn in the forage-based systems has always been low in the high input system (CS4, treatments 7-10) and has ranged from low to severe in the mechanically weeded system (CS5, treatments 11-13). An interesting comparison is the corn in treatments 6 and 12 at Arlington in 1996 and treatments 4 and 13 in 1997; both are mechanically weeded and we had severe levels of weed biomass in the cash-grain system and low to moderate levels in the forage-based system. This is consistent with the observation in these studies and others that annual grasses are less serious the first year following a forage crop than in annual cropping systems.

### Superimposed Trial Results

From 1994 to 1997, we treated small areas in the border rows of corn and soybeans in the organic system, CS3, to determine if herbicide use would increase crop yields and be a profitable decision. The results are summarized in Table 6. No applications were done at Arlington in 1995 because both CS3 corn and soybeans were very weed-free. Nor were treatments made at LAC in 1996 because crops were planted so late. The last column shows that for several cropping seasons at either location it would have been profitable to use herbicides to control escaping weeds in CS3. This was true in three of six site-years for corn and five of six site-years for soybeans.

Growers who do not produce organic crops can certainly make decisions at the time of the first cultivation to treat with post-emergence herbicides or not. This decision is not difficult to make. It was rather obvious at the time of herbicide application whether or not a profitable response would be observed. Non-organic growers could simply use the rule of thumb of "when in doubt, leave it out" in terms of herbicide use in this system. Additional cost savings were gained in this system in 1997 by using a banded post-emergence application. We applied the appropriate herbicides for the weeds present in a 15-inch band, cutting the herbicide cost by 50%. If this had not been done, treating soybeans at ARS this year would not have been profitable.

### Overall Summary

Weed seed banks are dynamic. Populations can change significantly (either increasing or decreasing) in only a few years. **Widest fluctuations in both weed banks and biomass occur in mechanically weeded cash grain systems. The forage-based mechanically weeded systems are more stable and have fewer annual grasses than the corresponding cash-grain system.** The best of both worlds (good yields with reduced herbicide use) would be forage-based systems that use a post-emergence broadleaf herbicide followed by cultivation, or the judicious use of post-emergence herbicides, on an as-needed basis, in the cash grain system.

Table 1. Weed seed bank changes in WICST at the Arlington Agricultural Research Station from 1990-1998.

| Trt | Cropping System | Seed bank variable    | 90     | 91     | 92      | 93     | 94     | 95     | 96     | 97     | 98     |
|-----|-----------------|-----------------------|--------|--------|---------|--------|--------|--------|--------|--------|--------|
| 1   | C               | Seeds/ft <sup>2</sup> | C 448  | C 166  | C 206   | C 266  | C 171  | C      | C 362  | C 262  | C 367  |
|     |                 | % brdlf               | 86     | 84     | 87      | 86     | 81     | --     | 92     | 97     | 79     |
|     |                 | % grass               | 14     | 16     | 13      | 14     | 49     | --     | 8      | 3      | 21     |
| 2   | C-S             | Seeds/ft <sup>2</sup> | FC     | S 144  | C       | S 215  | C      | S 283  | C      | S 209  | C      |
|     |                 | % brdlf               | --     | 70     | --      | 86     | --     | 93     | --     | 95     | --     |
|     |                 | % grass               | --     | 30     | --      | 14     | --     | 7      | --     | 5      | --     |
| 3   | S-C             | Seeds/ft <sup>2</sup> | S 429  | C 480  | S 571   | C      | S 1057 | C      | S 267  | C      | S 542  |
|     |                 | % brdlf               | 75     | 73     | 78      | --     | 88     | --     | 96     | --     | 88     |
|     |                 | % grass               | 25     | 27     | 22      | --     | 12     | --     | 4      | --     | 12     |
| 4   | W/Rc-C-S        | Seeds/ft <sup>2</sup> | FC     | FC     | S 1046  | W/Rc   | C 714  | S 477  | W/Rc   | C      | S 593  |
|     |                 | % brdlf               | --     | --     | 88      | --     | 64     | 51     | --     | --     | 21     |
|     |                 | % grass               | --     | --     | 12      | --     | 36     | 49     | --     | --     | 79     |
| 5   | W/Rc-C-S        | Seeds/ft <sup>2</sup> | S 206  | W 459  | C 894   | S 850  | W      | C      | S 339  | W      | C      |
|     |                 | % brdlf               | 68     | 80     | 85      | 83     | --     | --     | 95     | --     | --     |
|     |                 | % grass               | 32     | 20     | 15      | 17     | --     | --     | 5      | --     | --     |
| 6   | C-S-W/Rc        | Seeds/ft <sup>2</sup> | FC     | S 703  | W       | C 1079 | S 1005 | W      | C      | S 1301 | W      |
|     |                 | % brdlf               | --     | 88     | --      | 67     | 43     | --     | --     | 13     | --     |
|     |                 | % grass               | --     | 12     | --      | 33     | 57     | --     | --     | 87     | --     |
| 7   | A-A-A-C         | Seeds/ft <sup>2</sup> | A 472  | A 264  | A       | C      | A 239  | A      | A      | C      | A 303  |
|     |                 | % brdlf               | 82     | 81     | --      | --     | 93     | --     | --     | --     | 57     |
|     |                 | % grass               | 18     | 19     | --      | --     | 7      | --     | --     | --     | 43     |
| 8   | A-A-A-C         | Seeds/ft <sup>2</sup> | FC     | A 288  | A       | A      | C 1144 | A 346  | A      | A      | C      |
|     |                 | % brdlf               | --     | 59     | --      | --     | 99     | 96     | --     | --     | --     |
|     |                 | % grass               | --     | 41     | --      | --     | 1      | 4      | --     | --     | --     |
| 9   | A-A-A-C         | Seeds/ft <sup>2</sup> | FC     | FC     | A 584   | A      | A      | C 272  | A 210  | A      | A      |
|     |                 | % brdlf               | --     | --     | 90      | --     | --     | 94     | 83     | --     | --     |
|     |                 | % grass               | --     | --     | 10      | --     | --     | 6      | 17     | --     | --     |
| 10  | A-A-A-C         | Seeds/ft <sup>2</sup> | FC     | FC     | FC 720  | A 269  | A      | A      | C 373  | A 176  | A      |
|     |                 | % brdlf               | --     | --     | 93      | 88     | --     | --     | 60     | 86     | --     |
|     |                 | % grass               | --     | --     | 7       | 12     | --     | --     | 40     | 14     | --     |
| 11  | O/a-A-C         | Seeds/ft <sup>2</sup> | Oa 444 | A 755  | C 692   | Oa 339 | A      | C 391  | Oa 214 | A      | C      |
|     |                 | % brdlf               | 82     | 64     | 91      | 95     | --     | 77     | 63     | --     | --     |
|     |                 | % grass               | 18     | 36     | 9       | 5      | --     | 23     | 37     | --     | --     |
| 12  | O/a-A-C         | Seeds/ft <sup>2</sup> | FC     | Oa 546 | A       | C 506  | Oa 462 | A      | C 591  | Oa 397 | A      |
|     |                 | % brdlf               | --     | 82     | --      | 88     | 86     | --     | 57     | 58     | --     |
|     |                 | % grass               | --     | 18     | --      | 12     | 14     | --     | 43     | 42     | --     |
| 13  | O/a-A-C         | Seeds/ft <sup>2</sup> | FC     | FC     | Oa 1198 | A      | C 321  | Oa 279 | A      | C      | Oa 219 |
|     |                 | % brdlf               | --     | --     | 86      | --     | 90     | 83     | --     | --     | 77     |
|     |                 | % grass               | --     | --     | 14      | --     | 10     | 17     | --     | --     | 23     |
| 14  | Pasture         | Seeds/ft <sup>2</sup> | P 386  | P 401  | P       | P      | P      | P 383  | P 601  | P      | P      |
|     |                 | % brdlf               | 82     | 75     | --      | --     | --     | 89     | 73     | --     | --     |
|     |                 | % grass               | 18     | 25     | --      | --     | --     | 11     | 27     | --     | --     |

<sup>1</sup> Crop abbreviations: C = corn; S = soybean; Wh = wheat; Rc = red clover; FC = filler corn; A = alfalfa; O = oat

Table 2. Weed seed bank changes in WICST at the Lakeland Agricultural Complex from 1990 - 1998.

| Trt | Cropping System | Seed bank variable    | 90     | 91    | 92     | 93     | 94     | 95     | 96     | 97     | 98     |
|-----|-----------------|-----------------------|--------|-------|--------|--------|--------|--------|--------|--------|--------|
| 1   | C               | Seeds/ft <sup>2</sup> | C 190  | C 68  | C 152  | C 310  | C 361  | C      | C 141  | C 321  | C 736  |
|     |                 | % brdlf               | 87     | 72    | 80     | 74     | 56     | --     | 71     | 78     | 62     |
|     |                 | % grass               | 13     | 28    | 20     | 26     | 44     | --     | 29     | 22     | 38     |
| 2   | C - S           | Seeds/ft <sup>2</sup> | C      | S 22  | C      | S 206  | C      | S 515  | C      | S 537  | C      |
|     |                 | % brdlf               | --     | 50    | --     | 50     | --     | 49     | --     | 31     | --     |
|     |                 | % grass               | --     | 50    | --     | 50     | --     | 51     | --     | 69     | --     |
| 3   | S - C           | Seeds/ft <sup>2</sup> | S 193  | C 174 | S 106  | C      | S 131  | C      | S 459  | C      | S 201  |
|     |                 | % brdlf               | 28     | 22    | 51     | --     | 77     | --     | 27     | --     | 70     |
|     |                 | % grass               | 72     | 78    | 49     | --     | 23     | --     | 73     | --     | 30     |
| 4   | W/Rc-C-S        | Seeds/ft <sup>2</sup> | FC     | FC    | S 570  | W/Rc   | C 275  | S 422  | W/Rc   | C      | S 784  |
|     |                 | % brdlf               | --     | --    | 33     | --     | 70     | 66     | --     | --     | 29     |
|     |                 | % grass               | --     | --    | 67     | --     | 30     | 34     | --     | --     | 71     |
| 5   | W/Rc-C-S        | Seeds/ft <sup>2</sup> | S 196  | W 328 | C 1117 | S 1288 | W      | C      | S 613  | W      | C      |
|     |                 | % brdlf               | 42     | 7     | 42     | 44     | --     | --     | 32     | --     | --     |
|     |                 | % grass               | 58     | 93    | 58     | 56     | --     | --     | 68     | --     | --     |
| 6   | C-S-W/Rc        | Seeds/ft <sup>2</sup> | FC     | S 81  | W      | C 272  | S 1570 | W      | C      | S 772  | W      |
|     |                 | % brdlf               | --     | 47    | -      | 63     | 21     | --     | --     | 19     | --     |
|     |                 | % grass               | --     | 53    | --     | 37     | 79     | --     | --     | 81     | --     |
| 7   | A-A-A-C         | Seeds/ft <sup>2</sup> | A 236  | A 956 | A      | C      | A 315  | A      | A      | C      | A 400  |
|     |                 | % brdlf               | 47     | 14    | --     | --     | 84     | --     | --     | --     | 82     |
|     |                 | % grass               | 53     | 86    | --     | --     | 16     | --     | --     | --     | 18     |
| 8   | A-A-A-C         | Seeds/ft <sup>2</sup> | FC     | A 68  | A      | A      | C 228  | A 155  | A      | A      | C      |
|     |                 | % brdlf               | --     | 68    | --     | --     | 96     | 96     | --     | --     | --     |
|     |                 | % grass               | --     | 32    | --     | --     | 4      | 4      | --     | --     | --     |
| 9   | A-A-A-C         | Seeds/ft <sup>2</sup> | FC     | FC    | A 117  | A      | A      | C 202  | A 179  | A      | A      |
|     |                 | % brdlf               | --     | --    | 65     | --     | --     | 96     | 90     | --     | --     |
|     |                 | % grass               | --     | --    | 35     | --     | --     | 4      | 10     | --     | --     |
| 10  | A-A-A-C         | Seeds/ft <sup>2</sup> | FC     | FC    | FC 125 | A 380  | A      | A      | C 321  | A 298  | A      |
|     |                 | % brdlf               | --     | --    | 63     | 46     | --     | --     | 90     | 77     | --     |
|     |                 | % grass               | --     | --    | 37     | 54     | --     | --     | 10     | 23     | --     |
| 11  | O/a-A-C         | Seeds/ft <sup>2</sup> | Oa 307 | A 646 | C 454  | Oa 587 | A      | C 194  | Oa 214 | A      | C      |
|     |                 | % brdlf               | 28     | 11    | 31     | 46     | --     | 85     | 76     | --     | --     |
|     |                 | % grass               | 72     | 89    | 69     | 54     | --     | 15     | 24     | --     | --     |
| 12  | O/a-A-C         | Seeds/ft <sup>2</sup> | FC     | Oa 92 | A      | C 112  | Oa 625 | A      | C 141  | Oa 214 | A      |
|     |                 | % brdlf               | --     | 47    | --     | 88     | 19     | --     | 66     | 77     | --     |
|     |                 | % grass               | --     | 53    | --     | 12     | 81     | --     | 34     | 23     | --     |
| 13  | O/a-A-C         | Seeds/ft <sup>2</sup> | FC     | FC    | Oa 462 | A      | C 206  | Oa 251 | A      | C      | Oa 321 |
|     |                 | % brdlf               | --     | --    | 25     | --     | 64     | 57     | --     | --     | 94     |
|     |                 | % grass               | --     | --    | 75     | --     | 36     | 43     | --     | --     | 6      |
| 14  | Pasture         | Seeds/ft <sup>2</sup> | P 136  | P 951 | P      | P      | P      | P 171  | P 106  | P      | P      |
|     |                 | % brdlf               | 50     | 7     | --     | --     | --     | 77     | 76     | --     | --     |
|     |                 | % grass               | 50     | 93    | --     | --     | --     | 23     | 24     | --     | --     |

<sup>1</sup> Crop abbreviations: C = corn; S = soybean; Wh = wheat; Rc = red clover; FC = filler corn; A = alfalfa; O = oat

**Table 3. Weed biomass dry weight and percentage broadleaf & grass weeds in the WICST trials in early July at the Arlington Agricultural Research Station & the Lakeland Agricultural Complex 93-97.**

| Tri | Year/Crop system <sup>1</sup> |         | ARS |     |    |     |     | LAC |     |     |    |    |
|-----|-------------------------------|---------|-----|-----|----|-----|-----|-----|-----|-----|----|----|
|     |                               |         | 93  | 94  | 95 | 96  | 97  | 93  | 94  | 95  | 96 | 97 |
| 1   | 93-4-5-6-7<br>c-c-c-c-c       | lb/acre | 2   | 10  | 8  | 8   | 32  | <1  | 2   | 2   | 26 | 47 |
|     |                               | % bdlf  | 72  | 90  | 96 | 100 | 90  | 0   | 25  | 92  | 88 | 66 |
|     |                               | % grass | 28  | 10  | 4  | 0   | 10  | 100 | 75  | 8   | 12 | 34 |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |
| 2   | s-c-s-c-s                     | lb/acre | 12  | 2   | 4  | 1   | 51  | 19  | 59  | -   | 9  | 6  |
|     |                               | % bdlf  | 77  | 85  | 26 | 100 | 100 | 90  | 40  | -   | 15 | 77 |
|     |                               | % grass | 33  | 15  | 74 | 0   | 0   | 10  | 60  | -   | 85 | 23 |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |
| 3   | c-s-c-s-c                     | lb/acre | 4   | 2   | 85 | 26  | 28  | 3   | 9   | 28  | 17 | 26 |
|     |                               | % bdlf  | 48  | 0   | 22 | 83  | 66  | 96  | 95  | 27  | 3  | 89 |
|     |                               | % grass | 52  | 100 | 78 | 17  | 34  | 4   | 5   | 73  | 97 | 11 |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |
| 4   | wr-c-s-wr-c                   | lb/acre | -   | 255 | 25 | -   | 237 | -   | 117 | 10  | -  | 85 |
|     |                               | % bdlf  | -   | 75  | 11 | -   | 20  | -   | 83  | 26  | -  | 38 |
|     |                               | % grass | -   | 25  | 89 | -   | 80  | -   | 17  | 74  | -  | 62 |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |
| 5   | s-wr-c-s-wr                   | lb/acre | 44  | -   | 31 | 17  | -   | 44  | -   | 145 | 2  | -  |
|     |                               | % bdlf  | 88  | -   | 70 | 79  | -   | 31  | -   | 11  | 14 | -  |
|     |                               | % grass | 12  | -   | 30 | 21  | -   | 69  | -   | 89  | 86 | -  |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |
| 6   | c-s-wr-c-s                    | lb/acre | 161 | 157 | -  | 231 | 34  | 160 | 96  | -   | 60 | 82 |
|     |                               | % bdlf  | 19  | 47  | -  | 29  | 29  | 28  | 11  | -   | 6  | 7  |
|     |                               | % grass | 81  | 53  | -  | 71  | 71  | 72  | 89  | -   | 94 | 93 |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |
| 7   | c-a-a-a-c                     | lb/acre | 13  | -   | -  | -   | 22  | 18  | -   | -   | -  | 30 |
|     |                               | % bdlf  | 21  | -   | -  | -   | 90  | 76  | -   | -   | -  | 57 |
|     |                               | % grass | 79  | -   | -  | -   | 10  | 24  | -   | -   | -  | 43 |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |
| 8   | a-c-a-a-a                     | lb/acre | -   | 6   | -  | -   | -   | -   | 12  | -   | -  | -  |
|     |                               | % bdlf  | -   | 85  | -  | -   | -   | -   | 85  | -   | -  | -  |
|     |                               | % grass | -   | 15  | -  | -   | -   | -   | 15  | -   | -  | -  |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |
| 9   | a-a-c-a-a                     | lb/acre | -   | -   | 9  | -   | -   | -   | -   | 70  | -  | -  |
|     |                               | % bdlf  | -   | -   | 4  | -   | -   | -   | -   | 70  | -  | -  |
|     |                               | % grass | -   | -   | 96 | -   | -   | -   | -   | 30  | -  | -  |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |
| 10  | a-a-a-c-a                     | lb/acre | -   | -   | -  | 2   | -   | -   | -   | -   | 42 | -  |
|     |                               | % bdlf  | -   | -   | -  | 29  | -   | -   | -   | -   | 87 | -  |
|     |                               | % grass | -   | -   | -  | 71  | -   | -   | -   | -   | 13 | -  |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |
| 11  | o/a-a-c-o/a-a                 | lb/acre | -   | -   | 29 | -   | -   | -   | -   | 130 | -  | -  |
|     |                               | % bdlf  | -   | -   | 70 | -   | -   | -   | -   | 61  | -  | -  |
|     |                               | % grass | -   | -   | 30 | -   | -   | -   | -   | 39  | -  | -  |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |
| 12  | c-o/a-a-c-o/a                 | lb/acre | 46  | -   | -  | 16  | -   | 36  | -   | -   | 2  | -  |
|     |                               | % bdlf  | 50  | -   | -  | 34  | -   | 57  | -   | -   | 34 | -  |
|     |                               | % grass | 50  | -   | -  | 66  | -   | 43  | -   | -   | 66 | -  |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |
| 13  | a-c-o/a-a-c                   | lb/acre | -   | 131 | -  | -   | 57  | -   | 201 | -   | -  | 55 |
|     |                               | % bdlf  | -   | 90  | -  | -   | 90  | -   | 67  | -   | -  | 98 |
|     |                               | % grass | -   | 10  | -  | -   | 10  | -   | 33  | -   | -  | 2  |
|     |                               |         |     |     |    |     |     |     |     |     |    |    |

<sup>1</sup> Crop abbreviations: c = corn; s = soybean; w = wheat; r = red clover; a = alfalfa; o = oat

**Table 4. Summary of weed seed bank densities when grouped over certain periods of years and averaged over both sites.**

| Cropping system            | 1990-92                                                  | 1993-95 | 1996-98 |
|----------------------------|----------------------------------------------------------|---------|---------|
|                            | (seed bank population, number of seeds/ft <sup>2</sup> ) |         |         |
| CS1: Continuous Corn       | 205                                                      | 277     | 355     |
| CS2: Corn-soybean          | 244                                                      | 401     | 370     |
| CS 3: Corn-soyb-wh/r cl    | 467                                                      | 935     | 728     |
| CS 4: Alfalfa (3)-corn     | 294                                                      | 281     | 254     |
| CS 5: Oat/alfalfa-alf-corn | 508                                                      | 436     | 254     |
| CS 6: Permanent pasture    | 468                                                      | 272     | 350     |

**Table 5. The percentage of broadleaf weed seedlings found in the weed seed bank populations when grouped over certain periods of years.**

| Cropping system            | 1990-92                               |     | 1993-95 |     | 1996-98 |     |
|----------------------------|---------------------------------------|-----|---------|-----|---------|-----|
|                            | ARL                                   | LAC | ARL     | LAC | ARL     | LAC |
|                            | (% broadleaf weeds in weed seed bank) |     |         |     |         |     |
| CS1: Continuous corn       | 86                                    | 80  | 83      | 65  | 89      | 70  |
| CS2: Corn-soybean          | 74                                    | 43  | 89      | 59  | 93      | 43  |
| CS 3: Corn-soyb-wh/r cl    | 81                                    | 41  | 59      | 44  | 43      | 27  |
| CS 4: Alfalfa(3)-corn      | 77                                    | 60  | 92      | 75  | 75      | 83  |
| CS 5: Oat/alfalfa-alf-corn | 83                                    | 33  | 88      | 41  | 66      | 82  |
| CS 6: Permanent pasture    | 78                                    | 28  | 89      | 77  | 73      | 76  |

|                         |    |    |    |    |    |    |
|-------------------------|----|----|----|----|----|----|
| Avg for treatments 1-3: | 80 | 55 | 77 | 56 | 75 | 47 |
| Avg for treatments 4-5: | 80 | 46 | 90 | 58 | 70 | 82 |
| Avg for treatments 1-5: | 80 | 51 | 82 | 57 | 73 | 61 |

Table 6. Summary of response to controlling weeds in superimposed trials in CS3 from 1994 - 1997.

| Year | Location | Crop    | Yield, Bu/acre |        |                       | Profit (loss)        |
|------|----------|---------|----------------|--------|-----------------------|----------------------|
|      |          |         | no herb.       | + herb | % change <sup>1</sup> | \$/acre <sup>2</sup> |
| 1994 | ARL      | corn    | 186            | 201    | +8                    | .50                  |
| 1994 | LAC      | corn    | 179            | 202    | +13                   | 15.00                |
| 1994 | ARL      | soybean | 45             | 52     | +15                   | 21.75                |
| 1994 | LAC      | soybean | 41             | 58     | +41                   | 68.65                |
| 1995 | LAC      | corn    | 142            | 152    | +7                    | 1.55                 |
| 1995 | LAC      | soybean | 53             | 58     | +9                    | 14.80                |
| 1996 | ARL      | corn    | 76             | 107    | +41                   | 52.30                |
| 1996 | ARL      | soybean | 48             | 50     | +6                    | (14.30)              |
| 1997 | ARL      | corn    | 146            | 151    | +3                    | (5.60)               |
| 1997 | ARL      | soybean | 45             | 48     | +8                    | 6.10                 |
| 1997 | LAC      | corn    | 153            | 190    | +24                   | 73.80                |
| 1997 | LAC      | soybean | 44             | 52     | +18                   | 35.75                |

<sup>1</sup> Change as compared to no-herbicide system.

<sup>2</sup> Herbicides were broadcast applied in 1994-1996 and were band-applied (15-in) in 1997. The costs include the herbicide, any additives, and the application. Crop prices at the time of harvest were used to determine the value of the yield in treated and non-treated plots.

#### 4. WICST Intensive Rotational Grazing of Dairy Heifers in 1997 and 1998

Janet Riesterer<sup>1</sup>, Sandy Trower<sup>2</sup>, Scott Alt<sup>3</sup>, and Dan Undersander<sup>4</sup>

##### Introduction

Of the three dairy systems represented in the Wisconsin Integrated Cropping Systems Trial (WICST), rotational grazing is the lowest input system. Pastures were established at the Lakeland Agricultural Complex (LAC) and the Arlington Agricultural Research Station (ARS) in 1990. 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 every year at a reduced rate at both sites. 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. At LAC, the fall seeding of 1996 failed and there was no grass seeding there until the fall of 1997. Heavy red clover seeding rate of 1998 was to account for poor pasture conditions.

Table 1. WICST rotational grazing seeding dates and rates.

| year | Lakeland Ag Complex |                      |           | Arlington Ag Research Station |                                   |           |
|------|---------------------|----------------------|-----------|-------------------------------|-----------------------------------|-----------|
|      | Date                | species              | (lb/acre) | date                          | species                           | (lb/acre) |
| 1990 | 30-May              | Marathon red clover  | 6.1       | 23-Apr                        | Marathon red clover               | 7.0       |
|      |                     | Smooth Brome grass   | 3.0       |                               | Smooth Brome grass                | 8.0       |
|      |                     | Timothy              | 3.5       |                               | Timothy                           | 4.0       |
| 1992 |                     |                      |           | 30-Apr                        | Orchardgrass                      | 6.0       |
|      |                     |                      |           |                               | Brome grass                       | 12.0      |
|      |                     |                      |           |                               | Timothy                           | 6.0       |
|      |                     |                      |           | 31-Jul                        | Orchardgrass                      | 4.5       |
| 1993 | 7-Apr               | Arlington red clover | 20.0      | 9-Apr                         | Arlington red clover              | 12.0      |
| 1995 | 24-Mar              | Arlington red clover | 18.0      | 17-Mar                        | Arlington red clover <sup>†</sup> | 15.0      |
| 1996 | 9-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       |
|      |                     | Orchard grass        | 3.0       |                               |                                   |           |
|      |                     | Arlington red clover | 8.0       |                               |                                   |           |
| 1998 |                     | Arlington red clover | 15.0*     |                               |                                   |           |

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

‡ Reps 1 and 2 only

\* Heavy planting rate due to poor pasture conditions.

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### Pasture Management

Each paddock size was 0.7 acre at ARS and 0.83 acres at LAC. There was no grazing at LAC in 1997 and slow seedling establishment until mid-July delayed the grazing season of 1998. Plots at LAC were clipped on June 6<sup>th</sup> to prevent weeds and grass from going to seed and to create a uniform stand for grazing. Grazing of seven Holstein heifers occurred from July 23<sup>rd</sup> through October 27<sup>th</sup> in 1998 in four rotations among the paddocks.

At the start of grazing at ARS, a control group of six Holstein heifers and the trial group of 10 – 12 Holstein heifers were weighed on a shrunk-weight basis. The control group that would remain in confinement weighed an average of 460 pounds averaged over both years (1997 and 1998). The trial group of 10 – 12 heifers, averaging 500 pounds in both years, was placed in the paddocks and allowed to “flash graze” the entire paddock for one cycle of rotation. We use the flash grazing practice to control some of the spring-growth surge. In this first cycle, the heifers were on each paddock for three to four days. Thereafter, paddocks were divided into smaller sections by the use of temporary electric wire; the heifers were given access to an ungrazed area each day or two. Heifers were rotated weekly, as a group, among the four paddocks. Initially, heifers were supplemented with four pounds of grain per head per day (grain at ARS consisted mostly of cracked corn, oats, and soybean meal; grain at LAC was mostly high moisture barely). At the end of June 1997 and the end of May 1998, grain supplement was decreased to two pounds per head per day.

#### 1997

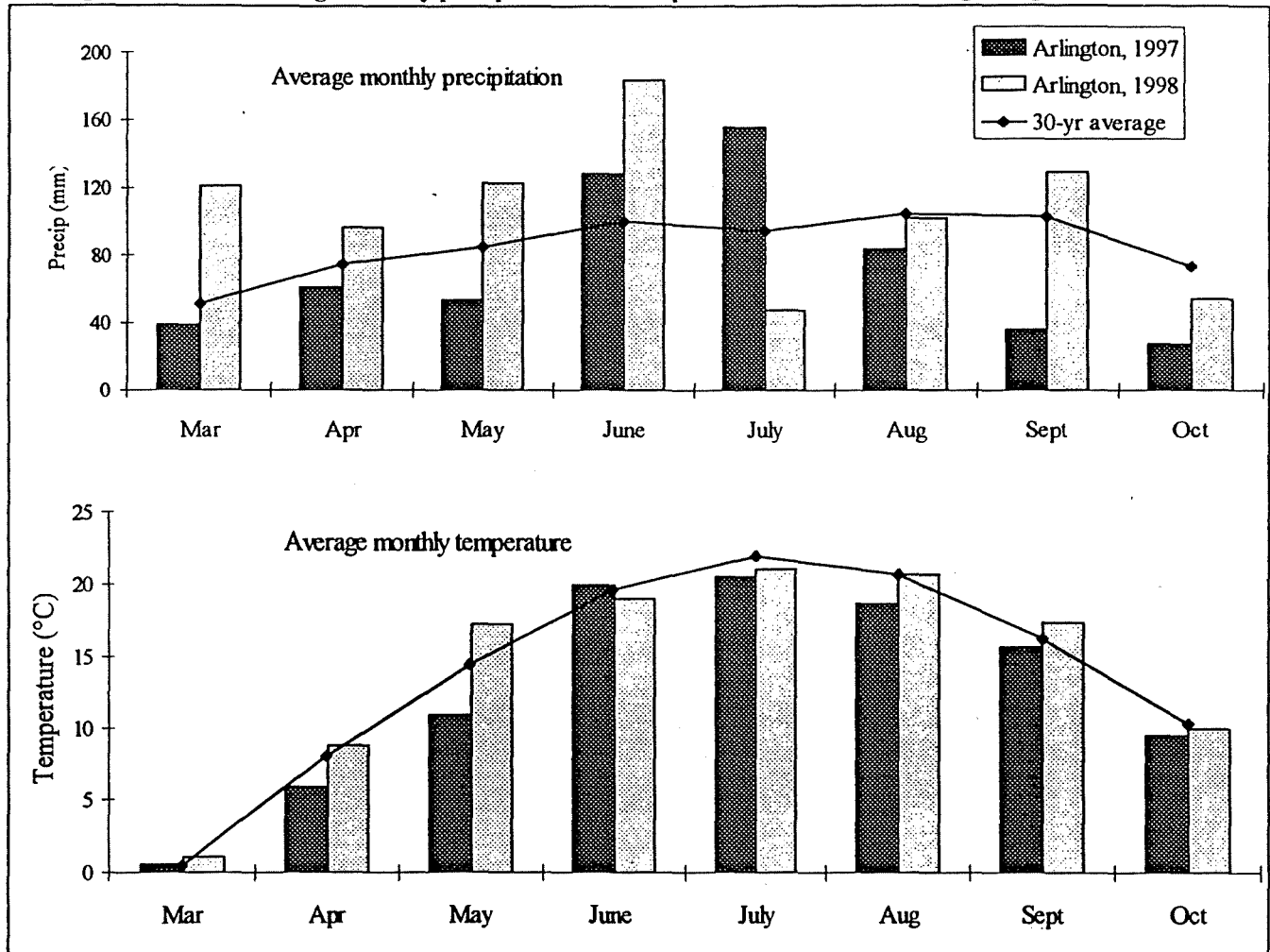
Grazing at ARS occurred from May 12<sup>th</sup> through September 15<sup>th</sup> in 1997 in four rotations among paddocks. Due to the cool, dry spring of 1997 (Figure 1), the grass growth rate was not as fast as anticipated. Therefore, three heifers were removed from the paddocks after the first cycle to slow the rotation. About one week later, three more heifers were removed from the paddocks. By mid-June, rainfall and temperatures were at or above normal and grass growth was faster than the intake of the six heifers. Grasses matured rapidly and one of the paddocks was mechanically harvested. Even though the heifers were rotated in three paddocks for one rotation, the forage was still growing faster than they could consume. Therefore, after heifers had grazed the area, the paddocks were mechanically clipped to remove seed heads and to stimulate vegetative growth. Paddock 2 was stockpiled beginning in early August and used later in the season when it was needed.

#### 1998

In 1998 at ARS, grazing commenced from April 28<sup>th</sup> through September 14<sup>th</sup> in six rotations among the paddocks. Heifers were rotated weekly, as a group, among the four paddocks. Early spring growth in 1998 due to above average rainfall and temperature (Figure 1) supplied ample forage to the heifers. Surplus forage on paddock 3 was harvested as hay on May 06<sup>th</sup> (1.2 tons DM/acre). Post-grazing clipping was necessary in late May and June to remove ungrazed and maturing plants. However, post-grazing clipping was not always done on time, which forced us to put heifers on low quality paddocks which were mature and heading out. Four heifers were removed from the trial between June 09<sup>th</sup> and June 15<sup>th</sup> to accommodate the slower pasture growth. Thirty-five pounds of supplemental hay was provided from June 17<sup>th</sup> to June 22<sup>nd</sup> and

again on August 14<sup>th</sup> to August 22<sup>nd</sup> to slow the heifer rotation and provide a longer rest period for the forage.

**Figure 1. ARS – Average monthly precipitation and temperature in 1997 and 1998 grazing seasons.**



### Animal Data

Mid-season weights were recorded on the six controls and the six animals remaining in the trial group (see Table 2). The heifers that were taken off the trial early were weighed the day after they were removed from the trial (group A and B, Table 2). This group's weight gain (or loss) may be due to stress and poor adjustment to the situation as well as poor forage quality and quantity at the beginning of the trial. The remaining six heifers (group C, Table 2) adapted to the pasture system and the frequent movement with final gains of 1.7 to 1.8 lb/head/day in 1997 and 1998. The control group weight gain averaged 2.2 lb/head/day over both years (group D, Table 2).

Table 2. Weight gain of pasture and confinement animals at Arlington, WI, WICST 1997 and 1998.

| Animal group |   |                           | On pasture |                          | In confinement |                          | Total                    |
|--------------|---|---------------------------|------------|--------------------------|----------------|--------------------------|--------------------------|
| ID           | # | Avg. initial weight (lbs) | # days     | weight gain/day (lb/day) | # days         | weight gain/day (lb/day) | weight gain/day (lb/day) |
| 1997 A       | 3 | 428                       | 17         | (-1.5)                   | 108            | -                        | 2.0*                     |
| B            | 3 | 518                       | 23         | 0.5                      | 102            | -                        | 2.2*                     |
| C            | 6 | 556                       | 125        | 1.8                      | 0              | -                        | 1.8                      |
| D            | 6 | 480                       | 0          | -                        | 125            | 2.1                      | 2.1                      |
| 1998 A       | 2 | 505                       | 42         | 0.4                      | -              | -                        | 0.4**                    |
| B            | 2 | 515                       | 47         | 1.3                      | -              | -                        | 1.3**                    |
| C            | 6 | 487                       | 138        | 1.7                      | 0              | -                        | 1.7                      |
| D            | 6 | 435                       | 0          | -                        | 138            | 2.2                      | 2.2                      |

\* Total weight gain was a combination of pasture and confinement time.

\*\* Total weight gain refers to gain during time on pasture. Final weights while in confinement were not taken.

Due to the failure in seed establishment at LAC in the fall of 1996, there was no heifer performance data taken in the summer of 1997. Table 3 shows the current summary of animal performance at both ARS and LAC from 1992-1998.

Table 3. Summary of animal weight gain for WICST rotational grazing for 1992 – 1998.

| Lakeland Agricultural Complex |                    |                 |                    | Arlington Ag Research Station |                 |                    |
|-------------------------------|--------------------|-----------------|--------------------|-------------------------------|-----------------|--------------------|
| Year                          | Total # of animals | 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              | 1.35               | 8                             | 137             | 1.8                |
|                               | 8                  | 152             | 1.64               |                               |                 |                    |
| 1994                          | 8                  | 178             | 2.02               | 8                             | 120             | 1.6                |
| 1995                          | 8                  | 154             | 1.91               | 8                             | 60              | 0.8                |
| 1996*                         | 3                  | 53              | 1.76               | 4                             | 36              | 1.3                |
|                               | 7                  | 56              | 1.49               | 3                             | 48              | 1.2                |
|                               |                    |                 |                    | 5                             | 134**           | 1.8                |
| 1997                          | -                  | -               | -                  | 3                             | 17              | (-1.5)             |
|                               |                    |                 |                    | 3                             | 23              | 0.5                |
|                               |                    |                 |                    | 6                             | 125             | 1.8                |
| 1998                          | 7                  | 96              | 2.2                | 2                             | 42              | 0.4                |
|                               |                    |                 |                    | 2                             | 47              | 1.3                |
|                               |                    |                 |                    | 6                             | 138             | 1.7                |

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

\*\* Days on pasture includes 6 days in confinement for mid-season shrink weights and deworming.

### Forage Quantity and Quality

Throughout the 1997 trial, weekly forage samples were collected at ARS. The samples represented forage that would be immediately grazed by the heifers. Random areas of the paddocks were sampled using a hand held electric grass shears and a PVC frame with an area of 0.5 square meters. Dry weights were recorded and samples were ground through a 2-mm screen in a Wiley hammer mill. Using NIRS, forage quality was estimated for crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF).

In both years, NDF levels ranged from 40 to 50%; ADF levels ranged from 20 to 32%; and CP levels ranged from 16 to 24% (Figures 2 and 3). Mid-season estimates of quality are reported in Table 4.

**Figure 2. Fiber concentration of forage in rotational grazing pasture system at Arlington, WI (WICST 1997 and 1998 growing seasons).**

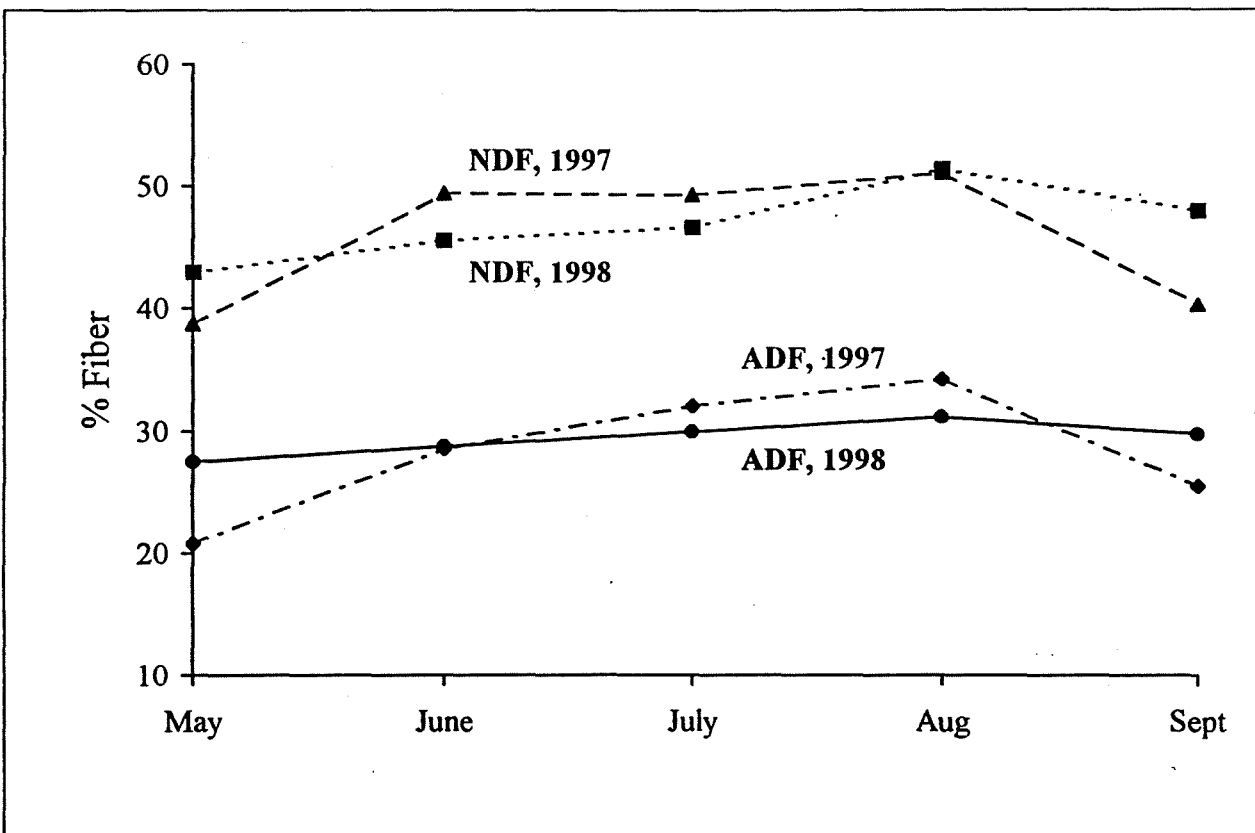


Figure 3. Crude protein concentration of forage in a rotational grazing pasture system at Arlington, WI (WICST 1997 and 1998).

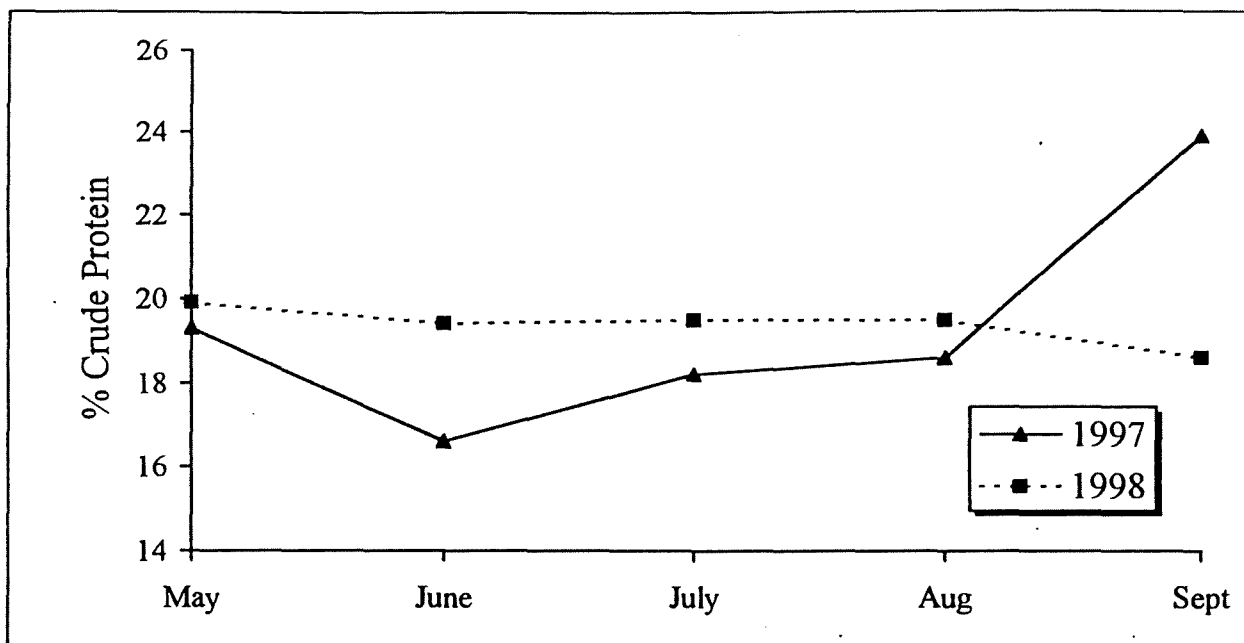


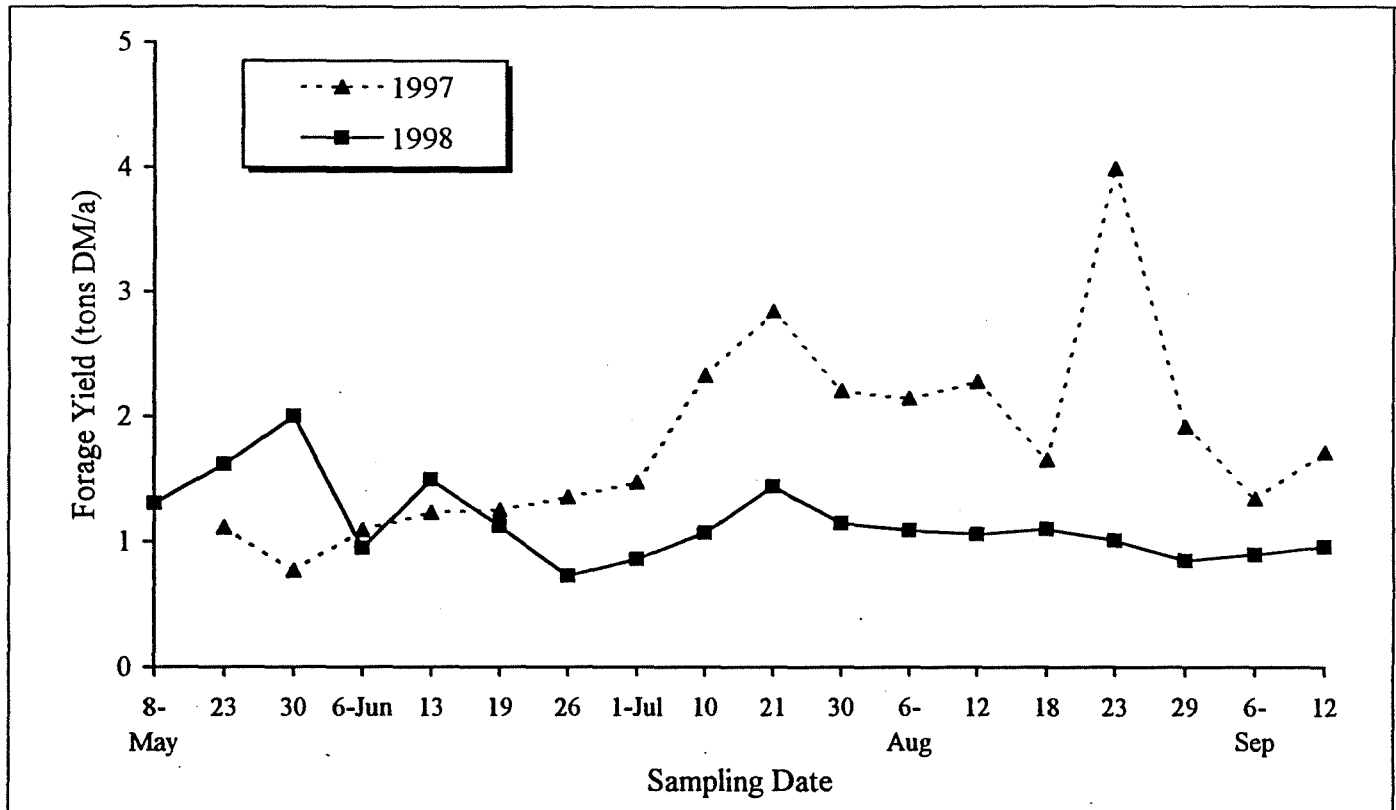
Table 4. Forage quality on WICST rotational grazing pastures for two periods each summer in 1993-1998.

| time period* | Arlington Ag Research Station |       |      | Lakeland Agricultural Complex |       |      |
|--------------|-------------------------------|-------|------|-------------------------------|-------|------|
|              | % ADF                         | % NDF | % CP | % ADF                         | % NDF | % CP |
| 7/1/93       | 28.9                          | 53.4  | 16.9 | 28.9                          | 50.5  | 16.4 |
| 8/1/93       | 32.0                          | 52.6  | 20.1 | 28.2                          | 44.6  | 21.8 |
| 7/1/94       | 31.8                          | 50.9  | 16.7 | 30.3                          | 49.4  | 15.6 |
| 8/1/94       | 31.5                          | 48.2  | 19.7 | 29.0                          | 46.7  | 18.7 |
| 7/1/95       | 35.0                          | 52.4  | 16.6 | 33.6                          | 50.5  | 17.2 |
| 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 | -                             | -     | -    |

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

Forage availability was measured as the dry weight from the weekly collected samples (Figure 4). Each paddock was not sampled equally but each was measured throughout the season. However, forage availability and dry matter intake (DMI) are not the same. Dry matter intake was calculated from equations of  $NE_M$  (Net Energy for Maintenance) and  $NE_G$  (Net Energy for Growth) entered into NIRS equations.

Figure 4. Forage availability of rotational grazing pasture system at weekly sampling dates at Arlington, WI (WICST 1997 and 1998).



Actual pasture production is difficult to determine. The pasture samples that have been collected regularly give an indication of amount of forage available to the animals but not what the animal actually consumes. To estimate the actual production of the pastures, we used animal energy consumption formulas, tables of feed composition, and animal nutrient requirements to determine pasture dry matter consumed by the grazing animals. 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 1985 NRC Publication on Nutrient Requirements for Beef Cattle (shown below) using average weight of each animal during the grazing period and their rate of gain.

$$NE_M \text{ (in Mcal/day)} = .077 * (\text{kg body weight})^{.75} \text{ and}$$

$$NE_G \text{ (in Mcal/day)} = .0608 * (\text{kg body weight})^{.75} * (\text{kg of body weight gain})^{1.119}$$

Daily dry matter consumption was calculated using the following equation:

$$\text{DMI} = (\text{daily NE}_M \text{ requirement} / \text{NE}_M \text{ per kg ration}) + (\text{daily NE}_G \text{ requirement} / \text{NE}_G \text{ per kg ration})$$

The pasture NE<sub>M</sub> and NE<sub>G</sub> (in Mcal/kg DM) used were an average of the following three values taken from the NRC feed energy tables:

- 1) NE<sub>M</sub> = 1.52 and NE<sub>G</sub> = 0.93 average early and medium bloom red clover
  - 2) NE<sub>M</sub> = 1.69 and NE<sub>G</sub> = 1.08 young orchardgrass
  - 3) NE<sub>M</sub> = 1.48 and NE<sub>G</sub> = 0.89 average early and medium maturity bromegrass
- Average) NE<sub>M</sub> = 1.56 and NE<sub>G</sub> = 0.97 grass/clover mix pasture

Energy value of supplemented grain mix is NE<sub>M</sub> = 1.96 and NE<sub>G</sub> = 1.30 and energy value of supplemented high moisture barley grain is NE<sub>M</sub> = 2.06 and NE<sub>G</sub> = 1.40.

The actual NE<sub>M</sub> and NE<sub>G</sub> 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 1998.

**Table 5. Estimated Forage Quality and Forage Production Using Animal Energy Requirements of WICST Rotational Grazing System, 1990-1998\*.**

|      | Arlington Ag Research Station |            |     | Lakeland Agricultural Complex |            |     |
|------|-------------------------------|------------|-----|-------------------------------|------------|-----|
|      | Yield                         | Quality* * |     | Yield                         | Quality* * |     |
| Year | tDM/acre                      | % CP       | RFV | tDM/acre                      | % CP       | RFV |
| 1990 | 4.15                          | 19         | 142 | 0.00                          | -          | -   |
| 1991 | 4.70                          | 17         | 113 | 3.39                          | 15         | 105 |
| 1992 | 2.81                          | 17         | 128 | 3.36                          | 17         | 118 |
| 1993 | 2.18                          | 20         | 133 | 2.54                          | 18         | 114 |
| 1994 | 3.86                          | 20         | 124 | 4.08                          | 20         | 137 |
| 1995 | 2.17                          | 16         | 103 | 3.58                          | 19         | 117 |
| 1996 | 1.67                          | 24         | 142 | 0.96                          |            |     |
| 1997 | 1.84                          | 19         | 130 |                               |            |     |
| 1998 | 2.94                          | 20         | 135 | 1.36***                       |            |     |

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

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

\*\*\* Does not include growth from before July 23<sup>rd</sup>.

Management intensive grazing (MIG) is an increasingly common and effective method used to reduce the amount of forage that must be mechanically harvested and stored. Management intensive grazing offers a low input system with excellent forage quality and profitable animal performance. The profit margin is higher with MIG than with conventional systems because of lower input costs (capital, interest, labor, fuel). Compared to continuously grazed pastures, MIG pastures have reduced forage trampling, more even manure distribution, and less refused forage. Most importantly, MIG allows a rest period for re-growth of the forage that improves productivity and palatability of the pasture. By managing both forage and animals, we can obtain economic and environmental benefits with MIG.



## 5. 1992-1998 Economic Analysis of the Wisconsin Integrated Cropping Systems Trial

Rick Klemme<sup>1</sup> and Don Schuster<sup>2</sup>

### Introduction

The 1998 economic analysis for the Wisconsin Cropping Systems Trials marks a new approach to evaluating the systems. In the past, the economic analysis has been compiled by different economists and agronomists that evaluated the data a year at a time. This year's evaluation uses a more consistent process over 1992-1998 for Cropping Systems (CS) 1, 2 and 3 (cash grain systems) and 1993-1998 for CS 4 and 5 (forage based systems). Each cropping system from 1992-1997 has been reevaluated, so comparison to prior reports should be made with this in mind. This report initially focuses on the economic analysis for the cash grain and then the forage based cropping systems. The remainder of the report then examines the changes that have been made in the economic analysis to provide a more consistent and realistic assessment of the five cropping systems.

### Economic Analysis

#### Economic Analysis (CS 1, 2 and 3) – Gross Margins

Cropping systems 1 through 6 are described in Figure 1. The 1992-98 WICST economic analysis calculated in terms of gross margins per acre for the cropping systems (CS) 1-3 for the Arlington and Lakeland sites (Figures 2 and 3). In 1998, CS2 had the highest gross margins at both sites followed by CS1. In 1998 corn yields were very good in both of these systems. Even with the lowest commodity prices in the history of the WICST, gross margins for CS1 and CS2 were the best or second best they have been. Cropping system 3 at Arlington had the best corn yield in the past seven years, while soybean and wheat yields were a little better than the average. But, these relatively good yields were not enough to offset poor prices. The price effect at Lakeland was felt more because the yields were just average compared to other years.

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 the 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 costs 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. Since 1994, the three cash grain-cropping systems have generally been

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able to generate \$200/acre in gross margins at Arlington. The Lakeland results have been less successful in that the gross margins have been less than \$200/acre more often than not.

1998. The gross margins for CS2 exceeded those of CS1 and CS3 in that order and at both sites. Gross margins at Lakeland for CS3 were substantially lower than that of CS1 and CS2 (Figure 2 and 3). The gross margins for CS2 in 1998 exceeded those of CS1, which in turn exceeded those of CS3. This was due to a number of factors including late planting, weed pressure, poor yields and low prices of wheat and soybean. This is the first time since 1992 that CS3 didn't have higher gross margins than CS1, at either site.

1992-98. Over this 7-year period Arlington's CS2 and CS3 have had higher average gross margins than CS1. The gross margin average for CS2 over CS1 was \$31.84 per acre or \$37,541 per year over 1200 acres. CS3's gross margin averaged \$25.45 per acre or \$30,540 per year over 1200 acres more than CS1.

Comparing Lakeland's CS1 gross margin average to CS2 and CS3 for the years 1992-1998 showed similar, yet more striking results than those at Arlington. The gross margin average for CS2 is \$70.92 per acre or \$85,106 per year higher than CS1. CS3 averaged \$51.98 per acre or \$62,374 per year more than CS1.

#### Economic Analysis (CS 4 and 5) – Gross Margins

Comparing the shorter term forage rotation, CS5, to the longer and more intensive forage rotation, CS4 (Figures 4 and 5). Over the period 1993-1998 these rotations generate similar amounts of gross margins per acre.

Comparing Arlington's CS4 gross margin to CS5 for the years 1993-1998 showed only a small difference of \$18.37 per acre or \$2755.25 per year on a 150-acre farm. Comparing Lakeland's CS4 gross margins to CS5 for the same time period shows even a smaller difference than Arlington with \$10.49 per acre or \$1573.25 per year. The 4 cut alfalfa management system being used for both CS4 and CS5 could be affecting CS4 more because of the problem of winter kill on the alfalfa and the need to maintain a longer stand in CS4.

#### Economic Analysis (CS 1, 2, and 3) - Net Returns to Land & Management

The net returns to land and management of cropping system's 1, 2 and 3 are calculated by subtracting the allocated overhead from the gross margins. Allocated overhead includes labor, interest, insurance, and depreciation expenses.

Three items not included in the allocated overhead are the rental rate for land, property taxes, and a management charge. These were excluded because no group consensus could be obtained about the rental or tax values or the appropriate management charge. Since these costs are common across systems, that is the land and management are there regardless of the system, we felt comfortable leaving these figures out. Readers of this document can deduct an appropriate value for rent, taxes, and management to arrive at a net return for the three systems with all costs included.

Machinery costs are a function of the following factors for each piece of farm equipment used in these budgets: number of times the equipment goes across the field, repair and energy cost, and labor, depreciation, and interest costs.

At Arlington, CS2 has the lowest average machinery costs over the 7-year period at \$49.93/a compared to \$54.19/a for CS1 and \$59.64/a for CS3. At Lakeland, machinery expense was also the lowest in CS2 at \$49.10/a compared to CS1, \$52.19/a and CS3 at \$54.84/a. Details can be found in the Tables 1 and 2.

The net returns to land and management for both Arlington and Lakeland CS1, CS2 and CS3 peaked in 1995. Arlington's net returns to land and management on average fell after 1995 but remained relatively constant and positive from 1996-98. Lakeland, on the other hand, had zero or negative net returns in 1996, but rebounded in most cases in 1997 and 98.

When comparing the cropping systems over the period 1992-98, CS2 and CS3 had average net returns to labor and management greater than CS1 at both Arlington and Lakeland. At Arlington, CS2 averaged over \$63/a or \$76,323 per 1200 acres more than CS1 and CS3 averaged almost \$25/a or \$29,693 per 1200 acres more than CS1. At Lakeland, CS2 averaged almost \$70/a or \$83,767 per 1200 acres more than CS1 and CS3 averaged almost \$53/a or \$63,447 per 1200 acres more than CS1.

### **Changes from Past Analyses**

Having a complete data set from this entire period of time gives the opportunity to re-analyze the data in a more consistent manner.

#### **Corn Moisture**

The most significant data problem in past analyses involved the reporting of corn moisture contents. They were reported for high moisture feed grain being fed to the dairy herds on the farms where the research trials were located. These high moisture contents increased the drying costs in the corn enterprises in CS 1, 2 and 3. Corn was being dried from moisture contents as high as 37% down to 15.5%. This moisture content is higher than would be normal for a cash grain operation. Using these values lowered the gross margins and net returns of CS 1 (100% in corn) more than those for CS 2 (50% corn) and CS 3 (33% corn), respectively.

To remedy this problem, project participants were surveyed to develop a solution that would lead to more realistic corn moisture contents and still evaluate any changes in the net returns of these cropping systems caused by differences in corn moistures. The project participants agreed to use the moisture contents from the same corn varieties tested in the Wisconsin's Corn Hybrid Trials (WCHT) location closest to the WICST research location. The moisture results from the Arlington WCHT plots were used for Arlington's results and the Janesville WCHT plots were used for the Lakeland results. It was also agreed that the WCHT result would serve as the base

moisture content for CS1 and then the differences in reported moisture contents from CS2 and CS3 would be added or subtracted from the WCHT to get the revised moisture contents.

Example:                   WCHT moisture for variety X is ... 24%  
                               CS1 reported moisture content is = 36%  
                               CS2 reported moisture content is = 33%  
                               CS3 reported moisture content is = 32%

The adjusted moisture content for CS1 is now 24%, CS2 is 21%, and CS3 is 20%. It would be from these adjusted moisture contents that the corn would be dried down to 15.5% at a cost of \$0.02 per point removed per bushel.

The reported moisture contents for corn grown in CS4 and CS5 were not altered because these are considered livestock cropping systems. With livestock, in most cases, corn is harvested at higher moisture contents and stored in high moisture facilities with no drying costs incurred.

### Labor Cost

In the past, labor costs associated with operating machinery were charged at a \$5 per hour rate in all years. This rate, though it may have been relevant, though low, in 1992 when the experiment started, did not increase over the years as wages have risen. These costs were updated for this analysis using the wages for farm workers reported in the National Agricultural Statistic Service's Lake Region (includes Wisconsin, Minnesota and Michigan). The following labor costs by year were used in the analysis:

|      |             |
|------|-------------|
| 1992 | \$5.35/hour |
| 1993 | \$6.01/hour |
| 1994 | \$5.94/hour |
| 1995 | \$6.47/hour |
| 1996 | \$6.64/hour |
| 1997 | \$7.29/hour |
| 1998 | \$7.35/hour |

### Corn and Soybean Price

The corn and soybean prices used the past evaluations have equaled the cash price taken at time of harvest from the nearest grain elevator. Unfortunately, this price – usually taken on a given day – could be a peak or valley for the grain price for the harvest period. Since the analysis assumes a 1200-acre farm farmed with standard practices, it would be impossible to harvest and market the grain in one day.

In order to solve this data problem, the Wisconsin Agricultural Statistic Service's cash grain reports were used. These prices represent the average daily price reported by country elevators from several regions in the state. The southeast region was used for the Lakeland site and the south central was used for Arlington. The average October price was used for both corn and soybeans.

The wheat price did not change. Since no area cash prices are recorded for wheat, the cash price at the time of harvest was used.

### Forage Price

In the past, forage (hay) prices for CS4 and CS5 have been computed at \$80 per ton. Project participants have been concerned about the reliability of this value that is the same regardless of the forage's quality. Since the alfalfa is harvested in a timely manner (probably more so that it would be on a farm), it was argued that alfalfa quality was high and should be compensated accordingly. However, the current analysis has attempted to be realistic with regard to assumptions made about how the results should be translated to a 150-acre farm situation. In actual farm situations, hay is not always harvested in a timely manner and its average quality may deviate from that achieved in WICST.

To adjust the forage price, the average relative feed value (RFV) was computed for the years 1993-1996. The average RFV for those years was 144. This 144 RFV was assigned a price of \$80 per tdm (ton of dry matter) and any deviations in RFV from 144 were used to adjust the forage price by adding or subtracting \$1 per RFV point. Example:

$$\begin{aligned}\text{RFV is } 160, \text{ haylage is worth } \$96/\text{tdm} \\ 160 - 144 = 16 + 80 = \$96/\text{tdm}\end{aligned}$$

$$\begin{aligned}\text{RFV is } 120, \text{ haylage is worth } \$56/\text{tdm} \\ 120 - 144 = -24 + 80 = \$56/\text{tdm}\end{aligned}$$

### CS3 Chemical Inputs

The debate over the use of chemicals in CS3 still continues. In past analyses, the herbicide input costs were omitted. There were many reasons for this omission. Sometimes, only the outside rows were sprayed to control border effect weeds. Since products from these rows were not harvested, the net returns were not affected by the spraying. In other situations, it was assumed that the crops could have been organically grown if adequate labor resources were available.

Since 1992, neither the Lakeland nor Arlington site has gone three years without chemical use. The system cannot be classified as organic, although it is very close. Therefore for this analysis, the sprayer has been included in the machinery since there are years in which herbicides have been applied to the interior (harvested) rows as a crop saving measure. In years where only the outside rows were sprayed, the chemical use was left off of the analysis. But, in years where Stinger was used to control thistle and years where Buctril, Accent, and Poast have been sprayed to rescue a crop, herbicide costs have been included.

### Machinery Set

The size of the farms has been set at 1200 acres for CS1, CS2 and CS3, which is representative of cash-grain farm sizes in south-central and southeast Wisconsin. Though previously 1000 acre

farm size was projected. Now all years are standardized to 1200, with a minimum differences in machinery costs. To obtain realistic machinery inputs surveys were sent to farmers on the WICST committee. These farmers provided input on tractor sizes and the width of tillage and planting equipment they would use to farm 1200 acres in each of the three WICTS cash-grain systems. We also looked at actual farm machinery sets used by farmers and county extension agents who had worked with UW Ag. Economist Gary Frank using ABCS. Using these data sets we chose a farm machinery set for each of the three systems (Table 1). Before entering the data into ABCS, we met with the three farmers from the Columbia County WICST committee and incorporated their suggestions regarding equipment size and purchase prices.<sup>1</sup>

In the years prior to 1994, CS2 was considered a conventional tillage system. In 1994, CS2 was converted to a no-till system. The machinery sets defined for CS2 in these two time periods are based on conventional tillage prior to 1994 and no-till thereafter.

For the most part, CS1, CS2, and CS3 have similar machinery set defined to be as similar as possible, but there are a few differences. CS1 and CS3 contain the same tillage systems and tractors. Because CS2 is a no-till system, it has a 140 horse power tractor instead of a 225 horse powered 4 wheel drive in CS1 and CS3. CS1 and CS2 use a 175 horse powered combine, while CS3 uses a 145 horse powered combine (only 400 acres in any given crop with harvesting spread over more months during the year). Grain hauling for CS 1 and 2 is the same, 2 tandem trucks and 1 350-bu. grain cart. CS 3 has 1 tandem truck, 1 350-bu. grain cart and 2 - 250 bu. gravity boxes for its grain hauling.

CS 4 and 5 are considered dairy cropping systems. We used the same equipment sets for both rotations and assumed a 150-acre farm. The equipment set was compiled by members of the WICST team and was refined at the summer field days at Lakeland in 1997.

**Figure 1. Schematic drawing of cropping systems in the Wisconsin Integrated Cropping Systems Trial.**

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

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<sup>1</sup> Mulder, Tom; The Wisconsin Integrated Cropping Systems Trial, 1995 p.36

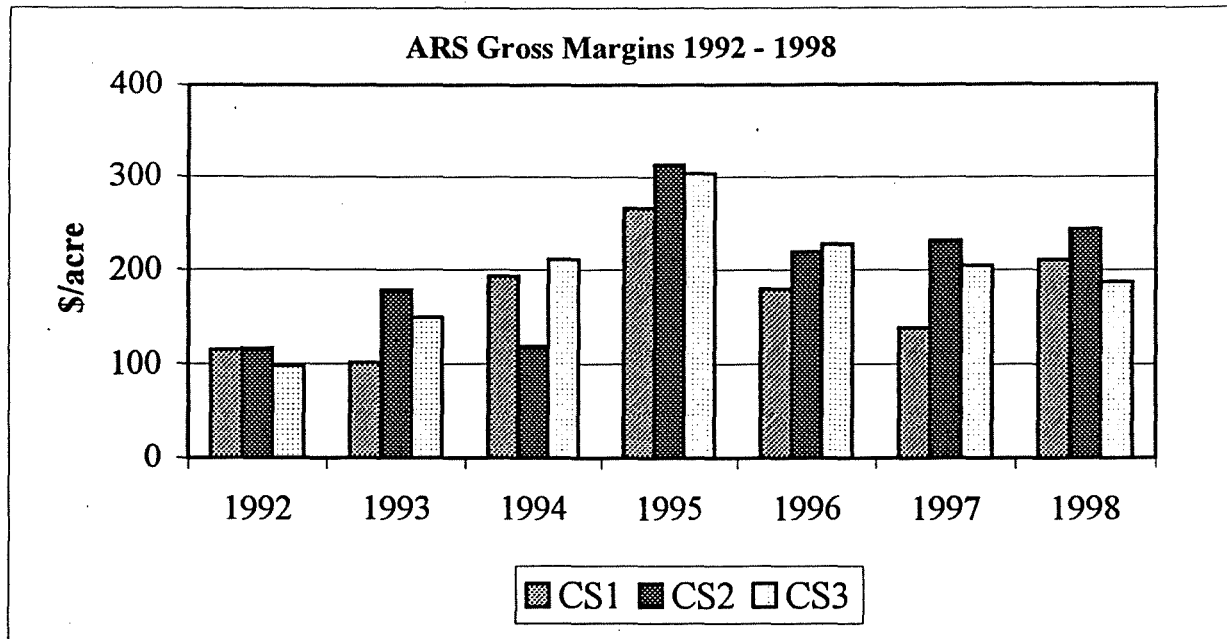
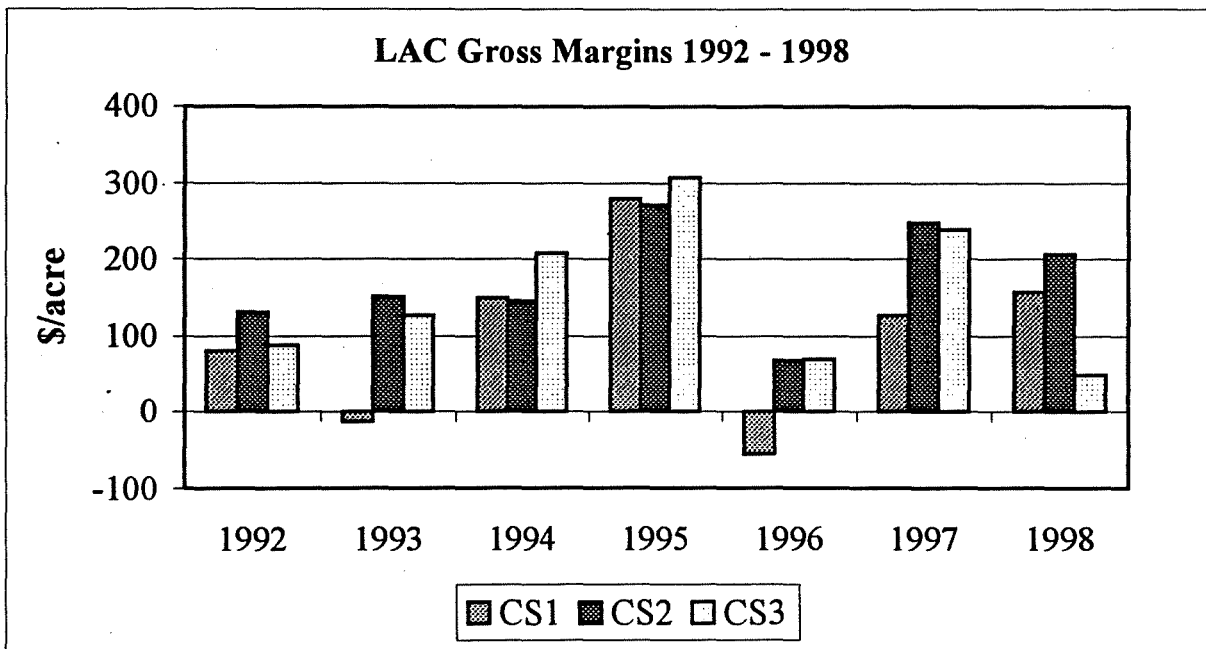
**Figure 2. Gross Margins – CS1, CS2, and CS3, Arlington Agricultural Research Station****Figure 3. Gross Margins – CS1, CS2, and CS3, Lakeland Agricultural Complex**

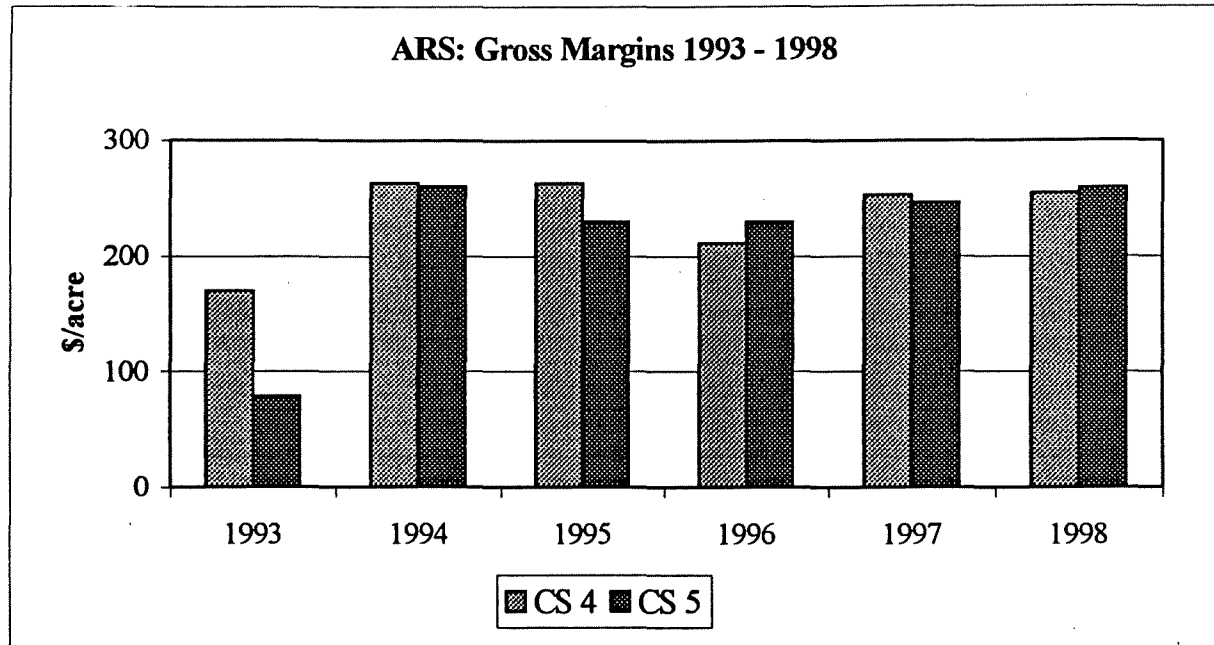
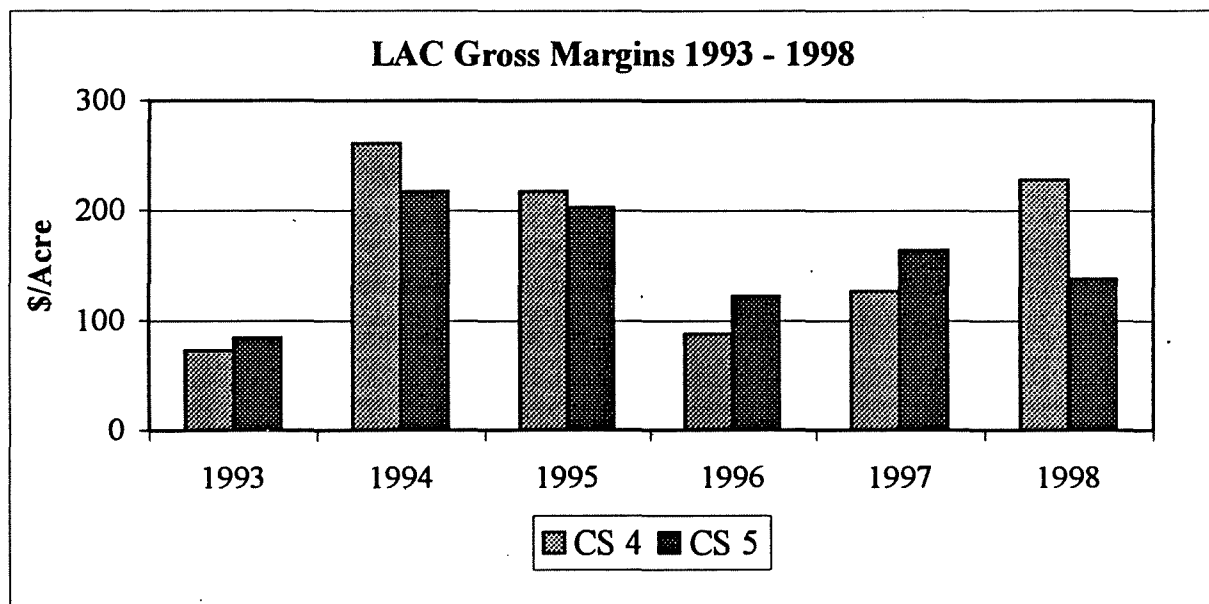
**Figure 4. Gross Margins – CS4 and CS5: Arlington Agricultural Research Station.****Figure 5. Gross Margins – CS4 and CS5: Lakeland Agricultural Complex.**

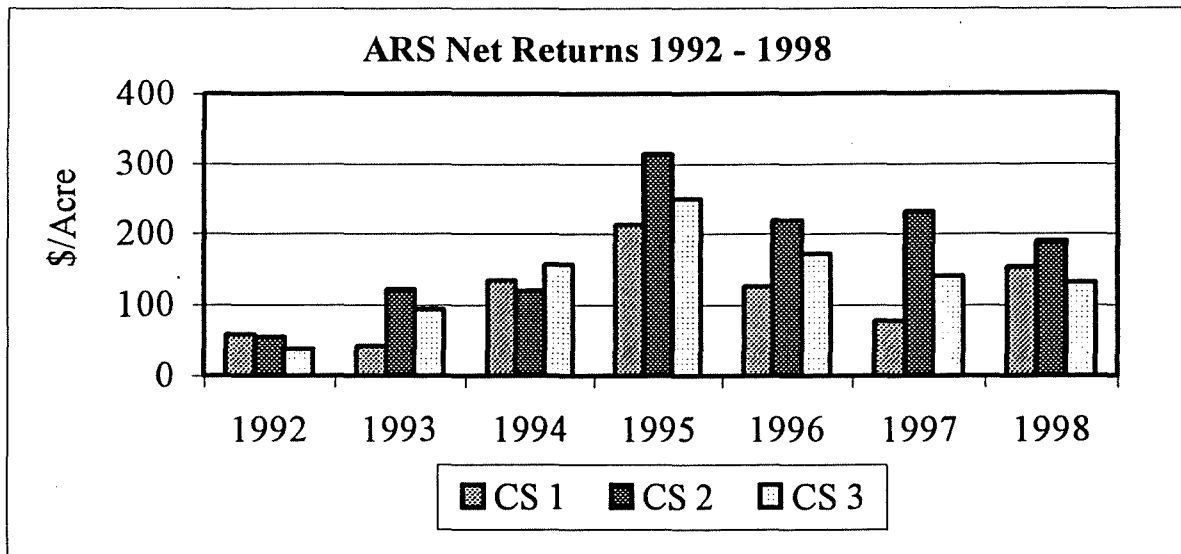
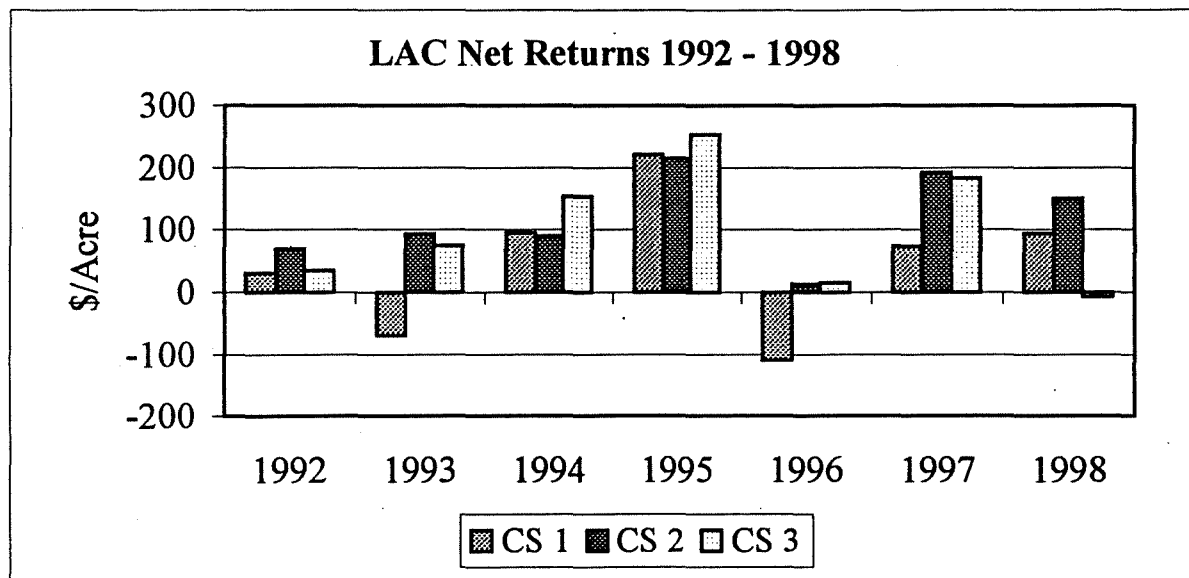
**Figure 6. Net Returns to Land and Management for CS1, CS2, and CS3 (\$/acre).****Figure 7. Net Returns to Land and Management for CS1, CS2, and CS3 (\$/acre).**

**Table 1. Field Equipment and Operations for the three WICST Cash-Grain Systems.****Cropping System 1 – Continuous Corn    Machinery Description: 1200-acre cash grain farm**

| <u>Power Unit</u>     | <u>Main Implement</u>          | <u>Cost of Implement (\$)</u> |
|-----------------------|--------------------------------|-------------------------------|
| Tractor 225 HP 4wd    | Plow, Chisel 12 ft             | 4,150                         |
| Tractor 225 HP 4wd    | Soil Finisher 25 ft            | 19,000                        |
| Tractor 120 HP        | Planter 12-30                  | 23,200                        |
| Tractor 75 HP         | Sprayer 60 ft boom             | 49,800                        |
| Tractor 75 HP         | Cultivator 06-30               | 8,800                         |
| Tractor 225 HP 4wd    | Fert. NH <sub>3</sub> (rented) | 1/ac                          |
| Combine, large 175 HP | Corn grain head 6-30           | 23,500                        |
| Tractor 120 HP        | Grain cart 350 bu              | 10,000                        |

| <u>Power Unit</u>  | <u>Cost of Power Unit (\$)</u> |
|--------------------|--------------------------------|
| Tractor 225 HP 4wd | 76,500                         |
| Tractor 120 HP     | 55,200                         |
| Tractor 75 HP      | 26,900                         |
| Combine, 175 HP    | 103,200                        |

| <u>Durables and other equipment</u> | <u>Cost of Durables and other equipment (\$)</u> |
|-------------------------------------|--------------------------------------------------|
| Fertilizer tank on a trailer        | 4,000                                            |
| Fuel tank and case                  | 6,000                                            |
| Shed 50' X 100"                     | 22,000                                           |
| Shop building                       | 40,000                                           |
| 2 Tandem Trucks                     | 51,600/each                                      |

| <u>Additional Costs</u> | <u>(\$/acre)</u> |
|-------------------------|------------------|
| Crop Scout              | 5                |

|                                          |                                                         |
|------------------------------------------|---------------------------------------------------------|
| <b>Cropping System 2 – Corn/Soybeans</b> | <b>Machinery Description: 1200-acre cash grain farm</b> |
|------------------------------------------|---------------------------------------------------------|

| <u>Power Unit</u>     | <u>Main Implement</u>           | <u>Cost of Implement (\$)</u> |
|-----------------------|---------------------------------|-------------------------------|
| Tractor 75 HP         | Planter 06-60 min-till (corn)   | 19,200                        |
| Tractor 140 HP        | Drill, min-till 15ft (soybeans) | 14,970                        |
| Tractor 75 HP         | Sprayer 60 ft boom              | 49,800                        |
| Tractor 120 HP        | Cultivator, min-till 6-30       | 7,100                         |
| Tractor 140 HP        | Fert. NH3 (rented)              | 1/acre                        |
| Combine, Large 175 HP | Soybean head 20 ft              | 13,800                        |
| Tractor 120 HP        | Grain cart 350 bu               | 10,000                        |
| Combine, Large 175 HP | Corn grain head 6-30            | 23,500                        |

| <u>Durables and other equipment</u> | <u>Cost of Durables and other equipment (\$)</u> |
|-------------------------------------|--------------------------------------------------|
| Fertilizer tank on a trailer        | 4,000                                            |
| Fuel tank and case                  | 6,000                                            |
| Shed 50' X 100"                     | 22,000                                           |
| Shop building                       | 40,000                                           |
| 2 Tandem Trucks                     | 51,600/each                                      |

| <u>Power Unit</u> | <u>Cost of Power Unit (\$)</u> |
|-------------------|--------------------------------|
| Tractor 140 HP    | 58,500                         |
| Tractor 120 HP    | 55,200                         |
| Tractor 75 HP     | 26,900                         |
| Combine, 175 HP   | 103,200                        |

| <u>Additional Costs</u> | <u>(\$/acre)</u> |
|-------------------------|------------------|
| Crop Scout              | 5                |

*Note: Starting in 1994, the cropping system went from conventional to a no-till system.*

|                                                                  |                                                            |
|------------------------------------------------------------------|------------------------------------------------------------|
| <b>Cropping System 3 – Corn/Soybeans/Winter Wheat-Red Clover</b> | <b>Machinery Description:</b><br>1200-acre cash-grain farm |
|------------------------------------------------------------------|------------------------------------------------------------|

| <u>Power Unit</u>   | <u>Main Implement</u>   | <u>Cost of Implement (\$)</u> |
|---------------------|-------------------------|-------------------------------|
| Tractor 225 HP 4wd  | Plow, Chisel 12 ft      | 4,150                         |
| Tractor 225 HP 4wd  | Soil Finisher 25 ft     | 19,000                        |
| Tractor 75 HP       | Planter 6-30            | 12,000                        |
| Tractor 75 HP       | Sprayer 47 ft boom      | 18,000                        |
| Tractor 75 HP       | Cultivator 06-30        | 3,700                         |
| Combine, med 145 HP | Corn grain head 6-30    | 23,500                        |
| Combine, med 145 HP | Grain head 15ft         | 7,900                         |
| Tractor 75 HP       | Rotary Hoe 30 ft        | 8,400                         |
| Tractor 75 HP       | Drill, double disk 13ft | 9,100                         |
| Tractor 120 HP      | Stalk chopper 15 ft     | 9,223                         |
| Tractor 75 HP       | Broadcast seeder        | 800                           |
| Tractor 75 HP       | 2 Gravity box 240 bu    | 2,100/each                    |
| Tractor 120 HP      | Grain cart 350 bu       | 10,000                        |

| <u>Power Unit</u>  | <u>Cost of Power Unit (\$)</u> |
|--------------------|--------------------------------|
| Tractor 225 HP 4wd | 76,500                         |
| Tractor 120 HP     | 55,200                         |
| Tractor 75 HP      | 26,900                         |
| Combine, 145 HP    | 87,500                         |

| <u>Durables and other equipment</u> | <u>Cost of Durables and other equipment (\$)</u> |
|-------------------------------------|--------------------------------------------------|
| Fertilizer tank on a trailer        | 4,000                                            |
| Fuel tank and case                  | 6,000                                            |
| Shed 50' X 100"                     | 22,000                                           |
| Shop building                       | 40,000                                           |
| Tandem Trucks                       | 51,600                                           |

| <u>Additional Costs</u> | <u>(\$/acre)</u> |
|-------------------------|------------------|
| Crop Scout              | 5                |

**Table 2. Field Equipment and Operations for the two WICST Dairy Cropping Systems.**

|                                              |                                                   |
|----------------------------------------------|---------------------------------------------------|
| <b>Cropping System 4 – Corn/Alfalfa</b>      | <b>Machinery Description: 150-acre dairy farm</b> |
| <b>Cropping System 5 – Corn/Oats-Alfalfa</b> |                                                   |

| <u>Power Unit</u>   | <u>Main Implement</u>   | <u>Cost of Implement (\$)</u> |
|---------------------|-------------------------|-------------------------------|
| Tractor 100 HP      | Plow, Chisel 8 ft       | 7,000                         |
| Tractor 75 HP       | Cultivator field 12 ft  | 3,100                         |
| Tractor 75 HP       | Planter 4-36            | 9,100                         |
| Tractor 60 HP       | Sprayer 30 ft boom      | 3,700                         |
| Tractor 75 HP       | Cultivator 4-36         | 3,100                         |
| Tractor 75 HP       | Rotary Hoe 15 ft        | 3,500                         |
| Tractor 75 HP       | Drill, PW 12ft          | 13,000                        |
| Tractor 100 HP      | Forage Harvester        | 16,000                        |
| Tractor 60 HP       | Forage Blower           | 4,200                         |
| Tractor 75 HP       | Mower Cond. 9 ft        | 10,800                        |
| Tractor 60 HP       | 2 Forage Wagons         | 7,800/ea                      |
| Tractor 75 HP       | Manure Spreader 225 bu. | 5,500                         |
| Tractor 75 HP       | Hay Baler               | 9,300                         |
| Tractor 60 HP       | Hay Rake 9 ft           | 3,300                         |
| Tractor 60 HP       | 2 Wagon Hay Racks       | 2,100/ea                      |
| Tractor 75 HP       | Disk, Tandem 16 ft      | 6,335                         |
| 5 HP electric motor | Bale Elevator           | 1,500                         |

| <u>Power Unit</u> | <u>Cost of Power Unit (\$)</u> |
|-------------------|--------------------------------|
| Tractor 100 HP    | 40,100                         |
| Tractor 75 HP     | 26,900                         |
| Tractor 60 HP     | 21,400                         |

| <u>Durables and other equipment</u> | <u>Cost of Durables and other equipment (\$)</u> |
|-------------------------------------|--------------------------------------------------|
| Shed 40' X 80"                      | 18,000                                           |
| 2 Fuel Tanks on Stands              | 1,200                                            |

| <u>Additional Costs</u> | <u>(\$/acre)</u> |
|-------------------------|------------------|
| Custom Combining        | 20               |
| Custom Roller Milling   | 3                |
| Custom Hauling          | 2                |



## 6. The Effects of Crop Rotations on the Nitrogen Availability to a Subsequent Corn Crop

Rhonda Graef<sup>1</sup>, Scott Alt<sup>2</sup>, Joshua Posner<sup>3</sup>, and Larry Bundy<sup>4</sup>

### Introduction

The primary goals of any cropping system are to optimize plant-available nitrogen (N), maintain profitability by reducing input costs, and conserve a precious resource base by minimizing pollution from nitrate-nitrogen (NO<sub>3</sub>-N). Nitrogen is an essential plant macronutrient and the major growth-limiting factor in most US agricultural soils. In the United States, NO<sub>3</sub>-N is a leading contaminant in groundwater, with 53% contributed by fertilizers and 27% by manure (Puckett, 1994). A major use of N fertilizer is for the production of corn (*Zea Mays*, L.), which receives approximately 40% of total N fertilizer (Committee on the Role of Alternative Farming Methods in Modern Production Agriculture, 1989). Corn has a high N requirement and losses of applied N may occur primarily by leaching and denitrification. Accurate determination of corn N requirements in specific production systems and efficient N management practices can minimize these losses (Bundy, 1997). Good N management provides the corn crop with an adequate, but not excessive, quantity of usable nitrogen. Research data on Wisconsin corn yields show that good corn yields are possible based on fertilizer N, as well as on organic N sources.

In general, corn yields on the Wisconsin Integrated Cropping Systems Trial have been good (Table 1). However, in each of the systems reported, nitrogen additions and management on corn have been different (Table 2). Research shows that optimum corn yields in southern Wisconsin occur with fertilization rates up to 160 lbs. N per acre (Bundy *et al.*, 1994). There are a number of ways to meet this application rate for a corn crop. For corn following corn, the recommended fertilizer rate of 160 lbs. N/a is adjusted for residual N from the previous year as measured by the Pre-Plant Nitrate Test (PPNT) (Bundy and Sturgul, 1994). Following soybeans or alfalfa, the N recommendation is adjusted for legume credits. The standard Wisconsin credits are 40 lbs. N for soybeans and up to 190 lbs. N/a for a good stand of alfalfa (70-100% alfalfa, more than 4 plants/ft<sup>2</sup>). These credits are more accurately measured by the use of the Pre-Sidedress Nitrate Test (PSNT) (Bundy and Sturgul, 1994). Manure applications also provide a N source. Estimations are that 30-35% of the total N in dairy manure is available for the following corn crop (Bundy *et al.*). The different sources of N contribute to the pool of N available to the corn plant for growth. Accounting for these contributions, understanding how they change over time and under varying soil conditions are important to efficient N management.

Over the years, it appears that the corn following soybeans (CS2) or corn following alfalfa + manure (CS5) were the highest yielding. Continuous corn (CS1) and corn following a red clover plowdown (CS3) have been less productive. **The purpose of this research was to see if yield differences could be attributed to nitrogen availability.**

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**Table 1. Corn Yields (bu/a) at Arlington Research Station and Lakeland Agricultural Complex (1993–1998).**

| <b>Crop System</b> |     | <b>1993</b> | <b>1994</b> | <b>1995</b> | <b>bu/a</b> | <b>1996</b>     | <b>1997</b>      | <b>1998</b>      |
|--------------------|-----|-------------|-------------|-------------|-------------|-----------------|------------------|------------------|
| <b>ARS</b>         |     |             |             |             |             |                 |                  |                  |
| Cont. Corn         | CS1 | 124         | 178         | 143         |             | 131             | 129 <sup>1</sup> | 196              |
| Corn – Sb          | CS2 | 130         | 190         | 168         |             | 140             | 157              | 213              |
| Corn – Sb – W      | CS3 | 87          | 188         | 156         |             | 83 <sup>2</sup> | 148              | 198              |
| Corn – O/Alf – Alf | CS5 | 165         | 197         | 167         |             | 151             | 155              | 227              |
| <b>LAC</b>         |     |             |             |             | <b>bu/a</b> |                 |                  |                  |
| Cont. Corn         | CS1 | 98          | 177         | 150         |             | 42 <sup>3</sup> | 113 <sup>1</sup> | 166              |
| Corn – Sb          | CS2 | 101         | 184         | 150         |             | 40 <sup>3</sup> | 154              | 172              |
| Corn – Sb – W      | CS3 | 78          | 187         | 131         |             | 45 <sup>3</sup> | 135              | 129 <sup>2</sup> |
| Corn – O/Alf – Alf | CS5 | 81          | 198         | 144         |             | 57 <sup>3</sup> | 151              | 93 <sup>2</sup>  |

<sup>1</sup> Corn yields in CS1 at both ARS and LAC suffered due to corn rootworm infestation.

<sup>2</sup> Mechanical weed control failed – intense weed pressure limited yields.

<sup>3</sup> Planted very late in the season due to weather problems.

**Table 2. Wisconsin Integrated Cropping Systems Trial Rotations.**

| <b>Cropping Systems</b> | <b>Rotation<br/>Amendments<br/>Input Level</b>                                                                        |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------|
| Cash Grain:<br>CS 1     | Continuous Corn (for grain)<br>Fertilizer (160 lbs N/a less PPNT results)<br>Herbicides and insecticides<br>High      |
| CS 2                    | Narrow Row Soybeans / Corn<br>Fertilizer (160 lbs N/a less legume credits)<br>Herbicides and insecticides<br>Moderate |
| CS 3                    | Wide Row Soybeans / Wheat & Red Clover / Corn<br>None<br>Low                                                          |
| Forage:<br>CS 5         | Oats and Alfalfa / Alfalfa / Corn<br>Manure (15 tons/a 2 times every 3 years)<br>Moderate                             |
| CS 6                    | Rotational Grazing<br>Manure (Approximately 10 tons/a/year)<br>Low                                                    |

Two studies were undertaken to address this issue in 1997 and 1998: 1) a *soil incubation study* of potentially mineralizable nitrogen at planting; and 2) a *field sampling study* to monitor soil inorganic N-levels. As a companion study, corn plant N uptake was also monitored in 1997 and 1998. In the incubation study, soils were sampled in early April of 1997 and 1998 (0-15 cm) in the plots about to be planted to corn and in the rotational grazing check plots. The soils were brought into the lab for the incubation study. During the spring and summer, the same plots were monitored for inorganic N on a two-week sampling schedule to a depth of 60 cm.

Our expectations were that during an 8-week incubation period, the forage based rotations with manure and substantial legume additions (CS5 and CS6) would have higher potential mineralization rates than the cash-grain rotations (CS1, CS2, and CS3). In addition, we expected the organically managed soils in cash-grain rotations (CS3) to have higher potentially mineralizable N rates than the cash-grain rotations under chemical-intensive management (CS1 and CS2).

In the field study, two cropping systems are managed with purchased N fertilizer (CS1 and CS2) and the other two are managed without purchased N fertilizer (CS3 and CS5). We hypothesized that inorganic N ( $\text{NO}_3^- + \text{NH}_4^+$ ) levels in the soil solution from organic sources would be adequate to permit equivalent corn yields in CS3 and CS5 as in the systems amended with purchased inorganic N (CS1 and CS2).

### Materials and Methods

The studies were conducted on plots established for the Wisconsin Integrated Cropping Systems Trial (WICST) project. In 1990, researchers established WICST to compare alternative production systems in a long-term study. The length of this trial offers the unique opportunity for researchers to study production systems in rotation cycles for more than six years. Two locations in southeastern Wisconsin maintain WICST plots – the University of Wisconsin-Madison Arlington Research Station (ARS) in Columbia County and the Lakeland Agricultural Complex (LAC) in Walworth County. Both sites are on prairie-derived silt-loam soils overlaying glacial till. The sites differ primarily in internal drainage regime, with LAC being more poorly drained (Posner, Casler, and Baldock, 1995). At both locations, the cropping systems are replicated four times and each plot is approximately 0.80 acre in size to facilitate the use of farm machinery. The six cropping systems of the WICST project separate into two groups, cash-grain and forage-based rotations (Table 2).

#### Incubation Study

The incubation study compared soils from five WICST cropping systems: CS1, CS2, CS3, CS5, and CS6 (note: CS6 was not included in the LAC study due to weather related problems). In mid-April, soil samples were collected from three of the four replicates at both sites. No fertilizer had yet been added to CS1 and CS2, but manure was added in the fall of 1996 and 1997 to CS5 at both sites. At LAC – 1996, fall undercutting of the red clover had taken place in CS3, but at ARS – 1996, this did not occur due to the quick freezing of the soil in November. Fall undercutting did occur at both sites in 1997.

We took ten soil cores (0.75" diameter (1.9 cm)) to a depth of 8 inches (20 cm) from each of

three of the four replicated corn plots and pasture plots. The 30 samples (2 sites, 5 rotations, and 3 replicates) were dried at 25°C, ground, thoroughly mixed, and sieved through a 2-mm screen. The procedure followed for the incubation study is based on work by Vanotti, Hergert, Walters, and Ferguson (1995).

A 66-gram sample from each treatment was weighed, placed in a graduated plastic cup, and compacted to 60 cc, which resulted in a soil bulk density of 1.10 g/cc. We added enough distilled water (~21.1g) to reach 60% water-filled pore space (WFPS<sup>2</sup>). The samples were sealed with a screw-on cap that had three small holes punched into it and were placed in an incubator maintained at 25°C. Every two weeks, for an eight-week period, we took a sub-sample, approximately 1 to 1.2 grams with a mini-probe. To maintain 60% water filled pore space, the incubating samples were sprayed with a fine mist each time sub-samples were taken. In 1998, this procedure was amended slightly to more accurately ensure that each sample was receiving the same amount of water. The sub-samples were oven dried at 45°C, weighed, and extracted with 2M KCl as described by Bundy and Meisinger (1994). The clear supernatant was sent to the University of WI-Madison Soil and Plant Analysis Laboratory<sup>3</sup> for total inorganic N analyses. Net mineralization was calculated as the increase in nitrate-N plus ammonium-N relative to initial levels.

### Field Soil Sampling

Two fifty foot row sections were flagged in separate rows of each plot being sampled; all soil and plant samples were taken from within these sections. At both sites, the sections were located at some distance in from the end of the plot (ARS, 150' and LAC, 50') and in the sixth row (the innermost row of the border). At the end of May and every two weeks thereafter, we took soil samples at depths of one (0-30 cm) and two feet (30-60 cm). In each section, we collected a composite sample at each depth; two probes of the composite came from within the corn row and two more came from between the rows. The composite samples from both plot sections were then bulked together. As a result, each plot had two composite samples – one from each depth. Samples were handled and processed at the UW-Madison Soil and Plant Analysis Lab for total inorganic N (nitrate and ammonium) content (Schulte, Bundy, and Peters).

### Field Plant Sampling

Whole plant samples were taken on the same dates as soil sampling to determine the amount of N-uptake by the corn crop. We harvested a total of ten plants, five sequential plants from each section, from each of our test plots. The plants collected were fed through a forage chopper and a “wet” weight was taken. When the whole plant samples became too large to manage, sub-samples were taken from the bulk of the chopped material (10 plants), weighed, and oven-dried at 120°F so that plant moisture percent could be calculated. The dried samples were sent to the UW-Madison Soil and Plant Analysis Lab for total N analyses. Table 3 shows the estimated “available” N for the corn phase of CS1, CS2, CS3, and CS5.

<sup>2</sup> WFPS =  $e_v$  / porosity = ( $e_m$  x bulk density) / porosity; porosity = 1 – bulk density / 2.65.

$e_m$  = (0.60 / 1.10) – (0.60 / 2.65) = 0.319 g water / g soil, then water to add = 66 g x 0.319 = 21.1 g.

<sup>3</sup> UW-Madison Soil and Plant Analysis Lab, 5711 Mineral Point Road, Madison, WI 53705-4453.

### Statistical Treatment of Data

Treatment values for incubation and yield data were separated using analysis of variance and protected LSD tests. For each location, a linear regression model was fitted using the data from the 2<sup>nd</sup>, 4<sup>th</sup>, 6<sup>th</sup>, and 8<sup>th</sup> weeks.

**Table 3. Estimated "available" N for 1997 and 1998 corn phase in WICST at ARS and LAC.**

| Cropping System |      | N Fertilizer (lb/a) | Crop N Credits <sup>1</sup> (lb/a) | Manure N Credits <sup>2</sup> (lb/a) | Total N (lb/a) |
|-----------------|------|---------------------|------------------------------------|--------------------------------------|----------------|
| <b>ARS</b>      |      |                     |                                    |                                      |                |
| CS1             | 1997 | 120                 | PPNT <sup>3</sup> : 40             | 0                                    | 160            |
|                 | 1998 | 145                 | PPNT: 15                           | 0                                    | 160            |
| CS2             | 1997 | 120                 | 40                                 | 0                                    | 160            |
|                 | 1998 | 95                  | 40<br>PPNT: 25                     | 0                                    | 160            |
| CS3             | 1997 | 0                   | 147                                | 0                                    | 147            |
|                 | 1998 | 0                   | 84<br>*Hairy Vetch                 | 0                                    | 84             |
| CS5             | 1997 | 0                   | 190                                | 60                                   | 250            |
|                 | 1998 | 0                   | 121                                | 60                                   | 181            |
| <b>LAC</b>      |      |                     |                                    |                                      |                |
| CS1             | 1997 | 65                  | PPNT: 95                           | 0                                    | 160            |
|                 | 1998 | 140                 | PPNT: 20                           | 0                                    | 160            |
| CS2             | 1997 | 120                 | 40                                 | 0                                    | 160            |
|                 | 1998 | 80                  | 40<br>PPNT: 40                     | 0                                    | 160            |
| CS3             | 1997 | 0                   | 67                                 | 0                                    | 67             |
|                 | 1998 | 0                   | n.a.                               | 0                                    |                |
| CS5             | 1997 | 0                   | 190                                | 60                                   | 250            |
|                 | 1998 | 0                   | n.a.                               | 60                                   |                |

<sup>1</sup> Soybean N credits = 40 lbs N/a; Alfalfa N credits = 190 lbs N/a for a good stand (more than 70% Alfalfa). Source: Nutrient Management Fast Facts, Nutrient and Pest Management Program (NPM), UW-Extension. Red Clover crop residue N credits from biomass samples taken before fall plowdown.

<sup>2</sup> Manure 1<sup>st</sup> year available N content = 4 lbs N/ton of incorporated manure (15 tons/a for CS5 at both sites).

<sup>3</sup> PPNT = Pre-Plant Nitrate Test

<sup>4</sup> Very wet soil limited rotary hoeing to one time and prevented cultivation, weeds became a severe problem.  
n.a. data not available due to poor conditions

## Discussion and Results

### Incubation Study

Potentially mineralizable N exists as organic N in soil organic matter, crop residue, and organic wastes such as manure (Meisinger, 1984). Returning crop residues to the soil can increase organic N reserves and N-supplying capacity of the soil (Vanotti *et al.*, 1995). Estimating soil N availability is an important factor in good N management. Incubation studies that measure mineral N production by microbial processes are generally recognized as an acceptable measure of the soil N mineralization potential because they use the same microbial processes that are active under field conditions (Meisinger, Magdoff, and Schepers, 1992). The results of the incubation study are shown in Figures 1(a-d) and 2(a-d) and Table 3 shows the initial level of inorganic N and the rate of mineralization for the first two weeks of the incubation study.

### *Starting levels of N (ppm)*

In early spring, inorganic N-levels were generally high in CS5-corn (Table 4), probably due to the 15 T/a of manure that is added to the plots in the fall each year prior to the corn planting. In 1997, continuous corn (CS1) at Lakeland also had high inorganic N levels, probably due to the poor corn yields in 1996 (Table 1) and the residual effect of fertilizer. These high numbers are reason for concern as they represent significant amounts of N that could be leached into the groundwater, prior to vigorous corn growth in late May and June.

**Table 4. Starting levels of inorganic N and rates of N-mineralization for initial 0-2 week phase for soils. Arlington Research Station (ARS) and Lakeland Agricultural Complex (LAC); 1997 and 1998.**

| Incubation Data<br>1997 and 1998       | Site   | CS1         | CS2         | CS3        | CS5        | CS6        |
|----------------------------------------|--------|-------------|-------------|------------|------------|------------|
| Starting level of<br>inorganic N (ppm) | ARS-97 | 19.20<br>ab | 17.33<br>b  | 14.40<br>b | 23.60<br>a | 14.37<br>b |
|                                        | ARS-98 | 17.10<br>b  | 19.10<br>ab | 18.13<br>b | 21.53<br>a | 21.57<br>a |
|                                        | LAC-97 | 25.33<br>a  | 16.23<br>b  | 17.97<br>b | 27.67<br>a | —          |
|                                        | LAC-98 | 19.80       | 18.60       | 21.43      | 21.13      | —          |
| 0-2 weeks<br>(ppm/week)                | ARS-97 | 12.66       | 14.98       | 12.45      | 15.57      | 18.82      |
|                                        | ARS-98 | 16.38       | 22.31       | 24.06      | 20.81      | 31.55      |
|                                        | LAC-97 | 11.57<br>b  | 15.52<br>b  | 17.67<br>b | 26.03<br>a | —          |
|                                        | LAC-98 | 22.97       | 26.55       | 26.71      | 29.70      | —          |

— Rotational grazing plots were being re-established in 1997 and 1998 due to heavy trampling during the wet 1996 season.

### *Initial flush of mineralization*

There is an initial flush of N-mineralization during the first two weeks in all five cropping systems for both locations (Figures 1a-d). This flush is a measure of the readily decomposable organic matter (OM) and its carbon-nitrogen ratio (C/N) and it was different between locations and systems. It is not surprising to find that initial mineralization rates for the chemically based CS1 is the lowest in three out of four site-years. While there were no significant differences in mineralization rates between the cropping systems at ARS in either 1997 or 1998, the high OM input system CS6 has a greater rate of mineralization in these first two weeks. At LAC-1997, CS5 has a significantly greater mineralization rate than the cash grain systems and in 1998 there were no significant differences. Microbial activity seems to be higher on these manured plots (CS5 and CS6) where an abundant N-rich substrate exists.

### *After initial mineralization phase*

Actual mineralization rates dropped precipitously after the first two weeks (Figures 2a-d). The weekly mineralization rate tended to remain high in CS6 (ARS) when compared with the other systems, but statistically, no significant differences are indicated in the mineralization rates for either site in either year between the cropping systems. Therefore, the regression lines (Figures 2a-d) of the systems over the weeks were parallel for both ARS and LAC. This suggests that after the decomposition of the most active component of the soil OM in the first two weeks, a more steady state conversion rate of organic N to inorganic N took place.

Overall accumulation in the forage-based systems tend to be higher than the cash-grain systems. The higher levels of organic matter in these soils (from legume and manure additions) may explain this phenomenon. While the higher initial levels of CS5 (1997) and CS6 (1998) may contribute to the higher overall accumulation, CS6 began the 1997 season with a significantly lower starting level.

These findings are only somewhat consistent with our first hypothesis –

Hypothesis 1: Forage rotations will have higher mineralization rates than cash-grain systems.

- Generally, initial levels in CS5 and CS6 are higher than in CS1, CS2, or CS3.
- Initial (0-2 week) mineralization rates are higher in CS5 and CS6 than in CS1, CS2, or CS3.
- However, CS5 and CS6 have similar mineralization rates as CS1, CS2, and CS3 between weeks 2 and 8. The mean slope for ARS-1997 and LAC-1997 was 4.8 ppm/week; in 1998 the mean slope at ARS was 3.9 ppm/week and at LAC, 3.6 ppm/week.

Hypothesis 2: Among the cash-grain systems CS3 would have higher rates than CS1 and CS2.

- Generally, there are no differences in initial levels.
- No differences in initial (0-2 week) mineralization rates.
- No differences between mineralization rates from weeks 2 through 8.

**Figure 1a. 1997 Incubation data from Arlington Research Station - ARS.**  
Initial 0-2 week phase after initiation of incubation.

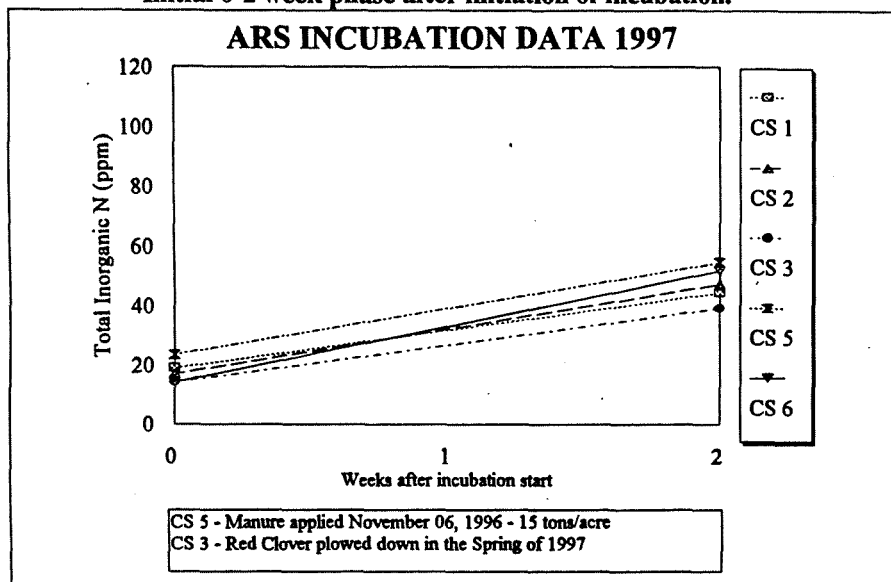


**Figure 1c. 1997 Incubation data from Lakeland Agricultural Complex - LAC.**  
Initial 0-2 week phase after initiation of incubation.

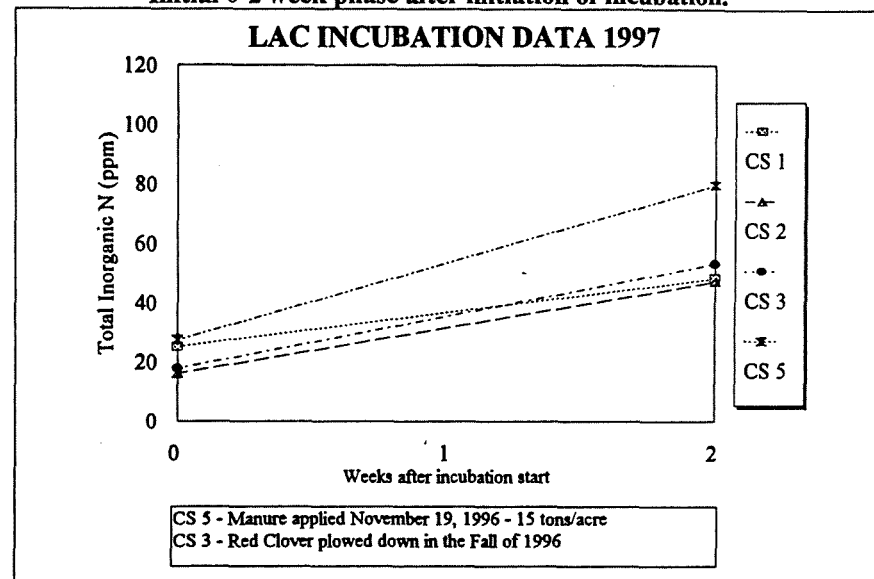


**Figure 1b. 1998 Incubation data from Arlington Research Station - ARS.**  
Initial 0-2 week phase after initiation of incubation.

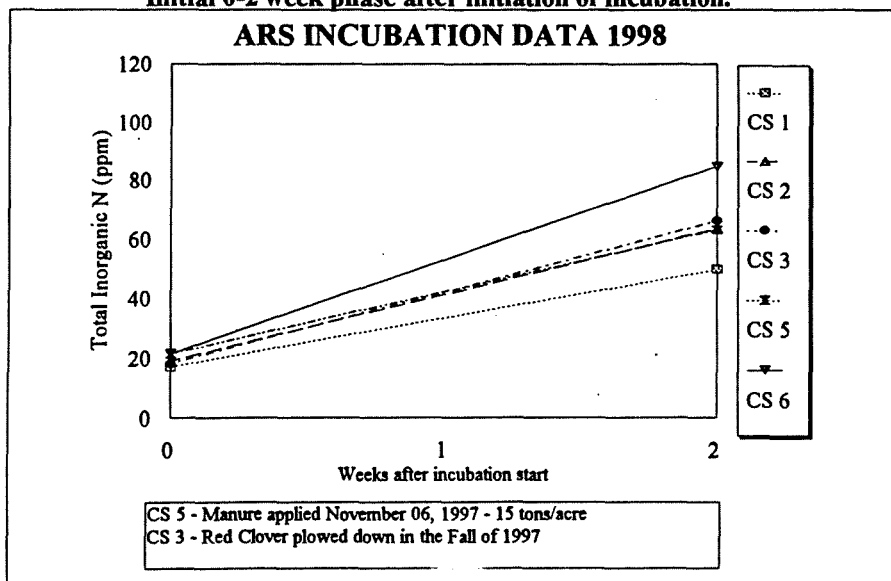


**Figure 1d. 1998 Incubation data from Lakeland Agricultural Complex - LAC.**  
Initial 0-2 week phase after initiation of incubation.

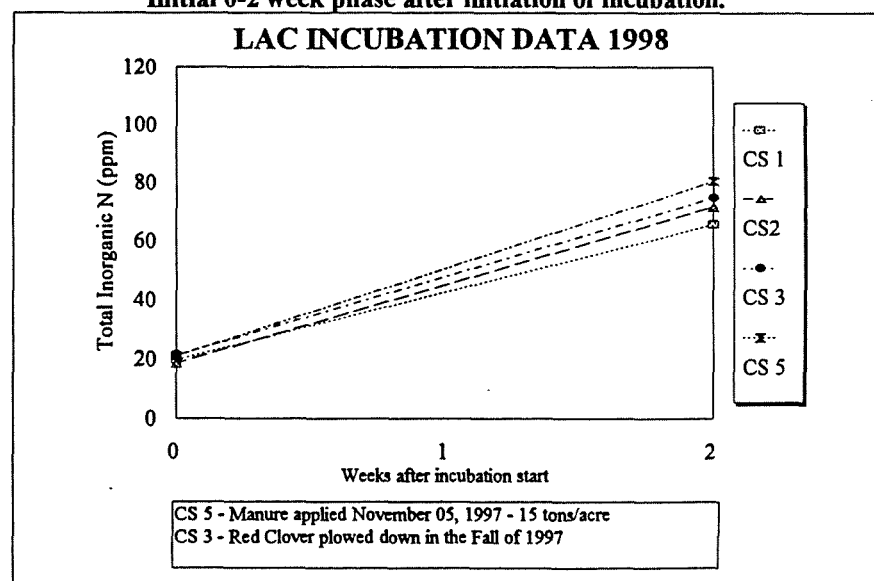


**Figure 2a. 1997 Incubation data from Arlington Research Station - ARS.  
2-8 week phase after initiation of incubation.**

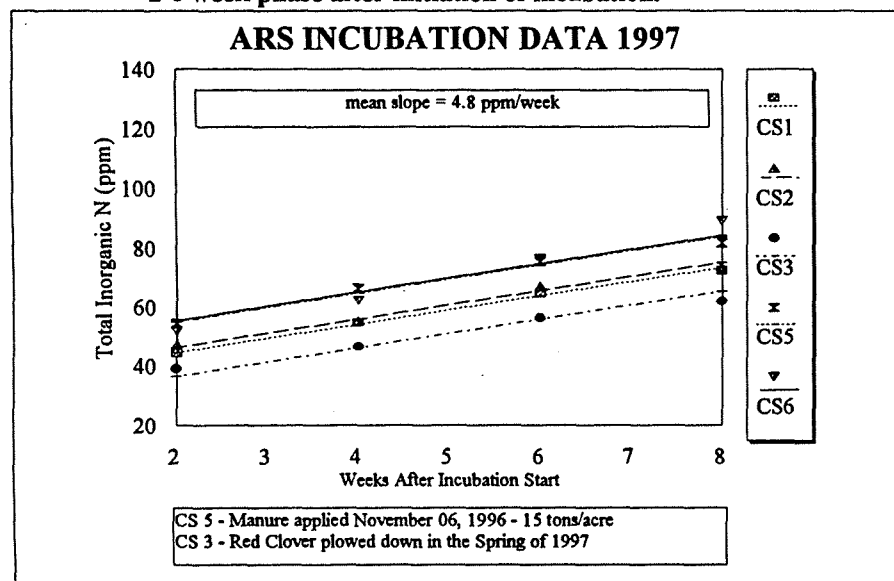


**Figure 2c. 1997 Incubation data from Lakeland Agricultural Complex - LAC.  
2-8 week phase after initiation of incubation.**

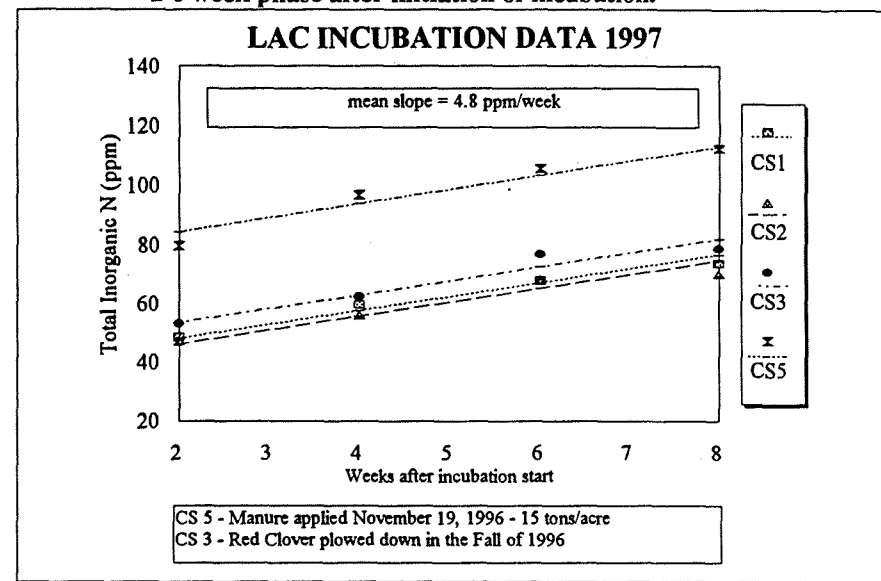


**Figure 2b. 1998 Incubation data from Arlington Research Station - ARS.  
2-8 week phase after initiation of incubation.**

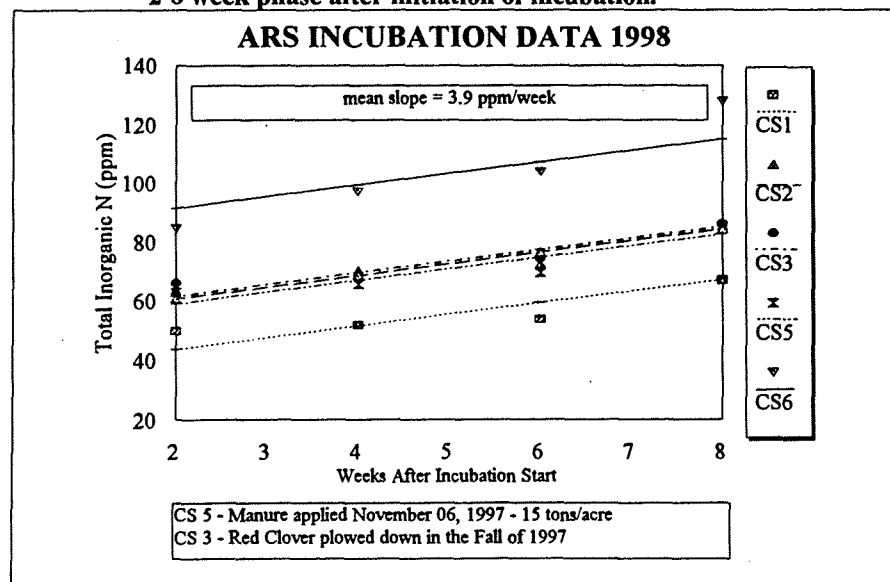
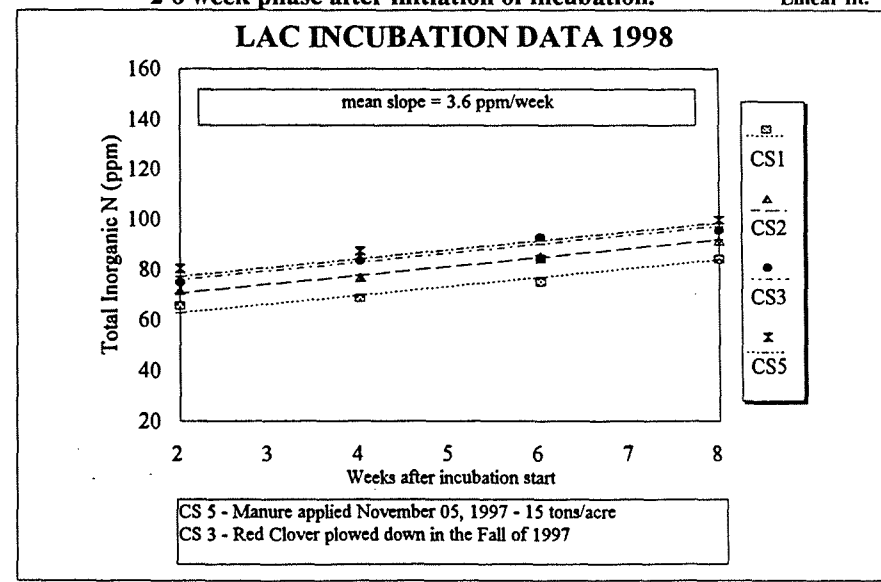


**Figure 2d. 1998 Incubation data from Lakeland Agricultural Complex - LAC.  
2-8 week phase after initiation of incubation.**



### Field Soil Study

Figures 3 a-d (ARS) and 4 a-d (LAC) show the total inorganic N (ppm) data for the soils in CS1, CS2, CS3, and CS5. In most site-years, except LAC-1998, CS3 and CS5 have a higher initial accumulation of inorganic N in the soil. These two systems rely on organic amendments (legumes, green manure, and manure) and incorporated residue for a nutrient base. The accessibility and quantity of organic materials for decomposition by soil biota in these two systems may explain the initial higher accumulation of N. This accumulation begins to decrease in mid- to late-June when the corn plant begins a period of rapid uptake.

The critical value for response to additional N is 21 ppm of inorganic N in the soil solution. Cornfields with soil N levels above 21 ppm will not benefit from additional N (Bundy and Sturgul 1994). The drop in soil test N for CS1 and CS2 in early June suggests that immobilization of N due to corn residue breakdown was resulting in a drop to "dangerously" low N-values. In 1997, the organic cropping systems (CS3 and CS5) maintained a soil N level above 21 ppm. The addition of N-fertilizer however, aided CS1 and CS2 in maintaining this level. By mid-July in 1998, all the cropping systems were below this critical level. For the 1998 season, the addition of N-fertilizer aided CS1 and CS2 in maintaining this critical level for a couple more weeks at LAC, but not at ARS.

Our third hypothesis stated that the inorganic N levels in soil solution from organic sources (CS3-Red Clover and CS5-Alfalfa, manure) would be comparable to soil N levels in systems amended with purchased inorganic N. The data indicates that this is true and that the pool of plant-available N is provided soon enough for the rapid growth period of the corn crop and that an adequate level is provided throughout the growing season. The levels of N in the lower part of the profile (30-60 cm) remained at reasonably low levels throughout the growing season.

**Figure 3a. Inorganic N (NO<sub>3</sub><sup>-</sup> and NH<sub>4</sub><sup>+</sup>) at 0-30 cm  
1997 Arlington Research Station**

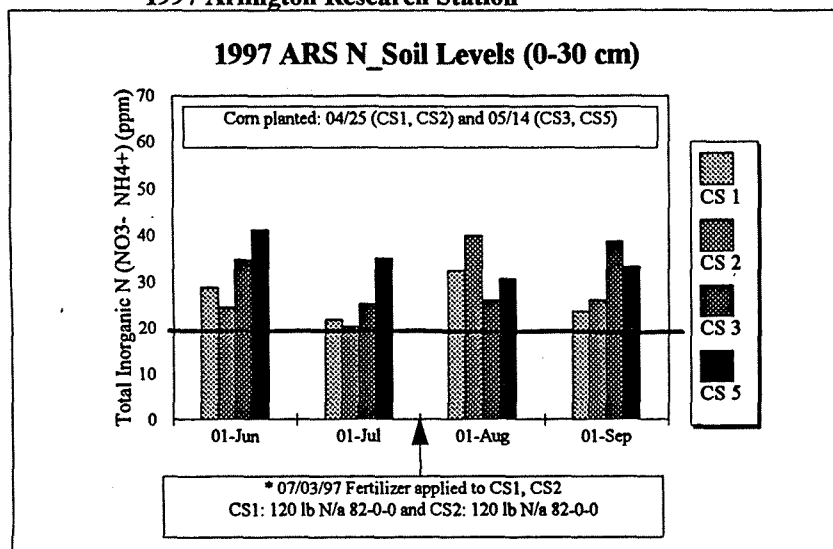


**Figure 3c. Inorganic N (NO<sub>3</sub><sup>-</sup> and NH<sub>4</sub><sup>+</sup>) at 0-30 cm  
1998 Arlington Research Station**

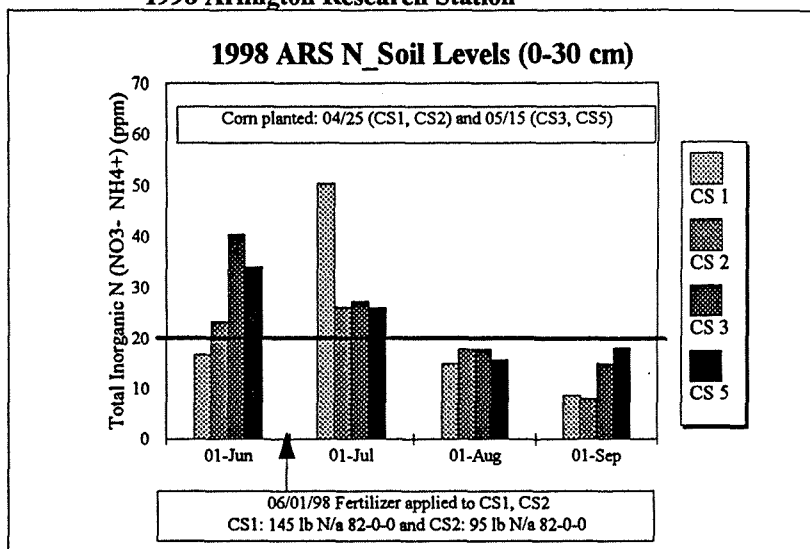


**Figure 3b. Inorganic N (NO<sub>3</sub><sup>-</sup> and NH<sub>4</sub><sup>+</sup>) at 30-60 cm  
1997 Arlington Research Station**

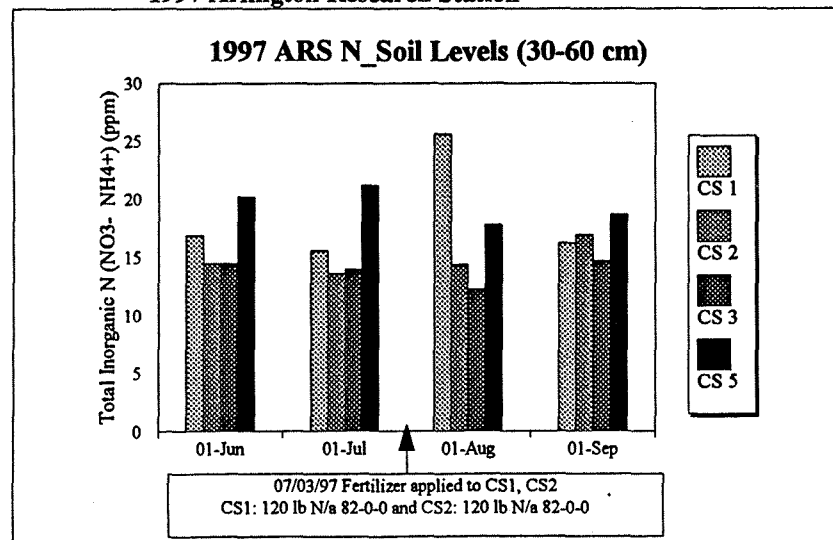
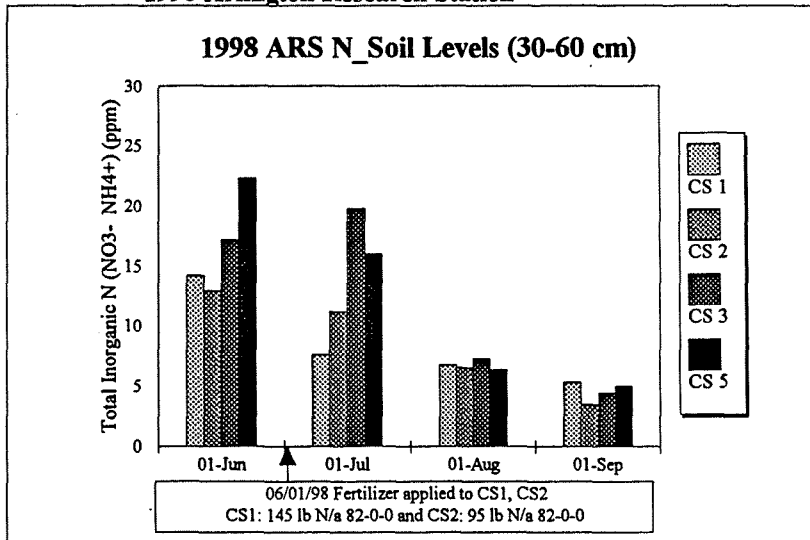


**Figure 3d. Inorganic N (NO<sub>3</sub><sup>-</sup> and NH<sub>4</sub><sup>+</sup>) at 30-60 cm  
1998 Arlington Research Station**



\* Solid lines in 0 - 30 cm graphs indicate critical value of 21 ppm at which the corn crop will not benefit from additional N.  
Arrows indicate between which samples fertilizer N was added to CS1 and CS2.

**Figure 4a. Inorganic N (NO<sub>3</sub><sup>-</sup> and NH<sub>4</sub><sup>+</sup>) at 0-30 cm  
1997 Lakeland Agricultural Complex**

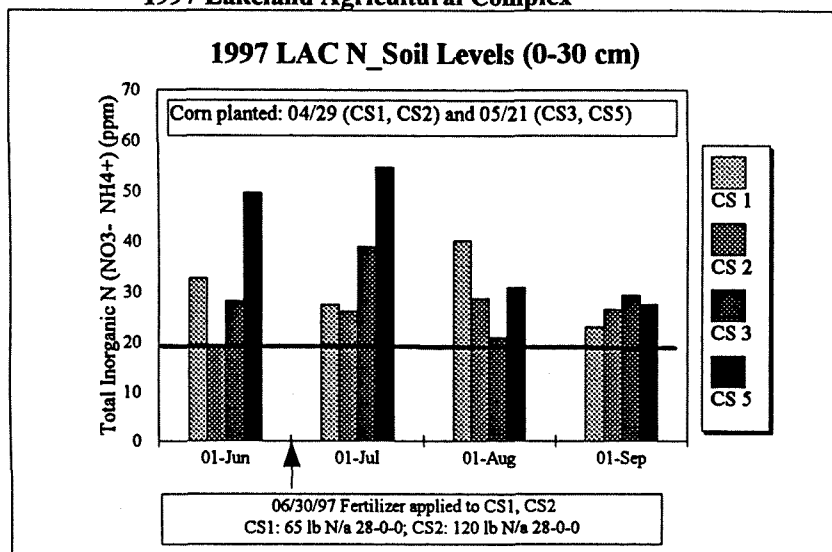


**Figure 4c. Inorganic N (NO<sub>3</sub><sup>-</sup> and NH<sub>4</sub><sup>+</sup>) at 0-30 cm  
1998 Lakeland Agricultural Complex**

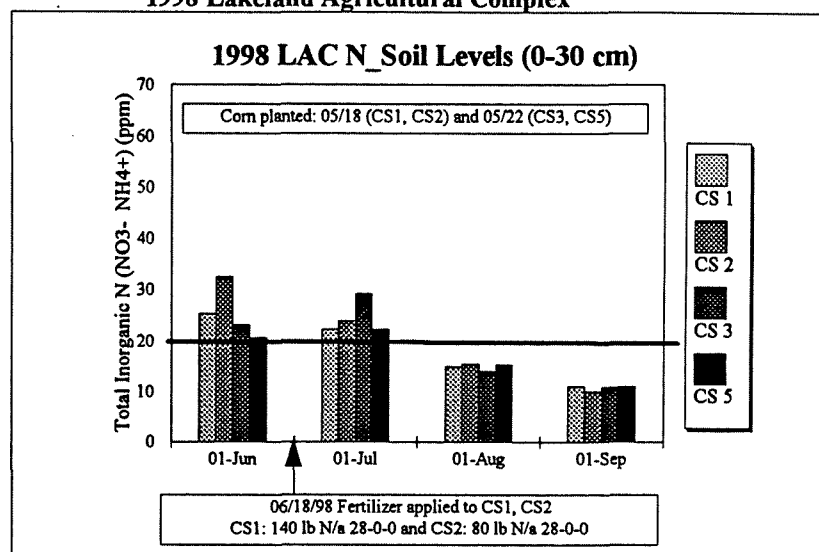


**Figure 4b. Inorganic N (NO<sub>3</sub><sup>-</sup> and NH<sub>4</sub><sup>+</sup>) at 30-60 cm  
1997 Lakeland Agricultural Complex**

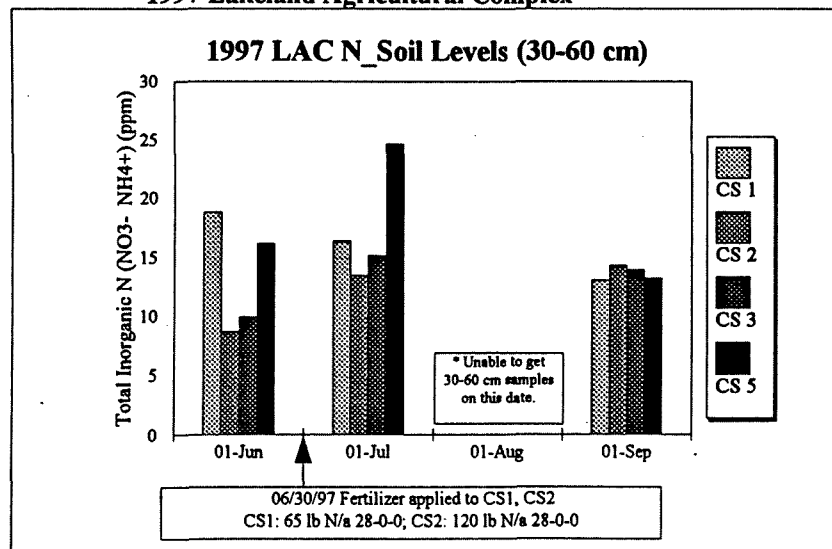
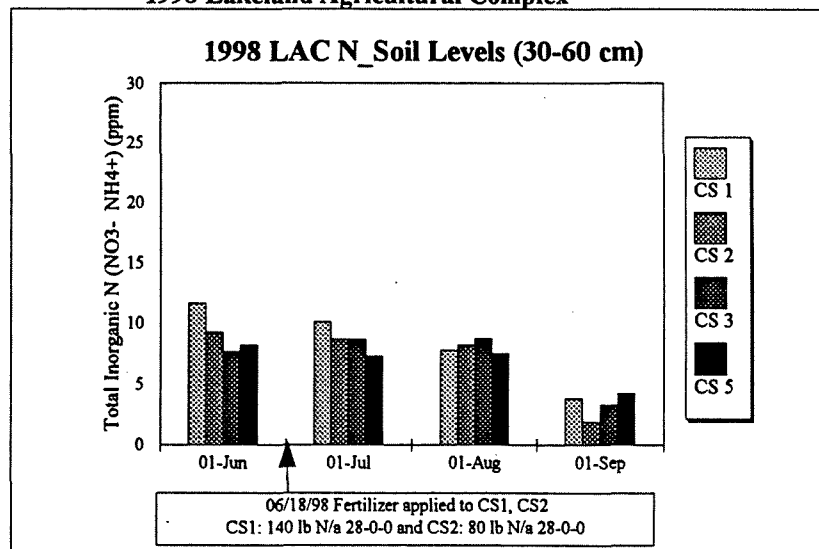


**Figure 4d. Inorganic N (NO<sub>3</sub><sup>-</sup> and NH<sub>4</sub><sup>+</sup>) at 30-60 cm  
1998 Lakeland Agricultural Complex**



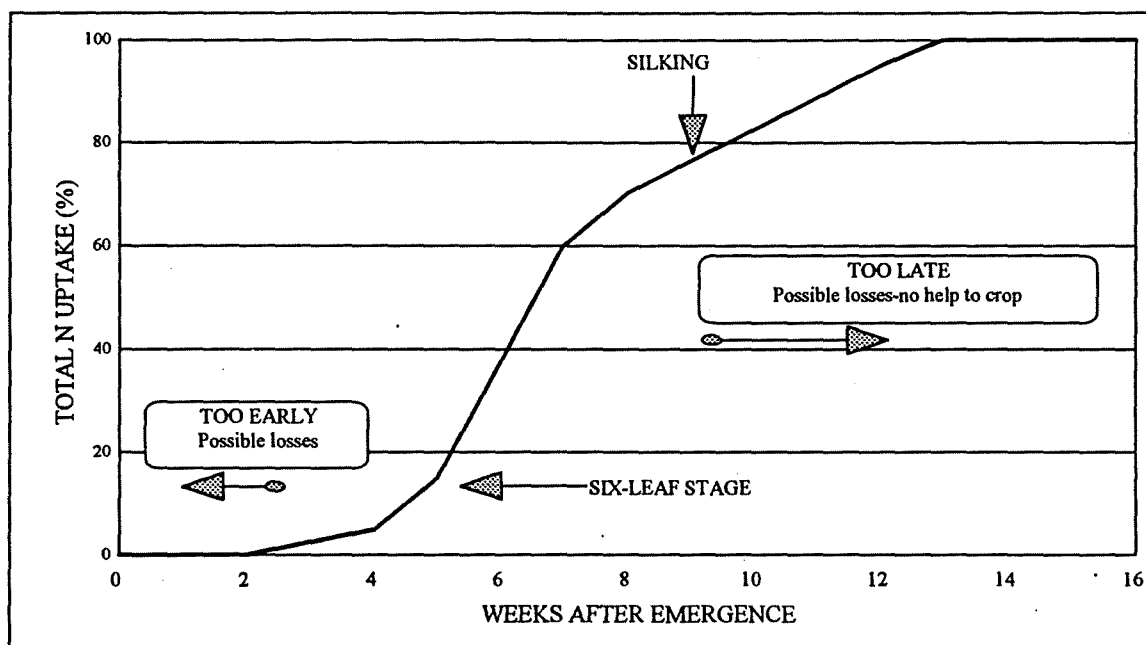
\* Solid lines in 0 - 30 cm graphs indicate critical value of 21 ppm at which the corn crop will not benefit from additional N.

Arrows indicate between which samples fertilizer N was added to CS1 and CS2.

### Field Plant Study

There are two critical stages in the nitrate-N uptake pattern of a corn plant. The first occurs approximately 3-4 weeks after plant emergence; the corn plant enters a period of rapid nutrient uptake. This is about the middle of a period of rapid leaf growth and stem elongation; the growing tip in the stem is about 6-8 inches (15-20 cm) above the soil surface. The uptake of nitrate-N continues at this rapid rate until near physiological maturity. The second critical stage occurs when about 75% of the plants reach the silking stage (9-10 weeks after emergence). At this point, most vegetative growth has ceased and the primary recipient of nitrogen is the developing cob and ear shank; this continues until physiological maturity (Hanway, 1963). Figure 5 illustrates these growth patterns.

**Figure 5. Nutrient uptake pattern for Corn.**



Source: Stute, J.K. 1996.

Figures 6 and 7 represent the total N uptake curves for corn plants sampled at ARS and LAC during the 1997 and 1998 growing season.

### **1997**

Although CS1 and CS2 were planted approximately two weeks prior to the organic systems (CS3 and CS5) in 1997, the uptake patterns are similar. Cool spring weather in 1997 may account for the initial slow growth in the first two systems. As the weather warmed, all the systems maintained similar uptake patterns with no significant differences. In CS5 at ARS and CS3 at LAC however, the plants N-uptake levels were slightly higher, particularly during the period of rapid uptake. This does not appear to have occurred because of a higher level of N

available in the soil. While CS3 and CS5 did have a higher level of soil-N early in the season, once fertilizer was applied to CS1 and CS2 these two systems had higher soil levels (Figures 3a and 4a), especially during July and the rapid uptake period.

### 1998

At LAC-1998, CS1 and CS2 were planted only four days prior to the organic systems (CS3 and CS5), and therefore, the initial uptake patterns are similar. Weather problems prevented timely mechanical weeding in CS3 and CS5, which resulted in severe weed pressure on the corn crop. The results are seen by the drop in plant N-uptake.

At ARS-1998, CS1 and CS2 were planted about two weeks prior to CS3 and CS5. While the initial samples were taken at approximately the same time in the year (mid-June) as in 1997, the growth stage was greater at ARS due to the favorable spring weather. Therefore, the initial samples for CS1 and CS2 are much higher. CS3 and CS5 follow the predictable pattern of uptake, while CS1 and CS2 show an unusual drop in uptake.

Yield data indicates that soil N levels supplied enough N to generate comparable yields in all four of the cropping systems sampled. The lower 1997 yield in CS1 for both ARS and LAC may be explained by the effect of the cool, dry spring and corn rootworm infestation. The climatic conditions delayed the infestation of corn rootworm and the effect of the insecticide used to control this pest had worn off by the time the rootworm became a problem. The lower yields in CS3 and CS5 at LAC in 1998 were the result of very wet conditions that limited crucial mechanical weeding operations and weeds became a severe problem in these two systems. The yield data for CS5 indicates the inorganic N levels in the soil solution from organic sources are adequate and have consistently produced comparable yields to those of CS2 and better yields than CS1 for the last six years. CS3 is less consistent, but in the years when management practices are well timed, the yields are comparable to the cropping systems amended with purchased inorganic N.

Figure 6a. Total N uptake (grams / 10 plants) ARS, 1997.

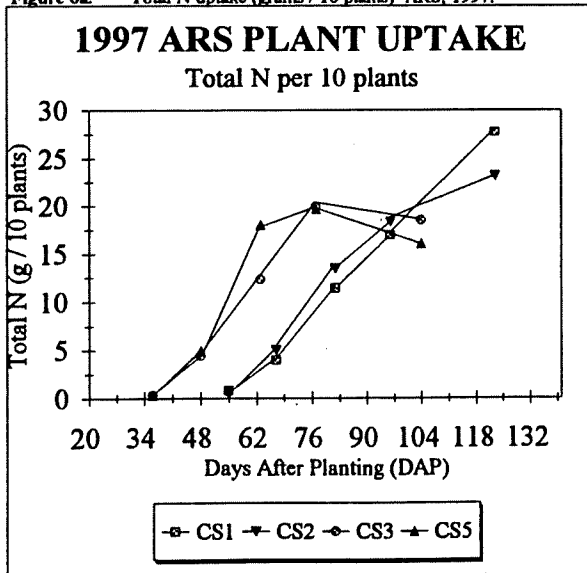


Figure 6b. Total N uptake (grams / 10 plants) LAC, 1997.

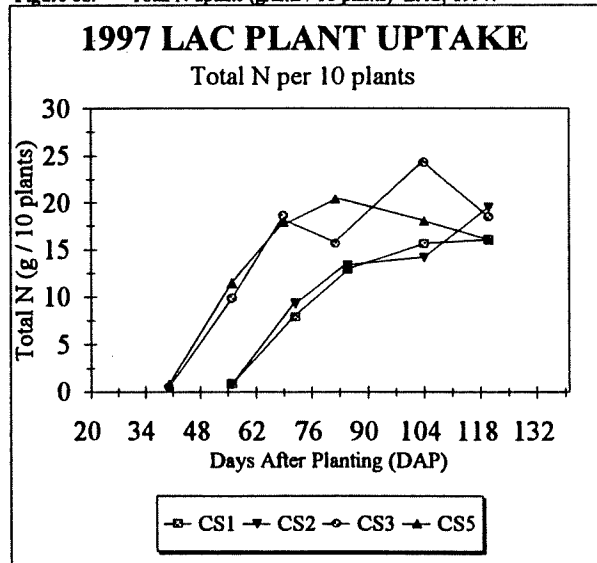


Figure 7a. Total N uptake (grams / 10 plants) ARS, 1998.

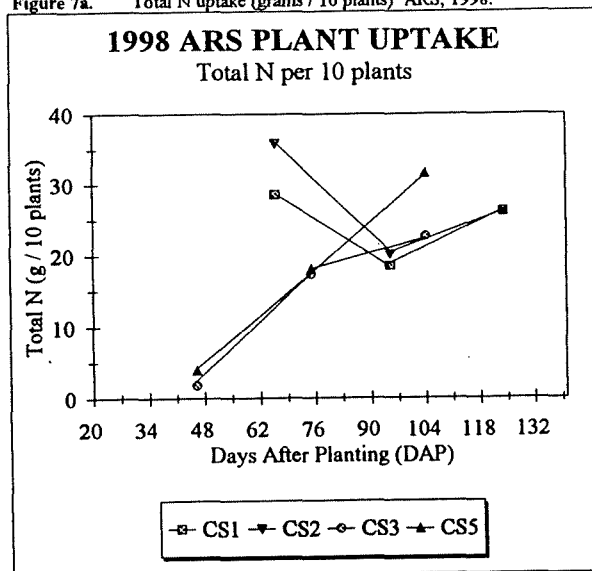
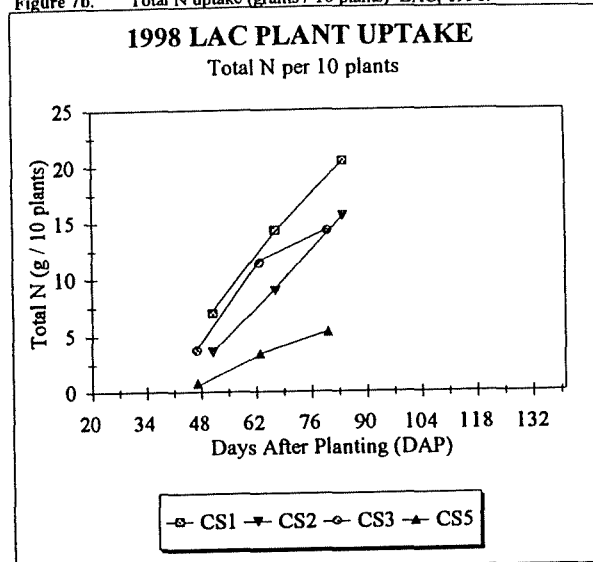


Figure 7b. Total N uptake (grams / 10 plants) LAC, 1998.



### Conclusion

Our results suggest that nitrogen was not limiting yields in 1997 and 1998. The forage-based systems appear to have higher initial mineralization rates than the cash-grain systems but drop to similar rates between weeks 2 and 8. Soil testing showed that inorganic N availability was relatively high under all N-management systems with soil test levels rarely dropping below 21 ppm during the May and June period. Soil tests actually remained quite high throughout the season in 1997. Differences in yield appear to be due primarily to agronomic practices and pest control (rootworm on CS1 – 1997 – ARS & LAC; weed control CS3 and CS5 – 1998 – LAC).

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## SATELLITE TRIALS

### 7. Chemlite: Corn Response to Commercial Fertilizer in Cropping System Three at Lakeland, 1997

Jim Stute<sup>1</sup>

#### Introduction

During the first several growing seasons of the WICST project, corn yield in Cropping System Three was less than expected. Satellite studies were initiated in 1994 at both locations to determine if supplemental nutrients, applied as starter, side dress N or a combination could increase yield. Results through 1996 are reported in the 1996 annual report. The study was continued in 1997 at the Lakeland site only.

#### Materials and Methods

In 1997, the study was conducted as a satellite on plots adjacent to the core trial. Treatments included 1) no additional fertilizer, 2) starter fertilizer (as 9-23-30, 100lb/a), 3) sidedress N (as 28-0-0, 60 lb N/a), and 4) both starter and sidedress. The red clover green manure was killed the previous fall by undercutting. Secondary tillage was conducted with a single pass finishing tool on April 25 and May 21. Corn, DeKalb 247 was planted on May 21 at 34,000 kernels/acre in 30-inch rows. Starter fertilizer was applied in a band 2 inches to the side and 2 inches below the seed furrow. Supplemental N was applied as a sidedress on July 9. Weed control consisted of rotary hoeing and cultivation. Corn was harvested for grain on October 22.

The experimental design was a randomized complete block with three replicates. Individual plots were 15 by 220 ft. Data were analyzed using analysis of variance, and means separated using an LSD at the 5% level of probability. A partial budget analysis approach was used to determine returns to additional nutrients using the following values: Drying – \$0.02/pt to 15%; Starter – \$198/ton; 28% – \$157/ton; N application – \$6.00/a; and Corn – \$2.50/bu.

#### Results

Both starter fertilizer and sidedress N increased corn yield, alone and in combination, although the yield increase from a combination was not significant (Table 1). A positive yield response was expected, given the unseasonably cool conditions and slow GDD (Growing Degree Days) accumulation (see Figure 4, LAC Accumulated Corn GDD, pg. 10), which presumably slowed mineralization of N from the green manure. A similar response was seen at Lakeland in 1996, also a year with below normal GGD accumulation in April and May. As in 1996, yield response was greatest where sidedress N was. From the seven site years of data in this study, it is apparent that corn following a red clover green manure responds to supplemental N in years with cool springs (Mulder, 1996). The decision to sidedress could be made easier by considering GGD accumulation to that point in the growing season and acting accordingly.

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Adding starter fertilizer or supplemental N increased the gross margin, but adding both resulted in a loss (Table 1). Based on data from both locations (Mulder, 1996) it appears that sidedressing N would produce the greatest return.

**Table 1. Effect of supplemental nutrients on yield of corn following wheat/ red clover, Lakeland 1997.**

| <b>Fertilizer Addition</b> | <b>Grain Moisture (%)</b> | <b>Grain Yield (bu/a)</b> | <b>Relative Return* (\$/a)</b> |
|----------------------------|---------------------------|---------------------------|--------------------------------|
| None                       | 26.6                      | 108.6                     | -                              |
| Starter                    | 26.0                      | 122.2                     | 21.11                          |
| Sidedress                  | 27.4                      | 131.0                     | 27.8                           |
| Starter + Sidedress        | 28.3                      | 116.7                     | -14.44                         |
| LSD (0.05)                 | NS                        | 10.7                      |                                |

\* Return relative to no fertilizer once additional costs and returns are calculated.

**Table 2. Corn yields from previous trials.**

| <b>Fertilizer addition</b> | <b>Arlington</b> |             |             | <b>Lakeland</b> |             |             |
|----------------------------|------------------|-------------|-------------|-----------------|-------------|-------------|
|                            | <b>1994</b>      | <b>1995</b> | <b>1996</b> | <b>1994</b>     | <b>1995</b> | <b>1996</b> |
| None                       | 190.3            | 166.5       | 61.5        | 179.8           | 128.0       | 32.4        |
| Starter only               | 185.8            | 164.3       | 62.4        | 158.4           | 137.1       | 35.1        |
| Side-dress only            | 186.2            | 164.7       | 72.6        | 174.0           | 137.1       | 63.7        |
| Starter + Side-dress       | 192.1            | 162.9       | 65.4        | 176.4           | 135.5       | 52.4        |
| LSD (0.05)                 | NS               | NS          | NS          | NS              | NS          | 16.3        |

### References

Mulder, T. 1996. Corn Response to commercial fertilizer in a low input cash grain system. 1996 WICST Technical Report, p36-37.

## KRUSENBAUM PROJECT

### 8. Krusenbaum Farm Project Update<sup>1</sup>

This case study documents the start-up of a successful alternative dairy farm in Wisconsin. Initially the vision was to establish a 97-hectare biodynamic farm with dairy and cash cropping. Low milk prices throughout most of 1991 and the heavy workload associated with conventional dairying forced the farm family to look for alternative strategies. They experimented with management-intensive grazing in 1992 and by the spring of 1994 had completed seeding their entire farm to sod. (Start-up and early phases)

The workload still remained too heavy and the family switched to seasonal dairying and out-wintering of their dry stock, reducing the mid-winter workload from 12 to 3.5 hours/day. By the end of 1995 net farm income from operations had risen from \$21,500/year (1990 and 1991) to \$54,000/year (1994 and 1995). (Intensive grazing phase)

This story is important because the farm family, with their alternative approach (biodynamic, grass-based, seasonal milking) were able to weather the stresses of entering dairy farming at a time when entry rates were very low and the existing dairy farmers faced substantial financial pressure. On-farm monitoring during this six-year study has shown that the grass-based system resulted in low purchased feed inputs (\$300/cow) and near equilibrium in whole-farm nutrient budgeting, while good herd management has resulted in maintaining high productivity (RHA=17,000 lbs.) and excellent herd health. In addition, renting the farm and careful money management has resulted in a low debt load (\$73/cow). This case study illustrates the complexities and adjustments associated with the initiation of an alternative farm business.

The influx of nearly \$30,000/year in 1994 and again in 1995 through the sale of dairy cows and machinery made it possible for the Krusenbaums to consider modifying their system again. In their search for an improved quality of life they built a New Zealand style milk parlor to lessen the time in the barn milking. To pay for the installation, they expanded the herd. The increased level of debt and larger herd are again testing the financial and environmental sustainability of the farm. The resource base is more heavily exploited, and management skills are at a premium, especially now as the entire industry has entered a more volatile milk price market. In a sequel to this report, we will document how the farm weathers this Expansion phase (1996 – 1998).

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<sup>1</sup> Introduction paragraph in 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) p.50.

## 1997-1998 RESEARCH WORK PLAN:

### I. Alleviating Soil Compaction:

Four strips were laid out on paddocks 1-5 (Figure 1) and the Aerway was used on December 4<sup>th</sup>, 1997 (2<sup>nd</sup> notch, 2.5-degree angle). The area will be tilled again with the Aerway in April 1998. After an initial flash grazing, we will try to leave these paddocks for haying in late May and then check for a difference in production.

### II. Soil Fertility Research:

- **Potassium Study** – Potassium sulfate will be applied two times (April, 1997 and April, 1998) at the rate of 400 lb/a on four of the plots (paddock 7c, -d; Figure 1) to bring the STK to recommended levels. We will get a sample from these eight plots just prior to each grazing during the summer.
- **Manure Nitrogen Study** – The Krusenbaums began stockpiling barn manure on paddock #10 in the summer of 1997 (11 loads at 8.1 tons/load). He will continue in the spring and summer of 1998 until he gets to about 40 tons/a (about 25 loads). The experiment will begin the following spring (1999) and we will see the effect of two years of manure additions on production.

### III. Outwintering Research:

- **Impact of outwintering on the animals** – five calves (7-8 months) and five bred heifers (17-18 months) were weighed on December 17<sup>th</sup>, 1997. They will be weighed again in the early spring of 1998.
- **Impact of outwintering on manure content** – Samples were taken in mid-November 1997 and split with one-half going to the lab, and one-half placed back on the ground in a protected area. At green-up (1<sup>st</sup> week of April), the remainder of the manure sample will be taken to the lab. This trial will be run again over the 1998/99 winter.

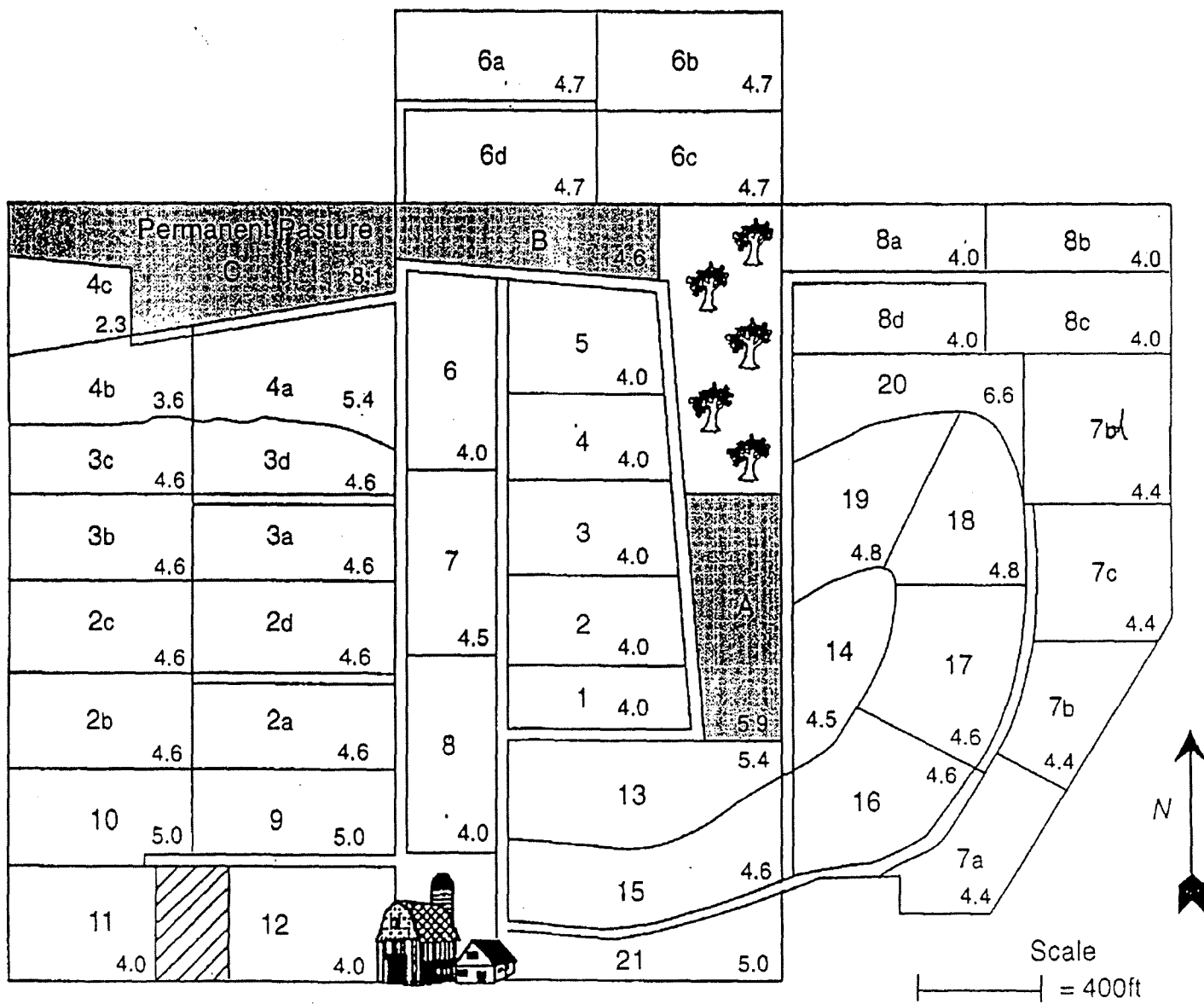


Figure 1. Krusenbaum Farm field map.



## 8a. Krusenbaum Farm Project: Financial Report

Gary Frank<sup>1</sup> and Altfrid Krusenbaum<sup>2</sup>

### Introduction

Over the past nine years (1990-1998), Krusenbaums have employed numerous conventional conservation and soil saving techniques and other holistic practices plus some less-conventional practices. One of those less-conventional practices was rotational grazing. They started rotational grazing in the spring of 1992.

In 1993, the decision was made to convert the conventional-rotational-grazing system currently employed to a grass-based-seasonal-calving system. This meant some delayed breeding and heifer purchases in 1993. Cows that would not fit into a seasonal calving system were to be sold at auction in January 1994. In the spring of 1996, they invested in a swing parlor.

### Incomes

(Table 1 – 1997 and Table 2 – 1998)

The income and expenses are shown on the attached Farm Earnings reports. The total milk income was \$191,630 and \$273,013 in 1997 and 1998 respectively and total accrual adjusted farm income was \$248,424 and 354,604.

### Expenses

The total accrual adjusted farm expense was \$202,637 and \$256,975 in 1997 and 1998 respectively. The amount of interest paid has approximately \$157 and \$146 per cow. This is well below the goal of \$300 (or less) per cow. However, the farm is paying rental expenses of \$191 and \$284 per cow in 1997 and 1998 respectively. This is somewhat higher than the average rental costs (\$120) plus property tax payments (\$66) per cow on other farms in 1997.

In 1997, veterinary fees and medicine expenses dropped to \$57 per cow and in 1998 it dropped even more to \$42 per cow. This is the first year veterinary and medicine costs have been below \$100 per cow. This is at the goal of \$50 per cow. 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 only \$50,993 of that was purchased feed!

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.

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<sup>1</sup> Outreach Program Manager, Agricultural and Applied Economics

<sup>2</sup> Dairy Farm Cooperator

### Net Worth (Table 3 – 1998)

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 and \$79,880 in 1998. Of this \$101,17, \$55,420 was Retained Earning. 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 and 1998 respectively was 9.84 and 22.37 percent on a fair market value (FMV) basis with appreciation. The ROROA was 6.42 and 14.88 percent on a cost basis without appreciation. The Wisconsin average ROROA, without appreciation, was 5.42 percent in 1997.

The Asset Turnover Ratio was 63 and 75 percent in 1997 and 1998 respectively. This is much higher than the Wisconsin average of 42 percent, however (Yes, another one.) they are renters and do not have the land asset to reduce their ratio.

### Cost of Production (Table 4 – 1997, Tables 5 and 6 – 1998)

The Basic Cost per Hundredweight Equivalent (CWT EQ) of producing milk was \$8.30 in 1997 and \$7.48 in 1998. The Basic Cost per CWT EQ in Wisconsin in 1997 was \$7.86. The Total Allocated Cost per CWT EQ on the Krusenbaum farm in 1997 was \$11.74 (\$11.83 in 1998) versus \$11.80 on Wisconsin farms in 1997. 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 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.

### Summary (Table 7 – 1998)

When comparing this farm to your farm or other farms, basis costs per CWT EQ is the best measure. This value neutralizes the effects on cash 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 this 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 \$440 per cow in 1997. The NFIFO in 1998 was \$97,630 or \$781 per cow.

Table 1.

*Farm Earnings*WICST 7<sup>th</sup> Annual Report 73

KRUSENBAUM FARM  
January 1997 through December 1997  
Enterprises Excluded : LABOR, PERSONAL

|                                                                  | Ending<br>Balance   | %                   |
|------------------------------------------------------------------|---------------------|---------------------|
| <b>Income</b>                                                    |                     |                     |
| 04 Sales of Livestock, Produce, Grains and Other Products Raised | \$196,569.07        | 92.57 %             |
| 05A Distributions Received from Cooperatives                     | \$899.50            | 0.42 %              |
| 06A Agricultural Program Payments                                | \$4,198.00          | 1.98 %              |
| 08 Crop Insurance Proceeds and Certain Disaster Payments         | \$6,093.85          | 2.87 %              |
| 09 Custom Hire (Machine Work) Income                             | \$2,082.00          | 0.98 %              |
| 10 Other Income, Including Gasoline/Fuel Tax Credit or Refund    | \$3,661.58          | 1.72 %              |
| 4798 Cost Basis Used Against Capital Sales                       | (\$29,600.10)       | (13.94%)            |
| 52 Sales of Raised or Purchased BLS Owned < 2 Years              | \$15,043.88         | 7.08 %              |
| 54 Sales of Other Farm Assets Owned >= 1 Year And Sold At A Loss | \$13,400.00         | 6.31 %              |
| <b>Income</b>                                                    |                     | <b>\$212,347.78</b> |
| <b>Expense</b>                                                   |                     |                     |
| 12 Breeding Fees                                                 | \$3,286.00          | 1.91 %              |
| 13 Chemicals                                                     | \$385.00            | 0.22 %              |
| 14 Conservation Expenses                                         | \$82.29             | 0.05 %              |
| 15 Custom Hire (Machine Work)                                    | \$9,226.83          | 5.35 %              |
| 17 Employee Benefit Program                                      | \$842.76            | 0.49 %              |
| 18 Feed Purchase                                                 | \$62,471.18         | 36.22 %             |
| 19 Fertilizer and Lime                                           | \$105.00            | 0.06 %              |
| 20 Freight and Trucking                                          | \$2,792.50          | 1.62 %              |
| 21 Gasoline, Fuel, and Oil                                       | \$4,625.50          | 2.68 %              |
| 22 Farm Insurance                                                | \$1,046.00          | 0.61 %              |
| 23B Other Interest                                               | \$14,527.49         | 8.42 %              |
| 24 Labor Hired                                                   | \$2,781.40          | 1.61 %              |
| 26B Rent/Lease Other                                             | \$20,960.00         | 12.15 %             |
| 27 Repairs and Maintenance                                       | \$11,373.22         | 6.59 %              |
| 28 Seeds and Plants Purchased                                    | \$5,484.28          | 3.18 %              |
| 30 Supplies Purchased                                            | \$15,088.55         | 8.75 %              |
| 32 Utilities                                                     | \$3,895.00          | 2.26 %              |
| 33 Veterinary Fees and Medicine                                  | \$6,283.75          | 3.64 %              |
| 34 Other Expenses                                                | \$7,213.83          | 4.18 %              |
| <b>Expense</b>                                                   |                     | <b>\$172,470.58</b> |
| <hr/>                                                            |                     |                     |
| Change in Feed Inventories                                       | \$17,676.64         |                     |
| Change in Raised Livestock                                       | \$18,400.00         |                     |
| Change in Accounts Receivable                                    | \$0.00              |                     |
| <b>TOTAL INCOME</b>                                              | <b>\$248,424.42</b> |                     |
| <hr/>                                                            |                     |                     |
| Depreciation Claimed                                             | \$30,166.09         |                     |
| <b>TOTAL EXPENSE</b>                                             | <b>\$202,636.67</b> |                     |
| <hr/>                                                            |                     |                     |
| <b>Net Farm Income</b>                                           | <b>\$45,787.75</b>  |                     |

Table 2.

# Farm Earnings

WICST 7<sup>th</sup> Annual Report

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KRUSENBAUM FARM  
January 1998 through December 1998  
Enterprises Excluded : LABOR, PERSONAL

|                                                                  | Ending<br>Balance   | %                   |
|------------------------------------------------------------------|---------------------|---------------------|
| <b>Income</b>                                                    |                     |                     |
| 04 Sales of Livestock, Produce, Grains and Other Products Raised | \$278,418.33        | 92.12 %             |
| 05A Distributions Received from Cooperatives                     | \$631.04            | 0.21 %              |
| 06A Agricultural Program Payments                                | \$4,346.00          | 1.44 %              |
| 09 Custom Hire (Machine Work) Income                             | \$5,377.60          | 1.78 %              |
| 10 Other Income, Including Gasoline/Fuel Tax Credit or Refund    | \$1,610.95          | 0.53 %              |
| 4798 Cost Basis Used Against Capital Sales                       | (\$19,624.44)       | (6.49%)             |
| 52 Sales of Raised or Purchased BLS Owned < 2 Years              | \$21,989.99         | 7.28 %              |
| 56 Sales of Other Farm Assets Owned >= 1 Year And Sold At A Gain | \$9,500.00          | 3.14 %              |
|                                                                  | <b>Income</b>       | <b>\$302,249.47</b> |
| <b>Expense</b>                                                   |                     |                     |
| 12 Breeding Fees                                                 | \$5,014.00          | 2.50 %              |
| 13 Chemicals                                                     | \$1,133.71          | 0.57 %              |
| 15 Custom Hire (Machine Work)                                    | \$15,946.50         | 7.96 %              |
| 18 Feed Purchase                                                 | \$50,993.28         | 25.46 %             |
| 20 Freight and Trucking                                          | \$2,542.00          | 1.27 %              |
| 21 Gasoline, Fuel, and Oil                                       | \$3,885.97          | 1.94 %              |
| 22 Farm Insurance                                                | \$524.00            | 0.26 %              |
| 23B Other Interest                                               | \$18,215.29         | 9.09 %              |
| 24 Labor Hired                                                   | \$9,202.39          | 4.59 %              |
| 26A Rent/Lease Equipment                                         | \$12,942.14         | 6.46 %              |
| 26B Rent/Lease Other                                             | \$22,575.00         | 11.27 %             |
| 27 Repairs and Maintenance                                       | \$18,502.77         | 9.24 %              |
| 28 Seeds and Plants Purchased                                    | \$5,331.98          | 2.66 %              |
| 29 Storage and Warehousing                                       | \$1,000.00          | 0.50 %              |
| 30 Supplies Purchased                                            | \$15,487.51         | 7.73 %              |
| 32 Utilities                                                     | \$4,690.68          | 2.34 %              |
| 33 Veterinary Fees and Medicine                                  | \$5,298.14          | 2.65 %              |
| 34 Other Expenses                                                | \$7,006.96          | 3.50 %              |
|                                                                  | <b>Expense</b>      | <b>\$200,292.32</b> |
| <b>Change in Feed Inventories</b>                                |                     |                     |
|                                                                  | \$25,355.00         |                     |
| <b>Change in Raised Livestock</b>                                |                     |                     |
|                                                                  | \$27,000.00         |                     |
| <b>Change in Accounts Receivable</b>                             |                     |                     |
|                                                                  | \$0.00              |                     |
| <b>TOTAL INCOME</b>                                              | <b>\$354,604.47</b> |                     |
| <b>Depreciation Claimed</b>                                      |                     |                     |
|                                                                  | \$56,682.22         |                     |
| <b>TOTAL EXPENSE</b>                                             | <b>\$256,974.54</b> |                     |
| <b>Net Farm Income</b>                                           | <b>\$97,629.93</b>  |                     |

Table 3.

# Net Worth Summary WICST 7<sup>th</sup> Annual Report 75

## KRUSENBAUM FARM

January 1998 through December 1998

Enterprises Excluded : LABOR, PERSONAL

|                                          | Cost Basis    |              | Market Basis |              |
|------------------------------------------|---------------|--------------|--------------|--------------|
|                                          | Beginning     | Ending       | Beginning    | Ending       |
| <b>ASSETS</b>                            |               |              |              |              |
| Current                                  |               |              |              |              |
| Cash Accounts                            | (\$4,521.07)  | (\$734.15)   |              |              |
| Prepaid Expenses                         | \$17,548.00   | \$12,016.12  |              |              |
| Feed Inventories                         | \$19,440.00   | \$46,535.00  |              |              |
| Resale Items                             | \$1,500.00    | \$1,500.00   |              |              |
| Accounts Receivable                      | \$0.00        | \$0.00       |              |              |
| Other Current Assets                     | \$0.00        | \$0.00       |              |              |
| Total Current                            | \$33,966.93   | \$59,316.97  |              |              |
| Non-Current                              |               |              |              |              |
| Raised Breeding Livestock                | \$96,400.00   | \$123,400.00 | \$140,400.00 | \$141,400.00 |
| Purchased Breeding                       | \$35,555.00   | \$35,125.00  | \$36,000.00  | \$60,000.00  |
| Machinery and Equipment                  | \$138,206.77  | \$136,643.74 | \$120,200.00 | \$140,200.00 |
| Buildings                                | \$118,329.54  | \$106,041.38 | \$70,000.00  | \$70,000.00  |
| Land                                     | \$0.00        | \$0.00       | \$0.00       | \$0.00       |
| Other Non-Current Assets                 | \$1,000.00    | \$1,075.00   | \$2,550.00   | \$2,550.00   |
| Total Non-Current                        | \$389,491.31  | \$402,285.12 | \$369,150.00 | \$414,150.00 |
| TOTAL ASSETS                             | \$423,458.24  | \$461,602.09 | \$403,116.93 | \$473,466.97 |
| <b>LIABILITIES</b>                       |               |              |              |              |
| Current                                  |               |              |              |              |
| Accounts Payable                         | \$7,376.70    | \$0.00       |              |              |
| Current Liabilities                      | \$0.00        | \$0.00       |              |              |
| Total Current                            | \$7,376.70    | \$0.00       |              |              |
| Non-Current                              |               |              |              |              |
| Intermediate Liabilities                 | \$59,341.76   | \$55,175.64  |              |              |
| Long Term Liabilities                    | \$189,028.60  | \$191,041.64 |              |              |
| Total Non-Current                        | \$248,370.36  | \$246,217.28 |              |              |
| TOTAL LIABILITIES                        | \$255,747.06  | \$246,217.28 |              |              |
| <b>STATEMENT OF EQUITIES (NET WORTH)</b> |               |              |              |              |
| Equity Items                             | Beginning     | Ending       | Change       |              |
| Contributed Capital                      | \$0.00        | \$0.00       | \$0.00       |              |
| Retained Earnings                        | \$167,711.18  | \$215,384.81 | \$47,673.63  |              |
| Valuation Adjustment                     | (\$20,341.31) | \$11,864.88  | \$32,206.19  |              |
| TOTAL EQUITIES (NET WORTH)               | \$147,369.87  | \$227,249.69 | \$79,879.82  |              |

Table 4.

# Cost of Producing Milk

WEST 7<sup>th</sup> Annual Report

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## KRUSENBAUM FARM

January 1997 through December 1997

Enterprises Excluded : PERSONAL

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|                          |                  |
|--------------------------|------------------|
| Total Farm Income        | \$248,424.42     |
| Average Milk Price       | \$13.36          |
| CWT EQs of Milk Produced | 18,594.64        |
| Total Allocated Costs    | \$218,218.59     |
| Total Interest Paid      | \$14,527.49      |
| Wages and Benefits Paid  | \$19,206.08      |
| Depreciation Claimed     | \$30,166.09      |
| <br>Total Basic Costs    | <br>\$154,318.93 |
| Basic Cost per CWT EQ    | \$8.30           |
| Total Margin             | \$94,105.49      |

### Costs per CWT EQ of Milk

---

|                                    |             |
|------------------------------------|-------------|
| Cost of Resale Items or Basis      | \$0.00      |
| Car and Truck Expenses             | \$0.00      |
| Chemicals                          | \$0.02      |
| Custom Hire (machine work)         | \$0.50      |
| Feed Purchased                     | \$3.36      |
| Fertilizers and Lime               | \$0.01      |
| Freight and Trucking               | \$0.15      |
| Gasoline, Fuel and Oil             | \$0.25      |
| Insurance (other than health)      | \$0.06      |
| Rent or Lease (Equipment)          | \$0.00      |
| Rent or Lease (Other)              | \$1.13      |
| Repairs and Maintenance            | \$0.61      |
| Seeds and Plants Purchased         | \$0.29      |
| Supplies Purchased                 | \$0.81      |
| Taxes                              | \$0.00      |
| Utilities                          | \$0.21      |
| Veterinary, Breeding, and Medicine | \$0.51      |
| Other Expenses                     | \$0.39      |
| <br>Basic Costs                    | <br>\$8.30  |
| <br>Mortgage Interest              | <br>\$0.00  |
| Other Interest                     | \$0.78      |
| Employee Benefit Programs          | \$0.53      |
| Labor Hired                        | \$0.51      |
| Depreciation                       | \$1.62      |
| <br>Other Costs                    | <br>\$3.44  |
| <br>Total Cost                     | <br>\$11.74 |

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Table 5.

# Cost of Producing Milk

WISCST 7<sup>th</sup> Annual Report

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## KRUSENBAUM FARM

January 1998 through December 1998

Enterprises Excluded : PERSONAL

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|                          |                  |
|--------------------------|------------------|
| Total Farm Income        | \$354,604.47     |
| Average Milk Price       | \$15.35          |
| CWT EQs of Milk Produced | 23,101.27        |
| Total Allocated Costs    | \$273,307.14     |
| Total Interest Paid      | \$18,215.29      |
| Wages and Benefits Paid  | \$25,534.99      |
| Depreciation Claimed     | \$56,682.22      |
| <br>Total Basic Costs    | <br>\$172,874.64 |
| Basic Cost per CWT EQ    | \$7.48           |
| Total Margin             | \$181,729.83     |

### Costs per CWT EQ of Milk

---

|                                    |             |
|------------------------------------|-------------|
| Cost of Resale Items or Basis      | \$0.00      |
| Car and Truck Expenses             | \$0.00      |
| Chemicals                          | \$0.05      |
| Custom Hire (machine work)         | \$0.69      |
| Feed Purchased                     | \$2.21      |
| Fertilizers and Lime               | \$0.00      |
| Freight and Trucking               | \$0.11      |
| Gasoline, Fuel and Oil             | \$0.17      |
| Insurance (other than health)      | \$0.02      |
| Rent or Lease (Equipment)          | \$0.56      |
| Rent or Lease (Other)              | \$0.98      |
| Repairs and Maintenance            | \$0.80      |
| Seeds and Plants Purchased         | \$0.23      |
| Supplies Purchased                 | \$0.67      |
| Taxes                              | \$0.00      |
| Utilities                          | \$0.20      |
| Veterinary, Breeding, and Medicine | \$0.45      |
| Other Expenses                     | \$0.35      |
| <br>Basic Costs                    | <br>\$7.48  |
| <br>Mortgage Interest              | <br>\$0.00  |
| Other Interest                     | \$0.79      |
| Employee Benefit Programs          | \$0.39      |
| Labor Hired                        | \$0.71      |
| Depreciation                       | \$2.45      |
| <br>Other Costs                    | <br>\$4.35  |
| <br>Total Cost                     | <br>\$11.83 |

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Table 6.

# *Cost of Producing Milk*

7<sup>th</sup> Annual Report

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## KRUSENBAUM FARM

January 1998 through December 1998

Enterprises Excluded : LABOR, PERSONAL

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|                          |                  |
|--------------------------|------------------|
| Total Farm Income        | \$354,604.47     |
| Average Milk Price       | \$15.35          |
| CWT EQs of Milk Produced | 23,101.27        |
| Total Allocated Costs    | \$256,974.54     |
| Total Interest Paid      | \$18,215.29      |
| Wages and Benefits Paid  | \$9,202.39       |
| Depreciation Claimed     | \$56,682.22      |
| <br>Total Basic Costs    | <br>\$172,874.64 |
| Basic Cost per CWT EQ    | \$7.48           |
| Total Margin             | \$181,729.83     |

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### Costs per CWT EQ of Milk

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|                                    |            |
|------------------------------------|------------|
| Cost of Resale Items or Basis      | \$0.00     |
| Car and Truck Expenses             | \$0.00     |
| Chemicals                          | \$0.05     |
| Custom Hire (machine work)         | \$0.69     |
| Feed Purchased                     | \$2.21     |
| Fertilizers and Lime               | \$0.00     |
| Freight and Trucking               | \$0.11     |
| Gasoline, Fuel and Oil             | \$0.17     |
| Insurance (other than health)      | \$0.02     |
| Rent or Lease (Equipment)          | \$0.56     |
| Rent or Lease (Other)              | \$0.98     |
| Repairs and Maintenance            | \$0.80     |
| Seeds and Plants Purchased         | \$0.23     |
| Supplies Purchased                 | \$0.67     |
| Taxes                              | \$0.00     |
| Utilities                          | \$0.20     |
| Veterinary, Breeding, and Medicine | \$0.45     |
| Other Expenses                     | \$0.35     |
| <br>Basic Costs                    | <br>\$7.48 |
| <br>Mortgage Interest              | <br>\$0.00 |
| Other Interest                     | \$0.79     |
| Employee Benefit Programs          | \$0.00     |
| Labor Hired                        | \$0.40     |
| Depreciation                       | \$2.45     |
| <br>Other Costs                    | <br>\$3.64 |
| Total Cost                         | \$11.12    |

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# Financial Measures

WICST 7<sup>th</sup> Annual Report

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Table 7.

## KRUSENBAUM FARM

January 1998 through December 1998  
Enterprises Excluded : LABOR, PERSONAL

|                                                                                                            | Cost Basis  | FMV with Appreciation |
|------------------------------------------------------------------------------------------------------------|-------------|-----------------------|
| <b>Profitability Measures</b>                                                                              |             |                       |
| Net Farm Income From Operations (NFIFO)                                                                    | \$97,629.93 | \$129,836.12          |
| (Total Farm Income - Total Farm Expense) x (12 / Month Number)                                             |             |                       |
| Return to Labor and Management                                                                             | \$88,052.53 | \$120,470.63          |
| NFIFO - (Avg. Total Net Worth x Interest Rate Charged on Owners Net Worth)                                 |             |                       |
| Return to Total Farm Assets                                                                                | 14.88 %     | 22.37 %               |
| (NFIFO + Interest Paid - Labor & Management Charge) / Avg. Total Assets                                    |             |                       |
| Return to Net Worth                                                                                        | 24.87 %     | 42.62 %               |
| (NFIFO - Labor & Management Charge) / Avg. Total Net Worth                                                 |             |                       |
| Net Profit Margin                                                                                          | 18.57 %     | 25.35 %               |
| (NFIFO + Interest Paid - Labor & Management Charge) / Total Farm Income                                    |             |                       |
| <b>Solvency Measures</b>                                                                                   |             |                       |
| Debt to Asset Ratio                                                                                        | 56.72 %     | 57.26 %               |
| Avg. Total Liabilities / Avg. Total Assets                                                                 |             |                       |
| Debt to Equity Ratio                                                                                       | 131.03 %    | 133.99 %              |
| Avg. Total Liabilities / Avg. Total Net Worth                                                              |             |                       |
| Change in Net Worth                                                                                        | \$47,673.63 | \$79,879.82           |
| Ending Net Worth - Beginning Net Worth                                                                     |             |                       |
| <b>Liquidity Measures</b>                                                                                  |             |                       |
| Current Liability to Asset Ratio                                                                           | 0.00        |                       |
| Ending Current Assets / Ending Current Liabilities                                                         |             |                       |
| Cash Operating Expense as a Percent of Cash Operating Income                                               |             |                       |
| Cash Farm Expense / Cash Farm Income                                                                       |             |                       |
| a.) Without Interest Paid                                                                                  | 60.24 %     |                       |
| b.) With Interest Paid                                                                                     | 66.27 %     |                       |
| Working Capital                                                                                            | \$0.00      |                       |
| Ending Current Assets - Ending Current Liabilities                                                         |             |                       |
| <b>Financial Efficiency</b>                                                                                |             |                       |
| Asset Turnover Ratio                                                                                       | 80.13 %     | 75.37 %               |
| Total Farm Income / Avg. Total Assets                                                                      |             |                       |
| Basic Costs Ratio                                                                                          | 44.15 %     |                       |
| (Total Farm Expense - Interest Paid - Depreciation Expense - Total Wages and Benefits) / Total Farm Income |             |                       |
| Wages and Benefits Ratio                                                                                   | 7.20 %      |                       |
| Total Wages and Benefits / Total Farm Income                                                               |             |                       |
| Interest Expense Ratio                                                                                     | 5.14 %      |                       |
| Interest Paid / Total Farm Income                                                                          |             |                       |
| Depreciation Expense Ratio                                                                                 | 15.98 %     |                       |
| Depreciation Expense / Total Farm Income                                                                   |             |                       |
| Net Farm Income from Operations Ratio                                                                      | 27.53 %     |                       |
| NFIFO / Total Farm Income                                                                                  |             |                       |
| <b>Repayment Capacity</b>                                                                                  |             |                       |
| Coverage Ratio                                                                                             | 146.00 %    |                       |
| (NFIFO + Depr + Intr - Estimated Family Living) / (Principal Payments + Interest Paid)                     |             |                       |
| Capital Replacement and Debt Repayment Margin                                                              | \$38,603.31 |                       |
| NFIFO + Depr - Estimated Family Living - Principal Payments                                                |             |                       |
| Apparent Family Living Draw                                                                                | \$49,956.30 |                       |
| NFIFO - Change in Net Worth                                                                                |             |                       |

Note: Report may not be meaningful if accounting period is < 1 year.



## **8b. Krusenbaum Dairy Herd Health and Production Report, 1997 and 1998**

Ken Nordlund, DVM<sup>1</sup>

This report summarizes major production and health results of the Krusenbaum dairy herd for calendar years 1997 and 1998. The report is based upon Dairy Herd Improvement (DHI) records from AgSource and upon field investigation reports from the UW School of Veterinary Medicine.

### **Herd Populations (*Figure 1*)**

**1997:** The herd totaled 94 cows in January 1997, increased to a high of 125 in May, and returned to 104 by December.

**1998:** Herd numbers started at 104 cows in January, reached a high of 126 in May and June, and declined to 114 in December. Herd numbers were more sustained in 1998.

### **Milk Production**

#### **Milk (*Figures 2 and 3*)**

**1997:** Rolling herd average (average annual milk production per cow averaged over the past 12 months) increased slightly through 1997 from 14,938 to 15,268 lb. Mature equivalent milk (ME305) declined through the first nine months of the year, but recovered to finish the year at 17,500 lb. as the herd showed very strong late lactation performance in the last months of the year.

**1998:** Rolling herd average showed a very strong increase in 1998, rising from 15,262 lb. to 17,401 lb. by December. Mature equivalent milk also increased to approximately 19,000 lb.

**Bulk Milk:** Figure 3 shows increased total milk sales in 1998 versus 1997. The increased output is due to increased milk production per cow per day as well as better maintenance of cow numbers through the grazing season in 1998.

#### **Milk components (*Figure 4*)**

**1997:** Milk production was extremely seasonal and reflects the fact that the majority of cows calved in March and April and reached peak milk in May (Figure 3). Milk components also reflected the seasonal trend but over the year, milk fat percent averaged 3.45% and milk protein percent averaged 3.2%. In May and July, herd milk fat percent reached alarmingly low levels of 2.8% and 2.76% respectively (Figure 4).

**1998:** Fat percent was higher in 1998 and reflects the efforts to improve forage intake and minimize ruminal acidosis. Fat percent over the 12-month period averaged 3.6%.

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<sup>1</sup> Clinical Professor, School of Veterinary Medicine, University of WI-Madison.

### Clinical diagnosis of subacute rumen acidosis

*1997:* Diagnostic work completed by the School of Veterinary Medicine in August 1997 showed strong evidence of subacute rumen acidosis in the herd. In conventional dairies, clinical signs of subacute acidosis may include reduced dry matter intake, reduced production, low body condition, low milk fat percent, diarrhea, laminitis, and a variety of clinical signs related to hematogenous rumen bacteria that may include abscesses in the liver and elsewhere. In the Krusenbaum herd, clinical signs included modest production, low body condition, low milk fat percent, and some diarrhea problems. The clinical signs of laminitis that are usually associated with ruminal acidosis are not expected to be as prevalent in a grazing herd. Diagnosis was made by rumenocentesis and the pH values found were conclusive.

The problem is caused by rations that are low in fiber and relatively high in starch. The rations formulated for the Krusenbaum herd have assumed that the average cow consumes approximately 28 lb. of dry matter from the pasture daily. With this assumption, the rations appear sound on paper. However, we believe the assumption to be optimistic and that actual pasture intake is closer to 20-22 lb. of dry matter per day. This lower-than-anticipated forage consumption from pasture would not balance the 17 lbs. of high moisture shelled corn per cow per day, and would explain both the rumen pH values that were found as well as the disappointing production and low body condition scores.

Dietary adjustments of supplementing hay to insure adequate fiber were made in September 1997 and the late lactation cows responded well. While actual milk per cow per day stabilized in October (Figure 3), the late stage of the lactation would have predicted a decline in milk. Adjusted monitors of milk production, such as ME305 and Management Level Milk, show a strong increase in production in the last months of the year.

*1998:* In 1998, the pastured cows were supplemented with approximately 9 lbs. per cow per day of corn silage on a dry matter basis throughout the grazing season. Ruminal pH was tested again in June 1998 and again found to be low and diagnostic of subacute ruminal acidosis. An additional ration change of reducing high moisture shelled corn from 17 lbs. per cow per day down to 15 lbs., and supplementing an added 4 lbs. of whole cottonseeds was implemented in mid-July. The combination of corn silage and cottonseed is credited with improving milk output from the herd in 1998.

### **Mastitis (Figure 5)**

*1997:* The herd made excellent progress in reducing somatic cell counts (SCC) in 1997, dropping from 646,000 in January to end the year at under 200,000. The high averages in January through March are blamed on outwintering the cows. Although only a small portion of the herd continued to milk through the winter, their SCC was high, particularly with the cows in their 2<sup>nd</sup> and greater lactation. This may be related to the difficulty of establishing and maintaining a dry bedding surface for outwintered cows.

*1998:* The herd continued to make excellent progress in minimizing mastitis in 1998, finishing the year with a somatic cell count of 97,000. This is a superb record and probably reflects the

improved housing conditions of the over-wintered cows, as well as some improvements in milking system cleaning that were implemented for 1998.

### **Reproduction (Figure 6)**

*1997:* The herd showed good to excellent reproductive performance, finishing the year with an average days open of 101. Industry goals are 100 days, but average performance is about 135 days. The breeding season consisted of 45 days of heat detection and artificial insemination (AI), followed by clean-up bulls for a limited period of time, and then a return to AI through the season. Calves sired by the beef bulls will be sold from the farm, and cows becoming pregnant in the second AI season will be sold as dairy replacements to other farms.

*1998:* Herd reproductive performance improved in 1998 with 89 cows reported as pregnant by the end of December. This compares with less than 70 in December 1997. Reported services per pregnancy averaged 1.47, which is excellent.

### **Genetics (Figure 7)**

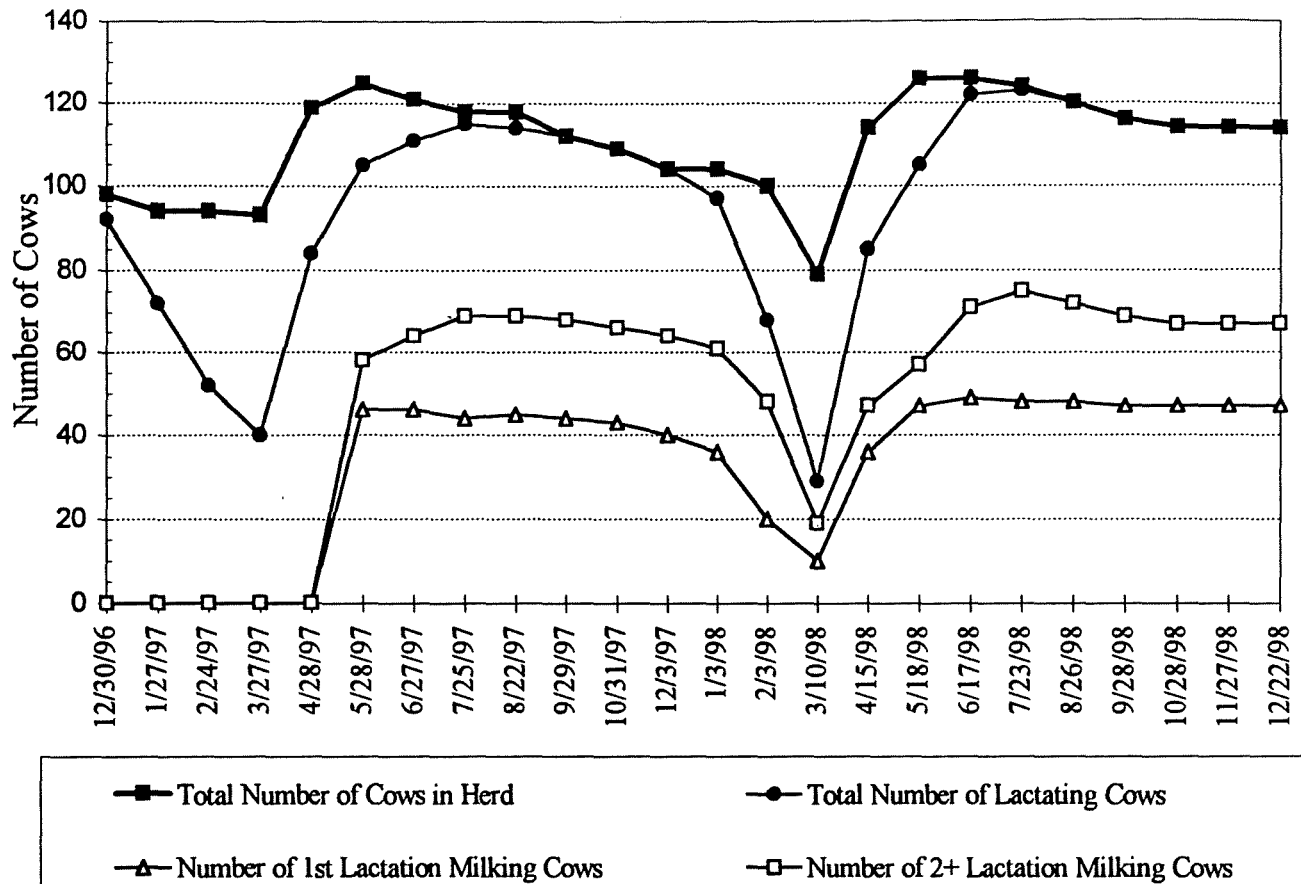
*1997:* The adult cows in the herd have similar genetic merit as older cows in the top 30% of the herds in the industry. However, semen selection in 1997 lost ground relative to the dairy industry. At the end of 1997, managers of higher production herds typical of the industry at large were using semen with an average PTA\$ (predicted transmitting ability) value of 180, but semen selected in the Krusenbaum farm in 1997 averaged 138 PTA\$. The reduction in PTA\$ semen reflects a focus on semen selection based upon body conformation characteristics, as well as the AI use of non-Holstein bulls in crossbreeding programs. The interval between semen selection and productive effect on the herd is a minimal 3 years.

*1998:* Semen selection for milk potential for milk production in the Krusenbaum dairy continued to lag behind the rest of the industry. Semen used in matings in 1998 and reported to DHI had an average PTA\$ of 173, while industry reference values exceeded PTA\$ 220.

### **Summary**

Overall, the management of the expanded herd has gone well. Individual cow milk production was disappointing in 1997, but the problem of subacute rumen acidosis was identified. Alterations of the ration by supplementing corn silage to increase forage availability, and reducing ration starch by substituting whole cottonseeds for shelled corn appears to have produced a strong milk production response in 1998. Improved herd performance was seen in areas of reproduction. The genetic trend of the herd is very mixed. Mastitis management shows marked improvements over prior years and has reached the level of excellent at the end of 1998.

Figure 1. Krusenbaum – Herd Populations (1997 and 1998).



Percent 1st Lactation Cows in milking herd on last test = 41.2

Percent Dry Cows on last test = 0

Number of tests in last 12 months = 12

Krusenbaum 35650824 (12/22/98) Herd

Figure 2. Krusenbaum - Rolling Herd Average, Heifer, and Cow ME's (12/96 - 12/98).

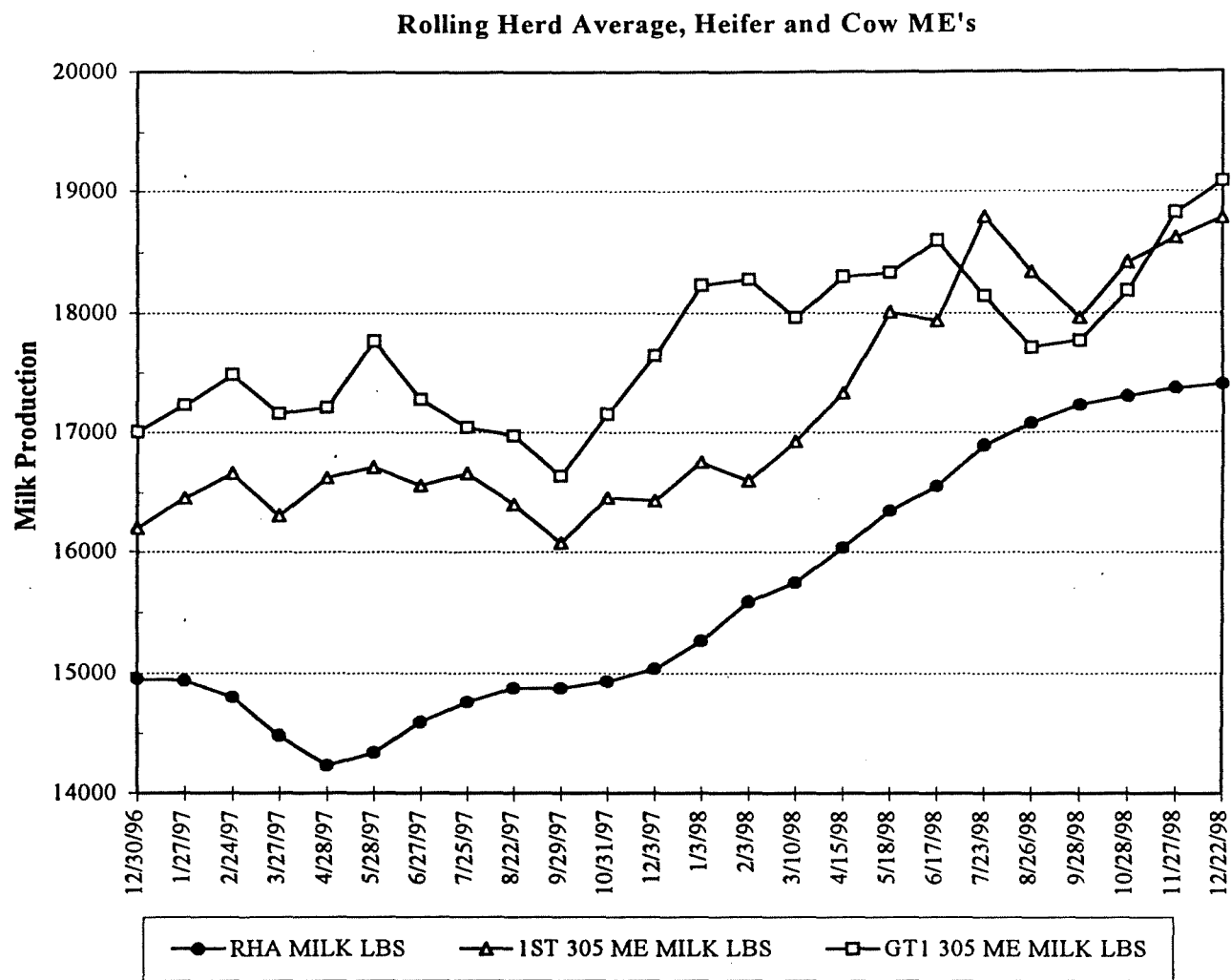


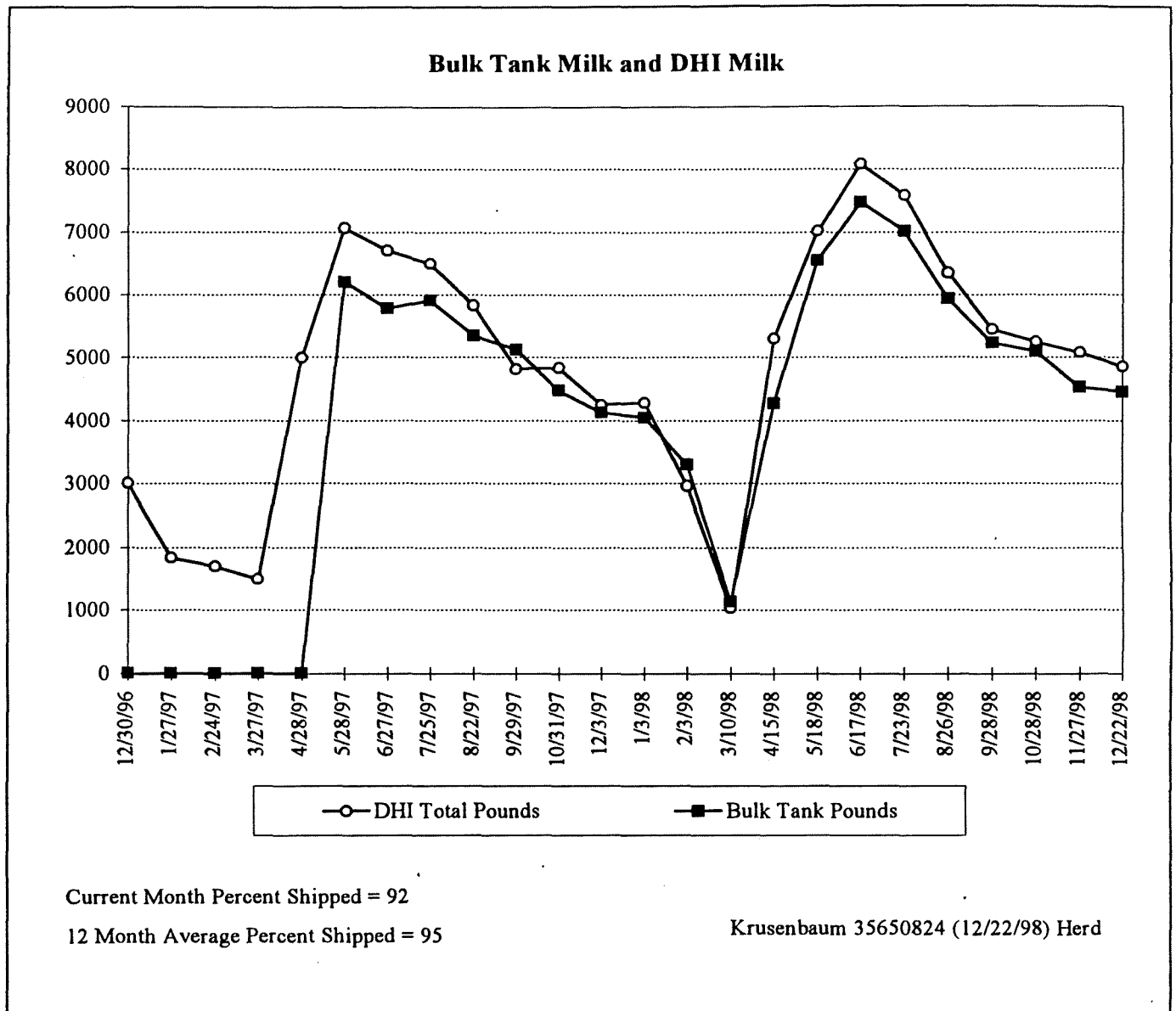
**Figure 3. Krusenbaum – Bulk Tank Milk and DHI Milk (12/96 – 12/98).**

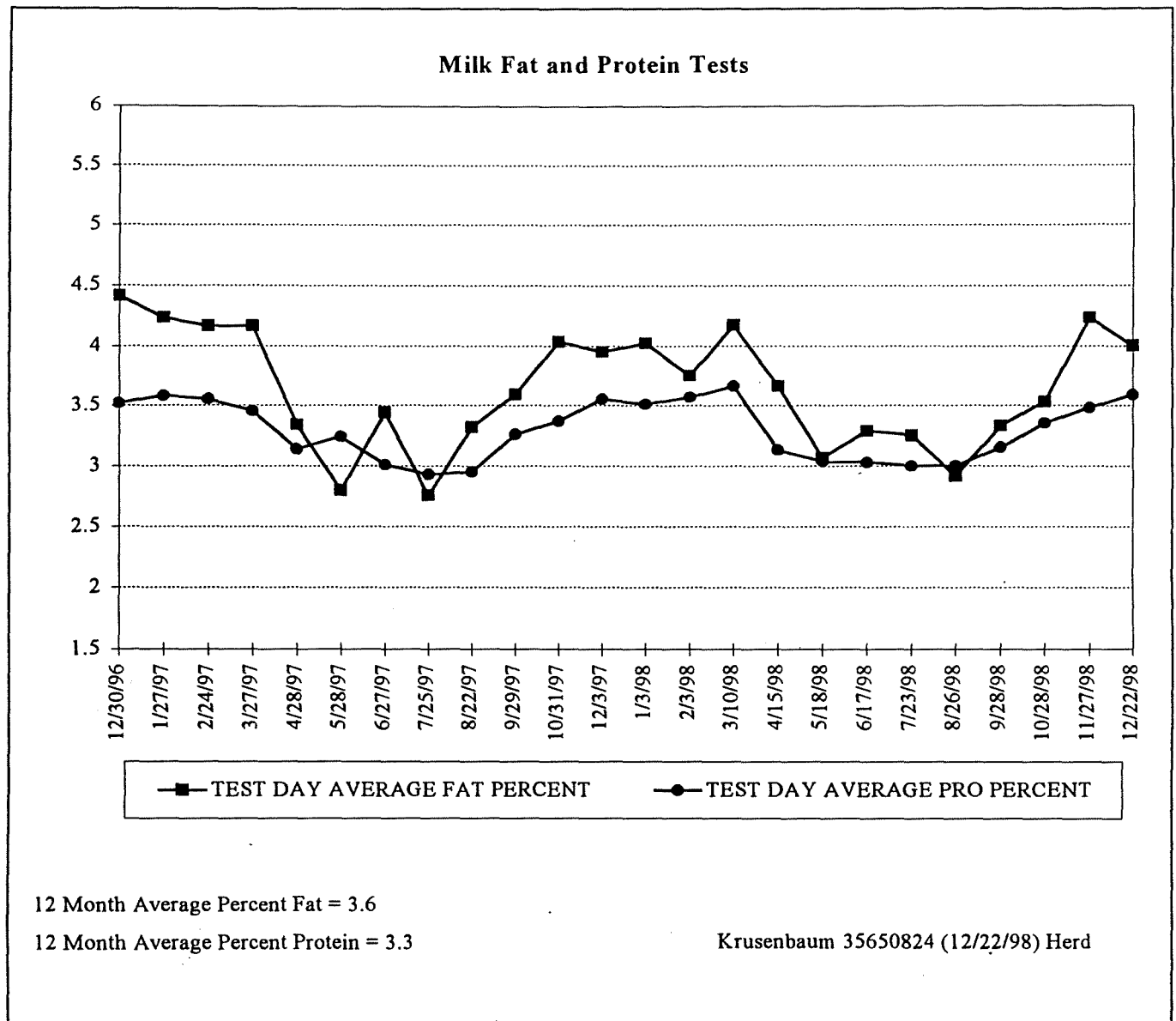
**Figure 4. Krusenbaum - Milk Fat and Protein Tests (12/96 – 12/98).**

Figure 5. Krusenbaum - Subclinical Mastitis Data (12/96 – 12/98).

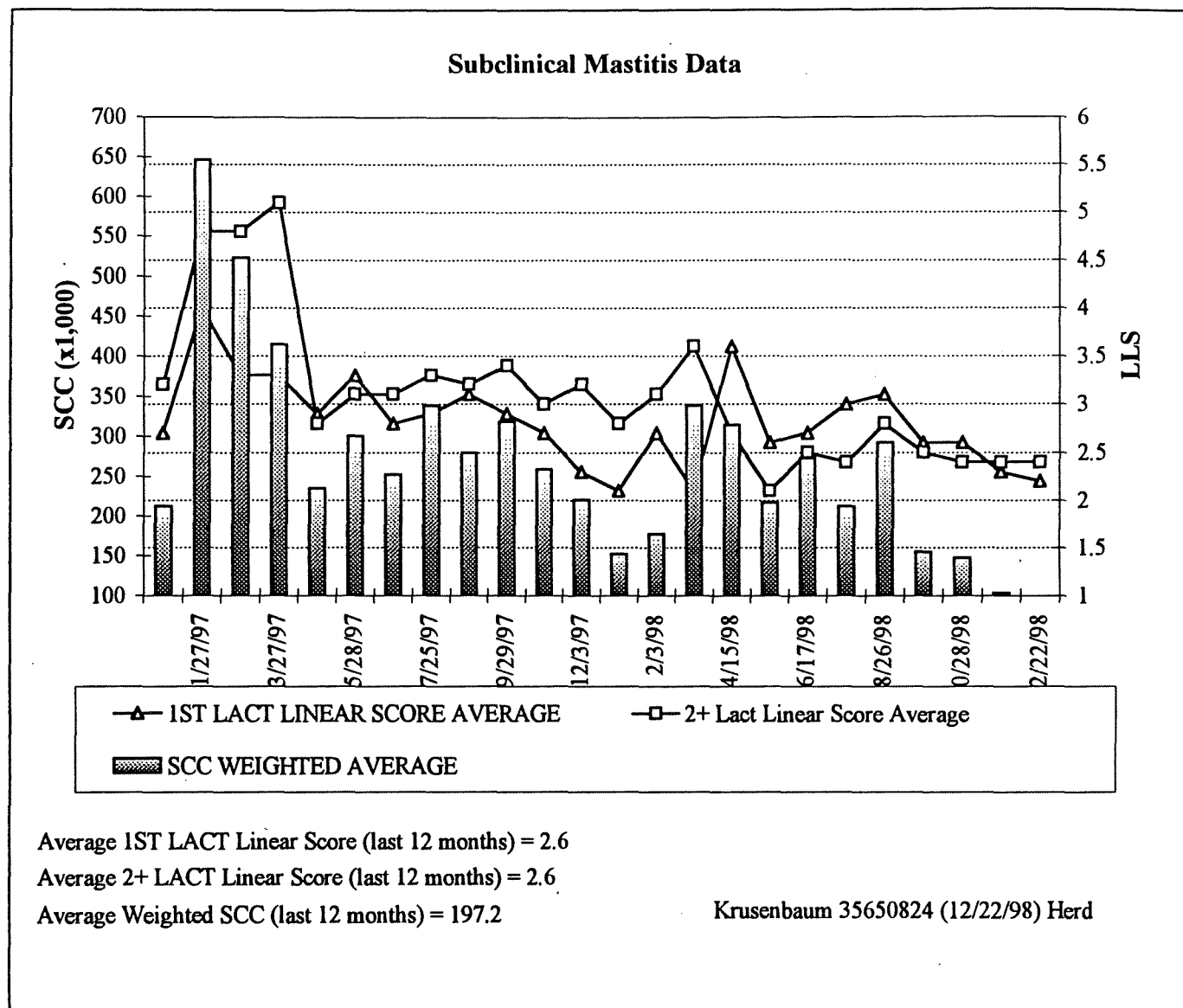
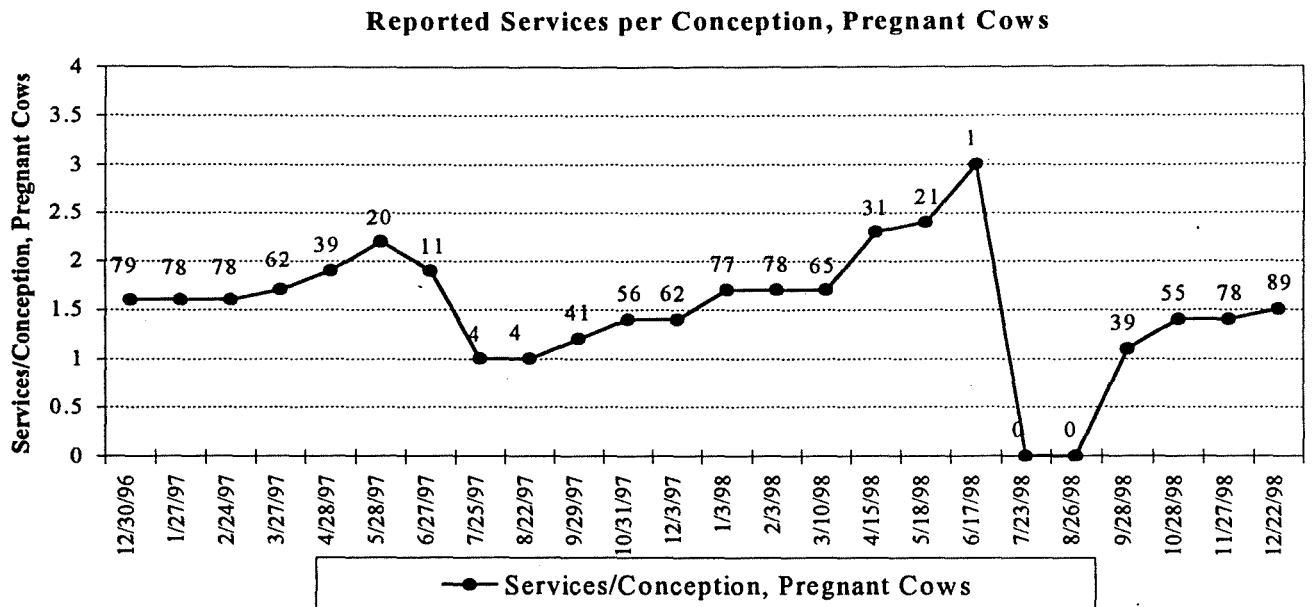


**Figure 6. Krusenbaum - Reported Services per Pregnancy, Pregnant Cows (12/96 – 12/98).**

Number Indicates Pregnant Cow Count

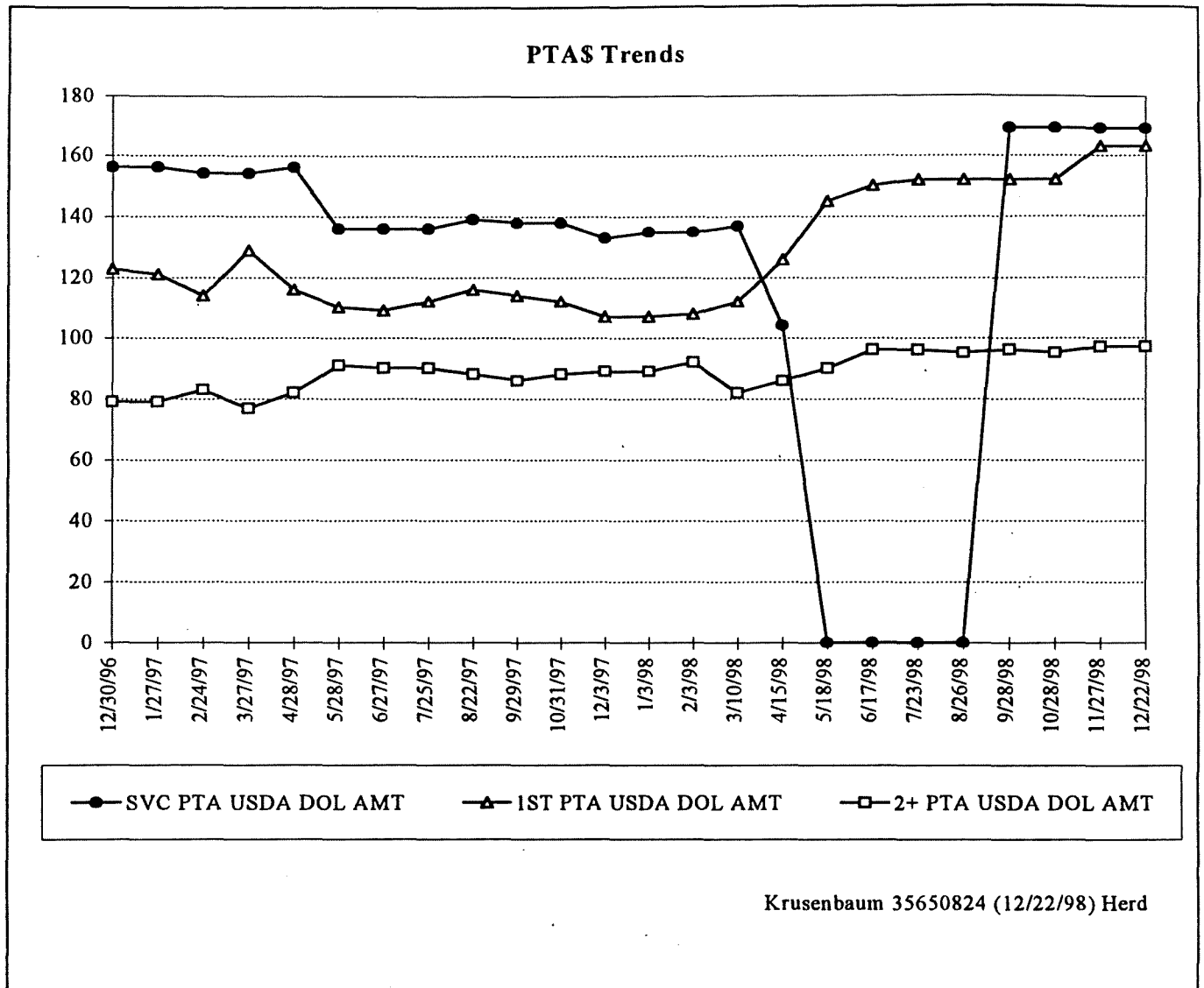
Krusenbaum 35650824 (12/22/98) Herd

Average Services per Conception, all cows = 1.5

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.

Figure 7. Krusenbaum – PTAS (12/96 – 12/98).



### 8c. Krusenbaum Farm Machinery Analysis, 1990-98

Ronald T. Schuler<sup>1</sup>

The machinery inventory has changed much throughout this study primarily due few changes in cropping and livestock enterprises on the Krusenbaum Farm. During the transition from intensive cropping to grazing, the little used machines have been sold and nearly all the remaining machines are used on a large number of acres. When machines are used on just a few acres, the costs of those operations per acre are large due the fixed costs.

The machines remaining are mower-conditioner, hay rake, round baler, bale wrapper, manure spreader and a rolling cultivator. Two older tractors remain as the primary power units on the farm. For the duration of this eight-year study many changes have taken place in the machinery inventory, Table 1.

**Table 1. Machinery inventory on the Krusenbaum Farm during eight-year study.**

| <u>Machine Power Units</u>  | <u>Age</u> | <u>Size (hp)</u> | <u>Purchase Price</u> |                  |
|-----------------------------|------------|------------------|-----------------------|------------------|
|                             |            |                  | <u>Actual</u>         | <u>New (MN)</u>  |
| John Deere 2630             | 21         | 65               | 8,900                 | 21,400           |
| Case 970                    | 22         | 86               | 6,000                 | 26,900           |
| Case 1175                   | 15         | 122              | 11,000                | 55,200 (sold)    |
| ATV                         |            |                  |                       |                  |
| <u>Tillage</u>              |            |                  |                       |                  |
| Moldboard plow              | 13         | 5-18's           | 2,350                 | 9,000 (sold)     |
| Tandem disk                 | 14         | 18 ft            | 1,625                 | 10,700 (sold)    |
| Field cultivator            | 12         | 18 ft            | 825                   | 4,700 (sold)     |
| Rotary hoe                  | 10         | 15 ft            | 1,500                 | 3,500 (not used) |
| Row cultivator              | 8          | 4-38             | 2,650                 | 5,400 (sold)     |
| Guidance system             |            |                  | 2,000                 | N/A (sold)       |
| Cultimulcher                |            | 12 ft            | 1,500                 | N/A              |
| Rolling cultivator (Aerway) | 2          | 10 ft            | 4,800                 | N/A (new)        |
| <u>Planting Equipment</u>   |            |                  |                       |                  |
| Grain drill                 | 11         | 12 ft            | 4,500                 | 13,200 (sold)    |
| Planter                     | 9          | 4-38             | 4,000                 | 9,100 (sold)     |
| <u>Harvesting</u>           |            |                  |                       |                  |
| Haybine                     | 11         | 9 ft             | 3,500                 | 33,500 (sold)    |
| Mower-conditioner           | 2          | 9 ft             | 11,150                | 14,320 (new)     |
| Baler (sm. Rect.)           | 9          | 9 ft             | 3,900                 | 9,300            |
| Rake                        | 9          | 9 ft             | 1,550                 | 3,300            |
| Baler (Round)               | 3          | 9 ft             | 21,600                | 17,000           |
| Bale wrapper                | 3          | N/A              | 13,000                | 13,900           |
| Bale feeder                 | 2          | N/A              | 5,500                 | N/A              |
| Manure spreader             | 1          | N/A              | 12,250                | 11,558           |

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Since the beginning of the machinery analysis in 1990, nine 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 four years old.

### Machinery Use:

During the last two to three years the annual acreage is approaching the average values used in the Minnesota Farm Machinery Estimates (Table 2). For example for the mower-conditioner was used on an average of 343 acres from 1996 to 1998. The published data use 349 acres per year for mower-conditioners. During the early years when the machinery inventory was large, the machinery usage was low.

Table 2. Annual use (acres/year) of machines compared to Minnesota data (1990 – 1998).

| <u>Machine</u>    | <u>MN</u> | <u>Krusenbaum</u> |             |             |             |             |             |                  |                  |                  |
|-------------------|-----------|-------------------|-------------|-------------|-------------|-------------|-------------|------------------|------------------|------------------|
|                   |           | <u>1990</u>       | <u>1991</u> | <u>1992</u> | <u>1993</u> | <u>1994</u> | <u>1995</u> | <u>1996</u>      | <u>1997</u>      | <u>1998</u>      |
| <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            | 434       |                   |             |             |             |             |             | 68               | 180              | 320              |
| <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 | 349       |                   |             |             |             |             |             | 300 <sup>1</sup> | 278              | 450              |
| Baler (sm. Rect.) | 756       | 199               | 213         | 40          | 121         | 0           | 0           | Sold             |                  |                  |
| Rake              | 698       | 156               | 193         | 66          | 265         | 79          | 170         | 100              | 150              | 260 <sup>4</sup> |
| Baler (Round)     | 603       |                   |             |             |             | 237         | 170         | 220              | 550 <sup>2</sup> | 450              |
| Bale wrapper      | 372       |                   |             |             |             |             | 170         | 130              | 300 <sup>3</sup> | 310              |
| Manure Spreader   | 349       |                   |             |             |             |             |             |                  | N/A              | N/A              |

<sup>1</sup> About 30 percent of these acres were custom work - but a neighbor did 100 acres of mowing for the Krusenbaum's.

<sup>2</sup> About 60% of these acres were custom work.

<sup>3</sup> About 40% of these acres were custom work.

<sup>4</sup> About 10% of these acres were custom work.

With an increase in grazing, the annual hours for the tractors should decrease. Some of this can attribute to a change from a self-propelled mower-conditioner to a pull-type machine and an increase in the forages being harvested. In 1998, there were 450 acres harvested, which include multiple cuttings during the growing season. The annual use for the two tractors (Table 3) has been variable throughout this study with a low of 660 hours in 1995 to a high of 970 hours in 1998. The hours for 1998 are near the published data of 500 for each tractor.

**Table 3. Annual Use (hours/year) for tractors compared to Minnesota data (1990 – 1998).**

| <u>Tractor model</u>  | <u>MN</u> | <u>Krusenbaum</u> |             |             |             |             |             |             |             |             |
|-----------------------|-----------|-------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                       |           | <u>1990</u>       | <u>1991</u> | <u>1992</u> | <u>1993</u> | <u>1994</u> | <u>1995</u> | <u>1996</u> | <u>1997</u> | <u>1998</u> |
| JD 2630               | 500       | 350               | 400         | 360         | 370         | 422         | 420         | 532         | 420         | 550         |
| Case 970              | 500       | 160               | 250         | 240         | 220         | 337         | 240         | 178*        | 300         | 420         |
| Case 1175             | 550       | 210               | 220         | 180         | 227         | 131         | Sold        |             |             |             |
| <b>Tractor Totals</b> |           | <b>720</b>        | <b>870</b>  | <b>780</b>  | <b>817</b>  | <b>890</b>  | <b>660</b>  | <b>710</b>  | <b>720</b>  | <b>970</b>  |
| ATV                   |           |                   |             | 300         | 235         | 390         | 400         | 300         | 260         | 225         |

\* Case tractor was not available for two months in 1996 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 on standard tables. 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.

**Table 4. Estimated annual cost (\$/acre) for 1990 – 1997 compared to Minnesota data and Wisconsin rental survey.**

| <u>Machine</u>               | <u>MN</u> | <u>WI</u><br><u>rent</u> | <u>Krusenbaum</u> |             |             |             |             |             |             |             |             |
|------------------------------|-----------|--------------------------|-------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                              |           |                          | <u>1990</u>       | <u>1991</u> | <u>1992</u> | <u>1993</u> | <u>1994</u> | <u>1995</u> | <u>1996</u> | <u>1997</u> | <u>1998</u> |
| <b><u>Tillage</u></b>        |           |                          |                   |             |             |             |             |             |             |             |             |
| Moldboard Plow               | 12.66     | 12.70                    | 27.04             | 17.02       | 29.86       | ----        | ----        | ----        | ----        | ----        | ----        |
| Tandem Disk                  | 4.95      | 9.25                     | 3.38              | 2.78        | 3.31        | 3.31        | 3.74        | ----        | ----        | ----        | ----        |
| Field Cultivator             | 3.44      | 9.25                     | 2.79              | 3.16        | 3.19        | ----        | ----        | ----        | ----        | ----        | ----        |
| Rotary Hoe                   | 1.55      | 5.25                     | 2.84              | 2.89        | 2.63        | 3.46        | 11.56       | ----        | ----        | ----        | ----        |
| Row Cultivator               | 5.05      | 7.05                     | 6.20              | 6.46        | 7.00        | 7.86        | 15.86       | ----        | ----        | ----        | ----        |
| with guidance                | N/A       | N/A                      | 6.58              | 6.96        | 7.87        | 9.33        | 24.48       | ----        | ----        | ----        | ----        |
| Cultimulcher                 | N/A       | 9.25                     |                   |             |             |             |             | 13.43       | N/A         |             |             |
| Aerway                       | 1.47      | N/A                      |                   |             |             |             |             |             | 9.83        | 6.05        | 5.25        |
| <b><u>Planting</u></b>       |           |                          |                   |             |             |             |             |             |             |             |             |
| Grain drill                  | 7.74      | 9.90                     | 20.79             | 21.85       | 26.38       | 16.46       | 21.63       | 54.80       | ----        | ----        | ----        |
| Planter                      | 7.19      | 10.60                    | 11.19             | 11.82       | 12.04       | 16.25       | 32.32       | ----        | ----        | ----        | ----        |
| <b><u>Harvesting</u></b>     |           |                          |                   |             |             |             |             |             |             |             |             |
| Haybine (SP)                 | 11.20     | 8.15                     | 4.69              | 4.86        | 7.52        | 6.30        | 5.50        | 6.38        | ----        | ----        | ----        |
| Mower-Cond.                  | 10.33     | 8.15                     |                   |             |             |             |             |             | 8.78        | 7.66        | 6.89        |
| Baler (sm. Rect.)            | 9.55      | 12.40                    | 7.83              | 7.99        | 12.04       | 10.77       | 8.56        | ----        | ----        | ----        | ----        |
| Rake                         | 5.74      | 4.20                     | 5.63              | 5.58        | 7.27        | 5.60        | 8.29        | 10.25       | 8.07        | 5.97        | 5.84        |
| Baler (Round)                | 13.93     | 6.95/bale                |                   |             |             |             |             | 10.65       | 14.53       | 10.87       | 11.89       |
| Bale wrapper                 | 17.43     | 6.70/bale                |                   |             |             |             |             | 8.63        | 12.10       | 7.09        | 6.91        |
| Manure spreader <sup>1</sup> | 31.51     | 34.40                    |                   |             |             |             |             |             |             | 75.30       | 54.47       |

<sup>1</sup> Manure spreader costs are expressed in cost per hour.

With the increase in annual machine use in recent years, the cost of each operation per acre is similar to the published data, Table 4. For example the round baler cost ranged from \$10.65 to \$14.53 per acre while the Minnesota data indicated a cost of \$13.93 per acre. The only machine used throughout the study was a hay rake. Its costs ranged from \$6.58 to \$10.25 per acre compared to the Minnesota data at \$5.74 per acre. The Wisconsin guide had a custom rate for raking at \$4.20.

The largest differences between published and the estimated annual costs occurs when the annual use is low, Table 4. Some examples are the moldboard plow, grain drill and planter. In many cases, the last year the Krusenbaum's owned these machines, the costs per acre were extremely high.

For the tractors, the hourly costs were much lower than the Minnesota data throughout this study (Table 5). This is due to low purchase price, which leads to very low fixed costs in comparison to the Minnesota data. The hourly cost throughout the study from \$8.21 to \$9.23 for the JD 2630, which compares very closely with the Minnesota data at \$9.36. While the Case 970 had costs ranging from \$6.02 to \$7.73 compared to \$11.92 for the Minnesota estimates. Also these tractor costs are well below the Wisconsin Custom Rate Guide which was \$16.90 for tractors in the 50 to 100 horsepower range. The ATV costs were not analyzed because data are not available for fuel consumption, repairs and depreciation. In addition, ATV's are not reported in the Minnesota data or the Wisconsin Custom Rate Guide.

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

| <u>Tractor model</u> | <u>MN</u> | <u>WI</u><br><u>rent</u> | <u>Krusenbaum</u> |             |             |             |             |             |             |             |             |
|----------------------|-----------|--------------------------|-------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                      |           |                          | <u>1990</u>       | <u>1991</u> | <u>1992</u> | <u>1993</u> | <u>1994</u> | <u>1995</u> | <u>1996</u> | <u>1997</u> | <u>1998</u> |
| JD 2630              | 9.36      | 16.90                    | 8.21              | 8.95        | 9.01        | 9.23        | 9.23        | 8.73        | 8.41        | 8.72        | 8.66        |
| Case 970             | 11.92     | 16.90                    | 7.42              | 6.60        | 7.19        | 6.88        | 6.36        | 6.67        | 7.73        | 6.38        | 6.02        |
| Case 1175            | 21.60     | 21.80                    | 9.37              | 9.40        | 11.92       | 10.10       | 15.07       | sold        | ----        | ----        | ----        |

At the beginning of this study, the Krusenbaum's purchased used machinery to keep costs down. They were very successful, but some machines received very little use from the beginning therefore their costs per acre were high. During the transition from intensive cropping to grazing the change in machinery inventory was gradual with the little used machinery being sold. The initial inventory went from eleven machines in 1990 to six machines in 1998 and from three to two tractors. Although the machinery in use during 1998 was acquired new, the costs per acre were low because the annual acres were high.

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**BIODIVERSITY PROJECT****9. The Relevance of Biodiversity to the Sustainability of Agricultural Systems: A Progress Report**

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Victoria Gollwitzer<sup>4</sup>, Erik Rebek<sup>5</sup> and Martha Rosemeyer<sup>6</sup>

The first objective of this project was to develop efficient sampling methodology to describe a broad spectrum of organisms in a wide range of agricultural systems of the WICST experiment. The second was to develop indices, or find indicator species, that characterize the biodiversity of that broad spectrum of organisms. The taxonomic assessment and statistical analysis are still in progress.

**Objective 1: Develop sampling methods**

**Sampling Plan.** The data were collected in 1995, 1996, and 1997 from plots at the two WICST sites: Arlington Agricultural Research Station; and Lakeland Agricultural Complex. The sampling plan consisted of three primary elements: 1) random sampling 2 of 50 quadrats (0.78 m wide by 3.13 m long) per plot per date; 2) sampling each plot eight times per season in 1995 and 1996 and twice in 1997, and 3) sampling a cluster of soil cores in each quadrat (three macrocores 6.25 cm diameter, and four microcores (1.87 cm diameter) taken to 10 cm depth. The larger cores were used for soil insect and nematode analysis and the smaller for extraction of microbial nucleic acids, microbial biomass, and labile C. The sampling plan also contained three additional elements: 1) decomposition bags were buried at the first sampling date and retrieved on subsequent sampling dates; 2) on a subset of dates, one corn plant plus the roots were harvested from the sampling quadrats and three other quadrats; and 3) two insect pitfall traps were installed in each plot after weed control practices were completed; the traps were emptied biweekly. The corn phase of three of the six cropping systems was sampled intensively (CS1, CS3, CS5) as was the pasture system (CS6). The team also sampled several other phases of CS3 and CS5 and in 1996 initiated sampling in relatively undisturbed grassland and restored prairie that were located within 10 kms of the trial sites.

**Sampling Date.** The peak frequency for most of the smaller organisms occurred from mid-June to mid-July. For earthworm activity and decomposition (litter bag), the peak activity was in late summer. Both time trends differ from the recommended spring/fall plan (Edwards, 1991).

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**Number of Samples.** The number of samples to take per plot per sampling date depends primarily on the relative variation between samples versus the variation between plots and sampling cost. The most variable data thus far is the nematode counts. With the high cost of labor per sample, the most efficient number of samples is in the range of two to five per plot.

## Objective 2: Characterizing Biodiversity

### **Microbial Diversity**

#### **Molecular Microbial Diversity. (Bill Hickey)**

Dr. Hickey's role has been to direct work on molecular analysis of biodiversity in soil microbial populations; because of space limitations this summary will be limited to his segment of the project. Initial experiments evaluated a variety of DNA extraction and purification methods for utility in processing the large numbers of samples generated by the extensive field sampling and in producing extracts that could be accurately quantified for DNA content. The latter was necessary to facilitate quantitative hybridization analysis by phylogenetic probes, a technique that was developed in parallel tests with a suite of ten phylogenetically nested probes. The DNA extraction method ultimately developed, combined a lysozyme/freeze-thaw technique modified with a proprietary agent to eliminate humic substances with purification by Wizard mini-columns. Compared to the original technique, this approach gave preparations that were more accurately assayed for DNA contents (i.e. little humic substance contamination) and had greater DNA yields. Phylogenetic probe analysis of soil DNA extracted by the modified technique and other more abrasive and/or time-consuming methods showed the former performed as well or better than the others in recovering DNA from cells considered difficult to lyse (i.e. fungi, Gram-positive bacteria). In subsequent tests, variability in the molecular analysis was examined with respect to DNA yields and probe hybridization analysis of soils (two samples from each of two field replicates, three lab sub-samples from each sample) from the corn phase of three different crop rotations (continuous corn, organic soybean-wheat/red clover-corn, oats/alfalfa-alfalfa hay-corn) and a pasture. The trend in DNA yields was consistent with the relative levels of microbial biomass as measured by the fumigation/incubation method (pasture, greatest biomass/DNA yield; continuous corn, lowest biomass/DNA yield). Variability in DNA yields was similar between rotations and between lab sub-samples and ranged from 19 to 40%. Hybridization analysis was done with the Eucarya, Bacteria, and Archaea, domain probes (duplicate hybridization analysis of each sub-sample with each probe) and showed that the relative abundance of Bacteria was greatest in the continuous corn (86 ± 3.6%), lowest in the pasture (46 ± 5.5%) and intermediate between these in the other soils. The Eucarya made up the balance of the population and so their abundance trend was the opposite of the Bacteria; Archaea were non-detectable (< 0.5%). Collectively, these results indicated that the DNA extraction/probe hybridization procedure developed could be applied effectively to distinguish differences in the microbial community composition of the field soils. In on-going work, microbial community composition is being further resolved with a battery of probes specific for subgroups within the Bacteria. In addition to this broad-level community composition information, experiments are also underway to characterize communities of ammonia-oxidizing bacteria by using PCR to amplify 16S rRNA genes from these organisms, which will then be examined by restriction enzyme digestion patterns and sequence analysis.

### **Molecular analysis of ammonia-oxidizing bacteria. (Victoria Gollwitzer)**

Communities of ammonia-oxidizing bacteria (AOB) were studied at WICST in three diverse agricultural cropping systems; CS1, CS3, and CS6, to determine how AOB populations varied as a function of cropping practices. Soil AOB populations were examined by three lines of molecular analysis: 1) amplified ribosomal rDNA restriction analysis (ARDRA) of whole soil extracts, 2) ARDRA of PCR products cloned from soil extracts, and 3) sequence analysis of selected clones. The ARDRA patterns were generated using PCR primers  $\beta$ AMOf and  $\beta$ AMOr followed by single enzyme digestions with *AluI* and *RsaI*. The ARDRA of the soil DNA extracts generated two AOB profiles when digested with *AluI*. The more biologically complex systems (CS3 and CS6) shared the same ARDRA pattern. The AOB profile established for CS1 differed from the other systems by the absence of one band at 427 bp. A two-tier ARDRA screen was developed to identify clones containing AOB ribosomal DNA. ARDRA patterns of individual AOB clones could be used to reconstruct those obtained from the soil extracts, indicating the AOB inserts examined were representative of those amplified *in situ*. Sequence analysis showed that the AOB ribosomal DNA cloned from the soil extracts and the enrichment cultures were similar and predominantly *Nitrosospria*-like. The latter results were consistent with other investigators, and suggested *Nitrosospria* may be more ecologically important in soil than previously believed (Gollwitzer, 1999).

### **Nematode diversity. (Ann MacGuidwin)**

Nematodes were extracted from a 100cc sub-sample of soil using a sieving-centrifugal floatation technique and from roots in the sample by incubation on Baermann funnels. Preserved specimens were randomly selected and the first 50 nematodes observed were identified using a compound microscope. The relative abundance of nematode taxa (44 genera have been identified so far) was determined from each 50-specimen sub-sample.

There was no statistical difference between systems in the number of nematodes recovered (2,852-3,016/100cc soil) for ARS 1995. However, when the nematodes were classified by trophic groups there were four statistically significant differences among the cropping systems. First, there was a greater proportion of plant feeding nematodes in the pasture compared to the other systems (Fig. 1a). The pasture also had a higher proportion of omnivores than the other systems, but the difference was not statistically significant (Fig. 1c). Second, CS3 had fewer predators than CS1 (Fig. 1b). Third, there were more fungal feeders in CS1 than in CS5 or CS6 and more in CS3 and CS5 than in CS6 (pasture, Fig. 1d). Finally, there was a smaller proportion of bacterial feeders in the pasture than in the other systems (Fig. 1e).

The fraction of plant feeding nematodes was the only variable to enter the model when a stepwise (forward) discriminant analysis was applied to all five groups. The overall classification success with this model was 50% and it identified the continuous corn (CS1) and pasture (CS6) well, but did not do well on the two low-input rotational systems. When the plant feeders were excluded, the fungal- and the bacterial-feeders entered the model. The classification success with the latter model was slightly better than first at 52%. The ratio of fungal to bacterial feeding nematodes was not significantly different between systems averaged over all dates, but there was a significant date by system interaction that needs further analysis. However, that ratio did differentiate between phases within systems.

### **Insect diversity. (Erik Rebek)**

Insect diversity was assessed by pitfall traps (1995, 1996), soil cores (1995, 1996, 1997) and litterbags (1995, 1996). All arthropods were identified to order and the data is in the process of being analyzed. Pitfall traps were used to capture epigeic (i.e. surface-active) species. Litter bags of corn stover were used to collect species associated with litter decomposition in agricultural soils. Soil cores were employed to capture species inhabiting upper and lower soil horizons. .. Two arthropod groups dominated the fauna collected in the litterbags: the *Collembola* (springtails) and the *Ascari* (mites). There were no differences among the cropping systems in numbers of springtails or mites considered separately. However, a multivariate analysis provided evidence that the two groups differed jointly between cropping systems. Collembola were selected as a group likely to distinguish these systems and they were identified to species.

The abundance and diversity of Collembola species were analyzed for each sampling method to compare four cropping systems encompassing a range of management intensities. The hypothesis was that low-input cropping systems would contain higher species abundance and diversity than would high-input cropping systems. Biological indicator species could then be identified and incorporated into determining crop management practices that are more conducive to soil community health and, presumably, sustainable agriculture.

Analysis of variance (ANOVA), a nested ANOVA procedure, repeated measures analysis and categorical data analysis were used to explore the role of cropping system management in Collembola population dynamics. Species responses to management pressure were difficult to identify because data were highly variable even among samples within a treatment. This suggests that other factors, in addition to cropping system, influence springtail populations, including abiotic components of the soil ecosystem such as soil moisture and temperature, and biotic (community) components such as trophic interactions (Rebek, 1998). Biodiversity analysis of the Collembola is detailed in this volume Rebek Section 12\_A and Rebek Section 12\_B.

**Earthworm activity in litterbags.** The above-mentioned litter bags were analyzed for weight loss and weight of earthworm casts. The casts were considered a proxy for earthworm activity, and residue decomposition calculated.

In late summer, the continuous corn system (CS1) generally had the lowest weight of earthworm casts in litterbags; CS3, CS5, and CS6 alternated in having the highest. The differences between systems were significant at both sites in 1995 ( $P < 0.05$ ), but not at either site in 1996. One of the phase differences, corn versus oats (alfalfa) in CS3, was also significant in 1995. The cold, wet spring followed by a dry fall, especially at LAC in 1996, probably reduced earthworm activity, hence significant results, in that season. Because earthworms seem to be one of the factors that differentiate the corn systems and phases within a system, continuing to measure their numbers and/or activity is a priority. The end-of-season decomposition percentage followed a fairly consistent pattern over both sites and years. Pasture was always the lowest at 30 to 45%. CS5 was highest in three of four site-years and was next-to-the-highest in the fourth at 38 to 82%. CS1 and CS3 were usually intermediate and close together. The differences between systems were significant in three of the four site-years. Decomposition is an ecosystem function, so it is encouraging that we have been able to distinguish the systems using such a simple technique.

Earthworm biodiversity is being assessed in the 1999 cropping season.

**Biodiversity indices.** The traditional indices of biodiversity (Shannon, Simpson) biodiversity for nematodes and Collembola at the family level have so far been consistently significant for systems across years except family richness (number of families) of nematodes. It appears that often the community profile changes although the diversity remains about the same, i.e. that the families change in response to the different systems but the total number of families remains the same. A change in community profile, but not striking differences in biodiversity, has been reported both in agroecosystem comparisons in the US and Europe as well.

**Discriminant analysis of nematode and insect family abundance.** Using a combined data set, discriminant analysis selected a model of three families of nematodes (*Helicotylenchidae*, *Cephalobidae*, and *Tylodoridae*) and one family of Collembola (*Entomobryidae*). This model classified CS5 and CS6 to 88% correct and did reasonably well overall (Figure 2). In the future we will continue to seek combinations of organisms that characterize different agricultural systems.

### References

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- Rebek, E. 1998. Cropping system effects on the diversity and abundance of Collembola in Southern Wisconsin. M.S., Entomology, University of Wisconsin-Madison.

**Figure 1.** Proportional abundance of plant-feeding (a), predatory (b), omnivorous (c), fungivorous (d), and bacterivorous nematodes (e) in monocultured corn (CS 1), corn-soybean-wheat/red clover (CS 3), corn-oat/alfalfa-alfalfa (CS 5), and pasture (CS 6) at the Arlington Research Station in 1995.

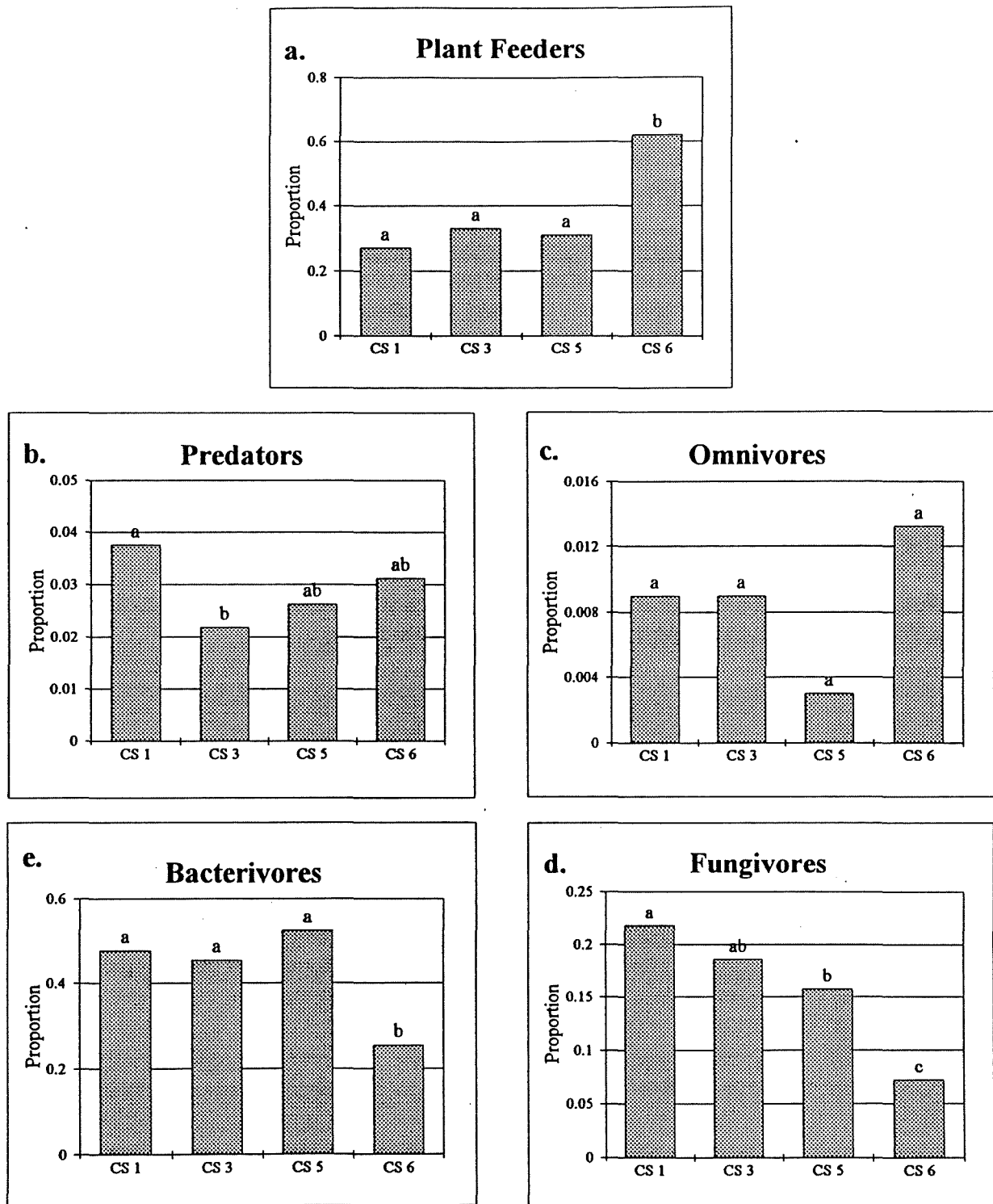
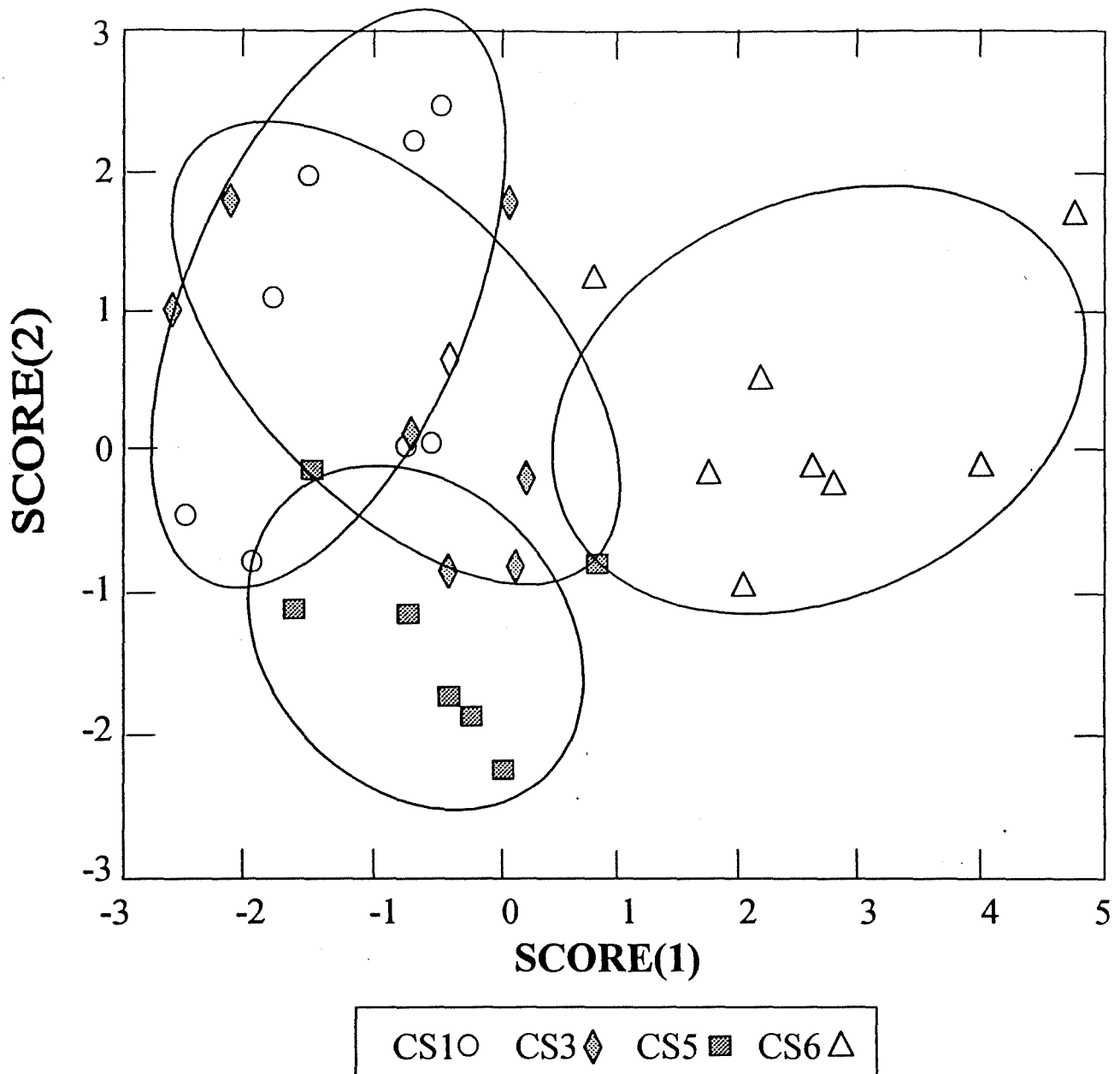


Figure 2. Discriminant analysis results for ARS 1995. Score (1) and Score (2) are linear combinations of three families of nematodes (*Helicotylenchidae*, *Cephalobidae*, and *Tylodoridae*) and one family of collembola (*Entomobryidae*).





## 10a. Soil Invertebrates: The Diversity of Collembola Associated with 1997 Soil Core Samples

E.J. Rebek, D.B. Hogg and D.K. Young<sup>1</sup>

### Background

Soil core sampling was initiated in 1995 to complement pitfall traps and decomposition bags used to survey the abundance and diversity of arthropods occurring in selected WICST plots. The soil cores allow us direct comparison of results with other investigators in the NRI Soil Biodiversity Team. Also, because soil core samples are independent of arthropod mobility and trophic (i.e. feeding) structure, this sampling technique represents a more absolute measure of the arthropod fauna existing at the sites.

The extraction efficiency for specimens in our soil core samples was not high enough for our study in 1995-96. We used a flotation technique that was sufficient for removing large organic matter (including arthropod fauna) from the soil, but smaller invertebrates were missed repeatedly. Since some groups of smaller arthropods may be extremely important in soil ecosystem processes, we developed a more efficient method of extraction in 1997. This method, Berlese funnel extraction, is especially efficient for Collembola or springtails, a familiar group of six-legged micro-arthropods. The ubiquity of this group offers the additional advantage of enabling comparison across all cropping systems and sampling methods.

### Methods

#### Sampling

Sampling was performed at the two sites studied in prior years: Arlington Research Station (ARS) in Columbia County, and Lakeland Agricultural Station (LAC) in Walworth County. Soil core samples were taken using a 2.5-inch diameter soil probe. Each sample consisted of three 6-inch cores, corresponding to 1104.5 cubic centimeters of soil. Each sample was taken at two randomly chosen areas in each plot (within two predetermined rows). The 1997 sampling regime included four systems in various phases of crop rotation: Cropping System 1 (CS1) continuous corn (treatment 1), CS3 corn (treatment 4), CS5 corn (treatment 13), and CS6 pasture (treatment 14). Thus, only the corn phases of cropping systems 1, 3, and 5 were sampled along with the rotationally grazed pasture phase of CS6. The treatments selected represent a spectrum of anthropogenic inputs. Treatment 1 is typical of corn systems in the Midwest and is placed at the high end of the spectrum with frequent chemical and physical inputs. Treatment 14 requires minimal input (e.g. grazing) and is placed at the low end of the spectrum.

We made a reduced sampling effort in 1997 in order to direct our attention toward more specific identifications of arthropods from prior sampling years. We sampled at ARS on June 03 and August 20 and at LAC on June 04 and August 27.

Extraction of arthropod specimens was performed using Berlese funnels. This apparatus consists of a light source mounted over a funnel containing a wire mesh that fits the circumference

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of the funnel. Soil invertebrates orient and move away from the heat and light, fall through the mesh and are funneled into a jar of alcohol that kills and preserves the specimens.

Soil samples were placed on the wire mesh for two days. Soil arthropods were recovered and taken to the lab to be counted and identified. Springtails were abundant and later identified to genus, a lower-level identification than previously executed for other arthropod groups. Seventeen genera were recovered representing five families (Table 1).

**Table 1. Collembola families and respective genera recovered from 1997 soil core samples.**

| <u>Isotomidae</u>  | <u>Entomobryidae</u> | <u>Sminthuridae</u> | <u>Onychiuridae</u> | <u>Hypogastruridae</u> |
|--------------------|----------------------|---------------------|---------------------|------------------------|
| <i>Proisotoma</i>  | <i>Entomobrya</i>    | <i>Sminthurus</i>   | <i>Onychiurus</i>   | <i>Friesea</i>         |
| <i>Isotoma</i>     | <i>Pseudosinella</i> | <i>Sminthurides</i> | <i>Tullbergia</i>   | <i>Pseudachorutes</i>  |
| <i>Folsomides</i>  | <i>Willowsia</i>     | <i>Bourletiella</i> |                     |                        |
| <i>Folsomia</i>    |                      |                     |                     |                        |
| <i>Isotomurus</i>  |                      |                     |                     |                        |
| <i>Cryptopygus</i> |                      |                     |                     |                        |
| <i>Anurophorus</i> |                      |                     |                     |                        |

### Analysis

Two mathematical formulae were used to analyze the diversity of the Collembola genera sampled from each treatment. The Shannon-Weaver index (H) places more emphasis on more common genera encountered in the soil community:

$$H = - \sum P_i * \log_e P_i$$

Where  $P_i$  is the proportion of the  $i^{\text{th}}$  genus. Hence, this measure relies on the natural log of the proportion of each genus recorded. The Shannon-Weaver indexes range from 0 (low diversity) to G (the total number of genera).

The Simpson index (D) emphasizes rarer genera encountered in the soil community:

$$D = 1 / \sum (n_i / N)^2$$

Where  $n_i$  = number of individuals of the  $i^{\text{th}}$  genus and  $N$  = total number of individuals in the community. Thus, the Simpson index is influenced by the non-transformed proportion of each genus recorded for each sample. The Simpson indexes range from 1 (low diversity) to G (the total number of genera).

Both formulae were run for each sample, the mean index for each treatment was calculated and Analysis of Variance (ANOVA) and Least Square Difference (LSD) tests were performed for each sample date.

## Results

Figure 1A shows the results of the ANOVA executed for the Shannon-Weaver indices and Figure 1B shows the results for the Simpson indices.

ANOVA found only one instance for significant treatment effects. June 4 at LAC revealed pasture (treatment 14) to be significantly more diverse than the corn treatments 4 and 13 when using the Shannon-Weaver index. Notice that no springtails were found in continuous corn (treatment 1) samples for June 4. This resulted in a non-value for both diversity indices for this treatment; ANOVA could not compute these "empty sets" because it needed some numerical value for the analysis. Hence, treatment 1 was thrown out by ANOVA even though the absence of springtails in this cropping system may have been significant.

The zero value assigned to treatment 13 on August 20 at ARS was a real value established by the Shannon-Weaver index. Only one genus was captured in this corn phase on this sample date, thereby earning the lowest diversity ranking. In contrast to the situation where Collembola were absent from samples, this treatment was included in the ANOVA analysis for this date. Therefore, no significant differences were found among the four treatments on August 20.

## Discussion

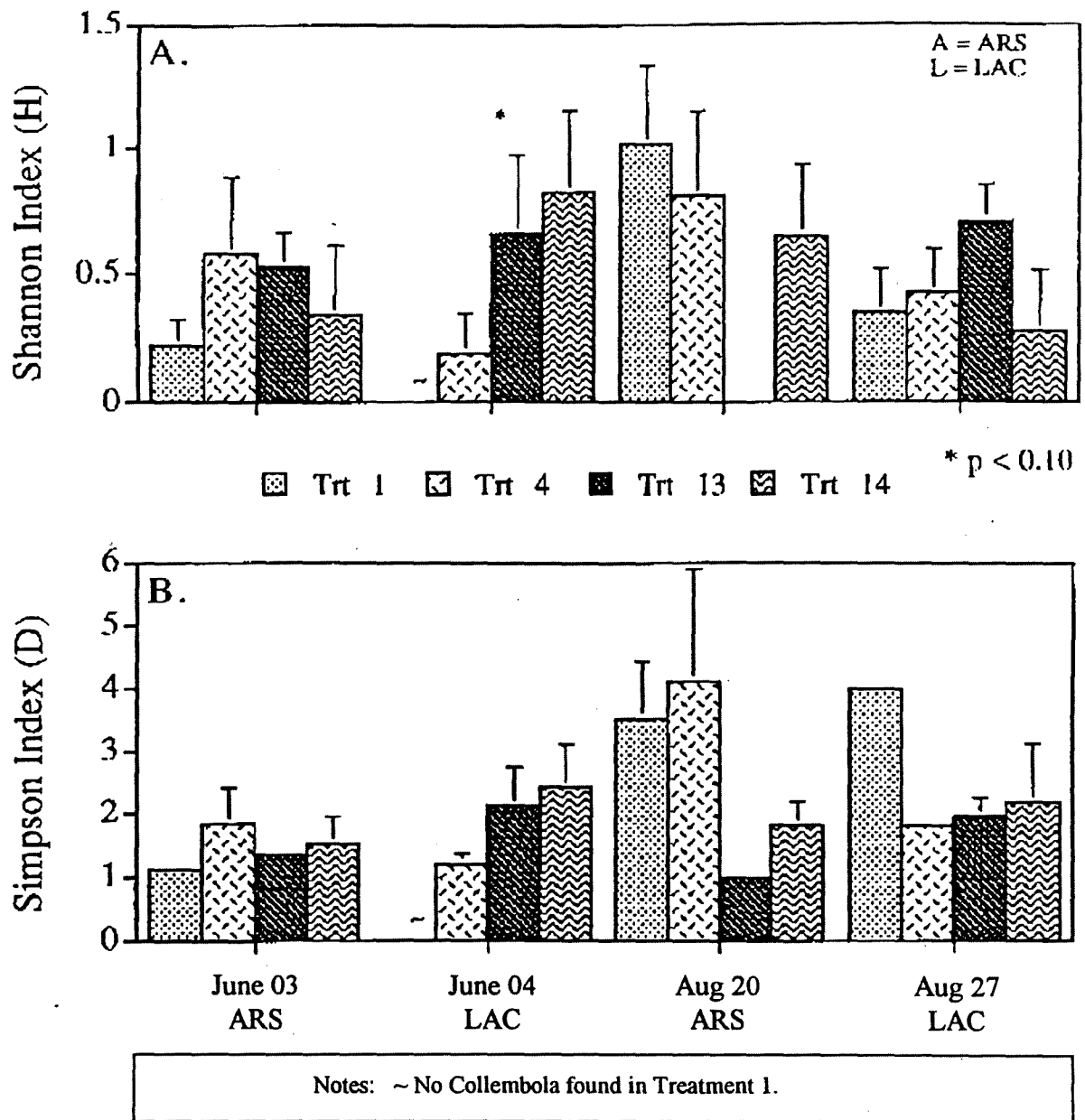
The results reveal a shortcoming in using ANOVA to analyze the outcomes of these diversity indices. First, treatments that did not produce specimens were removed from the analysis because the resulting value was an "empty set". Thus, these treatments were deemed insignificant by ANOVA in spite of the possibility of a real significant treatment effect supported by the lack of specimens. Second, we handled the results of the diversity indices additively by calculating the mean index for each treatment. However, the non-additive quality of these models did not intuitively lead one to use ANOVA. Therefore, the use of ANOVA to analyze these data may or may not have been correct. We are currently researching alternative statistical methods to bypass the dilemmas encountered in testing these diversity indices.

Throughout the WICST we have repeatedly stated that lower-level identifications would possibly reveal trends obscured from detection due to "swamping out" effects by higher taxonomic groups. Therefore, the general lack of significance among treatments for 1997 soil core samples was frustrating, but in light of the aforementioned statistical problems, we are not discouraged. Additionally, we are now focusing on species-level identifications for specific sampling dates, particularly those that offer some shred of significance at the genus level (i.e. June 4 at LAC for Shannon-Weaver). There are two advantages in using species for analysis: 1) species-level analyses may further tease out obscured trends and 2) in terms of evolution, alterations in microhabitat (e.g. chemical applications) only affect members of a species, not entire groups of higher taxa. Hence, using species of Collembola as indicators of soil quality is highly preferred.

Finally, the results shown are based on a highly reduced sampling effort. We sampled only twice at each site and only used soil cores during the 1997-sampling season. This skeletonized sampling plan was due to a growing need for more detailed analyses for data collected in prior years. Since the 1997 data are reduced, trends are inherently inconclusive. However, we realize the need for more powerful statistical tools and even more refined identifications. These improvements should prove valuable in determining the effects of cropping systems on Collembola abundance and diversity in southern Wisconsin.

Figure 1. Collembola diversity in 97 soil core samples (mean + standard error).

A) Shannon-Weaver index. B) Simpson index.



## **10b. Soil Invertebrates: The Diversity of Collembola Associated with Decomposition Bags in 1995 and 1996**

E.J. Rebek, D.B. Hogg, and D.K. Young<sup>1</sup>

### **Background**

Decomposition (litter) bag sampling served as the main focus of our soil arthropod research. The overwhelming numbers of specimens generated from our annual sampling has forced us to streamline our analyses and center on a ubiquitous and ecologically important group of soil arthropods: Collembola or springtails. These small, six-legged arthropods are paramount to the soil processes of decomposition and mineralization. The decomposition of decaying plant matter and subsequent release of nutrients (e.g. nitrogen) has been partly attributed to the fungivorous (fungal feeding) habits of Collembola.

Throughout this study the operational hypothesis has been that different levels of physical and chemical disturbances influence the abundance and diversity of soil arthropods in the WICST cropping systems. We are currently assessing various methods of quantifying the diversity of springtails in response to these different management practices. Statistical tests performed on these measurements will illuminate the role of disturbance in the population ecology of springtails.

### **Methods**

#### **Sampling**

Arlington Research Station (ARS) in Columbia County and Lakeland Agricultural Complex (LAC) in Walworth County were the study sites selected in both 1995 and 1996.

Litter bags with coarse mesh (pore size = 4 mm) were used in both years (Hogg et al., 1994). Litter bags were filled with corn stover and buried 6 inches below the soil surface. Sampling involved the scheduled removal of randomly selected bags from pre-determined locations within each plot (i.e. two rows).

The cropping systems and corresponding phases sampled in 1995 follow: Cropping System 1 (CS1) continuous corn (treatment 1), CS3 corn (treatment 4), CS3 soybean (treatment 6), CS5 corn (treatment 13), CS5 oats/alfalfa (treatment 12), and CS6 pasture (treatment 14). Treatments 6 and 12 were sampled every other sampling date.

The cropping systems and corresponding phases sampled in 1996 follow: CS1 continuous corn (treatment 1), CS3 corn (treatment 4), CS3 soybean (treatment 6), CS3 wheat/red clover (treatment 5), CS5 corn (treatment 13), CS6 pasture (treatment 14) and an undisturbed site (treatment 15) (Rebek et al. 1995, 1996 for sampling dates). Treatments 5, 6 and 15 were sampled every other sampling date. Planting and sampling were postponed until early July of 1996 because the soil was too wet due to heavy rain in Walworth County. The undisturbed sites chosen for sampling were Mud Lake Wildlife Refuge located near ARS and a site in Springfield, WI near LAC. Both sites had not been farmed for at least 20 years and served

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as comparisons to the agricultural research plots in 1996 only. Note that the treatment designations listed here for 1995 and 1996 follow those treatment assignments for 1997.

All soil arthropods were extracted from recovered litter bags using Berlese funnels (Rebek et al., 1997). Soil arthropods were collected from the funnels and taken to the lab to be counted and identified. Springtails were first classified to the family level and later identified to genus, a lower taxon than previously analyzed for other arthropod groups. The lower-level identification was performed to better elucidate trends in the diversity and abundance of springtails that may have been masked by family-level identifications. Twenty-two genera were recovered representing five families (Table 1).

### Analysis

Analyses of the springtail diversity follows that of the 1997 soil core study in this annual report (14B. The Diversity of Collembola Associated with 1997 Soil Core Samples; Rebek et. al., 1997).

**Table 1. Collembola families and respective genera recovered from 1995 and 1996 litter bag samples.**

| <u>Isotomidae</u>  | <u>Entomobryidae</u> | <u>Sminthuridae</u> | <u>Onychiuridae</u> | <u>Hypogastruridae</u> |
|--------------------|----------------------|---------------------|---------------------|------------------------|
| <i>Proisotoma</i>  | <i>Entomobrya</i>    | <i>Sminthurides</i> | <i>Onychiurus</i>   | <i>Friesea</i>         |
| <i>Isotoma</i>     | <i>Pseudosinella</i> | <i>Bourletiella</i> | <i>Tullbergia</i>   | <i>Hypogastrura</i>    |
| <i>Folsomides</i>  | <i>Willowsia</i>     | <i>Arrhopalites</i> |                     | <i>Microgastrura</i>   |
| <i>Folsomia</i>    | <i>Sinella</i>       |                     |                     | <i>Odontella</i>       |
| <i>Isotomurus</i>  | <i>Lepidocyrtus</i>  |                     |                     | <i>Schaefferia</i>     |
| <i>Cryptopygus</i> |                      |                     |                     |                        |
| <i>Amurophorus</i> |                      |                     |                     |                        |

### **Results**

Figures 1-4 depict the results of the Shannon-Weaver and Simpson diversity indices performed on the springtail genera found in 1995 and 1996 decomposition bags. The mean diversity index and standard error are plotted for each treatment in each sampling date. ANOVA was performed on all treatments collectively for each sampling date, but the treatments were split into three graphs for each figure in order to aid data interpretation. Note that certain dates show a value of zero for some treatments. This indicates one of three possibilities: 1) the treatment was not sampled (e.g. staggered sampling of treatments such as CS3 soybean); 2) the mean diversity index had a real value of zero for those treatments (Shannon-Weaver index only) which is interpreted as the presence of only one genus (i.e. low diversity); or 3) the mean value was an empty set due to the recovery of zero specimens for the entire treatment (ANOVA could not analyze these treatments). These alternative outcomes present us with a statistical problem in the overall analysis and will be discussed further (see discussion in Rebek et al., 1997).

#### 1995 Collembola diversity – Shannon-Weaver index:

The Shannon-Weaver index for 1995 springtail genera (Figure 1, A-C) resulted in a lack of significant treatment effects for any sampling date. Figure 1A is a comparison of the corn phases (CS1, CS3 and CS5) and the pasture phase (CS6). Figure 1B compares the corn and soybean treatments of CS3; while figure 1C depicts the corn and oats/alfalfa treatments of CS5.

Treatment 1 (continuous corn) had four dates where only one genus was found and its resulting mean index value was zero: July 5, August 1, and September 21 at LAC and August 22 at ARS.

Treatment 4 (CS3 corn) exhibited two dates where its mean index value was zero: August 29 and September 21 at LAC (late season).

In comparison, Treatment 13 (CS5 corn) had higher diversity than the other corn treatments early to mid-season. Treatment 13 had true zero index values for August 29 and September 21 at LAC and July 11 at ARS. July 18 sampling at ARS generated no Collembola specimens and thus, an empty set.

Treatment 14 (pasture) had true zero index values for July 11 and August 22 at ARS and August 16 and 29 at LAC.

Treatment 6 (CS3 soybean) was not sampled June 27, July 25 and August 22 at ARS nor July 5, August 1 and August 29 at LAC due to staggered sampling. This treatment had true zero values for mean diversity on August 8 at ARS and September 21 at LAC. In general, the soybean phase (Trt 6) had lower diversity than the corn phase (Trt 4) in CS3.

Treatment 12 (oats/alfalfa) was sampled in a staggered pattern as well. Thus, sampling did not occur June 13, July 11 and August 8 at ARS nor June 20, July 18, August 16 and September 21 at LAC. Its diversity exceeded that of the corresponding corn phase for CS5 on July 25 at ARS and August 1 at LAC.

All samples collected on September 14, 1995 at ARS were eliminated from analysis due to inclement weather conditions.

#### 1996 Collembola diversity – Shannon-Weaver index:

The Shannon-Weaver index for 1996 springtail genera is depicted in Figure 2, A-C. Figure 2A compares the corn phases of CS1, CS3 and CS5 and the pasture phase of CS6. Figure 2B compares corn, soybean and wheat/red clover phases of CS3. Treatment 15, the undisturbed site, is shown in figure 2C.

Some significant treatment effects were found on June 25 and August 20 at ARS and August 27 at LAC. Treatment 14 was highly significant in diversity from other treatments sampled on June 25 at ARS ( $p = 0.01$ ) and moderately significant on August 27 at LAC ( $p = 0.07$ ). Treatment 1 was significantly more diverse than other treatments sampled on August 20 at ARS ( $p = 0.09$ ). Note the higher diversity for treatment 5 (wheat/red clover) versus the other two treatments for CS3 on August 20 at ARS and July 30 and August 27 at LAC (Figure 2B). Most sampling dates revealed a lack of significant treatment effects in 1996 Shannon-Weaver analyses.

All zeros reported for treatments 4, 13, and 14 are real values established by the Shannon-Weaver index.

Treatment 6 was not sampled May 28, June 25, July 23 and September 3 at ARS nor July 16, August 13 and September 9 at LAC. August 27 at LAC had a true value of zero and no Collembola were found August 20 at ARS (i.e. empty set). Treatment 5 had the same outcomes

as Treatment 6, but August 20 at ARS and August 27 at LAC provided values greater than zero. Only July 9 at the ARS undisturbed site and July 16 at the LAC undisturbed site had true values of zero. The remaining non-values resulted from not sampling Treatment 15 those dates.

#### 1995 Collembola diversity – Simpson index:

The Simpson index for 1995 Collembola genera is shown in Figures 3, A-C. Figure 3A is a comparison of the corn phases (CS1, CS3 and CS5) and the pasture phase (CS6). Figure 3B compares the corn and soybean treatments of CS3, while Figure 3C depicts the corn and oats/alfalfa treatments of CS5.

Only one sampling date in 1995 showed significance for treatment effects using the Simpson index. Treatment 13 was significantly more diverse than the other treatments on July 5 at LAC ( $p = 0.04$ ). In fact, the treatments of CS5 as a whole were more diverse than other treatments.

The zeros reported for treatments 13 (July 18 at LAC) and 14 (September 21 at LAC) are empty sets. All zeros generated for treatments 6 and 12 are dates where these treatments were not sampled. All samples collected on September 14 at ARS were eliminated from analysis due to inclement weather conditions.

#### 1996 Collembola diversity – Simpson index:

The Simpson index for 1996 springtail genera is depicted in Figure 4, A-C. Figure 4A compares the corn phases (CS1, CS3 and CS5) and the pasture phase (CS6). Figure 4B compares corn, soybean and wheat/red clover phases of CS3. Treatment 15, the undisturbed site, is shown in figure 4C.

Only two sampling dates in 1996 showed significant treatment effects for the diversity of springtails using the Simpson index. Treatment 14 was significantly more diverse than the other treatments sampled on June 25 at ARS ( $p = 0.04$ ). Treatments 1 and 14 showed moderate significance for diversity of springtail genera on August 27 at LAC ( $p = 0.06$ ). In general, all 1996 treatments seemed to have equal mean diversity using the Simpson index.

Treatments 5 and 6 were not sampled on May 28, June 25, July 23 and September 3 at ARS nor July 16, August 13 and September 9 at LAC. No springtails were found in Treatment 6 samples on August 20 at ARS. Treatment 15 was not sampled May 28, June 25, July 23 and September 3 at the ARS undisturbed site. The LAC undisturbed site was not sampled July 30 and August 27.

## Discussion

We can extrapolate some meaningful interpretations from the data even though the normal result of our analyses was a lack of significant treatment effects. First, diversity of springtail genera was fairly even for all treatments. Only occasionally did one treatment significantly increase in diversity over the other treatments in the same sampling date. Second, overall diversity tended to remain stable throughout the growing season except for small increases in mid- to late summer. In comparison, Collembola abundance *decreased* as the growing season progressed (Rebek et al., 1995, 1996). Thus, abundance and diversity are somewhat inversely proportionate according to these results. Third, significance for treatment was similar for both Shannon-Weaver and Simpson indices. Additionally, LSD for treatment means resulted in very similar outcomes (Table 2). Because of discrete differences in emphasis it is important to use both measures in order to gain a more catholic view of springtail diversity.

The results of the significant LSDs suggest that in most cases, pasture (Trt 14) and continuous corn (Trt 1) were the most diverse treatments (Table 2). This result conflicts with the initial assumption that treatments with more anthropogenic inputs (i.e. treatment 1) would be less diverse than treatments with less reliance on those inputs (i.e. treatment 14). Our results suggest that treatments 1 and 14, extreme opposites on the spectrum of agricultural inputs, are very similar in diversity of Collembola genera.

LSDs occasionally found similarities between the results of the Shannon-Weaver and Simpson indices. Examples include June 25, 1996 at ARS and August 27, 1996 at LAC. LSD found pasture to be the most significantly diverse treatment in the analysis of both diversity indices on June 25. Additionally, treatments 1, 4, and 13 were arranged in order from most to least diverse in both indices. Pasture was regarded as the most significantly diverse treatment using the Shannon-Weaver index on August 27. In contrast, continuous corn and pasture were both found to be more diverse than the remaining treatments using the Simpson index on this date. Treatments 13, 5, 4, and 6 were arranged in the same order of diversity using both indices. These results offer a valuable comparison between the two diversity measures since the Shannon-Weaver index emphasizes more common genera while the Simpson index incorporates rarer genera in its analysis (Rebek et al., 1997). Dates when statistical measures indicated that both indices resulted in similar (if not identical) outcomes strengthen our hypothesis that differences in springtail diversity exist among the WICST plots.

The next step in our research illuminates what these treatment differences are. We have already determined pasture and continuous corn to be the most diverse treatments for certain dates, but there are two problems with our analysis. First, ANOVA may not be the best tool for testing our diversity data because ANOVA analyzes the variance of the mean diversity value, but these indices are not additive. This suggests that finding a mean index for each treatment based on the four samples (i.e. 2 samples x 2 plots) may not be sufficient. Hence, we must find a better test for analyzing our data. Second, these diversity indices are derived using springtail genera instead of species. Since selection pressures (e.g. chemical applications) act on species, not genera of organisms, the results we found based on genus-level identifications may still mask some of the significant outcomes of agricultural disturbance. We will attempt similar analyses for species-level identifications on selected dates with the intent of extracting even more precise data.

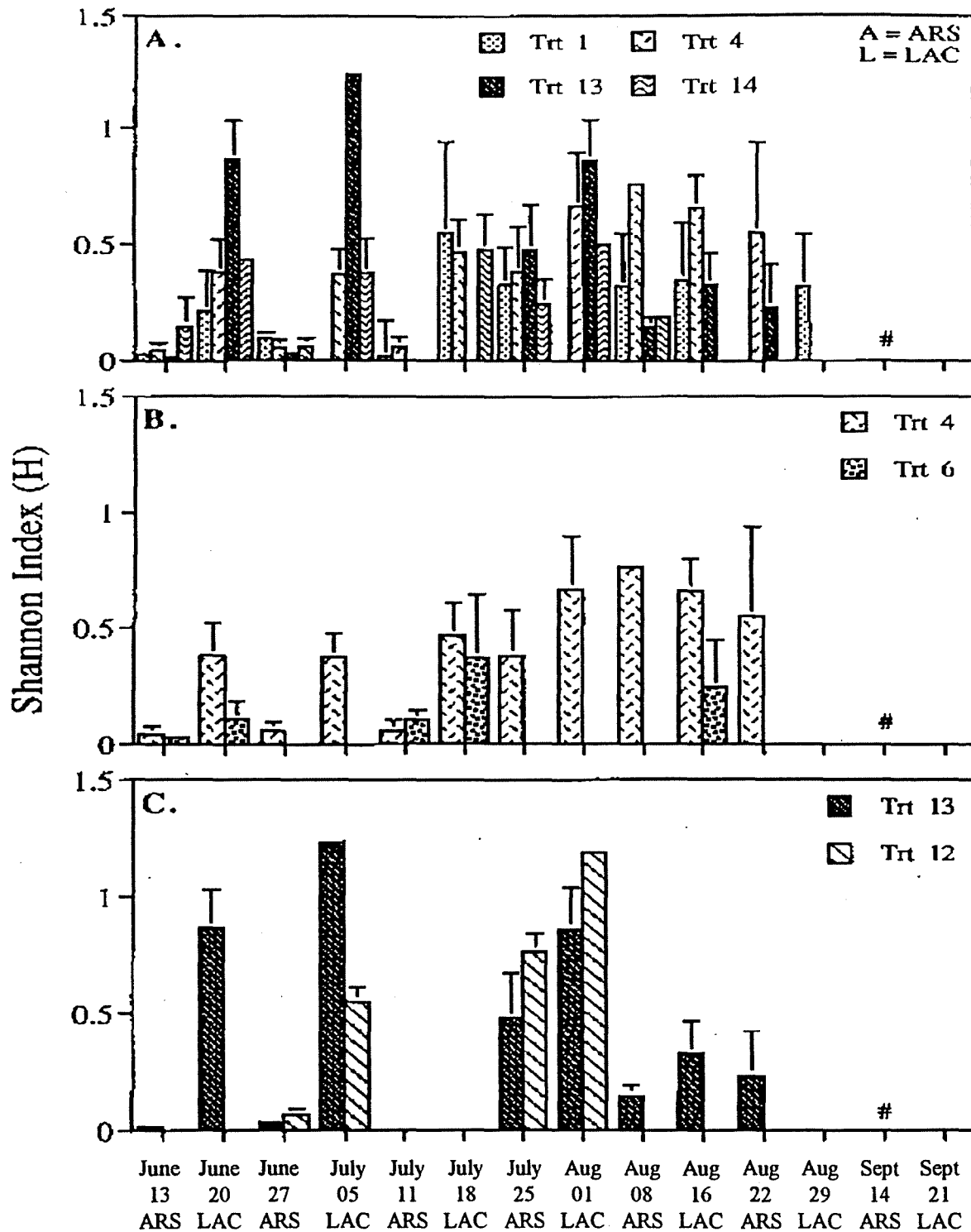
**Table 2. Significant dates and treatments found with ANOVA and LSD. The treatments listed are in order from most to least diverse.**

| <b>Shannon-Weaver Index</b> |                                                     | <b>Simpson Index</b>                          |                                                    |
|-----------------------------|-----------------------------------------------------|-----------------------------------------------|----------------------------------------------------|
| <b>1995</b>                 | <b>1996</b>                                         | <b>1995</b>                                   | <b>1996</b>                                        |
|                             | June 25 (ARS)<br>p = 0.01<br>14 > 1, 4, 13          |                                               | June 25 (ARS)<br>p = 0.04<br>14 > 1, 4, 13         |
|                             |                                                     | July 05 (LAC)<br>p = 0.04<br>13 > 6, 14, 4, 1 |                                                    |
|                             | August 20 (ARS)<br>p = 0.09<br>1 > 14, 6, 13, 4, 15 |                                               |                                                    |
|                             | August 27 (ARS)<br>p = 0.07<br>14 > 1, 13, 5, 4, 6  |                                               | August 27 (LAC)<br>p = 0.06<br>1, 14 > 13, 5, 4, 6 |

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Figure 1. Collembola diversity in 1995 decomposition bag samples using Shannon-Weaver index (mean + standard error). A) Corn phases of CS1, CS3, and CS5; and pasture phase of CS6. B) Corn and soybean phases of CS3. C) Corn and oats/alfalfa phases of CS5.



Note: # No Collembola sampled in any treatment for September 14 at ARS.

Figure 2. Collembola diversity in 1996 decomposition bag samples using Shannon-Weaver index (mean + standard error). A) Corn phases of CS1, CS3, and CS5; and pasture phase of CS6. B) Corn and soybean and wheat/red clover phases of CS3. C) Undisturbed site.

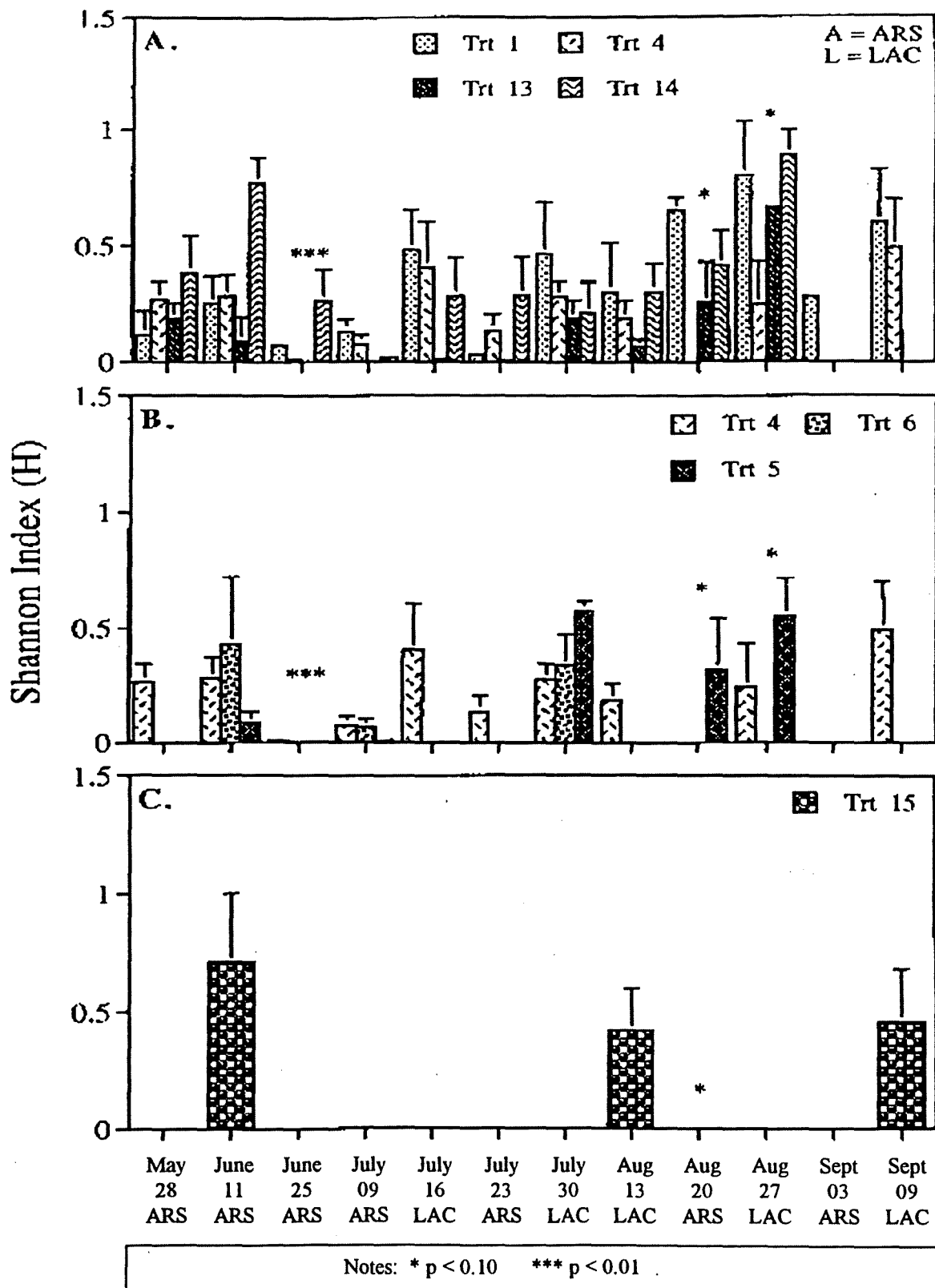
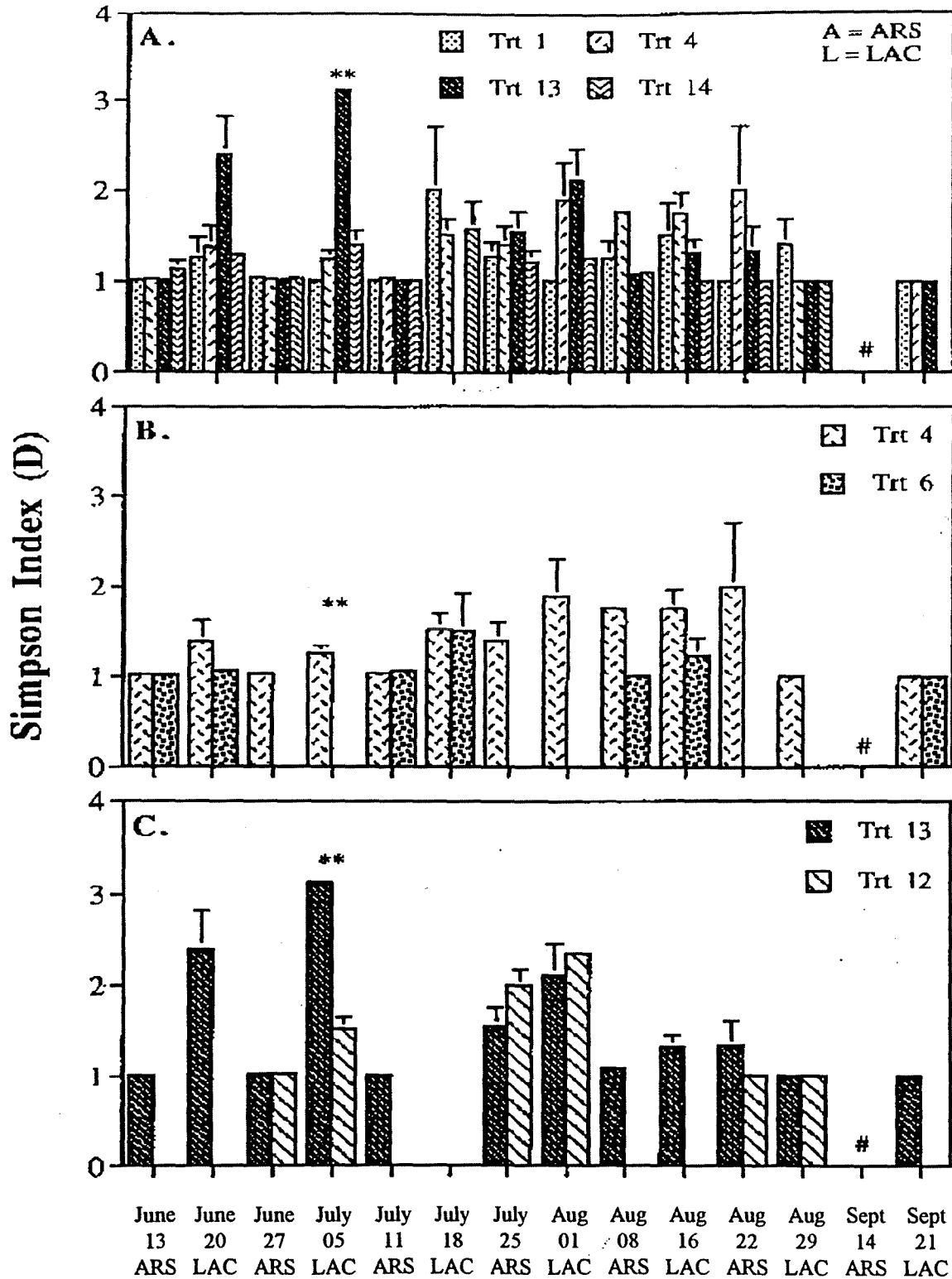
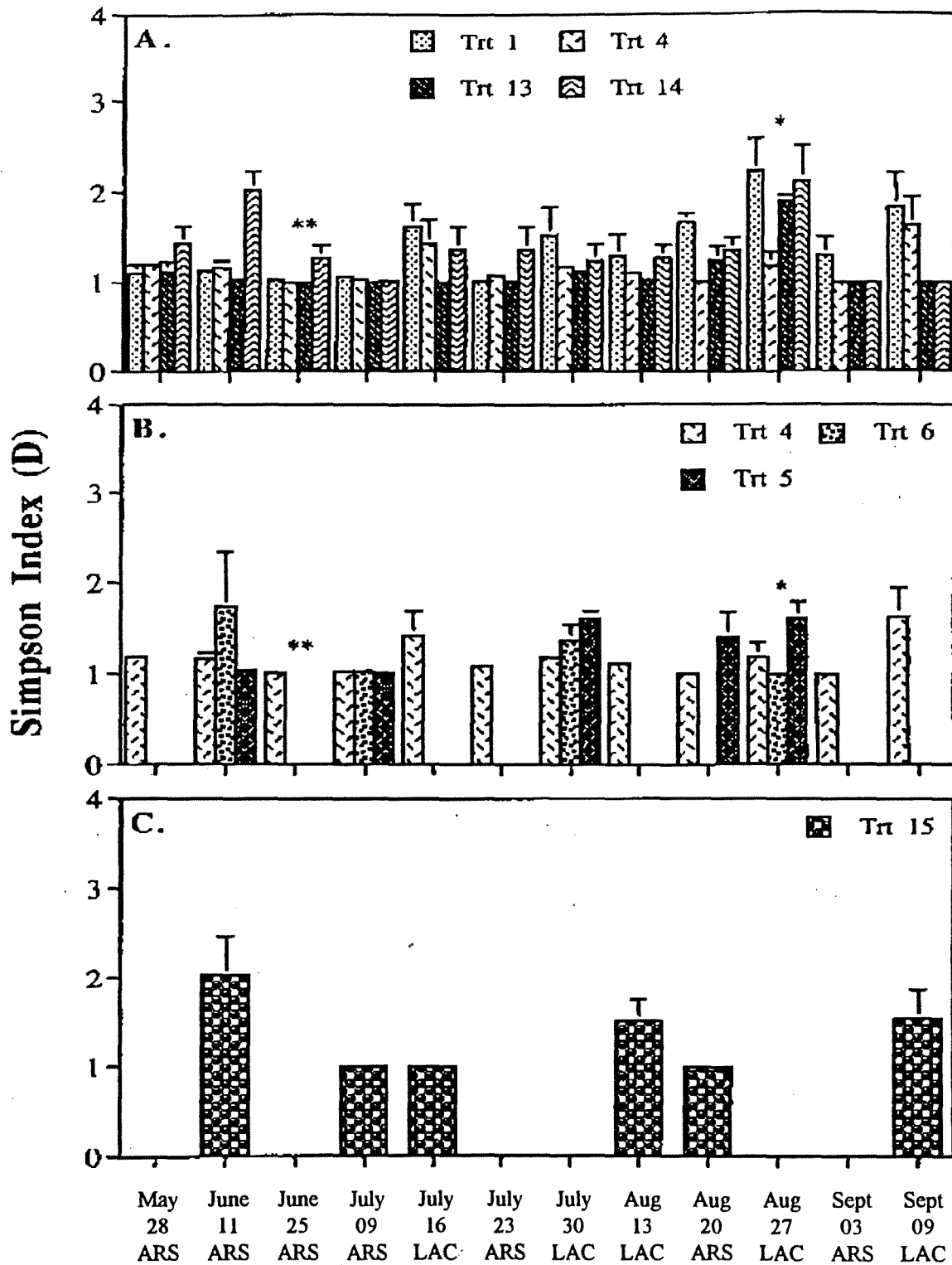


Figure 3. Collembola diversity in 1995 decomposition bag samples using Simpson index (mean + standard error). A) Corn phases of CS1, CS3, and CS5; and pasture phase of CS6. B) Corn and soybean phases of CS3. C) Corn and oats/alfalfa phases of CS5.



Notes: \*\*p < 0.05 # No Collembola sampled in any treatment for September 14 at ARS

Figure 4. Collembola diversity in 1996 decomposition bag samples using Simpson index (mean + standard error). A) Corn phases of CS1, CS3, and CS5; and pasture phase of CS6. B) Corn and soybean phases of CS3. C) Undisturbed site.



Notes: \* $p < 0.10$  \*\* $p < 0.05$

## 11. Changes in WICST Soil Quality 1993-1998

Victoria A. Gollwitzer<sup>1</sup>, Robin F. Harris<sup>2\*</sup>, and Martha E. Rosemeyer<sup>3</sup>

### Objective

The objective of this study was to monitor changes in various soil quality parameters under the four cropping systems selected for soil biodiversity measurements. The soil quality parameters were labile C (soil respiration), microbial biomass, and organic matter. The cropping systems evaluated were: continuous corn (CS1), the corn phase of a corn-soybean-wheat/red clover rotation (CS3), the corn phase of the corn-oats/alfalfa-alfalfa rotation (CS5), and a continuous pasture (CS6).

### Methods

In 1997 soil samples for soil quality analyses of microbial biomass and labile carbon were collected on 06/03 and 08/20/97 at ARS and on 06/04/97 and 08/27/97 at LAC in conjunction with the other biodiversity teams. Fall sampling for chemical analysis was conducted at ARS on 11/18/97 and at LAC on 11/16/97. Manure was applied at ARS on 11/6/97 and at LAC on 11/19/97. No measurements of microbial biomass and labile carbon were taken in 1998.

Soil samples for quantitative soil quality analyses were collected within the plots at predetermined, randomly selected points after sampling was conducted for the soil organisms. Three soil cores were removed using a 6.25 cm (2.5") diameter soil probe to a depth of 10-15 cm (4-6") from each point in a pattern around the macro and micro cores taken by the entomology and microbial diversity groups. The three cores were bagged together and the total volume of the sample was approximately 1000g. Fall samples, however, were collected in a manner similar to 1992-1994 nitrate research as follows (Iragavarapu et al., 1994). Five locations were sampled along a diagonal line across the plot. Two soil cores of 3/4" diameter were taken to a depth of 10 cm at each location and all ten cores for the plot were bulked. All samples collected during the season were stored in plastic bags and kept on ice during transfer to the lab. At the lab, samples were stored in sealed bags at 4°C until processing which was usually within 48 hours.

Samples were sieved through a 5 mm screen and large stones and plant debris removed. The screen was washed and dried between samples. For samples that were processed for microbial biomass and labile carbon, moisture content was determined by drying 20g at 105°C for 48 hours. Deionized water was added to the samples on a gravimetric basis, to correct the moisture of samples to approximate the moisture content of the wettest sample collected from each site and soil moisture was again measured. Labile carbon was determined by evaluating CO<sub>2</sub> evolution over a 14 day period at a humidity level of 100% at ambient lab temperature. On day four half the flasks were fumigated with chloroform and microbial biomass determined using the fumigation-incubation method after a 10-day incubation (Jenkinson and Ladd 1981).

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Chemical analyses performed on the fall samples were nitrate, extractable phosphorus, exchangeable potassium, organic matter, and pH and by the UW-Soil and Plant Analysis Laboratory (See Harris et al., 1994 for analytical procedures). Bulk density and soil porosity were not measured as had been done in previous years. Soil samples remaining after analyses were archived at 4°C.

The difference from continuous corn treatment was determined by student t tests. Regression lines of microbial biomass (using fall values only since they were comparable year to year) and fall organic matter from the years 1993 through 1997 for CS 1, CS3, CS5 and CS6 were statistically compared using MSTAT. When the slopes of the lines were significantly different then the systems are interpreted as significantly differently affecting the parameter over time.

## Results and Discussion

### 1997 Analytical Data

*Microbial biomass and labile carbon.* At both the Arlington and Lakeland sites, microbial biomass during the summer and the fall was significantly higher in the pasture system (CS6) when compared to continuous corn (CS1) (Table 1). This tendency was also reflected in the labile carbon measurements but they only were significantly higher in the summer. For microbial biomass and labile carbon, no significant differences were detected at either site when CS1 was compared to the corn phases of the other systems except at Lakeland during the summer the corn phase of CS5 labile carbon was significantly higher than CS1.

*Organic matter.* Pasture (CS6) is significantly higher in OM than continuous corn (CS1) at both sites (Table 1). The other cropping systems are not significantly different than CS1.

*Chemical properties:* Fall-measured nitrate, P, K and pH (Table 1). At Arlington, the CS3 was significantly lower in extractable phosphorus and exchangeable potassium due to lack of agrochemical inputs than CS1. The pH in CS3 was significantly higher than in CS1, which may be due to the absence of inorganic nitrogen fertilizer. The pasture also had a significantly lower level of extractable phosphorus than CS1. These same differences were observed in 1995 and 1996. As for nitrate levels, only the pasture (CS6) was significantly lower than continuous corn CS1. The corn phase of CS5 was significantly higher in nitrate than CS1, which may be attributed to the application of manure 12 days before sampling in this system.

Lakeland did not exhibit the same pattern. In 1997 the only significant system difference measured was between continuous corn and the pasture system, where exchangeable potassium was significantly higher in the pasture than that of CS1. This was also observed in 1996; where the highest level of exchangeable potassium was measured in the pasture system. However, the animals were removed from the paddocks in 1996 after about 50 days due to wet and unsuitable conditions and paddocks were allowed to recover without animals in 1997. The lack of vigor in the forage stand may be the cause of this build-up of K.

### Five year trends in microbial biomass and organic matter (1993-1997)

*Microbial biomass.* There are no significant differences between regression lines of the treatments at either site. At Arlington CS1, CS2 and CS3 all decrease in slope, though the pasture (CS6) increases (Figures 5 and 7). At Lakeland CS1 has a negative slope (-1.7) and CS3 and CS5 and CS6 are positive with slopes of 9.7, 4.1 and 16.9 respectively (Figures 6 and 8). In both Arlington and Lakeland over a five-year period the microbial biomass decreased in continuous corn (CS1) and increased in rotationally grazed pasture CS6. More years of data will confirm or deny these trends.

*Organic matter.* At Arlington regression lines of organic matter measurements of corn under CS1, CS3 and CS5 are not significantly different from one another and all are increasing. With more years of sampling, the trajectory of increasing CS5 organic matter in comparison to the relatively flat lines of CS1 and CS3 may be significant at ARS (Figure 1). Similarly at Lakeland the slightly decreasing slopes of CS1, CS3, and CS5 are not significantly different from one another (Figure 2). At Arlington although the regression line of pasture (CS6) shows a positive slope and CS1 has a negative slope there is no significant difference between (Figure 3). However, the regression lines of continuous corn (CS1) and pasture (CS6) are both weakly significantly different ( $P = 0.106$ ) at Lakeland (Figure 4). Also at the same site the regression line slope of the forage rotation CS5, which is decreasing, is significantly different from the rotationally grazed pasture (CS6), which is increasing in slope ( $P = 0.106$ ).

### Conclusions

Usually systems that use sufficient animal manures, green manures or no-tillage increase in soil organic matter over time from five to fifteen years (Magdoff 1992, Drinkwater et al 1998), though there are reports of significant organic matter changes in three years (Gallant et al. 1998). At both sites over these five years the biologically diverse pasture system (CS6) has increased in organic matter. However in green manure based system, CS3, the two sites behave differently—organic matter is slightly decreasing at Lakeland but increasing at Arlington, the same trend that we see in the least diverse system, continuous corn (CS1).

Over this five-year period the majority of the biologically-complex cropping systems (CS3 and CS6) have shown an increase in microbial biomass levels from the initial measurements made in 1993, whereas the opposite has occurred in continuous corn (CS1). Microbial biomass at both Arlington and Lakeland in the continuous corn system (CS1) has a more negative slope in comparison to the rotated corn cropping systems (CS3 and CS5).

Organic matter can influence microbial biomass levels in that heterotrophic microorganisms utilize organic matter to build cellular biomass. However there is not much correspondence between organic matter and microbial biomass in the data reported here. Of the regression lines graphed less than half the time both organic matter and microbial biomass have a positive slope or a negative slope (3/8 pairs of lines). The remainder do not correlate at this simple level – the regression lines are negatively sloped in organic matter and positively sloped in microbial or visa versa (in 5/8 pairs of lines). The pairs which show a correspondence are CS1 in Lakeland (both organic matter and microbial biomass decreasing) and CS6 at both sites (both organic matter and

microbial diversity are increasing). Since we do see the clearest trends in these treatments, this is probably an agroecologically significant finding

Microbial biomass is more sensitive to weather and date differences than organic matter, which may be why there are no significant differences in regression lines over five years. Calculating a regression line through variable temperate and moisture conditions in different years, even if all taken in the fall season, increases variability such that a significant linear trend in itself is more difficult to observe. However, at any one date, differences between treatments are more significant. On the other hand, organic matter is less temperature and moisture dependent at any one moment resulting in regression lines that can be more statistically separable from one another.

It is commonly thought that conventional agricultural practices have a negative effect on biodiversity and practicing sustainable agricultural practices will aid in maintaining diversity (Paoletti *et al.*, 1992). Our data tends to support that microbial biomass increases with more sustainable management methods but we do not know whether this greater abundance also reflects a greater diversity. Research on microbial diversity using molecular-microbiological techniques to answer these questions will be reported elsewhere in this volume (see Section 11. The Relevance of Biodiversity to the Sustainability of Agricultural Systems: A Progress Report).

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**Table 1. Analytical Soil Quality Indicator Properties for 1997 WICST Cropping Systems.**

| Soil Quality Properties        |                         | Analytical Data for Cropping Systems |     |      |                        |     |                  |                     |                  |                 |                         |                  |                  |
|--------------------------------|-------------------------|--------------------------------------|-----|------|------------------------|-----|------------------|---------------------|------------------|-----------------|-------------------------|------------------|------------------|
|                                |                         | CS1: Continuous corn                 |     |      | CS3: Wide row Soybeans |     |                  | CS5: Oats & Alfalfa |                  |                 | CS6: Continuous Pasture |                  |                  |
|                                |                         | Corn                                 |     |      | Corn phase             |     |                  | Corn phase          |                  |                 | Pasture                 |                  |                  |
| Name                           | Units                   | Spr                                  | Sum | Fall | Spr                    | Sum | Fall             | Spr                 | Sum              | Fall            | Spr                     | Sum              | Fall             |
| <b>ARLINGTON</b>               |                         |                                      |     |      |                        |     |                  |                     |                  |                 |                         |                  |                  |
| Nitrate <sup>1</sup>           | mg kg <sup>-1</sup>     | --                                   | --  | 17   | --                     | --  | 14               | --                  | --               | 42 <sup>a</sup> | --                      | --               | 8 <sup>a</sup>   |
| Extractable P <sup>1</sup>     | mg kg <sup>-1</sup>     | --                                   | --  | 94   | --                     | --  | 42 <sup>a</sup>  | --                  | --               | 90              | --                      | --               | 69 <sup>a</sup>  |
| Exchangeable K <sup>1</sup>    | mg kg <sup>-1</sup>     | --                                   | --  | 350  | --                     | --  | 160 <sup>a</sup> | --                  | --               | 323             | --                      | --               | 261              |
| pH <sup>1</sup>                | -log[H <sup>+</sup> ]   | --                                   | --  | 6.9  | --                     | --  | 7.2 <sup>a</sup> | --                  | --               | 7.0             | --                      | --               | 6.7              |
| Organic Matter <sup>1</sup>    | %                       | --                                   | --  | 4.8  | --                     | --  | 4.0              | --                  | --               | 5.1             | --                      | --               | 5.7 <sup>a</sup> |
| Labile Carbon <sup>2</sup>     | mg C g <sup>-1</sup>    | --                                   | 84  | 154  | --                     | 96  | 136              | --                  | 121              | 174             | --                      | 151 <sup>a</sup> | 197              |
| Microbial biomass <sup>2</sup> | mg C 100g <sup>-1</sup> | --                                   | 301 | 245  | --                     | 337 | 273              | --                  | 440              | 397             | --                      | 562 <sup>a</sup> | 476 <sup>a</sup> |
| Bulk Density                   | g cm <sup>-3</sup>      | --                                   | --  | --   | --                     | --  | --               | --                  | --               | --              | --                      | --               | --               |
| Total Porosity                 | %                       | --                                   | --  | --   | --                     | --  | --               | --                  | --               | --              | --                      | --               | --               |
| <b>LAKELAND</b>                |                         |                                      |     |      |                        |     |                  |                     |                  |                 |                         |                  |                  |
| Nitrate <sup>1</sup>           | mg kg <sup>-1</sup>     | --                                   | --  | 17   | --                     | --  | 18               | --                  | --               | 36              | --                      | --               | 32               |
| Extractable P <sup>1</sup>     | mg kg <sup>-1</sup>     | --                                   | --  | 50   | --                     | --  | 28               | --                  | --               | 74              | --                      | --               | 60               |
| Exchangeable K <sup>1</sup>    | mg kg <sup>-1</sup>     | --                                   | --  | 198  | --                     | --  | 158              | --                  | --               | 236             | --                      | --               | 303 <sup>a</sup> |
| pH <sup>1</sup>                | -log[H <sup>+</sup> ]   | --                                   | --  | 7.0  | --                     | --  | 6.6              | --                  | --               | 7.4             | --                      | --               | 7.4              |
| Organic Matter <sup>1</sup>    | %                       | --                                   | --  | 4.2  | --                     | --  | 4.9              | --                  | --               | 5.3             | --                      | --               | 6.3 <sup>a</sup> |
| Labile Carbon <sup>2</sup>     | mg C g <sup>-1</sup>    | --                                   | 80  | 134  | --                     | 86  | 133              | --                  | 139 <sup>a</sup> | 194             | --                      | 188 <sup>a</sup> | 237              |
| Microbial biomass <sup>2</sup> | mg C 100g <sup>-1</sup> | --                                   | 266 | 351  | --                     | 419 | 403              | --                  | 589              | 546             | --                      | 865 <sup>a</sup> | 854 <sup>a</sup> |
| Bulk Density                   | g cm <sup>-3</sup>      | --                                   | --  | --   | --                     | --  | --               | --                  | --               | --              | --                      | --               | --               |
| Total Porosity                 | %                       | --                                   | --  | --   | --                     | --  | --               | --                  | --               | --              | --                      | --               | --               |

<sup>1</sup> Analytical data are average of two replicate values from each plot and two plots were sampled at a depth of 0-9cm.

<sup>2</sup> Analytical data are average of two replicate values from two locations in each plot and two plots were sampled.

Statistical analysis: a = values significantly different from CS1 at a level of P<0.1.

**Figure 1. OM in corn phases of CS1, CS3, CS5. ARS 1993 - 1997.**

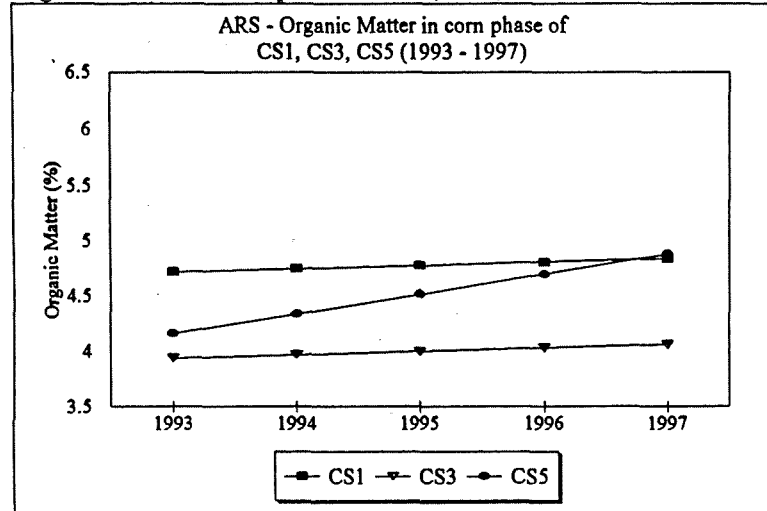


**Figure 3. Organic Matter in CS1 and CS6. ARS 1993 - 1997.**

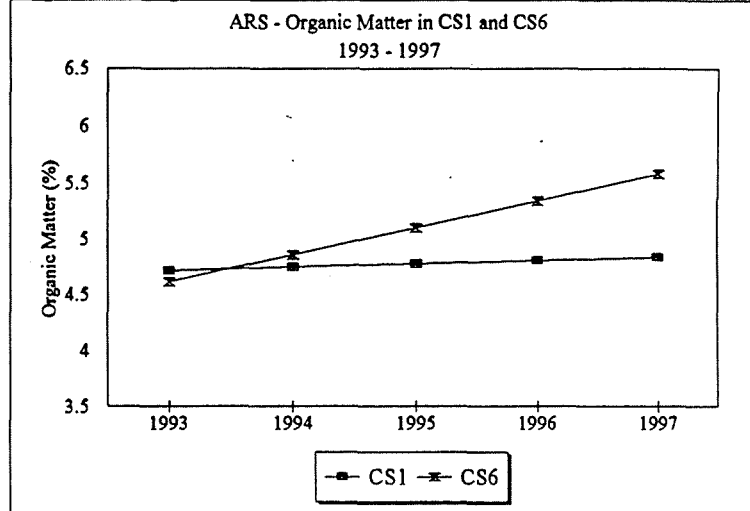


**Figure 2. OM in corn phases of CS1, CS3, CS5. LAC 1993 - 1997.**

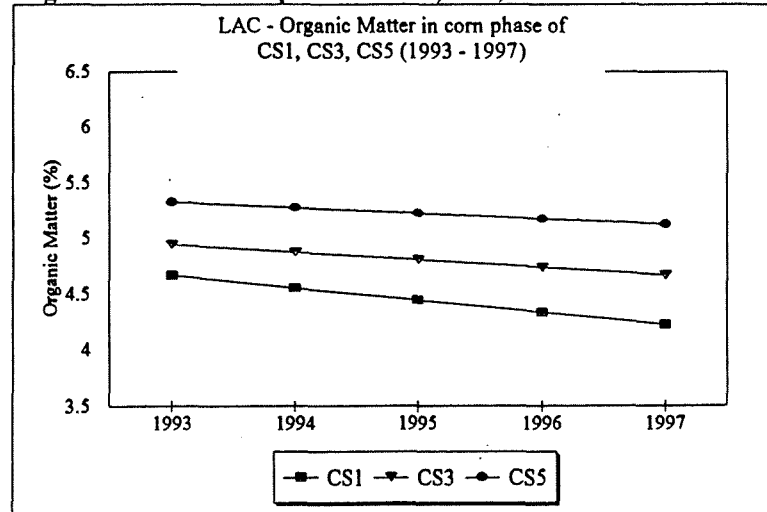


**Figure 4. Organic Matter in CS1 and CS6. LAC 1993 - 1997.**

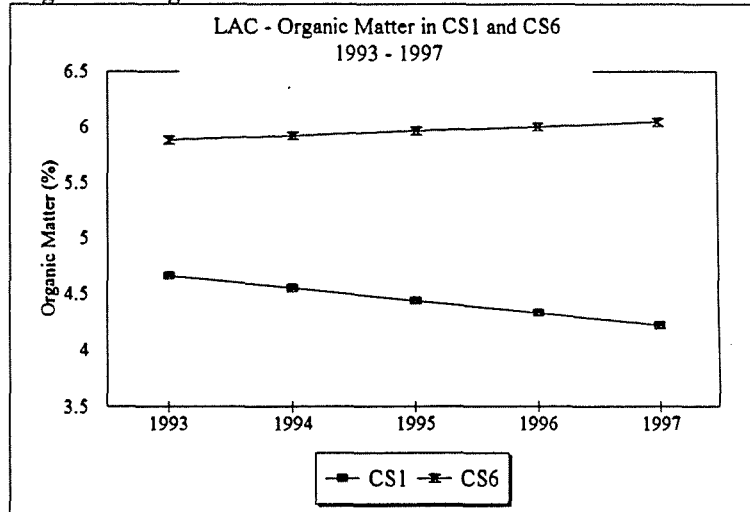


**Figure 5. Microbial Biomass in Corn phases. ARS 1993 - 1997.**

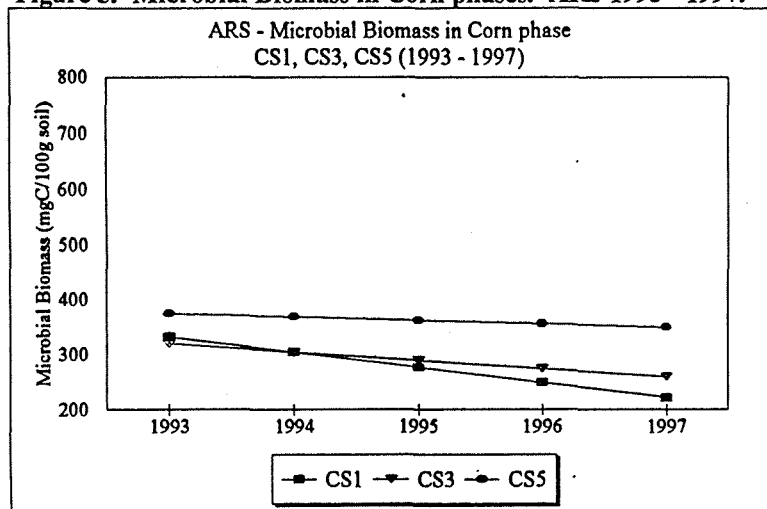


**Figure 7. Microbial Biomass in CS1 and CS6. ARS 1993 - 1997.**

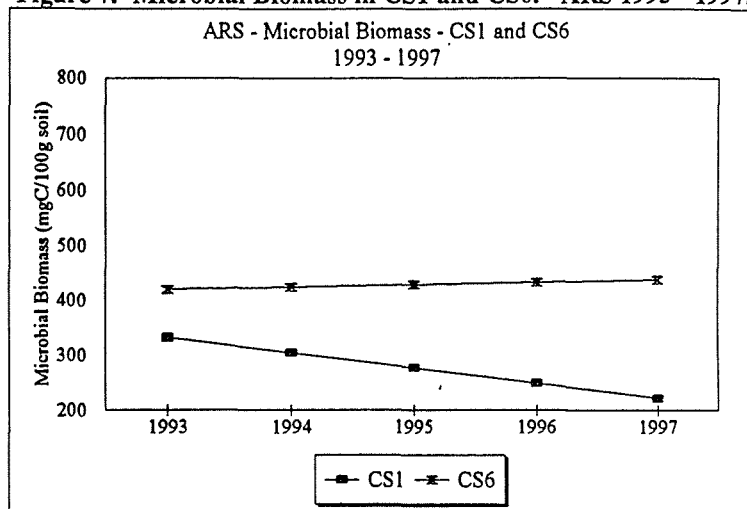


**Figure 6. Microbial Biomass in Corn phases. LAC 1993 - 1997.**

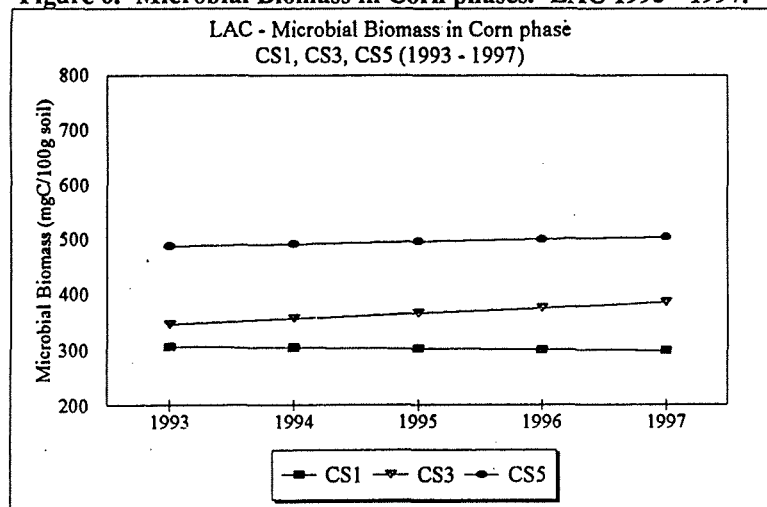
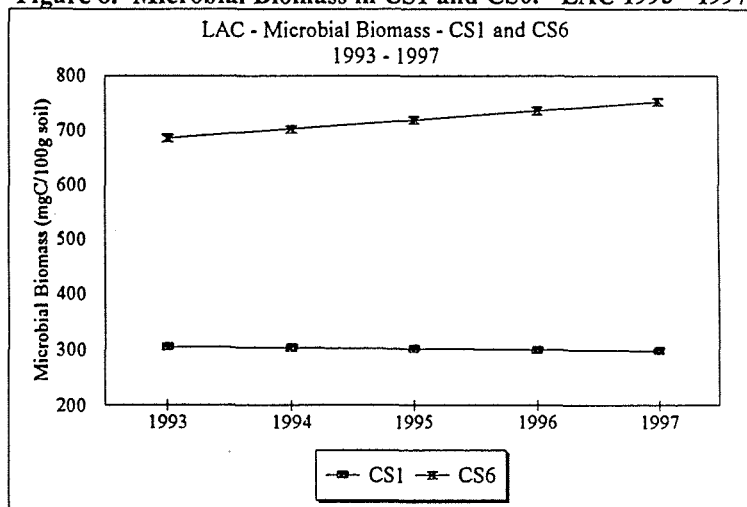


**Figure 8. Microbial Biomass in CS1 and CS6. LAC 1993 - 1997.**





## 12. The Dynamics of Root Growth under Different Management Systems

Walter Goldstein<sup>123</sup>

### Introduction

The Wisconsin Integrated Farming System Trials (WICST) were begun in 1989 to study farming systems that range from conventionally managed monoculture corn to systems which might qualify for organic production. The trials are carried out at the Arlington Research Station (ARS) and the Lakeland Agricultural Complex (LAC) on some of the most productive soils in the State of Wisconsin.

Research with the WICST has examined how farming systems influence soil biology, root growth and root health. Part of this effort has been to better understand why crops respond the way they do in different farming systems. In particular we would like to know why continuous corn (CS 1) often produces relatively lower yields than expected, and why the low-input, cash-grain system (CS 3) produces erratic corn yields.

Benson (1985) reviewed possible causes for the reduction of grain yield associated with growing corn in monoculture instead of in some kind of rotation. The reduction in yield was generally of the magnitude of 5-15% and it occurred even when the corn was fully fertilized with mineral fertilizers. Benson found that monoculture corn was more susceptible to moisture or temperature stresses in July and August. He suggested that the cause for this is that the rooting system of the corn is impaired when it is grown in monoculture. This impairment was thought to predispose the plant to stresses associated with lack of moisture, nutrients, and diseases and thereby lead to reductions in yield.

It makes sense that a rotation system might influence a crop primarily through its rooting system because the rooting system is the interface between the soil and the plant. In support of Benson's ideas, Nickel et al. (1995) found that corn that was rotated with soybeans produced more root length than monoculture corn. A difference in the size of the rooting system would be expected to affect nutrient extraction efficiency and moisture uptake. Increases in the size of the rooting system have been found to correlate with greater uptake of P and K (Barber and Mackay, 1986) and nitrate (Wiesler and Horst, 1991). Barber found that root length density at mid-silk was highly correlated with grain yield, especially if K fertilizer was not applied.

Though, to my knowledge, Benson's hypothesis has not been disproved, neither has any one of the many factors that are influenced by rotations been found to be mainly responsible for the impairment of root systems in continuous corn. Candidate factors may include degradation of soil

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<sup>2</sup> Sampling, washing, and counting root systems was done by Terry Lemahieu, Bill Barber, Sheryl Weisz, and others. Tom Mulder helped with determining sampling areas; Josh Posner helped with loading statistics; and Jon Baldock gave advice on statistical analyses.

<sup>3</sup> This research was done as part of a NRI research grant on soil biodiversity.

structure, increases in pathogenic potential of the soil, changes in soil chemistry, etc. Some evidence even exists (Anderson, et al. 1988) that corn itself might produce allelopathic chemicals that are toxic to subsequent crops of corn, primarily affecting early root growth.

The productivity of monoculture corn depends on application of sufficient quantities of mineral fertilizer, especially N, and choice of productive hybrids that utilize the full growing season. Nitrogen fertilizer seems to strongly increase root length of corn, while a comparison of various hybrids showed little difference in root growth (Durieux et al., 1994).

Farming systems that include growing forage legumes and raising animals are widely used by sustainable farmers to replace the use of N fertilizer and to create soils that produce good yields. The WICST has simulated such systems and found that they can be economically competitive with conventional farming systems, even without a premium for organic production (Klemme and Mulder, 1996).

The decomposing green manures and animal manures used in such systems may have beneficial effects besides their nutrients. Pallant et al (1997) recently compared corn root growth from four systems in a long-term trial at the Rodale Research Center. These systems were conventional corn-corn, soybeans-corn, and two low-input cropping systems, which utilized green manures, and one of which used animal manure. They found the highest root length density with the low-input cropping system + manure followed by the cash-grain, low-input system, then soybean-corn. Continuous corn produced the lowest root length density. They hypothesized a positive relationship between inputs of organic matter and root growth. On the other hand, Anderson et al. (1988) hypothesized that the positive effect of legumes in crop rotations with corn has to do with slow way in which their residues release nitrogen. There also exist indications in the older literature that farming systems influence the susceptibility of corn roots to root rots (Goldstein, 1992). Preliminary research results at the WICST by Voland and Rouse (1992) and Goldstein (1995) indicated differences in root health in favor of the low-input rotations.

This report summarizes three years of research on the growth of corn roots in the WICST trials, including data reported on earlier (Goldstein, 1995). Roots were examined from three cropping systems: CS 1 (continuous corn with inputs of synthetic fertilizers and pesticides); CS 3 (corn-soybean-winter wheat + red clover rotation with no synthetic fertilizers or pesticides); and CS 5 (corn-oats-alfalfa rotation with inputs of dairy manure). These comparisons indicate, in a step-wise manner, the addition of small grains + leguminous green manures or the latter coupled with use of cattle manure.

The research quantified the dynamics of root development for corn. The line intersect technique was utilized in order to estimate the root length and the health status of roots at different nodes. Intact rooting systems were sampled from plants at different dates. However, simple measurements with this technique do not yield an overall quantitative picture of root growth of corn. This is because the roots that decay and disappear into the soil are not measured at later dates. Therefore calculations, based on sequential measurements of nodal growth, were developed for estimating the amounts of roots that disappear between measurements. By

applying this method we could estimate seasonal root accumulation and total root production for the different systems.

Root production and grain yields were correlated. Also, because a positive relationship between available nitrate and the production of roots was expected, the root production was also correlated with the amounts of residual nitrate in the soil after the corn crop had been harvested.

In 1995 and 1996, root measurements were made on monolithic blocks taken from around the crown of the corn plant. To find out how such information compares to production in the entire field, in 1997 this kind of sampling was compared with trench samples that were representative of the entire 6 inch profile.

## **Materials and Methods**

### **Systems**

The farming systems which we examined have been described in depth in annual reports on the WICST (Anonymous, 1996). The monoculture corn system receives synthetic fertilizers and pesticides according to University of Wisconsin recommendations. In CS 1, nitrogen is applied in the form of starter fertilizer, and side-dressed anhydrous ammonia or liquid N fertilizers. The amount used is adjusted according to results from deep nitrate soil tests and best management practice recommendations. The yield goal is 180 bushels of grain and it is assumed that the corn plant needs 1.1 lb of N as NO<sub>3</sub> or NH<sub>4</sub> in order to produce a bushel of corn. Synthetic fertilizers and pesticides are used in system 1 but seldom or not at all in the other two systems. In cropping system 3 red clover is over-seeded into the winter wheat in the spring of the year and it is turned under as a green manure before growing corn. In CS 5, 15 t of manure is applied/acre in the fall to the alfalfa before growing corn.

These systems differ not only in rotation and inputs of fertilizers and pesticides, but also in when the corn was planted and which hybrids were chosen. Corn in the monoculture system (CS 1) was sometimes planted early. If that was the case a longer season hybrid was used than in the two other systems (see Table 1). For systems 3 and 5, early planting was avoided to minimize problems with diseases and weeds. A slightly higher seeding rate was used in systems 3 and 5 because rotary hoeing and cultivation were used as primary methods of weed control and these techniques are expected to thin out the stand.

**Table 1. Planting date, hybrid choice, planting rate and N application for different farming systems (1995-1997).**

| Year | Farm | System | Planting Date | Hybrid* | Relative Maturity | Seeding Rate | N Rate** |
|------|------|--------|---------------|---------|-------------------|--------------|----------|
|      |      |        |               |         | days              | seed/acre    | lbs/acre |
| 1995 | ARS  | CS1    | May 01        | P 3563  | 103               | 32,000       | 100      |
|      |      | CS3    | May 12        | P 3751  | 97                | 34,000       | 0        |
|      |      | CS5    | May 12        | P 3751  | 97                | 34,000       | Manure   |
| 1995 | LAC  | CS1    | May 19        | P 3751  | 97                | 31,200       | 110      |
|      |      | CS3    | May 20        | P 3751  | 97                | 33,800       | 0        |
|      |      | CS5    | May 20        | P 3751  | 97                | 33,800       | Manure   |
| 1996 | ARS  | CS1    | May 03        | P 3563  | 102               | 31,500       | 99       |
|      |      | CS3    | May 13        | DK 493  | 95                | 34,000       | 0        |
|      |      | CS5    | May 13        | DK 493  | 95                | 34,000       | Manure   |
| 1996 | LAC  | CS1    | June 26       | P 3979  | 75                | 31,500       | 116      |
|      |      | CS3    | June 26       | P 3979  | 75                | 34,000       | 0        |
|      |      | CS5    | June 26       | P 3979  | 75                | 34,000       | Manure   |
| 1997 | ARS  | CS1    | April 25      | GH 2441 | 105               | 30,150       | 126      |
|      |      | CS3    | May 14        | DK 471  | 97                | 34,000       | 0        |
|      |      | CS5    | May 14        | DK 471  | 99                | 34,000       | Manure   |
| 1997 | LAC  | CS1    | April 29      | GH 2441 | 105               | 32,000       | 74       |
|      |      | CS3    | May 21        | DK 471  | 97                | 34,000       | 0        |
|      |      | CS5    | May 21        | DK 471  | 97                | 34,000       | Manure   |

\* Abbreviations for Hybrid: P = Pioneer, DK = DeKalb, and GH = Golden Harvest

\*\* Cow manure was applied at the rate of 15 t/a on each year for CS5.

### **Root Measurements**

In 1995, 1996, and 1997 monolithic root samples were taken at different dates with a square tipped trowel (6x6x6 inch samples) around the root crown. These samples are referred to as crown-block samples. The number of samples taken per plot was 5, 4, and 3, in 1995, 1996, and 1997, respectively. In addition to these samples, in 1997 two samples of corn roots were taken per plot from a trench with the same square tipped trowel. The dimensions of the trench samples were 6 inches along the row (with the stem of the corn plant in the middle of that edge), 15 inches into the center of the space between rows, and six inches deep. As plants of corn were generally 6 inches apart in the row and the rows of corn were spaced 30 inches apart this sample was considered to be representative of the profile.

Samples were washed over a 1-mm sieve and preserved in water in an intact form for subsequent measurement. On the first sampling date all roots were measured. On subsequent dates the rooting system was dissected in half along its axis and only half the root system was subsequently measured. This was done in order to reduce the work-load and to make measurement of all the roots feasible in a timely fashion. Care was taken in all cases to leave the entire seminal rooting system with the sample used for measurement. The remaining root systems were dissected into seminal and adventitious roots.

Corn plants produce adventitious roots, first in an indistinct whorl at the base of the main stalk, and progressively through the season at the base of five higher order internodes. These adventitious roots were isolated according to their order of development into six groups associated with the leaf nodes 1-3, 4, 5, 6, 7, and 8.

Two root length density measurements were made according to the modified line-intersect method of Tennant (1975) on each group of roots. First the total number of root line intersections was counted to estimate total root length; second, the number of line intersections with necrotic and dead roots was counted to estimate the length associated with dying and dead roots. Roots were judged as being in the necrotic (dying) and dead category on the basis of their appearance, i.e., if they appeared to be decayed, if lesions were apparent. Determinations were generally made by a team of three people who interacted to strive for consensus in making judgements. Estimates of healthy roots were derived by simple subtraction from the values of total length and necrotic/dead length. Estimates of root length were finally expressed on the basis of cm of length per cm<sup>3</sup> of soil by converting from intersection counts to cm of length and adjustment according to whether the root system in question was halved or not.

Both sites were sampled on all three years (see Table 2). In 1995 samples were taken on five dates, sequentially through the season, about one-month apart. In 1996 and 1997 the fifth sampling date was omitted between the fourth and fifth date there had been hardly any change in total root production; we sampled only on four dates, again generally at monthly intervals. Sampling at LAC was later in 1996 than at other dates due to wet weather, which caused a late planting date. In general, the corn reached the stage of anthesis at the end of July and the first week of August. This time period was sampled for ARS in 1995 and 1996 and for LAC in 1995 and corresponded to the third sampling date.

In 1995, 1996, and 1997, crown-block monoliths were taken from three, four, and four replicates, respectively. An exception to this was LAC in 1996, where only two replicate samples were taken. Trench samples were taken from three replicates in 1997 on both sites on the same four dates in which the crown-block samples were taken.

**Table 2. The sampling dates for roots on the two farms expressed in Julian days and in conventional calendar dates.**

| Year | ARLINGTON   |                   | LAKELAND    |                   |
|------|-------------|-------------------|-------------|-------------------|
|      | Julian Date | Conventional Date | Julian Date | Conventional Date |
| 1995 | 164         | June 13           | 157         | June 06           |
|      | 192         | July 11           | 186         | July 05           |
|      | 220         | August 08         | 213         | August 01         |
|      | 248         | September 05      | 241         | August 29         |
|      | 276         | October 03        | 269         | September 26      |
| 1996 | 163         | June 11           | 198         | July 16           |
|      | 191         | July 09           | 212         | July 30           |
|      | 219         | August 06         | 240         | August 27         |
|      | 247         | September 03      | 271         | September 17      |
| 1997 | 155         | June 03           | 156         | June 04           |
|      | 183         | July 01           | 198         | July 16           |
|      | 233         | August 20         | 240         | August 27         |
|      | 291         | October 17        | 294         | October 20        |

**Root Length Accumulation**

Quantities of dead and dying (necrotic) roots accumulated continuously during the growing seasons. Death generally started with the seminal system and progressed towards higher orders of adventitious roots. At any given node, we measured a maximum root length sometime during the season. On subsequent dates the root length at this node decreased as the roots died and turned-over in the soil. On dates after the maximum length was measured, the amount of roots that disappeared in the soil between measurements could be estimated as the difference between the maximum total root length produced by the given rooting system minus the total root length achieved on any subsequent date. A more useful measurement of the total accumulated dead and dying roots for that node was calculated on subsequent dates according to the following simple formula:

$$A (de+dy) x = T_m - T_x + N_x$$

Where "A (de+dy) x" signifies the accumulated dead and dying roots on date x,  $T_m$  was the maximum total length achieved at that node and  $T_x$  and  $N_x$  are the total length and length of dead and dying roots achieved at the same node on date x.

In order to obtain estimates of dead and dying roots we averaged the sub-sample values in a given replicate on each date for the roots at each nodal whorl. Then we inspected the root data

on a node by node basis for each replicate to find on which date the roots at a node achieved their maximum length. At that date, and at previous dates, the amount of dead and dying roots was simply estimated as the measured length of its dead and dying roots. But on all subsequent dates the formula was applied to generate appropriate estimates of the accumulated dead and dying roots on a replicate by replicate basis.

On any given date, total root length was estimated as the sum of healthy root length plus the accumulated dead and dying root length. The percent of healthy roots was estimated on that same date by multiplying the healthy root length times 100, and dividing by the total root length.

Using this system of data analysis, values for total root length, accumulated dead and dying roots, healthy roots, and percent healthy roots were generated for each replicate, system, date, and site. Then the effects of date and system were tested with an MSTAT-C analysis of variance program (available from Michigan State University, East Lansing). A randomized complete block design was used with dates as the main plot factor and systems as a sub-plot factor. Means were inspected for date, system, and date x system interactions using least significant differences at the 5% level if F test values indicated a probability of significance < 5%. In a few cases systems differences were examined where the p value for the F test was < 10%.

The total amount of roots produced during a season was estimated at the final date, after root growth had practically ceased. This measurement was equivalent to the total root length at the final date and was the sum of the lengths of accumulated dead and dying roots at each node plus the length of any healthy roots.

For total root production, an analysis of variance was used to test the effects of three years, two sites, and three systems, using replications from each site-year. Because of variable numbers of replications a General Linear Models Program (available from SAS, Inc., Cary, N.C.) was used with a randomized, complete block design (years as the main plot factor, sites as the sub-plot factor, and systems as the sub-sub plot factor) to analyze variance. F test values for main plot factors and interactions were calculated using appropriate mean square errors. Contrasts were used to test for significant differences between systems.

The relationships between total root production and grain yield for the different farming systems were tested using a SAS program for regression (REG). First order polynomial regressions were fitted. This program was also used to make pairwise comparisons between systems to determine whether there were differences between coefficients and slopes. The procedure utilized dummy variables (Ott, 1977) as covariates. The linear equation that was tested was  $y = \beta_0 + \beta_1x_1 + \beta_2x_1^2 + \beta_3x_2 + \beta_4x_1x_2 + \beta_5x_1^2x_2 + \epsilon$ . The t test values for testing  $\beta_3x_2$ ,  $\beta_4x_1x_2$ , and  $\beta_5x_1^2x_2$ , indicated whether significant differences existed between systems for intercepts, first order slopes, and second order slopes, respectively.

#### Grain Yields and Nitrate Samples

The grain yields were obtained by combining whole plots. In the fall of each year nitrate samples were obtained by sampling to a depth of three feet (Iragavarapu et al., 1996). Values for

yield and nitrate for the specific plots from which root samples were taken were obtained from Joshua Posner's technicians at the UW-Madison, Dept. of Agronomy.

## Results

### Total Production of Roots, Grain Yield, and Residual Nitrate

Table 3 shows the effects of farming systems on total production of root density, grain yield, and residual nitrate in the fall. The farming systems had different effects on total root production ( $p < 0.0012$ ). CS 1 produced more roots than either of the other two systems (Table 3 and 4), while CS 5 tended, non-significantly, to produce more roots than CS 3.

There was no apparent link between the planting of a longer season hybrid in CS1 and greater root production for that system. Had there been, the site x year x system interaction should have been significant, but it was not ( $p < 0.122$ ). Furthermore, CS1 produced more roots than the other systems even in the two site-years where the same maturity hybrid was planted in all systems. To illustrate this, the ratio for CS1:CS3 for total root density was 1.37:1 and 1.24:1 on those two years, while the ratio of CS1:CS5 was 1.15:1 and 1.24:1.

There was a wide range in yields. 1996 was a remarkably cold and wet year and at the ARS, CS 3 had 60% as much root production as CS 1 and 56% of the yield. Averaged over the six site-years there was no difference in the yields of CS 1 and CS 3. Cropping system 5 produced significantly more grain yield than the other two systems.

The lowest amounts of residual NO<sub>3</sub> were found in CS 3 and the highest in CS 1. There was no significant difference in residual nitrate between CS 1 and CS 5.

There was a positive relationship between root production and grain yield (see Figure 1). A large amount of the variation in yields over the sites and years for a given system could be accounted for by the regression of total production of roots on grain yields (47%, 53%, and 63% for CS 1, CS 3, and CS 5, respectively).

The systems varied in their relationship between root growth and yield. The yield response curves peaked at 2.12, 1.74, and 1.63 cm/cm<sup>3</sup> of root for CS 1, CS 3, and CS 5, respectively. Assuming a dependent relationship between roots and yield, CS 5 appeared to achieve higher yields with lower amounts of roots while CS 1 appeared to achieve its highest yields only when there were many more roots. The response curve for CS 3 was intermediate to the other two systems and intercepts and slope coefficients did not differ significantly from either of the other systems. The intercepts, and first and second order slopes for CS 1 and CS 5 differed at  $p < 0.052$ , 0.019, and 0.012, respectively. The response curves for CS3 and 5 were initially steeper than for CS 1, which suggests that root growth might be an important factor at low levels than for CS 1.

The CS 1 had both the greatest root production and the highest amounts of residual nitrate, while CS 3 had the least of both. There was no significant correlation between root length and the amount of residual NO<sub>3</sub> in the soil for system 1 ( $R^2 = 2\%$ ) or system 5 ( $R^2 = 3\%$ ). However

29% of the variation in the yield of corn in system 3 could be accounted for by the regression of nitrate on root production ( $p < 0.015$ ). The cold and wet year of 1996 was associated with low yields and low residual nitrate for CS 3 on both sites.

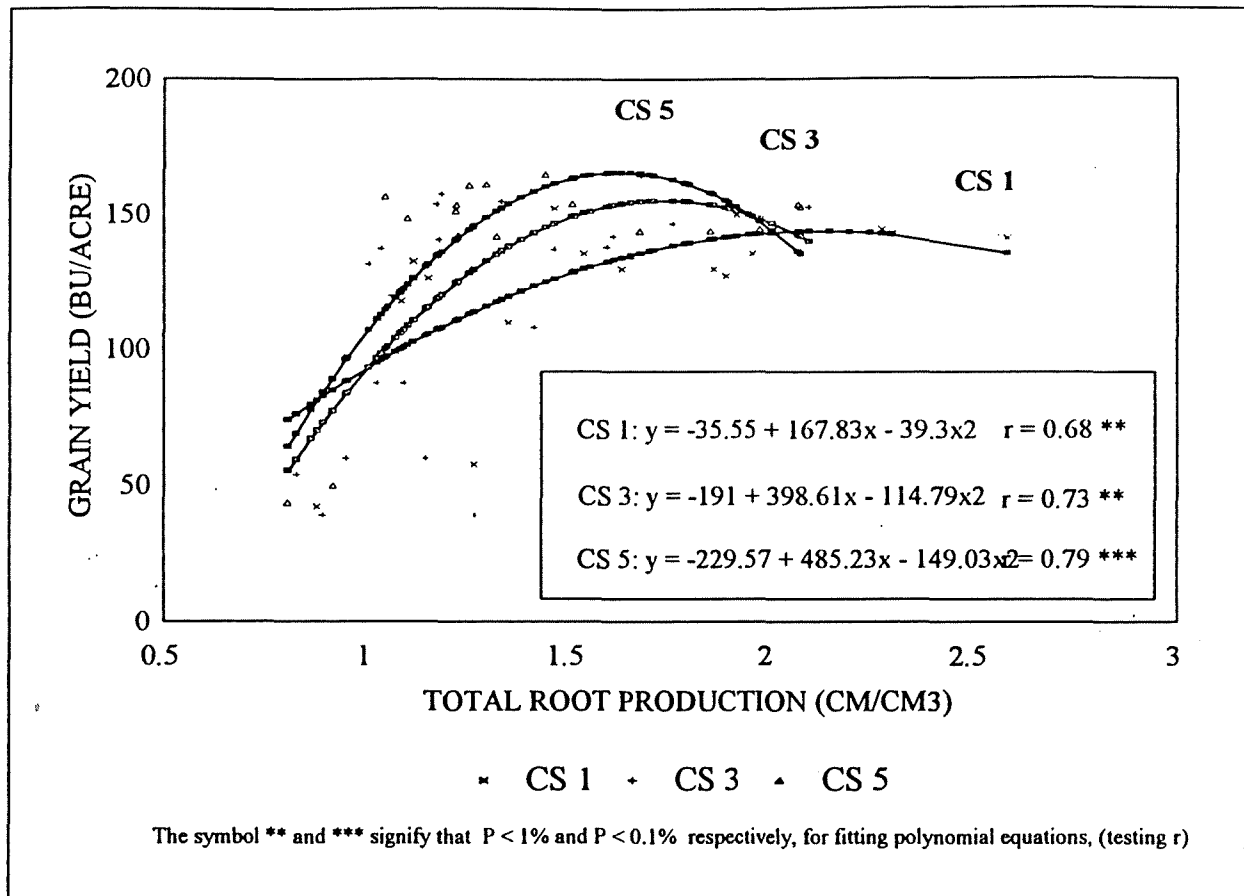
**Table 3. Total corn roots produced over the cropping season in different farming systems with the corresponding yields of grain and the quantities of  $\text{NO}_3^-$  available after harvest in the top 3 feet of soil.**

| Year           | Farm | Total Root Density             |             |             | Grain Yield         |            |            | Post-harvest $\text{NO}_3\text{-N}$ |            |            |
|----------------|------|--------------------------------|-------------|-------------|---------------------|------------|------------|-------------------------------------|------------|------------|
|                |      | CS1                            | CS3         | CS5         | CS1                 | CS3        | CS5        | CS1                                 | CS3        | CS5        |
|                |      | ----- cm/cm <sup>3</sup> ----- |             |             | ----- bu/acre ----- |            |            | ----- lbs/3-ft -----                |            |            |
| 1995           | ARS  | 2.30                           | 1.85        | 1.71        | 143                 | 154        | 157        | 176                                 | 131        | 179        |
|                | LAC  | 1.89                           | 1.38        | 1.65        | 149                 | 132        | 140        | 115                                 | 109        | 130        |
| 1996           | ARS  | 1.75                           | 1.05        | 1.70        | 132                 | 74         | 149        | 263                                 | 40         | 75         |
|                | LAC  | 1.07                           | 0.86        | 0.86        | 50                  | 47         | 47         | 194                                 | 76         | 99         |
| 1997           | ARS  | 1.41                           | 1.32        | 1.21        | 129                 | 148        | 155        | 115                                 | 129        | 180        |
|                | LAC  | 1.14                           | 1.16        | 1.28        | 113                 | 134        | 151        | 146                                 | 130        | 218        |
| <b>AVERAGE</b> |      | <b>1.60</b>                    | <b>1.28</b> | <b>1.43</b> | <b>123</b>          | <b>119</b> | <b>140</b> | <b>168</b>                          | <b>103</b> | <b>151</b> |

**Table 4. The significance of contrasts between different farming systems for total root production, yields, and post-harvest nitrate in the top 3 feet of soil.**

| Contrast   | Root Length |         | Grain Yield |         | Post-harvest $\text{NO}_3\text{-N}$ |         |
|------------|-------------|---------|-------------|---------|-------------------------------------|---------|
|            | F-test      | P level | F-test      | P level | F-test                              | P level |
| CS1 vs CS3 | 17.11       | 0.0003  | 2.27        | 0.1432  | 9.22                                | 0.0051  |
| CS1 vs CS5 | 5.99        | 0.0209  | 21.74       | 0.0001  | 0.97                                | 0.3324  |
| CS3 vs CS5 | 2.85        | 0.1026  | 38.05       | 0.0001  | 4.21                                | 0.0498  |

Figure 1. Root production and Grain yield, relationship for different farming systems.



### Seasonal Root Dynamics

The quantities of accumulated dying and dead root length, healthy root length, and total root length are shown in Figures 2-9. The results of nine analyses of variance are summarized in Table 5. Mean values for the different systems and appropriate l.s.d. values are given in Table 6.

With the exception of one site-year (Lakeland farm in 1997), casual inspection of the figures suggests a general tendency for CS 1 to produce more total root length across dates than CS 3 and sometimes more than CS 5. At ARS in 1995 and 1996 (crown block monoliths) and in 1997 (trench data) and at LAC in 1995 (crown block monoliths) there were significant differences between treatments with CS 1 producing more root length than CS 3. But only at ARS in 1995 did CS 1 produce more root length than CS 5. On the other hand, in 1997 at LAC, where the F test for systems had a  $p$  value  $< 8\%$ , the CS 5 produced more total root length than CS 1.

The same general tendency was apparent for dead and dying roots. Differences between systems were significant in 1996 at ARS, in 1997 at LAC, and at ARS in 1997 for the trench sample. A difference between systems was also apparent at  $p < 6\%$  for LAC in 1995. Again, CS 1 produced significantly more length than CS 3. The exception to the general tendency occurred in 1997 at LAC, where CS 5 produced more roots than CS 3.

There were fewer apparent differences between systems in the length of healthy roots and none for the percent healthy roots. In 1995 and 1996 at ARS, CS 1 produced more healthy root length than CS 3. In 1995, CS 1 also produced more than CS 5, while in 1996, CS 5 produced more than CS 3.

Inspection of the interactions between dates and systems revealed that in four of the six site-years the large relative increase in total root growth for CS 1 occurred mostly between the second and third samplings, in the weeks around anthesis.

At ARS in 1996, CS 3 and 5 showed a pattern of relatively earlier production of both total root length and accumulation of dead/dying roots length than did CS 1. This also seemed to be a year of exceptionally low growth of roots for CS 3. Total root length for CS 3 was less than half of that achieved by the other systems on the second date of sampling. On the third date it had almost caught up to the other systems but by the last sampling it lagged behind. Grain yields for CS 3 were also exceptionally low at this site-year (Table 3).

The pattern for CS 1 for later root growth was also obvious in some site years for healthy root length. CS 1 produced more than CS 3 only by the third sampling date (ARS 1995, 1997). Though CS 1 produced less than CS 5 on the second sampling date (LAC in 1995 and ARS in 1997), by the third harvest date, CS 1 had produced more than CS 5.

Though not always significant, there was a tendency for CS 3 and 5 to produce a higher percentage of healthy roots than CS 1 at the second sampling dates and less by the last samplings (ARS 1995 and 1997, Table 5).

Similarly, at ARS in 1997, though CS 5 accumulated more dead/dying root length by the third sampling date than had CS 1, CS 1 had more at the fourth date. In 1995 at ARS, CS 1 also had more than CS 5 at the final date.

There were no significant differences between systems in 1996 at LAC for any root characteristics, possibly because only two replications had been sampled. Nevertheless the general pattern of root dynamics seemed consistent with the other results (CS 1 producing more length with a pattern of prolonged production).

The root dynamics at LAC in 1997 were different than those achieved on the other site-years. In that year, CS 5 produced more total root length than either of the other systems (crown block samples, not trench). CS 5 also had less healthy root length and a lower percent of healthy roots than CS 1 at the second sampling date and greater length of dead/dying roots on the last date.

Also, CS 3 produced more healthy root length and a higher percent of healthy roots than CS 1 at the third date.

Inspection of the figures suggests again that there was little apparent relationship between choice of earlier or later hybrids and root growth differences between different farming systems. The length data for date x system interactions showed no cases where the earlier planting date for CS 1 had caused a significantly larger rooting system by the first sampling.

Casual comparisons of results from crown-block and trench samples suggest similar tendencies in root dynamics were revealed by the two different sampling methods. However, root growth for the trench system was about half of that found with the crown-block method.

### Discussion

Contrary to the findings of Nickel et al. (1995) and Pallant et al. (1997), monoculture corn in the WICST trials had higher root production than the other systems. At least from the standpoint of root length, this study seems to contradict Benson's hypothesis (1985), that growing corn in a high-input monoculture seems to impair rooting systems. These results also confirm results from others that showed lower rhizodeposition in low-input or organic farming systems than in conventional systems (Lutzow and Ottow, 1994; Swinnen et al., 1995).

The increased root production found in CS 1 was probably not due to earlier planting of later maturing hybrids on some of the years, as differences occurred irrespective of hybrid choice and there appeared to be little size advantage by the first sampling date for earlier planting. The major difference in root production between the systems generally occurred in the time period around anthesis.

Across years and sites, the production of roots appeared to correlate positively and strongly with yield. This is in line with findings of Barber (1986). But there was a very different relationship between root production and grain yields for the different farming systems. Assuming a dependent, positive relationship between the size of the rooting system and yield, the rooting systems of CS 5 and CS 3 were smaller and appeared to be more efficient at producing yield than did the rooting system of CS 1. Conversely, CS 1 needed to produce more roots in order to have a high yield than did the other systems.

The results do not tell us what is challenging corn in CS 1 to produce more roots in the period around anthesis. Nor do we know whether this enhanced production of roots was unequivocally positive for the formation of yields. Prolonged root production might have competed for photosynthate with the developing ear and thereby reduced yield.

One hypothesis is that differences in root growth might be at least partly due to differences in the levels of nitrate available for corn in the different systems. In fact, a significant correlation between root production and residual nitrate level for CS 3 might have indicated a nitrate limitation for that system in some years. However, residual nitrate did not correlate with root

production for CS 1 or CS 5, although there was a wide range in residual nitrate levels for the latter system. In 1995 CS 1 and CS 5 had similar amounts of residual nitrate, but CS 1 produced more roots. Also, CS 5 produced relatively more roots early on than CS 1. If nitrate was the factor causing prolonged root growth and decomposing organic manures produce nitrate later in the warmer parts of the season, then it would be expected that CS 3 and CS 5 would exhibit prolonged root growth; but they did not.

An alternative hypothesis is that differences in root growth were due to CS 1 having to outgrow a problem with root rot, and this cost CS 1 some of its potential yield. Circumstantial evidence for this idea is that in most site years at the second sampling date CS 5 had more healthy roots and a higher percent of healthy roots than CS 1, but this changed by the third date.

A third hypothesis is that corn grown in CS 3 and CS 5 had more efficient rooting systems due to increased mycorrhizal infection. Kothari et al. (1990a and 1990b) found that corn plants that were infected with *Glomus mosseae* produced only 59% as much root length as the control but were more efficient at uptake of several nutrients. Again there is insufficient evidence for disproving any of these theories.

In summary, intensifying the use of rotations and organic manures appears to increase the efficiency of the rooting system and the yield potential. Maintaining corn in monoculture requires a greater investment of the crop in root production and reduces yield potential. The mechanisms for how these effects work are still unclear.

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Table 5. Significance of the difference between dates, treatments, and treatments across dates for root characteristics.

| YEAR      | FARM            | ROOTS      | YEAR    | SITE   | DATE   | SYSTEMS  | DATE x<br>SYSTEMS |
|-----------|-----------------|------------|---------|--------|--------|----------|-------------------|
| 1995      | ARS             | total      | -       | -      | ****   | **       | n.s.              |
|           |                 | dead/dying | -       | -      | ****   | n.s.     | n.s.              |
|           |                 | healthy    | -       | -      | ****   | *        | *                 |
|           |                 | % healthy  | -       | -      | ****   | n.s.     | *                 |
| 1995      | LAC             | total      | -       | -      | ****   | *        | n.s.              |
|           |                 | dead/dying | -       | -      | ****   | +        | n.s.              |
|           |                 | healthy    | -       | -      | ****   | n.s.     | +                 |
|           |                 | % healthy  | -       | -      | ****   | n.s.     | n.s.              |
| 1996      | ARS             | total      | -       | -      | ****   | ***      | ***               |
|           |                 | dead/dying | -       | -      | ****   | *        | **                |
|           |                 | healthy    | -       | -      | ****   | *        | n.s.              |
|           |                 | % healthy  | -       | -      | ****   | n.s.     | n.s.              |
| 1996      | LAC             | total      | -       | -      | ****   | n.s.     | n.s.              |
|           |                 | dead/dying | -       | -      | ***    | n.s.     | n.s.              |
|           |                 | healthy    | -       | -      | ****   | n.s.     | n.s.              |
|           |                 | % healthy  | -       | -      | **     | n.s.     | n.s.              |
| 1997      | ARS             | total      | -       | -      | ****   | n.s.     | n.s.              |
|           |                 | dead/dying | -       | -      | ****   | n.s.     | *                 |
|           |                 | healthy    | -       | -      | ****   | n.s.     | *                 |
|           |                 | % healthy  | -       | -      | ****   | n.s.     | *                 |
| 1997      | LAC             | total      | -       | -      | ****   | +        | n.s.              |
|           |                 | dead/dying | -       | -      | ****   | +        | +                 |
|           |                 | healthy    | -       | -      | ****   | n.s.     | **                |
|           |                 | % healthy  | -       | -      | ****   | n.s.     | ***               |
| 1997      | ARS<br>(trench) | total      | -       | -      | ****   | **       | +                 |
|           |                 | dead/dying | -       | -      | ****   | *        | *                 |
|           |                 | healthy    | -       | -      | ****   | n.s.     | *                 |
|           |                 | % healthy  | -       | -      | ****   | n.s.     | +                 |
| 1997      | LAC<br>(trench) | total      | -       | -      | ****   | n.s.     | n.s.              |
|           |                 | dead/dying | -       | -      | ****   | n.s.     | n.s.              |
|           |                 | healthy    | -       | -      | ****   | n.s.     | n.s.              |
|           |                 | % healthy  | -       | -      | ****   | n.s.     | **                |
| 1995-1997 | both            | total      | ***     | **     | -      | *        | +                 |
| Symbols:  |                 |            | +       | *      | **     | ***      | ****              |
|           |                 |            | p < 10% | p < 5% | p < 1% | p < 0.1% | p < 0.01%         |

Table 6. Effects of farming systems on root characteristics – averaged over dates of sampling.

| YEAR | SITE            | FARMING<br>SYTEM | ROOT CHARACTERISTIC |                |         |              |
|------|-----------------|------------------|---------------------|----------------|---------|--------------|
|      |                 |                  | ALL<br>ROOTS        | DEAD/<br>DYING | HEALTHY | %<br>HEALTHY |
| 1995 | ARS             | CS 1             | 1.553               | 1.028          | 0.526   | 48.7         |
|      |                 | CS 3             | 1.266               | 0.859          | 0.407   | 48.4         |
|      |                 | CS 5             | 1.239               | 0.860          | 0.379   | 46.2         |
|      |                 | l.s.d 5%         | 0.180               | n.s.           | 0.099   | n.s.         |
|      |                 |                  |                     |                |         |              |
| 1995 | LAC             | CS 1             | 1.275               | 0.817          | 0.458   | 52.4         |
|      |                 | CS 3             | 0.929               | 0.553          | 0.376   | 56.4         |
|      |                 | CS 5             | 1.104               | 0.640          | 0.463   | 57.9         |
|      |                 | l.s.d 5%         | 0.223               | 0.222          | n.s.    | n.s.         |
|      |                 |                  |                     |                |         |              |
| 1996 | ARS             | CS 1             | 0.796               | 0.351          | 0.446   | 72.1         |
|      |                 | CS 3             | 0.517               | 0.219          | 0.298   | 69.9         |
|      |                 | CS 5             | 0.887               | 0.336          | 0.552   | 74.1         |
|      |                 | l.s.d 5%         | 0.106               | 0.098          | 0.160   | n.s.         |
|      |                 |                  |                     |                |         |              |
| 1996 | LAC             | CS 1             | 0.561               | 0.218          | 0.343   | 72.2         |
|      |                 | CS 3             | 0.458               | 0.155          | 0.303   | 77.4         |
|      |                 | CS 5             | 0.418               | 0.138          | 0.280   | 77.9         |
|      |                 | l.s.d. 5%        | n.s.                | n.s.           | n.s.    | n.s.         |
|      |                 |                  |                     |                |         |              |
| 1997 | ARS             | CS 1             | 0.779               | 0.515          | 0.264   | 58.0         |
|      |                 | CS 3             | 0.708               | 0.472          | 0.236   | 59.9         |
|      |                 | CS 5             | 0.697               | 0.493          | 0.205   | 56.1         |
|      |                 | l.s.d. 5%        | n.s.                | n.s.           | n.s.    | n.s.         |
|      |                 |                  |                     |                |         |              |
| 1997 | LAC             | CS 1             | 0.643               | 0.446          | 0.197   | 55.7         |
|      |                 | CS 3             | 0.645               | 0.402          | 0.243   | 56.3         |
|      |                 | CS 5             | 0.750               | 0.522          | 0.228   | 55.7         |
|      |                 | l.s.d. 5%        | 0.106               | 0.089          | n.s.    | n.s.         |
|      |                 |                  |                     |                |         |              |
| 1997 | ARS<br>(trench) | CS 1             | 0.407               | 0.276          | 0.131   | 56.6         |
|      |                 | CS 3             | 0.271               | 0.170          | 0.101   | 60.5         |
|      |                 | CS 5             | 0.316               | 0.230          | 0.086   | 56.0         |
|      |                 | l.s.d. 5%        | 0.080               | 0.065          | n.s.    | n.s.         |
|      |                 |                  |                     |                |         |              |
| 1997 | LAC<br>(trench) | CS 1             | 0.354               | 0.246          | 0.108   | 55.8         |
|      |                 | CS 3             | 0.322               | 0.217          | 0.105   | 51.8         |
|      |                 | CS 5             | 0.374               | 0.256          | 0.118   | 57.8         |
|      |                 | l.s.d. 5%        | n.s.                | n.s.           | n.s.    | n.s.         |
|      |                 |                  |                     |                |         |              |

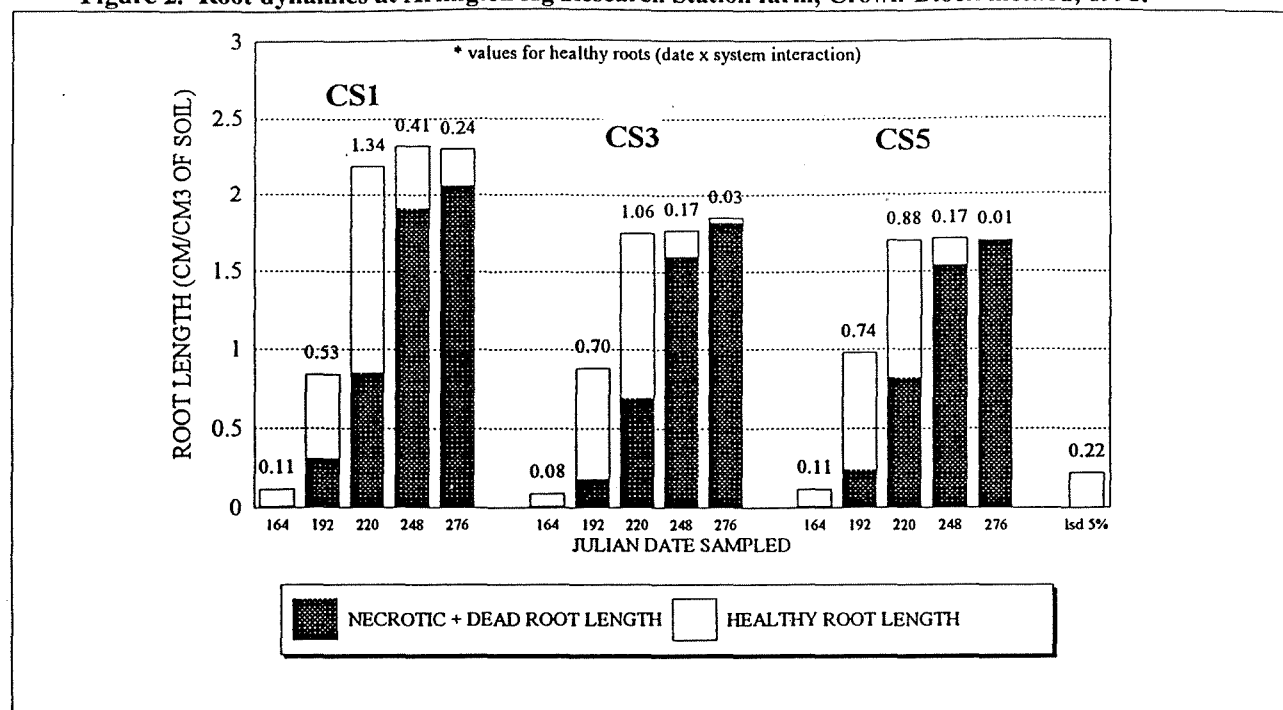
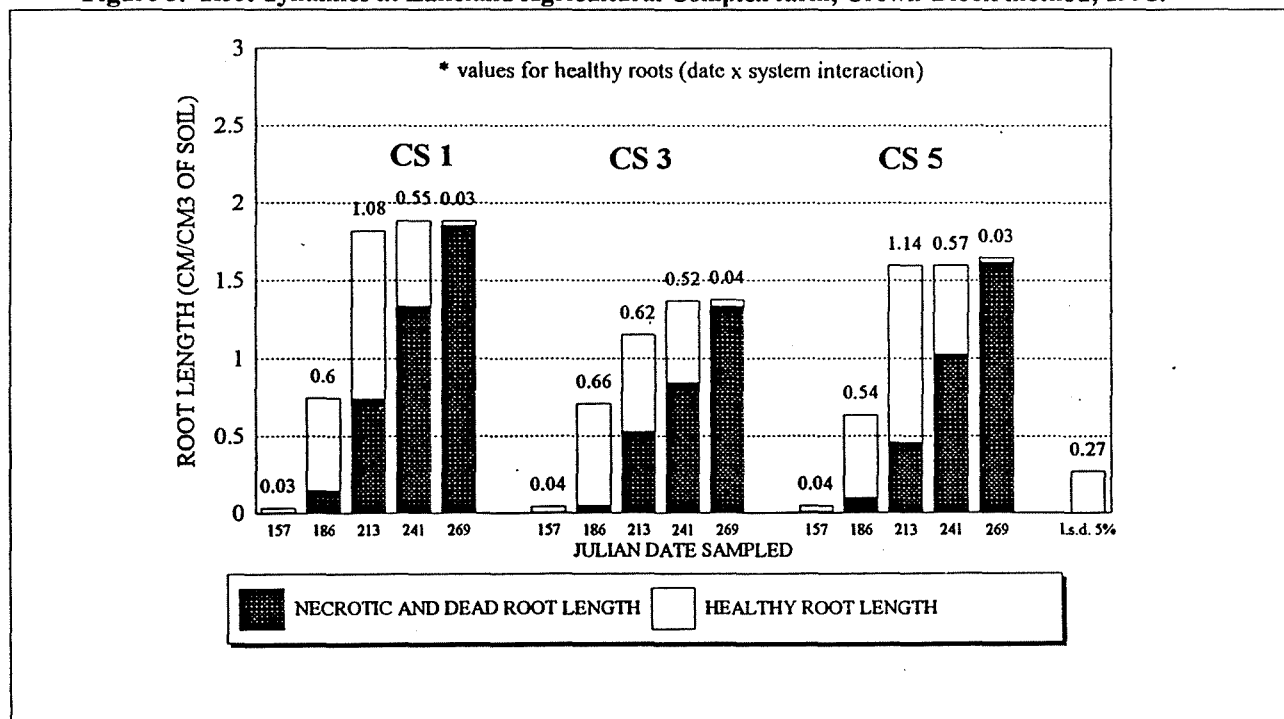
**Figure 2. Root dynamics at Arlington Ag Research Station farm, Crown-Block method, 1995.****Figure 3. Root dynamics at Lakeland Agricultural Complex farm, Crown-Block method, 1995.**

Figure 4. Root dynamics at Arlington Ag Research Station farm, Crown-Block method, 1996.

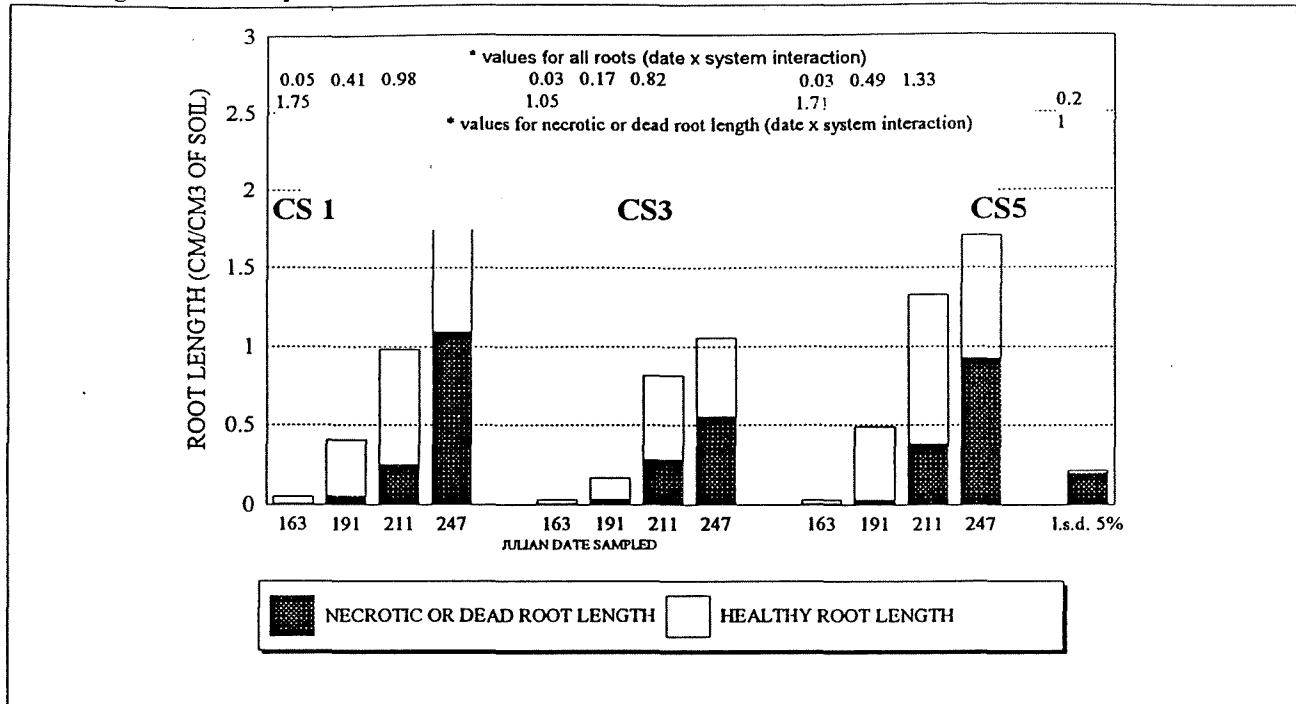


Figure 5. Root dynamics at Lakeland Agricultural Complex, Crown-Block method, 1996.

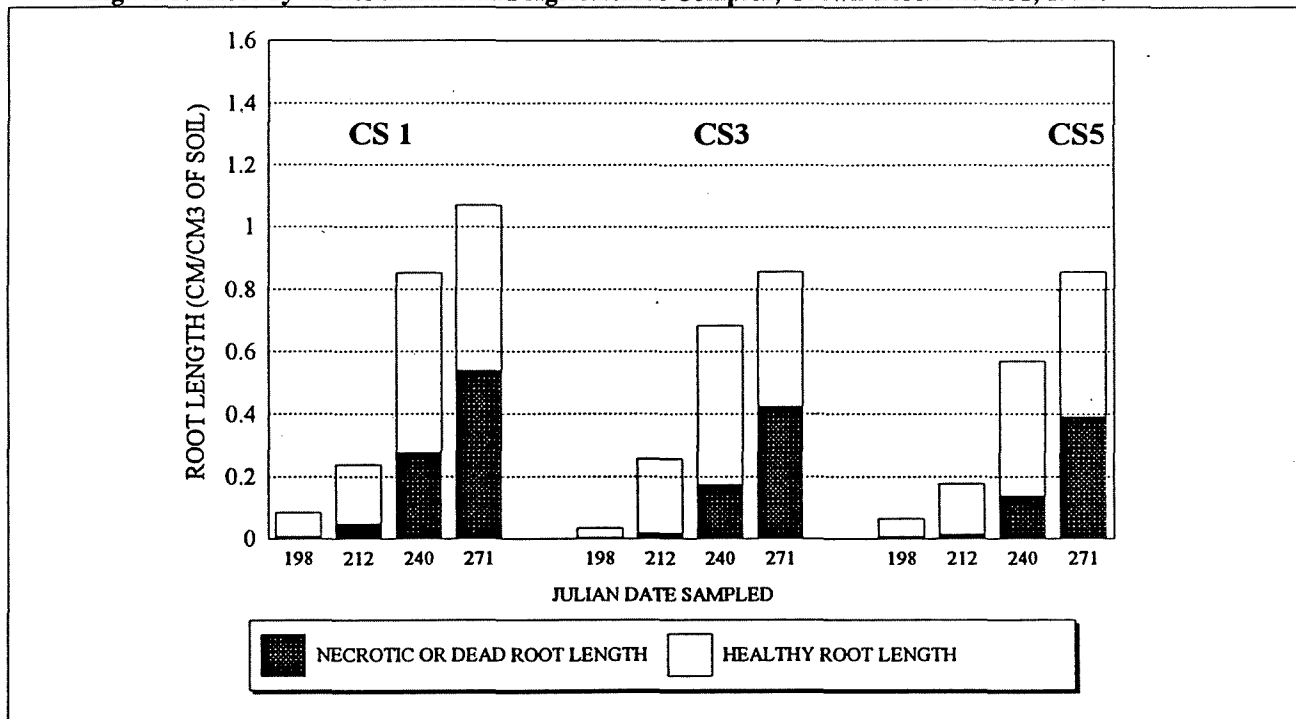


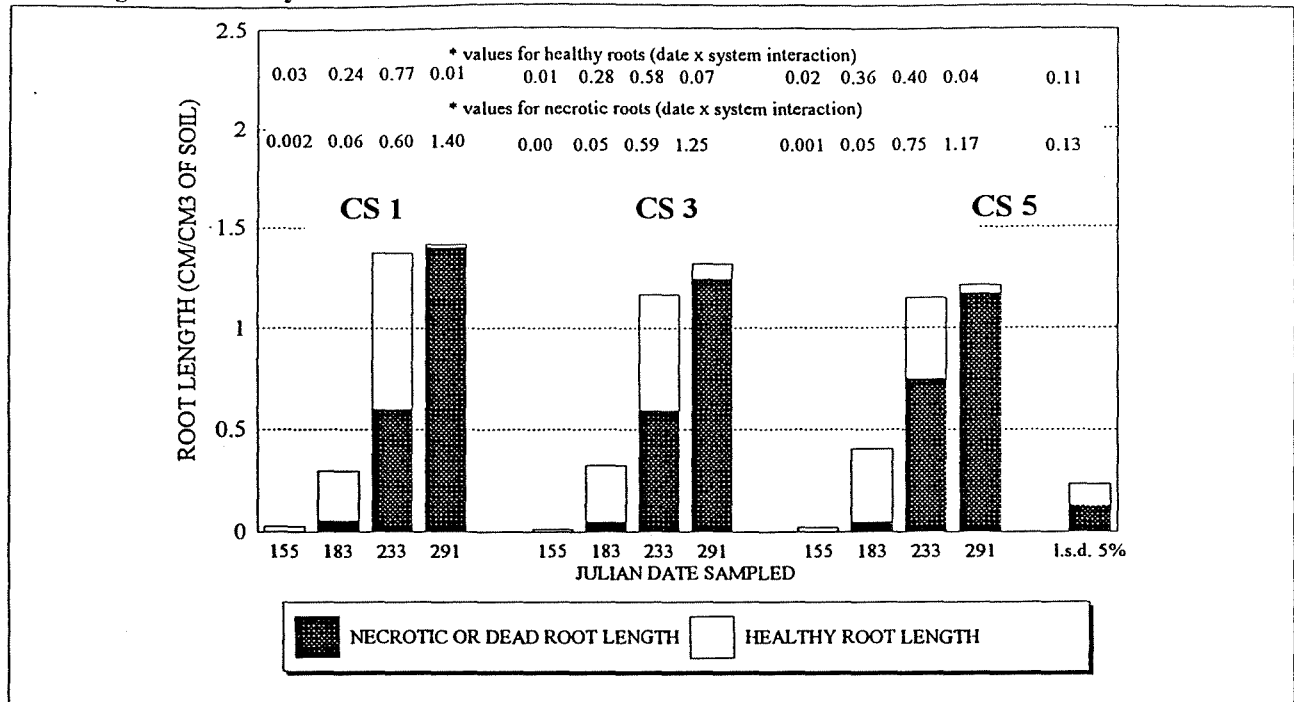
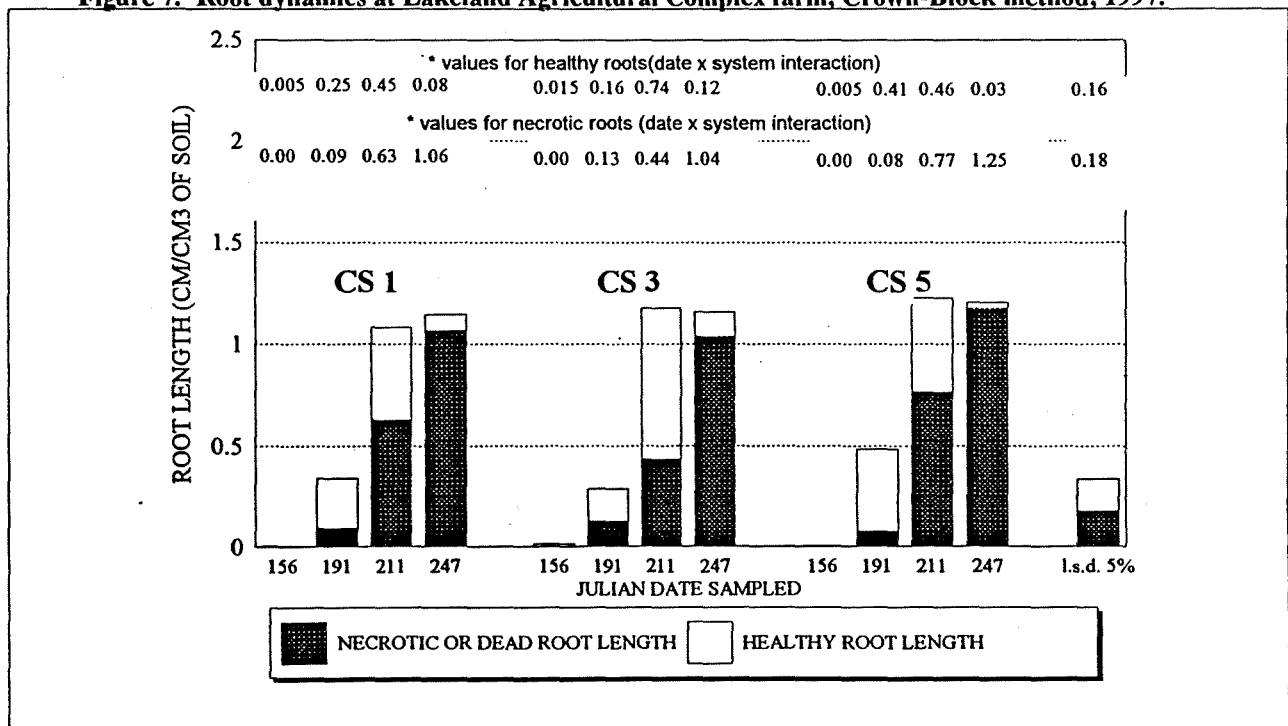
**Figure 6. Root dynamics at Arlington Ag Research Station farm, Crown-Block method, 1997.****Figure 7. Root dynamics at Lakeland Agricultural Complex farm, Crown-Block method, 1997.**

Figure 8. Root dynamics at Arlington Ag Research Station farm, Trench method, 1997.

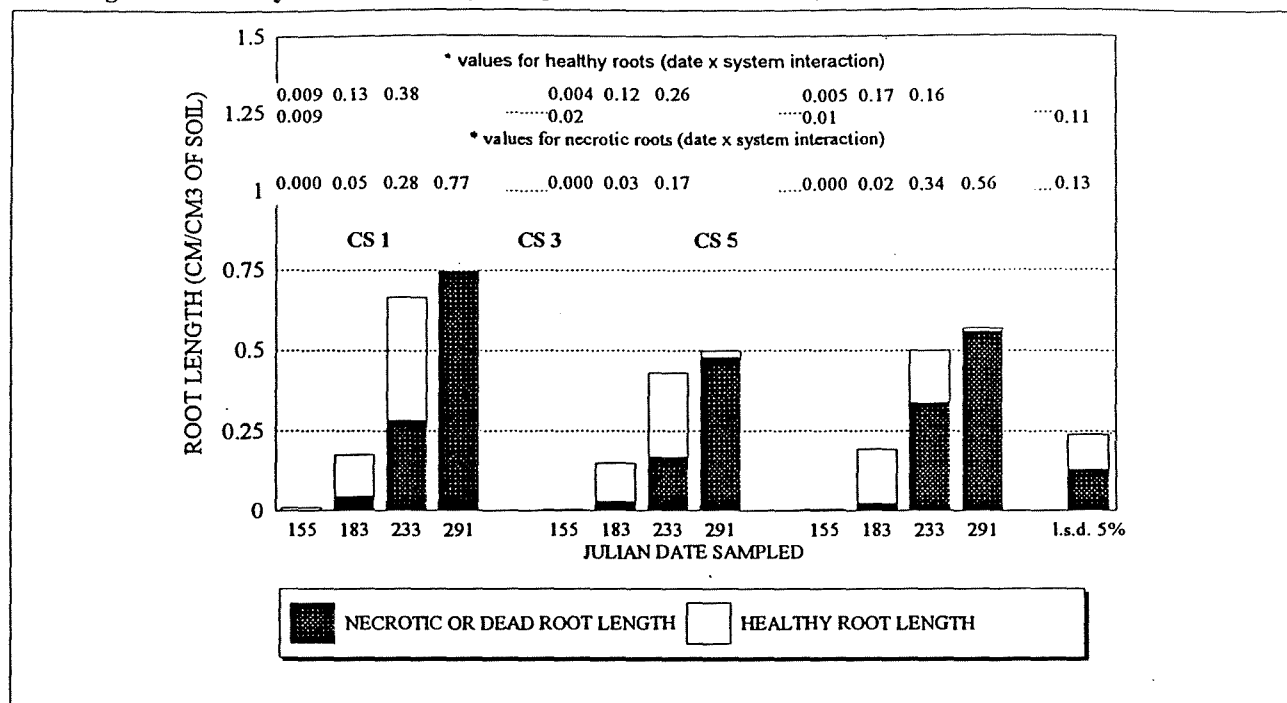
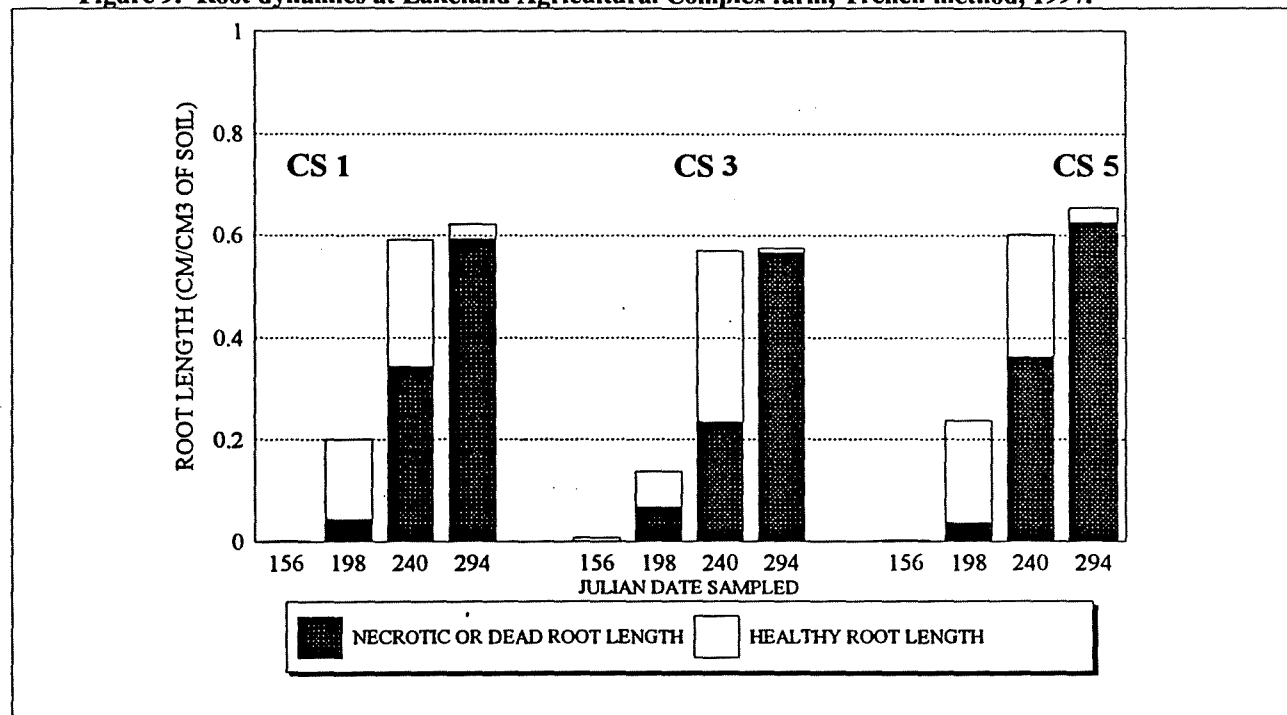


Figure 9. Root dynamics at Lakeland Agricultural Complex farm, Trench method, 1997.



## CROP – A Whole Farm Planning Tool

### 13. The Crop Rotation Options Program (CROP) for Whole-Farm Planning/Scenario Testing

Derek Fisher, Jon Baldock, and Josh Posner<sup>1</sup>

The Crop Rotation Options Program (CROP) is a computerized spreadsheet intended for use by farm advisors and educators as a tool for whole farm planning on cash grain and dairy operations. With minimal requirements for information describing a specific farm, the program provides estimates of crop and feed production, soil loss, field-by-field and whole-farm nutrient balance, dairy herd ration requirements and manure production (using a least-cost dairy ration balancing module), and whole-farm profitability. Additional modules for estimating labor requirements and feeding beef are presently under development.

CROP is a dynamic planning tool, not just a way to organize information or provide static assessments of farm performance. A change in one variable, such as herd size, is automatically reflected in several categories of output, representing the interconnections among agronomic, ecological and economic resources used by the farm. This integrated approach gives a farm planner the ability to easily consider implications of farm management changes that would be laborious to calculate without the use of a computer. As a result, the user can quickly identify farm management plans that reach economic and environmental goals.

The program is designed to be simple, practical and farmer-friendly. Rather than taking a partial budget or enterprise-by-enterprise approach to analyzing farm resources, CROP views the farm as a whole unit with much of the input and output expressed "per farm per year." This approach easily accounts for the interactions between legume and non-legume crops, between livestock and crop enterprises, etc., which are ignored or handled awkwardly in partial budgets or enterprise analyses. In some key measures, such as nutrient management and soil loss, CROP provides for field-by-field analyses.

#### CROP in Action

The CROP was used to compare the profitability of alternative production strategies for a 1,000-acre cash grain operation. Annual net returns to operator labor, management and land ownership were (-\$4,500) for continuous corn, (-\$32,100) for continuous soybeans, and +\$23,400 for a corn-soybean rotation. When wheat was added to the rotation, returns increased to +\$40,500. These results provide a simple example of where, in whole farm planning, the whole can be more than the sum of its parts. That is, if a simple sum of parts formula worked, then the

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<sup>1</sup> The Crop Rotation Options Program was developed by Jon Baldock of AGSTAT (an independent agricultural consulting firm in Verona, WI), Josh Posner, a professor of Agronomy at UW-Madison, and Derek Fisher, who has recently completed his M.S. in Agronomy at UW-Madison.

corn-soybean rotation should net one-half of the continuous corn (-\$2,250) plus one-half of the continuous soybean (-\$16,050) results, which comes to (-\$18,300). But in the corn-soybean rotation, net income is increased by \$41,700 to reach +\$23,400. This is due to the rotation effect (on yields), legume credits, reduced pesticide needs, and lower drying costs.

The predicted rate of soil loss for the corn-soybean-wheat rotation on land with slopes of 6 to 12% averaged 5.4 tons per acre when the land was chisel plowed. Adopting no-till reduced this estimate to 2.4 tons per acre.

In another case, the program was used to analyze herd expansion possibilities for a dairy operation. On this 310-acre farm, doubling the herd from 121 to 242 cows increased annual returns from \$13,300 to \$162,300. When average milk production was increased from 15,440 to 18,000 pounds per year, income jumped to \$222,600, but resulted in 149 tons of manure per year that could not be used by the crop rotation. The program showed that these surplus manure nutrients could be utilized, following a reduction in the rate of starter fertilizer application and an increase in crop yield.

### **CROP Availability**

In January of 1998 a beta testing version of CROP and its user manual were released to a group of extension agents, county land conservation staff, and crop consultants, who attended a one-day training workshop. The participants are now using the program with their clients to identify areas needing improvement.

The first market version of CROP is slated for release in the fall of 1998. Questions regarding CROP can be directed to Jon Baldock at (608) 845-7993, AGSTAT@aol.com, or Josh Posner at j.posner@cgiar.org.

## 1997 – 1998 OUTREACH

### 14. WICST 1997-1998 Educational Outreach for Columbia County Arlington Agricultural Research Station

Dwight Mueller<sup>1</sup>

Table 1 summarizes the outreach activities for WICST in 1997 and 1998. There was a continuation of activities that had been started in previous years. These included tours for 4<sup>th</sup> grade elementary students, and an UW Soil Science class, and the Prairies Jubilee and DeForest Middle School Science Field Days. In the winter, a presentation on WICST was made to farm students enrolled in the Farm Short Course program at the University of Wisconsin, and in 1997, the Columbia County Crop Production Club sponsored a meeting for producers. The WICST advisory committee formed this club in 1996. The crop production club meeting was very popular with over 125 farmers attending the meeting. Both farmers and researchers made presentations on a wide variety of topics. The WICST trials continue to be an excellent visual tool for demonstrating and discussing issues of sustainability such as crop rotation, environmental stewardship, economic sustainability, and biodiversity.

There were a significant number of foreign visitors that toured the WICST plots. Groups from Africa, Argentina, Brazil, Bulgaria, Germany, and Russia visited the site. There is tremendous interest in sustainable agricultural practices in these countries and touring the WICST site generated many questions and discussion. One of the highlights of the 1997 summer was a field tour for the Bascom Hill Society members. This group is composed of people who are large contributors to the University of Wisconsin.

In August 1997 and September 1998, WICST helped sponsor the annual Science field day for 250 DeForest 8<sup>th</sup> graders. This was an interactive hands-on field day and went very well. 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 biodiversity, crop production, and nitrogen. Each student had to collect data, which was later used for quizzes and exams in the classroom.

Once again WICST helped sponsor Prairies Jubilee Field Day with the Madison Audubon Society which attracted an audience of over 300 people. The Field Day included a stop at the WICST where an overview of issues and concerns related to Wisconsin agriculture was given. Displays were set up in our Public Events Building on WICST, groundwater, and alternatives for reducing pesticide and fertilizers for urban homeowners.

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<sup>1</sup> Farm Superintendent at Arlington Agricultural Research Station.

**Table 1. 1997 and 1998 Educational Activity Listing for Colombia County**

| <b>EVENT</b>                                      |        | <b>ATTENDING</b>  |
|---------------------------------------------------|--------|-------------------|
| Prairie Jubilee!                                  |        | 200               |
| Elementary School Students                        |        | 300               |
| Middle School Students (Science Field Day)        |        | 250               |
| UW Soil Science Summer School Class               |        | 50                |
| UW Short Course Presentation                      |        | 50                |
| Summer Institute of African Agricultural Research |        | 50                |
| Agronomy Field Day-WICST Featured                 | (1997) | 400               |
| No-till/Zone-till Seminar                         | (1997) | 125               |
| NFO State Board Tour                              | (1997) | 25                |
| Crop Production Tour                              | (1997) | 100               |
| German Dairy Farmers                              | (1998) | 15                |
| Brazilian tour                                    | (1998) | 20                |
| <b>Total</b>                                      |        | <b>1997: 1550</b> |
|                                                   |        | <b>1998: 935</b>  |

## 15. WICST Educational Outreach for Walworth County Lakeland Agricultural Complex

If everyone who reads this outreach report would ask themselves, "What can I do to support the sustainable future of our food production system?" and then use the following questions as a guide, we all can make a difference in the future. When you need to make a decision that could make a difference in the sustainability of our food production system, ask yourself: *"Will my decision be profitable for farmers? Will my decision help agriculture to be productive? Will my decision be environmentally sound? Will my decision be supported by the community outside of agriculture?"* If you can answer "yes" to all four questions, you too are helping to create a sustainable food production system that includes sustainable communities. Table 1 summarizes the events occurring at the Lakeland Agricultural Complex in Walworth County with a total attendance of 4,252 people.

**Table 1. Educational Activity Listing for Walworth County.**

| EVENT                                                                                                                                                         | ATTENDING |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| Private Pesticide Applicator Training and Certification (WICST Highlights Alternatives)                                                                       | 111       |
| WICST Winter Meeting (Walworth County Participants)                                                                                                           | 14        |
| Friends of Lakeland Ag Complex (a coalition of WICST supporters) – Winter Meeting                                                                             | 24        |
| WICST Cross Agency Training (local FSA, SCS, and Land Conservation Committee)                                                                                 | 19        |
| Farm/City Farm Bureau Ladies Banquet (WICST systems approach to change)                                                                                       | 97        |
| WICST Elementary School Ag Science Unit with SAM, the Sustainable Ag Mouse                                                                                    | 297       |
| WICST Elementary School Ag Science Unit Teacher Training                                                                                                      | 8         |
| Farm Bureau Dairy Breakfast (WICST presentation by display boards)                                                                                            | 2,200     |
| Wisconsin Association of County Board Extension Committee State Conference WICST Tour                                                                         | 187       |
| Friends of Lakeland Ag Complex WICST-sponsored "Taste of Walworth County Harvest"                                                                             | 257       |
| Integrated Food and Farming National Conference (Michigan, WICST input)                                                                                       | 27        |
| Ohio Farmers Tour WICST                                                                                                                                       | 78        |
| WICST Summer Site Committee's Meeting                                                                                                                         | 22        |
| National Rural Development Conference Tour of the WICST site                                                                                                  | 88        |
| Statewide Farm/City Banquet (WICST-supported Sustainable Community Development Utilizing Sustainable Agriculture evaluation criteria as a model)              | 323       |
| World Dairy Exposition (WICST Systems Project was an intricate part of the ATRA Booth manned by WICST representatives Lee Cunningham and Dan Forsythe, 5 days | 500       |



## 16. WICST Communications Activities 1997 – 1998.

K. Griffith<sup>1</sup>

This has been a year of reaping what was sowed in previous years. Despite much reduced hours devoted to communications (for personal reasons, the coordinator averaged about 15 hours a week in 1997 and much less in 1998), we seem to have hit our stride in many ways. The WICST newsletters were unusually well received, and our mailing list grew substantially from individuals asking to get on it. A number of events were well attended and well received. Modest effort yielded considerable high quality media attention. We note that while the Coordinator's role was reduced, the Michael Fields Agricultural Institute hired an experienced, professional journalist to better conduct outreach on the Institute's various programs, including WICST and the Small Grains Initiative. This has substantially raised the profiles of both the projects and their participants. Finally and most importantly, our data can now support strong statements about several key issues: the importance and benefits of expanded rotations, the importance of systems thinking, and the economic and agronomic viability of reduced input systems. That these messages are finding a receptive audience is evidenced by the number of calls we get in response to our newsletters and media coverage; increasingly frequent requests to reprint our materials; the growing number of unfamiliar faces at our events; and invitations to collaborate on related endeavors.

### Events

The following list of events includes only those at which WICST played a central role. There were numerous other events at which WICST offered a talk, a workshop, a plot tour or some other form of participation. A sampling of these is listed at the end.

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<sup>1</sup> Communications Coordinator, WICST and Michael Fields Agricultural Institute, W2493 County Road ES, East Troy, WI 53120.

| EVENT                                                                                                                                                                                    | ATTENDING       |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Prairies Jubilee! WICST ran several booths and offered a tour of the WICST plots                                                                                                         | 200             |
| Summer Oat Workshop – included visits to several oat fields and presentations on adding Oats and cover crops to a corn-soy rotation; also presentations of relevant WICST data           | 35              |
| How to Grow 100 Bushel Oats – presentations included economic and agronomic Information on why and how to add oats and a cover crop to a corn-soy rotation based on WICST and other data | 65              |
| Harvest Taste of Walworth County – tour of the WICST Lakeland Ag Complex plots                                                                                                           | 257             |
| WICST Winter meeting – discussion about 1997 WICST results, management issues, Agronomic decisions, data interpretation, outreach, etc.                                                  | 14              |
| WICST Elementary School Ag Science Unit with SAM, the Sustainable Ag Mouse<br>- introduction to agricultural sustainability through WICST                                                | 300<br>children |
| WICST Elementary School Ag Science Unit Teacher Training                                                                                                                                 | 8               |
| WICST Summer Field Day at the Lakeland Ag Complex, presentation of nitrate-N data and satellite projects.                                                                                | 30 farmers      |

| ADDITIONAL EVENTS                                                                                                                                                                  | ATTENDING |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| Private Pesticide Applicator Training and Certification<br>- WICST highlights offered as alternatives to pesticide use                                                             | 111       |
| WICST cross-agency training<br>– including local FSA, Soil Conservation Service and Land Conservation Committee                                                                    | 19        |
| Farm/City Farm Bureau Ladies Banquet - WICST system approach to change                                                                                                             | 97        |
| Wisconsin Women's Sustainable Farming Network – presentation on WICST                                                                                                              | 15        |
| Regional Corn Growers Association Annual Meeting in Wisconsin Dells and Southeast WI<br>- presentations on WICST, cover crops, expanded rotations, and the Small Grains Initiative | 400       |

| ADDITIONAL EVENTS (cont'd)                                                                                                                                                                     | Attending                   |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Farmer Workshop in Belvidere, Illinois<br>– presentations on WICST and Small Grains Initiative                                                                                                 | 70                          |
| Farm Bureau Dairy Breakfast at Lakeland Ag Complex – WICST display                                                                                                                             | 2,200                       |
| USDA Agricultural Research Service, Beltsville Area Research Station – Sustainable Agricultural Program, National Gathering – presentation on long term lessons from cropping systems research | 150                         |
| Producer meeting hosted by CFS Specialties – Small Grains Initiative presentation                                                                                                              | 60                          |
| World Dairy Expo – spoke with attendees and distributed WICST publications at a WICST display as part of the ATTRA booth                                                                       | 500 contacts<br>over 5 days |
| Practical Farmers of Iowa – two producer meetings in Iowa and one in Minnesota<br>– Small Grains Initiative presentations                                                                      |                             |
| Upper Midwest Organic Conference Workshop<br>- presentation on Small Grains Initiative using WICST data                                                                                        | 80                          |
| Pennsylvania Sustainable Agriculture Association annual conference<br>– two presentations, WICST results and Small Grains Initiative                                                           | 120                         |
| Green Bay Post-secondary education program – Small Grains Initiative presentation                                                                                                              | 200<br>ag students          |
| WI Crop Improvement Association annual meeting – Small Grains Initiative presentation                                                                                                          | 40                          |
| Wisconsin Association of County Board Extension Committee State Conference<br>- WICST tour                                                                                                     | 187                         |
| National Rural Development Conference – WICST tour                                                                                                                                             | 88                          |
| Statewide Farm/City Banquet - WICST supported Sustainable Community Development utilizing sustainable agriculture evaluation criteria as model                                                 | 323                         |
| Integrated Food and Farming Systems National Conference, Michigan<br>WICST input into planning and implementation                                                                              | 27                          |
| Small Grains Grower Meeting in Ashton, WI: Cover crop and economic data                                                                                                                        | 60                          |
| Nutrient and Pest Management Program field day in Deerfield, WI<br>- WICST economic and CS3 data                                                                                               | 20                          |
| Nutrient and Pest Management Program field day in Cambria, WI<br>- WICST economic and CS3 data                                                                                                 | 50                          |
| UWEX Small Grains Twilight Meeting in Manitowoc – WICST Economic data                                                                                                                          | 20                          |
| Sustainable Wisconsin Conference (booth and one-on-one discussions w/ about 50 people                                                                                                          |                             |
| Prairie's Jubilee! WICST boot and 12 attendees for presentation on "Biodiversity changes found in Wisconsin cropping systems and Wisconsin prairies"                                           |                             |
| Numerous private and small group tours of the WICST plots at the Lakeland Agricultural Complex and the Arlington Research Station.                                                             |                             |

## Publications

Newsletters (mailing list is about 2,200)

Seven newsletters: The titles listed below refer to the cover article of each issue. The newsletter's new format includes four pages on WICST and a four page insert on the Small Grains Initiative.

Featured articles:

Something old is new again: Mike Cerny on wheat, red clover, no-till, and GPS (spring '97)

Gary Sommers on wheat and oats (summer '97)

Why Norm Harris grows cover crops (winter '97)

Why Jay Goetz grows wheat and oats (Spring '98)

A Small Grains Initiative Packet

Profitable Farming Update #7: Why and how to add vetch to your cash grain rotation.

Profitable Farming Update #8: Wheat: New reasons for a traditional crop.

## Media work

The following list offers some highlights. It is not a complete listing of all articles, nor does it include radio spots or out-of-state coverage.

Agriview: "Energy tax might be good for farming"  
"Why would I want to plant winter wheat?"

American Farm Bureau Federation Web Site

"Story of the Day": "Diversifying equals profit for America's farmers"

The Beacon "What is Happening to Walworth County's Farm: Focus switches from Farming to research at Lakeland Ag Complex."

The Country Today: "Diversifying rotations offers many benefits, study finds"

Crop Protection Manager: "Feeling their oats: Midwest growers take another look at oats as a rotation crop"

The Furrow: "Making a place for oats in cash crop rotations"

Janesville Gazette: "Bringing Back Small Grains"  
"Can systems research put small grains in big picture?"  
"Delavan farmer tells how small grain helps"  
"County farm friends find opportunity in challenge"  
"Facing farming on the urban fringe"

NPM Fieldnotes: "A comeback for small grains?"

Innovation News: "Reduced input, diversified systems"

The Week "Research and education are what set Lakeland Ag Complex apart from other farms"

## Other

**CROP workshops:** The CROP spreadsheet, based on WICST and related data, and developed as a whole farm decision-making tool for farmers, began a new phase of development this year. A workshop attended by a diverse group of 30 (including producers, crop consultants, NRCS, Extension, Land Conservation and co-op personnel) was trained in its use and gave feedback on the functioning and usefulness of the program. Most of the attendees expressed interest in the concept of the program and could see its usefulness. One drawback that some of them experienced was difficulty in getting up to speed in using the spreadsheet. The difficulty stemmed from three sources: the complexity of the program, the fact that the first CROP workshop was essentially a trial run, and the unfamiliarity of thinking in terms of whole farm analysis. Several Extension and NRCS participants are using the program and/or continuing to evaluate it, and the CROP team is working to fine tune the program, the workshop, and the instruction manual to better help future users.

**Media Workshops:** The WICST Communications Coordinator received a grant from the WK Kellogg Foundation to offer media training to representatives of sustainable agriculture groups nationwide. Between August 1996 and March 1998 over 100 individuals were trained at four workshops presented by the Safe Energy Communication Council. Some trainees received intensive follow-up instruction at a Training of Trainers workshop in April 1998. At the first four workshops, the Coordinator delivered a keynote talk sharing lessons from WICST's media successes and challenges. The workshops were held as follows:

|                |                                  |
|----------------|----------------------------------|
| 1996: August   | Maryland                         |
| 1997: February | Iowa                             |
| 1998: February | New Mexico                       |
| March          | Minnesota                        |
| April          | Wisconsin (Training of Trainers) |

**Friends of the Lakeland Agricultural Complex (FLAC):** Changes on the Walworth County Board posed some new challenges and opportunities for WICST and FLAC. We continued to monitor the situation and provide information about the County Farm and its activities, including WICST, to key individuals on the County Board. WICST also worked with FLAC to host the Harvest Taste of Walworth County, an educational event on local agriculture for the general public.

**Federal policy:** We have continued to be involved in discussions with ARS about the creation of the Integrated Farming Systems Program, and to share WICST's experience as a template for the program. We have also been active in promoting (and protecting from budget cuts) the Fund for Rural America, a federal competitive grants program which awarded an offshoot of the WICST project (the Small Grains Initiative) \$420,000 in its first grant cycle.

**Regional hypoxia initiative:** WICST representative John Hall has been deeply involved in discussions with a regional group of agricultural, environmental and other organizations committed to addressing the problem of hypoxia (the "dead zone") in the Gulf of Mexico. WICST has provided key information on a major issue confronting the group: how to help

farmers in the upper Midwest corn belt to reduce their reliance on purchased nitrogen fertilizer. WICST data on soil nitrates under different cropping systems, and the agronomic and economic feasibility of replacing most purchased nitrogen with leguminous cover crops has been an important input into the discussions about possible solutions.

### **Successes and satisfactions**

A growing and diverse audience: There is a growing demand for the information WICST can provide. Our cumulative data on energy use, weeds and weed seeds, the “chem-lite” trials, expanded rotations, and the economics of the cash grain systems give us strong footing as we address some of the key challenges of agriculture in the region. Several of our media articles have generated numerous calls from producers asking to get on our mailing list. We are particularly pleased that a wide spectrum of producers, from conventional to organic, find our information and perspective helpful. Our articles have been reprinted on the American Farm Bureau Federation’s web page as the story of the day, and on the front page of The Organic Broadcaster, the newsletter of the upper Midwest Organic Crop Improvement Association. They have appeared as well in numerous other newsletters and in local and regional agricultural publications.

New collaborations and partnerships: The past year has spawned some new collaboration and closer ties with other projects. We are pleased that individuals from the Nutrient and Pest Management Program have attended several of our events, offered to spread the word on the Small Grains Initiative, and requested that WICST’s Jim Stute speak on cover crops at their events. We are also pleased at the usefulness of WICST’s data in the hypoxia initiative. We are particularly heartened by the strong, collaborative team that has formed to promote the production, processing and marketing of small grains in the upper Midwest through the Small Grains Initiative. This project builds closely on WICST’s experience with a low-input, diversified cash grain rotation (corn-soybeans-wheat/red clover), and has spawned numerous new partnerships, audiences, and venues for promoting the concept of expanded rotations.

A unified voice: The diversity of the WICST team has always been a strength. In the past it has also been a source of frustration as we tried to iron out differences and agree on what the WICST data permitted us to say. In the last 1-2 years, we have come to speak with increasing unity. Despite our significant differences, we are in large part able to agree on what the data mean, what is important for farmers and policy makers to hear from us, and what language to use to convey our messages.

Media workshops: Several of the media workshops were oversubscribed, and the evaluations have been highly enthusiastic. WICST has achieved a higher profile nationally, and is often cited as an example of a project that has made creative use of the mass media for getting its messages out. We are pleased that through the media workshops we have helped boost the sustainable agriculture movement on a national scale.

## Challenges

Resource constraints: Because of restrictions on the use of ARS funds (as well as very limited funds), WICST has a very small budget for communications activities at this point. Furthermore, the Coordinator is able to work only limited hours. This means that we are unable to push our agenda forward as aggressively as we would like. Most of the Coordinator's effort goes into the newsletter, occasional short publications and reports, and responding to information requests. Other members of the WICST team organize and participate in a variety of outreach events.

Data analysis: For various reasons, the data on the three forage rotations has still not been completely analyzed, so we have been unable to include a discussion of these systems in our communications activities. Half of the project is thus largely unknown to the public, and only incompletely processed by the WICST team.

Difficult messages: There are some aspects of WICST and the Small Grains Initiative that are difficult to communicate. Evaluations of our "How to Grow 100 Bushel Oats" workshop indicated uneven success in communicating the advantages of cover crops, in particular. The "systems thinking" message has done well in some ways with some audiences. Producers attending the event ranked the "rotation effect" high as a reason to include small grains in a corn-soybean rotation. However, they still compare the price of the small grain with the price of corn and beans and find it unattractive. They rarely seem to use "systems thinking" when doing the economic analysis of an expanded rotation. (We seem to have hit a responsive chord on this issue with our spring 1998 newsletter article on the economics of expanded rotations, however.)



## Appendix I-A. 1997 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION

| Corn rotations                     |                                                                                                                                                                              |                                                                                                                                                                                  |                                                                                  |                                                                                 |                                                                                                          |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| CROP-97<br>Rotation<br>Treatment # | Continuous<br>CORN<br>CS1<br>1                                                                                                                                               | CORN<br>CS2<br>3                                                                                                                                                                 | CORN<br>CS3<br>4                                                                 | CORN<br>CS4<br>7                                                                | CORN<br>CS5<br>13                                                                                        |
| Plot #'s                           | 109, 204,<br>306, 412                                                                                                                                                        | 101, 214,<br>303, 401                                                                                                                                                            | 104, 201,<br>301, 402                                                            | 111, 209,<br>305, 409                                                           | 114, 211,<br>312, 403                                                                                    |
| Primary<br>Tillage                 | 11/06/96<br>Chisel plow                                                                                                                                                      | No-till                                                                                                                                                                          | 04/10/97<br>Chisel w/sweeps<br>04/28/97 tw shank                                 | 04/10/97<br>Chisel plow                                                         | 04/10/97<br>Chisel w/sweeps                                                                              |
| Secondary<br>Tillage               | 04/24/97<br>Field Cultivator                                                                                                                                                 | None                                                                                                                                                                             | 05/14/97<br>Field Cultivator                                                     | 04/24/97<br>Field digger                                                        | 04/28/97 tw shank<br>05/14/97 Fld digger                                                                 |
| Planting Date                      | 04/25/97                                                                                                                                                                     | 04/25/97                                                                                                                                                                         | 05/14/97                                                                         | 04/25/97                                                                        | 05/14/97                                                                                                 |
| Variety                            | Gold.Harv.2441                                                                                                                                                               | Gold.Harv.2441                                                                                                                                                                   | Dekalb 471                                                                       | Gold.Harv.2441                                                                  | Dekalb 471                                                                                               |
| Rate                               | 32,000                                                                                                                                                                       | 32,000                                                                                                                                                                           | 34,000                                                                           | 32,000                                                                          | 34,000                                                                                                   |
| Starter<br>Fertilizer              | 100 Lb<br>6-24-24                                                                                                                                                            | 100 Lb<br>6-24-24                                                                                                                                                                | None                                                                             | 100 Lb<br>6-24-24                                                               | None                                                                                                     |
| Nitrogen<br>Fertilizer             | 120 Lb N/a<br>82-0-0<br>07/03/97<br>(not Rep 1)                                                                                                                              | 120 Lb N/a<br>82-0-0<br>07/03/97                                                                                                                                                 | None                                                                             | None                                                                            | None                                                                                                     |
| Manure                             | None                                                                                                                                                                         | None                                                                                                                                                                             | None                                                                             | 20 ton/a<br>11/06/96                                                            | 15 ton/a<br>11/06/96                                                                                     |
| Pesticides                         | 04/25/97<br>Force 3G (4 lb/a)<br><u>Post-emergence:</u><br>05/16-Dual (2 pt/a)<br>06/09-Buctril (1 pt/a)<br>06/14-Accent <sup>1</sup><br>(0.72oz/a)<br>06/26-Buctril (# 109) | Pre-plant: 04/25/97<br>Roundup Ultra<br>(1pt/a)<br>+ Am.Sulf. (3lb/a)<br><u>Post-emergence:</u><br>06/09-Buctril (1 pt/a)<br>06/09-Stinger (#214)<br>06/14-Accent<br>(0.72 oz/a) | None                                                                             | <u>Post-emergence:</u><br>06/09-Buctril (1 pt/a)<br>06/14-Accent<br>(0.72 oz/a) | None                                                                                                     |
| Rotary Hoe                         | 05/22/97                                                                                                                                                                     | None                                                                                                                                                                             | 05/22/97<br>05/23/97<br>05/28/97                                                 | None                                                                            | 05/22/97                                                                                                 |
| Cultivation                        | 06/23/97<br>06/25/97<br>07/03/97 (# 109)<br>07/10/97 (# 109)                                                                                                                 | None                                                                                                                                                                             | 06/12/97<br>06/13/97<br>06/17/97<br>06/23/97<br>06/25/97<br>07/03/97<br>07/10/97 | 06/23/97<br>06/25/97<br>06/28/97 (# 209)<br>07/03/97<br>07/10/97                | 06/12/97<br>06/13/97<br>06/17/97<br>06/23/97<br>06/25/97<br>06/28/97 (#211, 312)<br>07/03/97<br>07/10/97 |
| Harvest                            | 11/01/97                                                                                                                                                                     | 11/01/97                                                                                                                                                                         | 11/01/97                                                                         | 11/01/97                                                                        | 11/01/97                                                                                                 |
| Yield                              | 128.55 bu/a                                                                                                                                                                  | 157.43 bu/a                                                                                                                                                                      | 147.64 bu/a                                                                      | 159.05 bu/a                                                                     | 155.29 bu/a                                                                                              |
| Fall<br>Practices                  | 11/04/97<br>Stalk chop<br>11/20/97<br>Chisel plow                                                                                                                            | None                                                                                                                                                                             | 11/04/97<br>Stalk chop<br>11/20/97<br>Chisel plow                                | 11/04/97 Chop<br>11/06/97<br>Manure – 20 ton/a<br>11/20/97 Chisel               | 11/04/97 Chop<br>11/06/97<br>Manure – 15 ton/a<br>11/28/97 Chisel                                        |
| Crop-98                            | Corn                                                                                                                                                                         | Soybean                                                                                                                                                                          | Soybean                                                                          | D.S. Alfalfa                                                                    | Oats/Alfalfa                                                                                             |

<sup>1</sup> North and South ends of plots only

## Appendix I-A. 1997 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION

| Soybean and Wheat Rotations        |                                                                                                                                                              |                                                                                                          |                                                                                                                         |
|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| CROP-97<br>Rotation<br>Treatment # | NR Soybean<br>CS2<br>2                                                                                                                                       | WR Soybean/Wheat<br>CS3<br>6                                                                             | Wheat/Red Clover <sup>1</sup><br>CS3<br>5                                                                               |
| Plot #'s                           | 108, 206, 310, 408                                                                                                                                           | 102, 212, 313, 407                                                                                       | 106, 202, 307, 411                                                                                                      |
| Primary<br>Tillage                 | No-till                                                                                                                                                      | Chisel Plow<br>11/06/96                                                                                  | 10/06/96 Disk                                                                                                           |
| Secondary<br>Tillage               | None                                                                                                                                                         | Field Cultivation<br>05/05/97<br>05/15/97                                                                | None                                                                                                                    |
| Planting Date                      | 05/15/97                                                                                                                                                     | SB: 05/15/97<br>WW: 10/02/97                                                                             | 10/06/96 Winter Wheat<br>02/24/97 Red Clover<br>04/17/97 Spring Wheat <sup>2</sup><br>08/27/97 Hairy Vetch <sup>1</sup> |
| Variety<br>Rate                    | Asgrow 1900<br>250,000 seeds/a                                                                                                                               | Kaltenberg 241<br>190,000 seeds/a<br>Glacier 150 lb/a                                                    | 150 lb/a Glacier<br>15 lb/a Red Clover<br>100 lb/a Spring Wheat<br>25 lb/a Hairy Vetch                                  |
| Fertilizer                         | None                                                                                                                                                         | None                                                                                                     | None                                                                                                                    |
| Pesticides                         | <u>Pre-plant:</u><br>05/15/97<br>Roundup-Ultra (1 pt/a)<br>+ Am.Sulf. (3 lb/a) + NIS<br><u>Pre-emergence:</u><br>05/18 Pursuit (4 oz/a)<br>and Dual (2 pt/a) | None                                                                                                     | None                                                                                                                    |
| Rotary Hoe                         | None                                                                                                                                                         | 05/22/97<br>05/23/97<br>05/28/97                                                                         | None                                                                                                                    |
| Cultivation                        | None                                                                                                                                                         | 06/02/97 06/12/97<br>06/13/97 06/17/97<br>06/23/97 06/25/97<br>06/28/97 (#212, 313)<br>07/03/97 07/10/97 | None                                                                                                                    |
| Harvest                            | 10/10/97                                                                                                                                                     | 10/02/97                                                                                                 | 08/08/97                                                                                                                |
| Yield                              | 51.9 bu/a                                                                                                                                                    | 48.8 bu/a                                                                                                | 54.4 bu/a Wheat<br>0.96 tons/a straw                                                                                    |
| Fall<br>Practices                  | None                                                                                                                                                         | 10/02/97 digger<br>10/02/97 Double disk drill                                                            | 08/25/97 Field digger<br>11/20/97 Chisel Plow                                                                           |
| Crop 98                            | Corn                                                                                                                                                         | Wheat / Red Clover                                                                                       | Corn                                                                                                                    |

<sup>1</sup> CS3 red clover interseeding did not take, Hairy Vetch was sequentially seeded following the wheat harvest.<sup>2</sup> Moderate winterkill of winter wheat planted 10/06/96. Spring wheat overseeded.

## Appendix I-A. 1997 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION

| Forage rotations                   |                                                                |                                                 |                                                                             |                                                                   |                                                     |                                |
|------------------------------------|----------------------------------------------------------------|-------------------------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------|-----------------------------------------------------|--------------------------------|
| CROP-97<br>Rotation<br>Treatment # | D.S. Alfalfa<br>CS4<br>10                                      | Estab.<br>Alfalfa I<br>CS4<br>9                 | Estab.<br>Alfalfa II<br>CS4<br>8                                            | Oats/Alfalfa<br>CS5<br>12                                         | Estab.<br>Alfalfa I<br>CS5<br>11                    | Pasture<br>CS6<br>14           |
| bPlot #'s                          | 107, 205,<br>309, 404                                          | 105, 203,<br>308, 406                           | 113, 210,<br>311, 414                                                       | 103, 213,<br>314, 410                                             | 110, 208,<br>304, 413                               | 112, 207,<br>302, 405          |
| Primary<br>Tillage                 | 04/10/97<br>Chisel Plow                                        | None                                            | None                                                                        | 04/10/97<br>Chisel Plow                                           | None                                                | None                           |
| Secondary<br>Tillage               | 04/17/97<br>Disc and<br>Soil finisher                          | None                                            | None                                                                        | 04/17/97<br>Disc and<br>Soil Finisher                             | None                                                | None                           |
| Planting Date<br>Variety           | 04/17/97<br>Innovator+Z                                        | 04/08/96<br>ICI 631                             | 04/24/95<br>ICI 631<br>05/08/97 <sup>1</sup><br>Oat/pea/A.rye<br>Red Clover | 04/17/97<br>Bay Oats<br>Trapper Pea<br>Innovator+Z<br>P. Ryegrass | 04/08/96<br>ICI 631                                 | 04/05/97<br>Med. Red<br>Clover |
| Rate                               | 15 lb/a                                                        | 15 lb/a                                         | 64 lb/a Oats<br>20 lb/a Peas<br>3 lb/a A. rye<br>10 lb/a RClvr              | 50 lb/a Oats<br>50 lb/a Pea<br>15 lb/a Alf<br>2 lb/a Rye          | 15 lb/a                                             | 6 lb/a                         |
| Fertilizer                         | None                                                           | As required                                     | As required                                                                 | None                                                              | None                                                | None                           |
| Manure                             | 11/06/96<br>20 ton/a                                           | None                                            | None                                                                        | 11/06/96<br>15 ton/a                                              |                                                     | Grazing                        |
| Pesticides                         | Post-emerge:<br>06/14/97<br>Pursuit<br>(3 oz/a)<br>+ NIS + 28% | Post-emerge:<br>06/14/97<br>Pursuit<br>(3 oz/a) | 09/11/97<br>Roundup<br>(2 pts/a)                                            | None                                                              | None                                                | None                           |
| Harvest                            | 07/25/97<br>09/04/97                                           | 06/02/97<br>07/02/97<br>07/30/97<br>09/04/97    | 07/02/97<br>07/30/97<br>09/14/97                                            | Oatlage:<br>06/24/97<br>Hay:<br>09/04/97                          | 07/07/97<br>08/26/97<br>10/01/97                    | Rotational<br>Grazing          |
| Yield                              | 3.56 tDM/a                                                     | 5.08 tDM/a                                      | 4.50 tDM/a                                                                  | 4.66 tDM/a                                                        | 4.99 tDM/a                                          | 332.7 lb<br>gain/a             |
| Fall<br>Practices                  |                                                                |                                                 | 11/06/97<br>Manure 20 T/a<br>11/28/97<br>Chisel plow                        |                                                                   | 11/06/97<br>Manure 15T/a<br>11/28/97<br>Chisel plow |                                |
| Crop-98                            | Alf I                                                          | Alf II                                          | Corn                                                                        | Alf I                                                             | Corn                                                | Pasture                        |

<sup>1</sup> Winterkill required interseeding dead areas w/Oat, Annual Rye, Clover, and Peas.  
Total area reseeded: 1.4 acres; 0.35 acre/plot.

## Appendix I-1. 1997 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION

| Satellite plots – Cropping System 3 |                                                                                   |                                                                                                          |                                                                                                                         |
|-------------------------------------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| CROP-97<br>Rotation<br>Treatment #  | Corn<br>CS3<br>4                                                                  | WR Soybean/Wheat<br>CS3<br>6                                                                             | Wheat/Red Clover <sup>1</sup><br>CS3<br>5                                                                               |
| Primary<br>Tillage                  | 04/10/97 Chisel w/sweeps<br>04/28/97 Chisel w/tw shank                            | Chisel Plow<br>11/06/96                                                                                  | 10/06/96 Disk                                                                                                           |
| Secondary<br>Tillage                | 05/14/97 Field cultivator                                                         | Field Cultivation<br>05/05/97<br>05/15/97                                                                | None                                                                                                                    |
| Planting Date                       | 05/14/97                                                                          | 05/15/97                                                                                                 | 10/06/96 Winter Wheat<br>02/24/97 Red Clover<br>04/17/97 Spring Wheat <sup>2</sup><br>08/27/97 Hairy Vetch <sup>1</sup> |
| Variety<br>Rate                     | Dekalb 471<br>34,000                                                              | Kaltenberg 241<br>190,000 seeds/a                                                                        | 150 lb/a Glacier<br>15 lb/a Red Clover<br>100 lb/a Spring Wheat<br>25 lb/a Hairy Vetch                                  |
| Fertilizer                          | None                                                                              | None                                                                                                     | None                                                                                                                    |
| Pesticides                          | <u>Post-emergence:</u><br>06/09 Buctril (1 pt/a)<br>06/26 Accent (0.66 oz/a) Band | 06/24 Crop oil (2 pt/a)<br>Poast+ (1.5 pt/a)                                                             | None                                                                                                                    |
| Rotary Hoe                          | 05/22/97<br>05/23/97<br>05/28/97                                                  | 05/22/97<br>05/23/97<br>05/28/97                                                                         | None                                                                                                                    |
| Cultivation                         | 06/12/97 06/13/97<br>06/17/97 06/23/97<br>06/25/97 07/03/97<br>07/10/97           | 06/02/97 06/12/97<br>06/13/97 06/17/97<br>06/23/97 06/25/97<br>06/28/97 (#212, 213)<br>07/03/97 07/10/97 | None                                                                                                                    |
| Harvest                             | 11/01/97                                                                          | 10/02/97                                                                                                 | 08/08/97                                                                                                                |
| Yield                               | 236.9 bu/a                                                                        | 46.1 bu/a                                                                                                | 51.9 bu/a Wheat<br>0.99 tons/a straw                                                                                    |
| Fall<br>Practices                   | 11/04/97 Stalk chop<br>11/20/97 Chisel plow                                       | 10/02/97 digger<br>10/02/97 Double disk drill<br>Glacier W.Wheat (150 lb/a)                              | 08/25/97 Field digger<br>11/20/97 Chisel Plow                                                                           |
| Crop 98                             | Soybean                                                                           | Wheat / Red Clover                                                                                       | Corn                                                                                                                    |

<sup>1</sup> CS3 red clover interseeding did not take, Hairy Vetch was sequentially seeded following the wheat harvest.<sup>2</sup> Moderate winterkill of winter wheat planted 10/06/96. Spring wheat overseeded.

## Appendix I-B. 1997 WICST INPUT/OUTPUT DATA - LAKELAND AGRICULTURAL COMPLEX

| Corn rotations                     |                                                                                                                                                                                                     |                                                                                                                                                                                        |                                     |                                                                                                                                                |                                                        |
|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|
| CROP-97<br>Rotation<br>Treatment # | Continuous<br>CORN<br>CS1<br>1                                                                                                                                                                      | CORN<br>CS2<br>3                                                                                                                                                                       | CORN<br>CS3<br>4                    | CORN<br>CS4<br>7                                                                                                                               | CORN<br>CS5<br>13                                      |
| Plot #'s                           | 101, 210,<br>303, 401                                                                                                                                                                               | 113, 206,<br>311, 410                                                                                                                                                                  | 109, 204,<br>308, 404               | 103, 202,<br>310, 411                                                                                                                          | 114, 201,<br>313, 405                                  |
| Primary<br>Tillage                 | Chisel Plow<br>11/20/96                                                                                                                                                                             | No-till                                                                                                                                                                                | Chisel Plow<br>11/20/96 Sweeps      | Chisel Plow<br>04/10/97                                                                                                                        | Chisel Plow<br>11/20/96 Sweeps                         |
| Secondary<br>Tillage               | Mulchmaster<br>04/24/97                                                                                                                                                                             | None                                                                                                                                                                                   | Mulchmaster<br>04/25/97<br>05/20/97 | Mulchmaster<br>04/24/97                                                                                                                        | Mulchmaster<br>04/25/97<br>05/20/97                    |
| Planting Date                      | 04/29/97                                                                                                                                                                                            | 04/29/97                                                                                                                                                                               | 05/21/97                            | 04/29/97                                                                                                                                       | 05/21/97                                               |
| Variety                            | Gold.Harv.2441                                                                                                                                                                                      | Gold.Harv.2441                                                                                                                                                                         | Dekalb 471                          | Gold.Harv.2441                                                                                                                                 | Dekalb 471                                             |
| Rate                               | 32,000                                                                                                                                                                                              | 32,000                                                                                                                                                                                 | 34,000                              | 32,000                                                                                                                                         | 34,000                                                 |
| Starter<br>Fertilizer              | 100 Lb<br>9-23-30                                                                                                                                                                                   | 100 Lb<br>9-23-30                                                                                                                                                                      | None                                | 100 Lb<br>9-23-30                                                                                                                              | None                                                   |
| Nitrogen<br>Fertilizer             | 65 Lb N/a<br>28-0-0<br>06/30/97                                                                                                                                                                     | 120 Lb N/a<br>28-0-0<br>06/30/97                                                                                                                                                       | None                                | None                                                                                                                                           | None                                                   |
| Manure                             | None                                                                                                                                                                                                | None                                                                                                                                                                                   | None                                | 20 ton/a<br>11/16/96                                                                                                                           | 15 ton/a<br>11/19/96                                   |
| Pesticides                         | 04/29<br>Counter (6.5 lb/a)<br><u>Pre-emergence:</u><br>05/20/97<br>Dual (2 pt/a)<br><u>Post-emergence:</u><br>06/11- 2,4 D (½ pt/a)<br><sup>2</sup> 06/26-<br>Buctril (1 pt/a)<br>Accent (11 oz/a) | <u>Pre-emergence:</u><br>05/20/97<br>Dual (2 pt/a)<br>RoundupUltra (1pt/a)<br>+ Am.Sulf. (3lb/a)<br>+ NIS (1 qt/a)<br><u>Post-emergence:</u><br><sup>1</sup> 06/26-Buctril<br>(1 pt/a) | None                                | <u>Pre-emergence:</u><br>05/13/97<br>Dual (2 pt/a)<br><u>Post-emergence:</u><br>06/11- 2,4 D (½ pt/a)<br>06/26-Buctril (1 pt/a)<br>(plot #310) | None                                                   |
| Rotary Hoe                         | None                                                                                                                                                                                                | None                                                                                                                                                                                   | 06/02/97<br>06/09/97                | None                                                                                                                                           | 06/02/97<br>06/09/97                                   |
| Cultivation                        | 07/02/97<br>(#210, #401)                                                                                                                                                                            | None                                                                                                                                                                                   | 06/20/97<br>07/02/97                | None                                                                                                                                           | 06/20/97<br>07/02/97;<br>(not #201)                    |
| Harvest                            | 10/21/97                                                                                                                                                                                            | 10/21/97                                                                                                                                                                               | 10/21/97                            | 10/21/97                                                                                                                                       | 10/21/97                                               |
| Yield                              | 112.58 bu/a                                                                                                                                                                                         | 153.76 bu/a                                                                                                                                                                            | 133.47 bu/a                         | 160.02 bu/a                                                                                                                                    | 151.43 bu/a                                            |
| Fall<br>Practices                  | 11/04/97<br>Chisel                                                                                                                                                                                  | None                                                                                                                                                                                   | 11/04/97<br>Chisel                  | 11/04/97<br>Chisel plow<br>11/06/97<br>Manure 20 ton/a                                                                                         | 11/04/97<br>Chisel plow<br>11/06/97<br>Manure 15 ton/a |
| Crop-98                            | Corn                                                                                                                                                                                                | NR Soybean                                                                                                                                                                             | WR Soybean                          | D.S. Alfalfa                                                                                                                                   | Oats/Alfalfa                                           |

<sup>1</sup> Plots 113 & 206 treated with 0.40 pt/a Buctril by J.Doll.<sup>2</sup> Accent and Buctril applied only to Plots 101 and 303.

## Appendix I-B. 1997 WICST INPUT/OUTPUT DATA - LAKELAND AGRICULTURAL COMPLEX

## Soybean and Wheat Rotations

| <b>CROP-97<br/>Rotation<br/>Treatment #</b> | <b>NR Soybean<br/>CS2<br/>2</b>                                                                                                            | <b>WR Soybean/Wheat<br/>CS3<br/>6</b>                                         | <b>Wheat/Red Clover<br/>CS3<br/>5</b>                                                     |
|---------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| <b>Plot #'s</b>                             | 108, 203, 304, 409                                                                                                                         | 111, 208, 306, 407                                                            | 107, 205, 307, 406                                                                        |
| <b>Primary<br/>Tillage</b>                  | No-till                                                                                                                                    | Chisel Plow<br>11/20/96                                                       | Chisel Plow<br>11/20/96                                                                   |
| <b>Secondary<br/>Tillage</b>                | None                                                                                                                                       | Mulchmaster<br>04/25/97<br>05/20/97                                           | None                                                                                      |
| <b>Planting Date</b>                        | 05/20/97                                                                                                                                   | 05/21/97                                                                      | <u>Broadcast:</u><br>09/15/96 Winter Wheat<br><u>Frost seeded:</u><br>03/22/97 Red Clover |
| <b>Variety<br/>Rate</b>                     | Asgrow 1900<br>250,000 seeds/a                                                                                                             | Asgrow 1900<br>225,000 seeds/a                                                | 150 lb/a Merrimac W. Wheat<br>18 lb/a Medium Red Clover                                   |
| <b>Fertilizer</b>                           | None                                                                                                                                       | None                                                                          | None                                                                                      |
| <b>Pesticides</b>                           | <u>Pre-plant:</u><br>05/20/97<br>Roundup Ultra (2 pt/a)<br>+ Am.Sulf. (3 lb/a) + NIS<br><u>Post-emergence:</u><br>06/05 Pursuit (1.3 oz/a) | None                                                                          | None                                                                                      |
| <b>Rotary Hoe</b>                           | None                                                                                                                                       | 06/04/97                                                                      | None                                                                                      |
| <b>Cultivation</b>                          | None                                                                                                                                       | 06/20/97<br>06/30/97                                                          | None                                                                                      |
| <b>Harvest</b>                              | 10/02/97                                                                                                                                   | 10/02/97                                                                      | 08/01/97                                                                                  |
| <b>Yield</b>                                | 57.8 bu/a                                                                                                                                  | 48.56 bu/a                                                                    | 57.42 bu/a Wheat<br>1.11 ton/a straw                                                      |
| <b>Fall<br/>Practices</b>                   | None                                                                                                                                       | 10/03/97 soil finisher<br>10/03/97 no-till drill<br>Glacier W. Wheat (3 bu/a) | 11/05/97 Chisel plow w/sweeps                                                             |
| <b>Crop 98</b>                              | Corn                                                                                                                                       | Wheat / Red Clover                                                            | Corn                                                                                      |

## Appendix I-B. 1997 WICST INPUT/OUTPUT DATA - LAKELAND AGRICULTURAL COMPLEX

| Forage rotations                   |                                                                                          |                                                                                          |                                                                              |                                                                                     |                                                                       |                                                                                                        |
|------------------------------------|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| CROP-97<br>Rotation<br>Treatment # | D.S. Alfalfa<br>CS4<br>10                                                                | Estab.<br>Alfalfa I<br>CS4<br>9                                                          | Estab.<br>Alfalfa II<br>CS4<br>8                                             | Oats/Alfalfa<br>CS5<br>12                                                           | Estab.<br>Alfalfa I<br>CS5<br>11                                      | Pasture <sup>2</sup><br>CS6<br>14                                                                      |
| Plot #'s                           | 112, 214,<br>301, 403                                                                    | 110, 212,<br>302, 414                                                                    | 102, 209,<br>305, 402                                                        | 105, 207,<br>309, 412                                                               | 106, 211,<br>312, 413                                                 | 104, 213,<br>314, 408                                                                                  |
| Primary<br>Tillage                 | Chisel Plow<br>11/20/96                                                                  | ---                                                                                      | ---                                                                          | Chisel Plow<br>11/20/96                                                             | ---                                                                   | Chisel Plow<br>08/08/97                                                                                |
| Secondary<br>Tillage               | Mulchmaster<br>04/22/97                                                                  | ---                                                                                      | ---                                                                          | Mulchmaster<br>04/22/97                                                             | ---                                                                   | Mulchmaster<br>08/08/97<br>Soil finisher<br>08/19/97                                                   |
| Planting Date<br>Variety           | 04/24/97<br>Innovator+Z                                                                  | 04/18/96<br>08/22/96 <sup>1</sup><br>Innovator+Z                                         | 05/07/95<br>Magnum III                                                       | 04/24/97<br>Bay Oats<br>Trapper Pea<br>A:Innovator+Z<br>Perennial Rye<br>Red Clover | 04/18/96<br>Legendairy                                                | 08/21/97<br>Reed canary<br>Orchard grass                                                               |
| Rate                               | 18.5 lb/a                                                                                | 18.5 lb/a                                                                                | ---                                                                          | 40 lb/a Oats<br>60 lb/a Pea<br>12 lb/a Alf<br>2 lb/a P. Rye<br>4 lb/a Clover        | ---                                                                   | 8 lb/a-Reed<br>Canary grass<br>3 lb/a<br>Orchard grass                                                 |
| Fertilizer                         |                                                                                          |                                                                                          |                                                                              |                                                                                     |                                                                       |                                                                                                        |
| Manure                             | 11/06/96<br>20 ton/a                                                                     | None                                                                                     | None                                                                         | 11/06/96<br>15 ton/a                                                                |                                                                       |                                                                                                        |
| Pesticides                         | Post-emerge:<br>06/04/97<br>Pursuit (3oz/a)<br>+ NIS + 28%<br>08/01/97<br>Lorsban(1pt/a) | Post-emerge:<br>06/04/97<br>Pursuit (3oz/a)<br>+ NIS + 28%<br>08/01/97<br>Lorsban(1pt/a) | 08/01/97<br>Lorsban(1pt/a)<br>+AMS (3lb/a)<br>10/14/97<br>Roundup<br>(1qt/a) | None                                                                                | None                                                                  | 07/29/97<br>Roundup Ultra<br>(1.5 qt/a)<br>+AMS (3lb/a)<br>+NIS (1 pt/a)<br>10/10/97<br>2,4-D (1 pt/a) |
| Harvest                            | 07/09/97<br>09/04/97                                                                     | 07/09/97<br>09/04/97                                                                     | 06/04/97<br>07/09/97<br>09/04/97                                             | Oatlage:<br>06/23/97<br>09/04/97                                                    | 06/04/97<br>07/09/97<br>09/04/97                                      |                                                                                                        |
| Yield                              | 1.46 tDM/a                                                                               | 1.33 tDM/a                                                                               | 3.38 tDM/a                                                                   | 2.31 tDM/a                                                                          | 3.00 tDM/a                                                            |                                                                                                        |
| Fall<br>Practices                  |                                                                                          |                                                                                          | 11/04/97<br>Manure<br>20 ton/a<br>11/05/97<br>Chisel Plow<br>w/shank         |                                                                                     | 11/05/97<br>Manure<br>15 ton/a<br>11/05/97<br>Chisel Plow<br>w/sweeps | 08/06/97<br>20 ton/a                                                                                   |
| Crop-98                            | Alf I                                                                                    | Alf II                                                                                   | Corn                                                                         | Alf I                                                                               | Corn                                                                  | Pasture                                                                                                |

<sup>1</sup> Re-seeded due to waterlogged soils (Reps 1, 2, and 3) on 08/22/96.<sup>2</sup> Paddocks renovated this year due to wet 1996 and subsequent grazing damage. Weeds grazed off in June and July.

## Appendix II-A. 1998 WICST INPUT/OUTPUT DATA – ARLINGTON RESEARCH STATION

| Corn rotations                     |                                                                                                 |                                                                                                                                               |                                                           |                                                                              |                                                                             |
|------------------------------------|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| CROP-98<br>Rotation<br>Treatment # | Continuous<br>CORN<br>CS1<br>1                                                                  | CORN<br>CS2<br>2                                                                                                                              | CORN<br>CS3<br>5                                          | CORN<br>CS4<br>8                                                             | CORN<br>CS5<br>11                                                           |
| Plot #'s                           | 109, 204,<br>306, 412                                                                           | 108, 206,<br>310, 408                                                                                                                         | 106, 202,<br>307, 411                                     | 113, 210,<br>311, 414                                                        | 110, 208,<br>304, 413                                                       |
| Primary<br>Tillage                 | Chisel Plow<br>11/20/97                                                                         | No-till                                                                                                                                       | Chisel Plow<br>11/20/97<br>Chisel Plow<br>05/14/98 Sweeps | Chisel Plow<br>04/20/98 Sweeps                                               | Chisel Plow<br>04/20/98 Sweeps                                              |
| Secondary<br>Tillage               | Field Cult.<br>04/25/98                                                                         | None                                                                                                                                          | Field Cult.<br>05/15/98                                   | Field Cult.<br>04/25/98                                                      | Field Cult.<br>05/15/98                                                     |
| Planting Date                      | 04/25/98                                                                                        | 04/25/98                                                                                                                                      | 05/15/98                                                  | 04/25/98                                                                     | 05/15/98                                                                    |
| Variety                            | Gold.Harv.2441                                                                                  | Gold.Harv.2441                                                                                                                                | Dekalb 471                                                | Gold.Harv.2441                                                               | Dekalb 471                                                                  |
| Rate                               | 32,000                                                                                          | 32,000                                                                                                                                        | 34,500                                                    | 32,000                                                                       | 34,500                                                                      |
| Starter<br>Fertilizer              | 100 Lb/a<br>6-24-24                                                                             | 100 Lb<br>6-24-24                                                                                                                             | None                                                      | 100 Lb<br>6-24-24                                                            | None                                                                        |
| Nitrogen<br>Fertilizer             | 145 Lb N/a<br>82-0-0<br>06/01/98                                                                | 95 Lb N/a<br>82-0-0<br>06/01/98                                                                                                               | None                                                      | None                                                                         | None                                                                        |
| Manure                             | None                                                                                            | None                                                                                                                                          | None                                                      | 20 ton/a<br>11/06/97                                                         | 15 ton/a<br>11/06/97                                                        |
| Pesticides                         | 04/25/98<br>Counter Insecticide<br>05/06/98<br>Dual II (2 pt/a)<br>06/30/98<br>Buctril (1 pt/a) | <u>Pre-emerge:</u><br>04/30/98<br>Roundup Ultra<br>(1pt/a)<br><u>Post-emergence:</u><br>05/06-Dual II (2pt/a)<br>06/30/98<br>Buctril (1 pt/a) | None                                                      | <u>Post-emergence:</u><br>06/30/98<br>Buctril (1 pt/a)<br>Accent (0.67 oz/a) | None                                                                        |
| Cultivation                        | None                                                                                            | None                                                                                                                                          | 06/04/98<br>06/10/98                                      | None                                                                         | 06/04/98<br>06/10/98                                                        |
| Harvest                            | 10/20/98                                                                                        | 10/20/98                                                                                                                                      | 06/19/98<br>10/20/98                                      | None<br>10/20/98                                                             | 06/19/98<br>10/20/98                                                        |
| Yield                              | 196.21 bu/a                                                                                     | 212.59 bu/a                                                                                                                                   | 197.80 bu/a                                               | 226.81 bu/a                                                                  | 205.15 bu/a                                                                 |
| Fall<br>Practices                  | 10/28/98<br>Stalk chop<br>10/29/98<br>Chisel                                                    | None                                                                                                                                          | 10/28/98<br>Stalk chop<br>10/29/98<br>Chisel              | 10/27/98<br>Stalk chop<br>10/28/98<br>Manure 20tons/a<br>10/29/98<br>Chisel  | 10/27/98<br>Stalk chop<br>10/28/98<br>Manure 15tons/a<br>10/29/98<br>Chisel |
| Crop-99                            | Corn                                                                                            | Soybean                                                                                                                                       | Soybean                                                   | D.S. Alfalfa                                                                 | Oats/Alfalfa                                                                |

## Appendix II-A. 1998 WICST INPUT/OUTPUT DATA – ARLINGTON RESEARCH STATION

| Soybean and Wheat Rotations        |                                                                                                                |                                                                              |                                                         |
|------------------------------------|----------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------------|
| CROP-98<br>Rotation<br>Treatment # | NR Soybean<br>CS2<br>3                                                                                         | WR Soybean/Wheat<br>CS3<br>4                                                 | Wheat/Red Clover<br>CS3<br>6                            |
| Plot #'s                           | 101, 214, 303, 401                                                                                             | 104, 201, 301, 402                                                           | 102, 212, 313, 407                                      |
| Primary<br>Tillage                 | No-till                                                                                                        | 11/20/97<br>Chisel Plow                                                      | 10/02/97 digger                                         |
| Secondary<br>Tillage               | None                                                                                                           | Field Cultivation<br>05/15/98                                                | None                                                    |
| Planting Date                      | 05/10/98                                                                                                       | 05/15/98<br>10/12/98                                                         | 10/02/97 Winter Wheat<br>04/07/98 Red Clover            |
| Variety<br>Rate                    | Asgrow 2301<br>250,000 seeds/a                                                                                 | NK 23-12<br>190,000 seeds/a<br>Glacier Winter Wheat<br>130 lb/a              | 150 lb/a Glacier<br>15 lb/a Arl. Red Clover             |
| Fertilizer                         | None                                                                                                           | None                                                                         | None                                                    |
| Pesticides                         | <u>Pre-plant:</u><br>04/30/98<br>Roundup (1 pt/a)<br><u>Post-emergence:</u><br>06/08 Roundup-Ultra<br>(1 pt/a) | None                                                                         | None                                                    |
| Rotary Hoe                         | None                                                                                                           | 06/04/98<br>06/10/98                                                         | None                                                    |
| Cultivation                        | None                                                                                                           | 06/17/98<br>06/23/98<br>07/11/98                                             | None                                                    |
| Harvest                            | 10/13/98                                                                                                       | 10/11/98                                                                     | 07/17/98 Combined<br>07/18/98 Baler                     |
| Yield                              | 63.61 bu/a                                                                                                     | 51.89 bu/a                                                                   | 57.66 bu/a Wheat<br>0.59 tons/a straw                   |
| Fall<br>Practices                  | None                                                                                                           | 10/11/98 digger<br>10/12/98 Double disk drill<br>Glacier W. Wheat (130 lb/a) | 10/22/98 Stalk Chopper<br>11/17/98 Chisel Plow w/sweeps |
| Crop-99                            | Corn                                                                                                           | Wheat / Red Clover                                                           | Corn                                                    |

## Appendix II-A. 1998 WICST INPUT/OUTPUT DATA – ARLINGTON RESEARCH STATION

| Forage rotations                   |                                                                                           |                                              |                                                           |                                                       |                                                           |                       |
|------------------------------------|-------------------------------------------------------------------------------------------|----------------------------------------------|-----------------------------------------------------------|-------------------------------------------------------|-----------------------------------------------------------|-----------------------|
| CROP-98<br>Rotation<br>Treatment # | D.S. Alfalfa<br>CS4<br>7                                                                  | Estab.<br>Alfalfa I<br>CS4<br>10             | Estab.<br>Alfalfa II<br>CS4<br>9                          | Oats/Alfalfa<br>CS5<br>13                             | Estab.<br>Alfalfa I<br>CS5<br>12                          | Pasture<br>CS6<br>14  |
| Plot #'s                           | 111, 209,<br>305, 409                                                                     | 107, 205,<br>309, 404                        | 105, 203,<br>308, 406                                     | 114, 211,<br>312, 403                                 | 103, 213,<br>314, 410                                     | 112, 207,<br>302, 405 |
| Primary<br>Tillage                 | Chisel Plow<br>11/20/97                                                                   | None                                         | None                                                      | Chisel Plow<br>11/20/97                               | None                                                      | None                  |
| Secondary<br>Tillage               | Field Digger<br>04/15/98                                                                  | None                                         | None                                                      | Field Digger<br>04/15/98                              | None                                                      | None                  |
| Planting Date<br>Variety           | 04/15/98<br>Wintergreen                                                                   | 04/17/97<br>Innovator+Z                      | 04/08/96<br>ICI 631                                       | 04/15/98<br>Wintergrm Alf<br>Bay Oats<br>Trapper Peas | 04/17/97<br>Innovator+Z                                   |                       |
| Rate                               | 15 lb/a                                                                                   | 15 lb/a                                      | 15 lb/a                                                   | 11 lb/a Alf<br>50 lb/a Oats<br>50 lb/a Pea            | 12 lb/a                                                   |                       |
| Fertilizer                         | None                                                                                      |                                              |                                                           | None                                                  | None                                                      | None                  |
| Manure                             | 11/06/97<br>20 ton/a                                                                      | None                                         | None                                                      | 11/06/97<br>15 ton/a                                  | None                                                      | Grazing               |
| Pesticides                         | Post-emerge:<br>06/03/98<br>Pursuit<br>(1.08 oz/a)<br>06/24/98<br>Dimetholate<br>(1 pt/a) | None                                         | 10/26/98<br>Roundup<br>(1 pt/a)                           | None                                                  | 10/26/98<br>Roundup<br>(1 pt/a)                           | None                  |
| Harvest                            | 07/07/98<br>08/18/98                                                                      | 05/19/98<br>07/07/98<br>08/06/98<br>09/04/98 | 05/19/98<br>07/07/98<br>08/06/98<br>09/04/98              | Oatlage:<br>06/23/98<br>Haybine:<br>08/18/98          | 05/19/98<br>07/07/98<br>08/18/98<br>09/30/98              | Rotational<br>Grazing |
| Yield                              | 2.63 tDM/a                                                                                | 4.30 tDM/a                                   | 4.13 tDM/a                                                | Oatlage<br>4.29 tDM/a<br>Alfalfa<br>1.38 tDM/a        | 4.45 tDM/a                                                |                       |
| Fall<br>Practices                  |                                                                                           |                                              | 10/28/98<br>Manure<br>20 ton/a<br>11/17/98<br>Chisel Plow |                                                       | 10/28/98<br>Manure<br>15 ton/a<br>11/17/98<br>Chisel Plow |                       |
| Crop-99                            | Alf I                                                                                     | Alf II                                       | Corn                                                      | Alf I                                                 | Corn                                                      | Pasture               |

## Appendix II-A. 1998 WICST INPUT/OUTPUT DATA - ARLINGTON RESEARCH STATION

## Satellite plots – Cropping System 3

| <b>CROP-98<br/>Rotation<br/>Treatment #</b> | <b>Corn<br/>CS3<br/>5</b>                        | <b>WR Soybean/Wheat<br/>CS3<br/>4</b>                                        | <b>Wheat/Red Clover<br/>CS3<br/>6</b>                   |
|---------------------------------------------|--------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------------|
| <b>Primary<br/>Tillage</b>                  | 11/20/97 Chisel plow<br>05/14/98 Chisel w/sweeps | Chisel Plow<br>11/20/97                                                      | 10/02/97 Digger                                         |
| <b>Secondary<br/>Tillage</b>                | 05/15/98 Field cultivator                        | Field Cultivation<br>05/15/98                                                | None                                                    |
| <b>Planting Date</b>                        | 05/15/98                                         | SB: 05/15/98<br>WW: 10/12/98                                                 | 10/02/97 Winter Wheat<br>04/07/98 Red Clover            |
| <b>Variety<br/>Rate</b>                     | Dekalb 471<br>34,500                             | NK 23-12<br>190,000 seeds/a<br>Glacier Winter Wheat<br>130/lb/a              | 150 lb/a Glacier<br>15 lb/a Red Clover                  |
| <b>Fertilizer</b>                           | None                                             | None                                                                         | None                                                    |
| <b>Pesticides</b>                           | None                                             | None                                                                         | None                                                    |
| <b>Rotary Hoe</b>                           | None                                             | 06/04/98<br>06/10/98                                                         | None                                                    |
| <b>Cultivation</b>                          | 06/04/98<br>06/10/98<br>06/19/98                 | 06/17/98<br>06/23/98<br>07/11/98                                             | None                                                    |
| <b>Harvest</b>                              | 10/20/98                                         | 10/11/98                                                                     | 07/17/98 Combined<br>07/18/98 Baler                     |
| <b>Yield</b>                                | 199.7 bu/a                                       | 62.5 bu/a                                                                    | 59.2 bu/a Wheat<br>0.73 tons/a straw                    |
| <b>Fall<br/>Practices</b>                   | 10/28/98 Stalk chop<br>10/29/98 Chisel plow      | 10/11/98 digger<br>10/12/98 Double disk drill<br>Glacier W. Wheat (130 lb/a) | 10/22/98 Stalk chopper<br>11/17/98 Chisel Plow w/sweeps |
| <b>Crop 99</b>                              | <b>Soybean</b>                                   | <b>Wheat / Red Clover</b>                                                    | <b>Corn</b>                                             |

## Appendix II-B. 1998 WICST INPUT/OUTPUT DATA - LAKELAND AGRICULTURAL COMPLEX

| Corn rotations                     |                                                                                                                                                                                     |                                                                                                                                                                                      |                                                                                                              |                                                                 |                                                                                                              |
|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|
| CROP-98<br>Rotation<br>Treatment # | Continuous<br>CORN<br>CS1<br>1                                                                                                                                                      | CORN<br>CS2<br>2                                                                                                                                                                     | CORN <sup>1</sup><br>CS3<br>5                                                                                | CORN<br>CS4<br>8                                                | CORN <sup>2</sup><br>CS5<br>11                                                                               |
| Plot #'s                           | 101, 210,<br>303, 401                                                                                                                                                               | 108, 203,<br>304, 409                                                                                                                                                                | 107, 205,<br>307, 406                                                                                        | 102, 209,<br>305, 402                                           | 106, 211,<br>312, 413                                                                                        |
| Primary<br>Tillage                 | Chisel Plow<br>11/04/97                                                                                                                                                             | No-till                                                                                                                                                                              | None                                                                                                         | Chisel Plow<br>11/05/97                                         | Chisel Plow<br>11/05/97 Sweeps                                                                               |
| Secondary<br>Tillage               | Mulchmaster<br>04/25/98<br>05/18/98                                                                                                                                                 | None                                                                                                                                                                                 | Mulchmaster<br>05/18/98<br>05/21/98                                                                          | Mulchmaster<br>05/11/98<br>05/18/98                             | Mulchmaster<br>05/18/98<br>05/21/98                                                                          |
| Planting Date                      | 05/18/98                                                                                                                                                                            | 05/18/98                                                                                                                                                                             | 05/22/98                                                                                                     | 05/18/98                                                        | 05/22/98                                                                                                     |
| Variety                            | Gold.Harv.2441                                                                                                                                                                      | Gold.Harv.2441                                                                                                                                                                       | Dekalb 471                                                                                                   | Gold.Harv.2441                                                  | Dekalb 471                                                                                                   |
| Rate                               | 32,000                                                                                                                                                                              | 32,000                                                                                                                                                                               | 34,000                                                                                                       | 32,000                                                          | 34,000                                                                                                       |
| Starter<br>Fertilizer              | 100 Lb<br>9-23-30                                                                                                                                                                   | 250 Lb<br>9-23-30                                                                                                                                                                    | None                                                                                                         | 100 Lb<br>9-23-30                                               | None                                                                                                         |
| Nitrogen<br>Fertilizer             | 140 Lb N/a<br>(47 gal/a)<br>28-0-0<br>sidedress<br>06/18/98                                                                                                                         | 80 Lb N/a<br>(27 gal/a)<br>28-0-0<br>sidedress<br>06/18/98                                                                                                                           | None                                                                                                         | None                                                            | None                                                                                                         |
| Manure                             | None                                                                                                                                                                                | None                                                                                                                                                                                 | None                                                                                                         | 20 ton/a<br>11/04/97                                            | 15 ton/a<br>11/05/97                                                                                         |
| Pesticides                         | <u>Banded at planting:</u><br>05/18/98<br>Lorsban (8.7 lb/a)<br><u>Pre-emergence:</u><br>05/26/98 - Brdcast<br>Dual II (2 pt/a)<br><u>Post-emergence:</u><br>06/12-Buctril (1 pt/a) | <u>Pre-emergence:</u><br>05/26/98 - Brdcast<br>Dual II (2 pt/a)<br>RoundupUltra (2pt/a)<br>+ Am.Sulf. (3lb/a)<br>+ NIS (10 oz/a)<br><u>Post-emergence:</u><br>06/12-Buctril (1 pt/a) | <u><sup>1</sup>Post-emergence:</u><br>06/22/98<br>Accent (2/3 oz/a)<br>+ Am.Sulf. (3lb/a)<br>+ NIS (10 oz/a) | <u>Post-emergence:</u><br>06/12/98 -Brdcast<br>Buctril (1 pt/a) | <u><sup>2</sup>Post-emergence:</u><br>06/22/98<br>Accent (2/3 oz/a)<br>+ Am.Sulf. (3lb/a)<br>+ NIS (10 oz/a) |
| Rotary Hoe<br>Cultivation          | None<br>None                                                                                                                                                                        | None<br>None                                                                                                                                                                         | 06/02/98<br>None <sup>1</sup>                                                                                | None<br>None                                                    | None <sup>2</sup><br>None <sup>2</sup>                                                                       |
| Harvest                            | 11/02/98                                                                                                                                                                            | 11/02/98                                                                                                                                                                             | 11/02/98                                                                                                     | 11/02/98                                                        | 11/02/98                                                                                                     |
| Yield                              | 165.46 bu/a                                                                                                                                                                         | 172.16 bu/a                                                                                                                                                                          | 129.04 bu/a                                                                                                  | 172.17 bu/a                                                     | 92.69 bu/a                                                                                                   |
| Fall<br>Practices                  | 11/16/98<br>Chisel                                                                                                                                                                  | None                                                                                                                                                                                 | 11/16/98<br>Chisel plow                                                                                      | 11/16/98<br>Manure 20 ton/a<br>11/23/98<br>Chisel plow          | 11/16/98<br>Manure 15 ton/a<br>11/23/98<br>Chisel plow                                                       |
| Crop-99                            | Corn                                                                                                                                                                                | NR Soybean                                                                                                                                                                           | WR Soybean                                                                                                   | D.S. Alfalfa                                                    | Oats/Alfalfa                                                                                                 |

<sup>1</sup> Rescue Treatment: Wet soil limited rotary hoeing to 1X and prevented cultivation, forcing the rescue treatment.<sup>2</sup> Rescue Treatment: Poor (rough) soil surface prevented initial rotary hoeing, wet soil prevented subsequent rotary hoeing and cultivation. Quackgrass was a severe problem!

## Appendix II-B. 1998 WICST INPUT/OUTPUT DATA - LAKELAND AGRICULTURAL COMPLEX

## Soybean and Wheat Rotations

| CROP-98<br>Rotation<br>Treatment # | NR Soybean<br>CS2<br>3                                                                                                                                                                                                                        | WR Soybean/Wheat<br>CS3<br>4                                                         | Wheat/Red Clover<br>CS3<br>6                                         |
|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Plot #'s                           | 113, 206, 311, 410                                                                                                                                                                                                                            | 109, 204, 308, 404                                                                   | 111, 208, 306, 407                                                   |
| Primary<br>Tillage                 | No-till                                                                                                                                                                                                                                       | Chisel Plow<br>11/04/97                                                              | 10/03/97 Disk                                                        |
| Secondary<br>Tillage               | None                                                                                                                                                                                                                                          | Mulchmaster<br>05/18/98                                                              | None                                                                 |
| Planting Date                      | 05/13/98                                                                                                                                                                                                                                      | 05/19/98                                                                             | 10/03/97 Winter Wheat<br><u>Frost seeded:</u><br>03/30/98 Red Clover |
| Variety<br>Rate                    | Asgrow 2301<br>230,000 seeds/a                                                                                                                                                                                                                | NK 23-12<br>225,000 seeds/a                                                          | 150 lb/a Glacier W. Wheat<br>15 lb/a Arl. Med. Red Clover            |
| Fertilizer                         | None                                                                                                                                                                                                                                          | None                                                                                 | None                                                                 |
| Pesticides                         | <u>Pre-emergence:</u><br>05/11/98 - Brdcst<br>Roundup Ultra (1.5 pt/a),<br>+ 2,4-D ester (1 pt/a),<br>+ Am.Sulf. (3 lb/a)<br><u>Post-emergence:</u><br>06/14/98 - Brdcst<br>Roundup Ultra (2 pt/a),<br>+ Am.Sulf (3 lb/a),<br>+ NIS (10 oz/a) |                                                                                      |                                                                      |
| Rotary Hoe                         | None                                                                                                                                                                                                                                          | 05/25/98<br>06/02/98                                                                 | None                                                                 |
| Cultivation                        | None                                                                                                                                                                                                                                          | 06/12/98<br>06/24/98                                                                 | None                                                                 |
| Harvest                            | 09/28/98                                                                                                                                                                                                                                      | 09/28/98                                                                             | 07/20/98                                                             |
| Yield                              | 67.7 bu/a                                                                                                                                                                                                                                     | 45.01 bu/a                                                                           | 47.17 bu/a Wheat                                                     |
| Fall<br>Practices                  | None                                                                                                                                                                                                                                          | 09/29/98 Mulchmaster<br>09/29/98 JD 750 no-till drill<br>Glacier W. Wheat (125 lb/a) | 11/16/98 Chisel plow w/sweeps                                        |
| Crop 99                            | Corn                                                                                                                                                                                                                                          | Wheat / Red Clover                                                                   | Corn                                                                 |

## Appendix II-B. 1998 WICST INPUT/OUTPUT DATA - LAKELAND AGRICULTURAL COMPLEX

| Forage rotations                   |                          |                                  |                                                                          |                                                                                                                                                                                        |                                                                          |                                              |
|------------------------------------|--------------------------|----------------------------------|--------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------|
| CROP-98<br>Rotation<br>Treatment # | D.S. Alfalfa<br>CS4<br>7 | Estab.<br>Alfalfa I<br>CS4<br>10 | Estab.<br>Alfalfa II<br>CS4<br>9                                         | Oats/Mix<br>CS5<br>13                                                                                                                                                                  | Estab.<br>Alfalfa I<br>CS5<br>12                                         | Pasture<br>CS6<br>14                         |
| Plot #'s                           | 103, 202,<br>310, 411    | 112, 214,<br>301, 403            | 110, 212,<br>302, 414                                                    | 114, 201,<br>313, 405                                                                                                                                                                  | 105, 207,<br>309, 412                                                    | 104, 213,<br>314, 408                        |
| Primary<br>Tillage                 | 11/04/97<br>Chisel Plow  | ---                              | ---                                                                      | 11/04/97<br>Chisel Plow                                                                                                                                                                | ---                                                                      |                                              |
| Secondary<br>Tillage               | Mulchmaster<br>04/08/98  | ---                              | ---                                                                      | 04/08/98<br>Mulchmaster<br>04/15/98<br>Soil finisher                                                                                                                                   | ---                                                                      |                                              |
| Planting Date<br>Variety           | 04/13/98<br>Innovator+Z  | 04/24/97<br>Innovator+Z          | 04/18/96<br>08/22/96 <sup>1</sup><br>Legendary<br>Rushmore               | 04/13/98 &<br>04/25/98 <sup>2</sup><br>Commercial mix<br>w/trapper peas,<br>50/50 Oat/Pea<br><br>150 lb/a Mix<br>18 lb/a Forage<br>= 8lb Med RC,<br>+ 8 lb Pioneer,<br>+ 2 lb Ryegrass | 04/24/97<br>Innovator+Z<br>Ryegrass<br>Trapper Pea<br>Red Clover         | 03/30/98<br>Red Clover<br>Frost seeded       |
| Rate                               | 18 lb/a                  | 18.5 lb/a                        | 15 lb/a<br>15 lb/a                                                       |                                                                                                                                                                                        | 12 lb/a Alfalfa<br>2 lb/a P.Ryegr<br>50 lb/a T.Pea<br>4 lb/a Rclovr      | 15 lb/a <sup>3</sup>                         |
| Fertilizer                         |                          | As required                      | As required                                                              |                                                                                                                                                                                        |                                                                          |                                              |
| Manure                             | 11/06/97<br>20 ton/a     | None                             | None                                                                     | 11/06/97<br>15 ton/a                                                                                                                                                                   |                                                                          | Grazing<br>08/06/97<br>20 ton/a              |
| Pesticides                         | None                     | None                             | 10/15/98<br>Roundup Ultra<br>(2 qt/a)<br>+ AMS (3lb/a)<br>+ NIS (10oz/a) | None                                                                                                                                                                                   | 10/15/98<br>Roundup Ultra<br>(2 qt/a)<br>+ AMS (3lb/a)<br>+ NIS (10oz/a) |                                              |
| Harvest                            | 07/11/98<br>08/30/98     | 05/25/98<br>07/11/98<br>08/30/98 | 05/25/98<br>07/11/98<br>08/30/98                                         | <u>Oatlage:</u><br>06/24/98<br><u>Hay:</u><br>08/30/98                                                                                                                                 | 05/25/98<br>07/11/98<br>08/30/98                                         | Rotational<br>Grazing<br>06/06/98<br>Clipped |
| Yield                              | 3.12 tDM/a               | 4.53 tDM/a                       | 4.32 tDM/a                                                               | <u>Oats:</u><br>1.08 tDM/a<br><u>Hay:</u><br>1.89 tDM/a                                                                                                                                | 4.86 tDM/a                                                               |                                              |
| Fall<br>Practices                  | None                     | None                             | 11/16 Manure<br>(20 ton/a)<br>11/23 Chisel<br>Plow                       | None                                                                                                                                                                                   | 11/16 Manure<br>(15 ton/a)<br>11/23 Chisel<br>Plow                       | 11/16/98<br>Manure<br>(20 ton/a)             |
| Crop-99                            | Alf I                    | Alf II                           | Corn                                                                     | Alf I                                                                                                                                                                                  | Corn                                                                     | Pasture                                      |

<sup>1</sup> CS4: In 1996, D.S. alfalfa reps 1, 2, and 3 were lost to waterlogged soils, and replanted on 08/22/96.<sup>2</sup> Plots 201 and 405 planted on 04/13/98; Plots 114 and 313 were too wet (got stuck) and were planted 04/25/98.<sup>3</sup> Heavy planting rate due to poor pasture conditions.

# APPENDIX III-A. WICST Phosphorus and Potassium Annual Routine Soil Test Results (0-6") 1991-1998 Arlington Research Station.<sup>1</sup>

| Cropping System | CROP |     |     |     |     |     |     |     | PHOSPHORUS (ppm) |     |    |    |    |    |    |    | POTASSIUM (ppm) |     |     |     |     |     |     |     |
|-----------------|------|-----|-----|-----|-----|-----|-----|-----|------------------|-----|----|----|----|----|----|----|-----------------|-----|-----|-----|-----|-----|-----|-----|
| YR-Tmt          | 91   | 92  | 93  | 94  | 95  | 96  | 97  | 98  | 91               | 92  | 93 | 94 | 95 | 96 | 97 | 98 | 91              | 92  | 93  | 94  | 95  | 96  | 97  | 98  |
| CS1-1           | C    | C   | C   | C   | C   | C   | C   | C   | ---              | 93  | 84 | 91 | 88 | 91 | 83 | 82 | ---             | 219 | 295 | 228 | 241 | 257 | 254 | 229 |
| CS2-2           | C    | Sb  | C   | Sb  | C   | Sb  | C   | Sb  | ---              | 79  | 65 | 68 | 67 | 66 | 61 | 59 | ---             | 239 | 229 | 183 | 182 | 214 | 178 | 184 |
| CS2-3           | Sb   | C   | Sb  | C   | Sb  | C   | Sb  | C   | ---              | 89  | 78 | 89 | 72 | 83 | 72 | 75 | ---             | 198 | 264 | 214 | 208 | 230 | 224 | 212 |
| CS3-4           | W/r  | C   | Sb  | W/r | C   | Sb  | W/r | C   | ---              | 69  | 64 | 68 | 65 | 66 | 55 | 55 | ---             | 189 | 251 | 182 | 175 | 209 | 166 | 180 |
| CS3-5           | Sb   | W/r | C   | Sb  | W/r | C   | Sb  | W/r | ---              | --- | 57 | 63 | 52 | 57 | 56 | 47 | ---             | --- | 226 | 171 | 164 | 191 | 172 | 150 |
| CS3-6           | f    | Sb  | W/r | C   | Sb  | W/r | C   | Sb  | 57               | --- | 53 | 57 | 49 | 49 | 48 | 45 | 195             | --- | 201 | 142 | 149 | 155 | 136 | 131 |
| CS4-7           | A    | A   | C   | A   | A   | A   | C   | A   | ---              | 94  | 85 | 99 | 84 | 90 | 90 | 90 | ---             | 175 | 216 | 171 | 157 | 180 | 212 | 200 |
| CS4-8           | A    | A   | A   | C   | A   | A   | A   | C   | ---              | 105 | 81 | 92 | 93 | 94 | 81 | 91 | ---             | 203 | 170 | 154 | 184 | 189 | 153 | 166 |
| CS4-9           | f    | A   | A   | A   | C   | A   | A   | A   | 66               | --- | 62 | 65 | 74 | 91 | 72 | 66 | 214             | --- | 170 | 128 | 160 | 228 | 143 | 115 |
| CS4-10          | f    | f   | A   | A   | A   | C   | A   | A   | ---              | 77  | 71 | 72 | 67 | 77 | 76 | 63 | ---             | 189 | 224 | 155 | 153 | 196 | 205 | 141 |
| CS5-11          | A    | C   | O/a | A   | C   | O/a | A   | C   | ---              | 103 | 88 | 93 | 91 | 96 | 82 | 90 | ---             | 198 | 236 | 172 | 185 | 201 | 153 | 154 |
| CS5-12          | O/a  | A   | C   | O/a | A   | C   | O/a | A   | ---              | 72  | 67 | 72 | 64 | 72 | 66 | 59 | ---             | 181 | 210 | 144 | 127 | 143 | 128 | 98  |
| CS5-13          | f    | O/a | A   | C   | O/a | A   | C   | O/a | 84               | --- | 73 | 83 | 78 | 76 | 71 | 66 | 293             | --- | 211 | 173 | 180 | 174 | 153 | 153 |
| CS6-14          | P    | P   | P   | P   | P   | P   | P   | P   | ---              | --- | 82 | 84 | 75 | 74 | 73 | 64 | ---             | --- | 186 | 157 | 176 | 208 | 210 | 180 |

\* 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)

<sup>1</sup> Samples collected after crop harvest. The samples are a composite of 6 sets of 3 soil cores (3/4") 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 III-B. WICST Phosphorus and Potassium Annual Routine Soil Test Results (0-6") 1991-1998 Lakeland Agricultural Complex.<sup>1</sup>**

| Cropping System | CROP      |           |           |           |           |           |           |           | PHOSPHORUS (ppm) |           |           |           |           |           |           |           | POTASSIUM (ppm) |           |           |           |           |           |           |           |
|-----------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| <u>YR-Tmt</u>   | <u>91</u> | <u>92</u> | <u>93</u> | <u>94</u> | <u>95</u> | <u>96</u> | <u>97</u> | <u>98</u> | <u>91</u>        | <u>92</u> | <u>93</u> | <u>94</u> | <u>95</u> | <u>96</u> | <u>97</u> | <u>98</u> | <u>91</u>       | <u>92</u> | <u>93</u> | <u>94</u> | <u>95</u> | <u>96</u> | <u>97</u> | <u>98</u> |
| CS1-1           | C         | C         | C         | C         | C         | C         | C         | C         | ---              | 58        | 52        | 95        | 49        | 61        | 54        | 53        | ---             | 205       | 185       | 219       | 177       | 191       | 165       | 177       |
| CS2-2           | C         | Sb        | C         | Sb        | C         | Sb        | C         | Sb        | ---              | 52        | 47        | 64        | 39        | 41        | 43        | 37        | ---             | 186       | 158       | 177       | 137       | 132       | 132       | 133       |
| CS2-3           | Sb        | C         | Sb        | C         | Sb        | C         | Sb        | C         | ---              | 53        | 43        | 71        | 47        | 51        | 46        | 40        | ---             | 204       | 196       | 188       | 183       | 177       | 160       | 153       |
| CS3-4           | W/r       | C         | Sb        | W/r       | C         | Sb        | W/r       | C         | ---              | 46        | 39        | 56        | 39        | 43        | 35        | 37        | ---             | 173       | 181       | 161       | 154       | 155       | 150       | 157       |
| CS3-5           | Sb        | W/r       | C         | Sb        | W/r       | C         | Sb        | W/r       | ---              | ---       | 36        | 49        | 30        | 36        | 36        | 31        | ---             | ---       | 173       | 147       | 136       | 149       | 149       | 147       |
| CS3-6           | C         | Sb        | W/r       | C         | Sb        | W/r       | C         | Sb        | 49               | ---       | 39        | 46        | 37        | 37        | 34        | 34        | 183             | ---       | 179       | 152       | 156       | 152       | 141       | 142       |
| CS4-7           | A         | A         | C         | A         | A         | A         | C         | A         | ---              | 57        | 51        | 50        | 62        | 67        | 85        | 64        | ---             | 121       | 145       | 150       | 159       | 163       | 183       | 143       |
| CS4-8           | A         | A         | A         | C         | A         | A         | A         | C         | ---              | 52        | 52        | 43        | 77        | 74        | 62        | 73        | ---             | 171       | 165       | 150       | 256       | 206       | 150       | 190       |
| CS4-9           | f         | A         | A         | A         | C         | A         | A         | A         | 37               | ---       | 36        | 69        | 54        | 70        | 60        | 51        | 149             | ---       | 181       | 180       | 192       | 271       | 202       | 181       |
| CS4-10          | f         | f         | A         | A         | A         | C         | A         | A         | ---              | 59        | 62        | 52        | 62        | 89        | 75        | 80        | ---             | 181       | 203       | 150       | 152       | 220       | 184       | 184       |
| CS5-11          | A         | C         | O/a       | A         | C         | O/a       | A         | C         | ---              | 41        | 52        | 47        | 55        | 68        | 56        | 64        | ---             | 161       | 205       | 142       | 164       | 200       | 160       | 201       |
| CS5-12          | O/a       | A         | C         | O/a       | A         | C         | O/a       | A         | ---              | 55        | 48        | 45        | 53        | 72        | 73        | 68        | ---             | 159       | 181       | 130       | 151       | 188       | 178       | 143       |
| CS5-13          | f         | O/a       | A         | C         | O/a       | A         | C         | O/a       | 54               | ---       | 46        | 50        | 64        | 59        | 75        | 64        | 171             | ---       | 200       | 139       | 195       | 176       | 193       | 189       |
| CS6-14          | P         | P         | P         | P         | P         | P         | P         | P         | ---              | ---       | 41        | 46        | 42        | 61        | 60        | 54        | ---             | ---       | 166       | 132       | 177       | 240       | 228       | 230       |

\* 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)

<sup>1</sup> Samples collected after crop harvest. The samples are a composite of 6 sets of 3 soil cores (3/4") 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 IV-A. WICST Phosphorus Soil Depth Test Results (0-6", 6-12", 12-24", 24-36") Arlington Research Station<sup>1</sup>

| 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              | ns       |
| CS2 C-Sb        | 2    | 88              | 48       | 47              | 35       | 50              | 10       | 73              | ns       |
| CS2             | 3    | 98              | 66       | 43              | 30       | 24              | 28       | 51              | ns       |
| 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              | --       | 34              | --       | 51              | --       | 86              | --       |
| 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              | ns       |

<sup>1</sup> Sampling done in the 7<sup>th</sup> 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 IV-B. WICST Phosphorus Soil Depth Test Results (0-6", 6-12", 12-24", 24-36") Lakeland Agricultural Complex<sup>1</sup>

| Phosphorus      |       |                 |          |                 |          |                 |          |                 |          |
|-----------------|-------|-----------------|----------|-----------------|----------|-----------------|----------|-----------------|----------|
| 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 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              | --       | 46              | --       | 9               | --       | 8               | --       |
| 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       |

<sup>1</sup> Sampling done in the 7<sup>th</sup> 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 V-A. WICST Potassium Soil Depth Test Results (0-6", 6-12", 12-24", 24-36") Arlington Research Station<sup>1</sup>**

| <b>Potassium</b>       |              |                     |                 |                     |                 |                     |                 |                     |                 |
|------------------------|--------------|---------------------|-----------------|---------------------|-----------------|---------------------|-----------------|---------------------|-----------------|
| <b>Cropping System</b> | <b>Depth</b> | <b>0 – 6"</b>       |                 | <b>6 – 12"</b>      |                 | <b>12 – 24"</b>     |                 | <b>24 – 36"</b>     |                 |
|                        | <b>Year</b>  | <b>Initial Year</b> | <b>7th year</b> | <b>Initial Year</b> | <b>7th year</b> | <b>Initial year</b> | <b>7th year</b> | <b>Initial Year</b> | <b>7th year</b> |
| ----- ppm -----        |              |                     |                 |                     |                 |                     |                 |                     |                 |
| CS1 C                  | 1            | 257                 | 257             | 143                 | 100             | 125                 | 74              | 135                 | ns              |
| CS2 C-Sb               | 2            | 283                 | 144             | 126                 | 130             | 125                 | 124             | 123                 | ns              |
| CS2                    | 3            | 199                 | 214             | 121                 | 91              | 134                 | 83              | 155                 | ns              |
| 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                 | --              | 96                  | --              | 109                 | --              | 111                 | --              |
| 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                 | ns              |

<sup>1</sup> Sampling done in the 7<sup>th</sup> 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 V-B. WICST Potassium Soil Depth Test Results (0-6", 6-12", 12-24", 24-36") Lakeland Agricultural Complex<sup>1</sup>

| 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 |
|                 | Tri   | ----- 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             | --       | 135             | --       | 124             | --       | 133             | --       |
| 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       |

<sup>1</sup> Sampling done in the 7<sup>th</sup> 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 VI. Nitrate + Nitrite-N Concentration in Groundwater at the Lakeland Agricultural Complex.**

| 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 <sup>1</sup> |                    | 31.1                   | 2.1      | 2.3      | 2.8      | 0.9      | Empty    | 0.1      |          |
| ls <sup>2</sup> |                    | 6.9                    | 10.6     | ND       | 4.2      | 6.8      | Empty    | ---      |          |

\* Red Clover/Grass removed as hay 1991, grazed 1992 - 1998

<sup>1</sup> Check well #1 - 13 feet deep<sup>2</sup> Check well #2 - 28 feet deep

ND = no detection

APPENDIX VII. Energy Use and Output/Input Ratios for the Six WICST Cropping Systems 1990-1997.<sup>1</sup>

| Cropping System | Crop                            | Crops or number of completed rotations | Mean 1990 - 1997  |      |                      |      |
|-----------------|---------------------------------|----------------------------------------|-------------------|------|----------------------|------|
|                 |                                 |                                        | Energy input/year |      | Output/input average |      |
|                 |                                 |                                        | ARS               | LAC  | ARS                  | LAC  |
|                 |                                 | -- # --                                | --- Mcal/A ---    |      | ---- ratio ----      |      |
| 1               | Corn                            | 8                                      | 2556              | 1898 | 5.5                  | 6.2  |
| 2               | Soybean                         | 8                                      | 569               | 504  | 11.8                 | 14.1 |
|                 | Corn                            | 7                                      | 2546              | 1990 | 6.0                  | 6.9  |
|                 | System average <sup>2</sup>     | 7                                      | 1557              | 1247 | 7.0                  | 8.4  |
| 3               | Soybean/Wheat                   | 8                                      | 482               | 470  | 11.6                 | 9.5  |
|                 | Wheat/Red Clover                | 7                                      | 971               | 860  | 9.2                  | 9.8  |
|                 | Corn                            | 6                                      | 1830              | 1131 | 6.6                  | 9.0  |
|                 | System average                  | 6                                      | 1145              | 856  | 7.9                  | 9.6  |
| 4               | Direct Seeded Alfalfa           | 8                                      | 1446              | 1300 | 9.2                  | 2.7  |
|                 | Alfalfa I                       | 7                                      | 761               | 626  | 22.3                 | 21.6 |
|                 | Alfalfa II                      | 6                                      | 946               | 707  | 14.5                 | 18.8 |
|                 | Corn <sup>3</sup>               | 5                                      | 740               | 803  | 21.4                 | 16.7 |
|                 | System average                  | 5                                      | 926               | 868  | 14.8                 | 12.9 |
| 5               | Oats/Alfalfa                    | 8                                      | 1101              | 1002 | 11.1                 | 8.0  |
|                 | Alfalfa I                       | 7                                      | 653               | 588  | 24.8                 | 21.2 |
|                 | Corn <sup>3</sup>               | 6                                      | 695               | 675  | 20.4                 | 17.2 |
|                 | System average                  | 6                                      | 779               | 720  | 18.0                 | 14.4 |
| 6               | Rotational Grazing <sup>4</sup> | 8                                      | 519               | 298  | 22.2                 | 30.5 |

<sup>1</sup> See Appendix II in the 1992 Annual Report (pp. 118-121 for information on calculation of the energy values).<sup>2</sup> Averages calculated using data from years when all the crops of a particular system were grown.<sup>3</sup> Energy for corn drying not included since most dairy farmers feed animals high moisture corn.<sup>4</sup> Forage harvested mechanically until animals began grazing in 1992 at LAC and in 1993 at ARS; with grazing animals, energy output calculated using forage production, either harvested mechanically or an estimation of forage by grazing animals.

## APPENDIX VIII. WICST Corn and Soybean Populations, 1992 – 1998.

## 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> |
|-------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| ----- plants/acre ----- |             |             |             |             |             |             |             |
| <sup>1</sup> Corn       |             |             |             |             |             |             |             |
| CS1                     | 27,750      | 30,850      | 26,950      | 29,250      | 30,100      | 30,150      | 28,000      |
| CS2                     | 28,650      | 30,800      | 27,300      | 30,200      | 30,000      | 31,850      | 27,417      |
| CS3                     | 24,700      | 20,800      | 28,050      | 28,100      | 26,950      | 30,900      | 26,083      |
| CS4                     | -----       | 32,300      | 26,000      | 27,850      | 30,300      | 30,100      | 29,000      |
| CS5                     | -----       | 27,500      | 28,000      | 28,300      | 26,950      | 34,000      | 28,083      |
| <b>Soybean</b>          |             |             |             |             |             |             |             |
| <sup>2</sup> CS2        | 118,547     | 179,823     | 187,488     | 153,406     | 170,625     | 270,531     | 249,897     |
| <sup>3</sup> CS3        | 70,350      | 135,250     | 151,091     | 199,542     | 105,583     | 141,200     | *           |

<sup>1</sup> Corn – 1992: all Corn phases planted at 32,100 seeds/a; 1993: all Corn phases – 32,500 seeds/a;  
 1994-1996: CS1, 2, 4 – 31,500 and CS3, 5 – 34,000 seeds/a;  
 1997: CS1, 2, 4 – 32,000; and CS3, 5 – 34,000 seeds/a;  
 1998: CS1, 2, 4 – 32,000 and CS3, 5 – 34,500 seeds/a.

<sup>2</sup> Narrow row soybean – 1992-1996: CS2 planted at 235,000 seeds/a;  
 1997-1998: 250,000 seeds/a (rep 4 double planted in 1997).

<sup>3</sup> Wide row soybean – 1992-1993: CS3 planted at 156,000 seeds/a;  
 1994 and 1996: 175,000 seeds/a; 1995: 200,000 seeds/a;  
 1997-1998: 190,000 seeds/a.

\* Unable to get wide row soybean population counts in 1998.

## 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> |
|-------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| ----- plants/acre ----- |             |             |             |             |             |             |             |
| <sup>1</sup> Corn       |             |             |             |             |             |             |             |
| CS1                     | 29,050      | 30,150      | 28,200      | 28,200      | 27,600      | n.a.        | 32,000      |
| CS2                     | 24,500      | 29,900      | 27,900      | 28,900      | 26,350      | n.a.        | 31,000      |
| CS3                     | 24,250      | 21,100      | 30,350      | 28,200      | 26,850      | n.a.        | 25,000      |
| CS4                     | -----       | 31,250      | 30,050      | 29,250      | 26,400      | n.a.        | 28,000      |
| CS5                     | -----       | 21,400      | 30,850      | 28,850      | 25,850      | n.a.        | 28,000      |
| <b>Soybean</b>          |             |             |             |             |             |             |             |
| <sup>2</sup> CS2        | 97,000      | 139,228     | 143,278     | 176,879     | 236,209     | 298,501     | 145,352     |
| <sup>3</sup> CS3        | 122,952     | 86,950      | 113,050     | 118,500     | 80,458      | n.a.        | 167,500     |

<sup>1</sup> Corn – 1992-1993: all Corn phases planted at 32,000 seeds/a;  
 1994: CS1, 2, 4 – 32,000 and CS3, 5 – 35,000 seeds/a; 1995: CS1, 2, 4 – 31,200 and CS3, 5 – 33,800 seeds/a;  
 1996: CS1, 2, 4 – 31,500 and CS3, 5 – 34,000 seeds/a; 1997-1998: CS1, 2, 4 – 32,000 and CS3, 5 – 34,000 seeds/a;

<sup>2</sup> Narrow row soybean – 1992: CS2 planted at 196,000 seeds/a; 1993 – 199,500; 1994, 1998 – 230,000;  
 1995, 1996 – 235,000; 1997 – 250,000 seeds/a.

<sup>3</sup> Wide row soybean – 1992: CS3 planted at 156,000 seeds/a; 1993 – 156,000; 1994, 1996 – 175,000; 1995 – 151,000;  
 1997-1998 – 225,000 seeds/a.

n.a Counts not taken.

## A1 ENDIX IX. WICST Fall Legume Nitrogen for crop preceding the Corn phase 1991-1998.

## A. Arlington Agricultural Research Station

| Year               | Cropping Sys. | Crop                  | Foliage    |        | Roots      |        | Total     |
|--------------------|---------------|-----------------------|------------|--------|------------|--------|-----------|
|                    |               |                       | DM<br>lb/a | N<br>% | DM<br>lb/a | N<br>% | N<br>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               | 4             | Alfalfa <sup>1/</sup> | 1866       | 2.91   | 1233       | 3.36   | 94        |
| 1993               | 5             | Alfalfa <sup>1/</sup> | 1613       | 4.05   | 1443       | 2.18   | 97        |
| 1994 <sup>2/</sup> | 3             | Hairy Vetch           | 4325       | 3.29   | 134        | 3.24   | 146       |
| 1994               | 4             | Alfalfa <sup>1/</sup> | 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               | 4             | Alfalfa <sup>4/</sup> | 163        | 3.18   | 1235       | 2.51   | 36        |
| 1995               | 5             | Alfalfa <sup>4/</sup> | 308        | 3.59   | 2345       | 2.32   | 66        |
| 1996 <sup>5/</sup> | 3             | Red Clover            | 3213       | 3.01   | 1836       | 2.75   | 147       |
| 1997 <sup>6/</sup> | 3             | Hairy Vetch           | 1343       | 4.66   | 767        | 2.75   | 84        |
| 1998 <sup>7/</sup> | 3             | Red Clover            | 3229       | 2.36   | 1229       | 2.75   | 109       |
| 1998 <sup>7/</sup> | 4             | Alfalfa               | 1283       | 3.83   | 2582       | 2.75   | 107       |
| 1998 <sup>7/</sup> | 5             | Alfalfa               | 1635       | 3.50   | 2328       | 2.75   | 121       |

<sup>1/</sup> Spring seeded with red clover in 1993 because of severe winterkill to alfalfa.

<sup>2/</sup> 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.

<sup>4/</sup> 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.

<sup>5/</sup> Frozen soil did not allow root harvest in 1996. Previous data was used to estimate root biomass as 75 % of herbage and root nitrogen as 2.75%.

<sup>6/</sup> Root biomass estimated at 75% of herbage and root nitrogen as 2.75%.

<sup>7/</sup> 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 IX. WICST Fall Legume Nitrogen for following Corn Crop 1991-1998.

## B. Lakeland Agricultural Complex

| Year               | Rotation | Crop                  | Foliage    |        | Roots      |                    | Total     |
|--------------------|----------|-----------------------|------------|--------|------------|--------------------|-----------|
|                    |          |                       | DM<br>lb/a | N<br>% | DM<br>lb/a | N<br>%             | N<br>lb/a |
| 1991               | 3        | Red Clover            | 669        | 3.12   | 916        | 2.63 <sup>3/</sup> | 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               | 4        | Alfalfa <sup>1/</sup> | 2043       | 3.46   | 1251       | 2.74               | 104       |
| 1993               | 5        | Alfalfa <sup>1/</sup> | 2127       | 3.18   | 1222       | 2.72               | 101       |
| 1994               | 3        | Red Clover            | 1240       | 3.03   | 1182       | 2.52               | 67        |
| 1994               | 4        | Alfalfa <sup>1/</sup> | 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               | 4        | Alfalfa <sup>4/</sup> | 423        | 3.64   | 1884       | 2.49               | 62        |
| 1995               | 5        | Alfalfa <sup>4/</sup> | 896        | 3.36   | 1527       | 2.71               | 71        |
| 1996 <sup>5/</sup> | 3        | Red Clover            | 1501       | 2.91   | 858        | 2.75               | 67        |
| 1997               |          | No data available     |            |        |            |                    |           |
| 1998 <sup>7/</sup> |          |                       |            |        |            |                    |           |

<sup>1/</sup> Spring seeded with red clover in 1993 because of severe winterkill to alfalfa.

<sup>3/</sup> Root N was not analyzed, used same % root N as at Arlington.

<sup>4/</sup> 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.

<sup>5/</sup> Frozen soil did not allow root harvest in 1996. Previous data was used to estimate root biomass as 75 % of herbage and root nitrogen as 2.75%.

<sup>6/</sup> Root biomass estimated at 75% of herbage and root nitrogen as 2.75%.

<sup>7/</sup> Root nitrogen estimated as \_\_\_\_%. CS4 - last Alfalfa harvest 08/30/98, Roundup applied 10/15/98; CS5 - last Alfalfa harvest 08/30/98, Roundup applied 10/15/98.

Appendix X-A. WICST Nitrogen Additions as Purchased Fertilizers and Cattle Manure<sup>1</sup> 1990-1998.

| Crop System | CROP |      |      |      |      |      |      |      |      | ARLINGTON RESEARCH STATION |     |     |     |     |     |     |     |     |
|-------------|------|------|------|------|------|------|------|------|------|----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
|             |      |      |      |      |      |      |      |      |      | ----- lb/acre -----        |     |     |     |     |     |     |     |     |
| YR          | 90   | 91   | 92   | 93   | 94   | 95   | 96   | 97   | 98   | 90                         | 91  | 92  | 93  | 94  | 95  | 96  | 97  | 98  |
| CS1         | C    | C    | C    | C    | C    | C    | C    | C    | C    | 66                         | 126 | 141 | 166 | 124 | 106 | 99  | 126 | 151 |
| CS2         | Sb   | C    | Sb   | C    | Sb   | C    | Sb   | C    | Sb   | 0                          | 96  | 0   | 126 | 0   | 126 | 0   | 126 | 0   |
| CS2         | f    | Sb   | C    | Sb   | C    | Sb   | C    | Sb   | C    | ---                        | 0   | 126 | 0   | 126 | 0   | 126 | 0   | 126 |
| CS3         | Sb   | W/Rc | C    | Sb   | W/Rc | C    | Sb   | W/Rc | C    | 0                          | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| CS3         | f    | Sb   | W/Rc | C    | Sb   | W/Rc | C    | Sb   | W/Rc | ---                        | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| CS3         | f    | C    | Sb   | W/Rc | C    | Sb   | W/Rc | C    | Sb   | ---                        | --- | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| CS4         | A    | A    | A    | C    | A    | A    | A    | C    | A    | 238                        | 0   | 0   | 203 | 179 | 0   | 0   | 191 | 205 |
| CS4         | f    | A    | A    | A    | C    | A    | A    | A    | C    | ---                        | 265 | 0   | 0   | 185 | 211 | 0   | 0   | 211 |
| CS4         | f    | f    | A    | A    | A    | C    | A    | A    | A    | ---                        | --- | 215 | 0   | 0   | 217 | 196 | 0   | 0   |
| CS4         | f    | f    | f    | A    | A    | A    | C    | A    | A    | ---                        | --- | --- | 197 | 0   | 0   | 202 | 185 | 0   |
| CS5         | O/a  | A    | C    | O/a  | A    | C    | O/a  | A    | C    | 179                        | 0   | 161 | 148 | 0   | 158 | 147 | 0   | 154 |
| CS5         | f    | O/a  | A    | C    | O/a  | A    | C    | O/a  | A    | ---                        | 199 | 0   | 148 | 134 | 0   | 147 | 139 | 0   |
| CS5         | f    | f    | O/a  | A    | C    | O/a  | A    | C    | O/a  | ---                        | --- | 161 | 0   | 134 | 158 | 0   | 139 | 154 |
| CS6         | P    | P    | P    | P    | P    | P    | P    | P    | P    | 119                        | 132 | 107 | 82  | 68  | 44  | 97  | 110 | 132 |

f Filler corn (grown before initiation of each rotation).  
C Corn  
Sb Soybean – Narrow row in CS2 and wide row in CS3  
P Pasture

W/Rc Winter wheat followed by frost-seeded Red Clover.  
A Alfalfa  
O/a Alfalfa with Oats as a nurse crop.

<sup>1</sup> 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 10 t/a manure application (1990 – 1992) or estimated manure production of grazing animals in the pasture system (CS6). Nitrogen from green manure (alfalfa sod, red clover) plowdown is not included.

# Appendix X-B. WICST Nitrogen Additions as Purchased Fertilizers and Cattle Manure<sup>1</sup> 1990-1998.

| Crop System | CROP |      |      |      |      |      |      |      |      | LAKELAND AGRICULTURAL COMPLEX |     |     |     |     |     |     |                |                  |
|-------------|------|------|------|------|------|------|------|------|------|-------------------------------|-----|-----|-----|-----|-----|-----|----------------|------------------|
|             |      |      |      |      |      |      |      |      |      | ----- lb/acre -----           |     |     |     |     |     |     |                |                  |
| YR          | 90   | 91   | 92   | 93   | 94   | 95   | 96   | 97   | 98   | 90                            | 91  | 92  | 93  | 94  | 95  | 96  | 97             | 98               |
| CS1         | C    | C    | C    | C    | C    | C    | C    | C    | C    | 127                           | 104 | 142 | 157 | 76  | 108 | 116 | 74             | 149              |
| CS2         | Sb   | C    | Sb   | C    | Sb   | C    | Sb   | C    | Sb   | 0                             | 109 | 0   | 123 | 0   | 128 | 0   | 129            | 0                |
| CS2         | f    | Sb   | C    | Sb   | C    | Sb   | C    | Sb   | C    | ---                           | 0   | 124 | 0   | 111 | 0   | 126 | 0              | 103              |
| CS3         | Sb   | W/Rc | C    | Sb   | W/Rc | C    | Sb   | W/Rc | C    | 0                             | 0   | 0   | 0   | 0   | 0   | 0   | 0              | 0                |
| CS3         | f    | Sb   | W/Rc | C    | Sb   | W/Rc | C    | Sb   | W/Rc | ---                           | 0   | 0   | 0   | 0   | 0   | 0   | 0              | 0                |
| CS3         | f    | C    | Sb   | W/Rc | C    | Sb   | W/Rc | C    | Sb   | ---                           | --- | 0   | 0   | 0   | 0   | 0   | 0              | 0                |
| CS4         | A    | A    | A    | C    | A    | A    | A    | C    | A    | 250                           | 0   | 0   | 266 | 275 | 0   | 0   | 235            | 697 <sup>2</sup> |
| CS4         | f    | A    | A    | A    | C    | A    | A    | A    | C    | ---                           | 255 | 0   | 284 | 259 | 211 | 0   | 0              | 706 <sup>2</sup> |
| CS4         | f    | f    | A    | A    | A    | C    | A    | A    | A    | ---                           | --- | 255 | 0   | 0   | 269 | 266 | 0              | 0                |
| CS4         | f    | f    | f    | A    | A    | A    | C    | A    | A    | ---                           | --- | --- | 259 | 0   | 0   | 272 | 226            | 0                |
| CS5         | O/a  | A    | C    | O/a  | A    | C    | O/a  | A    | C    | 187                           | 0   | 192 | 201 | 0   | 194 | 199 | 0              | 523 <sup>2</sup> |
| CS5         | f    | O/a  | A    | C    | O/a  | A    | C    | O/a  | A    | ---                           | 191 | 0   | 201 | 207 | 0   | 199 | 170            | 0                |
| CS5         | f    | f    | O/a  | A    | C    | O/a  | A    | C    | O/a  | ---                           | --- | 192 | 0   | 207 | 194 | 0   | 170            | 523 <sup>2</sup> |
| CS6         | P    | P    | P    | P    | P    | P    | P    | P    | P    | 125                           | 127 | 99  | 117 | 112 | 94  | 44  | 0 <sup>3</sup> | 543 <sup>2</sup> |

\* 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.

<sup>1</sup> 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 10 t/a manure application (1990 – 1992) or estimated manure production of grazing animals in the pasture system (CS6). Nitrogen from green manure (alfalfa sod, red clover) plowdown is not included.

<sup>2</sup> Manure samples for LAC were very high in total N – CS4 and CS5 average was 35 lb/ton and CS6 average was 27 lb/ton.

<sup>3</sup> Pastures not grazed in 1997, reseeding year.

**APPENDIX XI-A. Fall Nitrates in the top 3-ft of the soil at the Arlington Research Station in 1990-1998.**

| ARLINGTON RESEARCH STATION |      |                       |                            |           |           |           |           |           |           |           |           |
|----------------------------|------|-----------------------|----------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Columbia County            |      |                       | ----- lb / 3 ft-acre ----- |           |           |           |           |           |           |           |           |
|                            |      | Year:                 | <u>90</u>                  | <u>91</u> | <u>92</u> | <u>93</u> | <u>94</u> | <u>95</u> | <u>96</u> | <u>97</u> | <u>98</u> |
| Corn:                      | CS1. | Continuous Corn       | 87                         | 48        | 97        | 102       | 154       | 179       | 164       | 115       | 141       |
|                            | CS2. | Corn after Soybeans   | *--                        | 41        | 105       | 105       | 166       | 141       | 170       | 128       | 71        |
|                            | CS3. | Corn after Red Clover | --                         | --        | 67        | 83        | 100       | 145       | 45        | 129       | 83        |
|                            | CS4. | Corn after Alfalfa    | --                         | --        | --        | 142       | 164       | 184       | 94        | 229       | 90        |
|                            | CS5. | Corn after Alfalfa    | --                         | --        | 101       | 118       | 150       | 202       | 82        | 180       | 110       |
| Soybean:                   | CS2. | Narrow-row Soybeans   | 78                         | 42        | 74        | 100       | 71        | 145       | 73        | 143       | 74        |
|                            | CS3. | Wide-row Soybeans     | 75                         | 25        | 66        | 89        | 83        | 140       | 76        | 127       | 68        |
| Wheat:                     | CS3. | Wheat / Red Clover    | --                         | 26        | 48        | 65        | 48        | 85        | 38        | 90        | 57        |
| Alfalfa:                   | CS4. | Direct-seeded Alfalfa | 46                         | 32        | 61        | 80        | 77        | 117       | 59        | 114       | 74        |
|                            | CS4. | Alfalfa Hay I         | --                         | 27        | 49        | 55        | 46        | 117       | 62        | 112       | 82        |
|                            | CS4. | Alfalfa Hay II        | --                         | --        | 60        | 69        | 46        | 105       | 61        | 141       | 70        |
|                            | CS5. | Alfalfa with Oats     | --                         | --        | --        | 103       | 67        | 101       | 65        | 97        | 62        |
|                            | CS5. | Alfalfa Hay           | --                         | --        | --        | 84        | 67        | 107       | 51        | 116       | 53        |
| Pasture:                   | CS6. | Rotational Grazing    | --                         | --        | --        | 91        | 58        | 98        | 90        | 100       | 70        |
| Check:                     |      |                       | 36                         | 26        | 28        | --        | 57        | 108       | 26        | 209       | 158       |

\* staggered start - soil nitrates not tested until after first season in the rotation.

Estimation equations for 3<sup>rd</sup> 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; 3<sup>rd</sup> 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.<sup>1</sup>

**1997 ARS  $Y = 9.07 + 0.709 * 2^d \text{ ft}$**  **n = 1943**  **$r^2 = 0.71$**

1998 - 3<sup>rd</sup> foot samples collected for all repetitions.

<sup>1</sup> 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 XI-B. Fall Nitrates in the top 3-ft of the soil at the LAC: 1990-1998.

| LAKELAND AGRICULTURAL COMPLEX |      |                       |                          |           |           |           |           |           |           |           |           |
|-------------------------------|------|-----------------------|--------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Walworth County               |      |                       | -----lb / 3 ft-acre----- |           |           |           |           |           |           |           |           |
|                               |      | Year:                 | <u>90</u>                | <u>91</u> | <u>92</u> | <u>93</u> | <u>94</u> | <u>95</u> | <u>96</u> | <u>97</u> | <u>98</u> |
| Corn:                         | CS1. | Continuous Corn       | 198                      | 132       | 86        | 134       | 126       | 135       | 160       | 146       | 83        |
|                               | CS2. | Corn after Soybeans   | *--                      | 125       | 78        | 57        | 80        | 146       | 80        | 107       | 73        |
|                               | CS3. | Corn after Red Clover | --                       | --        | 62        | 59        | 117       | 130       | 71        | 130       | 87        |
|                               | CS4. | Corn after Alfalfa    | --                       | --        | --        | 122       | 207       | 209       | 130       | 209       | 137       |
|                               | CS5. | Corn after Alfalfa    | --                       | --        | 81        | 79        | 178       | 160       | 102       | 218       | 109       |
| Soybean:                      | CS2. | Narrow-row Soybeans   | 55                       | 76        | 86        | 98        | 69        | 120       | 68        | 167       | 103       |
|                               | CS3. | Wide-row Soybeans     | 49                       | 34        | 63        | 69        | 97        | 125       | 70        | 137       | 75        |
| Wheat:                        | CS3. | Wheat / Red Clover    | --                       | 49        | 45        | 56        | 61        | 100       | 46        | 106       | 90        |
| Alfalfa:                      | CS4. | Direct-seeded Alfalfa | 34                       | 67        | 41        | 78        | 97        | 118       | 134       | 142       | 89        |
|                               | CS4. | Alfalfa Hay I         | --                       | 71        | 54        | 71        | 86        | 122       | 76        | 140       | 103       |
|                               | CS4. | Alfalfa Hay II        | --                       | --        | 63        | 59        | 93        | 128       | 75        | 152       | 87        |
|                               | CS5. | Alfalfa with Oats     | --                       | --        | --        | 53        | 75        | 131       | 63        | 141       | 85        |
|                               | CS5. | Alfalfa Hay           | --                       | --        | --        | 78        | 79        | 143       | 76        | 108       | 83        |
| Pasture:                      | CS6. | Rotational Grazing    | --                       | --        | --        | 66        | 111       | 125       | 103       | 218       | 146       |
| Check:                        |      |                       | 38                       | 35        | 29        | --        | 78        | 79        | 26        | --        | 72        |

\* staggered start - soil nitrates not tested until after first season in the rotation.

Estimation equations for 3<sup>rd</sup> 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; 3<sup>rd</sup> 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  $Y = 8.49 + 0.635 \cdot 2^d \text{ ft}$   $n = 28$   $r^2 = 0.72$

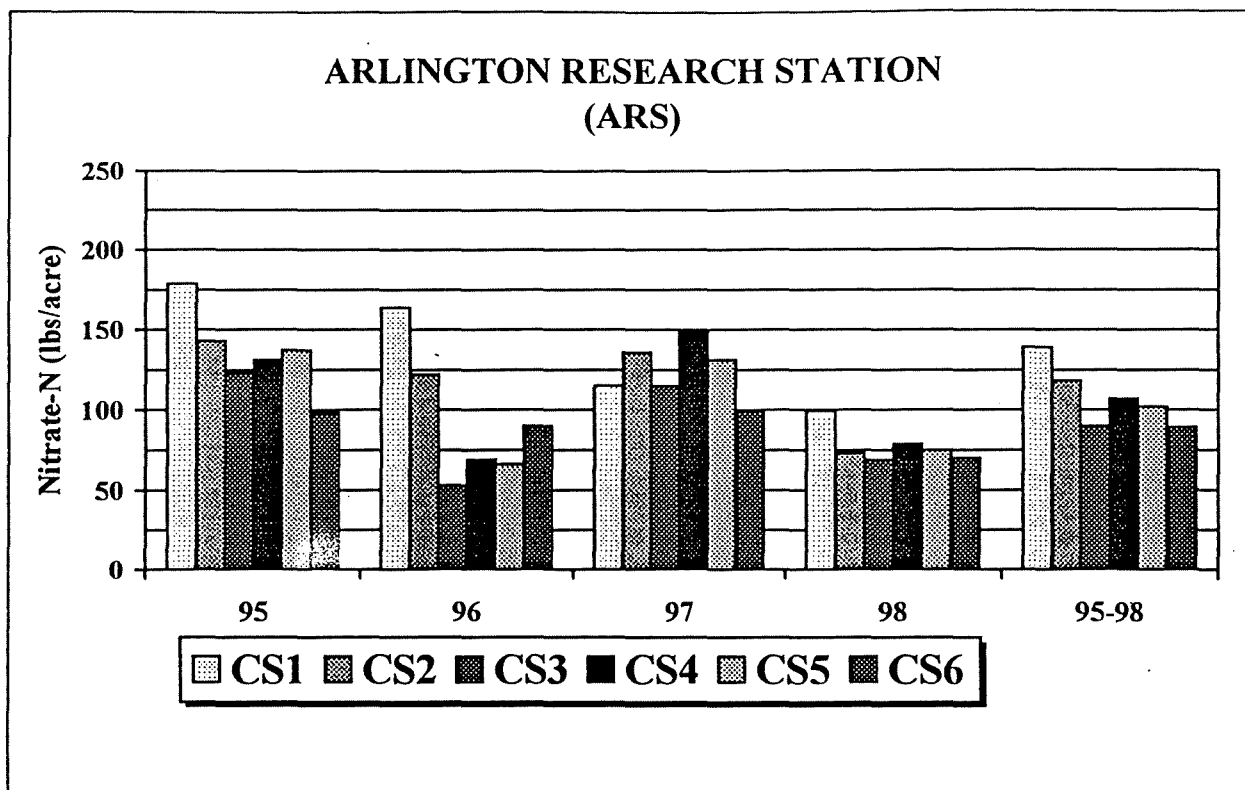
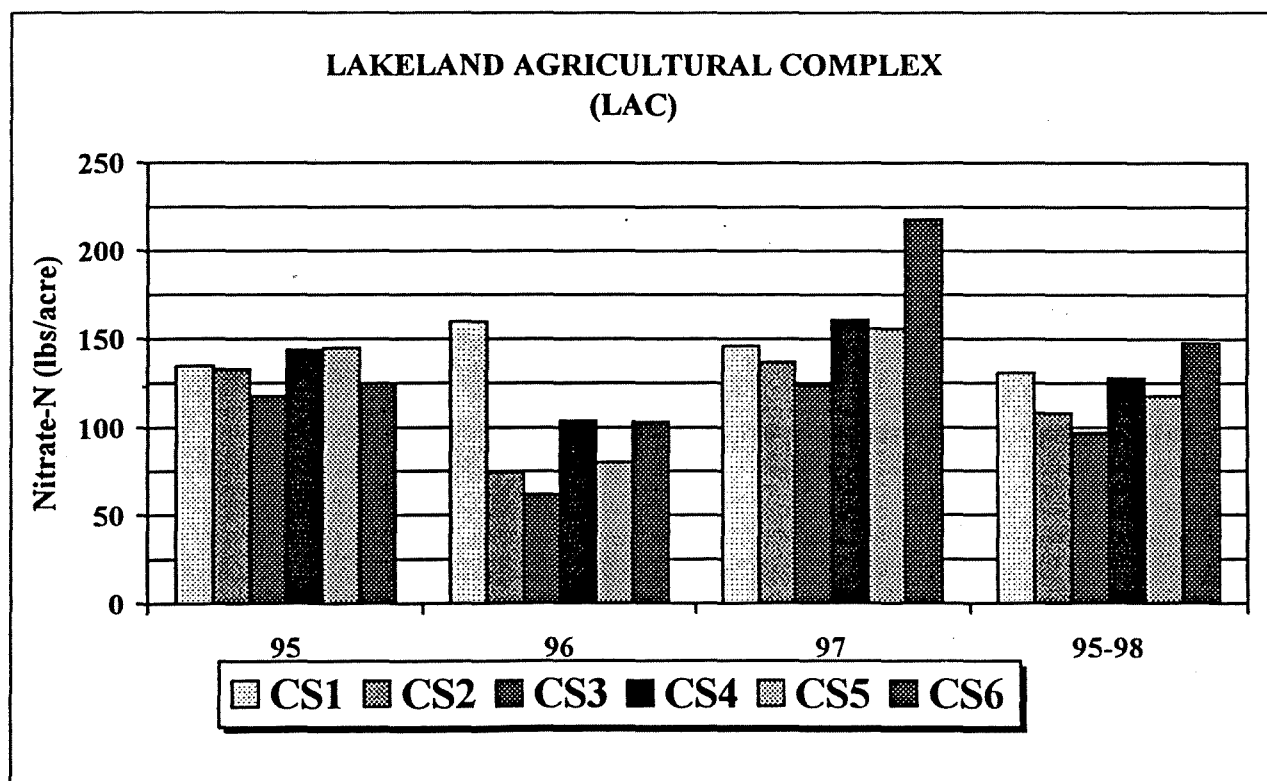
1996 LAC  $Y = 2.93 + 0.467 \cdot 2^d \text{ ft}$   $n = 28$   $r^2 = 0.61$

1997-98 - Used the following regression equation for third foot samples.<sup>1</sup>

1997 and 1998 LAC  $Y = 9.07 + 0.709 \cdot 2^d \text{ ft}$   $n = 1943$   $r^2 = 0.71$

<sup>1</sup> 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 XII. Graphic showing Fall Nitrates in the top 3-ft of the soil at ARS and LAC, 1995 – 1998.



**APPENDIX XIII. Potentially leachable fall nitrate in the 0 – 2 foot soil depth at ARS and LAC (1993 – 1998) with contrasts.**

| Environment:<br>Location:<br>Phase | Env1<br>LAC93                           | Env2<br>AR93 | Env3<br>AR94 | Env4<br>LAC94 | Env5<br>LAC95 | Env6<br>AR95 | Env7<br>AR96 | Env8<br>LAC96 | Env9<br>ARS97 | Env10<br>LAC97 | Env11<br>ARS98 | Env12<br>LAC98 | Average<br>Average |
|------------------------------------|-----------------------------------------|--------------|--------------|---------------|---------------|--------------|--------------|---------------|---------------|----------------|----------------|----------------|--------------------|
|                                    | -----NO <sub>3</sub> -N (lb/2ft-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           | 105.7              |
| 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           | 84.4               |
| 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           | 91.3               |
| 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           | 77.0               |
| CS3. Wh                            | 47.0                                    | 52.7         | 39.0         | 52.0          | 76.4          | 66.4         | 32.2         | 39.2          | 68.1          | 79.3           | 56.1           | 67.0           | 56.3               |
| 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           | 81.5               |
| 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           | 81.6               |
| 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           | 73.2               |
| 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           | 74.5               |
| 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          | 134.1              |
| 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           | 72.7               |
| 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           | 71.8               |
| 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           | 117.3              |
| 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           | 86.0               |
| <b>System</b>                      |                                         |              |              |               |               |              |              |               |               |                |                |                |                    |
| 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           | 105.7              |
| 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           | 87.9               |
| 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           | 71.6               |
| 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           | 90.8               |
| 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           | 87.8               |
| 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           | 86.0               |
| <b>Contrasts:</b>                  | -----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         | 0.1073             |
| 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         | 0.0006             |
| 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         | 0.0131             |
| 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         | 0.6613             |
| 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         | 0.5387             |
| 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         | 0.6108             |
| 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         | 0.2859             |
| Sb vs WhCS3                        | 0.0611                                  | 0.0971       | 0.0908       | 0.8199        | 0.1853        | 0.0011       | 0.0715       | 0.2330        | 0.0467        | 0.2559         | 0.1861         | 0.1804         | 0.7450             |
| 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             |
| 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         | 0.5182             |
| 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         | 0.3727             |
| 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         | 0.0038             |
| 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         | 0.9653             |
| 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         | 0.0056             |
| 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         | 0.8540             |
| Cash vs Fo (noce)                  | 0.3364                                  | 0.4700       | 0.3019       | 0.0006        | 0.0017        | 0.4423       | 0.1410       | 0.0014        | 0.0152        | 0.0043         | 0.2038         | 0.0019         | 0.0077             |
| 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         | 0.0718             |
| 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         | 0.5548             |

**Notes on Appendix XIII.**

1. On average, it appears that the cash-grain and forage systems do not differ in fall nitrate levels. However, CC is the rotation with the highest fall nitrate levels. If we remove CC from the analysis, then the forage rotations have higher fall nitrate levels than the cash grain systems ( $CS2 + CS3 < CS4 + CS5 + CS6$ ).
2. Corn is the “hot” phase in the forage rotation (manure + alfalfa credits) while equivalent to the other phases in CS2 (soybeans) and CS3 (soybeans or wheat/red clover).
3. Fall nitrates under CC (105 lbs/2-ft acre) > CS2 (88 lbs/2-ft acre) and > CS3 (72 lbs/2-ft acre).
4. If we take CC out of the analysis, the pasture system (86 lbs/2-ft acre) is not significantly lower than the other four systems ( $CS2 + CS3 + CS4 + CS5 = CS6$ ).

**Appendix XIV. 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)**

STUTSON, 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:**

STUTE, J.K. 1991. Integrating legume cover crops into cash grain production systems. M.Sc. Thesis. Agronomy Dept. University of Wisconsin-Madison.

**1992****Abstracts:**

BALDOCK, J.O. and J.L. POSNER. 1992. Crop rotations option program: computer aid to evaluating alternative cropping systems. American Society of Agronomy meetings. Minneapolis, MN. Nov. 1-6. Agronomy Abstracts p. 78.

GARLYND, M.J., A.V. KURAKOV, P.A. PORTER, and R.F. HARRIS. 1992. Descriptive and analytical characterization of soil quality/health. American Society of Agronomy meetings. Minneapolis, MN. Nov. 1-6. Agronomy Abstracts p. 257.

HARRIS, R.F. and D.F. BEZDICEK. 1992. Descriptive aspects of soil quality. Invited presentation in the symposium on "Defining soil quality for a sustainable environment. American Society of Agronomy meetings. Minneapolis, MN. Nov. 1-6. Agronomy Abstracts. p. 258.

HARRIS, R.F., M.J. GARLYND, P.A. PORTER, and A.V. KURAKOV. 1992. Farmer/Institution partnership in developing a soil quality/health report card. Participatory On-Farm Research and Education for Agricultural Sustainability. University of Illinois, Urbana-Champaign, IL. p. 223.

IRAGAVARAPU, T.K., J.L. POSNER, and G.D. BUBENZER. 1992. Using bromide to study water percolation and solute transit times under different crops. American Society of Agronomy meetings. Minneapolis, MN. Nov. 1-6. Agronomy Abstracts p. 327.

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