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## PROLOGUE

This is the fourth 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 four production years (1990, 1991, 1992, and 1993). In this report we discuss the results of the fifth year of field trials (1994). This is the second time we have had all the phases of the six rotations running concurrently, permitting us to again compare all the systems. We have also included research results of satellite trials conducted both on-farm and adjacent to the WICST core trials.

The project continues to benefit from farmer input, the institutional support of the College of Agriculture, the Wisconsin Extension Service, the Michael Fields Agricultural Institute, the Walworth County Board of Supervisors and the Kellogg Foundation. But most importantly, the project is gaining support from the agricultural community. Field days are well attended, various groups have toured the sites, additional faculty are setting up research plots at the Learning Centers, and a growing number of school children are coming to the sites for guided tours. In addition, results from the Learning Centers are beginning to appear in print (Appendix I). We are beginning to fulfill our underlying objective of serving as a forum for the open discussion of what directions Wisconsin agriculture should take in the 21st Century.

Summer, 1995

|                |                                                      |
|----------------|------------------------------------------------------|
| Jon Baldock    | Agricultural and Statistical Consulting              |
| Lee Cunningham | UW-Extension, Walworth County                        |
| Jerry Doll     | UW Agronomy Department                               |
| Lee Gross      | UW-Extension, Dane County                            |
| John Hall      | Michael Fields Agricultural Institute                |
| Dwight Mueller | Assistant Superintendent, Arlington Research Station |
| Tom Mulder     | Project Manager                                      |
| Josh Posner    | UW Agronomy Department                               |
| Sara Steele    | UW Continuing and Vocational Education               |
| Ray Saxby      | UW-Extension, Columbia County                        |
| Alan Wood      | Superintendent, Lakeland Agricultural Complex        |

We acknowledge with thanks the contributions to this project of those who assisted the two superintendents in managing the crops and animals - Darwin Frye, Paul Bergum, Bob Elderbrook, and Sandy Trower at Arlington and Jim Braatz at Lakeland.

## INTRODUCTION

In the fall of 1988 a group consisting of faculty from the College of Agriculture and 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 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. 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, the hypothesis developed was 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.

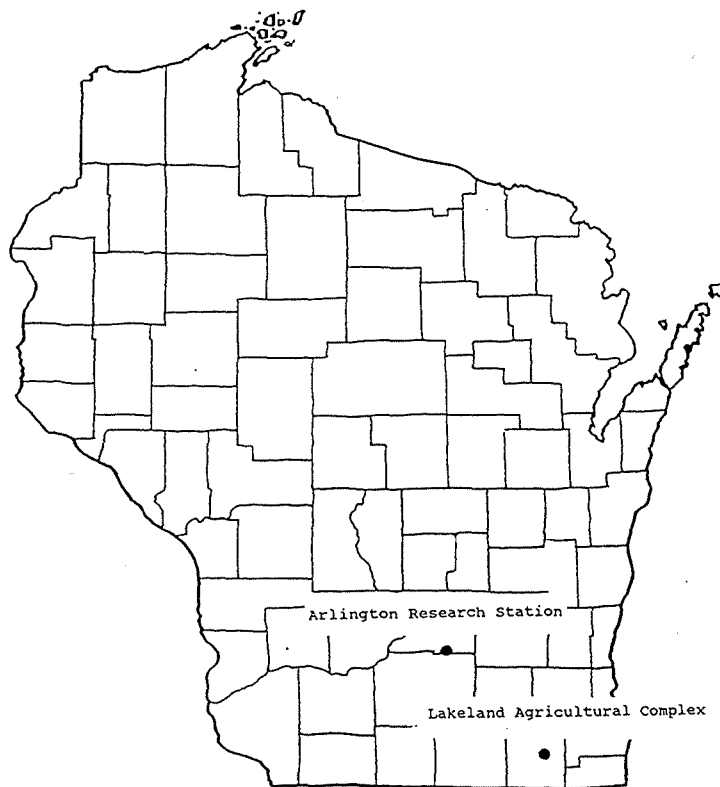
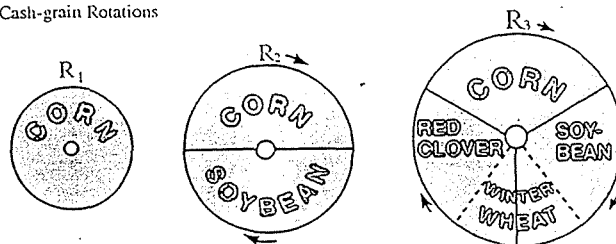
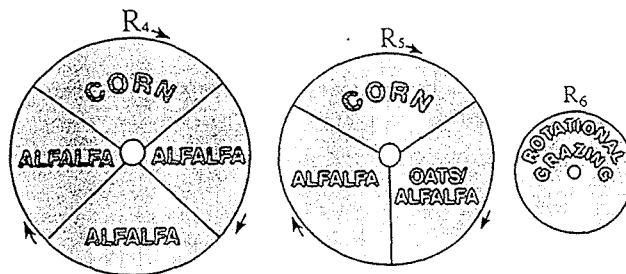


Figure 1. Outline of Major Land Resource Area 95B and Two Sites of the Wisconsin Integrated Cropping Systems Trial

Cash-grain Rotations



Forage-based Rotations



\*Area within the circle is proportional to the length of the rotation

Figure 2. Schematic Drawing of the Rotations in the Wisconsin Integrated Cropping Systems Trial

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

| 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 |
|--------------------------------------------------------------|-----------------------------------|--------------------------------------------------------|---------------------------------------------|-------------------------------------------|----------------------------------------|------------------------|--------------------------------------------------------------------|---------------------|--------------------------------|
|                                                              |                                   |                                                        |                                             |                                           |                                        | Fert N on corn<br>lb/a | Herbicide<br>Al/a                                                  | Insecticide<br>Al/a |                                |
| R <sub>1</sub><br>Cont. Corn                                 | 150 bu                            | 15,780                                                 | 2369                                        | 6.0                                       | 140                                    | 150                    | Atrazine 2 lb<br>Alachlor 2 lb                                     | Counter 1.4 lb      | 4.1                            |
| R <sub>2</sub><br>drilled soybean<br>corn                    | 55 bu<br>160 bu                   | 12,510                                                 | 1788                                        | 6.9                                       | 104                                    | 110                    | Bladex 2.5 lb<br>Alachlor 2.5 lb<br>Sencor .5 lb<br>Treflan 1.5 lb | 0                   | 4.0                            |
| R <sub>3</sub><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                            |
| R <sub>4</sub><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                            |
| R <sub>5</sub><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                            |
| R <sub>6</sub><br>rotational<br>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.

## I. YIELDS, WEATHER AND AGRONOMIC CALENDAR IN 1994

A. Wood\*, D. Mueller\*, T. Mulder\*\*, and J. Posner\*\*

Southern Wisconsin growing conditions were nearly perfect in 1994 and corn yields were the best since the beginning of the project. Statewide, only 1% of the winter wheat and 8% of the alfalfa acreages were damaged by winterkill (Wisconsin Crop Weather, Dec 8, 1994). Winter wheat and alfalfa at both sites overwintered well. Warmer and dryer than normal weather during April and May (see Table 2) allowed timely tillage and planting of crops. Crops were beginning to show signs of drought stress but recovered with the return of normal (Lakeland) and above average (Arlington) rainfall patterns in late June and grew well during a period of above average June and July temperatures (see Figure 3). Although good for crop growth, frequent rain showers during July and August made hay, wheat and oat harvest difficult. Harvesting of corn and soybean was aided by dry and sunny fall weather. Corn yields were excellent, wheat yields very good, and soybean and forage yields were average.

### A. Corn Phases:

Corn harvest moisture has been higher than desired the past two years, therefore the choice was made to choose shorter season corn varieties. The variety used in the R1, R2 and R4 systems was changed from a 109 day RM (Relative Maturity) to a 103day RM (Pioneer 3563) and the later planted R3 and R5 variety was changed from a 103day RM to 97day RM (Pioneer 3751). The earlier planted corn treatments with herbicides were planted at 32,000 seeds/a while the later plantings with mechanical weed control were planted at 34,000 seeds/a to compensate for loss by rotary hoeing. Corn planting dates at Arlington (ARS) were April 25 and May 5 while plantings at Lakeland (LAC) were all on May 4. Starter fertilizer and nitrogen additions followed the original protocol with deep nitrate soil test recommendations of 120 (ARS) and 70 (LAC) lb/a N. At ARS weeds were chemically managed in R1 and R2 corn with a pre-emergence application of Dual and a post-emergence application of Buctril and in R4 with Buctril alone. At LAC system R1 received Extrazine and Dual and a later application of Accent and Buctril to control common lambsquarters that were later tested and determined to be triazine resistant. System R2 at LAC received a Roundup burndown followed by Dual and R4 received Dual and Buctril. Mechanical weed control in R3 corn at LAC was accomplished with two rotary hoeings and two cultivations while the corn following alfalfa (R5) received a single rotary hoe pass followed by two cultivations. At ARS, the rotary hoe was used twice in each of these systems followed by four cultivations. Weed control was very good in the R5 and good in the R3 systems at both sites. Thistles which were more of a problem in the cash-grain than dairy systems and were more serious at LAC than ARS in 1994 were spot treated using Stinger. The decision was made in the spring by both county committees to not include the outside six rows of each corn plot when taking harvest weights. This was done to negate edge effect and it also allowed conducting small trials in these same rows. These rows were used to compare effect of starter and nitrogen fertilizer on R3 corn yield at ARS and at both sites to determine if an herbicide application would increase economic returns.

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\* Superintendents of the Lakeland Agricultural Complex and Arlington Research Station respectively.

\*\* Project manager and research coordinator of the Wisconsin Integrated Cropping Systems Trial.

## **B. Soybean Phases:**

Kaltenberg 241 (Maturity Class 2.4) was used at both sites for the R2 drilled beans and planted on May 3 (ARS) and May 6 (LAC). The R3 row beans were planted May 5 (ARS) and May 6 (LAC) with an earlier maturing Northrup King 1990 (Maturity Class 1.9) since wheat would be sequentially seeded on these plots. R2 drilled soybean plant population was low at ARS and the herbicide treatment of Pursuit and Pinnacle during dry weather appeared to damage the soybeans more than the weeds. Therefore the decision was made to replant June 15 using Kaltenberg 142 (Maturity Class 1.4) and later apply Reflex for weed control. Chemical weed control in the R2 drilled beans at LAC consisted of a burndown with Roundup followed by Pinnacle and Assure. In the R3 row beans, mechanical weed control consisted of two rotary hoeings and four cultivations at ARS and three rotary hoeings and three cultivations at LAC. R3 soybean yields were again reduced by poor weed control. As in the corn plots the outer six rows of the wide row soybeans were not included in harvest weights. Small trials were done at both sites to determine effect of herbicide applications on economic returns.

## **C. Wheat/red clover Phase:**

Wheat was planted mid-October following soybean harvest and a light tillage at both sites in September 1993. Red clover was frost seeded in mid-March (LAC) and early April (ARS) 1994. Although fall planting was late and wheat appeared stressed by the early summer dry weather, yields were very good. The red clover stand at LAC was very good while clover germination was very poor at ARS and the decision was made to plant hairy vetch following wheat harvest. The plots were fall undercut using a chisel plow with sweeps to facilitate corn seed bed preparation in the spring 1995.

## **D. Forage Phases:**

New seedings were put in on April 11 at LAC and April 18 at ARS. Forage from the R4 seeding was cut three times at both sites but one of the cuts at LAC was damaged by rain and chopped back into the field. Since weeds would have hampered grain harvest, the R5 oats were harvested as oatlage at both sites followed by a single harvest of alfalfa.

Reseeding of the established hay plots was not necessary in 1994. Although the R4 third year alfalfa had some winterkill damage from the previous winter, yields did not appear to be much lower than the second year alfalfa. Forage was cut four times at both sites but there were only three harvests at LAC since the August cut was damaged by rain and chopped back into the field. While the final cut was taken the end of August at ARS it was taken at mid-September at LAC. At ARS the final R5 harvest was taken the end of September to increase yield since it would be rotated to corn the next year and winter survival was not a concern. These plots were later chiseled plowed with sweeps. At ARS Roundup was fall applied to the R4 second year alfalfa in preparation for the following corn crop and later chisel plowed. Because of previous success with alfalfa kill by chisel plowing with sweeps, at LAC both R4 and R5 alfalfa plots to be planted to corn were fall chisel plowed. Prior to chisel plowing, manure was spread on all these plots at both sites as well as on R4 and R5 corn treatments scheduled for oats and alfalfa in 1995.

Grazing animals at ARS were not able to keep up with the early pasture growth and excess forage was mechanically harvested. Cattle were removed from the pastures at ARS the end of August when there was no longer adequate forage for grazing. Pastures regrew well with warm sunny September weather and this regrowth was later harvested mechanically. The agronomic diary and commentary by the farm superintendent for the Arlington site are in Appendix II and for the Lakeland site in Appendix III.

**Table 2. Growing season rainfall (inches) at the Wisconsin Integrated Cropping Systems Trial Sites.**

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

| <u>Month</u>               | <u>1994</u> | <u>1993</u> | <u>1992</u> | <u>30-yr avg<br/>1959-1988</u> |
|----------------------------|-------------|-------------|-------------|--------------------------------|
| April                      | 2.28(-0.71) | 7.06(+4.07) | 3.96(+0.97) | 2.99                           |
| May                        | 1.99(-1.20) | 4.52(+1.33) | 1.22(-2.97) | 3.19                           |
| June                       | 7.93(+4.13) | 6.10(+2.30) | 1.19(-2.61) | 3.80                           |
| July                       | 6.08(+2.62) | 9.40(+5.94) | 5.80(+2.34) | 3.46                           |
| August                     | 4.03(+0.14) | 3.20(-0.69) | 1.91(-1.98) | 3.89                           |
| September                  | 4.65(+0.42) | 4.20(-0.03) | 7.46(+3.23) | 4.23                           |
| Growing<br>Season<br>Total | 26.96       | 34.48       | 21.54       | 21.56                          |
| Yearly<br>Total            | 33.99       | 34.43       | 35.33       | 31.14                          |

**b. Lakeland Agricultural Complex**

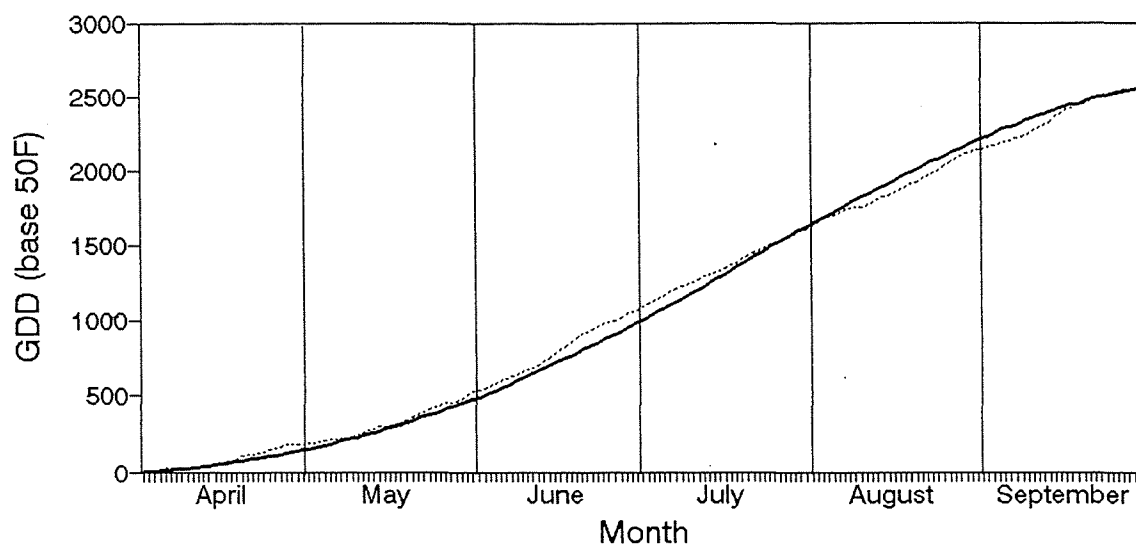
| <u>Month</u>                 | <u>1994<sup>2</sup></u> | <u>1993<sup>2</sup></u> | <u>1992<sup>2</sup></u> | <u>30-yr avg<br/>1959-1988<sup>3</sup></u> |
|------------------------------|-------------------------|-------------------------|-------------------------|--------------------------------------------|
| April                        | 2.50(-1.30)             | 5.55(+1.75)             | 2.21(-1.59)             | 3.80                                       |
| May                          | 0.62(-2.64)             | 1.90(-1.36)             | 0.50(-2.76)             | 3.26                                       |
| June                         | 3.81(-0.12)             | 8.50(+4.57)             | 1.35(-2.58)             | 3.93                                       |
| July                         | 3.28(-1.07)             | 4.35(+0.00)             | 7.18(+2.83)             | 4.35                                       |
| August                       | 2.68(-1.33)             | 2.80(-1.21)             | 2.60(-1.41)             | 4.01                                       |
| September                    | 1.82(-2.24)             | 3.59(-0.47)             | 4.43(+0.37)             | 4.06                                       |
| Growing<br>Season<br>Total   | 14.71                   | 26.69                   | 18.27                   | 23.41                                      |
| Yearly<br>Total <sup>3</sup> | 21.19                   | 34.10                   | 31.58                   | 37.53                                      |

<sup>1</sup>Data from Arlington National Weather Service Cooperative station.

<sup>2</sup>Data from Lakeland Ag. Complex Automated Weather Station.

<sup>3</sup>Data from Lake Geneva National Weather Service Cooperative station (7 miles southeast of the Lakeland Ag. Complex).

## a. Arlington Agricultural Research Station



## b. Lakeland Agricultural Complex

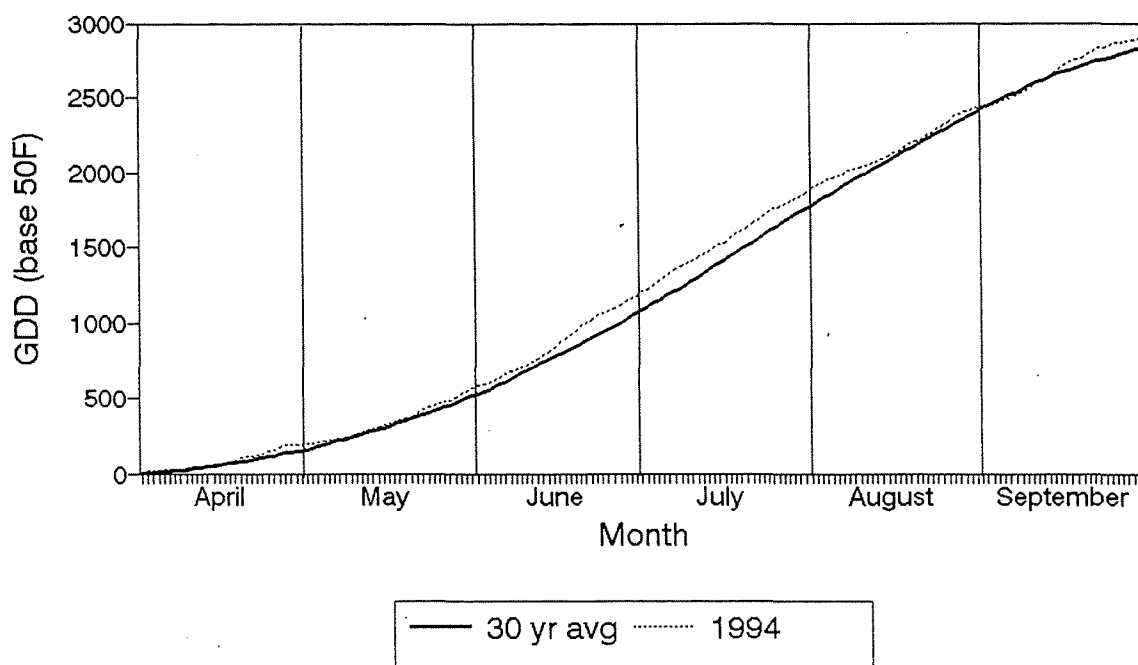


**Figure 3. Cumulative corn growing degree days for the two WICST sites**

\*  $GGD = (Daily\ Maximum\ (86^{\circ}) + Daily\ Minimum\ (50^{\circ}))/2 - 50^{\circ}$ ; where  $86^{\circ}$  is used if the Maximum exceeds  $86^{\circ}$  and  $50^{\circ}$  is used if the Minimum falls below  $50^{\circ}$ .

**Table 3. Yield Results for the Wisconsin Integrated Cropping Systems Trial (1990 - 1994)****a. Arlington Agricultural Research Station**

| Corn <sup>1</sup>                      | 1990                            | 1991              | 1992              | 1993              | 1994 <sup>2</sup> |
|----------------------------------------|---------------------------------|-------------------|-------------------|-------------------|-------------------|
|                                        | ----- bu/acre -----             |                   |                   |                   |                   |
| R <sub>1</sub> - Continuous corn       | 166.2                           | 160.0             | 144.0             | 123.7             | 178.1             |
| R <sub>2</sub> - Corn after soybean    | -                               | 185.7             | 150.1             | 129.8             | 190.2             |
| R <sub>3</sub> - Corn after red clover | -                               | -                 | 99.2              | 87.1              | 188.4             |
| R <sub>4</sub> - Corn after alfalfa    | -                               | -                 | -                 | 165.1             | 196.5             |
| R <sub>5</sub> - Corn after alfalfa    | -                               | -                 | 112.0             | 119.1             | 198.8             |
| LSD (P<0.05)                           | -                               | 4.0               | 12.6              | 7.4               | 9.9               |
| Soybean                                | 1990                            | 1991              | 1992              | 1993              | 1994              |
|                                        | ----- bu/acre -----             |                   |                   |                   |                   |
| R <sub>2</sub> - Drilled soybean       | 56.5                            | 58.5              | 30.1              | 52.8              | 42.7 <sup>3</sup> |
| R <sub>3</sub> - Row soybean           | 52.1                            | 49.2              | 38.0              | 53.3              | 44.4              |
| LSD (P<0.05)                           | NS                              | 6.1               | NS                | NS                | NS                |
| Wheat                                  | 1990                            | 1991              | 1992              | 1993              | 1994              |
|                                        | ----- bu/acre -----             |                   |                   |                   |                   |
| R <sub>3</sub> - Wheat                 | -                               | 63.6              | 45.2              | 28.6              | 60.9              |
| Seeded Alfalfa                         | 1990                            | 1991              | 1992              | 1993              | 1994              |
|                                        | ----- ton dry matter/acre ----- |                   |                   |                   |                   |
| R <sub>4</sub> - Direct seeded         | 4.27                            | 4.94              | 3.59              | 3.27              | 3.21              |
| R <sub>5</sub> - Oats/alfalfa          | 3.93 <sup>4</sup>               | 3.12 <sup>5</sup> | 2.63 <sup>4</sup> | 2.38 <sup>5</sup> | 3.37 <sup>4</sup> |
| LSD (P<0.05)                           | NS                              | 0.36              | 0.49              | 0.51              | NS                |
| Established Forage                     | 1990                            | 1991              | 1992              | 1993              | 1994              |
|                                        | ----- ton dry matter/acre ----- |                   |                   |                   |                   |
| R <sub>4</sub> - Hay I                 | -                               | 5.86              | 3.46              | 3.70              | 4.56              |
| R <sub>5</sub> - Hay I                 | -                               | 5.86              | 5.17              | 4.65              | 5.30              |
| R <sub>4</sub> - Hay II                | -                               | -                 | 3.99              | 3.25              | 3.68              |
| R <sub>6</sub> - Pasture               | 4.15                            | 4.70              | 2.81              | <sup>6</sup>      | <sup>6</sup>      |
| LSD (P<0.05)                           | -                               | 0.44              | 1.20              | 1.15              | 0.36              |

<sup>1</sup> Variety P 3563(103 day RM) in rotations 1,2, and 4 and P3751(97 day RM) in rotations 3 and 5.<sup>2</sup> Harvest moistures of corn in 1994 were R1: 26.4%, R2: 27.9%, R3: 27.2%, R4: 24.8%, and R5: 26.7%.<sup>3</sup> Soybeans replanted June 15 due to severe herbicide damage to soybeans and poor weed control.<sup>4</sup> Oats harvested as oatlage followed by one alfalfa harvest.<sup>5</sup> Oats harvested as grain (grain and straw converted to tons of dry matter per acre).<sup>6</sup> Intensive rotational grazing of heifers - 685 lb average weight gain/acre + 0.4 ton hay/acre with 1,386 lb supplemental grain/acre -1993, 549 lb average weight gain/acre + 2.16 ton hay/acre with 586 lb supplemental grain/acre -1994.

**Table 3. Yield Results (continued)****b. Lakeland Agricultural Complex**

| Corn <sup>1</sup>                      | 1990                            | 1991              | 1992              | 1993                | 1994 <sup>2</sup> |
|----------------------------------------|---------------------------------|-------------------|-------------------|---------------------|-------------------|
|                                        | ----- bu/acre -----             |                   |                   |                     |                   |
| R <sub>1</sub> - Continuous corn       | 165.5                           | 121.2             | 119.0             | 99.7                | 177.0             |
| R <sub>2</sub> - Corn after soybean    | -                               | 144.7             | 126.2             | 101.2               | 184.4             |
| R <sub>3</sub> - Corn after red clover | -                               | -                 | 73.0              | 77.7                | 187.0             |
| R <sub>4</sub> - Corn after alfalfa    | -                               | -                 | -                 | 113.3               | 211.3             |
| R <sub>5</sub> - Corn after alfalfa    | -                               | -                 | 101.7             | 80.6                | 198.3             |
| LSD (P<0.05)                           | -                               | 13.1              | 16.9              | 22.2                | 7.7               |
| Soybean                                | 1990                            | 1991              | 1992              | 1993                | 1994              |
|                                        | ----- bu/acre -----             |                   |                   |                     |                   |
| R <sub>2</sub> - Drilled soybean       | 58.3                            | 52.9              | 46.9              | 49.0                | 63.1              |
| R <sub>3</sub> - Row soybean           | 51.3                            | 54.5              | 51.9              | 32.3                | 47.4              |
| LSD (P<0.05)                           | 4.7                             | NS                | NS                | 12.7                | 2.3               |
| Wheat                                  | 1990                            | 1991              | 1992              | 1993                | 1994              |
|                                        | ----- bu/acre -----             |                   |                   |                     |                   |
| R <sub>3</sub> - Wheat                 | -                               | 32.1              | 25.7              | 22.3                | 50.9              |
| Seeded Alfalfa                         | 1990                            | 1991              | 1992              | 1993                | 1994              |
|                                        | ----- ton dry matter/acre ----- |                   |                   |                     |                   |
| R <sub>4</sub> - Direct seeded         | 0                               | 0.46              | 1.11              | 2.01 <sup>3</sup>   | 2.37 <sup>4</sup> |
| R <sub>5</sub> - Oats/alfalfa          | 0.89 <sup>5</sup>               | 2.47 <sup>6</sup> | 3.03 <sup>5</sup> | 1.67 <sup>6,7</sup> | 3.49 <sup>6</sup> |
| LSD (P<0.05)                           | 0.55                            | 0.63              | 1.02              | NS                  | 0.54              |
| Established Forage                     | 1990                            | 1991              | 1992              | 1993                | 1994              |
|                                        | ----- ton dry matter/acre ----- |                   |                   |                     |                   |
| R <sub>4</sub> - Hay I                 | -                               | 3.88              | 3.65              | 2.87                | 4.12 <sup>4</sup> |
| R <sub>5</sub> - Hay I                 | -                               | 3.49              | 3.54              | 3.37                | 3.82 <sup>4</sup> |
| R <sub>4</sub> - Hay II                | -                               | -                 | 3.57              | 2.61                | 4.05 <sup>4</sup> |
| R <sub>6</sub> - Pasture               | 0                               | 3.39              | <sup>8</sup>      | <sup>8</sup>        | <sup>8</sup>      |
| LSD (P<0.05)                           | -                               | NS                | NS                | NS                  | NS                |

<sup>1</sup> Variety P 3563(103 day RM) in rotations 1,2, and 4 and P3751(97 day RM) in rotations 3 and 5.

<sup>2</sup> Harvest moistures of corn in 1994 were R1: 18.6%, R2: 19.3%, R3: 17.9%, R4: 18.4%, R5: 16.9%.

<sup>3</sup> Only one harvest; yield from 1 of 4 reps (3 reps ruined by rain and chopped onto field).

<sup>4</sup> August cutting ruined by rain and chopped onto field.

<sup>5</sup> Oats harvested as grain (grain and straw converted to ton of dry matter per acre).

<sup>6</sup> Oats harvested as oatlage followed by one alfalfa harvest.

<sup>7</sup> Alfalfa yield was avg. from 3 of the 4 reps (1 rep ruined by rain and chopped onto field).

<sup>8</sup> Intensive rotational grazing of heifers - 918 lb average weight gain/acre -1992, 727 lb average weight gain/acre with supplementation of 512 lb grain and 102 lb hay/acre -1993, 850 lb average weight gain/acre with supplementation of 355 lb hay/acre - 1994.

## II. SOIL HEALTH AND SOIL LIFE

### A. Descriptive and Analytical Characterization of Soil Health and Quality for the Wisconsin Integrated Cropping Systems Trial

R.F. Harris, M.J. Garlynd, and D.E. Romig\*

#### Introduction

The project objective was to track the effect on soil health and quality of a shift from continuous corn to other WICST cropping systems during the initial period of 3-5 years following the shift. Because of the conceptual newness and related sparsity of guidelines and methodology in the soil health and quality area, the project has also involved development of new and refinement of existing descriptive and analytical tools for characterizing soil health and quality. Farmers tend to prefer the term soil health and favor qualitative, descriptive soil, plant, water, and animal/human properties to characterize healthy and unhealthy soil (Harris, 1992; Harris et al., 1992; Harris and Bezdicek, 1994; Romig et al., 1995, 1996). Scientists prefer the term soil quality and use quantitative, analytical soil properties for its characterization, although guidelines for assessing soil quality are still evolving (Doran and Parkin, 1994; Harris et al., 1994; Harris and Karlen, 1996). We use the terms soil health and quality interchangeably, with soil quality being the preferred term for generic use, and soil health reserved for discussion of the Wisconsin Soil Health Report Card. The current definition of soil quality is (Karlen et al., 1996; Harris and Karlen, 1996): "Soil quality is the fitness of a specific soil to function, within its capacity, and within natural and managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation".

The Wisconsin Integrated Cropping Systems Trial has played a key role in assessment, organization and use of farmer knowledge to develop a field tool, the Wisconsin Soil Health Scorecard (Appendix X), for characterizing and monitoring soil health by farmers and scientists. As described earlier (Harris et al., 1994) and in more detail in Romig et al. (1995, 1996), the Wisconsin Soil Health Scorecard was developed from structured interviews with 28 outside auditors of WICST focussing on how they recognize healthy and unhealthy soil. A major conceptual difference between the soil health properties in the Scorecard and the analytical soil quality properties measured by scientists is that integrated into the former are value judgements on the connection of the properties to soil health, whereas the connection of the analytical properties to soil quality requires additional subjective decision making (Karlen and Stott, 1994; Garlynd et al., 1994; Harris et al., 1994; Harris and Karlen, 1996).

This report focusses on the effect on soil quality of the shift from continuous corn to other WICST cropping systems at the end (1994) of the 3-5 years following the shift (Garlynd et al., 1995). The cropping systems evaluated were: continuous corn as compared to the corn phases of a soybean-corn, soybean-(wheat and red clover)-corn, (oats and alfalfa)-corn rotation, and a continuous pasture system. Year-integrated descriptive indicators of soil health were obtained using the Wisconsin Soil Health Scorecard. Spring, summer, and fall soil samples were analyzed for inorganic chemical

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\* Professor and Graduate Students, Dept. of Soil Science, Univ. of Wisconsin, Madison, respectively.

(ammonium, nitrate, available P and K), physical (bulk density, texture, water stable aggregates) and biotic (organic matter, microbial biomass C, labile C, dehydrogenase, and arginine hydrolysis) indicators of soil quality. The data were interpreted in accordance with the integrated framework for assessing soil quality described by Harris and Karlen (1996).

## **Materials and Methods**

### Cropping Systems

The WICST cropping systems evaluated for soil health and quality in 1994 were the Continuous Corn (CC) system (Rotation R1), as compared (in decreasing order of synthetic input) to the corn phases of the Soybean-Corn (Rotation R2), Oats & Alfalfa-Corn (Rotation R5), and Soybean-Wheat & Red Clover-Corn (Rotation R3) systems, and the Continuous Pasture system (Rotation R6); time scales for the shift from continuous corn were 3 years for R2, R3 and R5; and 5 years for R6. Both Arlington and Lakeland sites were evaluated. Replication involved three randomized plots for each cropping system; see Table 5 footnote for details.

### Soil Health Assessment

Soil health was measured using the Wisconsin Soil Health Scorecard (Romig et al., 1996; Appendix X). Direct soil descriptive properties such as structure, color, earthworms, surface crust and hardness were assessed by field technicians in the appropriate season during routine soil sampling. In the fall, the field operator at each site was asked to complete the Wisconsin Soil Health Scorecard, relying on their experience with the WICST plots to gauge the integrated soil properties (infiltration, water retention, drainage etc.) and non-soil target system properties (plant, animal, and water). The field operators were asked to recall and generalize how all three plots of a particular rotation behaved, noting any individual plots that deviated from the general behavior of the rotation. Scores concerning organic matter and pH are based on ranges of analytical measurements (Romig et al., 1996). Scorecard questions that were not responded to by the field operator or questions not appropriate for the particular rotation, such as tillage ease for the permanent pasture rotation, were left blank. Averages of three plots in each rotation were calculated for each indicator property.

The Wisconsin Soil Health Scorecard is a tool for assessment of the soil health status of a cropping system according to farmer criteria by evaluating indicator properties and examining their distribution within the three categories of health: healthy (3-4 points), impaired (1.5-2.5 points), and unhealthy (0-1 points). Ideally, one would prefer to see all of the properties score in the health category. Even if 90% or more of the indicators scored are healthy, the soil may still have serious problems with the remaining properties. For indicators either in the impaired and unhealthy categories, careful consideration is necessary to identify what caused the property to be in a less-than-optimum condition. Impaired indicator properties should be closely monitored over time to determine whether they are deteriorating or improving. Unhealthy properties need immediate attention and corrective action.

Limitations in the design and application of the Soil Health Scorecard as a research tool should be recognized. First, the scale on which the scorecard was constructed does not readily lend itself to typical statistical procedures, since many properties are measured

on an ordinal scale from worst case to best, instead of an interval level of measurement. Therefore, it's difficult to discern through statistical means the significant difference between treatments. A second limitation of the scorecard data results from the difficulty field operators had judging integrated properties. The use of field operators to score properties pertaining to year integrated observations creates a situation that brings up several reservations about using the Scorecard at the WICST. Field operators were asked to evaluate 15 plots of 5 different rotations over the entire growing season for 15 indicator properties. With such a difficult task of recalling so many details the sensitivity and level of scrutiny of their observations may not be optimum. In addition, the resiliency and uniformity of soils in research plots at both sites would limit level of discretion for improvement. They are high quality soils to begin with, inherently well suited to crop production. Furthermore, field operators only had a limited opportunity to become familiar with the individual descriptive indicators of the Wisconsin Soil Health Scorecard prior to its use in the field.

### Soil Quality Assessment

Spring 1994 samples were collected before tillage or planting on April 28 at Lakeland Agricultural Complex (LAC), and following chisel plowing and planting on April 27 at Arlington Research Station (ARS). Summer samples were taken on July 28 (LAC) and July 29 (ARS). Fall samples were collected at ARS on October 28 after corn senescence, but before corn grain harvest, and after corn harvest at LAC also on October 28. Sampling was done before any manure application at both sites.

The sampling procedure was as described previously (Harris et al., 1993, 1994). Samples were collected from blocks 1-3, examining 3 plots for each rotation under observation. Each plot had three 16m x 16m sampling stations established in them evenly spaced along their length. Each station was divided into a grid of sixteen 4m<sup>2</sup> substations. Two 3/4" cores from the plow layer (0-15cm) were collected from each substation. The cores from each plot were combined for a bulk sample consisting of 48 cores. This bulk sample represented one replicate for that respective rotation. Large cores (3" dia) were taken with a Uhlen sampler in spring and fall for measuring bulk density and porosity.

The rationale for the analytical methods can be found in the WICST third annual report (Harris et al., 1994). From a methodology standpoint, nitrate and ammonium nitrogen, organic matter, pH, extractable phosphorous, exchangeable Ca, Mg, and K, particle size distribution, and electrical conductivity were conducted at the UW Soil and Plant Test Laboratory in Madison (Schulte et al. 1987). Bulk density and total porosity were determined using the core method (Blake and Hartge, 1986; Danielson and Sutherland, 1986). Aggregate water stability was determined using the wet sieve method (Kemper and Rosenau, 1986). Biological activity in the soil was evaluated as: microbial biomass, labile organic carbon, arginine ammonification, and dehydrogenase activity. Microbial biomass was estimated by the fumigation incubation method (Jenkinson and Powlson, 1976): Fifty grams of 5mm sieved soil was preincubated for 4 days followed by a 24 hour fumigation; fumigated and unfumigated soils were then incubated for 10 days at 25°C; a K-value of 0.45 was used for conversion to microbial biomass. Labile carbon was measured by evolution of CO<sub>2</sub> during incubation of 50 grams of 5mm sieved moist soil at 25°C over a period of 14 days; CO<sub>2</sub> was trapped by 0.5 N NaOH and measured by Technicon Autoanalyzer II. Arginine ammonification was measured by a slightly modified standard procedure (centrifugation of KCl-soil extract was replaced by filtration) (Alef and

Kleiner, 1986). Dehydrogenase activity of soil was measured using the standard method (Casida et al., 1964).

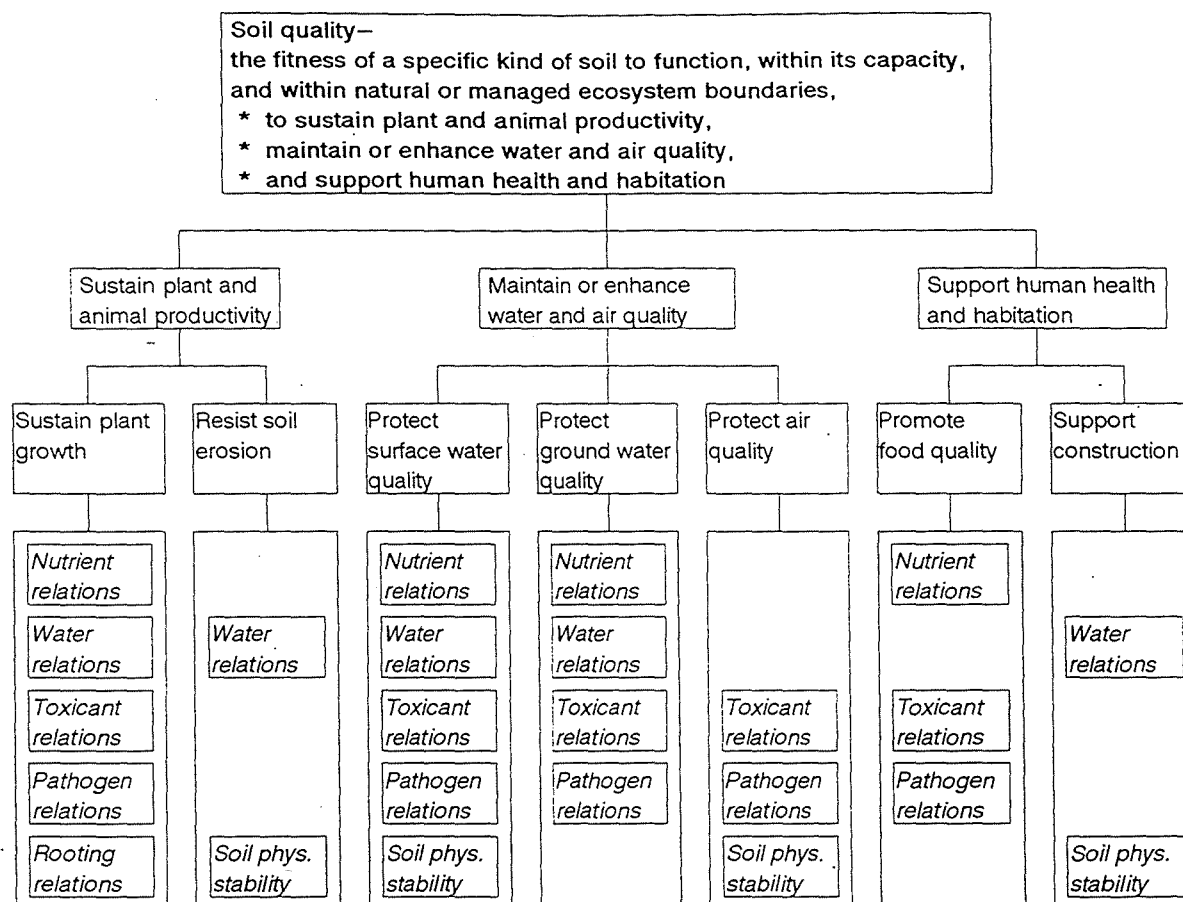
The data were subjected to statistical analysis using the SAS package (SAS Institute Inc., 1988) involving ANOVA and LSD computations. Statistical differences were determined at the 95% and the 99% certainty level, for each season, between the continuous corn and the other 1993 rotations. Statistical tests were not run if the F-test was above the 0.05 reliability threshold (Snedecor and Cochran 1980).

### **Research Approach**

Our research approach has evolved since the start of the project in accordance with advances in soil quality assessment, and now follows in principle the guidelines of the integrated framework for assessment of soil quality described recently by Harris and Karlen (1996) and summarized conceptually in Figure 4. For historical and available resource reasons we have focussed largely on the crop productivity function of soil quality. With respect to our soil quality assessment plan (Figure 4, footnote 3), we have used both a descriptive and an analytical approach for the WICST rotations.

For the descriptive approach, our data set was defined by the Wisconsin Soil Health Scorecard, which includes not only identification of soil health indicator properties but also provides a high-to-low scoring mechanism for each property with respect to fitness to support the crop productivity function. As a ground truth reference, we tracked the crop-based soil health scores for the WICST rotations (Table 4), as well as the soil-based soil health scores (Table 5). As identified in Table 5, to locate our soil health scorecard data in the integrated framework (Figure 4) we organized the data according to the soil quality indicator categories of the framework.

For the analytical approach, our data set was chosen to be consistent with evolving professional thinking on a minimum data set for soil quality characterization (Harris et al. 1994). As for the descriptive data, to locate our soil quality data in the integrated framework (Figure 4) we organized the data according to the soil quality indicator categories of the framework (Table 6, 7). However, unlike the soil health data, the soil quality data does not inherently include a soil quality score dimension. Precise identification of how individual soil quality indicator properties translate quantitatively into soil quality scores defining fitness to support a specific function is the major challenge for current and future soil quality research (Harris and Karlen, 1996). Sophisticated systems engineering approaches have been proposed (Karlen and Stott, 1994), but have not yet been developed for routine use. We propose a soil quality score approach patterned after the one used for soil health, and provides an illustration of soil quality assessment from the standpoint of soil nitrate data scored on a high-marginal-poor scale with respect to the sustain crop growth and protect water quality functions of soil quality (Table 8). The standard values defining high, marginal and poor soil quality scores for soil nitrate with respect to corn production and water quality protection were approximated from UW Nutrient and Pest Management (NPM) and soil fertility specialist recommendations for the two sites.



<sup>1</sup> The definition of soil quality is in bold print; the functions of soil quality are in normal print; and the categories of soil quality indicator properties supporting each function are in italics.

As shown in the figure, some categories of soil quality indicator properties support more than one function (e.g., "nutrient relations" supports the "sustain plant growth", "protect surface water quality", and "protect ground water quality" functions). Other categories support only one function (e.g., "rooting relations" supports only the "sustain plant growth" function).

<sup>2</sup> The nature of the soil quality indicator properties within each category, and how each property links mechanistically to soil quality assessment, is site and management objective dependent, but the following generalizations hold:

- \* Some soil properties will occur in the same category supporting different functions (e.g., soil nitrate, will occur in the "nutrient relations" category supporting the "sustain plant growth", "protect surface water quality" and "protect ground water" functions).
- \* Some soil properties will occur in different categories supporting the same function (e.g., soil pH will occur in the "nutrient relations" and "toxicant relations" categories supporting the "sustain plant growth" function).
- \* Each soil property within a given category supporting a given function must be related quantitatively to the function it supports, taking three dimensional landscape, climatic, and temporal issues into consideration.

<sup>3</sup> Following site and management objective analysis, the soil quality assessment plan will involve identification of:

- \* A descriptive and/or analytical data set of soil and supplementary properties to be measured, including a sampling protocol and identification of the location of the properties within the conceptual framework.
- \* A process for interpreting the soil quality indicator properties on a high-to-low quality scale with respect to the fitness of the soil to support a specified function.

Figure 4. Conceptual Framework for Soil Quality Assessment

## Results

### Soil Health Assessment

The WICST 1994 scores for the crop-based and soil-based soil health indicators are presented in Table 4 and 5, respectively. As noted in the table footnotes, the first superscript on the property name identifies the farmer-ranked relative importance of the property (FR, 1-43), and the second superscript identifies the location of the property in the Wisconsin Soil Health Scorecard location. The soil-based properties are grouped according to the soil quality indicator categories in Figure 4, and are listed in accordance with decreasing FR number within each category.

#### *Crop-Based Soil Health Scores*

The continuous corn reference system showed an average score of 3.6 at Arlington and 3.7 at Lakeland for the ten crop-based soil health indicators, identifying a solid healthy soil ranking for both sites (Table 4). All ten properties scored healthy, except for root development (FR 17) at Arlington, which was 2.7 (between impaired and healthy).

The other WICST rotations showed healthy average and individual scores similar to those shown by continuous corn, at both Arlington and Lakeland, although nutrient deficient (FR 15) scores were impaired for the wide row beans (2.5 at Arlington) and particularly the oats and alfalfa (1.7 at Arlington and 2.0 at Lakeland) rotations (Table 4).

In summary, the overall trend was that the crop-based soil health of all systems at both sites scored very high, and the shift from continuous corn to the other rotations had not resulted in a significant gain or loss in crop-based soil health.

#### *Soil-Based Soil Health Scores*

**Nutrient relations.** The average scores were healthy, and numerically similar for all systems and at both sites, except for a somewhat lower score for the wide row beans at Lakeland (Table 5). The latter was due to marginal scores for pH (FR 8), decomposition (FR 16) and biological activity (FR 36) at Lakeland, but this phenomenon was site rather than cropping system related since scores for the same properties at Arlington were all healthy.

**Water relations.** The average scores were healthy, and in the 3.7 to 4.0 range for all systems and at both sites, except for a lower score of 3.0 for continuous pasture at Lakeland due to impaired drainage (FR 6) and infiltration (FR 12) scores of 2.3 (Table 5). This was a site rather than cropping system effect since the drainage and infiltration were both healthy, 3.3 scores, at Arlington.

**Rooting relations.** The average scores were all healthy, but ranged from 2.9 to 3.9, with continuous corn showing relatively lower scores of 3.3 at Arlington and 2.9 at Lakeland (Table 5). The relatively low scores for continuous corn were due to impaired scores for earthworms (FR 3) and aeration (FR 35) at both sites. However, CC generally scored as high or higher than the other systems for the other indicators of rooting relations (tillage ease (FR 5), soil structure (FR 7), compaction (FR 11) and hardness (FR 28)).

**Physical stability.** The average scores were all healthy at Arlington, ranging from 2.8 to 4.0; and ranged from 2.3 (impaired) to 4.0 at Lakeland (Table 5). Except for uniformly high scores for the continuous pasture, and low surface crust (FR 24) scores for the narrow row beans at both sites, no other consistent trends between cropping systems were apparent. For example, the continuous corn (2.3) and oats and barley (2.6) systems were impaired at Lakeland but were both healthy (3.0 and 3.8, respectively) at Arlington. The lower average scores were due largely to low scores for surface cover (FR 23) in the non pasture systems, particularly at Lakeland.

**Other properties.** The average scores were all healthy, ranging from 3.3 to 3.8 (Table 5). No consistent trends were evident for the soil color (FR 13), feel (FR 21), or topsoil depth (FR 38) properties. However, for CC, soil smell (FR 25) was impaired at Arlington and relatively low (3.0) at Lakeland; this was obscured in the average scores because of the relatively high scores for the other properties.

**Total Average Soil-Based Scores.** The total average scores were in the healthy 3.3 to 3.8 range for all systems at both sites (Table 5), identifying an overall trend consistent with that shown for the crop-based indicators of soil health, i.e., the shift from continuous corn to the other rotations had not resulted in a significant gain or loss in soil-based soil health.

### Soil Quality Assessment

#### *Soil Quality Indicator Properties*

Analytical soil quality indicator properties for spring, summer and fall of 1994, grouped according to the standard categories in Figure 4, are presented in Table 6 and 7 for Arlington and Lakeland, respectively. Statistical analysis was confined to examination for significant differences between continuous corn (CC) and the other cropping systems.

**Nutrient relations.** Some of the inorganic soil quality indicator properties, namely, ammonium, extractable P, and exchangeable Ca and cation exchange capacity, showed no significant difference (except for one aberrant case of a significant difference) between CC and the other cropping systems for spring, summer and fall for both sites (Tables 6 and 7). Other inorganic properties, showed no significant difference at any time during the year between CC and the other systems at one site and inconsistent trends at the other site, namely pH and exchangeable K (not significantly different at Arlington and Lakeland, respectively); pH did show a trend towards a significant increase at Lakeland, but this did not hold throughout the year. Exchangeable Mg showed a trend towards being significantly higher for the other cropping systems versus CC, particularly for the wide row beans and continuous pasture, at both sites, but this did not hold for all temporal conditions for either Arlington or Lakeland. Soil nitrate at Arlington was significantly higher in the spring for narrow row beans and oats and alfalfa as compared to CC, and significantly lower in the spring for continuous pasture; no significant differences were shown at other times of the year. This trend was not repeated for Lakeland, since the only significant difference between CC and the other systems was a significantly higher value for oats and alfalfa in the fall.

**Table 4. Crop Property - Based on Soil Health Scores for 1994 WICST Rotations at Arlington and Lakeland.**

| Crop indicators of soil health <sup>1</sup> |       |                                                               |             | Arlington Cropping Systems <sup>2</sup> |                              |                              |                            |                          | Lakeland Cropping Systems <sup>2</sup> |                              |                              |                            |                          |
|---------------------------------------------|-------|---------------------------------------------------------------|-------------|-----------------------------------------|------------------------------|------------------------------|----------------------------|--------------------------|----------------------------------------|------------------------------|------------------------------|----------------------------|--------------------------|
| Property                                    | State | Description                                                   | Score range | R1<br>Contin.<br>corn                   | R2<br>Narrow<br>row<br>beans | R5<br>Oats<br>and<br>alfalfa | R3<br>Wide<br>row<br>beans | R6<br>Contin.<br>pasture | R1<br>Contin.<br>corn                  | R2<br>Narrow<br>row<br>beans | R5<br>Oats<br>and<br>alfalfa | R3<br>Wide<br>row<br>beans | R6<br>Contin.<br>pasture |
| Crop appearance <sup>2,25</sup>             | H     | Overall crop is dark green, large, tall, in a dense stand     | 3.0–4.0     | 3.0                                     | 4.0                          | 3.5                          | 3.7                        | 3.7                      | 3.7                                    | 3.3                          | 3.5                          | 4.0                        | 4.0                      |
|                                             | I     | Overall crop is light green, small, in a thin stand           | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Overall crop is poor, stunted, discolored, uneven stand       | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Yield <sup>1,0,35</sup>                     | H     | Corn greater than 130 bushels/acre                            | 3.0–4.0     | 4.0                                     | 4.0                          | 4.0                          | 4.0                        | 4.0                      | 4.0                                    | 4.0                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I     | Corn 85 to 130 bushels/acre                                   | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Corn less than 85 bushels/acre                                | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Nutrient deficient <sup>15,26</sup>         | H     | Crop has what it needs, shows little deficiency signs         | 3.0–4.0     | 3.3                                     | 3.5                          |                              |                            | 4.0                      | 3.8                                    | 4.0                          |                              | 3.2                        | 4.0                      |
|                                             | I     | Crop falls off or discolors as season progresses              | 1.5–2.5     |                                         |                              | 1.7                          | 2.5                        |                          |                                        |                              | 2.0                          |                            |                          |
|                                             | U     | Crop shows severe signs: blighted/streaky/spotty/discolored   | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Roots <sup>17,29</sup>                      | H     | Roots are deep, fully developed with lots of fine root hairs  | 3.0–4.0     |                                         | 3.7                          | 4.0                          | 4.0                        | 4.0                      | 3.0                                    | 3.3                          | 3.3                          | 3.0                        | 4.0                      |
|                                             | I     | Roots shallow, hard angles, limited developm., few fine roots | 1.5–2.5     | 2.7                                     |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Roots unhealthy (brown/diseased/spotted), poorly developed    | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Mature crop <sup>18,34</sup>                | H     | Rapid even growth, matures on time                            | 3.0–4.0     | 3.0                                     | 3.0                          | 3.3                          | 3.0                        |                          | 3.0                                    | 3.0                          | 3.3                          | 3.0                        |                          |
|                                             | I     | Uneven growth, late to mature                                 | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Crop slow to get started, never seems to mature               | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Growth rate <sup>19,28</sup>                | H     | Rapid even growth, matures on time                            | 3.0–4.0     | 3.8                                     | 4.0                          | 4.0                          | 4.0                        | 4.0                      | 3.7                                    | 4.0                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I     | Uneven growth, late to mature                                 | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Crop slow to get started, never seems to mature               | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Resists drought <sup>27,32</sup>            | H     | Plants withstand dry weather, recover fast                    | 3.0–4.0     | 4.0                                     | 4.0                          | 4.0                          | 3.7                        | 4.0                      | 4.0                                    | 4.0                          | 4.0                          | 3.7                        | 4.0                      |
|                                             | I     | Plants suffer in dry weather, slow to recover                 | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Plants dry out quickly, never recover                         | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Pests/disease <sup>29,33</sup>              | H     | Plants tolerate pests and disease well                        | 3.0–4.0     | 4.0                                     | 3.3                          | 4.0                          | 4.0                        | 4.0                      | 4.0                                    | 3.3                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I     | Plants stressed by diseases and insects                       | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Plants damaged severely by diseases and insects               | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Plant leaves <sup>33,31</sup>               | H     | Leaves are full, lush, dark green                             | 3.0–4.0     | 4.0                                     | 3.7                          | 4.0                          | 4.0                        | 4.0                      | 4.0                                    | 3.7                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I     | Leaves are small, narrow, light green                         | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Leaves are yellow, discolored, few in number                  | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Seed germination <sup>34,27</sup>           | H     | Seeds come up right away, good emergence                      | 3.0–4.0     | 4.0                                     | 4.0                          | 4.0                          | 4.0                        |                          | 4.0                                    | 4.0                          | 4.0                          | 4.0                        |                          |
|                                             | I     | Germination is uneven, seed must be planted deeper            | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Germination is poor, hard for crop to come out of ground      | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Average                                     | H     |                                                               | 3.0–4.0     | 3.6                                     | 3.7                          | 3.7                          | 3.7                        | 4.0                      | 3.7                                    | 3.7                          | 3.6                          | 3.7                        | 4.0                      |

The first superscript number qualifying each property corresponds to the farmer-based priority ranking, the second corresponds to the numbering system of the Wisconsin Soil Health Scorecard, which focusses on crop production (Romig et al., 1995, 1996). Abbreviations: H = Healthy; I = Impaired; U = Unhealthy.

<sup>2</sup> Scores are the average of three plots for each system.

**Table 5. Soil Property - Based on Soil Health Scores for 1994 WICST Rotations at Arlington and Lakeland.**

| Soil indicators of soil health <sup>1</sup> |       |                                                                  |             | Arlington Cropping Systems <sup>2</sup> |                              |                              |                            |                          | Lakeland Cropping Systems <sup>2</sup> |                              |                              |                            |                          |
|---------------------------------------------|-------|------------------------------------------------------------------|-------------|-----------------------------------------|------------------------------|------------------------------|----------------------------|--------------------------|----------------------------------------|------------------------------|------------------------------|----------------------------|--------------------------|
| Property                                    | State | Description                                                      | Score range | R1<br>Contin.<br>corn                   | R2<br>Narrow<br>row<br>beans | R5<br>Oats<br>and<br>alfalfa | R3<br>Wide<br>row<br>beans | R6<br>Contin.<br>pasture | R1<br>Contin.<br>corn                  | R2<br>Narrow<br>row<br>beans | R5<br>Oats<br>and<br>alfalfa | R3<br>Wide<br>row<br>beans | R6<br>Contin.<br>pasture |
| <u>Nutrient relations</u>                   |       |                                                                  |             |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Organic matter <sup>1,21</sup>              | H     | Organic matter 4–6%                                              | 3.0–4.0     | 4.0                                     | 3.6                          | 3.6                          | 3.7                        | 4.0                      | 4.0                                    | 4.0                          | 4.0                          | 3.6                        | 3.2                      |
|                                             | I     | Organic matter 2–4% or 6–8%                                      | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Organic matter <2% or >8%                                        | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| pH <sup>8,22</sup>                          | H     | pH 6.7–7.0                                                       | 3.0–4.0     | 3.0                                     | 3.2                          | 2.8                          | 3.0                        | 3.0                      | 3.3                                    | 3.6                          | 3.3                          |                            |                          |
|                                             | I     | pH 6.4–6.7 or 7.0–7.2                                            | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              | 1.6                        | 1.8                      |
|                                             | U     | pH <6.4 or >7.2                                                  | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Soil test—N,P,K <sup>9,23</sup>             | H     | All nutrient levels at recommended levels                        | 3.0–4.0     | 4.0                                     | 4.0                          | 4.0                          | 4.0                        | 4.0                      | 4.0                                    | 4.0                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I     | Soil tests below recommended levels, need extra inputs           | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Two or more nutrients very low, law of minimum                   | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Decomposition <sup>16,10</sup>              | H     | Rapid rotting of residues and manures                            | 3.0–4.0     |                                         |                              | 3.0                          |                            | 4.0                      |                                        |                              |                              |                            | 4.0                      |
|                                             | I     | Slow rotting of residues and manures                             | 1.5–2.5     | 2.0                                     | 2.0                          |                              | 2.3                        |                          | 2.0                                    | 2.0                          | 2.0                          | 2.0                        |                          |
|                                             | U     | Residues and manures do not break down in soil                   | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Soil fertility <sup>20,11</sup>             | H     | Fertility balanced, nutrients available, potential high          | 3.0–4.0     | 4.0                                     | 4.0                          | 4.0                          | 4.0                        | 4.0                      | 4.0                                    | 4.0                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I     | Fertility not balanced, needs help                               | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Poor fertility, nutrients do not move, potential very low        | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Micronutrients <sup>30,24</sup>             | H     | Levels of micronutrients high and balanced                       | 3.0–4.0     | 4.0                                     | 4.0                          | 4.0                          | 4.0                        | 4.0                      | 4.0                                    | 4.0                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I     | Micronutrients at a minimal level or not a concern               | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Severe shortage of micronutrients                                | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Biolog. activity <sup>36,19</sup>           | H     | Activity high, white wormlike threads, moss, algae plentiful     | 3.0–4.0     | 4.0                                     | 4.0                          | 4.0                          | 4.0                        | 4.0                      | 3.0                                    | 3.0                          | 3.3                          |                            |                          |
|                                             | I     | Moderate activity, some white wormlike threads, moss, algae      | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              | 1.3                        | 2.0                      |
|                                             | U     | Soil shows little biological activity, no signs of soil microbes | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Average                                     | H     |                                                                  | 3.0–4.0     | 3.6                                     | 3.5                          | 3.6                          | 3.6                        | 3.9                      | 3.5                                    | 3.5                          | 3.5                          | 2.9                        | 3.3                      |
| <u>Water relations</u>                      |       |                                                                  |             |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Drainage <sup>6,8</sup>                     | H     | Soil drains at good rate for crops, water moves through well     | 3.0–4.0     | 3.3                                     | 3.3                          | 3.3                          | 4.0                        | 3.3                      | 4.0                                    | 4.0                          | 3.7                          | 4.0                        |                          |
|                                             | I     | Soil drains slowly, slow to dry out                              | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            | 2.3                      |
|                                             | U     | Poor drainage, soil often waterlogged or over saturated          | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Infiltration <sup>12,7</sup>                | H     | Water soaks right in, soil is spongy, no ponding                 | 3.0–4.0     | 3.3                                     | 3.3                          | 3.3                          | 4.0                        | 3.3                      | 3.3                                    | 3.7                          | 4.0                          | 3.3                        |                          |
|                                             | I     | Water soaks in slow, some runoff/puddling after heavy rain       | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            | 2.3                      |
|                                             | U     | Water doesn't soak in, sits on top or runs off                   | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Water retention <sup>14,9</sup>             | H     | Soil holds moisture well, gives and takes water easily           | 3.0–4.0     | 4.0                                     | 4.0                          | 4.0                          | 4.0                        | 4.0                      | 4.0                                    | 4.0                          | 4.0                          | 4.0                        | 3.3                      |
|                                             | I     | Soil is drought prone in dry weather                             | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U     | Soil dries out too fast, droughty                                | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |

**Table 5. (continued) Soil Property - Based on Soil Health Scores for 1994 WICST Rotations at Arlington and Lakeland.**

| Soil indicators of soil health <sup>1</sup> |        |                                                               |             | Arlington Cropping Systems <sup>2</sup> |                              |                              |                            |                          | Lakeland Cropping Systems <sup>2</sup> |                              |                              |                            |                          |
|---------------------------------------------|--------|---------------------------------------------------------------|-------------|-----------------------------------------|------------------------------|------------------------------|----------------------------|--------------------------|----------------------------------------|------------------------------|------------------------------|----------------------------|--------------------------|
| Property                                    | Status | Description                                                   | Score range | R1<br>Contin.<br>corn                   | R2<br>Narrow<br>row<br>beans | R5<br>Oats<br>and<br>alfalfa | R3<br>Wide<br>row<br>beans | R6<br>Contin.<br>pasture | R1<br>Contin.<br>corn                  | R2<br>Narrow<br>row<br>beans | R5<br>Oats<br>and<br>alfalfa | R3<br>Wide<br>row<br>beans | R6<br>Contin.<br>pasture |
| <u>Water relations (continued)</u>          |        |                                                               |             |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Soil texture <sup>31,17</sup>               | H      | Texture is loamy                                              | 3.0–4.0     | 4.0                                     | 4.0                          | 4.0                          | 4.0                        | 4.0                      | 4.0                                    | 4.0                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I      | Texture is too heavy, or too tight, but presents no problem   | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U      | Texture is a problem, very sandy, clayey or rocky             | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Average                                     | H      |                                                               | 3.0–4.0     | 3.7                                     | 3.7                          | 3.7                          | 4.0                        | 3.7                      | 3.8                                    | 3.9                          | 3.9                          | 3.8                        | 3.0                      |
| <u>Rooting relations</u>                    |        |                                                               |             |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Earthworms <sup>3,1</sup>                   | H      | Worm holes and castings numerous                              | 3.0–4.0     |                                         | 3.3                          | 4.0                          | 3.3                        | 4.0                      |                                        | 3.3                          | 4.0                          | 4.0                        | 3.0                      |
|                                             | I      | Few worms or castings                                         | 1.5–2.5     | 2.3                                     |                              |                              |                            |                          | 2.0                                    |                              |                              |                            |                          |
|                                             | U      | Little sign of worm activity                                  | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Tillage ease <sup>5,3</sup>                 | H      | Plow field in higher gear, soil flows and falls apart, mellow | 3.0–4.0     | 4.0                                     | 4.0                          | 4.0                          | 4.0                        |                          | 4.0                                    | 4.0                          | 4.0                          | 3.7                        |                          |
|                                             | I      | Soil grabs plow, difficult to work, needs extra passes        | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U      | Plow scours hard, soil never works down                       | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Soil structure <sup>7,4</sup>               | H      | Soil is crumbly, granular                                     | 3.0–4.0     | 4.0                                     | 3.3                          | 4.0                          | 4.0                        | 4.0                      |                                        | 4.0                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I      | Soil is lumpy or will not hold together                       | 1.5–2.5     |                                         |                              |                              |                            |                          | 2.7                                    |                              |                              |                            |                          |
|                                             | U      | Soil is cloddy with big chunks, or dusty and powdery          | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Compaction <sup>11,6</sup>                  | H      | Soil stays loose, doesn't pack, no hardpan                    | 3.0–4.0     | 4.0                                     | 4.0                          | 4.0                          | 4.0                        | 4.0                      | 3.7                                    | 3.7                          | 4.0                          | 3.3                        | 3.0                      |
|                                             | I      | Soil packs down, thin hardpan or plow layer                   | 1.5–2.5     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U      | Soil is tight, compacted, cannot get into it, thick hardpan   | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Hardness <sup>28,15</sup>                   | H      | Soil is soft, crumbles easily under light pressure            | 3.0–4.0     | 3.3                                     |                              | 3.7                          | 3.7                        |                          | 3.0                                    |                              |                              | 3.3                        |                          |
|                                             | I      | Soil firm, breaks up between fingers by moderate pressure     | 1.5–2.5     |                                         | 2.7                          |                              |                            | 2.3                      |                                        | 2.3                          | 2.7                          |                            | 2.0                      |
|                                             | U      | Soil hard, dense or solid, not break between 2 fingers        | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Aeration <sup>35,18</sup>                   | H      | Soil is open, porous, breaths                                 | 3.0–4.0     |                                         | 3.0                          | 3.7                          | 3.7                        | 4.0                      |                                        | 3.3                          | 3.7                          | 4.0                        | 3.3                      |
|                                             | I      | Soil is dense, has a few pores                                | 1.5–2.5     | 2.3                                     |                              |                              |                            |                          | 2.0                                    |                              |                              |                            |                          |
|                                             | U      | Soil is tight, closed, almost no pores                        | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Average                                     | H      |                                                               | 3.0–4.0     | 3.3                                     | 3.4                          | 3.9                          | 3.8                        | 3.1                      | 2.9                                    | 3.4                          | 3.7                          | 3.7                        | 3.1                      |
| <u>Physical stability</u>                   |        |                                                               |             |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Erosion <sup>4,2</sup>                      | H      | Little erosion evident, topsoil resists water, wind erosion   | 3.0–4.0     | 4.0                                     | 4.0                          | 4.0                          | 4.0                        | 4.0                      |                                        | 4.0                          |                              | 3.3                        | 4.0                      |
|                                             | I      | Moderate erosion, signs of sheet, rill erosion, topsoil blows | 1.5–2.5     |                                         |                              |                              |                            |                          | 2.0                                    |                              | 2.7                          |                            |                          |
|                                             | U      | Severe erosion, considerable topsoil loss, gullies form       | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Surface cover <sup>23,14</sup>              | H      | Surface trashy, lots of mulch left on top or cover crop used  | 3.0–4.0     |                                         |                              | 4.0                          | 4.0                        | 4.0                      |                                        |                              |                              |                            | 4.0                      |
|                                             | I      | Surface has little residue, mostly buried                     | 1.5–2.5     | 2.0                                     | 2.0                          |                              |                            |                          | 2.0                                    | 2.3                          | 2.0                          | 1.3                        |                          |
|                                             | U      | Surface is clean, bare, residue removed/buried after harvest  | 0.0–1.0     |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |

**Table 5. (continued) Soil Property - Based on Soil Health Scores for 1994 WICST Rotations at Arlington and Lakeland.**

| Soil indicators of soil health <sup>1</sup> |        |                                                           |             |  | Arlington Cropping Systems <sup>2</sup> |                              |                              |                            |                          | Lakeland Cropping Systems <sup>2</sup> |                              |                              |                            |                          |
|---------------------------------------------|--------|-----------------------------------------------------------|-------------|--|-----------------------------------------|------------------------------|------------------------------|----------------------------|--------------------------|----------------------------------------|------------------------------|------------------------------|----------------------------|--------------------------|
| Property                                    | Status | Description                                               | Score range |  | R1<br>Contin.<br>corn                   | R2<br>Narrow<br>row<br>beans | R5<br>Oats<br>and<br>alfalfa | R3<br>Wide<br>row<br>beans | R6<br>Contin.<br>pasture | R1<br>Contin.<br>corn                  | R2<br>Narrow<br>row<br>beans | R5<br>Oats<br>and<br>alfalfa | R3<br>Wide<br>row<br>beans | R6<br>Contin.<br>pasture |
| <u>Physical stability (continued)</u>       |        |                                                           |             |  |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Surface crust <sup>24,13</sup>              | H      | Soil surface doesn't crust, porous, digs easily with hand | 3.0-4.0     |  | 3.0                                     |                              | 3.3                          | 4.0                        | 4.0                      | 3.0                                    |                              | 3.0                          | 4.0                        | 4.0                      |
|                                             | I      | Soil surface is smooth with few holes, thin crust         | 1.5-2.5     |  |                                         | 2.3                          |                              |                            |                          |                                        | 2.3                          |                              |                            |                          |
|                                             | U      | Soil surface is hard, cracked when dry, compacted         | 0.0-1.0     |  |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Average                                     | H      |                                                           | 3.0-4.0     |  | 3.0                                     | 2.8                          | 3.8                          | 4.0                        | 4.0                      |                                        | 2.9                          |                              | 2.9                        | 4.0                      |
|                                             | H      |                                                           | 1.5-2.5     |  |                                         |                              |                              |                            |                          | 2.3                                    |                              | 2.6                          |                            |                          |
| <u>Other properties</u>                     |        |                                                           |             |  |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Color (moist) <sup>13,5</sup>               | H      | Soil color is black, dark brown, or dark gray             | 3.0-4.0     |  | 4.0                                     | 3.3                          | 4.0                          | 3.3                        | 4.0                      | 3.7                                    | 4.0                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I      | Soil color is brown, gray, or reddish                     | 1.5-2.5     |  |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U      | Soil color is tan, light yellow, orange, or light gray    | 0.0-1.0     |  |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Feel <sup>21,12</sup>                       | H      | Soil is loose, fluffy, opens up after being squeezed      | 3.0-4.0     |  | 4.0                                     | 4.0                          | 4.0                          | 4.0                        | 4.0                      | 4.0                                    | 4.0                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I      | Soil is smooth or grainy, compresses when squeezed        | 1.5-2.5     |  |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U      | Soil is mucky, greasy, or sticky                          | 0.0-1.0     |  |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Soil smell <sup>25,16</sup>                 | H      | Soil has an earthy, sweet, fresh smell                    | 3.0-4.0     |  |                                         | 3.3                          | 4.0                          | 3.7                        | 4.0                      | 3.0                                    | 3.0                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I      | Soil has no odor or a mineral smell                       | 1.5-2.5     |  | 2.3                                     |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U      | Soil has sour, putrid or chemical smell                   | 0.0-1.0     |  |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Topsoil depth <sup>38,20</sup>              | H      | Topsoil is deep                                           | 3.0-4.0     |  | 4.0                                     | 4.0                          | 4.0                          | 4.0                        | 4.0                      | 4.0                                    | 4.0                          | 4.0                          | 4.0                        | 4.0                      |
|                                             | I      | Topsoil is shallow                                        | 1.5-2.5     |  |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
|                                             | U      | Subsoil is exposed or near surface                        | 0.0-1.0     |  |                                         |                              |                              |                            |                          |                                        |                              |                              |                            |                          |
| Average                                     | H      |                                                           | 3.0-4.0     |  | 3.4                                     | 3.5                          | 4.0                          | 3.7                        | 4.0                      | 3.6                                    | 3.7                          | 4.0                          | 4.0                        | 4.0                      |
| <u>Total Soil Average</u>                   | H      |                                                           | 3.0-4.0     |  | 3.4                                     | 3.5                          | 3.8                          | 3.7                        | 3.6                      | 3.3                                    | 3.5                          | 3.7                          | 3.5                        | 3.4                      |

The first superscript number qualifying each property corresponds to the farmer-based priority ranking, the second corresponds to the numbering system of the Wisconsin Soil Health Scorecard, which focusses on crop production (Romig et al., 1995, 1996). Abbreviations: H = Healthy; I = Impaired; U = Unhealthy.

<sup>2</sup> Scores are the average of three plots for each system.

Organic matter showed no significant difference between CC and the other cropping systems for spring, summer and fall, at both sites (Tables 6 and 7). Microbial biomass showed essentially no significant differences between CC and all other systems at Arlington (Table 6). For microbial biomass at Lakeland there was no response in the spring for all systems, and none in the fall except for a higher value for continuous pasture; but in the summer, microbial biomass was significantly higher for all systems compared to CC (Table 7). Labile C showed many instances of significant differences between CC and the other systems, but there was no consistent site, cropping system, or temporal trend; nor was there evidence of a summer increase in labile C for the other systems at Lakeland to parallel the significant increase in microbial biomass. The other two indices of biological activity, arginine ammonification and dehydrogenase activity, showed no significant differences between CC and any of the other systems at any time and at either site.

**Water relations.** Bulk density commonly showed significant differences between CC and the other systems, but there were no consistent temporal or site trends (Tables 6 and 7). Total porosity showed no significant differences at any time .

**Toxicant relations.** pH showed no significant difference at Arlington for CC versus the other systems; the small but significant 0.2 to 0.4 pH unit increase shown at Lakeland for spring and fall, respectively, did not hold for the summer (Tables 6 and 7). Electrical conductivity showed no significant differences at any time for either site.

**Rooting relations.** As identified under the water relations section, bulk density commonly showed significant differences between CC and the other systems, but there were no consistent temporal or site trends (Tables 6 and 7). Texture showed no significant differences for both sites, confirming the validity of the plots for comparative cropping system evaluation.

**Soil physical stability.** Water stable aggregation showed no statistical evidence of improvement or degradation as a result of the shift from CC to the corn rotation cropping systems (Tables 6 and 7). However, at Arlington the continuous pasture showed a significantly improved ability to regenerate its aggregate water stability during the summer and fall, especially for the >2mm water stable aggregates.

#### *Soil Quality Scores for Soil Nitrate*

Table 8 presents a soil quality assessment approach for soil nitrate scored on a high-marginal-poor scale analogous to the approach used for the Wisconsin Soil Health Scorecard (Table 5). The standard values defining high, marginal and poor soil quality scores for soil nitrate with respect to corn production and water quality protection were approximated from UW Nutrient and Pest Management (NPM) and soil fertility specialist recommendations for the two sites.

For continuous corn, soil nitrate was of high quality with respect to corn production in the spring, and marginal quality in the summer, at both Arlington and Lakeland (Table 8). However, with respect to water quality, soil nitrate was marginal in the spring, and poor in the fall at both sites; and marginal and marginal to poor in the summer, at Arlington and Lakeland, respectively.

Table 6. Arlington Analytical Soil Quality Indicator Properties for 1994 WICST Rotations.

| Soil Quality Properties               |                                         | Analytical Data <sup>1</sup> for Rotations     |      |      |                                                  |                  |                  |                                                |                  |                  |                                                  |      |                  |                                                 |                   |                   |
|---------------------------------------|-----------------------------------------|------------------------------------------------|------|------|--------------------------------------------------|------------------|------------------|------------------------------------------------|------------------|------------------|--------------------------------------------------|------|------------------|-------------------------------------------------|-------------------|-------------------|
| Name                                  | Units                                   | R1 continous corn<br>(C-C-C-C*-C) <sup>2</sup> |      |      | R2 narrow row beans<br>(B-C-B-C*-B) <sup>2</sup> |                  |                  | R5 oats & alfalfa<br>(O-A-C*-O-A) <sup>2</sup> |                  |                  | R3 wide row beans<br>(B-Cl-C*-B-Cl) <sup>2</sup> |      |                  | R6 contin. pasture<br>(P-P-P*-P-P) <sup>2</sup> |                   |                   |
|                                       |                                         | Spr                                            | Su   | Fall | Spr                                              | Su               | Fall             | Spr                                            | Su               | Fall             | Spr                                              | Su   | Fall             | Spr                                             | Su                | Fall              |
| <b>NUTRIENT RELATIONS</b>             |                                         |                                                |      |      |                                                  |                  |                  |                                                |                  |                  |                                                  |      |                  |                                                 |                   |                   |
| Nitrate                               | mg kg <sup>-1</sup>                     | 25                                             | 17   | 30   | 35 <sup>a</sup>                                  | 24               | 31               | 41 <sup>b</sup>                                | 26               | 37               | 23                                               | 18   | 29               | 15 <sup>a</sup>                                 | 19                | 17                |
| Ammonium                              | mg kg <sup>-1</sup>                     | 13                                             | 22   | 17   | 17                                               | 24               | 15               | 13                                             | 24               | 17               | 9                                                | 21   | 13               | 12                                              | 17                | 18                |
| Extractable P                         | mg kg <sup>-1</sup>                     | 85                                             | 105  | 105  | 89                                               | 96               | 89               | 69                                             | 93               | 93               | 45                                               | 57   | 54               | 75                                              | 83                | 84                |
| Exchangeable K                        | mg kg <sup>-1</sup>                     | 305                                            | 307  | 352  | 312                                              | 275              | 237              | 200                                            | 247              | 235 <sup>a</sup> | 147 <sup>a</sup>                                 | 163  | 175 <sup>b</sup> | 192 <sup>a</sup>                                | 218               | 210 <sup>a</sup>  |
| Exchangeable Ca                       | mg kg <sup>-1</sup>                     | 2000                                           | 2000 | 1867 | 2033                                             | 2133             | 2083             | 2017                                           | 2083             | 2033             | 2000                                             | 2333 | 2000             | 2083                                            | 2100              | 2100              |
| Exchangeable Mg                       | mg kg <sup>-1</sup>                     | 673                                            | 653  | 630  | 690                                              | 707 <sup>a</sup> | 697 <sup>b</sup> | 710                                            | 743 <sup>b</sup> | 733 <sup>b</sup> | 690                                              | 680  | 697 <sup>b</sup> | 683                                             | 713 <sup>a</sup>  | 723 <sup>b</sup>  |
| Cation exchange capacity              | meq 100g <sup>-1</sup>                  | 19                                             | 19   | 18   | 20                                               | 20               | 20               | 19                                             | 20               | 20               | 19                                               | 21   | 19               | 19                                              | 20                | 20                |
| pH                                    | -log[H <sup>+</sup> ]                   | 6.8                                            | 7.0  | 7.2  | 6.8                                              | 7.0              | 7.0              | 6.8                                            | 7.1              | 7.2              | 7.0                                              | 7.1  | 7.2              | 6.9                                             | 7.1               | 7.2               |
| Organic matter                        | %                                       | 4.6                                            | 4.7  | 4.7  | 4.6                                              | 4.9              | 4.2              | 4.2                                            | 4.6              | 4.1              | 3.8                                              | 4.6  | 3.8              | 4.8                                             | 5.0               | 4.4               |
| Labile carbon                         | ugC g <sup>-1</sup>                     | 259                                            | 277  | 146  | 198 <sup>a</sup>                                 | 227              | 59 <sup>a</sup>  | 207 <sup>a</sup>                               | 351 <sup>b</sup> | 91               | 189 <sup>a</sup>                                 | 291  | 226 <sup>a</sup> | 238                                             | 304               | 224 <sup>a</sup>  |
| Microbial biomass                     | mgC 100g <sup>-1</sup>                  | 311                                            | 342  | 346  | 289                                              | 252              | 337              | 295                                            | 299              | 465              | 243                                              | 261  | 281              | 476 <sup>a</sup>                                | 354               | 437               |
| Arginine ammonification               | ugN 10g <sup>-1</sup> h <sup>-1</sup>   | 27                                             | 30   | 21   | 28                                               | 26               | 25               | 24                                             | 30               | 37               | 23                                               | 32   | 25               | 24                                              | 31                | 30                |
| Dehydrogenase activity                | ugTPF 10g <sup>-1</sup> h <sup>-1</sup> | 48                                             | 43   | 43   | 37                                               | 36               | 44               | 42                                             | 44               | 35               | 45                                               | 41   | 43               | 71 <sup>b</sup>                                 | 52                | 50                |
| <b>WATER RELATIONS</b>                |                                         |                                                |      |      |                                                  |                  |                  |                                                |                  |                  |                                                  |      |                  |                                                 |                   |                   |
| Bulk density                          | g cm <sup>-3</sup>                      | 1.15                                           | —    | 1.15 | 1.24                                             | —                | 1.09             | 1.37 <sup>a</sup>                              | —                | 1.26             | 1.40 <sup>a</sup>                                | —    | 1.20             | 1.18                                            | —                 | 1.41 <sup>a</sup> |
| Total porosity                        | %                                       | 57                                             | —    | 57   | 53                                               | —                | 59               | 48                                             | —                | 52               | 47                                               | —    | 55               | 55                                              | —                 | 47                |
| <b>TOXICANT RELATIONS</b>             |                                         |                                                |      |      |                                                  |                  |                  |                                                |                  |                  |                                                  |      |                  |                                                 |                   |                   |
| pH                                    | -log[H <sup>+</sup> ]                   | 85                                             | 105  | 105  | 89                                               | 96               | 89               | 69                                             | 93               | 93               | 45                                               | 57   | 54               | 75                                              | 83                | 84                |
| Electrical conductivity               | x10 <sup>-5</sup> mhos cm <sup>-1</sup> | 6.8                                            | 7.0  | 7.2  | 6.8                                              | 7.0              | 7.0              | 6.8                                            | 7.1              | 7.2              | 7.0                                              | 7.1  | 7.2              | 6.9                                             | 7.1               | 7.2               |
|                                       |                                         | 9                                              | 9    | 9    | 11                                               | 10               | 13               | 12                                             | 11               | 11               | 5                                                | 8    | 13               | 7                                               | 7                 | 10                |
| <b>ROOTING RELATIONS</b>              |                                         |                                                |      |      |                                                  |                  |                  |                                                |                  |                  |                                                  |      |                  |                                                 |                   |                   |
| Bulk density                          | g cm <sup>-3</sup>                      | 1.15                                           | —    | 1.15 | 1.24                                             | —                | 1.09             | 1.37 <sup>a</sup>                              | —                | 1.26             | 1.40 <sup>a</sup>                                | —    | 1.20             | 1.18                                            | —                 | 1.41 <sup>a</sup> |
| Texture (sand)                        | %                                       | —                                              | 18   | —    | —                                                | 19               | —                | —                                              | 17               | —                | —                                                | 18   | —                | —                                               | 19                | —                 |
| (silt)                                | %                                       | —                                              | 65   | —    | —                                                | 64               | —                | —                                              | 64               | —                | —                                                | 65   | —                | —                                               | 64                | —                 |
| (clay)                                | %                                       | —                                              | 17   | —    | —                                                | 17               | —                | —                                              | 19               | —                | —                                                | 17   | —                | —                                               | 17                | —                 |
| <b>PHYSICAL STABILITY<sup>3</sup></b> |                                         |                                                |      |      |                                                  |                  |                  |                                                |                  |                  |                                                  |      |                  |                                                 |                   |                   |
| WSA >2 mm                             | %                                       | 3.0                                            | 10.3 | 3.8  | 5.3                                              | 6.6              | 4.8              | 4.8                                            | 8.5              | 4.8              | 5.6                                              | 11.5 | 8.0              | 6.1                                             | 14.8 <sup>a</sup> | 17.9 <sup>b</sup> |
| >.25mm                                | %                                       | 29                                             | 60   | 48   | 38                                               | 59               | 49               | 45                                             | 55               | 44               | 26                                               | 59   | 53               | 44                                              | 60                | 68 <sup>b</sup>   |

<sup>1</sup> Experimental data are average of 3 plots. See Table 5 for details.

Statistical analysis: a or b = values significantly different from R1 at a level of P<0.5 or P<.01, respectively.

<sup>2</sup> Abbreviations: C = Corn; A = Alfalfa; B = Soybeans; Cl = Wheat (fall seeded) and Red Clover (spring seeded); O = Interseeded Oats and Alfalfa;

P = pasture. \* indicates location in cropping rotation of 1994 sampling.

<sup>3</sup> Abbreviations: WSA = Water Stable Aggregates

Table 7. Lakeland Analytical Soil Quality Indicator Properties for 1994 WICST Rotations.

| Soil Quality Properties               |                                         | Analytical Data <sup>1</sup> for Rotations     |      |      |                                                  |                  |                  |                                                |                  |                  |                                                  |                  |                  |                                                 |                   |                  |
|---------------------------------------|-----------------------------------------|------------------------------------------------|------|------|--------------------------------------------------|------------------|------------------|------------------------------------------------|------------------|------------------|--------------------------------------------------|------------------|------------------|-------------------------------------------------|-------------------|------------------|
| Categories with related Properties    | Units                                   | R1 continous corn<br>(C-C-C-C*-C) <sup>2</sup> |      |      | R2 narrow row beans<br>(B-C-B-C*-B) <sup>2</sup> |                  |                  | R5 oats & alfalfa<br>(O-A-C*-O-A) <sup>2</sup> |                  |                  | R3 wide row beans<br>(B-Cl-C*-B-Cl) <sup>2</sup> |                  |                  | R6 contin. pasture<br>(P-P-P'-P-P) <sup>2</sup> |                   |                  |
|                                       |                                         | Spr                                            | Su   | Fall | Spr                                              | Su               | Fall             | Spr                                            | Su               | Fall             | Spr                                              | Su               | Fall             | Spr                                             | Su                | Fall             |
| <b>NUTRIENT RELATIONS</b>             |                                         |                                                |      |      |                                                  |                  |                  |                                                |                  |                  |                                                  |                  |                  |                                                 |                   |                  |
| Nitrate                               | mg kg <sup>-1</sup>                     | 23                                             | 32   | 31   | 32                                               | 27               | 35               | 38                                             | 31               | 58 <sup>b</sup>  | 33                                               | 16               | 35               | 14                                              | 19                | 36               |
| Ammonium                              | mg kg <sup>-1</sup>                     | 7                                              | 15   | 13   | 10                                               | 16               | 20               | 10                                             | 19               | 19               | 14                                               | 17               | 21               | 12                                              | 22                | 19               |
| Extractable P                         | mg kg <sup>-1</sup>                     | 42                                             | 56   | 50   | 43                                               | 41               | 44               | 60                                             | 77               | 65               | 37                                               | 46               | 48               | 41                                              | 48                | 43               |
| Exchangeable K                        | mg kg <sup>-1</sup>                     | 162                                            | 188  | 193  | 185                                              | 173              | 195              | 212                                            | 232              | 225              | 145                                              | 165              | 190              | 177                                             | 198               | 225              |
| Exchangeable Ca                       | mg kg <sup>-1</sup>                     | 2333                                           | 2333 | 2350 | 2317                                             | 2400             | 2350             | 2750                                           | 2983             | 2967             | 2300                                             | 2583             | 2550             | 2983                                            | 3183              | 3050             |
| Exchangeable Mg                       | mg kg <sup>-1</sup>                     | 740                                            | 763  | 787  | 700                                              | 797              | 803              | 967                                            | 1020             | 1057             | 687 <sup>a</sup>                                 | 813 <sup>a</sup> | 840              | 1043 <sup>a</sup>                               | 1073 <sup>a</sup> | 1070             |
| Cation exchange capacity              | meq 100g <sup>-1</sup>                  | 21                                             | 22   | 22   | 21                                               | 22               | 22               | 26                                             | 28               | 28               | 21                                               | 24               | 24               | 28 <sup>a</sup>                                 | 30                | 29               |
| pH                                    | -log[H <sup>+</sup> ]                   | 7.0                                            | 6.7  | 6.9  | 6.9                                              | 6.9 <sup>a</sup> | 7.1              | 7.2                                            | 7.2 <sup>b</sup> | 7.4              | 6.7 <sup>a</sup>                                 | 6.5              | 6.8              | 7.2 <sup>a</sup>                                | 7.1               | 7.3 <sup>b</sup> |
| Organic matter                        | %                                       | 4.8                                            | 4.6  | 4.6  | 4.9                                              | 4.9              | 4.8              | 5.2                                            | 5.9              | 5.9              | 5.2                                              | 5.3              | 5.2              | 6.8                                             | 6.1               | 5.9              |
| Labile carbon                         | ugC g <sup>-1</sup>                     | 138                                            | 333  | 106  | 205                                              | 284 <sup>a</sup> | 202 <sup>a</sup> | 264                                            | 282 <sup>a</sup> | 226 <sup>b</sup> | 227                                              | 291              | 212 <sup>a</sup> | 349 <sup>b</sup>                                | 235 <sup>b</sup>  | 127              |
| Microbial biomass                     | mgC 100g <sup>-1</sup>                  | 403                                            | 295  | 249  | 389                                              | 412 <sup>a</sup> | 244              | 379                                            | 631 <sup>b</sup> | 492              | 419                                              | 457 <sup>b</sup> | 270              | 479                                             | 714 <sup>b</sup>  | 728 <sup>a</sup> |
| Arginine ammonification               | ugN 10g <sup>-1</sup> h <sup>-1</sup>   | 25                                             | 33   | 33   | 30                                               | 27               | 43               | 42                                             | 27               | 51               | 34                                               | 25               | 45               | 24                                              | 24                | 48               |
| Dehydrogenase activity                | ugTPF 10g <sup>-1</sup> h <sup>-1</sup> | 42                                             | 30   | 44   | 46                                               | 30               | 46               | 50                                             | 42 <sup>a</sup>  | 59               | 34                                               | 23               | 39               | 63 <sup>a</sup>                                 | 36                | 53               |
| <b>WATER RELATIONS</b>                |                                         |                                                |      |      |                                                  |                  |                  |                                                |                  |                  |                                                  |                  |                  |                                                 |                   |                  |
| Bulk density                          | g cm <sup>-3</sup>                      | 1.12                                           | —    | 1.13 | 1.16                                             | —                | 1.17             | 0.96 <sup>a</sup>                              | —                | 1.05             | 0.95 <sup>b</sup>                                | —                | 1.12             | 1.24 <sup>b</sup>                               | —                 | 1.30             |
| Total porosity                        | %                                       | 58                                             | —    | 58   | 56                                               | —                | 56               | 64                                             | —                | 61               | 64                                               | —                | 58               | 53                                              | —                 | 51               |
| <b>TOXICANT RELATIONS</b>             |                                         |                                                |      |      |                                                  |                  |                  |                                                |                  |                  |                                                  |                  |                  |                                                 |                   |                  |
| pH                                    | -log[H <sup>+</sup> ]                   | 7.0                                            | 6.7  | 6.9  | 6.9                                              | 6.9 <sup>a</sup> | 7.1              | 7.2                                            | 7.2 <sup>b</sup> | 7.4              | 6.7 <sup>a</sup>                                 | 6.5              | 6.8              | 7.2 <sup>a</sup>                                | 7.1               | 7.3 <sup>b</sup> |
| Electrical conductivity               | x10 <sup>-5</sup> mhos cm <sup>-1</sup> | 8                                              | 12   | 11   | 11                                               | 9                | 9                | 11                                             | 15               | 15               | 10                                               | 11               | 13               | 6                                               | 11                | 11               |
| <b>ROOTING RELATIONS</b>              |                                         |                                                |      |      |                                                  |                  |                  |                                                |                  |                  |                                                  |                  |                  |                                                 |                   |                  |
| Bulk density                          | g cm <sup>-3</sup>                      | 1.12                                           | —    | 1.13 | 1.16                                             | —                | 1.17             | 0.96 <sup>a</sup>                              | —                | 1.05             | 0.95 <sup>b</sup>                                | —                | 1.12             | 1.24 <sup>b</sup>                               | —                 | 1.30             |
| Texture (sand)                        | %                                       | —                                              | 18   | —    | —                                                | 17               | —                | —                                              | 22               | —                | —                                                | 19               | —                | —                                               | 20                | —                |
| (silt)                                | %                                       | —                                              | 62   | —    | —                                                | 64               | —                | —                                              | 59               | —                | —                                                | 61               | —                | —                                               | 61                | —                |
| (clay)                                | %                                       | —                                              | 20   | —    | —                                                | 19               | —                | —                                              | 19               | —                | —                                                | 21               | —                | —                                               | 19                | —                |
| <b>PHYSICAL STABILITY<sup>3</sup></b> |                                         |                                                |      |      |                                                  |                  |                  |                                                |                  |                  |                                                  |                  |                  |                                                 |                   |                  |
| WSA >2 mm                             | %                                       | 4.4                                            | 9.4  | 13.3 | 7.9                                              | 12.3             | 12.0             | 9.9                                            | 17.0             | 13.8             | 9.9                                              | 18.0             | 15.5             | 10.3                                            | 21.4              | 12.3             |
| >.25mm                                | %                                       | 49                                             | 55   | 66   | 39                                               | 57               | 62               | 48                                             | 63               | 62               | 45                                               | 61               | 56               | 55                                              | 69                | 53               |

<sup>1</sup> Experimental data are average of 3 plots. See Table 5 for details.

Statistical analysis: a or b = values significantly different from R1 at a level of P<0.5 or P<.01, respectively.

<sup>2</sup> Abbreviations: C = Corn; A = Alfalfa; B = Soybeans; CI = Wheat (fall seeded) and Red Clover (spring seeded); O = Interseeded Oats and Alfalfa;

P = pasture. \* indicates location in cropping rotation of 1994 sampling.

<sup>3</sup> Abbreviations: WSA = Water Stable Aggregates

**Table 8. Analytical Soil Quality Scores for 1994 WICST Rotations at Arlington and Lakeland with Respect to Crop Production and Water Quality Protection: Soil Nitrate.**

| Cropping system                  |      | Soil quality status      | Soil nitrate (mg Kg <sup>-1</sup> ) |                           |                           |                           |                                    |                           |                           |                           |                           |                           |
|----------------------------------|------|--------------------------|-------------------------------------|---------------------------|---------------------------|---------------------------|------------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
|                                  |      |                          | Corn production                     |                           |                           |                           | Water quality                      |                           |                           |                           |                           |                           |
|                                  |      |                          | Arlington <sup>1</sup>              |                           | Lakeland <sup>1</sup>     |                           | Arlington <sup>1</sup>             |                           |                           | Lakeland <sup>1</sup>     |                           |                           |
| Name <sup>2</sup>                | Code |                          | Spring                              | Summer                    | Spring                    | Summer                    | Spring                             | Summer                    | Fall                      | Spring                    | Summer                    | Fall                      |
| Standard                         |      | High<br>Marginal<br>Poor | >20-25<br>10-25<br><10-15           | >20-25<br>10-25<br><10-15 | >20-25<br>10-25<br><10-15 | >20-25<br>10-25<br><10-15 | <10-15<br>10-35<br>>30-35          | <10-15<br>10-35<br>>30-35 | <10-15<br>10-20<br>>20-25 | <10-15<br>10-35<br>>30-35 | <10-15<br>10-35<br>>30-35 | <10-15<br>10-20<br>>20-25 |
| Continuous corn<br>C-C-C-C*-C    | R1   | High<br>Marginal<br>Poor | 25<br>25                            | 25<br>17                  | 23<br>23                  | 32                        | 25<br>17                           |                           | 30                        | 25<br>32                  | 32<br>31                  |                           |
| Narrow row beans<br>B-C-B-C*-B   | R2   | High<br>Marginal<br>Poor | 35 <sup>a</sup>                     | 24<br>24                  | 32                        | 27                        | 35 <sup>a</sup><br>35 <sup>a</sup> | 24                        | 31                        | 32                        | 27                        | 35                        |
| Oats and alfalfa<br>O-A-C*-O-A   | R5   | High<br>Marginal<br>Poor | 41 <sup>a</sup>                     | 26                        | 38                        | 31                        | 41 <sup>a</sup>                    | 26                        | 37                        | 38<br>31                  | 31<br>58 <sup>a</sup>     |                           |
| Wide row beans<br>B-CI-C*-B-CI   | R3   | High<br>Marginal<br>Poor | 23<br>23                            | 18                        | 33                        | 16                        | 23<br>18                           |                           | 29                        | 33                        | 16<br>35                  |                           |
| Continuous pasture<br>P-P-P*-P-P | R6   | High<br>Marginal<br>Poor |                                     |                           |                           |                           | 15 <sup>a</sup><br>15 <sup>a</sup> | 19                        | 17                        | 14<br>14                  | 19                        | 34                        |

<sup>1</sup> Soil nitrate standards for corn production and water quality protection were approximated from UW NPM and soil fertility specialist recommendations. The cropping systems proceed from left to right in order of increasing synthetic input. Experimental data are the average of 3 plots for each systems.

R1. In 1994 plots (treatment 1): #109, #204, #306 (Arlington); #101, #210, #303 (Lakeland).

R2. In 1994 plots (treatment 2): #108, #206, #310 (Arlington); #108, #203, #304 (Lakeland).

R5. In 1994 plots (treatment 13): #114, #211, #312 (Arlington); #114, #201, #313 (Lakeland).

R3. In 1994 plots (treatment 4): #104, #201, #301 (Arlington); #109, #204, #308 (Lakeland).

R6. In 1994 plots (treatment 14): #112, #207, #302 (Arlington); #104, #213, #314 (Lakeland).

Statistical analysis: a = value is significantly different from the corresponding value for R1 (P<.05).

<sup>3</sup> Abbreviations for cropping system rotations:

C = Corn; A = Alfalfa; B = Soybeans; CI = Wheat (fall seeded) and Red Clover (spring seeded); O = Interseeded Oats and Alfalfa; P = Pasture.

\* indicates 1994 location in the crop rotation.

Narrow row beans showed a similar overall trend in soil nitrate scores as CC. However, at Arlington, but not Lakeland, soil nitrate showed significantly higher quality with respect to production and conversely poorer quality with respect to water quality in the spring as compared to CC (Table 8).

Oats and alfalfa followed narrow row beans in comparative soil nitrate quality as compared to CC, but in addition showed significantly poorer soil quality with respect to water quality in the fall at Lakeland, but not Arlington (Table 8).

Wide row beans showed no significant difference in soil nitrate scores as compared to CC at any time for either sites (Table 8).

Continuous pasture was evaluated only in terms of soil nitrate scores with respect to water quality as compared to CC (Table 8). Continuous pasture showed a significantly higher soil nitrate score with respect to water quality as compared to CC at Arlington, but not at Lakeland. And a similar trend to CC, of marginal to poor scores in the summer and fall was shown at both sites for continuous pasture.

## **Discussion**

The high average crop-based soil health scores for all cropping systems at both sites (3.6 to 4.0 range, Table 4), and the similarly high average soil-based soil health scores for all cropping systems (3.3 to 3.8, Table 5), provides gross evidence that the shift from continuous corn (CC) to the other rotations has not resulted in a significant gain or loss in soil health during the 3 to 5 year period of the study. It should be recognized that the high state of soil health shown by the continuous corn on the historically well managed and inherently rich prairie soils of the WICST sites provides little room for any increase in soil health due to a shift from continuous corn, particularly during the short term. Average Scores at the soil health category and individual property level need to be scrutinized because they may obscure meaningful differences at either level. Nevertheless, the overall trend on soil quality indicators during the shift from continuous corn to the other cropping systems over the 3 to 5 year time period is essentially insignificant, upon closer examination of individual soil quality indicator properties, some differences were found. Predicted long term effects were reviewed previously (Harris et. al, 1994).

### Nutrient Relations

Soil health scores for nutrient relations showed no consistent site-independent trends for continuous corn versus the other cropping systems (Table 5). Similarly, there were no consistent significant differences between CC and other cropping systems for inorganic and biological soil quality indicators (Tables 6 and 7) and soil nitrate scores with respect to corn production and water quality protection (Table 8).

### Water Relations

Soil health scores for water relations were healthy for all systems and at both sites, except for a lower score for continuous pasture at Lakeland due to impaired drainage and infiltration (Table 5). This was supported by a significantly higher bulk density in the fall for continuous pasture versus CC (Table 7). However, a similar phenomenon was not shown at Arlington (Tables 5 and 6).

### Rooting Relations

Continuous corn showed relatively low soil health scores for water relations due to impaired scores for earthworms and aeration (Table 5). However, it is interesting to note that CC scored as high or higher than the other systems for the other soil health indicators of rooting relations. The analytical soil quality indicators of rooting relations, showed no consistent site-independent significant differences (bulk density) or no significant differences at any time (porosity) between CC and the other cropping systems (Tables 6 and 7). For example, whereas bulk density was significantly lower at Arlington for oats and alfalfa, and wide row beans, supporting the higher soil health scores for earthworms and aeration shown for these cropping systems at Arlington, the opposite was the case for Lakeland (Tables 5, 6 and 7).

### Physical Stability

Soil health scores for CC and the other non pasture systems were relatively low due largely to low scores for surface cover (Table 5). The uniformly high soil health scores for physical stability shown for continuous pasture were supported by significantly higher water stable aggregation as compared to CC at Lakeland (Table 6), but not at Arlington (Table 7).

### Other soil quality indicator properties

Soil health scores for soil color, feel and topsoil depth showed no consistent trend for CC versus the other systems, but the soil health scores for soil smell was lower for CC at both sites (Table 5). Soil pH was not significantly different for CC as compared to the other systems at Arlington. At Lakeland, pH showed a tendency to be significantly higher for the other systems, particularly continuous pasture, but the data are too variable to warrant mechanistic conjecture at this time. Electrical conductivity consistently showed no significant differences for CC versus the other systems under all temporal and site conditions.

## **Summary**

The effect on soil health and quality of an increase in cropping system intensity/decrease in synthetic input was evaluated at the end of the initial transition period of 3 to 5 years following a shift from continuous corn. The cropping systems compared to continuous corn were: corn phases of a corn-soybean, corn-oat-alfalfa, corn-soybean-wheat/red clover; and a grazed continuous pasture.

Our research approach followed in principle the guidelines of the integrated framework for assessment of soil quality described by Harris and Karlen (1996). This framework links the definition of soil quality, the functions of soil quality, and the categories of soil quality indicator properties supporting each soil quality function. Following site and management objective analysis, the soil quality assessment plan involves identification of (1) a descriptive and/or analytical data set of soil and supplementary properties to be measured, including a sampling protocol and identification of the location of the properties within the conceptual framework, and (2) a process for interpreting the soil quality indicator properties on a high-to-low quality scale with respect to the fitness of the soil to support a specified function.

We use the terms soil health and quality interchangeably, with soil quality being the preferred term for generic use, and soil health being reserved for discussion of the Wisconsin Soil Health Report Card. Year-integrated descriptive soil health scores were obtained using the Wisconsin Soil Health Scorecard. The focus of the latter is on the crop productivity function of soil quality, and soil health properties are scored on a healthy-impaired-unhealthy scale. Spring, summer, and fall soil samples were analyzed for inorganic chemical (nitrate, ammonium, extractable P, exchangeable K, Ca and Mg, CEC and pH), physical (bulk density, texture, water stable aggregates, electrical conductivity) and biotic (organic matter, microbial biomass C, labile C, arginine ammonification, and dehydrogenase) indicators of soil quality. A soil quality scoring approach patterned after the one used for soil health, is illustrated using soil nitrate data scored on a high-marginal-poor scale with respect to the soil quality functions of sustaining crop growth and protecting water quality. In accordance with the conceptual framework, the soil health and quality indicator properties were organized into the standard categories of nutrient relations, water relations, toxicant relations, rooting relations, and soil physical stability.

High average crop-based soil health scores for all cropping systems at both sites, and the similarly high average soil-based soil health scores for all cropping systems, provided gross evidence that the shift from continuous corn (CC) to the other rotations had not resulted in a significant gain or loss in soil health during the 3 to 5 year period of the study. It should be recognized that the high state of soil health shown by the continuous corn on the historically well managed and inherently rich prairie soils of the WICST sites provides little room for any increase in soil health due to a shift from continuous corn, particularly during the short term. Average Scores at the soil health category and individual property level need to be scrutinized because they may obscure meaningful differences at either level. Nevertheless, the overall trend on soil quality indicators during the shift from continuous corn to the other cropping systems over the 3 to 5 year time period is essentially insignificant, upon closer examination of individual soil quality indicator properties, some differences were found. One of the most noteworthy phenomena was that continuous corn showed relatively low soil health scores for rooting relations due to impaired scores for earthworms and aeration, but it is interesting to note that CC scored as high or higher than the other systems for the other soil health indicators of rooting relations. There were no consistent site-independent differences in any of the analytical soil quality indicators for continuous corn as compared to the other cropping systems.

#### References

- Alef, K. and D. Kleiner. 1986. Arginine ammonification. A simple method to estimate the microbial activity potential in soils. *Soil Biol. Biochem.* 18: 233-235.
- Bacaltchuk, B. and R. Powers. 1993. Baseline survey of WICST outside auditors. WICST Second Rpt. Univ. of WI, Arlington Research Station. pp. 104-109.
- Blake, G.R. and K.M. Hartge. 1986. Bulk density. *In* A. Klute (ed.) *Methods of soil analysis*. Part 1. Physical and mineralogical methods. Second edition. pp. 363-375. ASA, Madison, WI.
- Casida, L.E. Jr., D.A. Klein, and T. Santaro. 1964. Soil dehydrogenase activity. *Soil Sci.* 98:371-376.
- Danielson, R.E. and P.L. Sutherland. 1986. Porosity. *In* A. Klute (ed.) *Methods of soil analysis*. Part 1. Physical and mineralogical methods. Second Edition. pp. 443-461. ASA, Madison, WI.
- Doran, J.W. and T.B. Parkin. 1994. Defining and assessing soil quality. *In* J.W. Doran, D.C. Coleman, D.F. Bezdicek, and B.A. Stewart (ed.) *Defining soil quality for a sustainable environment*. *Soil Sci. Soc. Amer. Special Publ.* 35:1-21. ASA, Madison, WI.

- Garlynd, M.J., A.V. Kurakov, D.E. Romig, and R.F. Harris. 1994. Descriptive and analytical characterization of soil quality/health. *In* J.W. Doran, D.C. Coleman, D.F. Bezdicek, and B.A. Stewart (ed.) *Defining soil quality for a sustainable environment*. Soil Sci. Soc. Amer. Special Publ. 35:159-168. ASA, Madison, WI.
- Garlynd, M.J., D.E. Romig, and R.F. Harris. 1995. Effect of a cropping system shift from continuous corn on descriptive and analytical indicators of soil quality. *Agron. Abstr.* p. 58.
- Harris, R.F. 1992. Developing a soil health report card. *Proc. Wisc. Fert. AgLime Pest Mgmt. Conf.* 31:245-248.
- Harris, R.F. and D.F. Bezdicek. 1994. Descriptive aspects of soil quality. *In* J.W. Doran, D.C. Coleman, D.F. Bezdicek, and B.A. Stewart (ed.) *Defining soil quality for a sustainable environment*. Soil Sci. Soc. Am. Special Publ. 35:23-35. ASA, Madison, WI.
- Harris, R.F. and D.L. Karlen. 1996. Integrated framework for assessing soil quality and health. *In* J.W. Doran and A.J. Jones (ed.) *Handbook of methods for assessment of soil quality*. In preparation.
- Harris, R.F., M.J. Garlynd, and A.V. Kurakov. 1993. Corn baseline values of soil analytical component of soil quality/health: 1992 data from WICST. *WICST Second Rpt.* Univ. of WI, Arlington Research Station. pp. 24-32.
- Harris, R.F., M.J. Garlynd, and D.E. Romig. 1994. Descriptive and analytical characterization of soil health and quality for the Wisconsin Integrated Cropping Systems Trial. *WICST Third Rpt.* Univ. of WI, Arlington Research Station. pp. 7-25.
- Harris, R.F., M.J. Garwick, 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*. p. 223-224. Univ. of Illinois, Urbana-Champaign, IL.
- Jenkinson, D.S. and D.S. Powlson. 1976. The effect of biocidal treatments on metabolism in soil-V. Method for measuring soil biomass. *Soil Biol. Biochem.* 8:209-213.
- Karlen, D.L. and D.E. Stott. 1994. A framework for evaluating physical and chemical indicators of soil quality. *In* J.W. Doran, D.C. Coleman, D.F. Bezdicek, and B.A. Stewart (ed.) *Defining soil quality for a sustainable environment*. Soil Sci. Soc. Am. Special Publ. 35:53-72. ASA, Madison, WI.
- Karlen, D.L., M.J. Mausbach, J.W. Doran, R.G. Cline, R.F. Harris, and G.E. Schuman. 1996. Soil quality: Concept, rationale, and research needs. *Soil Sci. Soc. Amer. Proc.* Invited review paper. In revision.
- Kemper, W.D. and R.C. Rosenau. 1986. Aggregate stability and size distribution. *In* A. Klute (ed.) *Methods of soil analysis. Part 1. Physical and mineralogical methods*. Second Edition. pp. 425-442. ASA, Madison, WI.
- Romig, D.E., M.J. Garlynd, and R.F. Harris. 1996. Farmer-based assessment of soil quality: A soil health scorecard. *In* J.W. Doran and A.J. Jones (ed.) *Handbook of methods for assessment of soil quality*. In press.
- Romig, D.E., M.J. Garlynd, R.F. Harris, and K.M. McSweeney. 1995. How farmers assess soil health and quality. *J. Soil Water Conserv.* 50:225-232.
- Schulte, E.E., J.B. Peters, and P.R. Hodgson. 1987. WI procedures for soil testing, plant analysis and feed and forage analysis. No. 6. *Soil Fertility Series*. Dept. of Soil Science. College of Agric. and Life Sci. Univ. of Wisconsin-EXT. Madison, WI.
- SAS Institute Inc., 1988. *SAS/STAT Users Guide*, Release 6.03 Edition. Cary, NC: Sa Institute Inc.
- Snedecor, G.W. and W.C. Cochran. 1980. *Statistical methods*. Seventh edition. Iowa State Univ. Press, Ames, IA.

**B. Pitfall Trap Analysis of Soil Macroarthropods Associated  
with the Wisconsin Integrated Cropping Systems Trial, 1993**

D. K. Young, D. B. Hogg, and E. J. Rebek

***Background***

The Wisconsin Integrated Cropping Systems Trial has become a forum for examining the ecological ramifications, both short and long term, of different approaches to farming and philosophies of land stewardship. Like several other research groups, we have focused on the soil biota as one measure of environmental impacts of agriculture.

Our operational hypothesis for our studies of arthropod diversity is that *the level and frequency of soil disturbance (both chemical and physical) in the cropping systems will influence the numbers and kinds of arthropods existing in the plots*. Differences in arthropod populations could contribute to, as well as result from, changes in soil characteristics. The five corn rotations in 1993 (Table 9) provided a range of chemical inputs, from the high end (continuous corn) to essentially no inputs for a three year rotation; however, the levels of soil disturbance (see graphs for tillage dates) were not as clearly delineated in the systems.

***Methods***

As in the 1992 survey, the 1993 pitfall trap soil macroarthropod sampling was conducted at both the Arlington Research Station (ARS) and the Lakeland Agricultural Complex (LAC). Sampling was accomplished using pitfall traps between early July and the end of August (Table 10). This technique passively captures animals as they move on the soil surface. Although not an exhaustive species inventory strategy, we feel that this sampling method offers one standardized approach for treatment and site comparisons.

The corn phase of the five cropping systems that include corn was sampled. Treatments in the corn phase during the 1993 field season included, continuous corn (R1 [CC]), corn following soybeans (R2 [BC]), corn following wheat/red clover (R3 [BWC]), corn after two years of alfalfa (R4 [AAAC]), and corn following year one of alfalfa (R5 [OAC]).

Two pitfall traps were placed in each corn plot in each of the four replications at each site. Trapping began in early July and terminated the last week of August. At each collection samples from identical treatments were pooled for comparison; thus, the contents of 8 traps (2/plot x 4 replications/site) constituted the bulk sample for each treatment. Traps were emptied biweekly, providing four bulked collections from ARS and three from the LAC location (Table 10).

Like 1992, samples were first separated, cleaned, and sorted to the first level of taxonomic comparison. In this first sorting step, the material went through an alcohol wash to remove other organic debris and soil, and the specimens were sorted into major ("first order") taxonomic groupings. As we continue to process the material, groups of particular interest and diversity, such as the beetles (Coleoptera) will be further processed taxonomically. This will enable us to make more specific taxonomic comparisons, and to better identify "functional groups" in an ecological sense.

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\* Assoc. Professor, Professor and undergraduate student, Dept. of Entomology, Univ. of Wisconsin, Madison

**Table 9. Macroarthropod Sampling Plots Associated with the Corn Phases of Five Cropping Systems.**

| <u>System</u> | <u>1993 Crop</u> | <u>Previous Crops</u>                        |
|---------------|------------------|----------------------------------------------|
| R1            | Corn             | Corn, Corn                                   |
| R2            | Corn             | Soybean, Corn                                |
| R3            | Corn             | Wheat/Red Clover, Soybean                    |
| R4            | Corn             | Alfalfa II, Alfalfa I, Direct Seeded Alfalfa |
| R5            | Corn             | Alfalfa I, Oats/Alfalfa                      |

**Table 10. 1993 WICST Pitfall Sampling Dates**

| <u>Week</u> | <u>Location</u> | <u>Inclusive Dates</u> |
|-------------|-----------------|------------------------|
| 1           | ARS             | July 7-13, 1993        |
| 2           | LAC             | July 15-24, 1993       |
| 3           | ARS             | July 23-30, 1993       |
| 4           | LAC             | July 30-August 6, 1993 |
| 5           | ARS             | August 6-13, 1993      |
| 6           | LAC             | August 13-21, 1993     |
| 7           | ARS             | August 21-27, 1993     |

\* ARS (Arlington Ag. Res. Station, Columbia Co., WI); LAC (Lakeland Ag. Complex, Walworth Co., WI).

### **Results to Date**

As a means for comparison with 1992 data, we have completed the preliminary analysis (see Figures 5-12 showing results for each of the first order taxonomic groups: Diplopoda, *millipedes*; Chilopoda, *centipedes*; Opiliones, *harvestmen*; Araneae, *spiders*; Collembola, *springtails*; Orthoptera, *crickets, grasshoppers, etc.*; Coleoptera, *beetles*; and Formicidae, *ants*). As was true for 1992, the graphs clearly illustrate that even at this initial level of analysis, clear differences exist between both the treatments and sites.

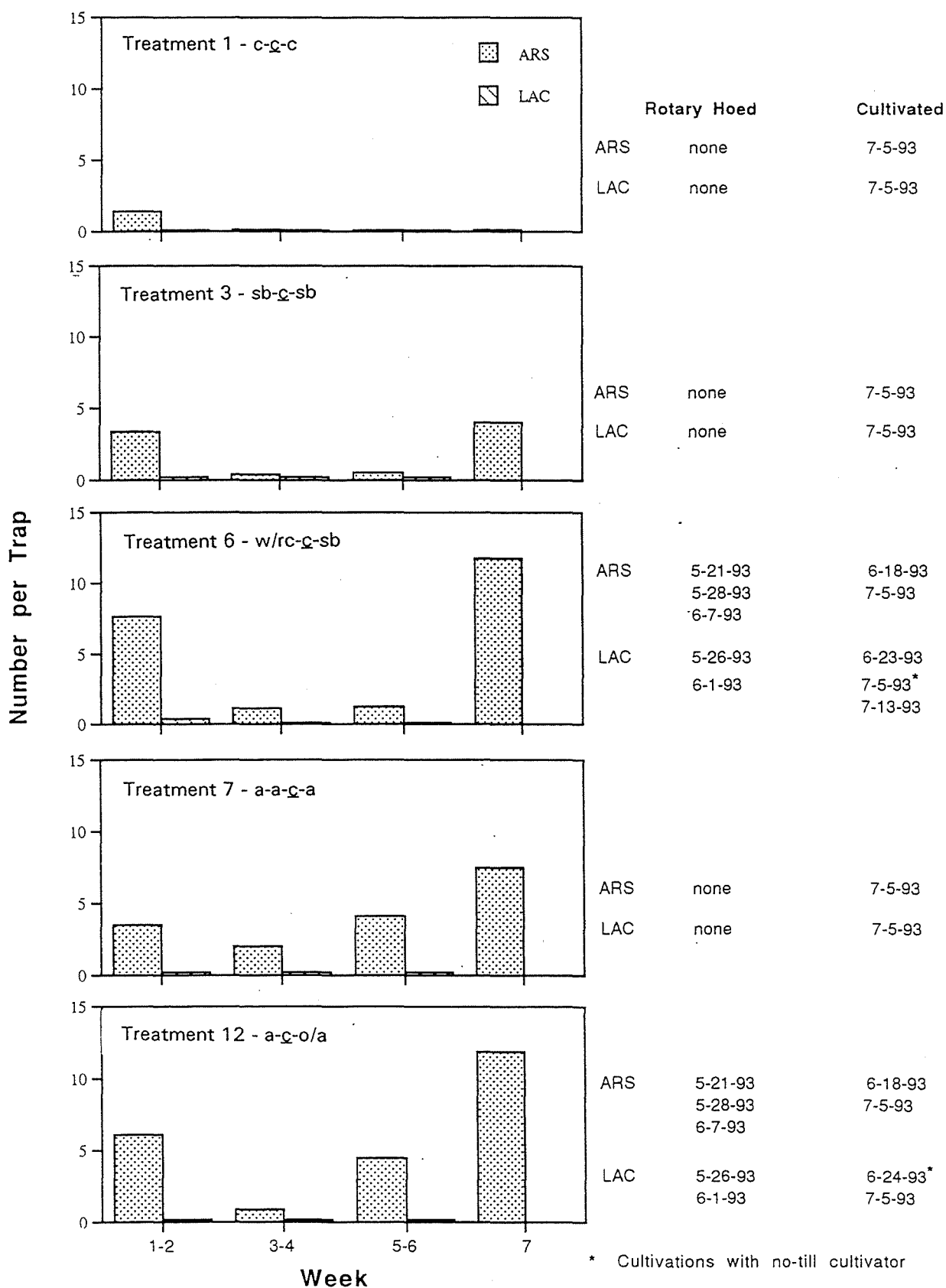
The Diplopoda, functionally scavengers for the most part, were almost entirely lacking at LAC, (Figure 5) as they were in 1992. It can also be seen that at ARS, millipede populations were higher in the systems with greater crop diversity (R2, R3, R4, and R5) as compared to continuous corn (R1). Once again, the peaks and dips in population abundances at certain times of the season were interesting and complex from one group to the next. For example, millipede populations at ARS showed a conspicuous reduction after the first sample was taken. This was followed by a gradual increase (R2, R4, R5) or a more abrupt increase (R3) later in the summer.

Chilopod and Opilione populations at LAC showed a fairly consistent peak over all treatments near weeks 5-6 (Figures 6 and 7). The [predaceous] Chilopoda were more abundant at LAC than ARS in 1992 (except in R1); such a distinction was not entirely obvious in 1993, although R1 (continuous corn) again showed nearly equal populations. Spiders were more common at LAC, where numbers were greatest at weeks 1-2 over all rotations (Figure 8). Perhaps significantly, Collembola - which probably serve as common prey of spiders - also showed the highest numbers at weeks 1-2 (LAC) (Figure 9).

During both 1992 and 1993, samples indicate that Orthoptera populations were much larger in corn following wheat/red clover, especially at LAC (Figure 10). The Coleoptera are represented primarily by a large, diverse and quite mobile group known as the ground beetles (family Carabidae). This group of mostly predaceous species was well represented at both sites throughout the sampling period, although the smallest numbers of individuals were consistently recovered at LAC at weeks 3-4 (for all treatments) (Figure 11).

Ants (family Formicidae) were notably scarce in R3, especially at LAC. While this rotation has one of the more aggressive soil disturbance schedules, the same may be said for R5, where populations were certainly not depressed (Figure 12). Ant numbers, in general, were low at LAC during the 1992 sampling season. The general increase in ant populations seen during August, 1992 for all treatments, did not take place during 1993.

While these graphic representations represent only the first order of taxonomic sorting, the data continue to support our initial research hypothesis for the study: *the level and frequency of soil disturbance (both chemical and physical) in the cropping systems influence the numbers and kinds of arthropods existing in the plots.*



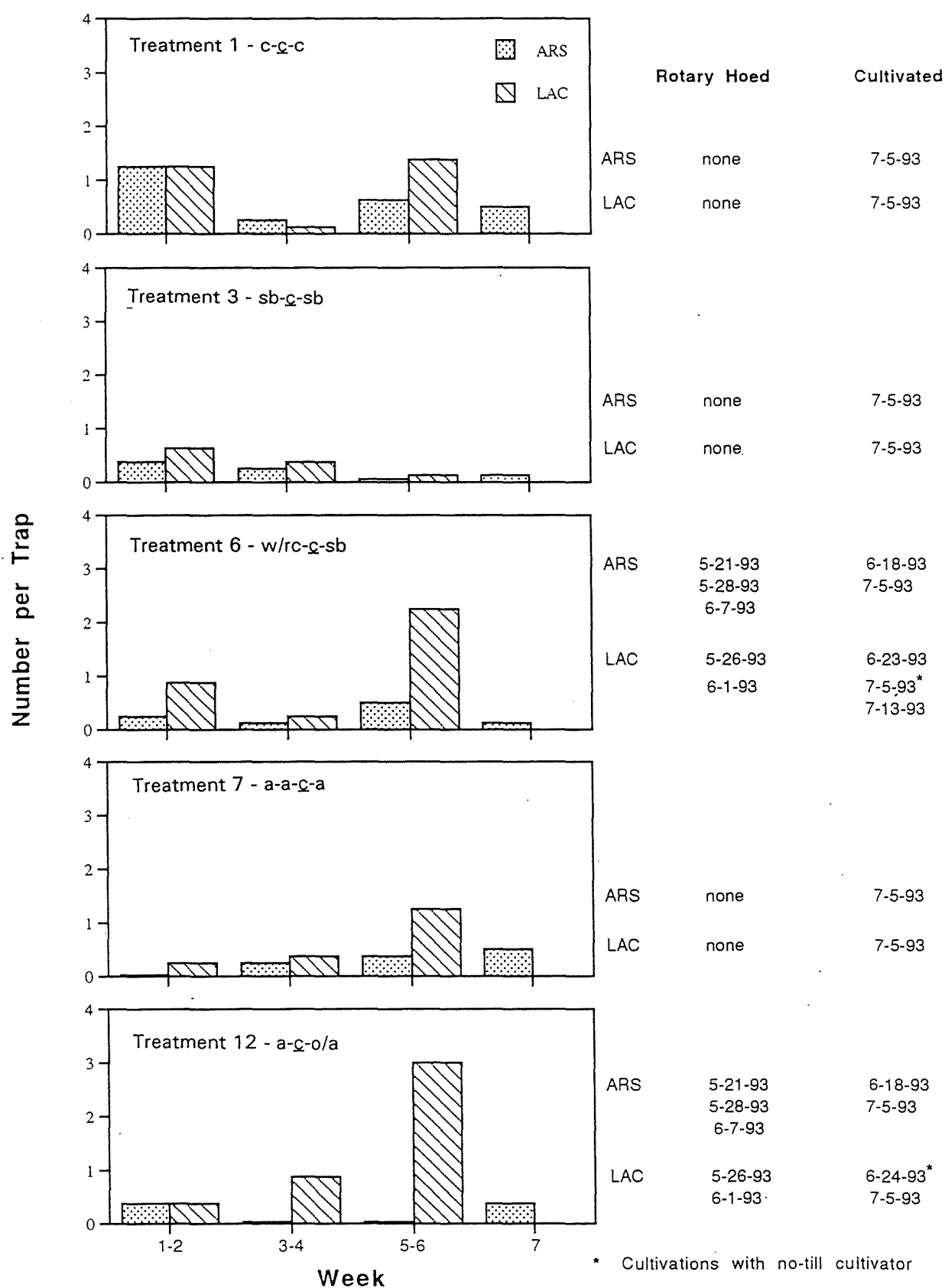


Figure 6. Chilopoda Captured in Pitfall Traps - 1993

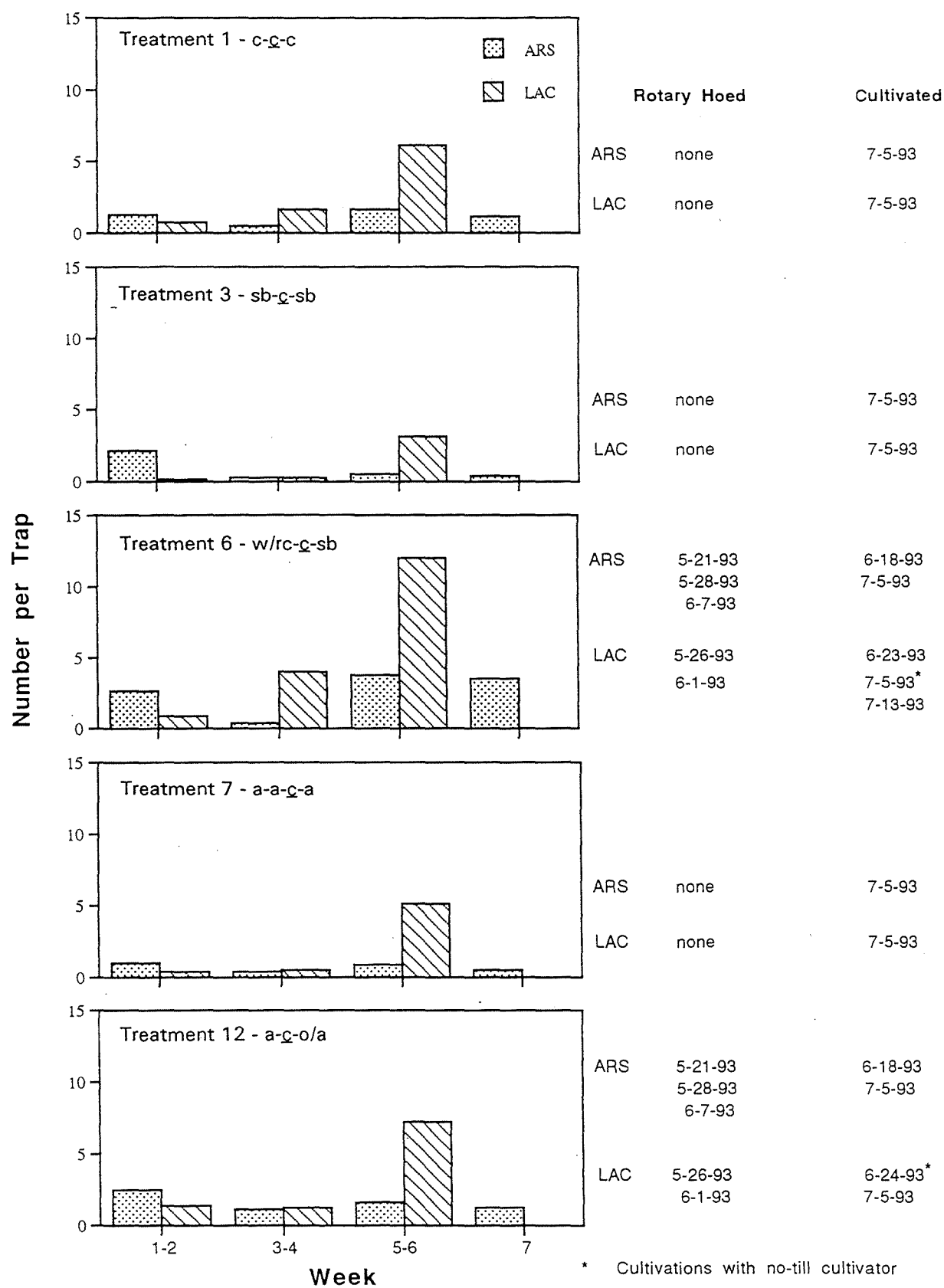


Figure 7. Opiliones Captured in Pitfall Traps - 1993

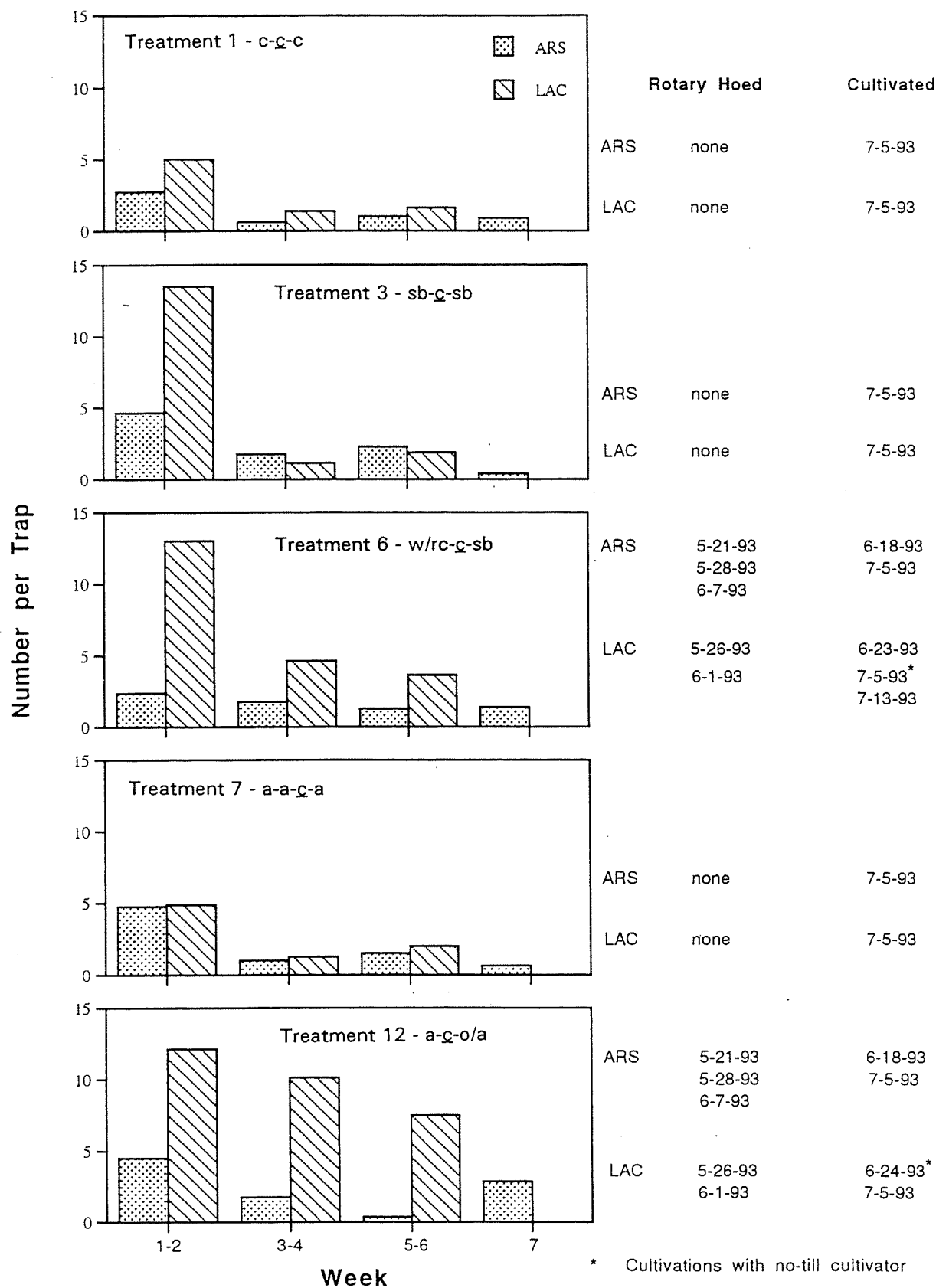


Figure 8. Araneae Captured in Pitfall Traps - 1993

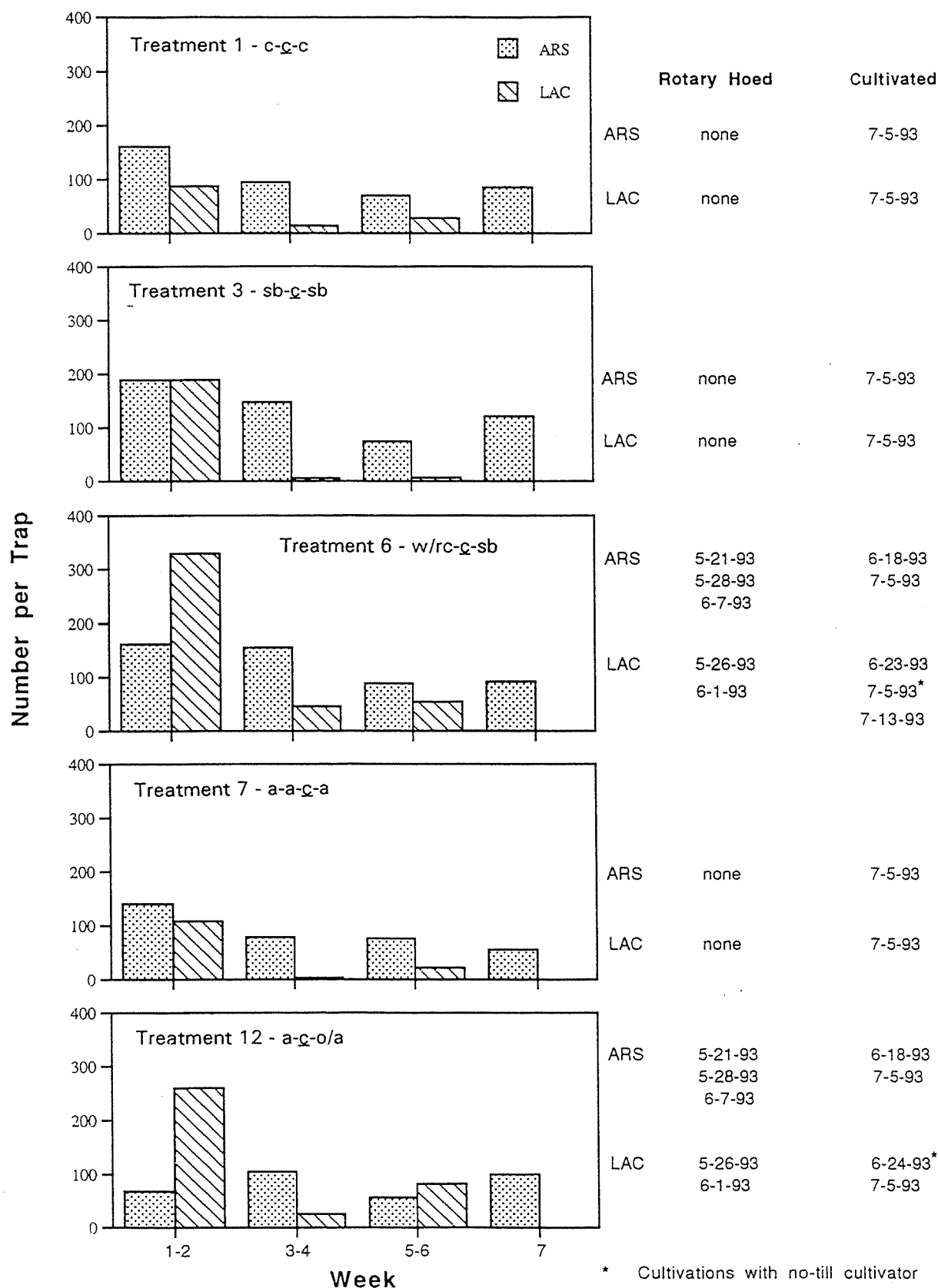


Figure 9. Collembola Captured in Pitfall Traps - 1993

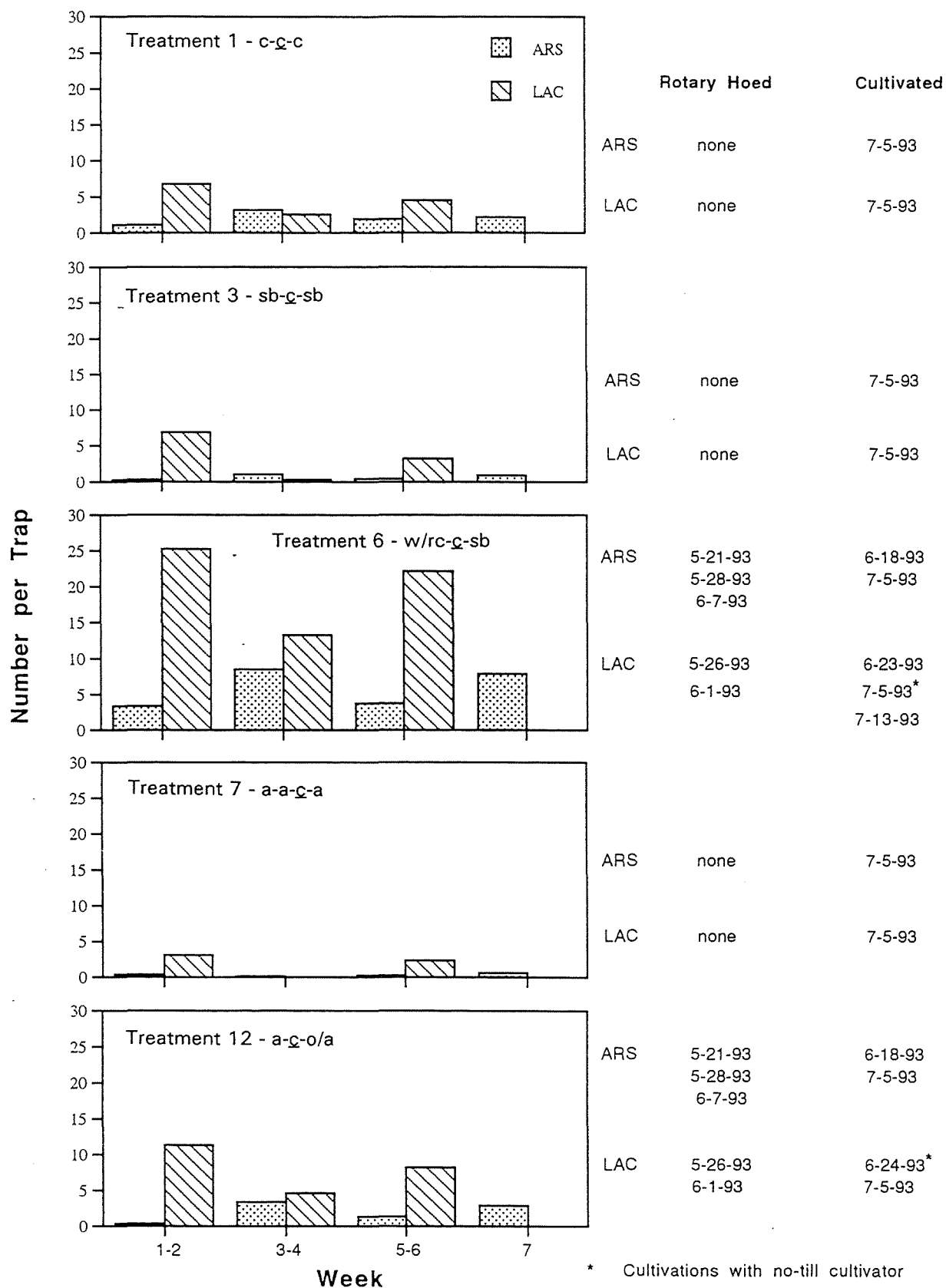


Figure 10. Orthoptera Captured in Pitfall Traps - 1993

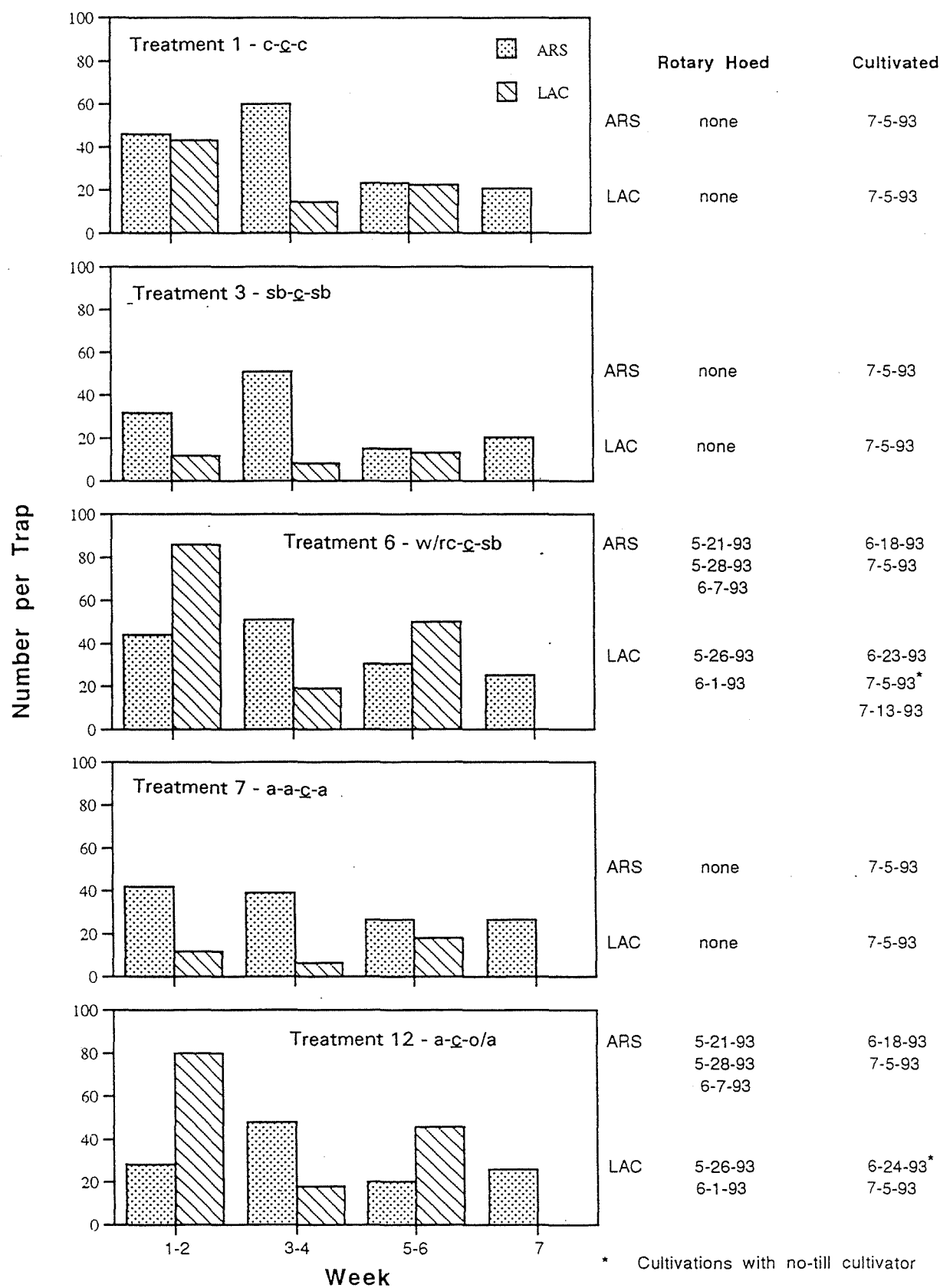


Figure 11. Coleoptera Captured in Pitfall Traps - 1993

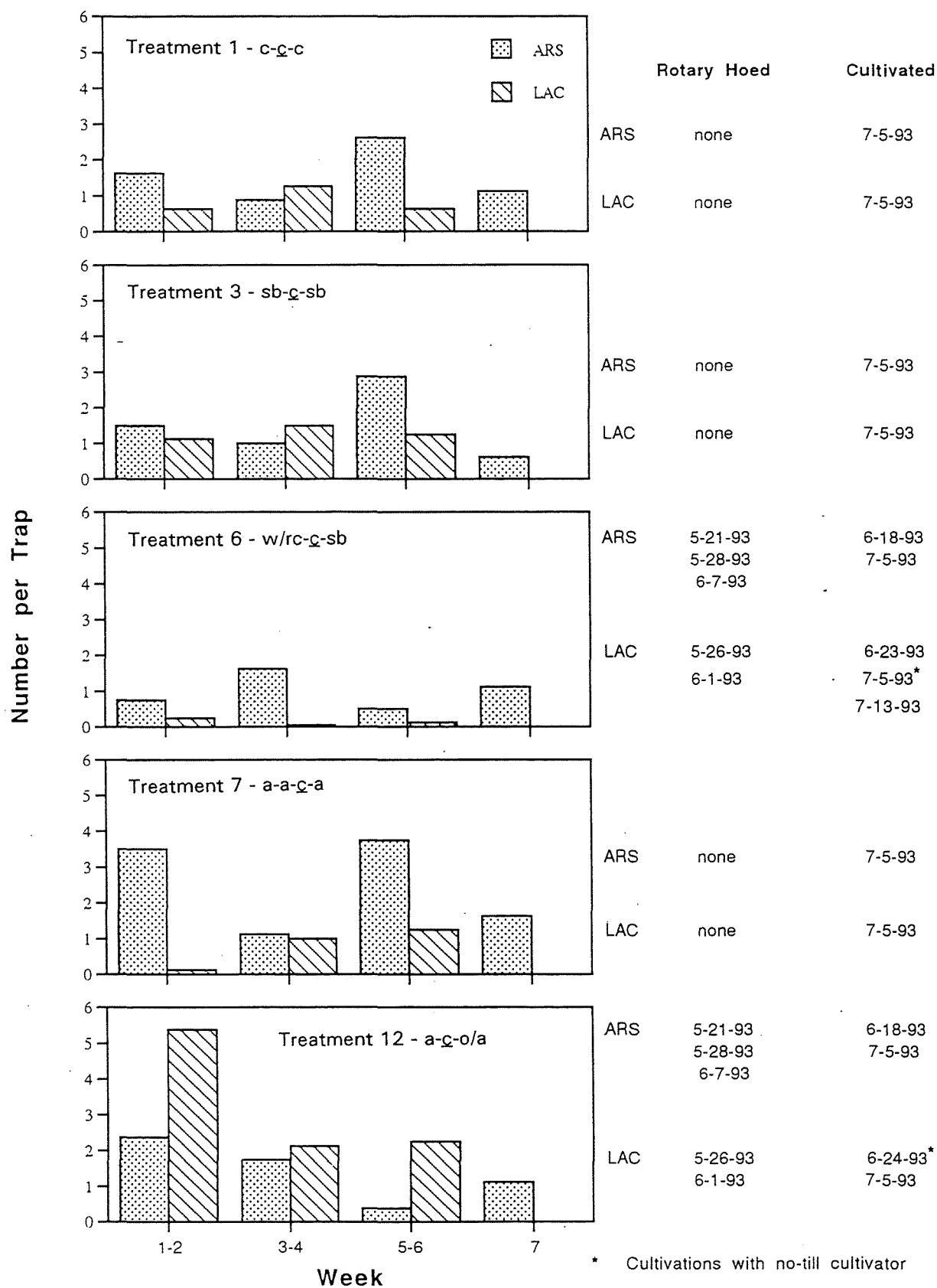


Figure 12. Formicidae Captured in Pitfall Traps - 1993

### C. Residue Decomposition and Associated Invertebrates: 1994 Results

Dave Hogg\*, Dan Young\*, Eric Rebek\*, Tom Mulder\*\*, Joe Hoffman\*\*

The litter bag study initiated in 1993 on the Wisconsin Integrated Cropping Systems Trial (WICST) was continued and expanded during 1994. The objectives of this study are to characterize the influence of crop rotation on residue decomposition, and to document the role of macro- and meso-invertebrates in the decomposition process. The latter was accomplished using litter bags with different pore sizes to isolate the influence of microorganisms and soil fauna in the decomposition process.

Briefly, our 1993 results (Hogg et al. 1994) suggested that various animals (arthropods and annelids) making up the soil fauna contributed significantly to residue decomposition. However, there was only weak evidence for differences in animal activity and no evidence for differences in decomposition rates among the three cropping systems studied.

#### Methods

Both the Arlington (ARS) and Lakeland (LAC) sites of the WICST were included in the 1994 litter bag sampling program. Bags with different mesh sizes were again utilized to indicate the relative importance of animal activity in the decomposition process (Edwards and Heath, 1963; Curry, 1969; Vossbrinck et al., 1979; House and Stinner, 1987). Small pore bags (0.0053 mm) were used to exclude annelids and arthropods, allowing only microorganisms to enter, and large pore bags (4 mm) allowed animals to enter.

Litter bags were buried in the ARS plots on May 11 and the LAC plots on May 16. Bags were retrieved at ARS on June 9, July 6, August 3, August 31 ("September" sample) and September 28 ("October" sample), and at LAC on June 16, July 13, August 10, September 7 and October 5.

Residue decomposition rates were monitored using the large pore bags in the R1 continuous corn system, in all three crops of the R3 (corn-soybean-wheat/red clover) system, in all three crops of the R5 (corn-oats-alfalfa) system and the R6 (pasture) system. Decomposition rates were monitored with the small pore bags in the corn phases of the R3 and R5 systems and in the R6 system. Litterbags (both small and large pore) containing brome grass, in addition to bags containing corn stover, were buried in the pasture plots. Methods were the same as used for the 1993 study with 12-15 grams of air-dried residue in each bag buried following preplant tillage and planting of the corn (see Hogg et al. 1994). Bags were buried in the top 6 inches of the soil profile at a 45 degree angle to the soil surface. Number of treatment sampled were increased in 1994 (only plots with crops following corn in systems R1, R3 and R5 were sampled in 1993) but the number of repetitions was reduced from four to three for the 1994 study.

#### Results

Residue decomposition levels estimated for the two sites are shown in Tables 11 and 12. Several points can be made from these data. For the large pore bags at both sites, treatment (cropping system and/or phase) differences were statistically significant for every month except June at LAC and September at ARS. However, no consistent pattern

\* Assoc. Professor, Professor and undergraduate student, Dept. of Entomology, Univ. of Wisconsin, Madison.

\*\* Research Specialist and undergraduate student, Dept. of Agronomy, Univ. of Wisconsin, Madison.

is evident among treatments. For example, in comparing the three corn phases (R1, R3 & R5), in only one of ten possible cases was there a statistically significant difference among average decomposition levels. (The exception was August at ARS, in which decomposition in R5 was significantly less than in R3). The results suggest also that decomposition levels were greater in the large pore bags than in the small pore bags, although these differences were not tested statistically: 53% versus 42% at LAC (September sample), and 61% versus 44% at ARS (September sample).

Numbers of animals extracted from the large pore bags are shown in Figures 13 and 14. The four most abundant groups recovered from the litter bags are categorized individually: Coleoptera (beetles), Diptera (flies), Diplopoda (millipedes) and Annelida (earthworms). The category "other invertebrates" includes springtails, spiders, mites, and miscellaneous other insect orders. At the LAC site, the greatest number of animals were recovered in the alfalfa phase of the intermediate-input forage system (R5), although curiously no animals were recovered from these plots in the August collection. At the ARS site, the greatest number of animals were recovered in the corn phase of the low-input grain system (R3). However, as with decomposition levels, no consistent pattern is evident among treatments, and there were no statistically significant differences in total numbers of animals extracted among cropping systems and/or phases (tested for each sample date).

A separate indicator of animal activity in the large pore bags is the quantity of earthworm castings and soil deposited by animals moving through the bags, which was measured for the August, September and October collections at both sites (Tables 11 and 12). At LAC, differences among systems/phases were statistically significant for each collection, with continuous corn (R1) and pasture (R6) tending to have the lowest levels of activity. At ARS, differences were significant for the August and September collections, and only continuous corn tended to stand out as having the lowest activity levels.

Several aspects of our 1994 results are similar to our 1993 results. Decomposition levels tended to be greater in the large pore litter bags than in the small pore bags, indicating that activity by macro- and meso-invertebrates is important to the decomposition process. However, there were no clear differences in either decomposition levels or animal numbers among cropping systems and/or phases. Quantities of earthworm castings and soil deposited by animals moving through the bags, a measurement not taken in 1993, did provide evidence of differences among cropping systems and might be a better indicator than sheer numbers of animal activity in the large pore bags.

#### References Cited

- Curry, J.P. 1969. The decomposition of organic matter in soil. Part I. The role of the fauna in decaying grassland herbage. *Soil Biol. Biochem.* 1: 253-258.
- Edwards, C.A. and G.W. Heath. 1963. The role of soil animals in breakdown of leaf material. pp. 76-84 *In* J. Doeksen and J. van der Drift [eds.], *Soil Organisms*. North-Holland Publ. Co., Amsterdam.
- Hogg, D.B., D.K. Young, H. Hoffman and E.J. Rebek. 1994. Residue decomposition following corn in three cropping systems: 1993 results. Third Report of the Wisconsin Integrated Cropping Systems Trial, University of Wisconsin-Madison, pp. 37-42.
- House, G.J. and R.E. Stinner. 1987. Decomposition of plant residue in no-tillage agroecosystems: Influence of litterbag mesh size and soil arthropods. *Pedobiologia* 30: 351-360.
- Vossbrinck, C.R., D.C. Coleman, and T.A. Wooley. 1979. Abiotic and biotic factors in litter decomposition in semiarid grassland. *Ecology* 60: 265-271.

Table 11. Lakeland Agricultural Complex Residue Bag Results - 1994

| Largepore Residue Bags    |              |                                 |                |                |                |               |
|---------------------------|--------------|---------------------------------|----------------|----------------|----------------|---------------|
| Residue Biomass Reduction |              |                                 |                |                |                |               |
| <u>Removal date</u>       |              | <u>June 16</u>                  | <u>July 13</u> | <u>Aug. 10</u> | <u>Sept. 7</u> | <u>Oct. 5</u> |
| <u>Treatment</u>          |              | ----- % biomass reduction ----- |                |                |                |               |
| R1                        | Corn         | 0.12                            | 0.23           | 0.47           | 0.55           | 0.67          |
| R3                        | Corn         | -0.03                           | 0.15           | 0.41           | 0.56           | 0.58          |
| R3                        | Wheat        | 0.0                             | -0.09          | 0.32           | 0.41           | 0.43          |
| R3                        | Soybean      | -0.05                           | 0.14           | 0.43           | 0.53           | 0.52          |
| R5                        | Alfalfa      | -0.12                           | -0.01          | 0.41           | 0.47           | 0.51          |
| R5                        | Oats/alfalfa | 0.05                            | 0.11           | 0.24           | 0.32           | 0.43          |
| R5                        | Corn         | 0.01                            | 0.22           | 0.40           | 0.57           | 0.67          |
| R6c*                      | Pasture      | 0.11                            | 0.12           | 0.24           | 0.51           | 0.46          |
| R6g**                     | Pasture      | -0.12                           | 0.31           | 0.50           | 0.47           | 0.65          |
| Isd (0.05)                |              | NS                              | .16            | .12            | .18            | .15           |

## Soil and Earthworm Castings

| <u>Removal date</u> |              | <u>Aug. 10</u>        | <u>Sept. 7</u> | <u>Oct. 5</u> |
|---------------------|--------------|-----------------------|----------------|---------------|
| <u>Treatment</u>    |              | ----- grams/bag ----- |                |               |
| R1                  | Corn         | 1.8                   | 10.0           | 7.7           |
| R3                  | Corn         | 18.9                  | 58.7           | 73.4          |
| R3                  | Wheat        | 15.6                  | 20.0           | 27.0          |
| R3                  | Soybean      | 16.9                  | 17.9           | 20.6          |
| R5                  | Alfalfa      | 21.1                  | 24.8           | 30.9          |
| R5                  | Oats/alfalfa | 10.1                  | 32.2           | 41.5          |
| R5                  | Corn         | 12.9                  | 42.2           | 59.2          |
| R6c                 | Pasture      | 3.3                   | 13.4           | 7.2           |
| R6g                 | Pasture      | 7.5                   | 10.8           | 9.2           |
| Isd (0.05)          |              | 9.9                   | 22.8           | 34.5          |

## Smallpore Residue Bags

## Residue Biomass Reduction

| <u>Removal date</u> |         | <u>June 16</u>                  | <u>July 13</u> | <u>Aug. 10</u> | <u>Sept. 7</u> |
|---------------------|---------|---------------------------------|----------------|----------------|----------------|
| <u>Treatment</u>    |         | ----- % biomass reduction ----- |                |                |                |
| R3                  | Corn    | 0.18                            | 0.34           | 0.43           | 0.39           |
| R5                  | Corn    | 0.09                            | 0.30           | 0.53           | 0.38           |
| R6c                 | Pasture | 0.22                            | 0.35           | 0.50           | 0.47           |
| R6g                 | Pasture | 0.16                            | 0.29           | 0.53           | 0.45           |
| Isd (0.05)          |         | NS                              | NS             | NS             | NS             |

\* Bag filled with corn residue.

\*\* Bag filled with bromegrass residue.

**Table 12. Arlington Agricultural Research Station Residue Bag Results - 1994**

| <b>Largepore Residue Bags</b> |              |                                 |               |               |                |                 |
|-------------------------------|--------------|---------------------------------|---------------|---------------|----------------|-----------------|
| Residue Biomass Reduction     |              |                                 |               |               |                |                 |
| <u>Removal date</u>           |              | <u>June 9</u>                   | <u>July 6</u> | <u>Aug. 3</u> | <u>Aug. 31</u> | <u>Sept. 28</u> |
| <u>Treatment</u>              |              | ----- % biomass reduction ----- |               |               |                |                 |
| R1                            | Corn         | 0.17                            | 0.15          | 0.50          | 0.65           | 0.62            |
| R3                            | Corn         | 0.06                            | 0.14          | 0.61          | 0.61           | 0.57            |
| R3                            | Wheat        | 0.08                            | 0.08          |               |                |                 |
| R3                            | Soybean      | 0.06                            | 0.15          | 0.39          | 0.60           | 0.66            |
| R5                            | Alfalfa      | 0.03                            | 0.07          | 0.30          | 0.62           | 0.74            |
| R5                            | Oats/alfalfa | 0.04                            | 0.14          | 0.48          | 0.63           | 0.69            |
| R5                            | Corn         | 0.08                            | 0.21          | 0.38          | 0.55           | 0.68            |
| R6c*                          | Pasture      | 0.10                            | 0.11          | 0.37          | 0.55           | 0.70            |
| R6g**                         | Pasture      | 0.18                            | 0.33          | 0.50          | 0.71           | 0.39            |
| Isd (0.05)                    |              | .14                             | 0.22          | 0.16          | NS             | 0.21            |

## Soil and Earthworm Castings

| <u>Removal date</u> |              | <u>Aug. 3</u>         | <u>Aug. 31</u> | <u>Sept. 28</u> |
|---------------------|--------------|-----------------------|----------------|-----------------|
| <u>Treatment</u>    |              | ----- grams/bag ----- |                |                 |
| R1                  | Corn         | 12.1                  | 22.5           | 33.7            |
| R3                  | Corn         | 34.0                  | 43.7           | 42.6            |
| R3                  | Soybean      | 27.0                  | 31.3           | 38.0            |
| R5                  | Alfalfa      | 28.1                  | 32.7           | 34.9            |
| R5                  | Oats/alfalfa | 46.6                  | 52.5           | 61.9            |
| R5                  | Corn         | 33.8                  | 66.8           | 69.2            |
| R6c                 | Pasture      | 43.7                  | 36.1           | 47.2            |
| R6g                 | Pasture      | 11.2                  | 30.9           | 42.6            |
| Isd (0.05)          |              | 27.4                  | 28.4           | NS              |

**Smallpore Residue Bags**

## Residue Biomass Reduction

| <u>Removal date</u> |         | <u>June 9</u>                   | <u>July 6</u> | <u>Aug. 3</u> | <u>Aug. 31</u> |
|---------------------|---------|---------------------------------|---------------|---------------|----------------|
| <u>Treatment</u>    |         | ----- % biomass reduction ----- |               |               |                |
| R3                  | Corn    | 0.19                            | 0.29          | 0.42          | 0.50           |
| R5                  | Corn    | 0.22                            | 0.40          | 0.42          | 0.43           |
| R6c                 | Pasture | 0.11                            | 0.36          | 0.44          | 0.41           |
| R6g                 | Pasture | 0.13                            | 0.42          | 0.44          | 0.41           |
| Isd (0.05)          |         | NS                              | NS            | NS            | NS             |

\* Bag filled with corn residue.

\*\* Bag filled with brome grass residue.

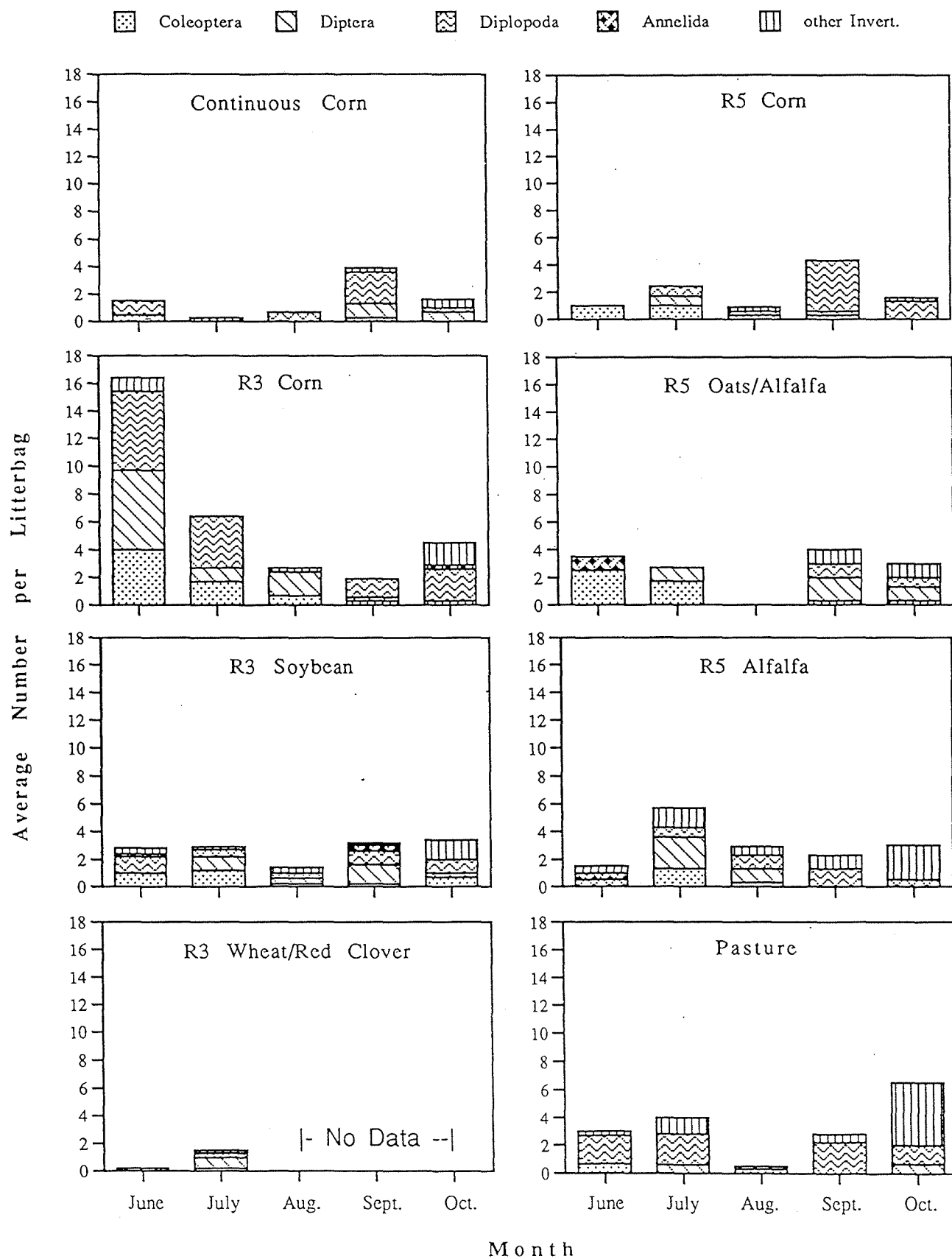


Figure 13. 1994 LAC Litterbag Data - Large Pore Bag Results

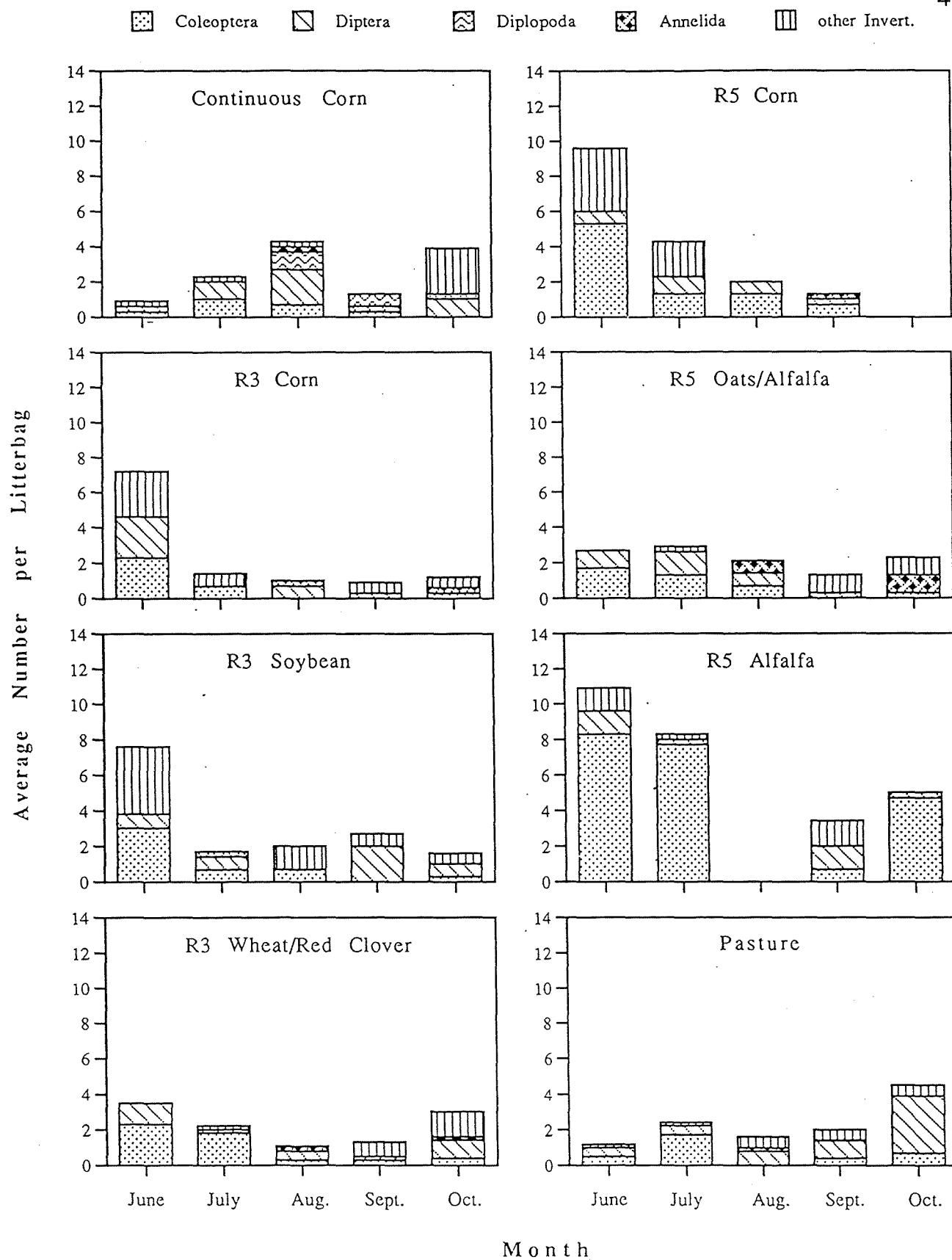


Figure 14. 1994 LAC Litterbag Data - Large Pore Bag Results

#### **D. Relevance of Biodiversity to the Sustainability of Agricultural Systems**

Jon Baldock\*

Biodiversity is widely considered to be an important measure of ecosystem health, underpinning ecosystem structure, function, and sustainability. Agricultural systems comprise the majority of all terrestrial ecosystems; thus, agriculture may be especially important to maintaining biodiversity. Past research has produced conflicting evidence on whether biodiversity is key to agricultural sustainability, and which agricultural practices promote and which impair ecosystem biodiversity. Clearly, a better understanding of these issues is needed if agriculture is to play its dual role of producing sufficient food and fiber while sustaining the resource base on which it depends.

With those factors in mind, an interdisciplinary group of scientists submitted a proposal to the United States Department of Agriculture's National Research Initiative Competitive Grants Program to study the biodiversity of the cropping systems in the WICST. The group included:

Jon Baldock, AGSTAT, Verona, WI  
 Walter Goldstein, Michael Fields Agricultural Institute, East Troy, WI  
 John Hall, Michael Fields Agricultural Institute, East Troy, WI  
 Robin Harris, Department of Soil Science, UW-Madison  
 William Hickey, Department of Soil Science, UW-Madison  
 David Hogg, Department of Entomology, UW-Madison  
 Ann MacGuidwin, Department of Plant Pathology, UW-Madison  
 Josh Posner, Department of Agronomy, UW-Madison  
 Doug Rouse, Department of Plant Pathology, UW-Madison  
 Dan Young, Department of Entomology, UW-Madison

We received notice that our proposal was successful in August 1994. Because of funding limitations we had to limit the initial phase of this project to two methodological objectives: 1) to develop methods to efficiently sample and describe a broad spectrum of organisms in a wide range of agricultural systems, and 2) to develop indices, or find indicator species, that characterize the biodiversity of that broad spectrum of organisms.

When the methods are refined we will submit another proposal to apply these methods to understanding differences between cropping systems and the relationship between biodiversity and ecosystem structure and functions associated with sustainability. Ultimately we hope to use the understanding gained in those studies to provide better guidance to farmers and others regarding which farming practices foster sustainability.

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\* Interim Project Coordinator and Project Statistician.

### III. 1994 WEED SEED BANK AND BIOMASS RESULTS

Jerry Doll, Tom Mulder and Josh Posner\*

We continued sampling weed seeds as in previous years by counting weed seedlings germinating in soil that had been collected from selected plots early in the spring. In order to increase the power of our statistical analysis we took six subsamples per plot, rather than the previous three. Each subsample contained five cores of three quarters of an inch diameter to six inches deep. The soil was mixed with sand, placed in plastic trays in the greenhouse and seedlings were counted and identified through three germination cycles. All plots that had been in corn in 1993 were sampled as well as those following wheat and red clover in system 3c (tmt. 4) and following alfalfa in systems 4b and 5c (tmnts. 8 and 13, respectively). The weed biomass present in the corn and soybean plots was measured by cutting all weeds taller than 4 inches when corn was approximately 36 inches tall. Weeds were dried and weighed and pounds of weeds per acre were calculated.

#### Seed bank results.

Weed seed populations in R1 have remained fairly steady with a slight decline at ARS (Arlington Research Station) and a slight increase at LAC (Lakeland Agricultural Complex) compared to 1993 and are relatively low compared to other systems (Tables 13 and 14). The overall trend is that seed banks are holding steady in this system at ARS and are increasing at LAC. Broadleaf species predominate at ARS while grasses are increasing at LAC.

The populations in the corn-soybean system (R2a) increased to the highest level yet at ARS but are low (less than 400 seedlings/ft<sup>2</sup>) at LAC and have generally decreased. Broadleaves have always predominated in this system at ARS. Grasses were more abundant than broadleaves initially in this system at LAC, but now broadleaves are more abundant.

Weed seed populations following corn in the corn-soybean-wheat/red clover system (3b) continue very high at ARS and increased nearly seven-fold at LAC compared to 1993. They are considered severe (over 1000 seedlings/ft<sup>2</sup>) at both sites. Our weed management strategy in this system has been to rotate a vigorously growing cool season cropping phase (wheat/red clover) with timely mechanical weedings during the two warm season cropping phases (corn and soybeans). Actual weed seed numbers have increased since the fields came out of a chemical weed control program in a corn/alfalfa system. We don't know yet if we are reaching a new equilibrium level of weed pressure, if weed seed numbers will continue to rise, or, as we improve our management of the system we will observe a weed seed decrease.

Weed seed populations following corn treated with herbicide in the high input corn-alfalfa system (R4a) are relatively low at both sites. However, in system R4b (following the last year of alfalfa), populations are very high at ARS and, while the seed bank has increased at LAC compared to the 1991 data, the density is still low. Soil samples are taken in the spring after manure has been applied in the fall and this may add weed seeds in this system. Nearly all weeds in this system are broadleaves at both sites.

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\* Professor, Research Specialist and Professor, Dept. of Agronomy, Univ. of Wisconsin, Madison

**Table 13. Weed seedbank changes in WICST at the Arlington Agricultural Research Station from 1990 - 1994.**

| <u>System</u> | <u>Crop rotation</u>               | <u>Tmt*</u> | <u>Variable</u>       | <u>90</u> | <u>91</u> | <u>92</u> | <u>93</u> | <u>94</u> |
|---------------|------------------------------------|-------------|-----------------------|-----------|-----------|-----------|-----------|-----------|
| R1            | <u>90-91-92-93-94</u><br>C-C-C-C-C | 1           | seeds/ft <sup>2</sup> | 448       | 166       | 206       | 266       | 171       |
|               |                                    |             | % bdlf                | 86        | 84        | 87        | 86        | 81        |
|               |                                    |             | % grass               | 14        | 16        | 13        | 14        | 19        |
|               |                                    |             |                       |           |           |           |           |           |
| R2a           | S-C-S-C-S                          | 3           | seeds/ft <sup>2</sup> | 429       | 480       | 571       | --        | 807       |
|               |                                    |             | % bdlf                | 75        | 73        | 78        | --        | 88        |
|               |                                    |             | % grass               | 25        | 27        | 22        | --        | 12        |
|               |                                    |             |                       |           |           |           |           |           |
| R2b           | C-S-C-S-C                          | 2           | seeds/ft <sup>2</sup> | --        | 144       | --        | 215       | --        |
|               |                                    |             | % bdlf                | --        | 70        | --        | 86        | --        |
|               |                                    |             | % grass               | --        | 30        | --        | 14        | --        |
|               |                                    |             |                       |           |           |           |           |           |
| R3a           | S-WR-C-S-WR                        | 5           | seeds/ft <sup>2</sup> | 206       | 459       | 894       | 850       | --        |
|               |                                    |             | % bdlf                | 68        | 80        | 85        | 83        | --        |
|               |                                    |             | % grass               | 32        | 20        | 15        | 17        | --        |
|               |                                    |             |                       |           |           |           |           |           |
| R3b           | C-S-WR-C-S                         | 6           | seeds/ft <sup>2</sup> | --        | 703       | --        | 1079      | 1035      |
|               |                                    |             | % bdlf                | --        | 88        | --        | 67        | 43        |
|               |                                    |             | % grass               | --        | 12        | --        | 33        | 57        |
|               |                                    |             |                       |           |           |           |           |           |
| R3c           | C-C-S-WR-C                         | 4           | seeds/ft <sup>2</sup> | --        | --        | 1066      | --        | 725       |
|               |                                    |             | % bdlf                | --        | --        | 88        | --        | 64        |
|               |                                    |             | % grass               | --        | --        | 12        | --        | 56        |
|               |                                    |             |                       |           |           |           |           |           |
| R4a           | A-A-A-C-A                          | 7           | seeds/ft <sup>2</sup> | 472       | 264       | --        | --        | 239       |
|               |                                    |             | % bdlf                | 82        | 81        | --        | --        | 93        |
|               |                                    |             | % grass               | 18        | 19        | --        | --        | 7         |
|               |                                    |             |                       |           |           |           |           |           |
| R4b           | C-A-A-A-C                          | 8           | seeds/ft <sup>2</sup> | --        | 288       | --        | --        | 1141      |
|               |                                    |             | % bdlf                | --        | 59        | --        | --        | 99        |
|               |                                    |             | % grass               | --        | 41        | --        | --        | 1         |
|               |                                    |             |                       |           |           |           |           |           |
| R4c           | C-C-A-A-A                          | 9           | seeds/ft <sup>2</sup> | --        | --        | 584       | --        | --        |
|               |                                    |             | % bdlf                | --        | --        | 90        | --        | --        |
|               |                                    |             | % grass               | --        | --        | 10        | --        | --        |
|               |                                    |             |                       |           |           |           |           |           |
| R4d           | C-C-C-A-A                          | 10          | seeds/ft <sup>2</sup> | --        | --        | 720       | 269       | --        |
|               |                                    |             | % bdlf                | --        | --        | 93        | 88        | --        |
|               |                                    |             | % grass               | --        | --        | 7         | 12        | --        |
|               |                                    |             |                       |           |           |           |           |           |
| R5a           | O/A-A-C-O/A-A                      | 11          | seeds/ft <sup>2</sup> | 444       | 755       | 692       | 339       | --        |
|               |                                    |             | % bdlf                | 82        | 64        | 91        | 95        | --        |
|               |                                    |             | % grass               | 18        | 36        | 9         | 5         | --        |
|               |                                    |             |                       |           |           |           |           |           |
| R5b           | C-O/A-A-C-O/A                      | 12          | seeds/ft <sup>2</sup> | --        | 546       | --        | 506       | 717       |
|               |                                    |             | % bdlf                | --        | 82        | --        | 88        | 86        |
|               |                                    |             | % grass               | --        | 18        | --        | 12        | 14        |
|               |                                    |             |                       |           |           |           |           |           |
| R5c           | C-C-O/A-A-C                        | 13          | seeds/ft <sup>2</sup> | --        | --        | 1198      | --        | 321       |
|               |                                    |             | % bdlf                | --        | --        | 86        | --        | 90        |
|               |                                    |             | % grass               | --        | --        | 14        | --        | 10        |
|               |                                    |             |                       |           |           |           |           |           |
| R6            | P-P-P-P-P                          | 14          | seeds/ft <sup>2</sup> | 386       | 405       | --        | --        | --        |
|               |                                    |             | % bdlf                | 82        | 75        | --        | --        | --        |
|               |                                    |             | % grass               | 18        | 25        | --        | --        | --        |
|               |                                    |             |                       |           |           |           |           |           |

\* Treatment number assigned to each crop phase of a each system.

**Table 14. Weed seedbank changes in WICST at the Lakeland Agricultural Complex from 1990 through 1994.**

| <u>System</u> | <u>Crop rotation</u>               | <u>Tmt*</u> |                       | <u>90</u> | <u>91</u> | <u>92</u> | <u>93</u> | <u>94</u> |
|---------------|------------------------------------|-------------|-----------------------|-----------|-----------|-----------|-----------|-----------|
| R1            | <u>90-91-92-93-94</u><br>C-C-C-C-C | 1           | seeds/ft <sup>2</sup> | 190       | 68        | 152       | 310       | 361       |
|               |                                    |             | % bdlf                | 87        | 72        | 80        | 74        | 56        |
|               |                                    |             | % grass               | 13        | 28        | 20        | 26        | 44        |
| R2a           | S-C-S-C-S                          | 3           | seeds/ft <sup>2</sup> | 193       | 174       | 106       | --        | 131       |
|               |                                    |             | % bdlf                | 28        | 22        | 51        | --        | 77        |
|               |                                    |             | % grass               | 72        | 78        | 49        | --        | 33        |
| R2b           | C-S-C-S-C                          | 2           | seeds/ft <sup>2</sup> | --        | 22        | --        | 206       | --        |
|               |                                    |             | % bdlf                | --        | 50        | --        | 50        | --        |
|               |                                    |             | % grass               | --        | 50        | --        | 50        | --        |
| R3a           | S-WR-C-S-WR                        | 5           | seeds/ft <sup>2</sup> | 196       | 328       | 1117      | 1288      | --        |
|               |                                    |             | % bdlf                | 42        | 7         | 42        | 44        | --        |
|               |                                    |             | % grass               | 58        | 93        | 58        | 56        | --        |
| R3b           | C-S-WR-C-S                         | 6           | seeds/ft <sup>2</sup> | --        | 81        | --        | 272       | 1570      |
|               |                                    |             | % bdlf                | --        | 42        | --        | 63        | 21        |
|               |                                    |             | % grass               | --        | 53        | --        | 37        | 79        |
| R3c           | C-C-S-WR-C                         | 4           | seeds/ft <sup>2</sup> | --        | --        | 570       | --        | 275       |
|               |                                    |             | % bdlf                | --        | --        | 33        | --        | 70        |
|               |                                    |             | % grass               | --        | --        | 67        | --        | 23        |
| R4a           | A-A-A-C-A                          | 7           | seeds/ft <sup>2</sup> | 236       | 956       | --        | --        | 315       |
|               |                                    |             | % bdlf                | 47        | 14        | --        | --        | 84        |
|               |                                    |             | % grass               | 53        | 86        | --        | --        | 16        |
| R4b           | C-A-A-A-C                          | 8           | seeds/ft <sup>2</sup> | --        | 68        | --        | --        | 228       |
|               |                                    |             | % bdlf                | --        | 68        | --        | --        | 96        |
|               |                                    |             | % grass               | --        | 32        | --        | --        | 4         |
| R4c           | C-C-A-A-A                          | 9           | seeds/ft <sup>2</sup> | --        | --        | 117       | --        | --        |
|               |                                    |             | % bdlf                | --        | --        | 65        | --        | --        |
|               |                                    |             | % grass               | --        | --        | 35        | --        | --        |
| R4d           | C-C-C-A-A                          | 10          | seeds/ft <sup>2</sup> | --        | --        | 125       | 380       | --        |
|               |                                    |             | % bdlf                | --        | --        | 63        | 46        | --        |
|               |                                    |             | % grass               | --        | --        | 37        | 54        | --        |
| R5a           | O/A-A-C-O/A-A                      | 11          | seeds/ft <sup>2</sup> | 307       | 646       | 454       | 587       | --        |
|               |                                    |             | % bdlf                | 28        | 11        | 31        | 46        | --        |
|               |                                    |             | % grass               | 72        | 89        | 69        | 54        | --        |
| R5b           | C-O/A-A-C-O/A                      | 12          | seeds/ft <sup>2</sup> | --        | 92        | --        | 112       | 625       |
|               |                                    |             | % bdlf                | --        | 47        | --        | 88        | 19        |
|               |                                    |             | % grass               | --        | 53        | --        | 12        | 81        |
| R5c           | C-C-O/A-A-C                        | 13          | seeds/ft <sup>2</sup> | --        | --        | 462       | --        | 206       |
|               |                                    |             | % bdlf                | --        | --        | 25        | --        | 64        |
|               |                                    |             | % grass               | --        | --        | 75        | --        | 36        |
| R6            | P-P-P-P-P                          | 14          | seeds/ft <sup>2</sup> | 136       | 951       | --        | --        | --        |
|               |                                    |             | % bdlf                | 50        | 7         | --        | --        | --        |
|               |                                    |             | % grass               | 50        | 93        | --        | --        | --        |

\* Treatment number assigned to each crop phase of a each system.

The apparent trend in the corn-oat/alfalfa-alfalfa system (R5) is the opposite of the previous system. Weed seed populations in system R5 reached their highest levels (now moderate, 400 to 700 seedlings/ft<sup>2</sup>) following corn (R5b) with mechanical weed control and their lowest levels (now low) in following alfalfa (5c). Even though manure was applied in 5c, no weed seed increase occurred. Seed bank densities have fluctuated in system 5a and are now low at ARS and moderate at LAC. Broadleaves dominate in system 5 at ARS and the species composition varies greatly between system 5b (high in grasses) and 5c (more broadleaves) at LAC.

In summary, the weed seed bank populations in the high and moderate input cash grain systems are relatively low (except for the corn-soybean system (2a) at ARS) and broadleaves generally comprise more than 85% of the population. Populations in the mechanically weeded cash grain systems are generally steady or decreasing, but are at high to severe levels except in system 3c at LAC. Broadleaves predominate in all system 3 phases except in 3b at LAC. In the high input livestock based systems, seed bank populations are highly variable by phase of the system and site, but populations are generally low. Broadleaf species are heavy to very heavy at both sites. In the medium input livestock systems, seed bank populations are low to moderate and density changes are generally consistent across locations, but often vary with the phase of the system.

#### Biomass results

Weed biomass was very low in system R1 at both sites, in corn of systems R2b at ARS and soybeans of system R2a at LAC, and the corn of both sites in system R4 (Table 15). Weed biomass was relatively high in corn and soybeans at both sites in system 3. Broadleaves predominated in corn and grasses in soybeans for all systems at ARS. Broadleaves dominated in corn in systems R3, R4 and R5 and in soybeans for system R2. Grasses predominated in systems R1 and R2 in corn and system R3 for soybeans at LAC.

#### Superimposed results.

For the first time in the history of these trials, we tried to determine the impact on yields and profitability of uncontrolled weeds in the mechanically weeded corn and soybeans of the low input cash grain system (R3). This was done by applying the appropriate postemergence herbicide treatment to two subplots four rows wide and 40 ft long in each of the four large plots for each crop at both locations. Treatments were applied after all the mechanical weeding was complete. Corn at both locations received a mixture of Clarity (dicamba) and Accent (nicosulfuron). The soybeans at ARS were treated with Assure II (quizalofop) and those at LAC with Assure II plus Pinnacle (thifensulfuron). Corn was treated on June 7 and soybeans on June 8 at ARS and both crops were treated on June 15 at LAC. Weed pressure and control ratings were taken 30 days after application and again at harvest.

Table 16 shows that in each crop at both locations uncontrolled weeds reduced yield. Yield increases in soybeans ranged from 7 bu/a at ARS to 17 bu at LAC and in corn from 15 bu/a at ARS to 23 bu at LAC. Yield losses per 10 lb of dry weight of weeds in early July (the biomass data) reveal the following: soybeans at ARS and LAC lost 3.0 and 0.5% yield/10 lb weeds, respectively, and corn at ARS and LAC lost 0.5 and 0.6% yield /10 lb weeds, respectively .

**Table 15. Weed biomass in the WICST trials at the Arlington Agricultural Research Station and the Lakeland Agricultural Complex for 1992, 1993 and 1994.**

| System | Crop rotation<br>92-93-94 | Tmt* |         | ARS |     |     | LAC |     |     |
|--------|---------------------------|------|---------|-----|-----|-----|-----|-----|-----|
|        |                           |      |         | 92  | 93  | 94  | 92  | 93  | 94  |
| R1     | C-C-C                     | 1    | lb/acre | 9   | 2   | 10  | 48  | < 1 | 2   |
|        |                           |      | % bdlf  | 100 | 72  | 90  | 77  | 0   | 25  |
|        |                           |      | % grass | 0   | 28  | 10  | 23  | 100 | 75  |
| R2b    | C-S-C                     | 2    | lb/acre | 27  | 12  | 2   | 16  | 19  | 59  |
|        |                           |      | % bdlf  | 82  | 77  | 85  | 63  | 90  | 40  |
|        |                           |      | % grass | 18  | 33  | 15  | 37  | 10  | 60  |
| R2a    | S-C-S                     | 3    | lb/acre | 179 | 4   | 28  | 160 | 3   | 9   |
|        |                           |      | % bdlf  | 61  | 48  | 0   | 100 | 96  | 95  |
|        |                           |      | % grass | 39  | 52  | 100 | 0   | 4   | 5   |
| R3c    | S-WR-C                    | 4    | lb/acre | 137 | -   | 255 | 21  | -   | 117 |
|        |                           |      | % bdlf  | 81  | -   | 75  | 10  | -   | 83  |
|        |                           |      | % grass | 19  | -   | 25  | 90  | -   | 17  |
| R3a    | C-S-WR                    | 5    | lb/acre | 46  | 44  | -   | 21  | 44  | -   |
|        |                           |      | % bdlf  | 87  | 88  | -   | 37  | 31  | -   |
|        |                           |      | % grass | 13  | 12  | -   | 63  | 69  | -   |
| R3b    | WR-C-S                    | 6    | lb/acre | -   | 161 | 242 | -   | 160 | 69  |
|        |                           |      | % bdlf  | -   | 19  | 47  | -   | 28  | 11  |
|        |                           |      | % grass | -   | 81  | 53  | -   | 72  | 89  |
| R4a    | A-C-A                     | 7    | lb/acre | -   | 13  | -   | -   | 18  | -   |
|        |                           |      | % bdlf  | -   | 21  | -   | -   | 76  | -   |
|        |                           |      | % grass | -   | 79  | -   | -   | 24  | -   |
| R4b    | A-A-C                     | 8    | lb/acre | -   | -   | 6   | -   | -   | 12  |
|        |                           |      | % bdlf  | -   | -   | 85  | -   | -   | 85  |
|        |                           |      | % grass | -   | -   | 15  | -   | -   | 15  |
| R5a    | C-O/A-A                   | 11   | lb/acre | 60  | -   | -   | 186 | -   | -   |
|        |                           |      | % bdlf  | 95  | -   | -   | 58  | -   | -   |
|        |                           |      | % grass | 5   | -   | -   | 42  | -   | -   |
| R5b    | A-C-O/A                   | 12   | lb/acre | -   | 46  | -   | -   | 36  | -   |
|        |                           |      | % bdlf  | -   | 50  | -   | -   | 57  | -   |
|        |                           |      | % grass | -   | 50  | -   | -   | 43  | -   |
| R5c    | O/A-A-C                   | 13   | lb/acre | -   | -   | 131 | -   | -   | 201 |
|        |                           |      | % bdlf  | -   | -   | 90  | -   | -   | 67  |
|        |                           |      | % grass | -   | -   | 10  | -   | -   | 33  |

\* Treatment number assigned to each crop phase of a each system.

Why were the soybeans at LAC affected so much more than the beans at ARS and the corn at either site? Part of the answer is that the uncontrolled weed with mechanical weeding was principally giant foxtail which is very competitive with soybeans. The plants were directly in the row which maximized competition and the early growing season was very dry so the main competition factor was for water. Later in the season foxtail competed for light because it was taller than the soybeans.

In three of the four cases, it would have been profitable to treat the escaping weeds. For corn at Arlington, it was a break-even situation between the loss in yield and the cost of treatment. Interestingly the corn yields in the low input corn-soybeans-wheat/red clover system (R3) were identical to those in the high input, continuous corn system (R1). If weeds had been removed from the corn in system 3, yields would have increased significantly. Thus it appears that weeds mask or prevent corn from capitalizing on the full benefit of crop system. We plan to have superimposed trials again in 1995 to determine if similar results are observed.

**Table 16. Effect of removing annual weeds with postemergence herbicides in corn and soybeans of the low input, cash grain system (R3) in 1994 (superimposed trials).**

| Site | Crop | Weed pressure <sup>1</sup><br>(%) |         | Yield, bu/acre |              |                 | Yield increase |                                | Tmt.<br>cost <sup>3</sup> |
|------|------|-----------------------------------|---------|----------------|--------------|-----------------|----------------|--------------------------------|---------------------------|
|      |      | Sum-<br>mer                       | Harvest | No herb        | With<br>herb | Differ-<br>ence | %              | Value,<br>\$/acre <sup>2</sup> | \$/acre                   |
| ARS  | Corn | 14                                | 12      | 186            | 201          | + 15            | 8.1            | 29.25                          | 28.75                     |
| LAC  | Corn | 10                                | 14      | 179            | 202          | + 23            | 12.8           | 43.70                          | 28.75                     |
| ARS  | Soy  | 12                                | 16      | 45.2           | 52.1         | + 6.9           | 15.3           | 34.85                          | 13.75                     |
| LAC  | Soy  | 8                                 | 22      | 40.8           | 57.6         | + 16.8          | 41.2           | 90.55                          | 21.9                      |

<sup>1</sup> Weed pressure is a visual estimate of weed volume in relation to crop volume. These ratings are presented only for the non-treated plots. Weed pressures were 1 to 3% in corn and 0 to 1% for summer and harvest evaluations in soybeans when herbicides were used.

<sup>2</sup> Value of increased yield calculated by multiplying value in dollars per bushel by the increase in bushels; values used were those at the time of harvest: corn at ARS \$1.90/bu and at LAC \$1.95/bu; soybeans at ARS \$5.05/bu and at LAC \$5.39.

<sup>3</sup> Costs are based on \$5.00 (labor and machinery costs) for the application and the following values for herbicides and additives:

- corn at ARS and LAC treated with .67 oz/a Accent (\$17.75), 0.5 pt/a Clarity (\$5.25) and 0.25% NIS (\$0.75) = \$23.75/acre.
- soybeans at ARS 7 oz/a Assure (\$7.75) and 1 qt/a crop oil concentrate (\$1.00) = \$8.75/acre.
- soybeans at LAC 7 oz/a Assure (\$7.75), 0.25 oz/a Pinnalce (\$7.40), 0.25% NIS (\$0.75) and 1 gal/acre 28%N (\$1.00) = \$16.90/acre.

#### IV. ROTATIONAL GRAZING OF DAIRY HEIFERS: A LOW-INPUT DAIRY ROTATION IN THE WISCONSIN INTEGRATED CROPPING SYSTEMS TRIAL

Sean Weber-Small\* and Dan Undersander\*

Pastures of smooth brome grass, timothy and red clover were established in 1990 at the Arlington Agricultural Research Station (ARS) and the Lakeland Agricultural Complex (LAC)\*\*. Fencing and water lines for pastures at both locations were built during the spring of 1992. Figures 15a and b show paddock layout. A grazing trial was established at LAC in 1992. Severe winterkill at ARS necessitated reseeding of the pasture grasses in 1992, thus grazing of paddocks was not possible until 1993. Red clover was broadcast seeded over pastures at both sites (20 lb/a at LAC, 12 lb/a at ARS) in early April 1993 for legume renovation and to fill areas where the grass stands were thin.

During the 1992 season the grazing trial conducted at LAC produced daily weight gains of 2.27 pounds/day (Figure 16). No data was collected for ARS in 1992. In 1993, grazing trials were conducted at both sites. The LAC site produced gains of 1.64 pounds/day while the ARS site produced gains of 1.76 pounds/day (Figure 16). Compared to the desired daily weight gain of 1.8 pounds/day, our results for the 1992 and 1993 seasons vary. This variability is best explained as functions of both management techniques and weather conditions. For example, the 1993 season was considered a wet year, negatively impacting the pasture growth at both sites. Optimization of management techniques in response to pasture growth and weather conditions is the key to attaining desired weight gains.

Weather conditions in 1994 (see chapter I) caused significantly slowed pasture growth during May and June while stimulating pasture growth during July and August, which is usually a period of slower growth for grasses. Although the rates of grass growth were shifted more than in a normal weather year, intensive grazing stressed the pastures, creating periods of no available forage.

Forage yields were determined by random sampling of each paddock. The amount of pasture allocated to the animals was calculated in a formula using animal weights, animal needs and forage yield. The paddock size generated by this formula was intended as guideline. In many movements, the animals were given larger areas to minimize the grazing pressure on the pasture.

Both sites removed forage periodically throughout the summer. LAC removed .4 tons/acre as hay while ARS removed 2.2 tons/acre as green chop. Both sites also supplemented the animals during season. LAC fed a total of 2 tons of hay during periods of pasture regrowth. ARS fed a total of 1476 lbs of grain from June 6 to July 17 due to poor animal weight gains and animal health concerns.

The duration of the LAC grazing trial was 178 days beginning on April 24 and concluding on October 19. The average starting and ending weights of the animals were 461 pounds and 813 pounds respectively, giving an average gain of 352 lb/animal. Average per acre weight gain was 847 pounds/acre. This gave a weight gain of 1.97 pounds/animal/day (Figure 16).

\* Research Assistant and Associate Professor, Dept. of Agronomy, University of Wisconsin, Madison.

\*\* Pasture establishment with brome grass (3 lb/a at LAC, 8 lb/a at ARS), timothy (3.5 lb/a at LAC, 11 lb/a at ARS), red clover (6 lb/a at LAC, 11 lb/a at ARS).

The duration of the ARS grazing trial was 118 days beginning on May 5 and concluding on August 31. The average starting and ending weights of the animals were 389 pounds and 578 pounds respectively giving an average gain of 189 lb/animal. Average per acre weight gains for all eight animals was 539 pounds/acre. This gave a weight gain of 1.60 pounds/animal/day (Figure 16).

Forage yields between the two sites were comparable throughout the summer, with ARS yields significantly higher for only the first three weeks (Figure 17). Crude protein (CP) was comparable and of good quality at both sites (Figure 18). Some of the greatest differences between the two sites were shown in the acid detergent fiber (ADF) measurements, the neutral detergent fiber (NDF) measurements and ultimately the relative feed value (RFV).

At ARS, the average ADF value was 31% while at LAC the average ADF value was 28% (Figure 19). Values ranging from 30-35% are required for forage to be considered of good quality. At ARS, the average NDF value was 49% while at LAC the average NDF value was 46% (Figure 20). Values less than 46% are considered to be of good quality. Both ADF and NDF are used to calculate the RFV where a value of 150 is representative of prime hay. At ARS, the average RFV was 124 while at LAC the average RFV was 137 (Figure 21). These quality differences and their effects on weight gains can be considered significant. Possibly the largest factor in the variability of quality between the sites is lack of a legume component at ARS.

Although there is always room for improvement, this years grazing trial produced weight gains very close to our target of 1.8 pounds/day. The key to moving ARS weight gains to the target weight gains is to keep the animal on pasture longer. Pasture and animal management efficiency are once again the pivotal ingredients to a successful study.

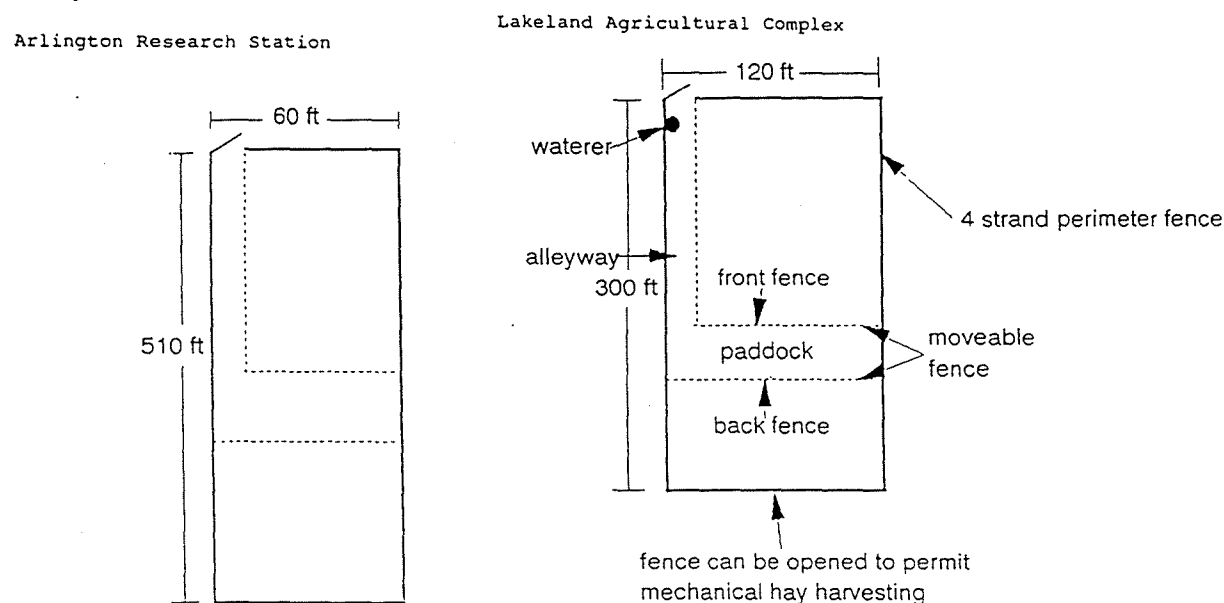


Figure 15. WICST Rotational Grazing Pasture Layout

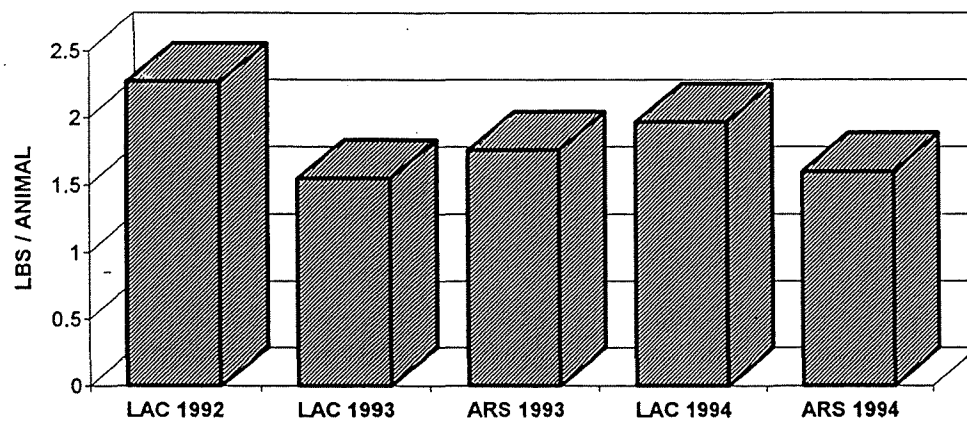


Figure 16. Rotational Grazing Weight Gain at the WICST Sites 1992-1994

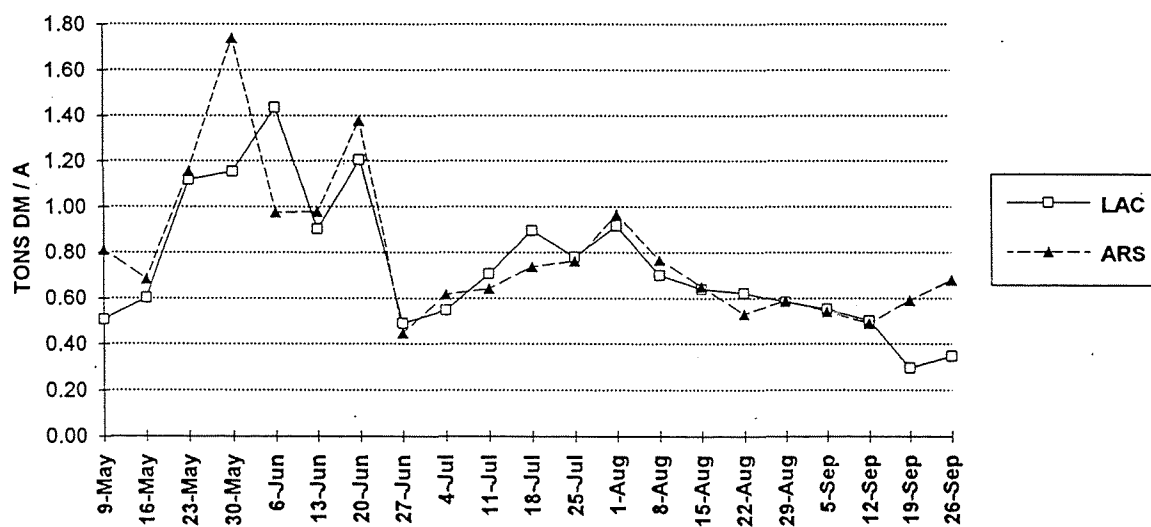
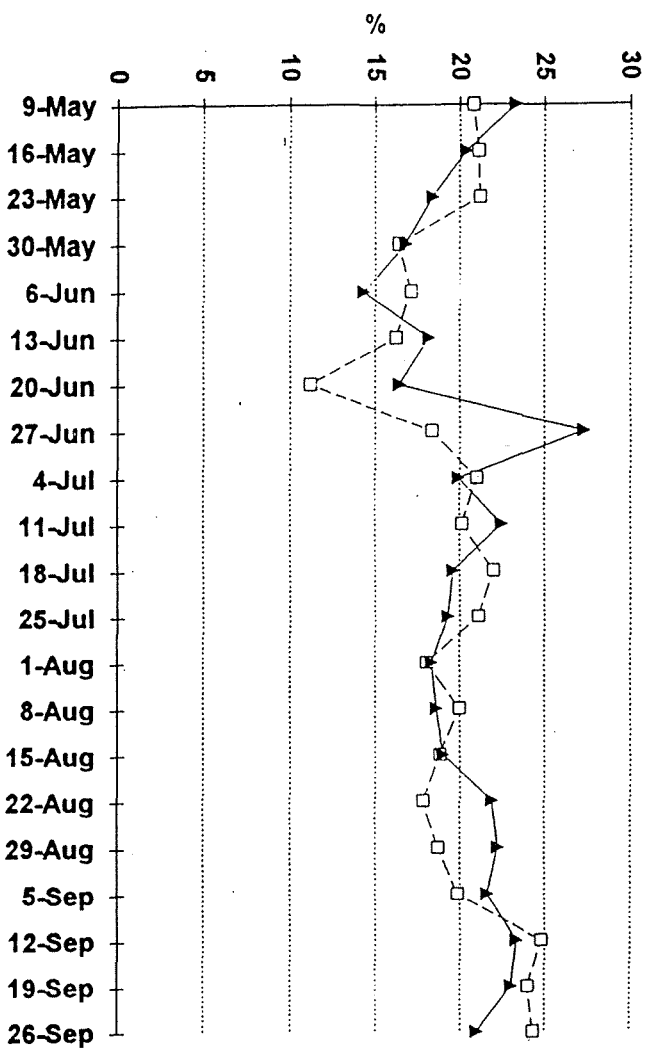
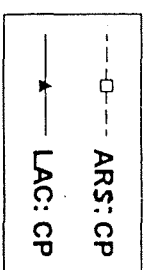
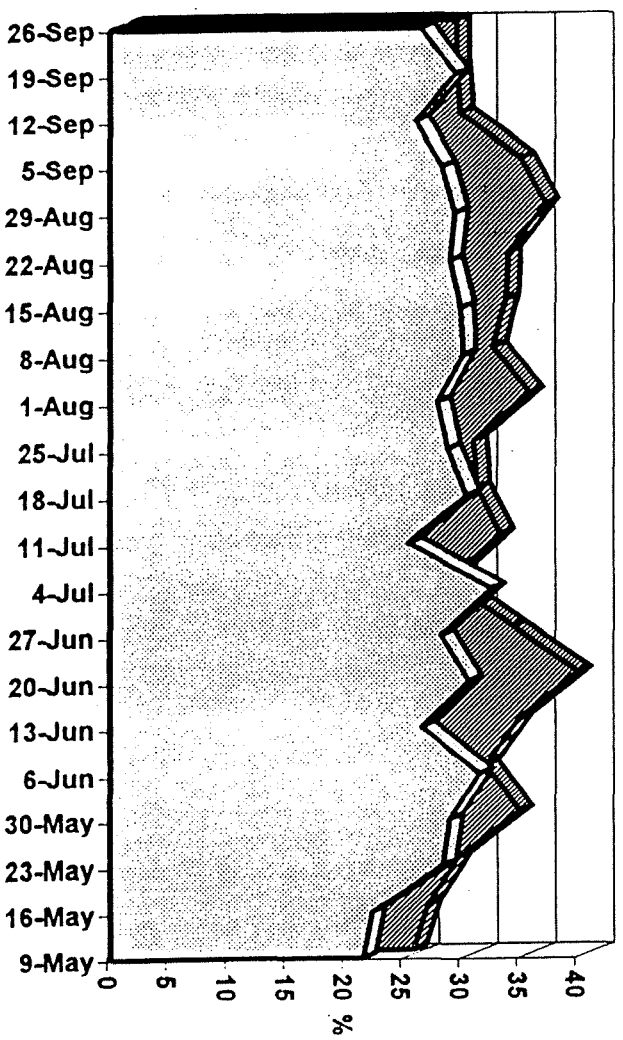


Figure 17. 1994 WICST Rotational Grazing Forage Yield Comparison



Optimum: 20%



Optimum: 30%

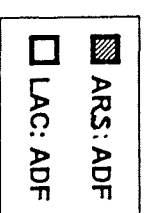


Figure 19. 1994 WICST Rotational Grazing ADF Comparison

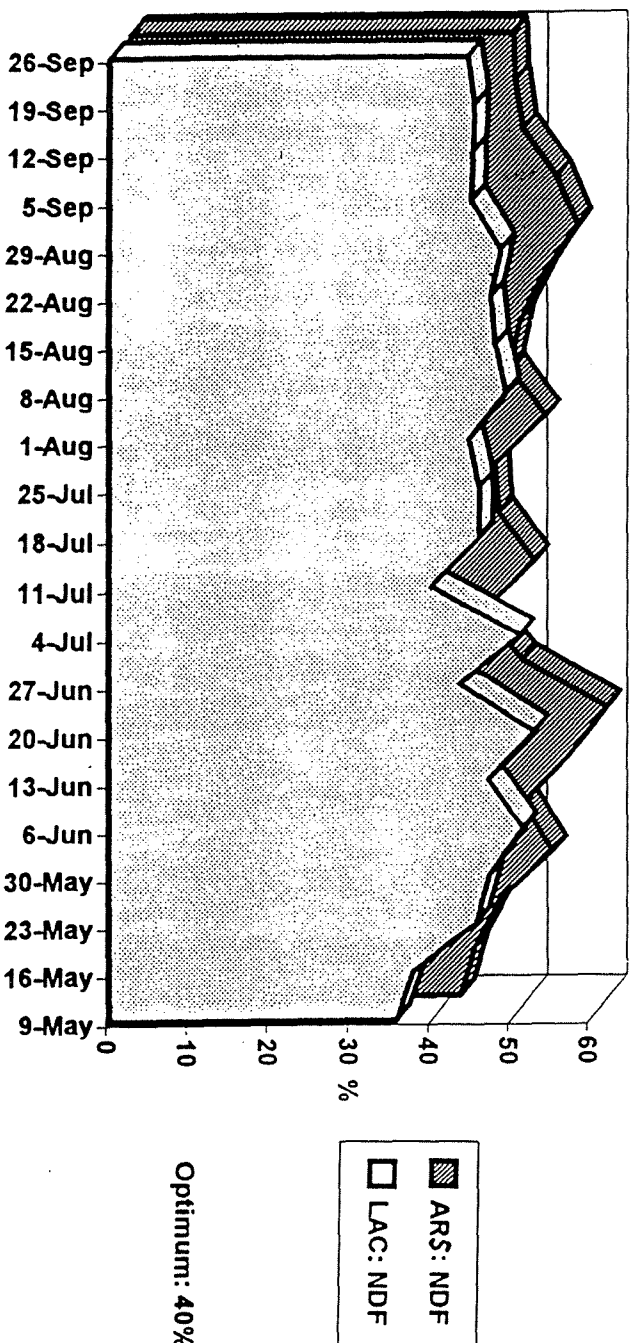


Figure 20. 1994 WICST Rotational Grazing NDF Comparison

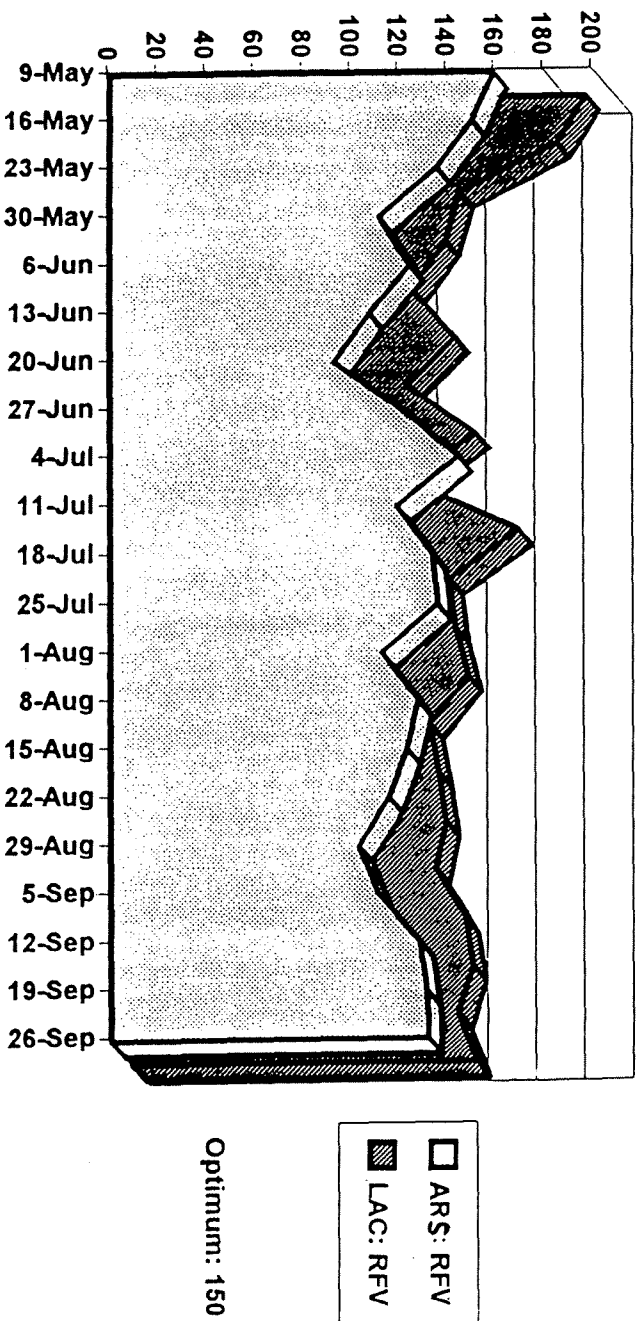


Figure 21. 1994 WICST Rotational Grazing RFV Comparison

## V. IMPROVING THE LOW-INPUT CASH GRAIN ROTATION

### A. Winter Wheat Studies

#### 1. Winter Wheat Establishment Following Soybeans

J. Hall\*, J.L. Posner\*\*, T.A. Mulder\*\*

##### Introduction

At the Lakeland Agriculture Complex, a WICST satellite experiment was designed to determine the best method for winter wheat establishment following soybeans. In the WICST corn-soybean-wheat/red clover rotation (R3), the winter wheat is fall established during the same growing season the soybeans are in production. The winter wheat can be planted either before or after soybean harvest. If planted before soybean harvest, wheat seed must be broadcast on the soil surface. Since ground driven broadcast equipment will damage the soybean plants, most farmers apply seed by airplane if using this seeding method.

##### Materials and Methods

Two varieties and four methods of wheat seeding were tested. The varieties chosen were Merrimac (lower yield potential but very winter hardy) and Cardinal (higher yield potential but less winter hardy). Seeding times/methods were 1)broadcast at soybean leaf yellowing, 2)broadcast at soybean leaf drop, 3)broadcast after soybean harvest, and 4)no-till drilled after soybean harvest. A four repetition, split-plot design was used with main plots (wheat varieties) 20 ft (8 30" soybean rows) by 210 ft. Subplots (times/methods) were 10 x 210 ft for the drilled and 10 x 70 ft for the broadcast wheat (see Figure 33, pg 103, Third Report). Broadcasting was by hand, scattering wheat seed at the rate of 3 bu/a. Drilling was with no-till drill at 3 bu/a. Harvest was with a small plot harvester. Harvest area was 5 x 70 ft. Yield from the three harvested plots in each drilled wheat plot (10 x 210 ft) were averaged for comparison with the broadcast wheat treatments.

Wheat planting dates are summarized in Table 17. No measurements were taken in 1992 due to severe winterkill of all treatments. Wheat agronomists estimate that 80% of the winter wheat stands in southern Wisconsin were lost that year (pers. comm. E. Oplinger). Harvest of the 1992 and 1993 plantings took place on July 19, 1993 and July 28, 1994.

##### Results

###### 1993

Winter kill and a cold wet spring reduced 1993 winter wheat yields. For both wheat varieties, wheat yield decreased as broadcast seeding was delayed and drilled wheat produced better than that broadcast after harvest (Figure 22). Over all times/methods, Cardinal yielded higher than the Merrimac variety. Combining varieties, yield was reduced significantly from 34 to 30 bu/A by delaying planting from soybean leaf yellowing to leaf drop and to 12 bu/A by waiting until after harvest. Drilled wheat yielded 29 bu/A which was not significantly different from broadcasting at leaf drop.

\* Agronomist, Michael Fields Agricultural Institute, East Troy, WI.

\*\* Professor and Research Specialist, Dept. of Agronomy, Univ. of Wisconsin, Madison.

1994

Wheat planting was slightly earlier in 1993 than 1992 and more important, winter weather was favorable. Again in 1994, wheat yield decreased for both varieties as seeding was delayed (Fig 23). Combining varieties, yield was lowest for the after harvest broadcast seeding while yields for the after harvest drilling and two before harvest broadcast seedings were not significantly different. Over all times/methods Cardinal again yielded higher than the Merrimac variety.

**Table 17. Wheat planting dates and soybean planting dates and yield for the wheat establishment study at the Lakeland Agricultural Complex.**

| Planting date                              | 1991            | 1992            | 1993            |
|--------------------------------------------|-----------------|-----------------|-----------------|
| Soybean                                    | 5/13            | 5/11            | 5/12            |
| Broadcast winter wheat                     |                 |                 |                 |
| T <sub>1</sub> - at soybean leaf yellowing | 8/29            | 9/17            | 9/11            |
| T <sub>2</sub> - at soybean leaf drop      | 9/13            | 9/24            | 9/22            |
| T <sub>3</sub> - after soybean harvest     | 10/22           | 10/14           | 10/8            |
| Drilled winter wheat                       |                 |                 |                 |
| T4 - no-till after soybean harvest         | 10/22           | 10/14           | 10/8            |
| Soybean yield (bu/a)                       | 55 <sup>1</sup> | 52 <sup>1</sup> | 32 <sup>2</sup> |

<sup>1</sup> Soybean variety Pioneer 9272

<sup>2</sup> Soybean variety Kaltenberg 241

### Conclusions

Our strategy for wheat establishment on the WICST R3 rotation was changed from aerial seeding at leaf yellowing (T1) in 1990 and 1991 to drilling after harvest (T4) since 1992. Prior to drilling a light tillage is done to level off the ridges and valleys formed by wide row soybean cultivation. These ridges and valleys appeared to reduce wheat winter survival of the aerially seeded wheat. Results from this satellite study show slight to no yield loss from the strategy change from aerial seeding to drilling and we feel that risk of winter kill is greatly reduced. On the main trials we have also changed varieties from Cardinal wheat to the winter hardy Glacier variety which has a higher yield potential than Merrimac.

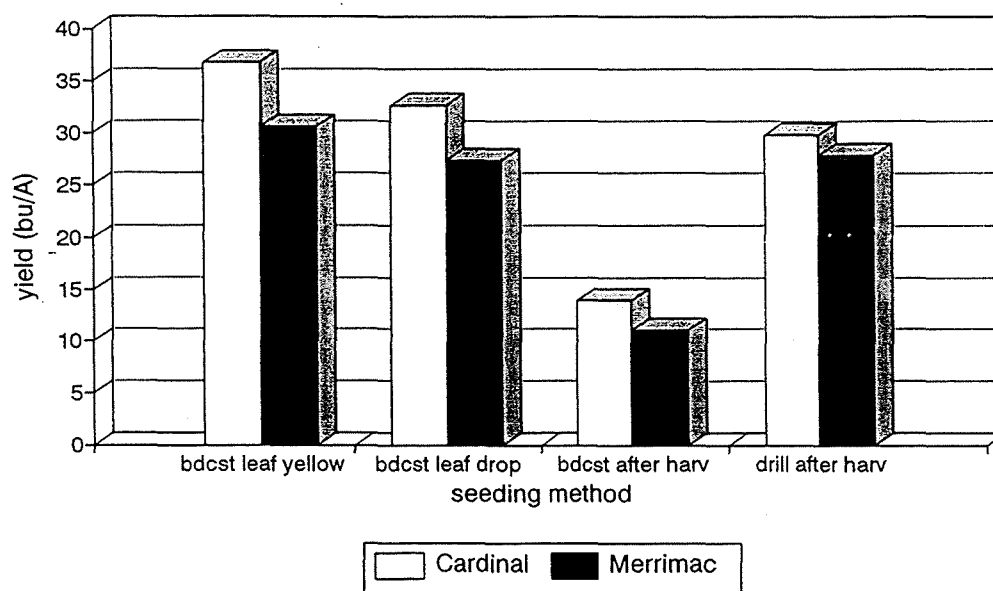


Figure 22. 1993 Wheat Yield by Variety and Method of Seeding - Lakeland Ag Complex

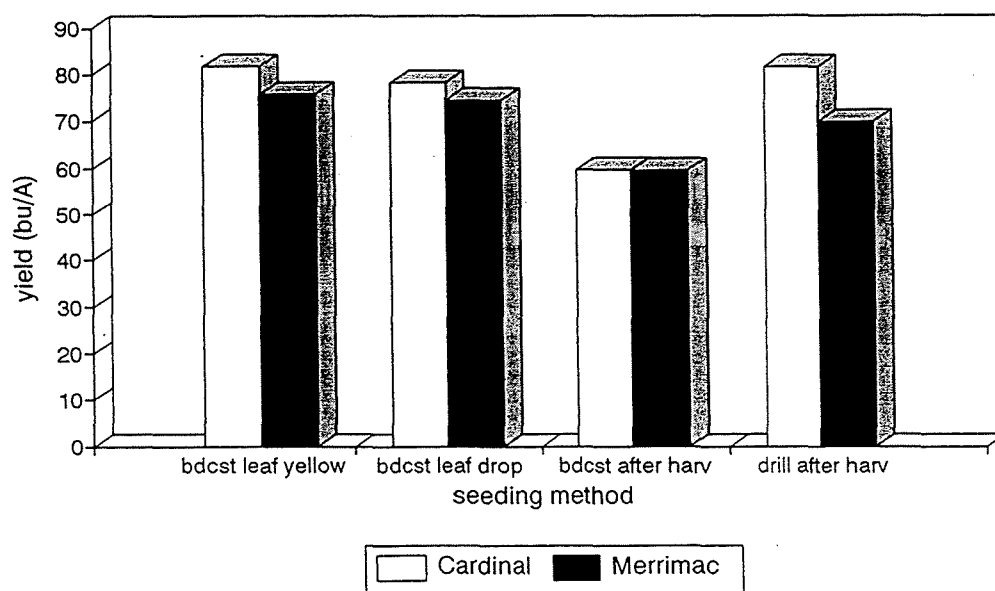


Figure 23. 1994 Wheat Yield by Variety and Method of Seeding - Lakeland Ag Complex

## 2. Wheat Row Spacing

J. Posner and T. Mulder\*

Wise use of crop rotations can reduce purchased inputs and decrease soil erosion. Legumes in a rotation can reduce requirements for purchased nitrogen and improve soil tilth. Each crop has a role in the system and therefore the failure of one crop will negatively affect the entire system. The challenge is to develop systems with low risk of a crop failure or a practical emergency strategy.

One of the Wisconsin Integrated Cropping System rotations is a three year rotation of corn - soybeans/winter wheat - winter wheat/red clover. One of the challenges of this rotation is frost seed establishment of a red clover crop with enough biomass to provide sufficient nitrogen for the following corn crop. An emergency strategy is to plant hairy vetch following wheat harvest. However, the hairy vetch seed is more expensive than red clover and requires soil tillage and planting in July when rainfall often arrives by thundershowers with high erosion potential. Are there ways to improve red clover production in this rotation without reducing the wheat yield?

A WICST satellite experiment was designed to determine if red clover establishment and production could be increased by increasing winter wheat row width. Two varieties of winter wheat, Glacier (bearded, very winter hardy) and Caldwell (beardless, less winter hardy) were planted in row widths of 7 and 10.5 inches, both at 30 seeds/ft<sup>2</sup> (1.6 bu/a) Sept 24, 1992 and Oct 6, 1993. Arlington clover with added inoculum was frost seeded with a hand operated cyclone seeder at 12 lb/a April 2, 1993 and 20 lb/a March 11, 1994. A check treatment was tilled and seeded with clover after wheat harvest. All treatments received 50 lb/a N as ammonium nitrate at wheat green up. Wheat was harvested Aug. 5, 1993 and July 25, 1994. Wheat stand counts of grain producing stalks were taken after wheat heading, wheat grain and straw weights were collected at harvest, and red clover weights after a killing frost.

In 1993 both variety and row spacing had no significant effect on wheat plant stands (Figure 24). Wheat stand appears to be lower for the wider row spacing in 1994, but the difference is not significant. Grain yields were higher for the Caldwell variety in 1993 (71 vs 59 bu/a) and higher for the more winter hardy Glacier variety in 1994 (61 vs 45 bu/a) following the late fall 1993 planting (Figure 25). In both years row width did not affect grain yield. Straw yield was similar to grain yield with the Caldwell straw yield higher in 1993 and the Glacier higher in 1994 (Figure 26). Row width did not affect straw yield either year. Clover yield was slightly higher in the 7-inch wheat row spacing in 1993 but in 1994 row spacing had no significant effect on clover growth (Figure 27). Wheat variety did not affect clover growth either year. Clover production was severely reduced by delaying planting until after wheat harvest.

We conclude that neither variety selection nor widening winter wheat row spacing are recommended practices for increasing Red Clover (and thus nitrogen) production for a following crop requiring high levels of nitrogen. From our past experience it is clear that weather and soil conditions at and following frost seeding have the greatest effect on Red Clover growth. Since we can not control the weather, a grower's strategy should be to have an alternative plan if the clover stand is unacceptable. One strategy is to plant a

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\* Professor and Research Specialist, Dept of Agronomy, Univ. of Wisconsin, Madison.

fast growing legume species after wheat harvest. Wisconsin research by Stute and Posner (1993) has shown that Hairy Vetch is one legume species that if planted following an oat crop can provide nitrogen amounts comparable to an underseeded crop of Red Clover.

#### References

Stute, J.K. and J.L. Posner. 1993. Legume cover crop options for grain rotations in Wisconsin. *Agron. J.* 85:1128-1132

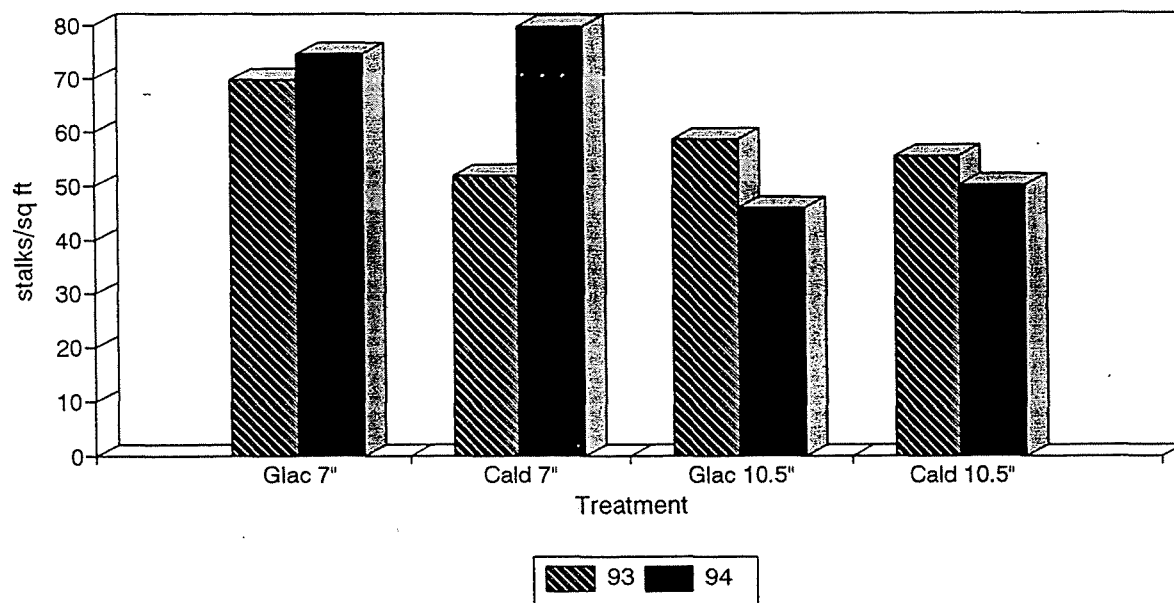


Figure 24. Plant Population for Two Varieties of Winter Wheat Planted at Two Row

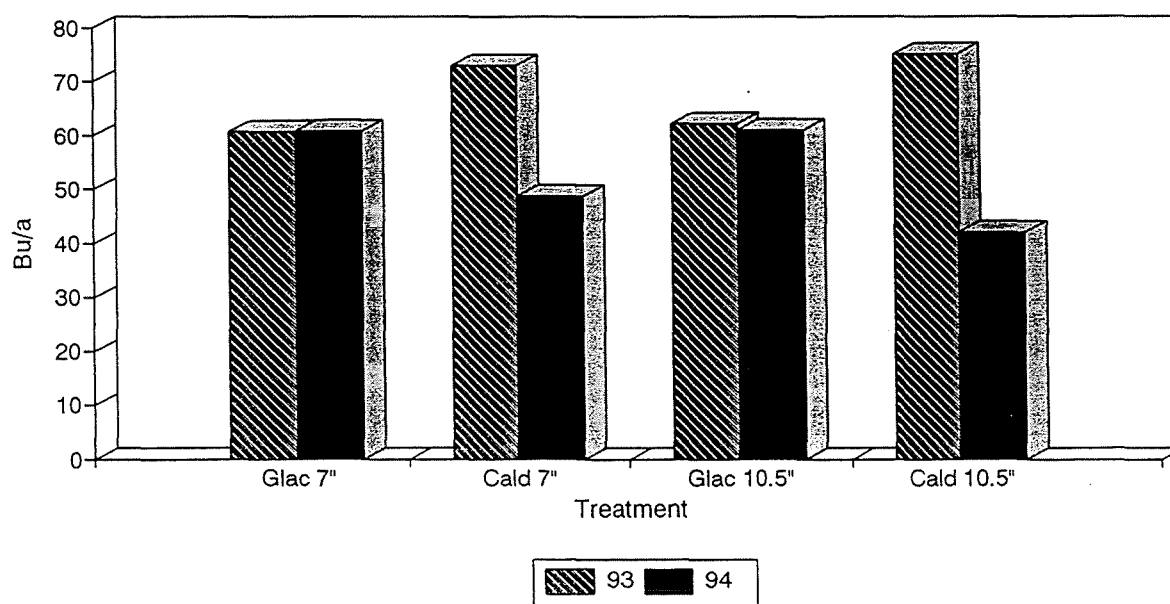


Figure 25. Grain Yield for Two Varieties of Winter Wheat Planted at Two Row Spacings.

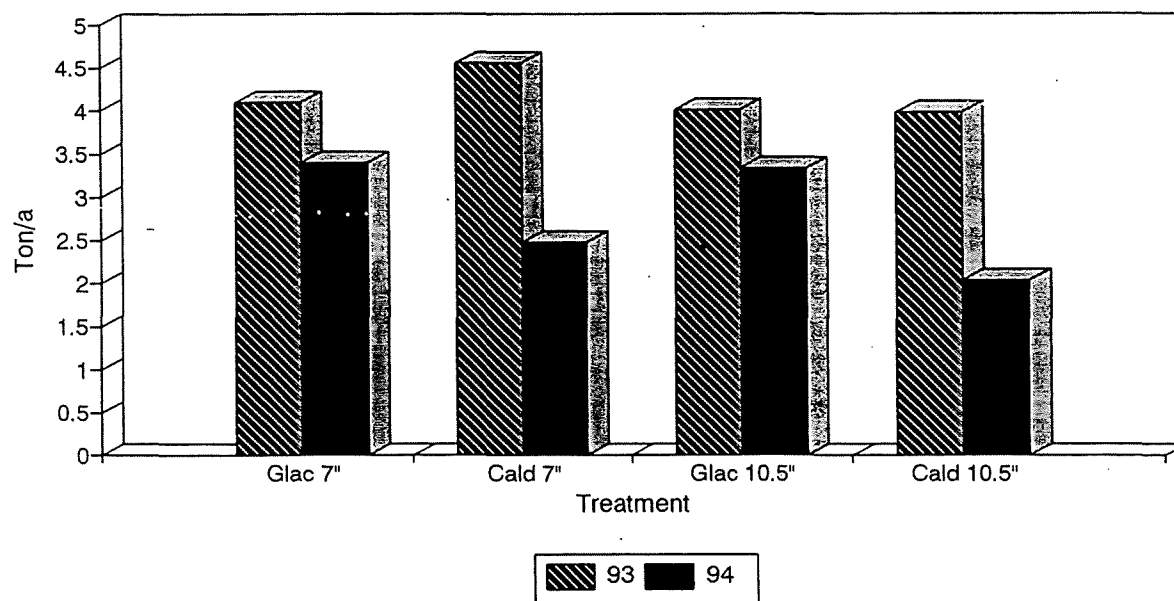


Figure 26. Straw Yield for Two Varieties of Winter Wheat planted at Two Row Spacings.

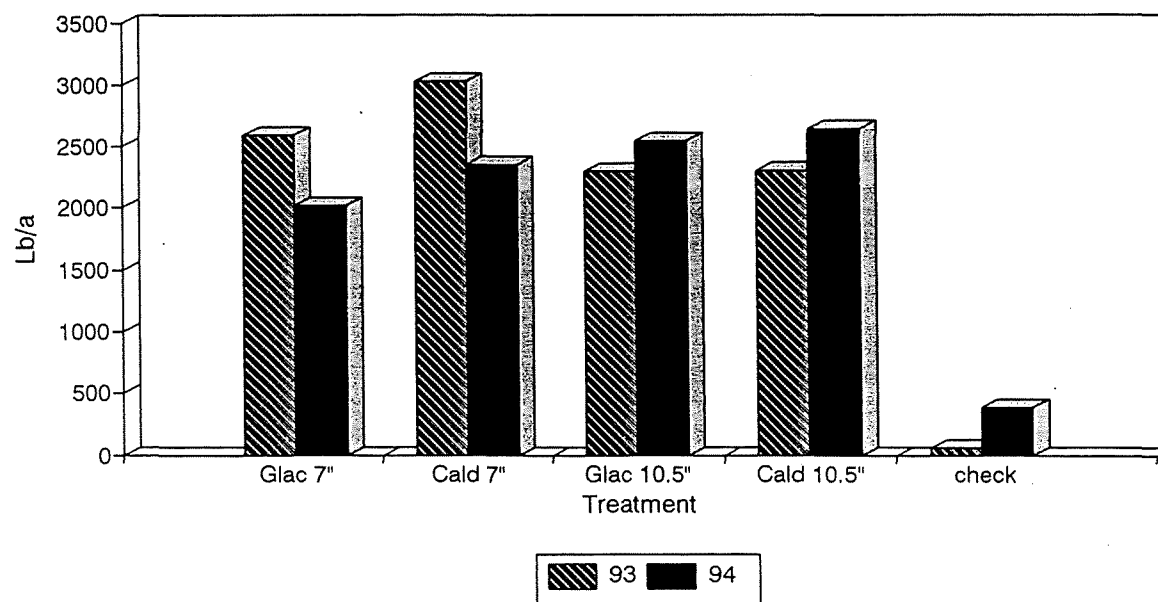


Figure 27. Yield for Red Clover Seeded in Two Varieties of Winter Wheat planted at Two Row Spacings.

## B. Cover Crop Research

### 1. On-farm Cover Crop Research and Demonstration Projects

J. Stute\*

#### Introduction

Use of cover crops will undoubtedly be a major component of sustainable farming systems of the future. Research and demonstration projects were conducted in 1994 to further our knowledge of cover crop species selection, management, and establishment alternatives, as well as demonstrate possibilities for cover crop use to the mainstream agricultural community.

#### 1. ALTERNATIVE SMALL GRAIN OPTIONS FOR LEGUME COVER CROP ESTABLISHMENT

##### Introduction

Winter wheat, the current small grain choice for legume establishment in the WICST low input, cash grain rotation (R3) offers the potential for greatest economic return based on yield and price, but often fails to achieve that potential due to yield reductions caused by partial to total winter-kill, common in southern Wisconsin. Spring grains (wheat, barley, oat) offer lower potential economic returns based on the same criteria, but may actually out-perform winter wheat in the long run, based on long-term yield stability.

The objective of this field study is to evaluate alternative small grain options to winter wheat, grown for the purpose of establishing a legume cover crop the year before corn in a crop rotation. This study is comparing winter wheat, spring wheat, barley and oat, grown with and without N fertilizer, for agronomic and economic performance. Red clover is intercropped with each small grain. Measures of agronomic performance include grain, straw and red clover yield, while measures of economic performance include gross return to each small grain. This is a report of 1994 data. Long-term stability, however, can only be assessed after several growing seasons.

##### Methods

This study was initiated in 1993 near East Troy, Wisconsin on a Fox silt loam soil. Four small grains: 'Howell' winter wheat; 'Roblin' spring wheat, 'Excel' spring barley, and 'Prairie' oat were established after soybean. All small grains were sown with a grain drill following disking at a seeding rate of 44 seeds/ft<sup>2</sup>. Winter wheat was sown on October 8 (1993), spring grains on April 6 (1994). 'Arlington' red clover was broadcast seeded into winter wheat on March 18, or companion seeded with the spring grains April 6. Seed was inoculated with the appropriate Rhizobia strain and seeded at a rate of 12 lb/acre. Nitrogen, as ammonium nitrate, was broadcast at a rate of 40 lb N/acre on May 10 to the treatments that received nitrogen fertilizer.

Grain yield was estimated by harvesting the plots with a plot combine July 24. Grain yield was corrected to 13% moisture. Straw was removed from the plots and weighed to determine yield. Red clover herbage yield was estimated by clipping plants at ground level in random 1/2m<sup>2</sup> areas within plots on October 22. Herbage was air-dried to determine

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\* UWEX Agriculture Agent, Racine and Kenosha Counties

dry mater yield, and the resulting material submitted to the University of Wisconsin Soil Testing Lab for N content determination.

The experimental design is a split plot arrangement of a randomized complete block with four replicates. Main plots were small grain species and sub plots were N fertilizer rates. Final plot size was 8x50 ft. Data were subject to analysis of variance procedures to determine significant main effects and interactions. Treatments were separated using a least significant difference at a 5% level of probability where significant main effects occurred. Gross returns were calculated by multiplying yield by market price at harvest time.

## Results

The 1994 growing season in Southeast Wisconsin could be characterized as hot and dry. Total season rainfall was six inches below normal, with 4.4 inches of the deficit accumulated between April 1 and July 31. In general, the grain yields reported in Table 18 were low relative to the remainder of the state due to extremely dry conditions in southeastern Wisconsin.

Small grain species had a significant effect on all variables while nitrogen fertilizer affected only straw (yield and economic return). Data in Table 18 was combined over N rates because of the lack of response to N for most variables. Gross returns to winter wheat were greatest for grain, straw and total, and were significantly greater than the other small grains for grain and total. Total returns for the other small grains were not significantly different.

**Table 18. Effect of small grain on yield and gross return and red clover Dry Matter yield and N accumulation averaged over two N rates.**

|              | Yield           |                  | Return *                  |                           |                           | Red Clover                   |                              |
|--------------|-----------------|------------------|---------------------------|---------------------------|---------------------------|------------------------------|------------------------------|
|              | Grain<br>(bu/a) | Straw<br>(ton/a) | Grain<br>-----<br>\$/acre | Straw<br>-----<br>\$/acre | Total<br>-----<br>\$/acre | DM<br>Yield<br>-----<br>lb/a | N<br>Accum.<br>-----<br>lb/a |
| Small grain  |                 |                  |                           |                           |                           |                              |                              |
| Winter Wheat | 34              | 1.27             | 119                       | 89                        | 208                       | 1780                         | 39                           |
| Spring Wheat | 27              | 1.04             | 83                        | 73                        | 156                       | 2252                         | 49                           |
| Barley       | 36              | 1.26             | 69                        | 88                        | 153                       | 2364                         | 52                           |
| Oat          | 48              | 1.04             | 61                        | 73                        | 134                       | 2169                         | 48                           |
| LSD (0.05)   | 4               | 0.14             | 23                        | 10                        | 29                        | 347                          | 8                            |

\* Market prices at harvest (\$/bu): wheat, \$3.45; barley, \$1.95; oat, \$1.25; straw \$70/ton.

The significant response of straw yield to N was consistent across all small grains species, accounting for a 17% yield increase (data not shown). At a straw price of \$70/ton, this yield increase translated into a mean increase in gross income of \$12.43/acre.

Small grain species had a significant effect on both red clover dry matter yield and N accumulation. Significantly lower yield of clover intercropped with winter wheat may have resulted from a number of factors including: greater season long competition from the highest yielding small grain (in terms of total dry matter/acre); poorer red clover stand

resulting from frost seeding (vs. companion seeding for the spring grains) or; greater early season competition from the already established small grain during the dry part of the growing season. Added N had no effect on either red clover dry matter yield or N accumulation.

### Summary

Winter wheat produced the greatest gross return (per acre) of the small grains in 1994. Added N (40 lb/acre) increased straw yield significantly, but did affect gross return. Red clover dry matter yield and N accumulation were significantly reduced by winter wheat. This study is ongoing, and will be repeated again in 1995 and 1996.

## 2. THE EFFECT OF SPECIES, SEEDING DATE AND SEEDING RATE ON NON-LEGUMINOUS COVER CROP YIELD

### Introduction

The practice of cover cropping will undoubtedly play a major role in a truly sustainable agriculture. Legumes will provide N to the cropping system while rapid growing non-legumes will conserve it in the system and also protect the soil resource. Much effort has already gone into developing legume cover crop systems which reduce N use, while little effort has gone into the later.

Rapid growing non-legume species may be a better option than legumes for seeding after short-season crops because of slow initial growth by legumes. Warm-season species may be more productive than cool-season species when seeded in mid-summer, while the reverse may be true as seeding dates become progressively later. As yield potential decreases with shortening growing season, increasing seeding rates may maintain dry matter yield and N "capture". The objective of this study was to determine the effects of species, seeding date, and seeding rate on cover crop productivity as measured by dry matter yield.

### Methods

A field study was conducted in 1993 and 1994 near East Troy, Wisconsin on a Fox silt loam soil. Five species: buckwheat (*Fagopyrum esculentum* L.); sorgum-sudan hybrid [*Sorghum sudanese* (Piper) Stapf.]; forage brassica (*Brassica rapa* ssp. *olifera*); oat (*Avena sativa* L.); and annual ryegrass (*Lolium multiflorum* L.) were seeded on three dates, Aug. 1, 15 and Sept. 1. These species were chosen because they are successfully used as cover crops elsewhere, seed is widely available, and they represent monocots and dicots of warm-season (sorgum-sudan and buckwheat) and cool-season (oat and forage brassica) species as well as an intermediate monocot (annual ryegrass). Species were also seeded at the recommended rate and a 1.33 times the recommended rate.

The experimental design was a randomized complete block with a split-split plot arrangement and four replicates. Main plots consisted of seeding date, sub-plots consisted of species, and sub-subplots consisted of seeding rate. Final plot size was 3x15 ft. Cover crops were drilled into small grain residue following harvest and disking for seedbed preparation and weed control. Dry matter yield was estimated by removing the above ground biomass from a 0.5 m<sup>2</sup> area in each plot, and air-drying the resulting material. Data were subject to analysis of variance procedures to detect significant main effects and interactions. Main effect means were separated using a least significant difference test at the 5% level of probability where appropriate.

## Results

Dry matter yield data for 1993 and 1994 are presented in Table 19. Both seeding date and species had a significant effect on dry matter yield while seeding rate did not. For this reason data are presented as mean of two seeding rates.

### Seeding Date

Dry matter yields from the Aug. 1 and 15 seeding dates were not significantly different in either year, and were both significantly greater than dry matter yield from the Sept. 1 seeding date. Mean dry matter yield within the Aug. 1 and 15 seeding dates were somewhat consistent, but rankings changed between years. Rainfall distribution during August was different in both years (data not shown), but rainfall occurred within 5 days of either seeding date, indicating that rainfall apparently was not a factor. Soil moisture appeared to be sufficient for germination when rainfall was low. The combination of both a lack of a significant difference between the Aug. 1 and 15 seeding dates and the change of ranking (dry matter yield for each seeding date) between years indicates that seeding date is not critical for maximizing dry matter yield provided cover crops are established in the first half of August. Combined over years, delayed planting from Aug. 15 to Sept. 1 resulted in a dry matter yield reduction of 63%, with a range of 58 to 70%.

**Table 19. Cover crop dry matter yield as affected by seeding date and species year in 1993 and 1994.**

| <u>Date</u> | <u>Species</u>  | <u>1993</u> | <u>1994</u> | <u>Mean</u> |
|-------------|-----------------|-------------|-------------|-------------|
| August 1    | Buckwheat       | 2165        | 1340        | 1753        |
|             | Sorgum-sudan    | 496         | 2917        | 1707        |
|             | Annual ryegrass | 2394        | 1206        | 1800        |
|             | Forage brassica | 4065        | 2588        | 3327        |
|             | Oat             | 1867        | 3013        | 2440        |
|             | Mean:           | 2197        | 2213        | 2205        |
| August 15   | Buckwheat       | 1778        | 1716        | 1747        |
|             | Sorgum-sudan    | 650         | 2934        | 1792        |
|             | Annual ryegrass | 1994        | 2918        | 2456        |
|             | Forage brassica | 2895        | 3026        | 2961        |
|             | Oat             | 2365        | 2471        | 2418        |
|             | Mean:           | 1936        | 2613        | 2276        |
| September 1 | Buckwheat       | 0           | 368         | 184         |
|             | Sorgum-sudan    | 0           | 0           | 0           |
|             | Annual ryegrass | 1179        | 1245        | 1212        |
|             | Forage brassica | 561         | 1826        | 1194        |
|             | Oat             | 1161        | 2050        | 1606        |
|             | Mean:           | 580         | 1098        | 839         |
| LSD (0.05)* |                 | 306         | 598         |             |

\* LSD applies to seeding date means

### Species

Species had a significant effect on dry matter yield in each year. Within seeding dates as well as combined over seeding dates, dry matter yield of oat and forage brassica were greatest, annual ryegrass intermediate, and those of buckwheat and sorgum-sudan least. The cool and intermediate season species appeared to grow well into the fall and only ceased after the onset of continuous nightly hard frosts. Both warm season species were killed by the first frost, limiting their dry matter yield potential. In addition, buckwheat initiated flowering about 45 days after planting, at which point vegetative growth, as well as rapid dry matter accumulation ceased. This rapid growth cycle does limit dry matter yield. However it also results in rapid early growth and the development of almost complete soil cover in a very short period. Sorgum-sudan hybrids probably should be planted earlier to maximize their dry matter yield potential.

### Species x Seeding Date Interaction

A significant species x seeding date interaction occurred in each year, presumably due to the growth characteristics of the individual species discussed above. The effect of this interaction on dry matter yield is presented in Figure 28. Over the range of seeding dates studied, the following trends appeared. Dry matter yield of cool-season species declined gradually in a linear fashion when seeded progressively later in the season, indicating that dry matter accumulation was limited by growing season length. Dry matter yield of annual ryegrass, the intermediate species increased over the first seeding date interval, then declined in a manner similar to that of the cool season species, a phenomenon defying explanation. Dry matter yield of the warm season species declined slightly over the first seeding date interval, then declined sharply over the second. The small decline in dry matter yield over the first interval indicates that potential dry matter yield had already been limited by species characteristics at the earliest seeding date, as previously discussed.

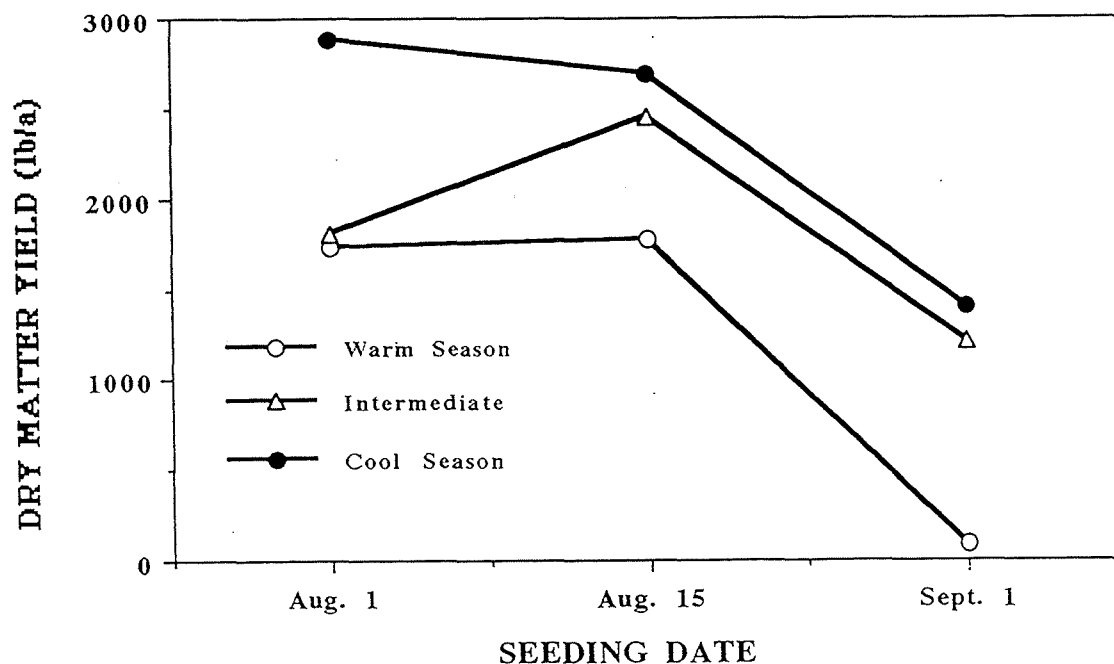


Figure 28. Interaction Between Species Type and Seeding Date.

### Summary

Oat, forage brassica, and annual ryegrass were effective producing dry matter over the seeding dates studied. When planted in the first half of August, dry matter yields of up to 2 ton/a were achieved. Dry matter yield was apparently limited only by length of the growing season for these species. Buckwheat and sorgum-sudan yields were limited by freezing. Buckwheat yield potential is also limited by a relatively short lifecycle, but it is very effective in producing groundcover in a short time period. Increasing seeding rate did not significantly increase dry matter yield of the non-leguminous cover crops.

### 3. 1994 COVER CROP DEMONSTRATIONS: LAKELAND AGRICULTURAL COMPLEX AND FARM PROGRESS DAYS

A cover crop demonstration plot was again established in 1994 at the Lakeland Agricultural Complex and also on the Manke Farm, site of the 1994 Farm Progress Days. The sites were identical and were comprised of 14 5x20 ft. plots, seeded in early August. Seven legume and six non-legume species were sown. Each plot was marked by a sign with species information including name, seeding rate, seed cost, and use (green manure, conservation, emergency forage). The demonstration was marked by a large sign bearing the WICST logo. A handout was available which discussed uses of cover crops, provided some characteristics of species available for use as cover crops in Wisconsin, provided some preliminary yield data information from a related study, and a description of the demonstration. Figure 29 includes the handout and other cover crop information from the demonstrations. Finally, the plots were sampled for forage quality 60 days after planting and the information posted at the site (Table 20).

**Table 20. Forage quality analysis of species used in the 1994 Cover Crop Demonstration, measured 60 Days After Planting\*.**

| Species         | Dry Matter (%) | Yield (ton/a) | CP (%) | ADF (%) | NDF (%) | RFV |
|-----------------|----------------|---------------|--------|---------|---------|-----|
| Hairy Vetch     | 16.9           | 0.96          | 24.6   | 19.7    | 28.1    | 244 |
| Purple Vetch    | 15.4           | 0.91          | 23.6   | 25.7    | 35.3    | 182 |
| Annual Medic    | 17.8           | 1.04          | 19.5   | 26.2    | 34.3    | 186 |
| Berseem Clover  | 14.3           | 1.08          | 23.4   | 19.7    | 51.4    | 133 |
| Crimson Clover  | 13.4           | 0.94          | 23.1   | 22.7    | 30.0    | 221 |
| Soybean         | 23.8           | 1.45          | 23.0   | 19.1    | 26.7    | 258 |
| Field Pea       | 14.2           | 2.16          | 18.8   | 28.9    | 38.8    | 159 |
| Buckwheat       | 24.3           | 1.48          | 13.7   | 20.6    | 34.0    | 199 |
| Annual Ryegrass | 13.6           | 0.97          | 21.9   | 23.6    | 38.4    | 171 |
| ForageBrassica  | 11.0           | 2.88          | 23.6   | 23.1    | 32.8    | 201 |
| Sorgum-Sudan    | 16.1           | 2.08          | 12.3   | 27.2    | 55.2    | 114 |
| Oat             | 17.6           | 1.55          | 14.1   | 34.0    | 57.7    | 101 |
| Rye             | 19.5           | 1.45          | 22.7   | 23.1    | 43.0    | 153 |
| Barley          | 18.8           | 1.26          | 15.6   | 31.3    | 54.3    | 111 |

\* Sampled October 6, 1994

| Strip | Cover Crop           | Seeding Rate<br>(lb/acre) | Seed Cost<br>(\$/acre) |
|-------|----------------------|---------------------------|------------------------|
| 1     | Hairy Vetch          | 30                        | 30                     |
| 2     | Purple Vetch         | 30                        | 30                     |
| 3     | Black Medic          | 12                        | 24                     |
| 4     | Berseem Clover       | 12                        | 18                     |
| 5     | Crimson Clover       | 12                        | 10                     |
| 6     | Soybean              | 120                       | 11*                    |
| 7     | Field Pea            | 120                       | 18                     |
| 8     | Buckwheat            | 45                        | 24                     |
| 9     | Annual Ryegrass      | 25                        | 16                     |
| 10    | Forage Brassica      | 5                         | 3                      |
| 11    | Sorghum-Sudan Hybrid | 30                        | 14                     |
| 12    | Oat                  | 96                        | 4*                     |
| 13    | Rye                  | 112                       | 4*                     |

\* using bin run seed at current market prices

Herbage yield of selected cover crops when seeded in early August and harvested in mid October.

| Species         | Dry Matter<br>(lb/acre) | N<br>(lb/acre) | Crude Protein<br>(%) |
|-----------------|-------------------------|----------------|----------------------|
| Oat             | 1867                    | 63             | 21                   |
| Buckwheat       | 2165                    | 48             | 14                   |
| Sorghum-Sudan   | 496                     | 18             | 23                   |
| Forage Brassica | 4065                    | 147            | 23                   |
| Annual Ryegrass | 2394                    | 79             | 21                   |

1993 growing season data from East Troy, WI.

For further information, please contact either:

|                |                         |          |
|----------------|-------------------------|----------|
| Jim Stute      | UWEX Racine/Kenosha Co. | 886-8460 |
| Lee Cunningham | UWEX Walworth Co.       | 741-3190 |

## WICST COVER CROP DEMONSTRATION

Welcome to the WICST cover crop demonstration. The purpose of these plots is to demonstrate which species work and which do not when planted as cover crops in early August here in southern Wisconsin.

### Why consider planting a cover crop?

Cover crops can perform many roles as part of a well managed farming system. As:

### Green Manures

Legume cover crops fix nitrogen, providing it to high N demand crops like corn, reducing both the fertilizer bill and the dependence on fossil energy. Seeding year green manures such as red clover and hairy vetch are proven N sources for corn in Wisconsin.

### Cover Crops

Rapid growing cover crops such as oats or buckwheat can produce substantial amounts of dry matter and excellent ground cover when planted after crops which leave little residue behind, such as wheat, peas, snap beans, soybeans, and corn silage. Producing ground cover after these crops will not only reduce soil erosion, but could help meet conservation compliance requirements.

### Catch Crops

In addition to providing ground cover, rapid growing cover crops can take up "leftover" soil nitrate-nitrogen, saving it for future crops while preventing it from leaching (protecting ground water).

### Emergency Forage

Some rapid growing species can produce substantial amounts of high quality forage when seeded after harvest of short season crops.

WICST = Wisconsin Integrated Cropping Systems Trial

TABLE 1. General characteristics of several widely available species which can be used as cover crops in Southern Wisconsin.

| Cover Crop Species                          | Life Cycle                   | Tolerance to: |         | pH Range | Seeding Rate (lb/acre) | Seed Cost (\$/lb) | Establishment Opportunities                                                                                                              | Comments                                                                                                                                                            |
|---------------------------------------------|------------------------------|---------------|---------|----------|------------------------|-------------------|------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                             |                              | Cold          | Drought |          |                        |                   |                                                                                                                                          |                                                                                                                                                                     |
| LEGUMES: For Use as a N Source              |                              |               |         |          |                        |                   |                                                                                                                                          |                                                                                                                                                                     |
| Hairy Vetch                                 | Annual                       | High          | Med.+   | 6-7      | 25-40                  | 0.70-1.50         | <ul style="list-style-type: none"><li>• set-aside acres</li><li>• after short season crops</li></ul>                                     | <ul style="list-style-type: none"><li>• high N yield potential</li><li>• do not companion seed with small grains (lodging)</li></ul>                                |
| Yellow Sweetclover                          | Biennial                     | High          | Med.+   | 6.5-7.5  | 10-25                  | 0.40-0.80         | <ul style="list-style-type: none"><li>• set-aside acres</li><li>• with small grains</li><li>• after short season crops</li></ul>         | <ul style="list-style-type: none"><li>• cheapest legume seed</li><li>• high % of hard seed</li><li>• deep tap root breaks up hardpan</li></ul>                      |
| Red Clover                                  | Biennial and Perennial types | Med.+         | Low+    | 6.2-7.0  | 10-20                  | 0.80-2.00         | <ul style="list-style-type: none"><li>• with small grains</li><li>• frost seed into wheat</li></ul>                                      | <ul style="list-style-type: none"><li>• best legume for companion seeding</li><li>• choose cheaper varieties</li><li>• tolerates clipping well</li></ul>            |
| NON LEGUMES: For Use as Cover or Trap Crops |                              |               |         |          |                        |                   |                                                                                                                                          |                                                                                                                                                                     |
| Annual Ryegrass                             | Annual                       | Med.+         | Med.+   | 5-8      | 20-25                  | 0.25-0.50         | <ul style="list-style-type: none"><li>• after short season crops</li><li>• interseed into corn and soybean at last cultivation</li></ul> | <ul style="list-style-type: none"><li>• rapid germination and early growth</li></ul>                                                                                |
| Oats                                        | Annual                       | High          | Med.+   | 5-8      | 64-128                 | 0.05-0.20         | <ul style="list-style-type: none"><li>• after short season crops</li></ul>                                                               | <ul style="list-style-type: none"><li>• cheapest cover crop if bin-run seed</li></ul>                                                                               |
| Sorghum-Sudan Hybrids                       | Annual                       | Low           | High    | 5-8      | 20-40                  | 0.25-0.50         | <ul style="list-style-type: none"><li>• after short season crops</li></ul>                                                               | <ul style="list-style-type: none"><li>• best when planted in mid-summer</li><li>• highest yield potential of all cover crops</li></ul>                              |
| Dwarf Essex Rape                            | Annual                       | High          | Low     | 5-8      | 3-8                    | 0.50-0.80         | <ul style="list-style-type: none"><li>• after short season crops</li></ul>                                                               | <ul style="list-style-type: none"><li>• good cool season growth</li></ul>                                                                                           |
| Buckwheat                                   | Annual                       | Low           | Low+    | 5-8      | 30-60                  | 0.20-0.60         | <ul style="list-style-type: none"><li>• after short season crops</li></ul>                                                               | <ul style="list-style-type: none"><li>• rapid germination and early growth</li><li>• easily killed by frost</li><li>• potential weed if allowed to mature</li></ul> |
| Winter Rye                                  | Winter Annual                | High          | Med.+   | 5-8      | 56-160                 | 0.10-0.40         | <ul style="list-style-type: none"><li>• after short season crops</li><li>• interseed into soybeans at leaf yellow</li></ul>              | <ul style="list-style-type: none"><li>• won't winterkill</li><li>• rapid growth in spring</li><li>• can be grazed over-winter</li></ul>                             |

Figure 29. Cover Crop Demonstration Information and Handout

## **2. Performance, Economics and Adoption of Cover Crops in Wisconsin Cash Grain Rotations: On-farm Trials**

Ellen Mallory\* and Joshua Posner\*\*

### **Introduction**

Wisconsin's agricultural community is being challenged to develop solutions to environmental concerns, such as soil erosion and groundwater pollution, while maintaining farmers' economic viability. Cover crops can play a vital role in addressing this challenge. Cover crops reduce soil erosion and nitrate leaching by physically protecting the soil and preventing runoff, improving soil structure and fertility, and scavenging excess nitrogen at the end of the season. Additionally, leguminous cover crops provide cash grain farmers with an on-farm source of nitrogen.

An optimal time to include cover crops into Wisconsin cash grain systems is following sole-seeded small grains or processing crops. Typically, the half million acres (WDATCP, 1993) on which these short season crops are grown annually in Wisconsin are either tilled or left fallow after harvest (July to early August) and then planted to corn the following spring. Leguminous cover crops could protect soil from erosion after short-season crop harvest and contribute N to the following corn crop. An on-station study screened a variety of forage legumes and two seeding times within the context of a two-year oat/corn rotation. Two cover crop options were identified as the most promising species in terms of biomass and N production: companion-seeded red clover and sequentially-seeded hairy vetch each yielded up to 150 lb N/acre (Stute, 1991).

Given the potential demonstrated in the on-station studies, we decided to take this cover crop system "on-farm". The previous work had been done on highly productive soils and we felt that it was necessary to test the system on soils lower in organic matter, with coarser texture and on steeper slopes. Also, we desired an evaluation by farmers of the benefits, economics, machinery needs and labor requirements of the system.

In collaboration with five farmers and one Future Farmers of America group, we evaluated the cover crop system over a variety of soil types, short-season crops and farmer management techniques. We compared four cover crop options in terms of their ability to protect the soil after short season crop harvest and provide nitrogen to a following corn crop. Additionally, we assessed the relative profitability and the adoption potential of the system.

### **Materials and Methods**

The cover crop study was conducted from 1992 to 1994 on five private farms and one high school demonstration field in south-central Wisconsin. We selected sites based on farmer interest and on soil type, such that a range of soil types were represented in the study: three sandy loams and three silt loams, ranging from 1 to 4.1% organic matter and 0 to 12 % slope (Table 21).

The experimental design at all sites was a randomized complete block with three replications, and a split plot arrangement of N fertilizer rates in the fallow check plots during the corn year.

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\* Research technician, Univ. of Maine, formerly graduate student, UW Agronomy Dept.

\*\* Professor, Dept. of Agronomy, Univ. of Wisconsin, Madison.

**Table 21. Site characteristics and management practices.**

| Farm | Soil type  | Organic matter (%) | Short-season crop | Seedbed prep for sequential seeding | Cover crop kill method  |
|------|------------|--------------------|-------------------|-------------------------------------|-------------------------|
| A    | Sandy loam | 1.0                | Winter wheat      | None (no-till)                      | Banvel (0.5 pt/ac)      |
| B    | Silt loam  | 4.1                | Winter wheat      | Chisel 1x<br>Field cultivator 1x    | Chisel plow with sweeps |
| C    | Sandy loam | 1.5                | Oats              | Disk 2x                             | Disk 2x                 |
| D    | Silt loam  | 1.0                | Snapbeans         | Disk 2x                             | Round-up (2 pt/ac)      |
| E    | Silt loam  | 2.3                | Peas              | None (no-till)                      | Disk 2x                 |

In Phase I, farmers grew one of four short-season crops (winter wheat, oats, peas or snapbeans) with the following cover crop treatments:

1. Companion seeded red clover (10-12 lb/a)
2. Sequentially seeded hairy vetch (30 lb/a)
3. Sequentially seeded oats (1.5 bu/a)
4. No cover crop (weedy fallow)

There were two exceptions. Klahn and Manke (the snapbean farmers) established red clover following snapbean harvest (sequentially seeded) instead of companion seeding. All farmers applied the appropriate inoculant before seeding and all included a weedy fallow check plot as a treatment.

In 1993, the farmers planted corn (Phase II) on these fields. Corn following the weedy fallow plots was fertilized at six different nitrogen rates and used for yield comparisons with corn following the cover crops. As well, each farmer started the cover crop phase one of the rotation again on a separate demonstration field. These plots were planted to corn in 1994.

#### Phase I - Cover crop phase (1992 and 1993)

"Companion-seeded" red clover was either frost-seeded into winter wheat, drilled with oats at oat seeding, or broadcast-seeded immediately following pea seeding. "Sequential seeding" refers to establishing cover crops after short-season crop harvest. Each farmer decided how to establish the sequentially seeded cover crops. Seedbed preparation ranged from intensive to none.

Ground cover measurements were taken in all plots immediately following cover crop seeding and at 2, 4 and 6 weeks after seeding. A final measure was taken after the first killing frost. At that time, aboveground biomass cuts were taken and divided into cover crop, weed and volunteer crop fractions. Dry matter weights and nitrogen analysis were used to estimate total dry matter and nitrogen contribution of each cover crop treatment.

#### Phase II - Corn phase (1993 and 1994)

Farmers killed the cover crops in early spring, with tillage or herbicides, and then grew corn by their usual practices (with the exclusion of N fertilizer). Corn following the weedy fallow check plot was hand fertilized at six N rates (0 to 200 lb N/acre) at planting.

To compare N availability between the cover crop and fertilizer plots, soil nitrate samples were taken at the V-6 stage of corn growth ("Pre-sidedress nitrate test", (Fox et al., 1989)). As well, soil nitrate samples were taken at the one and two foot depths at the sandy sites to watch for leaching in 1993.

Corn grain yields were determined by hand harvesting 20 feet of the two center rows of each plot. Ears were shelled and grain subsamples were taken to determine moisture and percent N. Yields were corrected to 15.5% moisture. Yield data from the Manke plots are missing because the corn was harvested before yield samples could be taken.

To evaluate relative profitability, gross margins (gross returns - variable costs) were calculated for each treatment. Short-season crop production was not included in the analysis since it was found that, in 9 of 11 cases, short-season crop yields were not affected by cover crop treatment.

Energy use was calculated by using energy value estimates (Pimental, 1980) of the fertilizers, pesticides and diesel fuel used in each treatment.

## Results and Discussion

### Short season crop yields

Growers have expressed a concern that companion-seeded red clover might depress short-season crop yields through competition. Generally speaking, companion-seeded red clover had no significant effect on main crop yields (data not shown). Exceptions occurred in two farm-years: 1992 farm C (oat straw) and 1993 farm E (peas). In both cases yields were lower in the companion-seeded red clover plots than in the control plots. While it is not known what caused lower straw yields, in the case of the peas, companion-seeded red clover may have depressed yields directly by competing with the pea crop, and/or indirectly by creating an environment favorable to root rot (*Aphanomyces euteiches*).

### Soil protection

The potential for erosion is relatively high during the period when sequential seeding occurs. Wischmeier and Smith (1978) estimate that, in the geographical area that contains Wisconsin, 28% of yearly erosive rainfall occurs between July 15 and September 1. Therefore, if erosion control is a primary concern, it is important to choose a combination of cover crop and seeding method that provides adequate cover during these periods.

Establishment methods which did not involve tillage after short-season crop harvest maintained the most cover (Table 22). In particular, companion-seeded red clover provided close to 100% cover after main crop harvest. High levels of cover were also maintained by the sequential treatments that were no-till drilled. In contrast, sequential treatments established with seedbed preparation reduced cover significantly. There was a two week period after seeding when ground cover was low and erosion might be a concern (data not shown). However, cover rose to 50% by week four in most cases, and in all cases was 80% going into the winter (Table 22).

Results from the fallow plots indicate that small grain residue, plus weeds, can provide adequate cover if undisturbed. However, this may not be a desirable alternative from a weed management standpoint. The most potentially erosive situation of all the treatments was created after vegetable crop harvest when the fields were worked to control weeds and other pests, and no cover crop was planted. Crop residue and weed growth provided only 23 to 26% cover going into the winter.

**Table 22. Percent ground cover immediately following short-season crop harvest and sequential cover crop seeding (week 0), and after the first killing frost in the fall (mid-October).**

| Cover crop                        |   |  | Week 0                       | Mid-October |
|-----------------------------------|---|--|------------------------------|-------------|
| Mid-season soil disturbance       | n |  | Range                        | Range       |
| Red clover                        |   |  | ----- ground cover (%) ----- |             |
| No disturbance (companion-seeded) | 8 |  | 75 - 100                     | 100         |
| Seedbed preparation and drill     | 2 |  | 8 - 9                        | 23 - 26     |
| Hairy vetch                       |   |  |                              |             |
| No-till drill                     | 3 |  | 42 - 75                      | 82 - 100    |
| Seedbed preparation and drill     | 7 |  | 8 - 36                       | 78 - 100    |
| Oats                              |   |  |                              |             |
| No-till drill                     | 3 |  | same as                      | 91 - 100    |
| Seedbed preparation and drill     | 7 |  | for vetch                    | 76 - 100    |
| Weedy fallow (no cover crop)      |   |  |                              |             |
| No disturbance                    | 8 |  | 51 - 97                      | 75 - 100    |
| Tillage for pest control          | 2 |  | 8 - 9                        | 23 - 26     |

#### Cover crop nitrogen accumulation

The nitrogen contribution of the cover crop treatments varied widely between and within sites (Table 23). However, both hairy vetch and red clover demonstrated the ability to accumulate significant quantities of N by the fall of the seeding year. Companion-seeded clover (26.5 to 118.1 lb N/acre) yielded more than sequentially seeded clover (1.9 to 48.8 lb N/acre). Hairy vetch was the most variable of the cover crops (4.9 to 162 lb N/acre), yet yielded more than 100 lb N/acre at five of the eleven farm-years.

**Table 23. Nitrogen accumulation in cover crop and total aboveground biomass (1992 and 1993).**

|                                                   | Farm A |       | Farm B |       | Farm C |       | Farm D |       | Farm E |       |
|---------------------------------------------------|--------|-------|--------|-------|--------|-------|--------|-------|--------|-------|
|                                                   | CC     | Total | CC     | Total | CC     | Total | CC     | Total | CC     | Total |
| ----- Above-ground biomass nitrogen (lb/ac) ----- |        |       |        |       |        |       |        |       |        |       |
| 1992                                              |        |       |        |       |        |       |        |       |        |       |
| Comp. red clover                                  | 26.5   | 36.6  | 86.9   | 92.7  | 49.3   | 50.7  | -      | -     | 44.1   | 69.6  |
| Sequ. red clover                                  | -      | -     | -      | -     | -      | -     | 29.6   | 42.3  | 39.5   | 60.7  |
| Sequ. hairy vetch                                 | 26.8   | 32.9  | 7.0    | 53.3  | 16.3   | 21.5  | 103.2  | 114.0 | 111.0  | 123.3 |
| Sequ. oats                                        | 14.5   | 14.6  | 54.4   | 54.1  | 7.4    | 7.4   | 84.7   | 84.9  | 67.7   | 87.7  |
| Sequ. buckwheat                                   | -      | -     | -      | -     | -      | -     | -      | -     | 15.0   | 46.9  |
| Weedy fallow                                      | -      | 17.9  | -      | 38.6  | -      | 8.2   | -      | 12.3  | -      | 28.8  |
| LSD (0.05)                                        | NS     | NS    | 36.6   | 19.7  | 14.0   | 9.5   | 40.8   | 32.4  | 46.9   | 41.9  |
| 1993                                              |        |       |        |       |        |       |        |       |        |       |
| Comp. red clover                                  | 76.0   | 79.1  | 101.8  | 103.4 | 42.9   | 50.1  | -      | -     | 118.1  | 118.8 |
| Sequ. red clover                                  | -      | -     | -      | -     | -      | -     | 48.8   | 56.5  | 1.9    | 43.9  |
| Sequ. hairy vetch                                 | 45.1   | 60.6  | 162.8  | 164.3 | 6.1    | 23.1  | 107.2  | 112.1 | 110.2  | 127.0 |
| Sequ. oats                                        | 15.7   | 26.6  | 38.2   | 39.6  | 19.5   | 19.5  | 69.4   | 73.2  | 45.7   | 60.1  |
| Sequ. buckwheat                                   | -      | -     | -      | -     | -      | -     | -      | -     | 28.3   | 43.8  |
| Weedy fallow                                      | -      | 18.2  | -      | 20.1  | -      | 15.3  | -      | 15.4  | -      | 49.7  |
| LSD (0.05)                                        | 14.1   | 12.8  | 71.6   | 53.1  | 8.9    | 10.8  | 23.5   | 21.6  | 17.5   | 19.1  |

Oat N content ranged from 7.4 to 84.7 lb N/acre. It was higher following leguminous main crops (peas and snapbeans) than small grains, which is consistent with observations that the N content of grass cover crops depends largely on soil N availability (Reeves, 1994). In many cases, oats yielded more N than weedy fallow which demonstrates the ability of oats to scavenge late-season N (Shipley et al., 1992).

#### Nitrogen loss in 1993

Corn yields were lower than usual at some of the sites in 1993, most likely due to loss of N during the excessively wet 1993 season (Table 24). We monitored soil nitrate levels in the beginning of the season at farms A and C, both sandy soils, and saw evidence of significant N loss from the top two feet of soil (data not shown). Results from the pre-sidedress soil nitrate test also suggest that N left the system or, in the case of the cover crops, mineralized slowly. No significant differences could be detected between the cover crop treatments at any of the sites in spite of the differences in N contribution by the crops the previous fall (data not shown). Additionally, PSNT levels did not differ significantly between the N fertilizer treatments at farms A, C and E.

#### Corn grain yields in 1993

Grain yields following the cover crops (as a group) were not statistically different than those following the weedy fallow plot (no fertilizer) (Table 24). However, corn following leguminous cover crops did yield more than corn following the non-legumes.

**Table 24. 1993 Corn grain yields following cover crops (no additional N) and weedy fallow (0 - 200 lb N/acre fertilizer).**

| Treatment                  | Farm, 1993                          |     |     |     |     | Farm, 1994 |     |     |     |
|----------------------------|-------------------------------------|-----|-----|-----|-----|------------|-----|-----|-----|
|                            | A                                   | B   | C   | D   | E   | A          | B   | C   | E   |
|                            | ----- Corn grain yield (bu/a) ----- |     |     |     |     |            |     |     |     |
| Comp. red clover           | 55                                  | 153 | 120 | -   | 157 | 166        | 221 | 142 | 111 |
| Sequ. red clover           | -                                   | -   | -   | 165 | 133 | -          | -   | -   | 73  |
| Sequ. hairy vetch          | 107                                 | 156 | 107 | 169 | 161 | 143        | 227 | 107 | 145 |
| Sequ. oats                 | 43                                  | 437 | 69  | 146 | 132 | 110        | 183 | 88  | 110 |
| Sequ. buckwheat            | -                                   | -   | -   | -   | 127 | -          | -   | -   | 123 |
| Weedy fallow (0 N)         | 29                                  | 146 | 81  | 148 | 129 | 108        | 182 | 78  | 77  |
| LSD (0.05)                 | 37                                  | NS  | NS  | NS  | NS  | 21         | 30  | 39  | NS  |
| Contrasts:                 |                                     |     |     |     |     |            |     |     |     |
| Cover crop vs. WF (0 N)    | **                                  | NS  | NS  | NS  | NS  | **         | *   | *   | †   |
| Legume vs. non-legume      | *                                   | †   | *   | NS  | †   | **         | **  | *   | NS  |
| Red clover vs. hairy vetch | *                                   | NS  | NS  | NS  | NS  | *          | NS  | †   | *   |
| Weedy fallow               |                                     |     |     |     |     |            |     |     |     |
| 0 N                        | 29                                  | 146 | 81  | 148 | 129 | 108        | 182 | 78  | 77  |
| 40 N                       | 25                                  | 166 | 92  | 175 | 157 | 154        | 201 | 102 | 102 |
| 80 N                       | 52                                  | 170 | 127 | 178 | 143 | 167        | 228 | 148 | 134 |
| 120 N                      | 89                                  | 175 | 145 | 184 | 156 | 173        | 230 | 165 | 165 |
| 160 N                      | 102                                 | 180 | 162 | 179 | 175 | 180        | 227 | 175 | 171 |
| 200 N                      | 101                                 | 177 | 150 | 198 | 158 | 174        | 231 | 176 | 168 |
| LSD (0.05)                 | 32                                  | 10  | 17  | NS  | NS  | 27         | 24  | 18  | 26  |

†, \*, \*\* Significant at the 0.10, 0.05 and 0.01 probability levels.

Corn following red clover and hairy vetch yielded similarly, except at farm A. Corn yields following the vetch at farm A exceeded corn fertilized at 200 lb N. Observations taken during the corn season suggest that this result may be due as much to weed control as to N benefits provided by the vetch. Farmer A killed his cover crops with herbicides and no-till drilled his corn. Due to excessive moisture, he was unable to get into the field again to cultivate or spray for weed control. Consequently, weed pressure was extremely high in all but his vetch plot. The killed vetch formed a thick mat which prevented weeds from germinating.

#### Corn Yields in 1994

Corn grain yields in 1994 were greater, on average, than in 1993, reflecting a much more favorable growing season (Table 24). At all of the sites in 1994, corn following companion red-clover and sequential hairy vetch yielded more than corn following oats or weedy fallow (no additional nitrogen). As in 1993, corn following the two leguminous cover crops produced statistically similar yields except at farm A.

#### Fertilizer replacement value of the cover crops

The corn yield data was used to calculate the Fertilizer Replacement Value (FRV), or fertilizer equivalence, of the cover crops. FRV refers to the amount of inorganic nitrogen fertilizer needed to produce a crop yield equal to that of an unfertilized crop that follows a cover crop. It should be noted that the FRV actually measures the overall effect of the cover crop and can not distinguish between N effects and other effects that the cover crop might have (such as the weed control effect of the vetch at farm A in 1993). Nonetheless, as an accurate estimate of the overall effects of cover crops the FRV can have economic significance to farmers.

Fertilizer replacement values for the leguminous cover crops in this trial range from 13 to 84 lb N/acre in 1993 and from 33 to 99 lb N/acre in 1994 (Table 25). Fertilizer replacement values for oats were not estimable in five of the nine farm-years because yields were lower following oats than following weedy fallow at 0 lb N/acre. Buckwheat also had a negative effect on corn yields in 1993 preventing an estimate of its FRV.

**Table 25. Estimates of cover crop fertilizer replacement value (FRV).**

| Treatment         | Farm, 1993                                           |    |    |    |    | Farm, 1994 |    |    |    |
|-------------------|------------------------------------------------------|----|----|----|----|------------|----|----|----|
|                   | A                                                    | B  | C  | D  | E  | A          | B  | C  | E  |
|                   | ----- Fertilizer Replacement Value (lb N/acre) ----- |    |    |    |    |            |    |    |    |
| Comp. red clover  | 73                                                   | 13 | 67 | -  | 67 | 78         | 79 | 79 | 42 |
| Sequ. red clover  | -                                                    | -  | -  | 36 | 0  | -          | -  | -  | 1  |
| Sequ. hairy vetch | 196                                                  | 22 | 45 | 49 | 84 | 38         | 99 | 33 | 92 |
| Sequ. oats        | 52                                                   | †  | †  | †  | †  | †          | 2  | 14 | 41 |
| Sequ. buckwheat   | -                                                    | -  | -  | -  | †  | -          | -  | -  | 58 |

† FRV estimate was below the zero fertilizer control.

#### **Economic Analysis**

To evaluate relative profitability, gross margins (gross returns - variable costs) were calculated for each treatment. Short-season crop production was not included in the analysis since it was found that, in 9 of 11 cases, short-season crop yields were not affected by cover crop treatment.

Gross margins for both cover crop and fertilizer treatments were positive in most cases (Table 26). Negative gross margins occurred at farm A in 1993 where excessively wet weather prevented weed control, likely caused N loss, and resulted in low corn yields. The only other case where a gross margin was negative was the oat treatment at farm C in 1993 where N leaching was observed and yields were also relatively low.

As a sole source of N, cover crops were never the most profitable option. Rather, the weedy fallow treatment with 160, or 200, lb N/acre of fertilizer produced the greatest gross margin of all of the treatments at each farm. The average difference in gross margin between the best cover crop treatment (red clover in 8 of 9 cases) and the best fertilizer treatment was \$35.89/acre. Overall, hairy vetch was the most expensive treatment, due primarily to high seed cost (about \$1.00/lb seeded at 30 lb/acre).

Cover crop treatments are disadvantaged by two shortcomings of this type of experiment and economic analysis. First, the cover crops options were not necessarily tested under economically optimal conditions (i.e. optimal fertilizer rates, seeding rates, establishment and kill methods, etc.). For example, other studies have shown that the gross margin of corn following a cover crop is greater than that of corn with no cover crop, when both corn crops are optimally fertilized (Frye et al., 1985; Hanson et al., 1993). Second, the analysis does not account for long-term benefits of cover crops such as erosion control and improved soil physical conditions. Although it is difficult to place monetary value on these long-term benefits, they have value in terms of maintaining the future profitability of cropping systems.

**Table 26. Gross margins of corn that followed either cover crops (no additional N) or weedy fallow (0 - 200 lb N/acre fertilizer).**

| Treatment          | Farm, 1993                          |     |     |     |     | Farm, 1994 |     |     |     |
|--------------------|-------------------------------------|-----|-----|-----|-----|------------|-----|-----|-----|
|                    | A                                   | B   | C   | D   | E   | A          | B   | C   | E   |
|                    | ----- Gross margins (\$/acre) ----- |     |     |     |     |            |     |     |     |
| Comp. red clover   | -21                                 | 114 | 68  | -   | 127 | 232        | 331 | 175 | 119 |
| Sequ. red clover   | -                                   | -   | -   | 130 | 87  | -          | -   | -   | 38  |
| Sequ. hairy vetch  | 25                                  | 90  | 22  | 116 | 109 | 167        | 318 | 80  | 164 |
| Sequ. oats         | -23                                 | 91  | -8  | 123 | 99  | 130        | 259 | 75  | 127 |
| Sequ. buckwheat    | -                                   | -   | -   | -   | 77  | -          | -   | -   | 140 |
| Weedy fallow (0 N) | -48                                 | 120 | 23  | 134 | 102 | 134        | 271 | 65  | 68  |
| LSD (0.05)         | 49                                  | NS  | NS  | NS  | NS  | 42         | NS  | 78  | NS  |
| Weedy fallow       |                                     |     |     |     |     |            |     |     |     |
| 0 N                | -48                                 | 120 | 23  | 134 | 102 | 134        | 271 | 65  | 68  |
| 40 N               | -45                                 | 141 | 33  | 167 | 139 | 221        | 303 | 106 | 111 |
| 80 N               | -15                                 | 143 | 85  | 168 | 111 | 241        | 353 | 192 | 171 |
| 120 N              | 28                                  | 145 | 110 | 172 | 126 | 250        | 351 | 219 | 228 |
| 160 N              | 40                                  | 147 | 133 | 159 | 150 | 258        | 341 | 235 | 237 |
| 200 N              | 34                                  | 138 | 109 | 184 | 118 | 242        | 343 | 232 | 225 |
| LSD (0.05)         | 37                                  | 14  | 28  | NS  | NS  | 56         | 43  | 37  | 53  |

Another benefit of cover crops, reducing our dependence on fossil fuels, is also hidden in the economics but is revealed in the energy analysis (Table 27). In all cases, cover crop treatments used less energy than the lowest rate fertilizer treatment (40 lb N/acre). Although relatively inexpensive, commercial fertilizers are extremely energy intensive.

**Table 27. Energy use for production of corn that followed either cover crops (no additional N) or weedy fallow (0 - 200 N lb/acre fertilizer).**

| Treatment         | Farm                          |      |      |      |      |
|-------------------|-------------------------------|------|------|------|------|
|                   | A                             | B    | C    | D    | E    |
|                   | ----- Energy (btu/acre) ----- |      |      |      |      |
| Comp. red clover  | 8.6                           | 11.6 | 12.0 | -    | 12.7 |
| Sequ. red clover  | -                             | -    | -    | 12.9 | 13.2 |
| Sequ. hairy vetch | 9.2                           | 14.0 | 13.7 | 12.9 | 13.2 |
| Sequ. oats        | 8.8                           | 14.0 | 11.8 | 11.6 | 12.5 |
| Sequ. buckwheat   | -                             | -    | -    | -    | 12.5 |
| Weedy fallow      |                               |      |      |      |      |
| 0 N               | 7.7                           | 11.6 | 11.1 | 11.2 | 12.1 |
| 40 N              | 14.4                          | 18.3 | 17.8 | 17.8 | 18.7 |
| 80 N              | 20.4                          | 24.3 | 23.8 | 23.8 | 24.7 |
| 120 N             | 26.4                          | 30.3 | 29.8 | 29.8 | 30.7 |
| 160 N             | 32.4                          | 36.3 | 35.8 | 35.8 | 36.7 |
| 200 N             | 38.4                          | 42.3 | 41.8 | 41.8 | 42.7 |

### Farmer Interviews

The purpose of interviewing the farmers participating in the cover crop trial was to formalize the listening aspect of our on-farm work. An understanding of why these farmers will or will not adopt cover crops can help focus future cover crop research and extension efforts.

#### Reasons farmers consider using cover crops

The number one reason that the farmers in this study consider using cover crops is to control erosion. The farmers said that they are "willing to spend some money to maintain soil productivity" (Farmer A) because, "you can't put a price on the soil protection, but you know what can happen if it's bare" (Farmer D). These farmers also said that the nitrogen benefits are an important factor in their decision to use cover crops, although secondary to erosion control, and some mentioned the soil improvement benefits as well. Ironically, the researchers who developed this cover crop system through on-station testing considered the nitrogen benefits as primary, and erosion control secondary (Stute and Posner, 1993).

#### Farmers' concerns about using cover crops

Cost was mentioned first by all of the farmers when asked what factors would affect their decision to use cover crops. Farmers considered the direct costs associated with cover crops (seed, seeding and killing costs) and also the indirect costs, in terms of any negative effects the cover crops might have on main crops. For example, although companion-seeded red clover was relatively inexpensive, provided excellent ground cover and contributed substantial nitrogen, the wheat farmers said that they will not use it because it can interfere with straw harvest and given the current wheat market, they can earn as much from clean straw as from grain (Oplinger et al., 1992).

Some of the farmers expressed concern that overwintering covers could negatively impact the following corn crop by depleting spring soil moisture and/or becoming a weed (other indirect costs). However, most said that both of these potential problems could be addressed with proper management.

Farmers were not concerned with the possible machinery changes and labor demand associated with using cover crops. One farmer mentioned that he wouldn't sequentially seed cover crops unless he had a no-till drill. But, in general, cash grain farmers already have the machinery needed to plant and manage cover crops. Additionally, the work associated with cover crops coincides with slow times during the season for cash grain farmers -- early spring and mid-summer.

### **Adoption Potential of the Cover Crop System**

Rogers (1983) outlines five characteristics of technologies that influence their chances of being accepted and used by farmers: compatibility, complexity, trialability, observability and relative advantage. Cover crops have many of these characteristics. As a new technology, cover crops are relatively simple and trialable. The farmers in this trial had no difficulty understanding the cover crop system, recognizing the potential benefits and trying it out on a small scale. In most cases, cover crops were also compatible with the farmers existing systems. No rotation or machinery changes were required, nor was work added during peak labor periods. The only case where a cover crop was incompatible was the red clover in winter wheat. Cover crops might be considered relatively observable, as well, since their effects on ground cover and on cash crop yields can be easily noted by the farmers and their neighbors. However, the long-term benefits of cover crops require many seasons of observation.

The characteristic which will decide the adoption fate of cover crops is their relative advantage, as perceived by farmers. Farmers weigh the possible benefits (erosion control, nitrogen production, soil improvement) and the possible drawbacks (cost, moisture and weed problems, effect on cash crops) and compare the balance to their current practices. All of the farmers interviewed agreed that the relative advantage of cover crops is high if their current practice leaves the ground bare and in need of cover, as in the case of canning crops or low yielding wheat. But when no-till methods provide good cover, the relative advantage of cover crops is not so certain and depends on the benefits and drawbacks recognized by each farmer.

### **Conclusions**

The farmers participating in the trials indicated that their decisions to adopt cover crops would be based on, first, their need for ground cover, and second, the profitability of using cover crops as a source of nitrogen. Cover crops proved to be a viable erosion control strategy. However, when valued solely as a source of nitrogen, cover crops were not an economical alternative to nitrogen fertilizer.

Based on these results, we suggest focusing future cover crop efforts on: a) outreach to farmers growing crops that do not provide sufficient ground cover, such as vegetable crops; and b) optimizing the cover crop system in order to increase its profitability as compared to nitrogen fertilizer. Specifically, work is needed to determine economically optimal management systems (e.g., seeding rates, establishment and kill methods, nitrogen fertilizer use, etc.) as well as to select or develop improved cover crop varieties.

We also suggest to other researchers that they build into their on-farm research open-ended adoption interviews or questionnaires, such as the one used here, to solicit information that will help direct cover crop research and extension efforts.

## REFERENCES

- Frye, W.W., W.G. Smith, and R.J. Williams. 1985. Economics of winter cover crops as a source of nitrogen for no-till corn. *J. Soil and Water Conserv.* 40:246-249.
- Fox, R.H., G.W. Roth, K.V. Iversen, and W.P. Piekielek. 1989. Soil and tissue nitrate tests compared for predicting soil nitrogen availability to corn. *Agron. J.* 81:971-974.
- Hanson, J.C., E. Lichtenberg, A.M. Decker, and A.J. Clark. 1993. Profitability of no-tillage corn following a hairy vetch cover crop. *J. Prod. Agric.* 6:432-437.
- Oplinger, E.S., K.G. Silveira and R.A. Forsberg. 1992. Oat management for straw production. UWEX Publ. 26.43-0. Madison, Wisconsin.
- Pimental, D. 1980. Handbook of Energy Utilization in Agriculture. CRC Press, Inc., Boca Raton, FL.
- Reeves, D.W. 1994. Cover crops and rotations. p.125-172. *In* J.C. Hatfield and B.A. Stewart (ed.) Advances in Soil Science: Crop Residue Management. Lewis Publ., Boca Raton, FL.
- Rogers, E.M. 1983. Diffusion of innovations. The Free Press, Macmillan Publ. Co., New York, NY.
- Shipley, P.R., J.J. Meisinger, and A.M. Decker. 1992. Conserving residual corn fertilizer nitrogen with winter cover crops. *Agron. J.* 84:869-876.
- Stute, J.K. 1991. Integrating legume cover crops into cash grain production systems. M.S. thesis. University of Wisconsin, Madison.
- Stute, J.K. and J.L. Posner. 1993. Legume cover crop options for grain rotations in Wisconsin. *Agron. J.* 85:1128-1132.
- Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall erosion losses: A guide to conservation planning. Agriculture Handbook No. 537, USDA, Washington, D.C.
- Wisconsin Department of Agriculture, Trade, and Consumer Protection. 1993. Wisconsin 1993: Agricultural Statistics. WDATCP, Wis. Statistics Serv., Madison.

### 3. Alternative Legumes for Cover Crops

J. Stute\*

A satellite trial was established at the Lakeland site to evaluate the potential of different legumes that were either interseeded (frost-seeded) into winter wheat or sequentially seeded following wheat harvest. The alternative legumes included three annual medic species, sweet clover and hairy vetch. These were compared to red clover which is currently being used as the primary cover crop in the corn/soybean/wheat + clover rotation.

Potential advantages of the medics include their rapid growth, early maturity and ability to easily winter-kill for use in reduced tillage systems. Hairy vetch can be established successfully following wheat harvest in situations where an interseeded legume is either not wanted or has not been established well. Finally, sweet clover may have potential due to its low cost.

The results from 1994 (Table 28) showed that the annual medics and sweet clover were less productive than red clover when spring interseeded, but slightly more productive when planted after wheat harvest. Hairy vetch was the most productive species in both dry matter yield and nitrogen accumulation when sequentially seeded. This indicates that red clover or hairy vetch are probably still the best cover crop choices depending on planting time and method. However, the annual medics may be useful in systems that want to avoid using tillage or chemicals to kill cover crops prior to corn planting. The trial will be conducted again in 1995.

**Table 28. Cover Crop Dry Matter Yield, Crude Protein & Final Nitrogen Accumulation  
WICST, Lakeland Farm, Elkhorn, WI, 1994**

| <u>Cover Crop</u>   | <u>Spring Interseeded</u> |             |                     | <u>Sequentially Seeded</u> |             |                     |
|---------------------|---------------------------|-------------|---------------------|----------------------------|-------------|---------------------|
|                     | Dry Matter<br>(lbs/a)     | C.P.<br>(%) | Nitrogen<br>(lbs/a) | Dry Matter<br>(lbs/a)      | C.P.<br>(%) | Nitrogen<br>(lbs/a) |
| Sava snail medic    | 1720                      | 18.6        | 51                  | 1509                       | 19.1        | 46                  |
| Santiago burr medic | 1115                      | 17.9        | 32                  | 1196                       | 14.3        | 27                  |
| Caliph barrel medic | 1360                      | 18.3        | 40                  | 1280                       | 16.1        | 33                  |
| Sweet clover        | 3199                      | 8.8         | 45                  | 1460                       | 18.1        | 42                  |
| Red clover          | 4486                      | 12.3        | 88                  | 1080                       | 17.3        | 30                  |
| Hairy vetch         | ----                      | ----        | --                  | 3204                       | 26.2        | 134                 |
| Control*            | ----                      | ----        | --                  | 1071                       | 15.4        | 26                  |

\*no cover crop (weeds and volunteer wheat)

\* UWEX Agriculture Agent, Racine and Kenosha Counties

### C. Field Effects of Commercial Fertilizer Additions to a Low Input Cash Grain System

John Hall\*, Dwight Mueller\*\*, Alan Wood\*\*\*, Paul Bergum\*\*, Tom Mulder\*\*\*\*

#### Introduction

The corn yields in the WICST corn-soybean-wheat/red clover (R3) rotation have been lower than desired the past two years. These lower yields were thought to be caused by either weeds or low fertility. Satellite trials were initiated at both sites in 1994 to determine the cause of the low yields and to find out whether adding some purchased inputs would be cost effective.

#### Materials and Methods

##### Arlington:-

The effects of adding starter fertilizer and sidedress nitrogen were tested at Arlington in the edge rows of R3 corn plots. Weed and weed free comparisons were also tested in the edge rows at both sites (see chapter III.B.). We were able to use these rows since we had decided to negate the edge effect on the outer two rows of each plot by leaving one harvest pass (6 rows) along the edge of each plot planted to corn when measuring yield. This allowed us to do some testing on the inner four rows of this 6-row strip. At Lakeland, fertilizer additions were tested on a satellite plot in conjunction with a trial comparing clover kill by fall chisel plowing, spring chisel plowing and a spring herbicide application followed by no-till corn planting.

At Arlington the experiment was a randomized complete block design. Plot size was 40 ft x 15 ft (6 30-in. rows) for a total area of 160 x 15 ft along the west edge of each R3 corn plot. The four randomized treatments were 1) no additional fertilizer, 2) starter only (100 lb/a 6-24-24), 3) only sidedress N (135 lb/a 33-0-0), and 4) starter and sidedress. Corn was planted on May 5, and sidedress N applied on May 14, 1994. Starter was applied with the corn planter by engaging and disengaging the fertilizer drive unit while sidedress N was hand spread on the soil surface two inches from the corn row. Soil preparation and row-cultivation were identical to that of the main plots (see appendix VI.) Corn was hand harvested, mechanically shelled, weighed, and moisture determined on Oct. 17, 1994. The harvest area was 30 ft. of two rows (4th and 5th rows from edge of plot).

##### Lakeland:

The experimental at Lakeland was a randomized complete block, split plot design. Main plots were 1) fall clover kill by chisel plowing with sweeps at 3 in-depth, 2) spring clover kill by chisel plowing, 3) spring herbicide kill of clover followed by no-till corn. Sub plots were identical to those at Arlington except starter application rate was 33 gal/a (338 lb/a) 4-10-10. Main plot size was 20 x 220 ft and subplots 10 x 110 ft. Fall chisel plowing in the tilled treatments and a Roundup application for clover kill in the no-till treatments clover were done Nov 11, 1993. Since the chisel plow was not available in the spring, a mulchmaster<sup>1</sup> with sweeps was used on April 24, 1994 for both the spring clover kill and

\* Agronomist, Michael Fields Agricultural Institute, East Troy, WI.

\*\* Assist. Superintendent and Field Assistant, UW Arlington Res. Sta., Arlington, WI.

\*\*\* Superintendent, Lakeland Ag. Complex, Elkhorn, WI.

\*\*\*\* Research Specialist, Dept. of Agronomy, Univ. of Wisconsin, Madison.

<sup>1</sup>One pass tillage tool, John Deere, Co. Moline, IL

an early tillage on the fall clover-killed treatments. Each of these treatments also received a second pass with the mulchmaster May 5. Fertilizer was applied by planter and by hand as at Arlington. Corn was planted on May 6, and sidedress N applied on May 12. All treatments were cultivated once on June 21 with a disk and sweep no-till cultivator. Harvest was by small plot harvester, harvesting the center two rows of the four-row plots (110 x 5 ft harvest area). Corn was weighed and moisture determined after harvest on October 26.

#### Results:

##### Arlington:

Yield averages for the four treatments ranged from 186 to 192 bu/a but there were no significant differences (see Figure 30). There was therefore no economic benefit to the fertilizer additions.

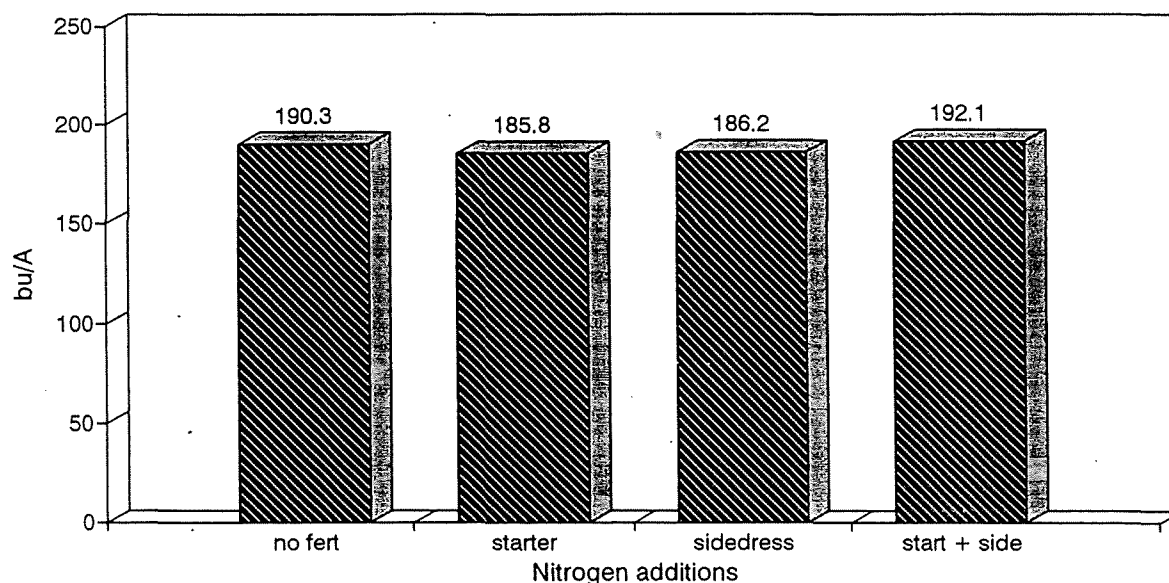


Figure 30. Yield of R3 Corn Following Red Clover at Arlington - 1994

##### Lakeland:

No-till corn yield was significantly lower (Figure 31) and grain moisture at harvest was significantly higher than for the chisel plowed clover treatments. Some, if not all of this difference can be attributed to improper planter adjustment. Seeds were planted too shallow and the soil surface was dry which delayed germination. When analyzing only the two chisel plowed clover treatments, there was no significant difference for yields or grain moisture between fall and spring kill of clover. For the fertilizer treatments, applying starter and sidedress N fertilizer increased yield compared to only starter but yields for no fertilizer and sidedress N alone treatments were not significantly different than either of the remaining two treatments. Fertilizer additions had no effect on grain moisture.

### Conclusions:

The 1994 growing season was excellent for corn production in Wisconsin with warm sunny days early in the season and adequate rainfall as the corn plants began to set ears. In a year with less ideal weather conditions, effects of these fertilizer additions may be measurable. We plan to continue this trial at both sites in 1995.

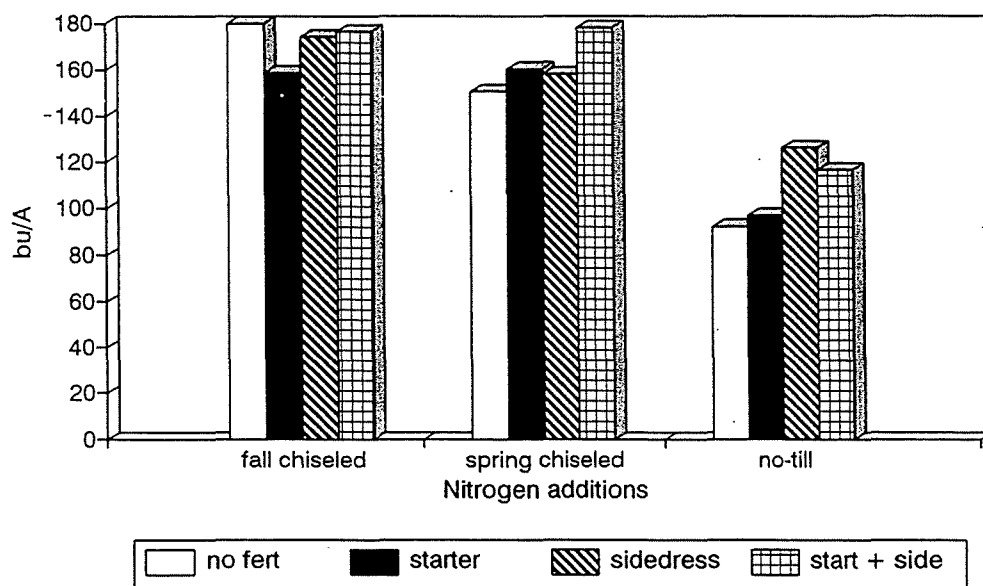


Figure 31. Yield of Corn Following Red Clover in Lakeland Satellite 4.2 - 1994.

#### **D. Additional Trials on the Corn-Soybean-Wheat/Red Clover Rotation.**

Jon Baldock\*, Josh Posner\*\*, and Tom Mulder\*\*

In spite of very low corn yields and below average wheat yields, Cropping System 3 (CS3) has been at least as profitable as the continuous corn system. That important result probably would not have been observed if we had not adopted a systems approach in the WICST. However, it is also important to note that because the systems approach does not include a control treatment for every treatment factor, we can not tell how much of the profitability of CS3 is due to the low purchased input philosophy and how much of it is due to the Corn-Soybean-Wheat(red clover) rotation. Consequently, some project participants have advocated modifications to CS3 based on alternative agricultural philosophies; while others have promoted changes based on more conventional Best Management Practices (BMP). During the winter of 1994 the County Committees approved plans to compare one, or both, of those ideas on the satellite plots rather than make changes to the plots in the main trial. The following paragraphs discuss the implementation of the two satellite comparison trials that they approved.

#### **BMP Inputs for the Corn-Soybean-Wheat/Red Clover Rotation**

The major changes that the BMP advocates suggested for this rotation were to use a little commercial fertilizer, especially in the corn phase, and to use herbicides as needed to get better weed control. Three types of trials were approved to examine those features. First, a starter and nitrogen fertilizer trial on corn was approved at both the Arlington and Lakeland sites. At Lakeland this trial was implemented on one of the satellite plots and at Arlington it was imposed on the border rows of the main plots. Second, herbicide treatments were included when they appeared needed in the corn and soybean phases. These treatments were included in the border rows of the main plots at both sites. Finally, the complete BMP Corn-Soybean-Wheat/Red Clover System was planned for satellite plots at both sites. The specific cultural practices included in this system are

**Corn** - The corn phase will adopt most of the practices used for the CS3 corn. That would simplify the field work and it should improve the corn yields. Some additions would be adding starter fertilizer, early planting (and a full-season hybrid), early nitrogen, and some herbicides. The red clover should contribute about three times as much N as soybeans (i.e., 120 lb. N/acre according to Jim Stute's recent data<sup>2</sup>), so this new system should receive about 40 lb. manufactured N/a. The best time to apply that would be just before to just after planting when the mineralization of the red clover N maybe too slow to fully meet the corn needs.

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\* Interim Project Coordinator and Project Statistician.

\*\* Professor and Research Specialist, Dept of Agronomy, Univ. of Wisconsin, Madison.

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<sup>2</sup> STUTE, J.K. 1994. Legume cover crops as a nitrogen source for corn. Ph.D. Thesis. Agronomy Dept. University of Wisconsin-Madison.

**Soybeans** - The soybeans will be handled similarly to the current CS3 beans because those yields have been very good and it would simplify the field work. The one exception to following the existing CS3 system is that we will be more willing to treat with herbicides if there appears to be a weed problem.

**Wheat/Red Clover** - Two changes are planned for the wheat phase: 1) 30 lbs N/a will be applied either in the fall between bean harvest and planting wheat or early spring, and 2) that any P and K recommended by the UW Soils Lab soil test program will be applied.

#### **Inputs for the Corn-Soybean-Wheat/Red Clover) Rotation**

The farmers on the Walworth County Committee were particularly interested in studying this cropping system, so they set up a three treatment trial to compare it to the CS3 as it is in the main WICST trial and the BMP version discussed above. The specific practices for this cropping system have not been finalized. This group is still sifting through a large number of possibilities that center around various calcium and organic amendments. Hopefully, they will soon arrive at one set of improvements for the system and prepare a summary for distribution.

## **VI. GROSS MARGINS COMPARISON OF THREE CASH GRAIN CROPPING SYSTEMS 1991-1994**

R.G. Gumz\*, W.E. Saupe\*, R.M. Klemme\*, and J.L. Posner\*\*

At a research site in Walworth County, a corn-soybean cropping system generated significantly higher gross margins than continuous corn in each of the first four years of the Wisconsin Integrated Cropping Systems Trial (WICST). Corn-soybean gross margins were also higher than those from a corn-soybean-wheat/red clover cropping system that used relatively low levels of purchased inputs, in the three years when all crops in both cropping systems were grown (statistically significant differences in 1992 and 1993). The gross margins from the corn-soybean-wheat/red clover cropping system were higher than from continuous corn during the same three years (statistically significant difference in 1994 only).

In a similar experiment conducted at a site in Columbia County the results have been comparable, with the exception that in 1994 the corn-soybean cropping system ranked third among the three cash grain cropping systems because soybean replanting resulted in lower yields and increased costs. These findings are from 1990-1994 data from 0.8 acre replicated experimental plots operated with conventional farm tractors and implements.

In this report the long-term Wisconsin Integrated Cropping Systems Trial is first described. We then turn to the economic analyses, which includes individual crop enterprise analyses for 1994 and the cropping systems' gross margins for 1990-1994. Future directions in analysis and education are also reported.

### **The Wisconsin Integrated Cropping Systems Trial (WICST)**

Crop experiments usually focus on a single crop and provide data only about that crop. Some "rotation studies" combine information from such individual crop experiments, weighting each crop by the number of years it appears in a hypothetical rotation. While useful, those analyses miss the beneficial interactions that can occur among the crops because of the cropping sequence, i.e., the "rotation effect". Also, some crop rotation studies do not take full advantage of the differences between crop rotations that allow changes in inputs, such as reduced tillage, lower pesticide use, and manure application.

The long-term Wisconsin Integrated Cropping Systems Trial (WICST) addresses that weakness. In the WICST, all input and production data are collected for each crop as it is grown in the specified sequence, accurately capturing the crop treatment effects plus the effects caused by the cropping system. The focus is on the profitability of a system of production, i.e., on the entire cropping system rather than on comparisons between individual crops.

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\* Research Assistant and Professors, Dept. of Agricultural Economics, Univ. of Wisconsin, Madison.

\*\* Professor, Dept. of Agronomy, Univ of Wisconsin, Madison.

## Distinctive Characteristics of the WICST

The WICST was created in 1989 by a coalition of farmers from southern Wisconsin plus scientists from the College of Agricultural and Life Sciences, Cooperative Extension, Lakeland Agricultural Complex, and the Michael Fields Agricultural Institute. The two locations of the trial are the University of Wisconsin-Madison Arlington Agricultural Research Station in Columbia County and the Lakeland Agricultural Complex in Walworth County. The WICST is a unique experiment in the following ways:

- The WICST focuses on cropping systems instead of individual crops and has an expected duration of at least 12 years.
- It is conducted using actual farm size tractors and equipment on four replicated experimental plots, each about 0.8 acre in size.
- Farmers collaborate with county Extension faculty, University research scientists, and the Michael Fields Agricultural Institute in selecting which cropping systems to include and in determining what economic analyses would be most useful.
- Response to short term production problems is based on how a farmer would respond, e.g., spot spray herbicide as needed, reseed selected areas.
- Due to the long duration of the trial, varieties, pesticides, and agronomic techniques are allowed to change as University of Wisconsin-Extension recommendations evolve.
- The trial allows measuring and evaluating some of the environmental effects of different cropping systems, for example, the Nitrate + Nitrite N concentration in the groundwater.

## The Three Cash Cropping Systems

The farmers, county Extension faculty, and research scientists on the planning committee selected three cash cropping systems for long-term study in the WICST.

Continuous corn is planted in 30" rows in chisel-plowed soil, fertilized with a starter and anhydrous ammonia according to soil nutrient tests, cultivated once, and weeds and pests controlled with agricultural chemicals as standardly used by farmers.

In the corn-soybean cropping system both the corn and soybeans were no-till planted in 1994. Prior to that, conventional tillage had been used for the soybeans. In this cropping system pests are controlled by chemicals, nitrogen fertilizer is applied based on UW recommendations (120 pounds of nitrogen per acre for corn), and the soybeans are drilled in narrow rows.

In the corn-soybean-wheat/red clover system the corn and soybeans receive no commercial fertilizer. Soybeans are planted in wide rows and, like corn, are rotary hoed and cultivated. Soybeans may receive a rescue herbicide treatment if weed pressure is severe. The wheat is fall seeded into the soybean stubble without application of herbicide

or commercial fertilizer.<sup>3</sup> Red clover is frost seeded into the wheat in early spring and serves as the nitrogen source for the subsequent corn crop.

Scientists and field staff involved with the physical and biological aspects of the trial record the inputs and production data for the four replicates of each crop. For the economic analyses, those physical data are summarized by each crop in the system. Observed input costs and other operating costs, on-farm value of production, and the gross margins are calculated and presented in an enterprise analysis format. The gross margins for individual crops are summed to determine the per acre gross margins for each cropping system.

### **Individual-Crop Enterprise Analyses for 1994**

Individual crop analyses are based on established farm enterprise accounting techniques. These include data on the market value of production (gross returns) and on the direct (variable) input costs. Gross margins are then calculated as the gross returns minus variable costs.

Neither depreciation nor the opportunity cost of owned capital and unpaid family labor and management are subtracted in calculating gross margins. Thus, gross margins represent the returns to the farm's unpaid fixed resources in labor, management, capital, and land. Gross margins is an appropriate measure to determine which cropping system yields the largest returns to the farmer's fixed resources.

The crop enterprise methodology is illustrated in Table 29 using the input and production data from the continuous corn enterprise at the Lakeland Agricultural Complex for 1994. The average yield from the four plots (replicates) was 177.04 bushels per acre in 1994. Farm products are priced at harvest time on the farm, and storage and transportation costs are thus excluded. Given a harvest time price of \$1.95 per bushel, the continuous corn enterprise generated gross returns of \$345.23 per acre.

In all cases, corn yields are corrected for moisture and reported as bushels of No. 2 corn per acre. The price per bushel reflects the discounts in the market place for low test weights, if any. Drying costs are included as a variable cost and, on occasion, have been the highest variable costs in poor field drying years. This is particularly important in comparing the three cropping systems as the corn acreage comprises all, one-half, or one-third of the rotations, respectively. In addition, machinery complements could readily differ among the cropping systems, which will be addressed in future analyses.

**The direct (variable) costs** totalled \$175.23 per acre, the sum of the physical quantities of each input times its cost per unit. Variable costs included the observed costs of purchased seed, fertilizer, and pesticides; custom operations that were hired, if any; leased equipment, if any; and grain drying. The estimated fuel and repair costs of field machine operations were also included for all operations from tillage following the harvest of the

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<sup>3</sup> During 1990-1992 the winter wheat was aerially seeded into the standing soybeans before leaf drop. In 1993 and 1994 it was drilled into the soybean stubble after harvest. In all years, red clover was frost seeded over the winter wheat in the following March and took over as a green manure crop after the wheat was harvested.

previous crop through the harvest of the current crop.<sup>4</sup> An imputed charge for interest on the operating capital (inputs) reported in the budget is included, but only for the fraction of the year between incurring the expense and harvesting the crop.

The **gross margin** is the residual after subtracting the variable costs and represents the returns to labor, management, capital, and land. This was \$170.00 per acre for continuous corn grown at the Lakeland Agricultural Complex in Walworth County in 1994 (see Table 29).

**Table 29. Costs and Returns per Acre for Continuous Corn System, Lakeland Agricultural Complex, -1994.**

| Crop and Item                     | Yield or Quantity | Unit | Price or Factor | Dollars per Acre |
|-----------------------------------|-------------------|------|-----------------|------------------|
| <b>CORN:</b>                      |                   |      |                 |                  |
| Gross Returns                     |                   |      |                 |                  |
| Corn @ 15.5% moisture             | 177.04            | Bu.  | \$ 1.95         | \$345.23         |
| Direct Costs                      |                   |      |                 |                  |
| Seed (Pioneer 3563)               | 0.40              | Bag  | 76.48           | 30.59            |
| 28% N Fertilizer (\$146 per ton)  | 166.00 *          | Lb.  | 0.073           | 12.12            |
| 28% N Fertilizer (\$146 per ton)  | 85.50 *           | Lb.  | 0.073           | 6.24             |
| Starter (4-10-10) (\$112 per ton) | 132.00            | Lb.  | 0.056           | 7.39             |
| Dual 8E                           | 2.50              | Pt.  | 7.19            | 17.98            |
| Accent                            | 0.67              | Oz.  | 27.71           | 18.57            |
| Stinger                           | 0.31              | Oz.  | 2.83            | 0.87             |
| Preference                        | 0.40              | Qt.  | 3.78            | 1.51             |
| Ammonium Sulfate                  | 2.50              | Lb.  | 0.35            | 0.88             |
| Extrazine II DF                   | 2.50              | Lb.  | 3.92            | 9.80             |
| Counter                           | 6.50              | Lb.  | 2.54            | 16.51            |
| Buctril                           | 1.50              | Pt.  | 6.11            | 9.17             |
| Drying (2¢ per point from 18.6%)  | 177.04            | Bu.  | --              | 11.11            |
| Fuel                              | 7.74              | Gal. | 0.83            | 6.44             |
| Repairs                           | 1.00              | \$   | 16.13           | 16.13            |
| Interest on operating capital     | 165.28            | \$   | 0.06            | 9.92             |
| Total Direct Costs                |                   |      |                 | \$175.23         |
| <b>Gross Margin for Corn</b>      |                   |      |                 | <b>\$170.00</b>  |

\* Based on deep nitrate soil test two weeks before planting.

<sup>4</sup> These estimated costs are based on the observed field operations and tractors and machinery used on the research sites. Fuel consumptions and machinery repairs could not be readily measured on the experimental plots and are calculated instead from the Minnesota Farm Machinery Economic Cost Estimates for 1992 for similar size equipment.

The **gross returns**, **direct costs**, and the **gross margins** were calculated in a similar manner for each crop in the corn-soybean and corn-soybean-wheat/red clover cropping systems. These are reported for 1994 in Table 30, for both the Lakeland and Arlington research sites. For reference, note that the first line in both the upper and lower panels of Table 30 represents the continuous corn system. In that single crop system, the enterprise budget results are also the system results. Crop enterprise budgets for each crop in systems R1 through R5 at both Arlington and Lakeland are presented in appendix XI.

The analysis pertains to gross margins for crop production only through harvest, with crops valued at harvest time prices on the farm. To that point in the farm business the production practices, costs, and gross margins are the same regardless of the producer's ultimate disposition of the crop. Analysis of producer's options for feeding the crop to livestock on the farm or for the timing and place of sale off the farm have not been included in the study to date.

**Table 30. Costs and Returns per Acre for Crops Grown in Three Cropping Systems at the Lakeland Agricultural Complex and Arlington Research Station, 1994.**

| Location and Cropping System   | Crop     | Yield<br>Bu. per Acre | Dollars Per Acre |                 |                  |
|--------------------------------|----------|-----------------------|------------------|-----------------|------------------|
|                                |          |                       | Gross<br>Returns | Direct<br>Costs | Gross<br>Margins |
| Lakeland Agricultural Complex: |          |                       |                  |                 |                  |
| Continuous Corn                | Corn     | 177.04                | \$345.23         | \$175.23        | \$170.00         |
| Corn-Soybean                   | Corn     | 184.39                | 359.56           | 126.09          | 233.47           |
|                                | Soybeans | 63.09                 | 340.04           | 86.57           | 253.47           |
| Corn-Soybean-Wheat             | Corn     | 187.01                | 364.66           | 73.06           | 291.60           |
|                                | Soybeans | 47.4                  | 255.32           | 52.40           | 202.92           |
|                                | Wheat*   | 50.86                 | 299.27           | 82.52           | 216.76           |
| Arlington Research Station:    |          |                       |                  |                 |                  |
| Continuous Corn                | Corn     | 178.1                 | \$338.44         | \$156.24        | \$182.20         |
| Corn-Soybean                   | Corn     | 190.2                 | 361.29           | 140.33          | 220.96           |
|                                | Soybeans | 42.7                  | 215.76           | 117.25          | 98.51            |
| Corn-Soybean-Wheat             | Corn     | 188.40                | 357.96           | 101.43          | 256.53           |
|                                | Soybeans | 44.43                 | 224.35           | 55.49           | 168.86           |
|                                | Wheat*   | 60.95                 | 268.27           | 80.29           | 187.98           |

\* In addition to the harvested grain, wheat included 1.44 ton of straw @ \$62.50 per ton at Arlington. At Lakeland wheat included 1.87 ton of straw @ \$60 per ton and 0.38 ton of red clover hay at \$96.25 per ton.

## Cash Cropping System Returns for 1990-1994

The crop enterprise analysis and cropping system analysis are identical in the case of continuous corn, as the cropping system consists of a single enterprise — corn. The other cropping systems in the WICST contain two or more crops, and they are managed in the same way they would be on a farm. That is, with the corn-soybean system, half the cropland is in corn and half in soybeans each year. One-third of the cropland is in corn, one-third in soybeans, and one-third in wheat each year in the corn-soybean-wheat/red clover system.

Crop enterprise data have now been collected and analyzed for five years. Crop yields and rotation gross margins are summarized for the three cash cropping systems for all five years at both research locations in Table 31. Because of the need to establish each rotation, continuous corn data were available beginning with the first year of the study, corn-soybean cropping system data after the second year, and the corn-soybean-wheat/red clover cropping system data after the third year. To validly compare the gross margins of the three cropping systems, only data from the years in which all crops in each cropping system were grown can be used, i.e. data for 1992 - 1994.

**1992-1994 Results at Lakeland Agricultural Complex** The data for 1992-1994 are averaged in the last column of Table 30. At the Lakeland Agricultural Complex site in Walworth County the average gross margin for the corn and soybean cropping system was \$209.14 per acre, calculated as the mean of \$137.45 in 1992, \$246.50 in 1993, and \$243.47 in 1994. This compares to the 1992-1994 average gross margin for the crops in the corn-soybean-wheat/red clover cropping system of \$151.05. The average gross margin from continuous corn was \$107.75 for the three years.

**1992-1994 Results at Arlington** The system gross margin for the corn-soybean cropping system at the Arlington Research Station (Columbia County) site for 1992-1994 was \$168.25 per acre, calculated as the mean of \$137.81 in 1992, \$207.21 in 1993, and \$159.74 in 1994. This compares to the 1992-1994 gross margins of \$154.73 per acre for the corn-soybean-wheat/red clover cropping system and \$142.99 per acre for continuous corn.

**Variability Among the Years** In addition to providing information for comparing the mean gross margins of the rotations, the long-term nature of the WICST rotation studies also provides insight into the variability in gross margins over time. However, only the 1992-1994 data are appropriate for comparing variability among all three cropping systems (Table 31 and Figure 32).

**"Rescue Treatment" in Corn and Soybeans** A basic concept of the WICST is that it provides flexibility to respond to new information or conditions in a way consistent with how farmers would react, while retaining the integrity of the experiments. An example was the study of the effect of removing annual weeds in corn and soybeans with post-emergence herbicides in the low input, corn-soybean-wheat/red clover cropping system in 1994. The trials were in the buffer rows and did not affect plot yields. Applying herbicides reduced weed pressure and increased corn and soybean yields. Added costs of the treatment were about breakeven with the added returns from increased yields in corn at the Arlington Research Station while added returns were greater than the added costs in the corn at the Lakeland Agricultural Complex and in the soybeans at both locations.

**Table 31. Crop Yields and Cropping System Gross Margins per Acre for Three Cash Cropping Systems at the Lakeland Agricultural Complex and Arlington Research Station, 1990-1994.**

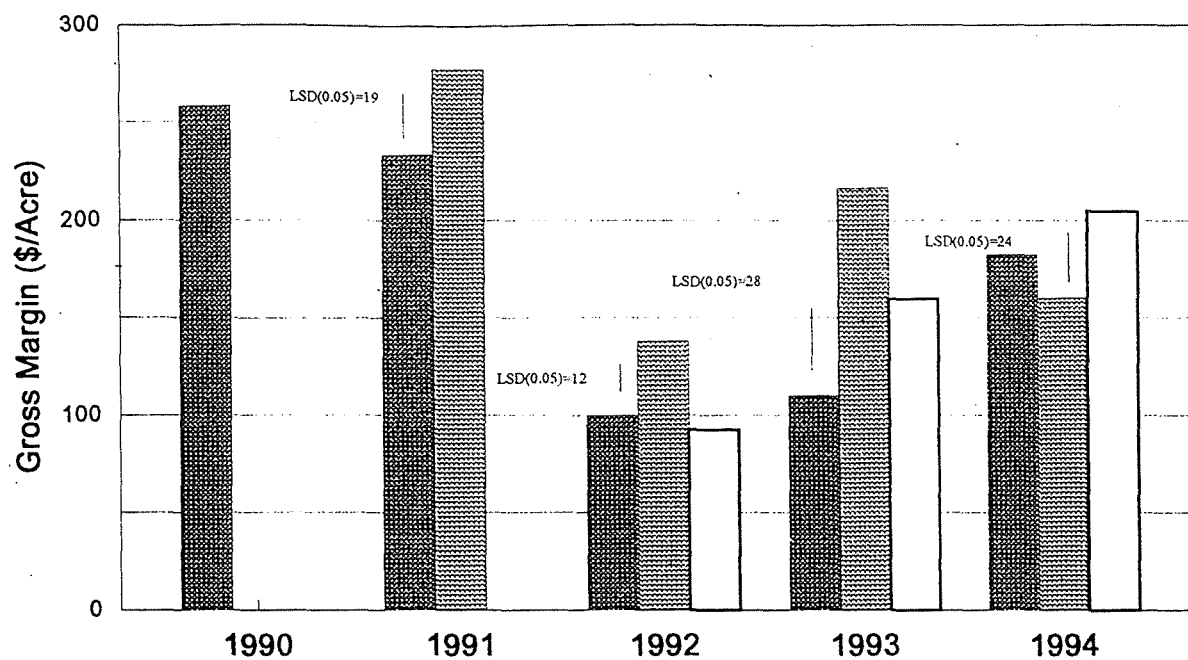
|                                       | 1990     | 1991     | 1992     | 1993     | 1994     | 1992-94* |
|---------------------------------------|----------|----------|----------|----------|----------|----------|
| <b>Lakeland Agricultural Complex:</b> |          |          |          |          |          |          |
| <b>Continuous Corn</b>                |          |          |          |          |          |          |
| Corn Yield                            | 163.6    | 121.2    | 119.1    | 99.7     | 177.04   | 131.94   |
| Mean Gross Margin                     | \$207.43 | \$157.09 | \$62.47  | \$90.80  | \$170.03 | \$107.75 |
| <b>Corn-Soybean</b>                   |          |          |          |          |          |          |
| Corn Yield                            |          | 144.7    | 126.3    | 101.2    | 184.39   | 137.29   |
| Soybean Yield                         | 52.8     | 58.7     | 46.9     | 49.0     | 63.09    | 52.99    |
| Mean Gross Margin                     |          | \$220.47 | \$137.45 | \$246.50 | \$243.47 | \$209.14 |
| <b>Corn-Soybean-Wheat/Red Clover</b>  |          |          |          |          |          |          |
| Corn Yield                            |          |          | 73.0     | 77.7     | 187.01   | 112.57   |
| Soybean Yield                         | 54.3     | 51.6     | 51.9     | 32.3     | 47.4     | 43.86    |
| Wheat Yield                           |          | 32.1     | 25.7     | 22.3     | 50.86    | 32.95    |
| Mean Gross Margin                     |          |          | \$91.74  | \$124.32 | \$237.09 | \$151.05 |
| <b>Arlington Research Station:</b>    |          |          |          |          |          |          |
| <b>Continuous Corn</b>                |          |          |          |          |          |          |
| Corn Yield                            | 165.8    | 160.0    | 144.1    | 123.8    | 178.1    | 148.66   |
| Mean Gross Margin                     | \$270.27 | \$228.20 | \$99.56  | \$147.21 | \$182.2  | \$142.99 |
| <b>Corn-Soybean</b>                   |          |          |          |          |          |          |
| Corn Yield                            |          | 184.7    | 150.4    | 129.8    | 190.2    | 156.80   |
| Soybean Yield                         | 56.7     | 60.4     | 48.5     | 52.8     | 42.7     | 48.00    |
| Mean Gross Margin                     |          | \$267.79 | \$137.81 | \$207.21 | \$159.74 | \$168.25 |
| <b>Corn-Soybean-Wheat/Red Clover</b>  |          |          |          |          |          |          |
| Corn Yield                            |          |          | 99.2     | 87.1     | 188.40   | 124.90   |
| Soybean Yield                         | 52.4     | 59.2     | 38.0     | 53.3     | 44.43    | 45.24    |
| Wheat Yield                           |          | 63.6     | 45.2     | 28.6     | 60.95    | 44.91    |
| Mean Gross Margin                     |          |          | \$92.82  | \$166.94 | \$204.45 | \$154.73 |

\* The purpose of the average is to compare cropping systems for the years in which a full set of crops were grown in all cropping systems, i.e., in 1992 - 1994.

### **Future Directions in Analysis and Education**

The future direction of WICST analyses and issues will continue to be addressed in the advisory sessions held with farm, academic, and environmental groups and gleaned from feedback at field days. In addition to the analyses of the trials, another important objective of WICST is the dissemination of project results in a useful way to a range of audiences, including farmers, environmentalists, policy makers, urban consumers, students, and others. Examples of future work are reported below.

## Arlington



## Lakeland

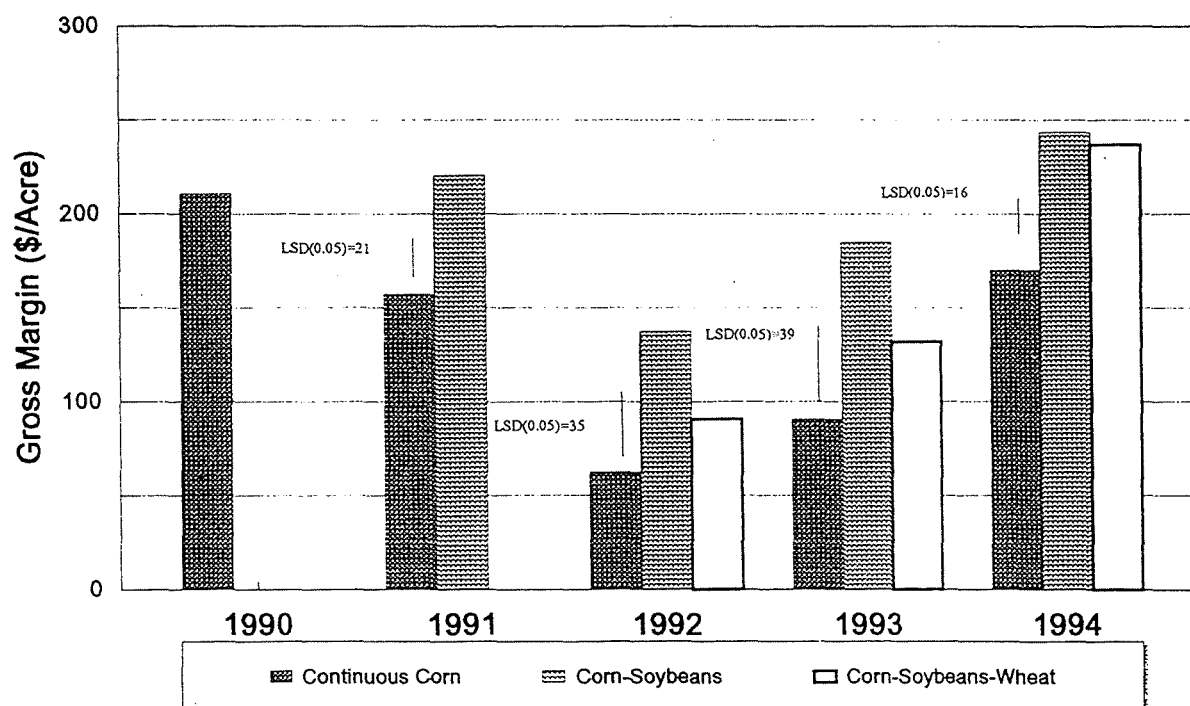


Figure 32. Cropping System Gross Margins by Year, Arlington Research Station and Lakeland Agricultural Complex (gross margins per acre)

**Additional Economic Analyses** Feedback from the farmers, Extension Agents, and others involved in the evaluation have shaped the economic analysis process. Most of the suggestions concerning economic analysis from the evaluation meetings with farmers have been included in the analysis, including using harvest prices to calculate total crop value, using gross margins as the key profit indicator, using commercial interest rates, and examining the rotations from a system's perspective.

Other economic issues remain more elusive and require further discussion. These include pricing the forage crops raised in the ruminant livestock rotations, valuation of cattle manure produced in those rotations, developing a process for determining environmental costs, valuation of unpaid family labor, and the consequences of crop diversification regarding the size and diversity of the farm machinery set.

**Sources of Variation in Gross Margins** With each additional year of data, a more complete economic analysis of the WICST information can be made. For example, wide variation in gross margins between years has already been observed. However, valid comparisons about which cropping systems have the least variability and which have the most variability will require several more years of data. Also, it may require more than one cycle through a rotation for all the "rotation effects" to be observed.

**Differing Environmental Impacts** The WICST include data collection that in the longer run will provide information about the differing environmental impacts across systems in terms of soil erosion and movement of fertilizers and pesticides through the soil. Finally, as the study progresses there will be additional data that will permit increased reliability in addressing the transition from continuous corn to alternative cash crop systems.

**Forage Based Cropping Systems** The WICST project also includes three forage-based cropping systems. System 4 is a four year cropping system with one year of corn followed by three years of alfalfa. System 5 is a three year cropping system of corn, oats/alfalfa, and alfalfa without pesticides or commercial fertilizer. System 6 is a pasture-based, rotational grazing system. The crops grown in Systems 4 and 5 are mechanically harvested for dairy herd feed. System 6, on the other hand, has been grazed by dairy heifers beginning in 1992 at Lakeland and in 1993 at the Arlington site. The gross margins analyses of these three cropping systems will be presented in a future issue of "Managing the Farm", published by the UW-Madison Department of Agricultural Economics.

## VII. REFINING THE SAMPLING PLAN FOR ROUTINE SOIL TESTS

Jon Baldock\*, Emmett Schulte\*\*, Mike Casler\*\*\* and Tom Mulder\*\*\*

Sound management of agricultural production systems requires routine testing for soil organic matter, acidity, P, and K. Unfortunately, representative soil samples are difficult to obtain due to the inherent variability of most soils and the additional variability introduced by farming activities. Early soil tests confirmed that there was a wide range of soil test levels at both WICST sites. The variability in soil test levels can be minimized by developing a statistically sound sampling plan based on addressing five questions:

- 1- Can the soil cores be adequately mixed into composite samples?
- 2- How many composite samples per plot should be taken?
- 3- How many cores should be taken per composite sample?
- 4- What sampling pattern should be used to take the soil cores?
- 5- Are there transformations of the data that stabilize or reduce the variability?

In this Report, we examine these five questions with emphasis on the soil P and K levels because they are usually more variable than either organic matter or acidity.

### Can the soil cores be adequately mixed into composite samples?

Composite samples are usually less variable than individual soil cores, but before adopting a sampling scheme involving compositing it is necessary to ascertain how well soil cores are mixed. That question is moot if entire composite samples will be analyzed. However, the University of Wisconsin Soil Testing Lab, like most laboratories, analyzes a small portion of each sample so we need to address the mixing issue.

Ideally, the composite sample would be so well mixed that there would be no variation between subsamples taken from it. To test how well the mixing procedures at the University of Wisconsin Soil Testing Lab met that condition, we asked them to analyze five subsamples from ten composite soil samples that had already been ground and mixed (those samples were not from the WICST trial, but that should not affect the conclusions). The resulting variance components for laboratory subsamples was 0.78 (ppm<sup>2</sup>) for P and 25 (ppm<sup>2</sup>) for K. Those components were more than 1000 times smaller than the sampling errors obtained in WICST soil tests. Thus, the mixing procedures used at the University of Wisconsin Soil Testing Lab are excellent.

The excellent mixing obtained in the University of Wisconsin Soil Testing Lab suggests that the mixing should be done there, instead of in the field, and that the maximum number of cores/composite sample should be determined by how much soil can be easily fed into the University of Wisconsin Soil Testing Lab's grinder-mixer. (That amount is 5 to 7 standard, 6-inch cores according to John Parsen at the UW Lab).

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\* Interim Project Coordinator and Project Statistician.

\*\* Emeritus Professor, Dept. of Soil Science, Univ. of Wisconsin, Madison.

\*\*\* Professor and Research Specialist, Dept of Agronomy, Univ. of Wisconsin, Madison.

**How many composite samples per plot should be taken and how many cores per composite sample should be taken?**

The usual goal of a sampling plan is to obtain as precise an estimate of the treatment means as possible with as few samples as possible. In soil sampling that usually means as few composite samples as possible to keep the cost of analyses down and as few cores per sample as possible to limit the field work. Thus, these questions are closely related, so we will consider them together.

The precision is maximized by minimizing the variance or standard error of a treatment mean. Snedecor and Cochran (1967) give the formula for the variance of a mean,  $S_x^2$ , in three-stage (nested) sampling as

$$S_x^2 = \frac{S_{core}^2}{csr} + \frac{S_{composite}^2}{sr} + \frac{S_{plot}^2}{r} \quad [1]$$

where the numerators are the respective variance components and there are  $r$  repetitions,  $s$  composite samples per plot, and  $c$  cores per composite. To develop a sampling plan we need to obtain estimates of the variance components (the numerators in Eq. 1) and consider what combination of  $c$ ,  $s$ , and  $r$  produce the lowest variance of a mean for the least cost.

One of Emmett Shulte's students, Josu de Gaubeka (1969), obtained the necessary data to estimate the variance components by imposing a large lattice on three fields in Wisconsin (Arlington, Baxter, and Oxnem), so that the intersection points on the lattice were 75 to 234 feet apart. At each intersection on the large lattice he took nine cores in a  $3 \times 3$  arrangement. This smaller grid was 3 feet square so the cores were spaced 18 inches apart. The variance components that he estimated are given in Table 32.

**Table 32. Variance components for soil test levels at three sites (adapted from de Gaubeka, 1969).**

| Component       | Arlington |      | Baxter |      | Oxnem |     |
|-----------------|-----------|------|--------|------|-------|-----|
|                 | P         | K    | P      | K    | P     | K   |
| exp. error      | 297       | 1645 | 1314   | 1339 | 7.2   | 910 |
| sampling. error | 350       | 4226 | 326    | 307  | 6.9   | 330 |
| mean, ppm       | 52        | 242  | 78     | 102  | 6.7   | 112 |

The Arlington P and K levels and their variances were very high, similar to the WICST plots. In fact the WICST trial at Arlington is in the field that de Gaubeka sampled (Emmett Schulte personal communication). In order to get the variance components we needed for plots, composite samples within plots, and individual cores, we reanalyzed de Gaubeka's Arlington data. To do that we postulated that a plot consisted of two adjacent grids. That resulted in 18 plots, each with two samples of nine cores per sample. (Although the nine cores in each sample were analyzed separately, we refer to it as a composite sample to be consistent with the following discussion.) Table 33 shows the resulting mean squares and variance components.

With those estimates of the variance components and Eq. 1, it is possible to determine the variance of mean for any sampling plan; that is, any combination of repetitions, composites/plot, and cores/composite. Spreadsheet tables and graphs streamline this task. Figure 33 shows the variance of a mean P level as a function of the number of composites/plot and the number of cores/composite. The number of replications has already been set at four, so the effect of  $r$  is not shown. The curves in Figure 33 are typical of inverse functions such as Eq. 1. That is, there is a rapid decrease in the variance of a mean as the number of cores increases, then there is a sharp curve, and finally the variance levels off and approaches a horizontal asymptote (which is given by the last term in Eq 1.). In this case the curvature occurs in the range of three to six composites/plot. Similarly, there is a large drop in the overall level as the number of composites/plot increases from one to three; and there is very little reduction in the variance of a mean after that. Figure 34 shows the analogous graph for K and the interpretation is the same as for Figure 33.

**Table 33. Mean squares and variance components for plots, composite samples, and cores (Arlington data from de Gaubeka, 1969).**

| Source     | df  | P, ppm <sup>2</sup> |            | K, ppm <sup>2</sup> |            |
|------------|-----|---------------------|------------|---------------------|------------|
|            |     | Mean square         | Component* | Mean square         | Component* |
| plots      | 17  | 4254                | 133.2      | 25294               | 679.5      |
| composites | 18  | 1856                | 167.4      | 13063               | 980.7      |
| cores      | 288 | 349.2               | 349.2      | 4236.6              | 4236.6     |

\* Snedecor and Cochran (1967) give the formulas to obtain variance components from ANOVA.

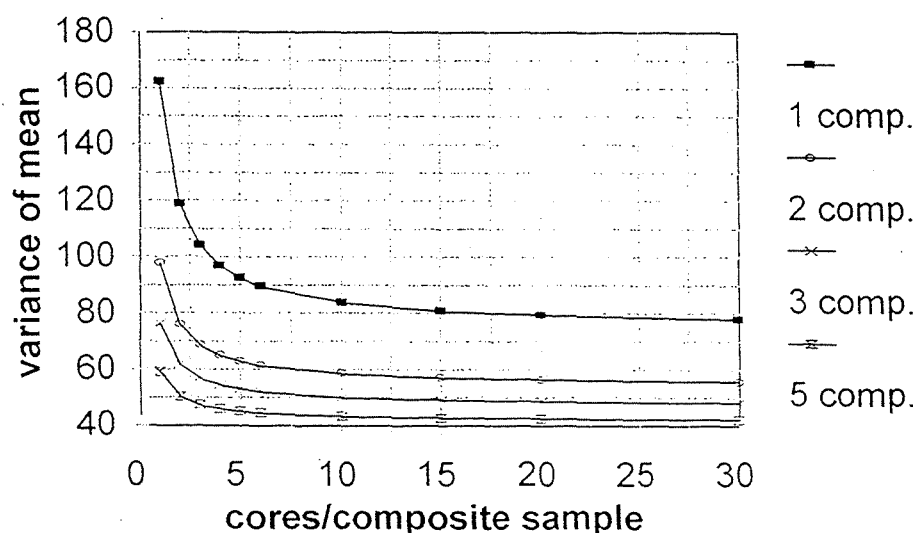


**Figure 33. Variance of Mean - P for Several Sampling Plans**

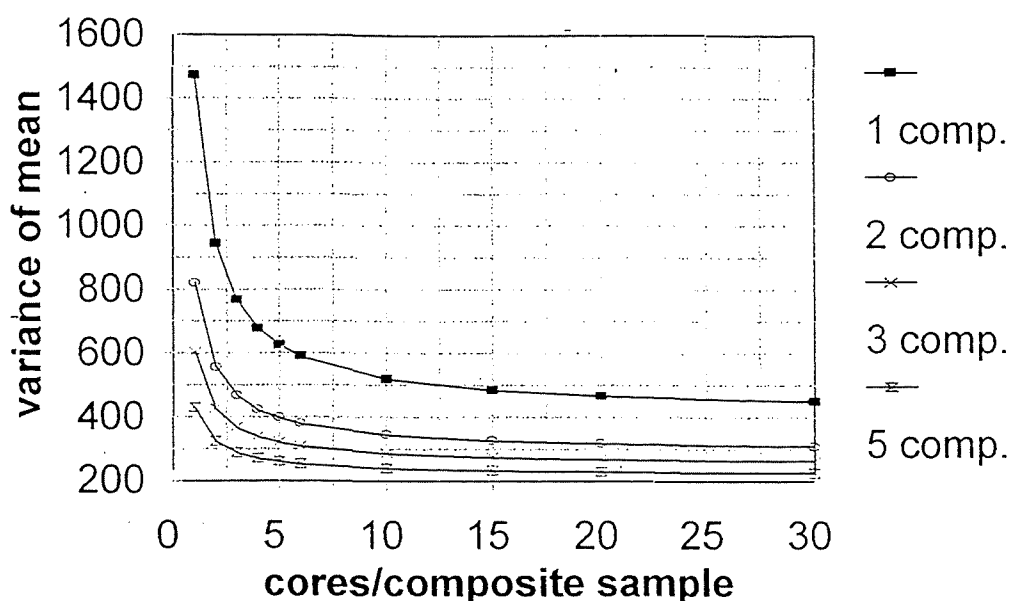


Figure 34. Variance of Mean - K for Several Sampling Plans

From these graphs, we suggest that one good sampling plan would be to take 3 composite samples/plot, each of which contains six cores (Figure 33). One might argue that four or five composites would be better, but from Figures 33 and 34 it is clear that taking more than that would have a very small effect on the variance of a mean. It also appears to us that six cores per composite will be sufficient. Again one might argue that one to five more would be good insurance. However, six fits nicely with the size samples that the University of Wisconsin Soil Testing Lab can mix and grind (see page 93) and with the best sampling pattern (see next page).

Establishing a sampling plan graphically as in the previous paragraph may seem a little too approximate. That is, some may claim that setting sampling plans by the formulas given in many statistics texts would be more exact. We argue that the graphical method is better for three reasons. First, most of the apparent increase in accuracy for using an equation is illusory because there is no guarantee that the variance components of subsequent samplings will be the same as those used to design the sampling plan. Second, the formula method often results in very inefficient sampling plans. That results from the asymptotic nature of Eq. 1. Thus, simply using an optimum sample size formula will often force the result to be on the flat part of the curve where large increases in sample sizes are needed to reduce the variance of a mean. For example, for three composite samples/plot, increasing the cores per sample from six to thirty only decreases the standard error of the mean by 4% for P and by 15% for K; but it requires at least three times as much labor. To help avoid inefficient plans some formulas include the costs of each sampling stage (Snedecor and Cochran, 1967), but those formulas do not solve the problem as well as at the graphs. Finally, if a more quantitative estimate of the variance of a mean for a sampling scheme is needed, then the spreadsheet used to generate the graphs can easily provide it.

### What sampling pattern should be used to take the soil cores?

Once the questions of how many composite samples to take and how many cores to put in each composite have been answered, it is important to consider whether random or systematic sampling should be used. Banding fertilizer (e.g., starter) is an obvious non-random pattern, such that there would be strips of high nutrient levels separated by strips of much lower fertility running across the field or plot. Consequently, a sampling plan that addresses this systematic variation should be more effective than a totally random sampling pattern.

One way to deal with the fertilizer band problem is to avoid sampling from bands. There are two problems with that approach: 1) the location of bands from the previous years are not known, and 2) avoiding the bands can easily underestimate the fertility of the field and lead to overfertilization. Another method would be to design a stratified random sampling procedure, in which the fertilizer bands and the nonfertilizer bands would be sampled in proportion to the area of the field that they occupied. Kitchen et al. (1990) determined that for bands in known locations 30 inches apart, the appropriate ratio for cores in the band to cores outside the band was 1:20. Unfortunately, we can't use that scheme directly because we are not certain which side of the row the starter band is on, nor do we know where the bands from the previous years are located. Kitchen et al. (1990) suggested combining random and systematic sampling plans for such situations. However, they arrived at that conclusion based on a mathematical model that did not consider the possible combinations of previous years bands. Also, they did not consider a sampling plan that takes many cores across the row, which would be the most reasonable way to estimate the true mean for that point in the field. (The logical extension of that is to sample a slot across the row. In fact, Emmett Schulte says someone has a patent on a modified chain saw to do that.) Another method to avoid the systematic variation problem is to take more composite samples, or more cores per composite, or both. However, that plan would substantially increase the cost and labor.

The cores that de Gaubeka took on a 3 x 3 grid were not as close together as we would like, but they do furnish some information on the effect banding has on the sampling variability. When we calculated the average of all nine points in the 3 x 3 grids, the high-low strip arrangement was apparent, especially for K (Figure 35). That pattern was fairly consistent because when we ran the ANOVA for compositing the cores in groups of 3 horizontally versus vertically there was a large difference in the variance components. For P the variance component for one axis of the grid was 76.3 versus 4.61 for the other axis, and for K the variances components were 1101 versus 156.1. That is strong evidence that the variation in soil test P and K was in bands running parallel to the first axis and that the variance of a mean could be substantially reduced if that pattern was addressed.

The effect compositing and of taking cores along the bands or across the bands can be demonstrated using Eq. 1. Using our recommendation of taking 18 cores per plot, but all composited into one sample as the starting point, we estimate the standard error of the mean would be 40.5 for P and 140 for K. If we took 3 composite samples of 6 cores each along the bands, the standard errors would be reduced by 46% for both P and K; which illustrates the advantages of appropriate compositing. However, if we took the composites across the bands, then the standard errors would be reduced to 13.4 for P and 39.7 for K, which are 39% and 47% reductions over sampling along the bands.

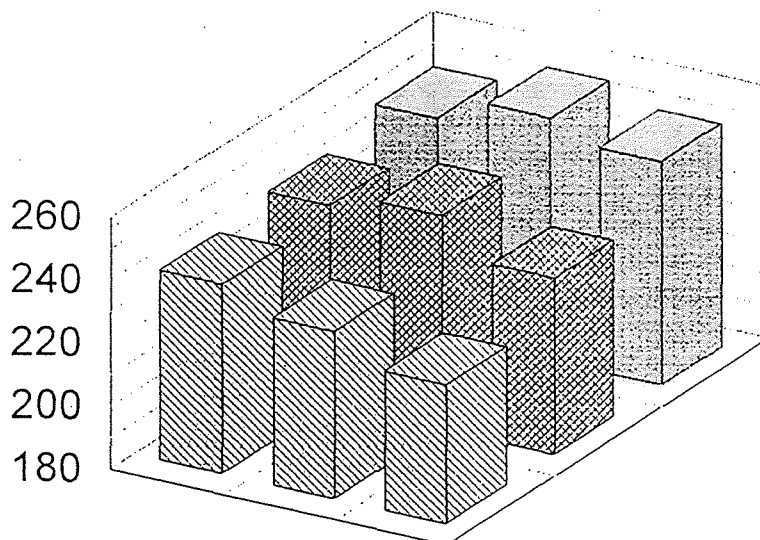


**Figure 35. Average Grid Point K Levels from de Gaubeka (1969).**

Based on this evidence and Kitchen's estimate (Kitchen et al., 1990) that the high P band is quite narrow (it decays exponentially so that the P concentration returns to the background level 2.5 inches either side of the center) an even more effective plan might be to take more cores, or a slice, and only cover half the row width. (Investigating some of those possibilities would be a good masters thesis for someone.) Until we get better information on the pattern of variations on this microscale, we suggest taking cores in groups of three across half the width of the corn rows. When the current crop is a row crop, then one core should be taken in the row, one halfway between the rows, and the third between those two (Figure 36). When the current crop is not a row crop the same pattern should be used, but a ruler or some other measuring device will be needed to maintain the correct pattern.

#### **Will data transformations stabilize or reduce the variance?**

Examining de Gaubeka's data and the WICST data together shows there is positive correlation between sampling error and the mean; which indicates the linear additive model is tenuous. That is, when the sampling error is a function of the mean, then the model is not additive and a log or square root transformation will frequently improve the homogeneity of the variance. The ln transformation also often reduces the overall variability. In fact, applying the ln transformation to de Gaubeka's data for Arlington reduced the CV for P from 36% down to 8% and for K from 27% to 5%. Consequently, doing the statistical analyses of the WICST soil test data on the ln scale could improve the homogeneity of the variances and reduce the variance of the means.

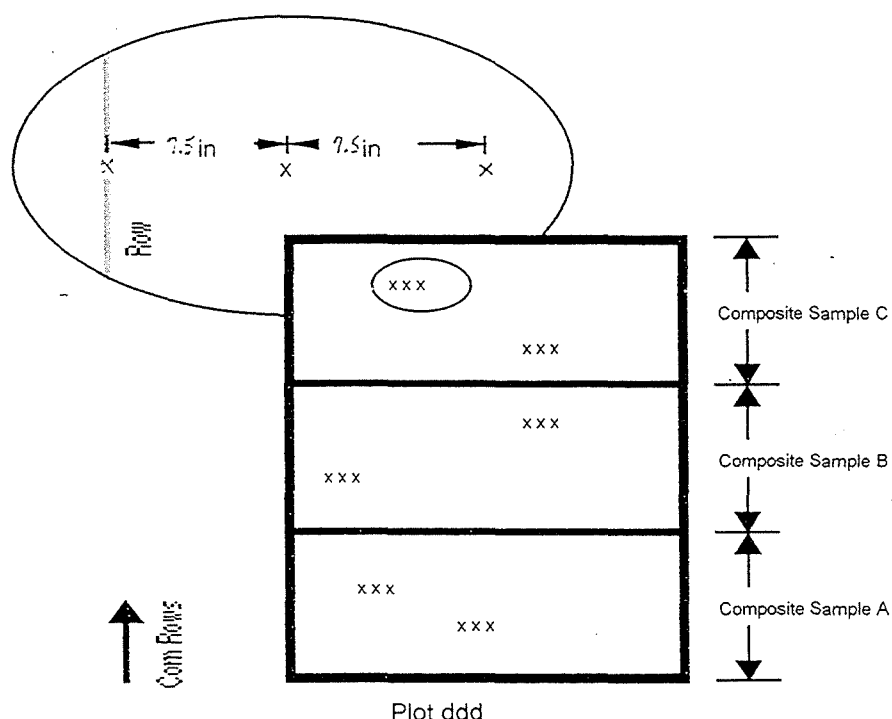


**Figure 36. Proposed Soil Sampling Plan for Routine Soil Tests in WICST**

### Conclusions

We conclude that taking three composite samples per plot in which each composite contains six cores will be near the minimum possible variance and will conserve labor and expenses. We also recommend that the six cores be taken in two groups of three, such that the three cores in a group are taken in the row, 7.5, and 15 inches from the row (or the equivalent in nonrow crops). Based on the preliminary sampling, we expect this sampling scheme to result in variances of the mean that are less than 15% above the minimum possible level. We also expect that if the  $\ln$  transformation is used the homogeneity of the variances will be improved and the CVs will be below 10%.

### Literature Cited

- de Gaubeka, J. 1970. The influence of soil variability and time of sampling on soil test results. M.Sc. Thesis. University of Wisconsin, Madison.
- Kitchen, N.R., J.L. Havlin, and D.G. Westfall. Soil sampling under no-till banded phosphorus. Soil Sci. Soc. Am. J. 54:1661-1665.
- Snedecor and Cochran. 1967. Statistical methods. 6th ed. Iowa State Univ. Press. Ames, IA.

## VIII. EVALUATION STUDIES

### A. Survey of Close Participants

S. Steele \*

This year's evaluation of the WICST project is based on minimally directive interviews with the researchers, extension agents and farmers who are most closely involved with WICST. The interviews were completed in January and February of 1995. They had three purposes:

1. To determine what, if anything, had been gained by those who carried out WICST.
2. To determine how well the collaboration is working.
3. To secure suggestions for next steps.

In addition, the interviews also gave the new project evaluator an opportunity to become acquainted with the roles that various people played in the project.

### What Individuals Gained

Interviews with the thirty-five main participants revealed that learning and gains were individualized and unique to the background of the person. Therefore the list that follows is made up of the perceptions of individuals and is not the consensus of the group. Although some of the participants learned from experiences with specific practices like aerial seeding, rotational grazing, or alternative sources of fertilizer, most of the interviewees talked of other kinds of learning and gains. The learning and gains went beyond the findings of specific research experiments. The responses clustered into the following areas:

- o Farming systems as balance points
- o Multiple interacting systems
- o Observation over time
- o Learning from farmers and farming conditions
- o Learning about multidisciplinary teamwork and from diverse viewpoints
- o Learning about methodology

### Farming Systems Involve Identifying Balancing Points

The main theme of the trials is that of cropping systems. A secondary theme is that of environmental sensitivity. As a result of functioning within these two parameters, balancing point emerged from the interviews as a key concept. Individual learning related to balancing points were as follows.

Farming systems involve complex interactions among specific farming decisions. While individual practices can be seen as a do or not do situation, when those practices are considered within a system, often a balance point has to be found. Where many farmers previously only considered production, today's farmer needs to balance profitability, environmental sensitivity, social sensitivity, and production. Both the quality of the natural resources and the farmer's ownership of the land need to be sustained. The trials are showing evidence that in some instances lower production may be more profitable if costs are lowered. Decisions which appropriately balance the four main elements often involve compromise. For example, low mechanical tillage which protects soil from erosion and

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\* Professor, Department of Continuing and Vocational Education, UW-Madison.

nutrient loss relies upon chemical pest control. High chemical use, however, involves higher off-farm inputs, kills off helpful organisms as well as pests, and may result in chemical problems in ground water. The farmer needs to strike a balance between the mechanical and chemical weed and insect control in achieving profitability and environmental protection. The balance point may differ according to the weather and history of the field. Various kinds of sustainability have to reach a balance so that the environment, family farms, and food for non-farm populations are all sustained.

Achieving that balance point is an art. The point of balance is likely to differ from farm to farm. Rather than attempting to promote one best rotation, those involved in the project are concluding that the best rotation may differ depending upon other factors. Some participants indicate that how profit per acre is figured is particularly sensitive. Some doubt that although the low chemical input trials seem to be showing profit, the overall amount of profit per farm would be great enough to sustain the level of living to which they are accustomed. Some feel that the most important product from the project is the recognition that building a sustainable system is a process. The project is helping to identify some of the criteria that the farmer needs to think of when applying that process. Farmers need to look at ideology and methodology to develop their own systems that fit their own operation.

Both fields and farmers go through a transitioning period in changing from one system to another. Soil build up or depletion seldom shows in one or two years. The weed seed bank is not apparent for two or three years. Some farmers also need time to transition. Farmers used only to thinking in terms of production sometimes are uncomfortable aiming at profitability achieved with lower production. Farmers who take pride in clean fields have to get used to practices which do not look "clean." The project has taught a lot about the practical problems which have to be dealt with to take ideas which look good on paper and put them into actual practice. The role of risk as an element in a farming system needs to be understood.

Farming systems as well as new or old technology are based on assumptions. To understand strengths, weaknesses and the value of a system, one must understand the assumptions and whether they hold true in a given situation. Various systems can work but the farmer has to have the kind of thinking and orientation (mentality) that fits a particular system. Different production systems require different attitudes and values. For some, changes in these areas come slowly. Although farmers and others interested in production are more aware of what happens above the ground and easily recognizable things like diversity in cropping systems, entomologists are helping the team to understand biodiversity in the sense of how diversity in insects and organisms on and within the soil are affected by various systems and how they affect those systems. Team members are learning about natural predators which help control pests that damage farm crops.

### Multiple Interacting Systems

Some commented that the project provided an opportunity for a greater understanding of how systems interact. One very active team member said that he gained from the opportunity to look at the whole picture and not just small parts of the picture. As one of the agribusiness participants said, the project helped to take blinders off and to get a broader view of what was going on in the farming community, including some of the problems farmers face in balancing profitability and environmental sensitivity.

Because the project is community based, farm production systems are the most visible in the discussion. However, different team members entered the project involved in different systems. For example, for the researcher who previously had been primarily interested in labor, money and the cyclical patterns of marketing prices, the project became a place to retool and to add agro-ecological factors and the impact on soil health, erosion, and food quality to his criteria.

He learned a great deal about both ecological and farming systems and most importantly, the ecological implications of farming systems through his work with the project. Researchers who have been deeply involved in ecological systems are learning more about how these systems affect and are affected by agricultural production systems.

A basic researcher mentioned the satisfaction he got from being part of a team that was testing a widely held belief that greater biodiversity (insects and organisms) will result in greater sustainability. WICST has been able to get University people to look at whole systems and how recommendations from a specific discipline may affect and be affected by the total system. Another participant said that he originally viewed it as a research project on six systems but now looks at systems not crops and considers ideology and methodology in developing systems that fit operations. He is more aware that what might work well here might not work well on another farm. A farmer said the trials helped him look at more specific things that happen in a system, for example, how herbicide is handled and whether it is needed; economic aspects of pest problems; benefits of no till. Another farmer pointed out that he had gained from the project's emphasis on income per acre rather than yield per acre. Profit per acre should be the bottom line.

### Observation over Time

Most felt that the project provided a unique learning activity in that the same rotations and components were observed for several years. The longitudinal observations create a greater understanding of the importance of considering the effects of the past history of a field as well as greater understanding of how a soil transitions as tillage practices change. Longitudinal studies of rotations on the same plots also provide an opportunity for determining whether weed colonies will grow stronger under some rotations and tillage practices than with others.

It was pointed out that here, too, balance is needed between sufficient time to watch a system over multiple years and the need to adapt to new regulations and ideas. The world of and around farming changes rapidly and sometimes unexpectedly.

A long-term project may show that we understand environmental sustainability less well than experts think they do. The project is generating more questions than answers, but that may be valuable because the questions start us thinking about what is really going on. Questions may be more valuable learning experiences than the answers.

### Learning from Farmers and Farming Conditions

Another cluster of responses indicated the value of interacting with the farmer members of the team. Several of the campus based partners felt that some of their greatest gains came from learning from the farmer members of the team. They learned what farmers see as systems and respected the artistry needed to keep a system functioning properly. Farmers may have a better sense of system than do those researchers whose primary experience has been with small, highly controlled experiments.

One team member commented that he was impressed with how innovative and adaptive farmers are. Many are willing to work with a system for the two or three years it takes to work the kinks out. We are finding some of those kinks in the cropping trials and working out what might be done. Another pointed out that farmers who are sustained and move into the next century will have to be thinkers, willing to change, not just follow the crowd. They will have to be adaptable and think for themselves. They will have to be more observant and better individual decision-makers rather than simply accepting blanket recommendations of what seems good for most farms.

On the other hand, one of the farmer participants said he gained a lot from the experience of hashing things through as an accepted equal with his Extension agent and college specialists. In addition, several of the graduate students and researchers indicated that examining rotations and components in conditions closer to actual farm conditions gave them a greater understanding that farmers usually did not make a decision about a particular component in isolation but considered how it fit into a total system.

A basic researcher said that he learned a lot from gaining experience in living through the frustration of something not going as expected. He found that some good ideas were not as easy to put into practice as he had expected. He feels he is less naive in what he tells farmers now. He is more aware of the skills that farmers need that go well beyond book knowledge. Another basic researcher said that he is less critical when farmers do not do things that are known to control pests. For example, it is well proven that rotating between corn and soybeans will destroy corn root worm. More insecticide is used against this pest than any other. He has come to understand why dairy farmers need to use alfalfa rather than soybeans in most of their rotations.

It was clear both from the interviews and from observing the spring 1995 steering committee meetings that farmer steering committee members are interested in influencing the general public fully as much or more than taking the information to other farmers. Two farmers felt that the Learning Centers had an important role to play in showing the non-farm public that farmers are interested in sustaining the natural environment. However, it is also important to help the general public understand that the farmer has to balance making a living and protecting the environment. Speaking directly to that point, another farmer who is a school board member, said that many teachers today grew up only in the chemical era and view farm use of chemicals as bad. He was concerned that students and teachers gain a more balanced understanding.

#### Learning about Multidisciplinary Teamwork and from Diverse Viewpoints

Some said that their greatest gain came through learning in a multi-disciplinary setting and how to be a team member in such a setting. A farmer said that one of the gains he valued most was seeing different perspectives and not just one way of doing things. He feels the project has helped him to a more global view and a different attitude. He felt this project also helped the university have and be viewed as having more than one perspective.

An Extension agent said that he had not only gained reinforcement in terms of understanding farming systems and sustainability but that he had had a very positive change related to working in a multi-discipline team. "There is no substitute for regular interaction between 'opposing' parties when policy is decided. Having a mix of people involved has allowed me to better understand where the 'sustainable or non-traditional' folk are coming from. Our society needs to do this when discussing ag policy." The learning from both conventional

and organic supporters was important also to the farm managers. A team member who was more involved in policy recently said he learned a lot about how to do on-farm research and became better at evaluating activities and interpreting data.

One participant said that the greatest benefit he saw was the forum it provided to address issues in agricultural production that affect more than just one sector. An agent commented that he was somewhat flattered that researchers wanted agents directly involved. He felt that agents could help keep the project practical. He had been critical of specialization and researchers only talking to their own field.

He was pleased to see how well the consortium in the project worked. Another said he had gained a great deal from looking at several perspectives, particularly exploring the similarities and differences between beliefs about non-organic and conventional farming.

A long-time researcher, whose area might interface with most other departments, said that his greatest gain was getting better acquainted with knowledgeable people from several disciplines and now feeling more comfortable in discussing questions and issues with them.

#### Learning about Methodology

Some commented on what they had learned about methodology. The project has had to devise new ways of measuring ecological impact and adjust ways of examining economic results. Multidisciplinary research on the same plots, especially when part of a working farm or when replicating actual farm situations, requires an excellent coordinator to see that field activities are done when they should be but without disrupting specific observations - for example, not destroying insect traps. When working with larger plots, the sampling method has to change.

An Extension agent became much more appreciative of the business side of research and that dollars are hard to secure. He learned more about what specialists have to do in maintaining and being able to do practical research. He hadn't been aware of how difficult it is to get funds to test new ideas. One person who was not an Extension agent but had a responsibility for the visitor center role of the Research Station, said that one of the greatest gains that he had secured from the project was more understanding and a different orientation toward outreach, especially outreach to non-farm audiences.

Others whose research did not involve direct farm application valued learning more about how their work might relate to and help agricultural production. There is value in observing the same things at two different sights. Arlington has premier prairie soil. Lakeland has prairie soil, but it is heavier textured. Lakeland is farther south than Arlington. However, one farmer pointed out that both are better soils than many farmers have, and there is some question as to how well the findings apply.

#### **Diversity is Typical of the Project**

The list of learning is not a consensus list, but a list contributed to by different individuals. That very fact is representative of the way in which the project brought people with diverse backgrounds together including diverse backgrounds in conventional and alternative farming systems as well as differences in discipline backgrounds and positions. It is not surprising that participants received different gains from the project.

Most of the interviewees responded in terms of their own gains. One, long established in the sustainability area who had not known many of the other participants prior to the project, commented on how much he had seen several of the participants change in their understanding and broaden their thinking.

### **Example of a Knowledge Creation Team**

Whether the WICST collaborators realize it or not, they epitomize a knowledge creation team. Intellectual teamwork and knowledge creation is currently getting a good deal of attention in business as businesses strive for ways to maintain a competitive edge. The scholarly study of knowledge creation teams has been summarized as follows:

Knowledge creation teams generate new knowledge by accessing past experience and learning both within the team and outside it, transforming and translating it with the team's strategic goals, and transferring it throughout the organization via a network of communications. This information and communication intensive teamwork or "intellectual teamwork," embraces an information processing paradigm utilizing highly refined communication and information technologies (Galegher, 1990; Nonaka, 1991b). . . . (Tom Olscheske, Introduction to Dissertation Proposal, 1993)

In the case of WICST, the teams are both accessing past experience and learning from their current team efforts. They are transforming and translating that information and then transferring it not through one organization but through several.

Nonaka, who examined knowledge creation and transfer by new product development teams within Japanese companies, describes knowledge creation by these new product teams as an "information creation process."

It is a process in which new knowledge is created via transforming learning processes between team members as they draw on internal and external sources of expertise, that is to say, on the organization's knowledge base. New knowledge is generated during the transformation process of knowledge. This transformation process inter-converts knowledge between explicit forms, knowledge that can be articulated and structured, and tacit forms, knowledge that is experiential and internalized by individuals. This generative process is synergistic with the creation and transfer of new knowledge (a firm's intellectual assets) within the team and throughout the organization (Olscheski, 1993).

Some team members may be more aware of and accepting of the fact that the information which is coming from WICST is "created" by them. There may be a tendency for some physical science researchers and those who associate with such researchers to think that the knowledge comes directly from the physical elements studied and that all the researcher does is to report that information. In some cases, that may be true. But when the physical interplays with the social, as it does in the case of WICST, the knowledge creation team cannot stop just with what the physical elements of soil, plants, and yields say, but must, as an interdisciplinary team, decipher those findings and convert them into meaningful implications usable in the current context of Wisconsin Agriculture.

The WICST collaborative activities also relate closely to the following description of what is likely to occur in team learning.

Team learning is dependent on the cultural (values and beliefs) and conceptual frameworks (mental models) of both the individual and the team to develop effective knowledge creation. Therefore, both individual and team learning processes are involved in knowledge development (Olscheski, 1993).

The interviews and observation of the county steering committees indicate that diverse cultural and conceptual frameworks were brought into play during the five years of working together. Some of the diversity in frameworks which had to be accommodated were listed by the director as:

- o "Granola heads" and "nozzleheads" (holistic ideas or small researchable details).
- o Farmers/superintendents and researchers.
- o Basic researchers, applied researchers, educators, producers.
- o Members of the agricultural community with different production philosophies (profit, production, organic).
- o Researchers with different commitments to community involvement in research.
- o Different discipline backgrounds.

When one thinks about the differences in conceptual frameworks which sat around the table a few times, it is amazing the amount that got done. However, in relation to the last part of the sentence in the quotation, this story tells the story of what individuals have gained from the group. It is not clear at this point, what the group would agree upon as new learning projected by the majority of the group as a group.

There is considerable evidence in the way that people responded to the interview questions about personal gain that they were, in effect, doing what Nonaka describes as creation, which goes beyond the purpose of the cropping system trials.

Nonaka contends that when team members create and invent new knowledge, they are also reinventing themselves, the company, and even the world. They create and transform their cultural traditions. The organization learns as the individual learns -- as individual team members are assimilated by the group culture. The team as an organism learns by assimilating individual learning, consolidating its cultural orientation, and transforming its world view. (Olscheski, 1993).

### **How Well the Collaborative Is Working**

In regard to the second purpose of the interviews, most of the participants were comfortable with the kind and amount of communication that was occurring. However, a preliminary analysis done for the cluster evaluation indicates that the project has been functioning through multi-discipline cooperation rather interdisciplinary collaboration. There has been only limited periods of in depth sharing and discussion.

### **Next Steps**

Good individual suggestions were appearing from the interviews, but no groundswell of consensus on any one problem or direction that needed attention. However, suggestions about next steps did cluster. The points under a particular label are seldom the same, but several people made a point related to a particular area. The number who wanted more involvement of farmers and more studying of cropping systems on farms with varied soil conditions was about the same as the number making a specific suggestion about the trials or about outreach. The clusters that emerged and the number of comments related to each topic were as follows.

Overall: vision and goals, 8; internal working relationships, 8;  
 Collaboration: on-farm studies, 11; special populations, 6; get others involved, 5; CALS involvement, 3;  
 Current Operations: changes in trials, 12; emphasize economics, 2; internal communications, 5; outreach, 11;  
 Other: 9.

### Vision and Goals

There was a sense from some of the participants that they no longer had a clear feeling of the mission of the project. This concern was expressed in a variety of ways: "We are beginning to figure out what we are talking about. We may not have spent enough time talking about what we want out of the project, given the many different perspectives included in the group." "Frustration - defining better goals and when we talk about change what do we mean by it. Some concern that the pressure is too much for low input. Going in lots of directions in outreach but how does outreach tie back to the project. No plan for what should be the outcome of outreach." "Need something to outline what we are doing, hold on to and refer to." "Beginning now to have something to say. Get some kind of commitment that will focus."

"Need to decide what we should and should not talk about out of the project." "We are in transition. Questions posed in research format. Interpreting those? Larger goals and objectives, Taking data and looking again at original questions and getting interpretations." "Need renewed interest and focus. Interest in the project was high at the start, but is fading now."

### Internal Working Relationships

Some commented that the project has not provided sufficient time for interaction. "As a group WICST has not had the degree of blending that we should have. We tend to report rather than discuss." "More face-to-face interaction would help everyone have a better idea of what is going on." "There is little interaction and I have felt some frustration. It is broken down into a multi-disciplinary approach. People feel frustrated if they can't do their own piece of the research their way because it affects others. Core people are more open minded. CALS researchers are not used to interdisciplinary. "More regular meetings not just in the winter but during the growing season to answer current problems or concerns. Each year is different and changes happen fast, needing quick discussions, that could speed up planting and harvesting."

On the other hand, a few felt that they were not getting sufficient value from the meetings they did attend. "Reducing the number of meetings would be helpful to me. Narrowing the agendas to the most critical topics would allow more time for discussion when we do meet face to face. Our meetings have been productive, but time investment is excessive for the payback. Some decisions have been made via mail. Perhaps that needs to be utilized for less important decisions. My main bother has been the poor payback for the time invested. I realize it is a very long-term project, but I need to have something concrete to take to my clientele. My solution to this is to limit my time investment until the project has generated some programmable results."

### On-farm Studies

The need for more farm activity was expressed in a variety of ways. "On farm validation may be a key future function. Cover crop satellite study on five farms is a good example. Monitor whole farms around sites for context. Valuable to see on different farms." "The trials have a problem of keeping up with changes as fast as they are happening. Goals needed to be adjusted after the first and second years. For example, went from reduced tillage to no till." "Next step, involve farmers in major changes in their operations. Help them put changes into their farming. Changes built not just around practices but a holistic

approach to farming." "Increase the number of farmers and the amount of time that researchers spend with farmers. However, all torn in many directions and hard to give time." "We need to tie in agricultural professional education including farms within 20 miles which are using parts of the system."

Some pointed to a limitation of the conditions presented at the two centers. "Limitations of the sites - flat, good soil, prior history of care of fields. Need to show in more locales. Need to go out to more farmers and show things on the farm. Need to advance to real farm situations." "Trials are on the best farmland, but farmers in surrounding areas have much more variable land with more sand, rock, clay, etc. so some of the information from the trials is difficult for farmers to accept and work with." "Weather is an important factor. Need to see effect on farms as well as plots."

Others spoke of the importance of better understanding farmers. "It is important to spend more time sounding out farmers and bringing their ideas back to the team. What are they thinking about? What would they like to see done? Find out where the cutting edge is and where research is needed to back it up." "Try to better understand and deal with objections of some farmers to some systems. For example, some do not like combining soybeans. Are used to rotating corn and alfalfa." "We don't use resources to deal with questions that are on farmer's minds. We don't seem to work up interest in them. We need to venture into social questions as well as the practical."

### Special Populations

Three spoke to the involvement of more agribusiness personnel. "Agribusiness people need to be helped to look at farmer's views of systems. If farmers are going to change, the agribusiness people who support them are going to have to change the way they do business. For some this may mean a shift from sales to service." "Agribusinesses are smart enough to recognize there are some tremendous questions as they face social acceptability. Resistance from agribusiness may be due to communication and misunderstanding. Concern that they will be put out of business. Need to somehow get the point across so that they can see viability in reduced input. Profitability for their clients and help them share in that profit. Nothing is more convincing than to get out there and see the rotation which is not using herbicide and nitrogen."

Others suggested the importance of using the trials to reach beyond the agricultural community. "Help society make decisions on facts, not just on emotions. Understand farmers position of having to balance profitability, environmental protection, and socially acceptable activities. Nature of what sustainable agriculture involves." "We need to work with legislature and policy makers and consider how current laws and policies may provide barriers to some sustainable practices. Example, effect of corn base." "It is important to get information to politicians, high school educators, etc."

### Get Others Involved

Several suggested that more people needed to be involved. However, the suggestions were diverse. "Get nutrient pest management people more involved; "UW-Veterinarian may have strong influence at Arlington but apparently is not part of the project." "The committee needs to change and include rotational grazer; Need more agribusiness involvement." "I would like to see more players brought into the decision making process. Look to the very same people who are driving policy today: Environmental decade, Farm Bureau, NFU, etc. We are top heavy with the politically impotent." "Why aren't more people involved? For

example, why isn't Ag Engineering involved? "Need to bring new blood in. More weed science and Extension crop agronomists need to be brought in. "Frustration with the lack of buy-in of the concept by some of the perceived specialists. Open up to be more broad minded. If chemicals had not come along we would have had mechanical down to a science." "Need to get buy-in from CALS. Trials need to continue." "We've put a lot into providing resources, funding, other opportunities for grad students and researchers but it has not worked out very well. We need a new strategy."

### Changes in Trials

Although suggestions were made about the rotations, there was little clustering. Two spoke about the grazing system that was used. "Do a better job with rotational grazing." "Revisit the grazing arrangement. Use a system other than real animals on the grazing plot. Two animals isn't enough, but space not large enough for more. Does not permit herd flexibility. Not credible with grazers. Takes too much staff time for value of having two animals on the plot."

A few spoke specifically to one or more of the trials. "Too big a gap between medium to high to virtually no input systems. Need to consider intermediate level with starter or supplemental nitrogen when no livestock."

"Rotation 3 needs to be kept organic." "Don't split rotation number 3. Video documentary of one or both plots in one or both sites. Draw attention and get people interested in coming out. Both are photogenic at different times of year. "Change wide row soybeans to spraying rather than mechanical."

"I would like to see changes made that are needed to make each system the best it can be. We started in 1994 with some ideas. Now hopefully we can take what we have learned and improve as we go without abandoning our original goals."

Two were opposed to changes in the basic trials. "It is important that project continue as planned as much as possible. The fruitful years of data are just starting. Maintain integrity of 6 cropping systems. Management philosophies - could change rotation but keep management principles. Do not make major changes." "I believe that the project should not deviate too far from the present plans, such as dividing plots in half, etc. It is a long term pros and cons on the project plots that we are trying to get the evaluations intact. Any deviations suggested should be used in the form of a satellite plot in another area of the farm if the concern is great enough."

Other suggestions seemed to encourage more satellite research. "Continue cover crop work and show how it fits into a system. Within each system look at strengths and weaknesses. Make each component stronger. Economics of small grain yields." "Diversify into other crops. Try rye, try cereal grains. Corn hard on the soil. Lot of genetic things coming down the pike. Farm land has to produce because of tax burden on the land." "Another concern is that due to the long-term nature of the project, it is unable to respond quickly to changes in the ag environment. Markets, prices, labor supplies, technology, etc. continue to change while the base project remains unchanged. I don't know what to do about this."

Two spoke of economic analysis. "Try to give an economic context which will make it easier for farmers to live with their conservation plans and see benefit. Can't just sell it as better for the land." "Hone in on a few key systems and look at labor and profitability. Look at conservation plan."

### Internal Communications

Only a few commented on internal communications. "More frequent updating of whole group on what is going on. What are the farm managers encountering. For example learned late about replanting because of herbicide damage." "Communication between Lakeland and Madison might be improved - seem hesitant to call for advice or to let Madison people know about changes. Record keeping a bit of a problem." "Frustrations are being worked out so that judgment calls are smoother." "Frustrations. Waiting for something else to get done before we could harvest, spread manure, etc."

### Outreach

There was interest in how to make results more usable to the public. "Need concerted effort in planning educational outreach." "More reaping of what we have found out to date." "The flow of information has been slow. There is a benefit of getting this project on video. More people could learn of the compromises that farmers are faced with as they try to stay/become "sustainable"." "Information and education/dissemination. Talk more about alternatives and decision making. Start building a data base of questions and answers based upon the research." "Biggest task is getting information out to the public. Not necessarily just the farmers, but the urban population. Show them that we are farming in an environmentally responsible manner. Chemicals are an economic necessity in farming but they are used responsibly."

"Get WICST information into existing newsletters; vehicles beyond Ag agents."

"Disappointed that there has not been more in print than annual report. Not bring out much of the experience." "We shouldn't pile up stacks of publications. Consider video." "Use WICST as a spring board for making sustainability a greater part of Extension efforts."

"Difficult to take whole project and use it in county programs, but can take parts like crop budgets." "Think of ways of getting small groups going. What do they see as barriers to looking at systems for what they are. Looking at processes not specific practices. Looking at balance. What are the draw backs that are keeping people from seeing overall evaluation?"

### Other

Among the other comments, the following seem most important. "Research doesn't interest corn growers. Most of it is obsolete. Most systems do not generate enough dollars to survive." "WICST project has changed dramatically, but farmers understanding of and approaches to environmental protection also have changed in the five years." "Must be able to accommodate changes - changes in the team, changes in team members' life situations. Such changes are much more visible and need more attention in long-term than in short term projects."

### **In Conclusion**

It is difficult to keep a large project team moving together productively for five years. Changes occur both with and around the team. It was apparent from the interviews that although some were very aware of these changes that most were very comfortable with what the project was accomplishing and enthusiastic about continuing and broadening the project.

## **B. Evaluation of the Cover Crop System by the Participating Farmers: Interviews**

Ellen Mallory\*

### **Introduction**

The diffusion-adoption model is widely accepted as a theory of how farmers become aware of and begin using new technologies (Rogers, 1983). The model consists of five sequential stages: awareness, information, evaluation, trial and adoption. Stages can be skipped and rejection of the technology can occur at any point. While this framework may accurately describe the adoption-diffusion process from the farmer's perspective, it does not recognize that the process also involves and educates researchers (Wake et al., 1988). Farmers learn about a new technology and how they may or not be able to adapt it to their system. Researchers learn how the technology performs under various, real farm conditions, as well as, how it is perceived by farmers. Much can be learned by both parties during the adoption-diffusion process.

Unfortunately, under the longstanding Agriculture Extension model (Rogers, 1983) there are one or two layers of extension and/or agribusiness personnel between researchers and farmers in the typical adoption-diffusion process. Farmers learn about new technologies from county extension agents and local agribusiness dealers, who, in turn, receive information from state extension specialists and researchers. A major disadvantage to this centralized, top-down approach to research and diffusion is the limited contact between researchers and farmers.

On-farm research facilitates the interaction between farmers and researchers and, thereby, accelerates the adoption process (Byerlee et al., 1982; Ehrenfeld, 1987). First, research conducted on working farms tends to be more relevant, more visible and more credible to the participating farmers and their neighbors (Anderson, 1992). Second, participating farmers begin the necessary process of adapting the generalized technology to their particular situations. And last, by listening to the participating farmers, researchers learn about farmers' constraints and their decision-making process, knowledge which the researchers apply to future research and extension efforts.

Of course, the adoption of technologies does not depend solely on the manner in which they are developed. Rogers (1983) outlines five characteristics of technologies themselves that influence their chances of being accepted and used by farmers. First, relative advantage is the degree to which farmers perceive an innovation to be better than their current practice. This includes the economic benefits of the practice. Second, compatibility refers to how consistent a new technology is with the current practices, needs and values of farmers. Third, complexity expresses the degree to which farmers perceive a practice to be difficult to understand and use. Fourth, trialability refers to how easy it is for farmers to experiment with the innovation. And fifth, observability is the degree to which farmers can see the outcome of a technology. Based on these characteristics, some technologies are more likely to be adopted than others.

There are also many reasons why farmers do not adopt a particular technology. Nowak (1992) has divided these reasons into two general categories, distinguishing between farmers who are unable and those who are unwilling to adopt. Reasons why a farmer is unable to adopt are: information is lacking or scarce, costs of obtaining information are too high, practice is too complex, implementation costs are too high, labor requirements are considered

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\* Research technician, Univ. of Maine, formerly graduate student, UW Agronomy Dept.

excessive, planning horizon is too short to incorporate long-term benefits, availability and accessibility of supporting resources is limited, managerial skills are inadequate, and the farmer has little or no control over the adoption decision.

Farmers may also be unwilling to adopt for the following reasons: information is inconsistent, information is irrelevant, new technology conflicts with current production goals, farmer is unaware of the technology or its promoters, practice is inappropriate for the physical setting, practice increases risk of negative outcomes, and farmer believes in traditional practice. In order to increase the adoption of a practice, it is essential to understand the reasons why farmers are unable or unwilling to adopt.

The purpose of interviewing the farmers participating in the cover crop trial was to formalize the listening aspect of our on-farm work. An understanding of why they will or will not adopt cover crops can help focus future cover crop research and extension efforts.

The objectives of the interviews with the farmers were to:

- a) determine if the cooperating farmers will or will not use cover crops after the completion of the trial;
- b) identify the factors that the farmers perceive to be the incentives and disincentives to cover crop adoption, and which of these are most important in their adoption decision;
- c) provide a directive for future cover crop work.

### **Interview Methods**

Five farmers and one Future Farmers of America leader were interviewed at their homes between March 21 and March 30, 1994. (For the sake of simplicity, they will all be referred to as "farmers".) All of the farmers have been involved in the cover crop trial since March 1992, except Tom Manke who joined in the spring of 1993. The trial consists of a two-year short season crop/cover crop - corn rotation, initiated at each farm in 1992, and again in 1993 on separate fields. By the time of the interview each farmer, except Tom M., had observed one and one half rotations: two seasons of cover crop (1992 and 1993), and one season of corn (1993). One week before the interviews, the farmers received 1992 and 1993 results of the cover crop and corn yields from their plots.

The interviews were informal. They lasted, on average, one hour and were taped. A series of open-ended questions were used to initiate discussion of certain topics and were followed by more detailed questions when specific information was desired.

### **Characteristics of the Participating Farmers**

The farmers participating in the cover crop trial are not necessarily representative of cash grain farmers in Wisconsin. Their ages range from 32 to 48 years. While all have completed high school or one year of college, others have finished college, a master's, or Ph.D. program. They farm from 150 to 1800 acres, and all but the FFA leader are enrolled in the federal feedgrain programs. All of the farmers regularly reduce fertilizer rates when following a legume crop; most of them credit 40 lbs N/acre for soybeans, which is consistent with current university recommendations.

## Summaries of Individual Interviews

### BRAD FRANZ

Brad Franz farms with his father on 1,800 acres, half of which are rented and most of which are on sandy soils. Corn, soybeans and winter wheat are his main crops, and he is in the corn and wheat feed-grain programs. Brad is planting more and more of his acres using no-till methods. As a result, he usually meets or exceeds the soil conservation plan for his farm. Brad also raises 60 Holstein steers, but they do not produce enough manure to meet his crop's nitrogen needs. He relies mostly on N fertilizer.

Brad typically follows his wheat crops with no-till corn, fertilized at 145 lb N/acre. If the wheat yield is good, Brad says the wheat residue meets his ground cover needs. However, wheat yields tend to be lower on his sandy soils. Low soil moisture is also a concern on these soils. As alternatives to fall following after winter wheat, Brad wanted to look at cover crops primarily for their ability to control erosion and produce nitrogen. Additionally, Brad believes that a cover crop, killed in the fall or early spring, will conserve soil moisture by: a) providing a mulch to protect against drying spring winds and b) enhancing the water holding capacity of the soil, over the long-term, through the addition of organic matter.

Brad is experimenting on his own with the cover crops, in addition to managing the cover crop trial. During the first year of the trial, Brad compared two methods of frost seeding red clover. He found that broadcasting clover, a cheaper and faster method, was as effective as running a grain drill over the frozen ground. Last year, Brad planted hairy vetch, oats, and vetch plus oats after wheat harvest to look at their performance on a larger scale (about two acres each). He is also comparing fall versus spring killing of the vetch.

Hairy vetch is the cover crop that most interests Brad. He likes the fact that it can be established after wheat harvest, will grow rapidly and provide ground cover, and will fix nitrogen. Vetch's biggest drawback is its high seed cost, which has motivated Brad to start thinking about producing the seed himself. Oats also grow rapidly when seeded mid-summer and provides good cover. Unlike vetch, an advantage of oats is their inability to survive the winter. Although they doesn't fix nitrogen, Brad still thinks oats are worth looking at for soil protection.

Brad has decided that frost-seeded red clover does not fit his system because it interferes with his winter wheat crop. When harvesting wheat straw, Brad is faced with the decision to cut high to avoid the clover herbage and forfeit straw yields, or cut at a normal height and forfeit clean straw. According to Brad, "[s]traw is a fairly big part of the profit on wheat, [and] clean straw is definitely a must if you are going to sell it." Additionally, Brad likes to have the option to spray for weeds in his wheat crop, which he can't do if the red clover is there.

After two years of experimenting, Brad is not sure if he will adopt the cover crop system or not, but he is clear about what will be the deciding factor. "Profit - that's the bottom line. We don't want to do something that's not profitable. But we will experiment here and there, trying to find something that will work and that is economical." Brad says he will keep looking at cover crops on sandy soils where wheat yields are low and erosion is a problem. "But we would probably only stick with a cover crop if we can get something back out of it, like the N, without it being too expensive."

When asked, "How expensive is too expensive?", Brad said, "It's usually based on alternatives. . . [Y]ou can't put a price on the soil protection but you know what can happen if it's bare. If you can figure that you have [enough soil] protection, [then] the cover crop, if you're using it for N, gets compared to what it would cost for commercial N and application. If it was with some crops that leave the soil quite bare, then it's worth more to put a cover crop on. For wheat, it all depends on the yield. It's one of those decisions you have to make when the time comes."

Brad listed several of cover crop benefits associated with the addition of organic matter to the soil, and said they were especially important on sandy soils. These include improved water holding capacity and greater nutrient and herbicide efficiencies, which are associated with higher cation exchange capacities. However, Brad treats these as added benefits rather than factors upon which an adoption decision might be based.

Brad doesn't see many drawbacks to using vetch or oats, besides the seed and establishment costs. Brad says that these cover crops fit well into his rotation with winter wheat and that no machinery changes are necessary. Killing the vetch is not a problem because he usually applies an herbicide before no-tilling anyway. The only extra labor required is for seeding, which occurs during a typically slow time, mid-summer after wheat harvest. Brad did mention that spring moisture could be depleted by an overwintering cover crop, but he felt that this could easily be avoided by killing the cover in the fall or early spring. He has succeeded in killing vetch and clover with herbicides.

Two changes are occurring on Brad's farm that will influence his decision to adopt cover crops. First, Brad is switching to more no-till production and finding that, on most fields, he doesn't need a cover crop for erosion control. In that case, for Brad to use a cover crop, he says that it will have to pay for itself in terms of commercial fertilizer savings. Second, Brad is thinking of dropping some or all wheat acreage from his rotation because it is not very profitable. If he does this, Brad does not think cover crops will fit anywhere in his system.

#### NORM HARRIS

Norm Harris grew up on a farm, but after high school, he went to work as an aircraft technician at the Madison airforce base. Thirteen years later, Norm returned to farming. He said, "I just didn't like working for the government. . . . They just don't care. There was no incentive, no pride in your work. . . . There's a lot of pride in farming, you know, driving past a nice field."

Norm owns and farms 410 acres adjacent to the UW Arlington Research Station. He is in the feed grain program for corn and wheat, and also grows soybeans, sweetcorn and peas.

Norm's concern for protecting and building his soil motivated him to get involved in the cover crop trial. Norm regularly seeds his set-aside acres with a cover crop mix (oats and mammoth red clover) and says he is willing to spend some money to maintain his soil productivity. "So many farmers are just concerned about the bottom line. . . . But you have to look at more than that. You have to look at the future." When he thinks about using a cover crop, Norm says he considers the following factors, in order of importance: erosion, economics, N production and added organic matter.

For the trial, Norm wanted to look at cover crop options following winter wheat. In general, Norm said he was impressed with the "mellowness" of his soil after the hairy vetch and red clover, and with the subsequent corn yields. He did not notice these effects with the oats. Norm, like Brad, decided against using companion-seeded red clover because he found that it limited his ability to produce sufficient amounts of clean wheat straw. "Last year we almost got as much money for our [clean] straw as for the grain. It's a disadvantage to us to have the red clover in there."

Like Brad again, Norm is experimenting with cover crops on his own and has focused on hairy vetch. Norm has been comparing vetch and mammoth clover in two systems: seeded with oats on his set-aside and seeded alone following winter wheat. He says his main concern with vetch is the high seed cost and suggests looking at other, more economical, cover crop species. He is also a little worried that the vetch might become a weed, but thinks that it would be easy enough to kill with a corn herbicide. Otherwise, Norm says that the field operations required to grow vetch, or any other cover crop, coincide with slow times during the season, and that he has not had to make any machinery changes.

Norm thinks that the trial has been an effective way to introduce cover crops to him and his neighbors. Although he had seen cover crop work at the research station during field days, he said "I wouldn't be trying it [on my own] if I hadn't gone through this project." He was also encouraged by the number of people who saw the roadside DATCP Sustainable Agriculture Project sign by his plots and stopped to see the cover crops. In fact, he said, "I know one young farmer was very excited. . . . I wouldn't be surprised if we see some cover crops out there [on his farm]." However, Norm thinks we need to involve and inform more farmers, "so that more people can see that it is a good thing, and more of the bigger farmers will then, hopefully, try it."

#### GARY WATERWORTH

"I'm supposed to talk about production, production, production . . . I may get in trouble for some things. Production agriculture to me is fine. Let's go ahead and get all these big yields. But let's not do it at the expense of ducks and draining wetlands and ruining the soil. I guess if I could tell someone just starting out, just take care of what you've got. You know, there are different ways of doing it."

Gary Waterworth teaches agriculture and leads the Future Farmers of America group at the Rio junior and senior high school. After college, Gary taught for six years in Oregon, Wisconsin, and then farmed on his father's dairy farm for seven years before starting at Rio high school. When teaching, he says he tries to make the students aware of the environmental impacts of agriculture.

Gary focuses on the erosion control and nitrogen benefits of cover crops, both of which he thinks are extremely important on sandy soils like those at the Rio high school. He thinks nitrogen may become the more important of the two as more and more farmers meet their ground cover needs with minimum or no tillage methods. In addition to the quantity of nitrogen that cover crops provide to the next crop, Gary thinks that cover crops may be a better nitrogen source on sandy soils, as compared to anhydrous, because cover crops release nitrogen slowly over the season.

Of the two leguminous cover crops, Gary was more impressed with the red clover. "To me it looked like red clover gave so much better cover, so much more foliage compared to the hairy vetch in the fall. . . . In the spring [the vetch] looked nicer, I'll grant it that. But the clover looked better. The fact that we were working so much more [cover crop dry matter] into the soil made me think that there'd be more N there." Gary also noticed that the corn looked better after the red clover. In fact, "a couple of those patches where we had red clover, we had just as good looking corn as where we put on commercial N."

Gary is realistic about farmers' economic constraints, and a bit pessimistic about their acceptance of cover crops. "I think the whole issue for us with cover crops is that you've got to be able to show that [they] will monetarily benefit. . . . Just telling [people] that the organic matter might be higher, that the soil texture will be nicer, I don't think most people understand that or appreciate that or care about that, particularly when money is tight." Therefore, in order for cover crops to be adopted by farmers, cover crops will have to pay for themselves in N fertilizer savings.

Cover crops can pay for themselves, Gary thinks, but he notes that there are additional obstacles to adoption. "The biggest problem is going to be changing peoples attitudes." Like Norm, Gary thinks outreach is critical. We must "keep showing the benefits and keep getting the information out. Over time it will make an impact. Things are slow to change."

#### TOM KLAHN AND TOM MANKE

Tom Klahn and Tom Manke are co-hosts of the 1994 Farm Progress Days - "Pride of the Prairie". They agreed to take part in the cover crop trial so that plots could be used as a demonstration for Farm Progress Days. Both farmers grow snapbeans and, like many vegetable growers, regularly plant an oat cover crop after harvest for erosion protection. They were interested in trying red clover and hairy vetch to see if they could get as good a cover as they do with oats and also the nitrogen benefit. Each farmer is conducting the cover crop trial once on their farm. Tom Klahn started the rotation in 1992 after snapbeans and Tom Manke started in 1993 after peas.

# TOM KLAHN

Tom farms 1,400 acres, 950 of which are rented, and runs a 120-sow, farrow to finish operation. He is in the corn and wheat feed grain programs. Tom also grows soybeans, green beans and sweetcorn. He uses minimum tillage when he can and is in the process of moving towards no-till.

Tom plants most of his snapbean crop on rented land, where he is just as concerned about soil protection as on his own land. "We're real sensitive for a couple of reasons. One of them is it's not our ground. The landlords see erosion and they're always inclined to think that we're not doing the best job, or that someone else could do a better job. And when you need that ground, when you want to protect that base, then it's important to do a good job."

Tom's adoption decision, therefore, is not whether or not he is going to use cover crops after snapbeans; but rather, which one to use. Tom likes oats because "they are cheap, are easy to seed, kill out over winter, and definitely help with erosion", but they don't fix nitrogen. He wanted to try the legume cover crops because he's noticed that "any time you [include legumes] your corn crop really responds. It seems like a different form of nitrogen. [Whether] it's more readily available or more stable or what . . . you always can detect a difference in the following year's corn crop."

Tom says he would consider a number of factors when deciding which cover crop to use. The most important factor would be if he is on owned or rented land, and, if on rented, how long the contract extends. "To put red clover or something out there [on a rented farm] and then lose the farm would be sort of expensive." If Tom knows he has a farm for a couple of years and could use a legume cover crop, then the next thing he considers is the economics. He'd want to know if the total cost (seed, seeding and killing costs) exceeds that of oats, and if that cost difference is recuperated in nitrogen fertilizer savings.

Tom hasn't decided yet if he'll switch from oats to a legume cover crop. He wasn't very impressed with the red clover and hairy vetch stands in his plot, compared to the oats. However, he did mention that he noticed good establishment of the legumes in Tom Manke and Brad Franz's fields, and therefore, is still willing to consider a legume alternative.

Tom would like more information about the legumes before he tries them on a large scale. He is very concerned that hairy vetch would become a weed problem. "[The trial] was my first experience with it. [It seems] close to being a weed, but maybe I'm all wet on that. . . If I get it into my fenceline, or into those grass [waterways], I wonder if I've started a problem? Whereas, if I get clover in there I don't think about it at all. No problem." Tom has encountered red clover before and knows that it is easy enough to control. He wants the same assurance about hairy vetch in order to reduce the perceived risk associated with using it as a cover.

Tom would also like more information about inexpensive methods to seed the legumes. One of the drawbacks he sees with switching to the legumes is that he would have to use a drill to establish them. Not only does drilling take more time and energy than broadcasting, but "it works just like a tillage tool" on the soil. He'd be more inclined to use a legume if he could broadcast seed it. Additionally, Tom says he like to see more information on the overall economics of using cover crops.

Like Norm and Gary, Tom thinks more effort should be directed towards outreach. "You are going to have to create an awareness at some point. Even if you get this researched completely, you're still going to have to sell it." He suggested targeting the canning companies for two reasons. First, vegetable crop growers are perhaps the most in need of cover crops for erosion control. Unlike small grains, snapbeans and peas do not leave much residue. Second, the canners "have a lot of influence and they have a lot of contacts. They could help spread the word."

### TOM MANKE

Tom Manke grows corn, soybeans, peas and snapbeans on his 700-acre farm. Like Tom Klahn, he has been using an oat cover crop after snapbeans and peas for years. "On snapbean and pea ground, we think that it is pretty important because it's pretty bare afterwards. We hate to leave it open, or fall till and leave it open, so we use a cover crop." Second to erosion control, Tom cites nitrogen production as a reason to use cover crops. However, the potential soil building aspect of cover crops does not interest him since his soil organic matter levels are relatively high.

Tom has been pleased with oats as a cover crop. "It's virtually free, covers well and is dead the next spring. You don't have to worry about any chemicals or anything to get rid of it." Tom switched from rye to oats a number of year ago because he found that the rye depleted spring moisture when it wasn't killed early enough. His ideal cover crop would be "something that's fast growing and that covers good. And something that will give you some nitrogen credits. But not something that's hard to kill out." Ultimately, though, "I guess if you are going to look for a cover crop, you're going to look at the bottom line and look at the cost of the seed."

At the time of the interview, Tom had only seen the summer and fall growth of the cover crops in his plots, but said he was generally pleased with the ground cover that all three provided.

### JON BALDOCK

"We've looked at production as the main goal for a number of years. And then people realized that that wasn't always synonymous with profitability. So then we started looking at profitability as the main goal. But, there's a third factor that needs to be maintained simultaneously along with those other two, and that is protection of the environment and soil resources. We can't just focus on one. It's a simultaneous equation."

Jon Baldock is a farmer, crop consultant, contract researcher and statistical consultant. Of the 150 acres he works, Jon uses about 35 acres each year for experiment plots. On the rest, he grows corn, soybeans, wheat and some sweet corn and peas. He is a consultant to 10 to 15 mostly cash grain farmers, and to a number of researchers at the University of Wisconsin. Jon helped design the on-farm cover crop trial and wanted to have plots on his farm so that he could work with cover crops he had never tried before (hairy vetch and buckwheat), compare covers that winterkill to those that don't, and have access to detailed data from measurements and monitoring than he would not have been able to do on his own.

Jon's reasons for considering a cover crop are: 1) erosion - "Any time you have a short season crop it sure makes sense to look at cover crops, particularly if you are trying to comply with conservation plans. And even if you are not."; 2) organic matter - "Some people refer to organic farmers as a special group of farmers, but I think we're all basically organic farmers. That organic matter is really one of the keys to how much moisture and nutrients we can hold, so anything we can do to increase that organic matter in the soil is good and cover crops are a great opportunity to do that."; and 3) nitrogen - "And to some extent the nitrogen contribution that you can make to another crop helps pay for the cost of doing it." Additionally, Jon says, cover crops can provide weed control and, for livestock producers, a source of forage.

When Jon is thinking of using a cover crop, he first considers the cost and the possibility that the cover may disrupt his cash crops. He also considers if the cover crop might cause moisture or weed problems the following spring. Jon has had problems in the past with red clover becoming a weed in his corn. Last year, Jon found that he could overcome this problem by changing his management strategy; instead of letting the clover overwinter and disking it in the spring, Jon sprayed the clover in the late fall. "It looks to me like where we sprayed it and killed it out it's just exactly what I would want for cover this time of year. And it's not going to come back to haunt me."

Jon likes the red clover, now that he's learned how to control it. He says he would use it with peas again, but he's decided not to grow any more peas. He is, however, using it with winter wheat, and has convinced one of his clients to do the same. Jon says his experience with the other cover crops has "whet my appetite to try some things that we didn't have in the trial." He was impressed with the hairy vetch but wants to try mixing it with oats or buckwheat to provide better cover early on and to cut the seed cost.

### Overall Summary REASONS FARMERS CONSIDER USING COVER CROPS

#### Cover crops for erosion control

Erosion control is the primary reason this group of farmers considers using cover crops (Table 34). Although most of the farmers said that their decision to adopt would be based on "the bottom line" -- economics, it appears that they all place some value on protecting their soil resources. One explanation could be that they are concerned about meeting "T" (tolerable soil loss by erosion) in order to remain eligible for program payments, yet none of them said that government programs affected their decision to adopt cover crops (Table 35). Instead, the farmers factor erosion control into their economic analysis. They are "willing to spend some money to maintain soil productivity" (Norm) because "you can't put a price on the soil protection, but you know what can happen if it's bare" (Brad).

The potential role of cover crops in controlling erosion may be shrinking as more and more farmers meet their ground cover needs by using minimum and no-till methods. According to Tom Manke, "If we're in the situation where everybody's no-tilling then I guess there wouldn't be any reason to use them, unless you can justify them for N credits." A number of the farmers echoed this outlook, but they also identified situation where cover crops will still be needed. Brad, for instance, said that he doesn't have enough residue after no-till wheat when his yields are low. Another situation where cover crops are still needed is following canning crops. As Tom M. said, "No-till is out of the question for most canning crops, for peas and greenbeans definitely."

**Table 34. Benefits, ranked in order of what motivated them to consider adopting cover crops.**

|                                 | B.Franz | N.Harris | G.Waterworth | T.Klahn | T.Manke | J.Bal |
|---------------------------------|---------|----------|--------------|---------|---------|-------|
| Erosion control                 | 1       | 1        | 1            | 1       | 1       | 1     |
| Nitrogen production             | 2       | 2        | 2            | 2       | 2       | 3     |
| Add OM/"build" soil             | 3       | 3        | 3            |         |         | 2     |
| Slow release source of nitrogen |         |          | 4            |         |         |       |
| Weed suppression                |         |          |              |         |         | 4     |

#### Cover crops as a source of nitrogen

All of the farmers credit legume crops, such as soybeans, and recognize the nitrogen value of a leguminous cover. In addition to the N fertilizer value, Tom K. and Gary have observed that organic sources of nitrogen produce a greater crop response than fertilizer, perhaps because they are less likely to leach. Brad, Norm and Jon noted that cover crops, both legumes and nonlegumes, could improve the overall productivity of the soil through the addition of organic matter. However, only Norm and Jon expressed a willingness to invest in the soil

productivity benefits of cover crops. Tom K., Tom M. and Brad agreed that the decision to use a cover crop as a nitrogen source is based solely on a cost/benefit comparison to commercial fertilizer.

## FACTORS THAT AFFECT FARMERS' ADOPTION DECISION

### Cost

Cost was mentioned first by all of the farmers when asked what factors would affect their decision to use cover crops (Table 35). Cover crop cost includes seed, seeding and killing costs, all of which vary widely depending on the particular cover crop. Hairy vetch seed currently costs about \$17 per acre more than red clover and \$27 per acre more than oats. While a number of the farmers were pleased with the performance of hairy vetch, they all said that the high seed cost made it more difficult to justify using vetch. Seeding costs also differ between the cover crops depending on the establishment method used. Tom K. mentioned that he would prefer using cover crops that could be broadcast because it takes less time and energy than drilling. Lastly, the time, energy and, possibly, chemical costs associated with killing the covers that overwinter may factor into a farmer's decision to adopt, as was the case with Tom K., Tom M. and Jon (Table 35). Brad, however, said killing costs are not a consideration because he usually sprays his field before no-tilling corn anyway.

### Effects on cash crops

The farmers were also concerned about how the cover crops might affect their cash crops (Table 35). Four said they would consider how a companion-seeded cover might affect their short season crop. For instance, Brad and Norm decided not to seed red clover with winter wheat because the clover can interfere with straw harvest. Some of the farmers were also concerned that overwintering covers could have negative impacts on the following corn crop by depleting spring soil moisture and/or becoming a weed. However, most said that both of these potential problems could be addressed with proper management.

### Machinery changes and labor needs

Machinery changes and labor needs are both factors that the farmers said they would consider, but neither dissuade farmer's from using cover crops (Table 35). Almost all of the farmers said that they already have the machinery needed to plant and manage cover crops. The exception was Jon who said that he probably wouldn't use hairy vetch because he would want to no-till plant it and he doesn't have a no-till drill. Labor needs are not a concern to the farmers because the work associated with cover crops coincides with slow times during the season -- early spring and mid-summer.

### Risk

Another factor that might affect a farmer's decision to use cover crops is the attendant risk (Ott and Hargrove, 1989). The farmers in this group were asked to define a risky agricultural practice and say if they consider cover crops to be risky. Two types of risk were defined by the farmers: short-term, economic risk and long-term, environmental risk. All of the farmers identified some economic risks associated with using cover crops. The one that was mentioned most often is the possibility that poorly controlled cover crops can become weeds. Brad also thought that cover crops were a less reliable source of nitrogen, compared to commercial fertilizer, because their performance varied among years and sites. In contrast, Gary said that cover crops as a source of N were less risky than anhydrous on sandy soils. Overall, most of the farmers said that using cover crops was not economically riskier than their usual practices. "When you get right down to it, farming is risky" (Gary), and "as farmers, we're used to taking risks" (Brad).

"There's another risk that we're just learning to focus on and that's the risk of losing soil and ... not maintaining enough organic matter to maintain productive soils." (Jon) Almost all of the farmers recognized that, in terms of long-range risks, cover crops offer "a little bit of insurance" (Norm). The question is then, as discussed above, how much are farmers willing to invest for that insurance.

**Table 35. Factors that affect farmers decision to adopt cover crops.**

|                                                      | B.Franz | N.Harris | G.Waterworth | T.Klahn | T.Manke | J.Bal |
|------------------------------------------------------|---------|----------|--------------|---------|---------|-------|
| Cost of seeding and managing the covers              | yes     | yes      | yes          | yes     | yes     | yes   |
| Machinery changes                                    | no      | no       | no           | no      | no      | yes   |
| Time and labor                                       | no      | no       | no           | no      | no      | no    |
| Companion-seeded cover may disrupt short-season crop | yes     | yes      |              | yes     |         | yes   |
| Have to kill species that over winter                | no      |          |              | yes     | yes     | yes   |
| Overwintering species may deplete spring moisture    | no      |          | no           | yes     | yes     | yes   |
| Overwintering species may become a weed in next crop | no      | yes      | no           | yes     | yes     | yes   |
| Government programs                                  | no      | no       | no           | no      | no      | no    |

\* Blank space indicates that the factor was not discussed.

### **Farm size**

Some of the farmers think that farm size influences a farmers' willingness to invest in the long-range, and short-range, benefits of cover crops. Gary felt that "small farmers have a tendency to take care of their land better than large farmers." Norm and Tom M. said that large farmers wouldn't be willing to spend the money and time needed to plant cover crops on their large acreage. In contrast, Tom K. thinks that cover crops are suited less to smaller farms (because their rotations are so tight) and are needed more on larger farms (because they have larger fields, which are more prone to erosion). Brad and Jon said that farm size has nothing to do with cover crop adoption. "Most farmers stay busy enough that their time is short. Whether they're on a small or big farm, they're geared accordingly." (Brad) "It's got more to do with the attitude of the operator than with farm size." (Jon) These last opinions reflect the findings of Lockeretz et al. (1981) who reported that there was no relationship between farm size and farmers using alternative agriculture practices in the Midwest.

### **Adoption Potential of the Cover Crop System**

Most of the farmers hadn't decided, at the time of the interview, if they would use cover crops on a large acre basis in the future. They were relatively unexperienced with cover crops when the trial started and said they want to either experiment more on their own (Brad

and Norm) or see more results from other research that assure them of the relative benefits (Tom K.). Only Jon was certain that he will use red clover in winter wheat, but he has had many years of experience with cover crops and is also familiar with the research literature. All of the farmers warned that the adoption process is slow for any practice.

Cover crops have many of the characteristics described by Rogers (1983) that enhance their likelihood of being adopted. Cover crops as a new technology are relatively incomplex and triable. The farmers in this trial had no difficulty understanding the cover crop system, recognizing the potential benefits and trying it out on a small scale. Cover crops are relatively observable, as well. While their long-term effects may be elusive, their effects on ground cover and on cash crop yields can be readily observed by the farmers and their neighbors. In most cases, cover crops are also compatible with the farmers existing systems. No rotation or machinery changes are required, nor is work added during peak labor periods. The only case where a cover crop was incompatible was the red clover in winter wheat.

The characteristic which will decide the adoption fate of cover crops is their relative advantage, as perceived by farmers. Farmers weigh the possible benefits (erosion control, nitrogen production, soil improvement) and the possible drawbacks (cost, moisture and weed problems, effect on cash crops) and compare the balance to their current practices. All of the farmers interviewed agreed that the relative advantage of cover crops is high if their current practice leaves the ground bare and in need of cover, as in the case of canning crops or low yielding wheat. But when no-till methods provide good cover, the relative advantage of cover crops is not so certain and depends on the benefits and drawbacks recognized by each farmer.

## FUTURE RESEARCH AND OUTREACH NEEDS

### Identification of suitable cover crop species

Most farmers in this group said that research is needed to find cover crop species that are suited to farmer needs. The interviewed farmers said that the ideal cover crop would: have inexpensive seed; be cold and drought tolerant for late summer seeding; establish easily and grow rapidly to provide cover; winterkill to eliminate killing costs or be easy to kill to avoid possible soil moisture and weed problems in the spring; and fix enough nitrogen to pay for itself in fertilizer savings.

Each cover crop in the trial had some of these desired characteristics, but none had all. The farmers said they liked oats because they are cheap, establish easily and grow quickly, and are cold tolerant yet winterkill, but they don't fix nitrogen. Companion-seeded red clover provides good cover to prevent erosion and nitrogen to a subsequent corn crop, but interferes with wheat straw harvest and does not winterkill. Hairy vetch can be seeded after short-season crop harvest, and provides good cover and nitrogen, but it doesn't winterkill either and its seed is expensive. There are probably cover crop species that are better suited to farmer needs than these three, but it is doubtful that one species will have all the desired characteristics (Meisinger et al., 1991). Jon suggested trying mixes of cover crop species, slow growing species with fast growing species, nonlegumes with legumes, to meet farmer needs.

### Other research needs

Farmers in this group also wanted more information about the type of N credits they could depend on from the different cover crops, as well as better assessments of how cover crop systems perform economically compared to conventional systems. In order to improve the

economics of using cover crops, several of the farmers suggested identifying effective and inexpensive sequential seeding methods for each cover crop species. For instance, Tom K. wanted to know if red clover would establish and give good cover when broadcast mid-summer. He and Tom M. also said that they wanted more information about the potential for cover crops to become weed problems before they would be comfortable using cover crops on a large acre basis.

### **Outreach**

"Even if you get this researched completely, you're still going to have to sell it. . . . You are going to have to create an awareness at some point" (Tom K.). Norm, Gary and Tom K. stressed the importance of outreach to the future of cover crops. Tom suggested focusing outreach effort on canning companies because they have contact with and influence over a large number of farmers who need erosion protection following canning crops. Norm thought that adoption of cover crops would start with small farmers and then, if the benefits prove to be great enough, the large farmers would follow.

All of the farmers warned that the adoption process is slow. As Jon said, "Those who are interested, for the erosion control and the possible N benefits, are doing it kind of slow, doing it where they think they can get the most benefit and they're going to do a little bit more and a little bit more . . . as they get more comfortable doing it." Outreach is important to increase farmers' awareness of and confidence in cover crops. "If we can keep showing benefits and keep getting the information out, and if people buy into it on a small scale, eventually it will work its way across." (Gary)

## **CONCLUSIONS FROM THE ON-FARM COVER CROP TRIALS**

### **Future cover crop research and outreach needs**

The farmers participating in the trials indicated that their decisions to adopt cover crops would be based on, first, their need for ground cover, and second, the profitability of using cover crops as a source of nitrogen. Results from the corn phase of the rotation indicate that cover crops, when valued solely as a source of N, are not an economical alternative to nitrogen fertilizer. Even though the poor response of corn to the cover crops may be due, in part, to the unusually wet 1993 season, our results emphasize the importance of focusing future efforts on: a) outreach to farmers growing crops that do not provide sufficient ground cover, such as vegetable crops; and b) optimizing the cover crop system in order to increase its profitability as compared to nitrogen fertilizer.

Towards the goal of increasing cover crop profitability, further screening studies might identify cover crop species, or mixes of species, that could meet preferences expressed by the farmers. For example, farmers said they would prefer a cover crop that, among other things, can be sequentially seeded, fixes nitrogen, and winterkills. Purple vetch (*Vicia atropurpurea*), while not as well known as hairy vetch, grows more vigorously in fall weather and winterkills. Added nitrogen yields and no killing costs could make purple vetch a more profitable option than hairy vetch in the present cover crop system, depending on relative seed costs.

Breeding efforts could also improve cover crop options for farmers. Some of the species used as cover crops, such as red clover, have been bred for their use as forages. However, characteristics desired in a forage, such as winterhardiness and persistence, are not necessarily desired in a cover crop. To date, little or no effort has been placed on developing varieties specifically for use as cover crops.

In addition to cover crop selection and breeding, research to determine economically optimal management systems (e.g., seeding rates, establishment and kill methods, and nitrogen fertilizer use) will also increase the profitability of the cover crop system and its attractiveness to farmers.

### **On-farm cover crop trials**

Perhaps the most consistent result from the on-farm trials was the variation observed in cover crop performance among farms and among years. Each cover crop demonstrated the potential to provide high levels of ground cover and produce biomass (and N) yields comparable to those obtained in the on-station screening study (Stute, 1994). Each cover crop also demonstrated the potential to perform poorly. While much of the variation in ground cover can be traced to the method by which cover crops were established, there were not enough farm-years to isolate the factor(s) responsible for the variation in biomass and N yields. Possible factors include soil type, weather and management.

Variation resulting from lack of control over environmental and management factors is commonly cited as one of the major drawbacks of on-farm research. Management issues are particularly troublesome. Often, systems developed on-station under one management style must be adapted to each particular farm setting. Until the farmers and researchers learn what management systems work best in each situation, results from the trials may be discouraging. Less than optimal management may also occur because of poor communication between researchers and farmers and/or low priority given by busy farmers to small experimental fields. All of the above factors played some role in the outcome of the on-farm cover crop trials.

The variable results from the on-farm trials made it difficult to make generalizations about cover crop performance. While this situation supports a valid criticism of on-farm research, it is also one of primary justifications for evaluating systems on-farm. The fact that cover crop performance is relatively sensitive to farm setting and management style underscores the importance for researchers to work with these sources of variation if adoption of cover crop practices is the ultimate goal.

### **References**

- Anderson, M.D. 1992., Reasons for new interest in on-farm research. *Biol. Agric. and Hort.* 8:235-249.
- Byerlee, D., L. Harrington and D.L. Winkelmann. 1982. Farming systems research: Issues in research strategy and technology design. *Am. J. Agric. Econ.* 64:897-904.
- Ehrenfeld, D. 1987. Sustainable agriculture and the challenge of place. *Amer. J. Altern. Agric.* 2:184-187.
- Lockeretz, W., D. Shearer, and D.H. Kohl. 1981. Organic farming in the corn belt. *Science.* 211:540-547.
- Nowak, P. 1992. Why farmers adopt production technology. *J. Soil Water Conserv.* 47:14-16.
- Meisinger, J.J., W.L. Hargrove, R. L. Mikkelsen, J.R. Williams and V.W. Benson. 1991. Effect of cover crops on groundwater quality. p.57-68 *In* W.L. Hargrove (ed.) Cover Crops for Clean Water. Soil Conserv. Soc. Am. , Ankeny, Iowa.
- Ott, S.L. and W.L. Hargrove. 1989. Profits and risks of using crimson clover and hairy vetch cover crops in no-till corn production. *Am. J. Altern. Agric.* 4:65-70.
- Rogers, E.M. 1983. Diffusion of Innovations. The Free Press, Macmillan Publ. Co., of New York, NY.
- Stute, J.K. 1994. Legume cover crops as a nitrogen source for corn. Ph.D. Thesis. University of Wisconsin, Madison.
- Wake, J., C. Kiker and P. Hildebrand. 1988. Systematic learning of agricultural technologies. *Ag. Systems.* 27:179-193.

## IX. OUTREACH ACTIVITIES

### A. WICST Educational Outreach Program 1994 - Walworth County

L. Cunningham \*

As the WICST project evolves each year the individuals participating take on new challenges along with repeating some outreach activities that have proven to be successful in the past. Nineteen Ninety-four was no exception. We continued to build on our outreach efforts through the experiences we have had over the last six years since the WICST project started in 1989. The winter WICST Advisory meeting held in February, 1994 addressed three key issues that had been identified by the Integrated Farming Systems Network of projects. The Advisory committee responded to the following requests for input on these three issues:

1. List the ways the WICST project can foster change in the attitudes of people, who work within Educational Institutions, toward sustainable agriculture systems.
2. List the ways the WICST project can influence public agricultural policy.
3. List the ways the WICST project can help to create a vehicle for information exchange.

The input received from the Advisory Committee (summarized in the 1993 WICST annual report) served as a guide for many of the outreach activities conducted in 1994. The following will be a brief summary of those activities. Some of the overall impact of the WICST project is validated by the mere fact that these events and actions became a reality.

### FOSTERING CHANGE IN INSTITUTIONS

In the area of fostering change within Educational Institutions a number of things have taken place. A Sustainable Agriculture Task Force was created within the University of Wisconsin Extension by the State Agriculture Extension Program Director, Dr. Richard Vattthauer.

The initial goal of the University of Wisconsin Extension Sustainable Agriculture Task Force was to insure that the issue of sustainability of agriculture was recognized and addressed in program efforts throughout Extension's four year Ag program planning process.

The task force includes University of Wisconsin Agricultural Specialists, with Extension education appointments as well as research appointments. Dr. Jerry Doll, Weed Control Specialist heads the task force. Dr. Rick Klemme represents the Center for Integrated Agricultural Systems. The following program areas within the University Extension System are represented by individuals working within each one: Ag/Agbusiness, Dairy, Meat Animals, Fruit Crops, Forage Crops, Grain Crops, Horticulture and Vegetable Crops. Dr. John Hall, Michael Fields Agricultural Institute and Lee Cunningham, Agricultural Extension Agent for Walworth County are also very active members of the Task Force. The recognition of and the desired participation of Dr. Hall and Lee Cunningham on the University of Wisconsin Extension Sustainable Ag Task Force is a direct result of the acceptance of the WICST project and its participants as premier sustainable agriculture educational resources.

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\* Walworth County UW-Extension Agri/business Agent.

Initial steps were taken, in the spring of 1994, by the individuals on the task force to insure sustainability was included as a key issue in the overall strategic program planning process in each area of Extension educational programming they represented.

A survey of Agricultural Extension Agents was conducted to ascertain what the perceived sustainable agriculture professional development training needs were. This information was to be used to further identify specific training offerings to be implemented in the future.

During 1994 the Extension System began the next four year strategic program planning process. In December, 1994 a state-wide Extension Agriculture program issue identification/planning conference was held in Madison. Lee Cunningham was asked to present the status of and the future need to include sustainable agriculture as a key issue to be addressed in program planning by all Extension personnel. In January, 1995 the Extension State Agriculture Program Director identified two issues that must be addressed in all plans of work. Those two issues are how the individual's plan of work addresses improved environmental stewardship and farming systems profitability. These have been two key components utilized to define sustainability within the WICST project and are now being implemented into Extension program planning throughout the State.

The goal of the Sustainable Agriculture Task Force was expanded to include the development of and the implementation of a sustainable agriculture training program for Extension and related agency personnel. Under the 1990 Farm Bill, Chapter Three funds were made available for state Extension agencies to develop a training needs assessment for sustainable agriculture. From those efforts a grant proposal has been submitted to the North Central Region SARE Program with the WICST project playing a key role in the sustainable agriculture educational training for Extension Agents in Wisconsin, Iowa and Minnesota.

The Walworth WICST site hosted a field day for the Sustainable Agriculture Task Force and subsequent sustainable ag training planning meeting with representatives from an expanded audience that included individuals from the Agricultural Supply Industry, Wisconsin Farm Bureau, Department of Natural Resources, Soil Conservation Service, Department of Agriculture Trade and Consumer Protection, Land Conservation Committee, Extension and Farmers. The North Central Region SARE Program Coordinator, George Bird also attended this preliminary planning meeting. By providing the forum for this meeting and by providing an outside classroom that delivered sustainable agriculture systems people could see, feel and personally experience the WICST once again proved itself to be an outstanding resource for educational training.

The Board of Directors from the Henry Wallace Institute For Alternative Agriculture (Publishers of the Journal For Alternative Agriculture) toured the WICST outside classroom. By providing this outreach event the WICST project was identified by a wider audience as a potential resource that could help to foster change in attitudes within educational institutions.

The Elementary Classroom teaching unit (SAM) was evaluated by 4th grade teachers and was subsequently structured to fit into the 3rd grade science curriculum in five classrooms at the Elkhorn Elementary School. One hundred fifty-seven students completed the classroom phase of the sustainable agriculture unit and then visited the WICST outside classroom as the culminating educational activity. The teachers involved continue to be

influenced by the learning experience provided by the WICST outside classroom. By influencing this group the WICST project has fostered change at the elementary school level of an educational institution.

The Vocational School (Gateway Technical College) utilized the WICST project as a classroom for crops and soils as well as dairy offerings during the year. This outreach effort provided learning opportunities for farmers as well as staff members from another educational institution.

The agenda of the 1995 Winter Advisory Meeting was expanded so the WICST project provided the forum for input on sustainability of our present food production system from representatives of the banking industry, the Wisconsin Farm Bureau President and a sustainable agriculture farmer. This panel discussion was followed up by the State Extension Agriculture Program Director presenting a list of things Extension could do to insure that the future of agriculture in the State of Wisconsin is more sustainable. A presentation by the Associate Dean of the College of Agriculture & Life Sciences, who oversees the research agenda for the College, discussed what research could do to insure the sustainability of Wisconsin's future agriculture systems. Fred Kirschenmann (a farmer and member of the National Sustainable Agriculture Council) presented a list of things farmers could do to insure the sustainable future of our farmer driven food production system. (A summary of these presentations can be found in the appendix of this report). The feedback from many people who attended this outreach event was very positive and the WICST project was recognized as the vehicle that made this forum possible.

## **INFLUENCE PUBLIC AG POLICY**

From the input from the 1994 WICST Advisory Committee winter meeting it was determined that one more year of transitional data was needed to further substantiate the changes occurring in the WICST systems before efforts could be made in the public policy arena. During 1994 the WICST participants have further developed strategies to be implemented in future efforts in this area. The Michael Fields Institute will take the lead role in these efforts. The WICST project has been offered to federal, state and county elected officials as a sustainable agriculture educational resource throughout the year.

## **WICST OUTREACH EFFORTS THAT HAVE EXPANDED ITS EMPHASIS ON BEING A VEHICLE FOR SUSTAINABLE AGRICULTURE INFORMATION EXCHANGE**

The Walworth County Agricultural Extension Agent met with seventy-one farmers through five classes involving hands-on field experiences in the WICST outside classroom. Emphasis was put on systems analysis and visual experiences that were made possible only because the WICST outside classroom provided side-by-side comparisons of production systems. All the farmers attending these outreach events agreed that present and future regulations will probably force them to implement different systems on their farms. They further agreed that they were glad that the WICST site in their county was addressing alternative systems that could be implemented on their own operations.

Twenty-six ASCS Directors and staff members from 12 counties took part in a WICST field day designed to answer their specific questions so they could better understand the sustainable agriculture systems approach to food production and to relate how sustainable agriculture must be integrated into the Federal agriculture programs they administer through their county offices. The State ASCS Coordinator also took part in this outreach activity. A number of individual farmers were referred to the WICST site and the Walworth County Agricultural Agent by ASCS Directors who took part in the field day.

The Walworth County Agricultural Extension Agent presented the WICST project as an alternative educational vehicle to 120 agronomists at the Agronomy Society meeting in Indiana. Twenty-five inquiries were generated from around the midwest from this outreach activity. -

The Milwaukee State Journal chose to produce a feature story in their Sunday Magazine section on sustainable agriculture after WICST collaborators helped the paper to recognize the importance of a sustainable food production system to their readers. The WICST project was highlighted and was the catalyst that made this outreach effort a reality. The readership of this paper is state-wide and thus has increased the WICST project's visibility as a sustainable agriculture resource to a wider audience.

The Walworth County Agricultural Agent was the featured speaker on Wisconsin Public Radio for a one hour show highlighting the need to have a sustainable agricultural food production system in this country. The point was made that if we as a society are not successful in maintaining a sustainable food production system we will also fail to exist as a society. The general public audience was successfully reached by this effort, which generated 36 follow up inquiries for additional information as well as requests to visit the WICST outside classroom.

The National Association of Counties organization (NACo) chose the WICST project to receive the NACo award for achievement in the area of an innovative local government related educational program. Over 700 applications were received by the NACo awards committee in 1994.

A priority watershed project was identified in Walworth and Racine Counties by the local Land Conservation Committee. The WICST project has and will continue to provide educational opportunities for everyone participating in the development of whole farm plans and implementation of more sustainable systems on farms in the watershed. Future outreach efforts for the WICST project have been identified as this watershed project is used as a model for others.

Thirty-six high school career counselors took part in a WICST field day. Emphasis was placed on using the WICST outside classroom as a part of a science curriculum at the high school level. The need for a sustainable food production system was also emphasized with this group of educators who influence the career choices of students with whom they come into contact.

A farmer field day was held at the Krusenbaum farm which has developed a rotational grazing system for a dairy herd that is on a seasonal milking system, thus utilizing on-farm resources to their fullest while attempting to minimize off-farm inputs. This WICST satellite farm has implemented many innovations tested in the WICST core experiments and is also

testing the whole farm system approach to decision making. A farmer panel was also utilized during this field day. The farmers on the panel represented grazing systems for sheep, beef and dairy operations. The farmer-to-farmer interaction proved very valuable.

The Stute WICST satellite farm field day emphasized the utilization of cover crops in sustainable systems. Mr. Stute focused on fine tuning cover crop management. He used the WICST corn-soybean-wheat/red clover (R3) rotation as a base system. Farmers saw cover crops used as valuable components in a whole system approach to sustainability. Jim Stute's expertise with cover crops continues to be a tremendous asset to our overall outreach efforts. Jim has also become the Agricultural Extension Agent for Racine and Kenosha Counties. He has expanded the sustainable agriculture programming efforts to those counties and utilizes the WICST project as a valuable sustainable agricultural resource.

The WICST annual fall field day took on a different approach in that farmers were the presenters this year. The farmers related their own personal experiences on their farming operations to the different systems represented in the WICST project outside classroom. The same format was used that has proven to be successful in the past WICST field days. Participants were allowed to progress from one farmer presenter to another at their own pace and to enter into discussions with presenters which promoted dialogue between participants as well as presenters. This method continues to promote sharing of experiences and strengthens the potential for learning to take place.

A new innovation to the outreach efforts was used in 1994 and will be continued in 1995. Weekly walks through the WICST outside classroom were conducted each Wednesday morning rain or shine. Some walks were attended by only two or three of the WICST collaborators and others were joined by farmers, bankers, local elected officials, researchers, and students. These informal discussion groups stimulated interaction between individuals as they talked about what was seen each week. This outreach activity provided many excellent learning opportunities for a wide range of people who chose to participate.

The Walworth County Agricultural Extension Agent utilized the WICST outside classroom over 55 times during 1994 with individual farmers who came to him seeking information on a wide range of topics. Because the WICST project provides six different systems and related satellite projects around the outside of the core experiment it has proven to be a tremendous asset that can be used on a one-on-one basis. Other Extension Agents have also visited the WICST site with the local agent.

The Lakeland Ag Complex Manager, Alan Wood has broadened his personal outreach efforts to include an international group of farmers from Lithuania. He has gone to Lithuania twice and is presently planning an educational opportunity for the Lithuanian farmers which will include a month-long visit to the United States and center around WICST information as well as visits to other sustainable agriculture projects and farm systems in the midwest.

Alan Wood and Lee Cunningham have made WICST-related sustainable agriculture presentations to a number of groups of farmers in Wisconsin and other states. They were speakers at the Indiana Sustainable Agriculture Association's annual meeting in 1994. John Hall was also a featured speaker at a meeting of the Illinois Stewardship Alliance.

The staff at the Michael Fields Agricultural Institute have received numerous inquiries and visits from individuals and groups that want information on sustainable agricultural practices

and have ultimately toured the WICST site. Michael Fields Agricultural Institute has continued to utilize the WICST outside classroom as the major demonstration site for many of its outreach efforts.

This outreach report would be incomplete if it did not emphasize that the WICST project prides itself on being a long term systems analysis project. Obtaining and understanding results takes time. The WICST project has only been in existence since 1989. We are now seeing recognizable differences between the systems involved in the core experiment. We have just begun to reap the benefits of this project. The next 10 to 12 years will be even more important in the long term search for sustainable agricultural systems. When we all finally realize that sustainability relates to long term changes that will effect how food is produced after we are all dead and gone we will be able to recognize the importance of continuing this project today, next year and into the foreseeable future.

**Table 36. Educational Activity Listing for Walworth County**

|                                          | No<br><u>Attending</u> |
|------------------------------------------|------------------------|
| Henry Wallace Institute Board            | 12                     |
| Sustainable Ag. Extension Working Group  | 36                     |
| Fall WICST Field Day                     | 189                    |
| Woody's Weekly Walkabout                 | 44                     |
| ASCS Personnel                           | 26                     |
| Farmers in Extension Classes             | 71                     |
| Career Counselors                        | 58                     |
| Third Grade Students                     | 157                    |
| High School Counselors                   | 36                     |
| Third World County Extension Specialists | <u>26</u>              |
| Total                                    | 655                    |

**B. WICST Educational Outreach Program 1994 - Columbia County**

Dwight Mueller\*

In 1994, the WICST Columbia County Outreach was highlighted by an increase in field tours, a field day with the Madison Audubon Society, a demonstration at Wisconsin Farm Progress Days, and interaction with local elementary and middle school teachers in developing science projects involving the WICST plots.

Many people visited the WICST trial in 1994 (Table 37). A significant increase in foreign visitors toured the site. They had a keen interest in the trial and how information from the study would apply in their countries. Some of the foreign visitors were interested in how many of these practices have already been implemented in their countries. We also had an increase in field tours for students, including the DeForest 4th grade and summer school classes and a University of Wisconsin summer class that discussed the merits and challenges of farming in a more sustainable manner.

Perhaps the highlight of the year was co-hosting a field day, "Prairies Jubilee", with the Madison Audubon Society. This field day attracted a large urban audience that toured both the nearby Goose Pond Sanctuary and a field tour of the WICST trials. On the field tour we presented talks on reducing chemical usage, how rotational grazing could increase upland bird populations and a presentation by one of our WICST farmer committee members on his experiences with sustainable agricultural practices. There was very good discussion and both the Audubon Society members and our WICST county committee felt the day went very well. Plans are to hold the field day again next year.

Wisconsin Farm Progress Day, which attracts nearly 100,000 visitors each year, was held September 20-22 in Columbia County. We helped support a demonstration on cover crops in the education complex. This was a project initiated by Jim Stute to demonstrate how cover crops could be used after short season crops to reduce soil erosion, add organic matter to the soil, and supply nitrogen for next season's crop. Jim felt the demonstration was a success with particularly high numbers on the middle day of the three day event.

This past year we made contact with DeForest elementary and middle school teachers on how we could incorporate agro-environmental demonstrations and curriculum into their classrooms. I made several demonstrations to elementary students, using a groundwater and soil erosion model, on how groundwater can be contaminated and how soil erosion occurs. Both were very visual and the students responded with a lot of interest and questions to the demonstration. Sample soils were used to illustrate different soil types and we discussed how soils need to be protected and how they play a role in filtering chemicals from possible groundwater contamination. Our hope is to expand the program and possibly use the WICST trials as a field lab for student study.

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\* Assistant Superintendent, Arlington Ag. Research Station, Arlington, WI.

**Table 37. Educational Activity Listing for Columbia County**


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|                                                               | No.<br><u>Attending</u> |
|---------------------------------------------------------------|-------------------------|
| WICST Summer Meeting                                          | 40                      |
| Prairie Jubilee (Ducks and Butter Field Day)                  | 200                     |
| Elementary School Students                                    | 335                     |
| Dept. of Agriculture, Trade and Consumer Protection Employees | 50                      |
| Agricultural Extension Teaching Course                        | 30                      |
| Delegations from Thailand, Zimbabwe, Tajikistan, and Russia   | 30                      |
| 4-H Agriscience World Tour Group                              | 40                      |
| U.S. Food System Delegation                                   | 25                      |
| United Kingdom - Nuffield Farming Group                       | 25                      |
| UW Soil Science Summer School Class                           | <u>25</u>               |
| Total                                                         | 800                     |

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**APPENDIX I.****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-1, 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-1, Denver, Co. Agronomy Abstracts p 155.

**Proceedings**

DOLL, J. and T. MULDER. 1991. Reduced herbicide rates- The Wisconsin experience. Proc. Crop Protection and Production Conference. Iowa State University Dec. 3-4. pages 35-38.

MULDER, T. and J. DOLL. 1991 Best management practices for corn weed control. NCWSS Proceedings. 46:13

STEVENSON, G. W. and J. L. POSNER. 1991. Multidisciplinary, radially-organized teams: A model and strategy for addressing challenges to agricultural research in the 1990's. paper presented at the Conference on Innovative Policies for Agricultural Research. Nov. 21-22 Boston. MA.

**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.

**Thesis**

STUTE, J. K. 1991. Integrating legume cover crops into cash grain production systems. M.Sc. Thesis. Agronomy Dept. University of Wisconsin-Madison.

## APPENDIX I. (Cont.)

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

POSNER, J. L. and M. D. CASLER. 1992. The Wisconsin integrated cropping systems trial: Combining agro-ecology with production agronomy. American Society of Agronomy meetings. Minneapolis, MN. Nov. 1-6. Agronomy Abstracts p 154.

STUTE, J. K. and J. L. POSNER. 1992. Legume cover crops as a N source for corn in an oat-corn rotation. American Society of Agronomy meetings. Minneapolis, MN. Nov. 1-6. Agronomy Abstracts p 292.

**Proceedings**

DOLL, J. and T. MULDER. 1992. Comparisons of cultivators and early season weed management strategies in corn. NCWSS Proceedings. 47:in press

DOLL, J. and T. MULDER. 1992. Update on effectiveness of mechanical weed control. Proceedings of the 1992 Fertilizer, Agrilime and Pest Management Conference. Jan 21-23, 1992. Vol 31:182-190.

HARRIS, R. F. 1992. Developing a soil health report card. Proceedings of the 1992 Fertilizer, Agrilime and Pest Management Conference. Jan 21-23, 1992. Vol 31:245-248

POSNER, J. L., L. Cunningham, J. Doll, J. Hall, D. Mueller, T. Mulder, R. Saxby and A. Wood. 1992. The Wisconsin integrated cropping systems trial: Bridging the gap between station research, the producer, and the consumer. Farming Systems Research and Extension Conference. MSU, East Lansing. Sept 13-18.

**Extension Bulletins**

DOLL, J., R. DOERSCH, R. PROOST and P. KIVLIN. 1992. Reduced herbicide rates: Aspects to consider. Univ. of Wisconsin-Extension A3563. 8pp

KLEMME, R. M., W. E. SAUPE and J. L. POSNER. 1992. Corn-soybean compared with continuous corn in the Wisconsin Integrated Cropping Systems Trials. In Managing the Farm. Vol. 25:5:1-7. Dept. of Agricultural Economics, Univ. of Wisconsin-Madison

**Thesis**

MULDER, T. 1992. Corn weed management systems: Attempting to reduce herbicide use and increase effectiveness of mechanical weed control. M.Sc. Thesis. Agronomy Dept. Univ. of Wisconsin-Madison.

## APPENDIX I. (Cont.)

**Teaching Module**

CUNNINGHAM, L. 1992. Soils, crops, agriculture and me: an agricultural awareness unit for fifth graders. Unpublished documents available from the University of Wisconsin-Extension, Elkhorn, WI.

1993

**Abstracts**

BALDOCK, J.O. and J.L. POSNER. 1993. Cropping systems for improved manure management. American Society of Agronomy meetings. Cincinnati, OH. Nov. 7-12. Agronomy Abstracts p 144.

IRAGAVARAPU, T. K., J. L. POSNER and G. D. BUBENZER. 1993. Study of water and solute movement through soil under natural field conditions. In abstracts of Agricultural Research to Protect Water Quality. Soil and Water Conservation Society meeting held at the Radisson Hotel, Minneapolis, MN Feb. 21-24. p 36.

IRAGAVARAPU, T. K., J. L. POSNER and L. BUNDY. 1993. Soil nitrate levels under three cash grain rotations in southern Wisconsin. In abstracts of Agricultural Research to Protect Water Quality. Soil and Water Conservation Society meeting held at the Radisson Hotel, Minneapolis, MN Feb. 21-24. p36.

MALLORY, E.B. and J.L. POSNER. 1993. Adding a cover crop to cash grain rotations in southern Wisconsin. American Society of Agronomy meetings. Cincinnati, OH. Nov. 7-12. Agronomy Abstracts p 140.

STUTE, J.K. and J.L. POSNER. 1993. Legume cover crops as an N source for corn in an oat-corn rotation. American Society of Agronomy meetings. Cincinnati, OH. Nov. 7-12. Agronomy Abstracts p 288.

**Extension Bulletins**

GUMZ, R.G., W.E. SAUPE, R.M. KLEMME and J.L. POSNER 1993. A preliminary economic comparison of three cash grain rotations. Managing the farm vol. 26:1:1-11. Ag. Economics Dept. UW-Madison, WI.

**Proceedings**

STUTE, J. K., and J. L. POSNER. 1993. Legume cover crops as an N source for corn in an oat-corn rotation. Proc. 1993 Fertilizer, Agronomy and Pest Mgmt. Conf. 32:113-118.

**Publications**

MULDER, T.A. and J.D. DOLL. 1993. Integrating reduced herbicide use with mechanical weeding in corn. Weed Tech. 2:382-389.

STUTE, J.K. and J.L. POSNER. 1993. Legume cover crop options for grain rotations in Wisconsin. Agron. J. 85:1128-1132

**Thesis**

IRAGAVARAPU, T. K. 1993. Monitoring the environmental impacts of alternative cropping systems: studies on water movement, fall soil nitrate levels, and phosphorous and potassium nutrient budgets. Ph.D. Thesis. Agronomy Dept. University of Wisconsin-Madison.

1994

**Abstracts**

DOLL, J.D., T.A. MULDER, J.L. POSNER and M.D. CASLER. 1994. Weed seedbank changes in the Wisconsin integrated cropping systems trial (WICST) after five years. American Society of Agronomy Meeting, Seattle, WA., Nov 13-18. Agronomy Abstracts. p 89.

## APPENDIX I. (Cont.)

GARLYND, M.J., D.E.ROMIG, and R.F. HARRIS. 1994. Characterization of soil health and soil quality of selected sites in Wisconsin. American Society of Agronomy Meeting, Seattle, WA., Nov 13-18. Agronomy Abstracts. p288.

HARRIS, R.F. , M.J. GARLYND and D.E. ROMIG. 1994. Farmer and scientist based scorecards for assessment and monitoring of soil health and quality. North Central Branch Meeting, Am Soc. of Agronomy, Des Moines, IA, Aug 1-3. Agron. Abstr. Appendix 5. p1.

KLEMME, R.M., R. GUMZ, T. MULDER, J. POSNER and W.E. SAUPE. 1994. An economic comparison of three cash grain rotations. American Society of Agronomy Meeting, Seattle, WA., Nov 13-18. Agronomy Abstracts. p 89.

MALLORY, E.B., T.A.MULDER, J.L. POSNER and J.O. BALDOCK. 1994. Performance, economics and adoption of cover crops in Wisconsin cash grain rotations: on-farm trials. American Society of Agronomy Meeting, Seattle, WA., Nov 13-18. Agronomy Abstracts. p 167.

MULDER,T. and J. HALL. 1994. The Wisconsin integrated cropping systems trial - a learning center for studying alternative production strategies. North Central Branch Meeting, Am Soc. of Agronomy, Des Moines, IA, Aug 1-3. Agron. Abstr. Appendix 5. p1.

ROMIG, D.E., M.J. GARLYND, and R.F. HARRIS. 1994. Farmer-based soil health scorecard. American Society of Agronomy Meeting, Seattle, WA., Nov 13-18. Agronomy Abstracts. p288.

#### Extension Bulletins

GUMZ, R.G., W.E. SAUPE, R.M. KLEMME and J.L. POSNER 1994. A four year gross margins comparison of three cash grain rotations. Managing the farm vol. 27:1:1-9. Ag. Economics Dept. UW-Madison, WI.

#### Publications

GARLYND, M. J., A. V. KURAKOV, D. E. ROMIG and R. F. HARRIS. 1994. Descriptive and analytical characterization of soil quality/health. In: Defining Soil Quality for a Sustainable Environment. J. W. Doran et al. (eds). Soil Sci. Soc. Amer. Special Pub. 35:159-168.

HARRIS, R. F. and D. F. BEZDICEK. 1994. Descriptive aspects of soil quality. In: Defining Soil Quality for a Sustainable Environment. J. W. Doran et al. (eds). Soil Sci. Soc. Amer. Special Pub. 35:23-35.

KRAUTH, S.J. and D.K. YOUNG. 1994. First records of Encocephalidae (Hemiptera-Heteroptera) from Wisconsin. Ent. News 105(3):159-160.

MULDER, T.A. and J.D. DOLL. 1994. Reduced input corn weed control: The effects of planting date, early season weed control, and row-crop cultivator selection. J. Prod. Agric. 7:256-260.

STEVENSON, G.W., J. L. POSNER, J. HALL, L. CUNNINGHAM and J. HARRISON. 1994. Radially organized teams: a transition model for addressing challenges in agricultural research and extension in the 1990's. Am. J. Altern. Agric. 9:76-83.

#### Thesis

STUTE, J.K. 1994. Legume cover crops as a nitrogen source for corn. Ph.D. Thesis. Agronomy Dept. University of Wisconsin-Madison.

MALLORY, E.B. 1994. Performance, profitability and adoption of cover crops in Wisconsin cash grain rotations: on-farm trials. M.Sc. Thesis. Agronomy Dept. University of Wisconsin-Madison.

**APPENDIX II. Arlington Agricultural Research Station - 1994 WICST Agronomic Report**  
**D. Mueller and P. Bergum \***

Unlike the past two growing seasons, the 1994 climatic conditions were more favorable. Temperatures were near normal resulting in cumulative growing degree days near the 30 year average (Figure 3). Rainfall was somewhat below average in April and May and well above average in July and August. Crops had adequate moisture the entire cropping season although harvesting the forage in June and July was challenging because of the lack of sun and dry weather. Yields were excellent for corn across all rotations. Wheat and alfalfa yields were good although previous winter-kill damage hurt R4-Hayll yields. Soybean yields were less than yields from other soybean fields at the station. The possible reasons for this are discussed below.

**R1:** Weed and insect control, and plant stands were very good. In addition to the broadcast applications of Dual and Butril, spot applications of Stinger were applied to control patches of Canada Thistle. Corn yields within this rotation were the highest since this trial started (Table 3).

**R2:** Similar to the previous three years, R2 corn yields were greater than yields from R1. In 1994 they averaged approximately 7% higher. This data supports many studies which report increased corn yields following soybeans as compared to corn following corn. Weed and insect control and plant stands were all very good in the corn phase of this rotation. In addition to the broadcast applications of Dual and Butril, spot applications of Stringer were made to control; Canada Thistle.

Drilled soybeans were no-tilled for the first time this year and the results were disappointing. In June, due to poor weed control and plant populations, the decision was made to replant with a 1.4 maturity soybean. Several factors appeared to contribute to this failure including poor seed soil contact, lack of use of a contact herbicide, less than optimum timing for post-emergence herbicide applications, herbicide crop injury and dry weather shortly after planting. Even though no vegetation was apparent at planting, weeds appeared shortly thereafter and there was a consensus among the committee and in particular the two no-till farmer committee members, that we should have used a low rate of roundup as a contact herbicide to control the early flush of weeds. The feeling was that weeds had germinated even though they were difficult to observe. Current plans are to use a contact herbicide for 1995. Windy conditions postponed several attempts at spraying post-emergence herbicides and weeds were at a larger than optimum size when the herbicide was applied. Windy conditions on the Arlington Prairie can severely narrow your window of opportunity for applying chemicals and this must be considered if you are going to a post-emergence program for weed control. After the herbicide application we had a warm dry spell. Broadleaf weeds, particularly Lambsquarter, appeared to be set back but looked like they would survive. Soybean plants suffered some herbicide injury and many plants either died or looked like they would have trouble surviving. As a result of these observations there was a consensus by several people, to till the soybeans under and replant.

**R3:** This past year, we had the good yields for all phases of this rotation. Corn yields were excellent with dramatic increases in yields over previous years. In past years corn yields for R3 were significantly lower than other corn phase rotations, however, in 1994, yields were similar to other corn phase rotations. Mechanical weed control was better than it had been in past years. Weather and other factors may have played a role, but I feel a major influence was the equipment operator. Paul Bergum, on the AARS staff, has had the responsibility of carrying out the mechanical weed management. This past season, he had greater latitude to decide when to rotary hoe and cultivate. Obviously timing is very critical to these systems, and he did an excellent job of deciding when these practices were needed. Despite the improvement in mechanical weed control, in row weeds continue to be difficult to control. Corn in R3 was planted approximately 10% higher (34,000 seeds/A) than corn planted in R1, R2, or R4. Experience from previous years, showed that plant stands were reduced by about 10% due to rotary hoeing and cultivating.

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\* Assistant Superintendent and Field Assistant, Arlington Agricultural Research Station.

Wheat yielded very well this year reflecting better plant stands and little or no winter injury. Following the soybean harvest in 1993, a leveling pass was performed with a disk to prepare a more uniform seedbed. The wheat was then seeded with a drill rather than aerially applied as it had been planted in previous years. Red Clover was frost seeded in March under the wheat but a poor stand established. After the wheat was harvested, it was decided to plant Hairy Vetch. This was planted after preplant tillage on July 29th at a rate of 30 lbs/A.

Yields for the soybean phase of R3 continue to be respectable. Stand establishment and early season weed control were good but later in the season grasses and some broadleaf weeds emerged in row and were not fully controlled. In row weed control continues to be a difficult challenge in both corn and soybeans. Attempting to throw enough soil around the soybean or corn plant to cover weeds and not bury the corn or soybean plant is difficult. In addition many of the weeds in the soybean planting emerged after canopy had developed and it was difficult to cultivate at this time.

Several questions have been raised in regard to management changes in R3. Should we use a starter fertilizer and sidedress additional nitrogen in the corn phase? Should we fertilize the wheat? These are issues our county committees will continue to address.

**R4:** In the corn phase of R4, yields were excellent nearly reaching 200 bu/A. This was the second year that the R4 corn yields were the highest of any rotation. Alfalfa yields were mixed. The first established year alfalfa yields were good reflecting the variable growing season and lack of any winter damage to the alfalfa stand. The second year phase of alfalfa continued to yield below expectations. Significant winterkill occurred over the winter of 92-93 and this phase of the rotation was inter-seeded with perennial rye grass in the spring of 93. Yields in this phase were good for first cut but well below average for the subsequent three cuts. The more favorable growing season allowed for us to return to a four cut system. The past two years we were able to cut only three times due to winter damage and cooler than normal temperatures.

**R5:** Corn yields were the highest of all corn phase rotations. This is in stark contrast to the previous two years where corn yields were significantly below the high input corn rotations. As previously mentioned mechanical weed control was much better this year and in all likelihood this is the reason corn yields were much better in this rotation. Corn was planted approximately 10% higher (34,000 seeds/A) in R5 than R1, R2, or R4. Previous experience has shown that rotary hoeing and cultivating reduced plant populations by about 10%.

As in 1993, the oats were harvested as oatlage. There was a concern about weed competition and its affect on oat yields and grain harvest. In addition many on the committee feel harvesting it as oatlage is as good an alternative as harvesting the oats as grain. Since the station has a need for oatlage, it is the preferred harvesting alternative to grain.

The R5-Hay1 phase yielded very well. Since this phase will be returned to corn next year, it was decided to harvest the alfalfa four times rather than three. In addition the last harvest was taken in late September to maximize the stress to the alfalfa plant going into winter.

**R6:** Animal weight gains for the season averaged 1.6 lb/day and 549 lb grain per acre. Animals averaged 390 lb when they were put on pasture May 2, 1994. After poor weight gains the first month they were supplemented with 5 lb grain/day from June 6 until July 17. Animals could not keep up with early forage growth and excess forage was mechanically harvested May 31. Animals were removed from pasture August 31 when pastures were not producing enough feed to support the animals. Regrowth was harvested October 21. In addition to grazing, a total of 2.16 T/A of hay was harvested from these plots. In 1995 we plan to put out larger animals and feed grain the first two weeks of grazing while animals adapt to the new system.

**APPENDIX III. Lakeland Agricultural Complex - 1994 WICST Agronomic Report**  
**A. Wood\***

For the first time in 4 years, Mother Nature provided an early spring. Field operations started April 7<sup>th</sup> and progressed into planting and finally on to weed control methods. Mother Nature soon turned her hand in May and the first 20 days of June, becoming hot and dry. Rainfall for May was a scant 0.67 inches and 0.49 inches for the first 20 days of June, while the last 10 days provided 3.02 inches of rain. The average temperature for June was 71.8° with several 90°+ days in early June. On the 15<sup>th</sup> of June, if anyone would have told me that we would be harvesting 200+ bushel corn in the fall; I would have thought that they would need to be committed. As it turned out the remainder of the growing season was near perfect for crop production and we did indeed exceed 200 bushels/acre on some systems.

The hot dry weather of May and June stressed the continuous corn (R1) to the extent that there were dramatic visual differences between the R1 system and the corn in the remaining systems. This year 3 of the 4 replications had R1 corn alongside corn of R4. By the 20<sup>th</sup> of June there was 2 feet of height difference in favor of the R4 corn (same hybrid and planting date). Corn in the R2, R3 and R5 systems also were visibly better than R1 corn in height and color.

Soybeans also responded to the excellent weather conditions with R2 yields exceeding 60 bushels/acre and R3 yields of near 50 bushels/acre. Some initial leaf cupping and shortening of the soybean internodes due to herbicide injury did not severely effect yields in R2. Giant Foxtail control in the row became difficult because of tractor tire tracks running very close to the row during the first rotary hoeing of R3 soybeans.

This was the first year that we experienced good wheat yields. I think part of the success is due to drilling the winter wheat instead of aerial seeding and the winter was very good in terms of providing protection to the winter wheat.

Forage rotations in general provided no problems in 1994. Heifer performance (2.0 lbs./day gain) on the intensive rotational grazing plots (R6) performed above the minimum goal of 1.8 lbs./day gain.

Participating in the Weekly WICST Walkabout gave me the opportunity to see how each of the systems responded to both the good and bad of Mother Nature. The real significance of having systems side by side is being able to observe the changes throughout the growing season.

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\* Superintendent at the Lakeland Agricultural Complex

#### **APPENDIX IV. Effect of Cropping System on Nitrate + Nitrate-N Concentration in the Groundwater at the Lakeland Agricultural Complex**

T. K. Iragavarapu\*, T. A. Mulder\*\*, J.O. Baldock\*\*, and J.L. Posner\*\*

Much of the work on the effect of cropping systems on groundwater quality has been conducted in high risk situations such as on sandy soils with significant supplemental irrigation, or where excessively large nitrogen additions have been applied. At the Lakeland site, on a typical midwestern silt-loam soil, the groundwater is usually within 5 to 10 feet of the surface. In the early spring of 1991, PVC wells (1.5 in.i.d.) were installed to a 12-foot depth. The lower 4 feet were perforated. Sampling of the wells has been conducted since that time in the fall of each cropping season. A complete description of this monitoring activity was described in the Second Annual Technical Report (pages 65-75).

As can be seen in the appendix IV table a, nitrate + nitrite-N levels were highest following corn in the cash grain R1 (continuous corn) and R2 (corn-soybean) systems that had applications of commercial nitrogen and lowest in the R6 rotational grazing system. Nitrate + nitrite-N levels were lower in the R3 (corn-soybean-wheat/red clover) system than the the other higher input cash grain systems. In the R4 and R5 dairy systems, the higher levels of nitrate + nitrite-N than in 1993 are evidence of mineralization of nitrogen from the previous alfalfa crop and manure applications. Missing numbers from two of the wells (R3 and R6) reflect the dry fall weather that lowered the water table below the depth of those wells. The cropping systems nitrogen levels appear to be leveling off following the previous downward trend from 1991 through 1993. Although the numbers are still well above the two check wells (last two rows), all the samples in 1994 were below the safe limit of 45ppm (nitrate + nitrite N).

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\* Postdoctoral Research Associate, Southern Experiment Station, Waseca, MN.

\*\* Project manager, interim Project Coordinator and Project statistician, and Project Coordinator, respectively.

APPENDIX IV. Table a. Nitrate + Nitrate-N Concentration in the Groundwater at the LAC: 1991-1994.

| Field ID#       | Treatment #  | water collection dates |         |          |          |
|-----------------|--------------|------------------------|---------|----------|----------|
|                 |              | 12/10/91               | 12/9/92 | 11/23/93 | 11/23/94 |
|                 |              | ----- ppm -----        |         |          |          |
| 101             | 1            | 41.5                   | 39.7    | 29.2     | 21.3     |
| 210             | 1            | 48.5                   | 44.2    | 42.0     | 27.1     |
| 303             | 1            | 21.3                   | 36.4    | 28.5     | 18.0     |
| Mean            |              | 37.1                   | 40.3    | 33.2     | 22.1     |
| Crop            | cont. Corn   | C                      | C       | C        | C        |
| 108             | 2            | 60.5                   | 47.8    | 45.6     | 49.8     |
| 203             | 2            | 14.0                   | 20.0    | 18.7     | 19.1     |
| 304             | 2            | 20.1                   | 20.1    | 16.4     | 14.8     |
| Mean            |              | 31.5                   | 29.3    | 26.9     | 27.9     |
| Crop            | C-Sb Sb      | Sb                     | C       | Sb       | C        |
| 111             | 6            | 43.8                   | 18.4    | 14.5     | --       |
| 208             | 6            | 28.6                   | 38.4    | 21.3     | 16.3     |
| 306             | 6            | 42.3                   | 23.8    | 23.1     | 19.1     |
| Mean            |              | 38.2                   | 26.9    | 19.6     | 17.7     |
| Crop            | Sb-W/rc-C    | Sb                     | W/rc    | C        | Sb       |
| 102             | 8            | 15.1                   | 4.8     | 2.9      | 10.3     |
| 209             | 8            | 6.8                    | 14.4    | 20.1     | 25.3     |
| 305             | 8            | 10.3                   | 5.7     | 9.0      | 14.3     |
| Mean            |              | 10.7                   | 8.3     | 10.7     | 16.6     |
| Crop            | C-A-A-A      | A                      | A       | A        | C        |
| 105             | 12           | 15.4                   | 10.8    | 10.4     | 14.8     |
| 207             | 12           | 49.7                   | 38.7    | 26.1     | 28.1     |
| 309             | 12           | 7.3                    | 8.3     | 13.3     | 14.7     |
| Mean            |              | 24.1                   | 19.3    | 16.6     | 19.2     |
| Crop            | O/A-A-C      | O/A                    | A       | C        | O/A      |
| 104             | 14           | 21.3                   | 21.4    | 18.4     | 21.1     |
| 213             | 14           | 2.2                    | 2.8     | 3.3      | 2.2      |
| 314             | 14           | 63.2                   | 30.0    | 16.1     | --       |
| Mean            |              | 28.9                   | 18.1    | 12.6     | 11.7     |
| Crop            | Rot. grazing | *                      | RG      | RG       | RG       |
| 1s <sup>1</sup> | -            | 31.1                   | 2.1     | 2.32     | 2.8      |
| 1d <sup>2</sup> | -            | 6.9                    | 10.6    | ND       | 4.2      |

\* Red Clover/Grass removed as hay 1991, grazed 1992 - 1994

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

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

ND = no detection

## APPENDIX V. WICST P and K Fertility Budgets by Rotation (1989-1994)

T.K. Iragavarapu\*, T.A. Mulder\*\*, J.O. Baldock\*\*, and J.L. Posner\*\*

During the past 30 years, high-input systems have resulted in a build-up of soil fertility on many conventional farms. On the other hand, most scientists believe that low- or zero-input systems will mine the soil and ultimately reach an equilibrium at an uneconomically low yield level. The cropping systems in the WICST include BMP (Best Management Practice) inputs and the zero-input extreme, hence it was decided to monitor soil fertility levels with routine soil testing.

In 1990, 1991, and 1992 five 1.5" diameter soil cores were taken per plot and bulked. Sampling was done at 0-6", 6-12", 12-24", and 24-36" every fall. A more complete description of this monitoring activity was presented in the Second Technical Report (pg 60-64). Starting in 1993, it was decided to sample all four depths only once in each cycle (in the fall of the corn phase), but to continue sampling the 0-6" depth every year. It was also decided that three samples per plot would be submitted to the laboratory for chemical analysis. Each sample would be made up of six cores taken in sets of three (at 0", 8", and 16" on a line perpendicular to the crop rows). This set of three samples would help mask the field variability caused by previous bands of starter fertilizer.

Tables of the treatment-by-year means (tables a and b) for the soil test levels and net plant nutrient inputs (tables c and d) are included at the end of this appendix. Interestingly, phosphorus soil test levels (Bray-I extract) have increased in 1994 compared to 1993 in all rotations except in R4 and R5 dairy rotations at Lakeland. At both sites, however, phosphorus soil test levels have dropped since the initiation of the experiment except in the continuous corn (R1) and corn-soybean (R2) rotations at Lakeland. The initial available P levels were well above (ARS-89 ppm; LAC-62 ppm) the optimum (20 ppm). Because of the high fertility levels, BMPs have dictated that P and K additions should be minimized. Consequently, additions in the cash grain rotations have been less than removal so it is not surprising that soil test levels are dropping toward the recommended levels. In the dairy rotations however, the additions of manure result in P inputs that are somewhat greater than off take. Nevertheless, the soil test levels are dropping in those rotations too; probably because the nutrient inputs are in an organic form which may not be as easily extracted by the soil test procedures.

As with phosphorus, the initial potassium levels at both sites (ARS-237 ppm; LAC-187 ppm) were well above the optimum (90 ppm). Again, the soil test levels are dropping in all the rotations. The drop in soil test K is more in the dairy rotations at the Arlington site.

In summary, the treatment mean soil P and K levels are beginning to show some interesting trends and difference. However, extreme caution should be exercised in using those data until they are subjected to rigorous statistical analyses.

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\* Postdoctoral Research Associate, Southern Experiment Station, Waseca, MN.

\*\* Project manager, interim Project Coordinator and Project Statistician, and Project Coordinator, respectively.

APPENDIX V. Table a. WICST Soil Test Results(0-6") 1989-1994 Arlington Agricultural Research Station. Samples collected after crop harvest.

| Year   | Crop            |          |          |          |     |     | Phosphorus |    |    |     |    |    | Potassium |     |     |     |     |     |
|--------|-----------------|----------|----------|----------|-----|-----|------------|----|----|-----|----|----|-----------|-----|-----|-----|-----|-----|
|        | 89              | 90       | 91       | 92       | 93  | 94  | 89         | 90 | 91 | 92  | 93 | 94 | 89        | 90  | 91  | 92  | 93  | 94  |
| System | ----- ppm ----- |          |          |          |     |     |            |    |    |     |    |    |           |     |     |     |     |     |
| R1     | <i>f</i>        | C        | C        | C        | C   | C   | 105        | -  | -  | 93  | 84 | 91 | 257       | -   | -   | 219 | 295 | 228 |
| R2     | <i>f</i>        | Sb       | C        | Sb       | C   | Sb  | 98         | -  | -  | 79  | 65 | 68 | 199       | -   | -   | 239 | 229 | 183 |
| R2     | <i>f</i>        | <i>f</i> | Sb       | C        | Sb  | C   | -          | 88 | -  | 89  | 78 | 89 | -         | 283 | -   | 198 | 264 | 214 |
| R3     | <i>f</i>        | Sb       | W/c      | C        | Sb  | W/c | 105        | -  | -  | 69  | 64 | 68 | 236       | -   | -   | 189 | 251 | 182 |
| R3     | <i>f</i>        | <i>f</i> | Sb       | W/c      | C   | Sb  | -          | 69 | -  | -   | 57 | 63 | -         | 200 | -   | -   | 226 | 171 |
| R3     | <i>f</i>        | <i>f</i> | <i>f</i> | Sb       | W/c | C   | -          | -  | 57 | -   | 53 | 57 | -         | -   | 195 | -   | 201 | 142 |
| R4     | <i>f</i>        | A        | A        | A        | C   | A   | 115        | -  | -  | 94  | 85 | 99 | 277       | -   | -   | 175 | 216 | 171 |
| R4     | <i>f</i>        | <i>f</i> | A        | A        | A   | C   | -          | 93 | -  | 105 | 81 | 92 | -         | 256 | -   | 203 | 170 | 154 |
| R4     | <i>f</i>        | <i>f</i> | <i>f</i> | A        | A   | A   | -          | -  | 66 | -   | 62 | 65 | -         | -   | 214 | -   | 170 | 128 |
| R4     | <i>f</i>        | <i>f</i> | <i>f</i> | <i>f</i> | A   | A   | -          | -  | -  | 77  | 71 | 72 | -         | -   | -   | 189 | 224 | 155 |
| R5     | <i>f</i>        | O/a      | A        | C        | O/a | A   | 110        | -  | -  | 103 | 88 | 93 | 250       | -   | -   | 198 | 236 | 172 |
| R5     | <i>f</i>        | <i>f</i> | O/a      | A        | C   | O/a | -          | 70 | -  | 72  | 67 | 72 | -         | 211 | -   | 181 | 210 | 144 |
| R5     | <i>f</i>        | <i>f</i> | <i>f</i> | O/a      | A   | C   | -          | -  | 84 | -   | 73 | 83 | -         | -   | 293 | -   | 211 | 173 |
| R6     | <i>f</i>        | P        | P        | P        | P   | P   | 114        | -  | -  | -   | 82 | 84 | 266       | -   | -   | -   | 186 | 157 |

\* 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)

**APPENDIX V. Table b. WICST Soil Test Results(0-6") 1989-1994 Lakeland Agricultural Complex. Samples collected after crop harvest.**

| Year   | Crop     |          |          |          |     |     | Phosphorus |    |    |    |    |    | Potassium |     |     |     |     |     |
|--------|----------|----------|----------|----------|-----|-----|------------|----|----|----|----|----|-----------|-----|-----|-----|-----|-----|
|        | 89       | 90       | 91       | 92       | 93  | 94  | 89         | 90 | 91 | 92 | 93 | 94 | 89        | 90  | 91  | 92  | 93  | 94  |
| System | -----    |          |          |          |     |     | ppm        |    |    |    |    |    | -----     |     |     |     |     |     |
| R1     | <i>f</i> | C        | C        | C        | C   | C   | 66         | -  | -  | 58 | 52 | 95 | 196       | -   | -   | 205 | 185 | 219 |
| R2     | <i>f</i> | Sb       | C        | Sb       | C   | Sb  | 59         | -  | -  | 52 | 47 | 64 | 178       | -   | -   | 186 | 158 | 177 |
| R2     | <i>f</i> | <i>f</i> | Sb       | C        | Sb  | C   | -          | 65 | -  | 53 | 43 | 71 | -         | 193 | -   | 204 | 196 | 188 |
| R3     | <i>f</i> | Sb       | W/c      | C        | Sb  | W/c | 64         | -  | -  | 46 | 39 | 56 | 195       | -   | -   | 173 | 181 | 161 |
| R3     | <i>f</i> | <i>f</i> | Sb       | W/c      | C   | Sb  | -          | 54 | -  | -  | 36 | 49 | -         | 153 | -   | -   | 173 | 147 |
| R3     | <i>f</i> | <i>f</i> | <i>f</i> | Sb       | W/c | C   | -          | -  | 49 | -  | 39 | 46 | -         | -   | 183 | -   | 179 | 152 |
| R4     | <i>f</i> | A        | A        | A        | C   | A   | 76         | -  | -  | 57 | 51 | 50 | 148       | -   | -   | 121 | 145 | 150 |
| R4     | <i>f</i> | <i>f</i> | A        | A        | A   | C   | -          | 59 | -  | 52 | 52 | 43 | -         | 179 | -   | 171 | 165 | 150 |
| R4     | <i>f</i> | <i>f</i> | <i>f</i> | A        | A   | A   | -          | -  | 37 | -  | 36 | 69 | -         | -   | 149 | -   | 181 | 180 |
| R4     | <i>f</i> | <i>f</i> | <i>f</i> | <i>f</i> | A   | A   | -          | -  | -  | 59 | 62 | 52 | -         | -   | -   | 181 | 203 | 150 |
| R5     | <i>f</i> | O/a      | A        | C        | O/a | A   | 53         | -  | -  | 41 | 52 | 47 | 163       | -   | -   | 161 | 205 | 142 |
| R5     | <i>f</i> | <i>f</i> | O/a      | A        | C   | O/a | -          | 68 | -  | 55 | 48 | 45 | -         | 213 | -   | 159 | 181 | 130 |
| R5     | <i>f</i> | <i>f</i> | <i>f</i> | O/a      | A   | C   | -          | -  | 54 | -  | 46 | 50 | -         | -   | 171 | -   | 200 | 139 |
| R6     | <i>f</i> | P        | P        | P        | P   | P   | 63         | -  | -  | -  | 41 | 46 | 181       | -   | -   | -   | 166 | 132 |

\* 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)

APPENDIX V. Table c. WICST Nutrient Balance 1989-1994- Arlington Agricultural Research Station.

| Year   | Crop             |     |     |     |     | Phosphorus |      |      |      |      | Potassium |       |       |       |       |
|--------|------------------|-----|-----|-----|-----|------------|------|------|------|------|-----------|-------|-------|-------|-------|
|        | 90               | 91  | 92  | 93  | 94  | 1990       | 1991 | 1992 | 1993 | 1994 | 1990      | 1991  | 1992  | 1993  | 1994  |
| System | ----- lb/A ----- |     |     |     |     |            |      |      |      |      |           |       |       |       |       |
| R1     | C                | C   | C   | C   | C   | - 15       | - 14 | - 11 | - 4  | - 7  | - 8       | - 8   | - 6   | - 4   | - 23  |
| R2     | Sb               | C   | Sb  | C   | Sb  | - 21       | - 18 | - 11 | - 6  | - 16 | - 62      | - 12  | - 33  | - 7   | - 48  |
| R2     | f                | Sb  | C   | Sb  | C   | -          | - 23 | - 9  | - 20 | - 7  | -         | - 67  | - 5   | - 69  | - 24  |
| R3     | Sb               | W/c | C   | Sb  | W/c | - 21       | - 16 | - 15 | - 25 | - 16 | - 56      | - 33  | - 19  | - 61  | - 27  |
| R3     | f                | Sb  | W/c | C   | Sb  | -          | - 18 | - 10 | - 12 | - 15 | -         | - 57  | - 17  | - 19  | - 46  |
| R3     | f                | f   | Sb  | W/c | C   | -          | -    | - 14 | - 16 | - 28 | -         | -     | - 42  | - 81  | - 36  |
| R4     | A                | A   | A   | C   | A   | + 34       | - 31 | - 26 | + 55 | + 51 | - 94      | - 296 | - 212 | + 253 | - 161 |
| R4     | f                | A   | A   | A   | C   | -          | + 39 | - 23 | - 23 | + 62 | -         | - 125 | - 212 | - 206 | + 70  |
| R4     | f                | f   | A   | A   | A   | -          | -    | + 41 | - 29 | - 26 | -         | -     | - 13  | - 225 | - 222 |
| R4     | f                | f   | f   | A   | A   | -          | -    | -    | + 45 | - 28 | -         | -     | -     | + 74  | - 282 |
| R5     | O/a              | A   | C   | O/a | A   | + 31       | - 32 | + 32 | + 52 | - 31 | - 122     | - 316 | + 178 | + 73  | - 336 |
| R5     | f                | O/a | A   | C   | O/a | -          | + 27 | - 30 | + 52 | + 33 | -         | + 5   | - 261 | + 146 | - 229 |
| R5     | f                | f   | O/a | A   | C   | -          | -    | + 30 | - 24 | + 24 | -         | -     | - 34  | - 258 | + 35  |
| R6     | P                | P   | P   | P   | P   | + 13       | + 5  | + 16 | + 2  | + 7  | - 213     | - 184 | - 51  | - 1   | - 116 |

\* Nutrient additions by fertilizer or manure and removal by crop harvesting in R1-R5. Nutrient additions from manure, fertilizer, fed hay, and fed grain and removal from live weight gain of animals and harvested hay in R6.

f = filler corn (grown before initiation of each rotation)

APPENDIX V. Table d. WICST Nutrient Balance 1989-1994- Lakeland Agricultural Complex.

| Year   | Crop           |     |     |     |     | Phosphorus |      |      |      |      | Potassium |       |       |       |       |
|--------|----------------|-----|-----|-----|-----|------------|------|------|------|------|-----------|-------|-------|-------|-------|
|        | 90             | 91  | 92  | 93  | 94  | 1990       | 1991 | 1992 | 1993 | 1994 | 1990      | 1991  | 1992  | 1993  | 1994  |
| System | -----lb/A----- |     |     |     |     |            |      |      |      |      |           |       |       |       |       |
| R1     | C              | C   | C   | C   | C   | - 14       | - 16 | - 17 | - 5  | - 9  | - 13      | - 14  | - 20  | - 6   | - 35  |
| R2     | Sb             | C   | Sb  | C   | Sb  | - 15       | - 11 | - 17 | - 6  | - 13 | - 47      | 0     | - 52  | - 6   | - 35  |
| R2     | f              | Sb  | C   | Sb  | C   | -          | - 20 | - 20 | - 17 | - 22 | -         | - 65  | - 23  | - 58  | - 64  |
| R3     | Sb_            | W/c | C   | Sb  | W/c | - 15       | - 8  | - 12 | - 10 | - 23 | - 48      | - 16  | - 18  | - 35  | - 47  |
| R3     | f              | Sb  | W/c | C   | Sb  | -          | - 17 | - 6  | - 11 | - 16 | -         | - 56  | - 6   | - 18  | - 59  |
| R3     | f              | f   | Sb  | W/c | C   | -          | -    | - 19 | - 16 | - 12 | -         | -     | - 59  | - 91  | - 35  |
| R4     | A              | A   | A   | C   | A   | +99        | - 21 | - 25 | - 8  | +135 | +279      | - 214 | - 206 | - 9   | +23   |
| R4     | f              | A   | A   | A   | C   | -          | +122 | - 25 | - 19 | +151 | -         | +257  | - 227 | - 190 | +137  |
| R4     | f              | f   | A   | A   | A   | -          | -    | +20  | - 20 | -23  | -         | -     | +414  | - 176 | - 210 |
| R4     | f              | f   | f   | A   | A   | -          | -    |      | +87  | - 23 | -         | -     | -     | +295  | - 227 |
| R5     | O/a            | A   | C   | O/a | A   | +64        | - 20 | +28  | +146 | - 22 | +183      | - 172 | +409  | +191  | - 215 |
| R5     | f              | O/a | A   | C   | O/a | -          | +53  | - 23 | +145 | +93  | -         | +92   | - 207 | +278  | - 15  |
| R5     | f              | f   | O/a | A   | C   | -          | -    | +36  | - 25 | +88  | -         | -     | +283  | - 230 | +79   |
| R6     | P              | P   | P   | P   | P   | +41        | +16  | - 6  | +1   | +27  | +133      | - 97  | - 1   | +30   | +5    |

\* Nutrient additions by fertilizer or manure and removal by crop harvesting in R1-R5. Nutrient additions from manure, fertilizer, fed hay, and fed grain and removal from live weight gain of animals and harvested hay in R6

f = filler corn (grown before initiation of each rotation)

# APPENDIX VI. Fall Nitrate Monitoring Under Different Cropping Systems (1990-1994)

T.K. Iragavarapu\*, T.A. Mulder\*\*, J.O. Baldock\*\*, and J.L. Posner\*\*

The amount of inorganic N remaining in the soil profile following crop harvest is an important factor that reflects the nitrate leaching potential of a particular field situation (Magdoff, 1991). That is, the accumulated nitrate-nitrogen ( $\text{NO}_3\text{-N}$ ) is often, but not always is subject to significant leaching losses in late fall and early spring. There are two major reasons  $\text{NO}_3\text{-N}$  would be left in the soil after crop uptake has ceased: a) N uptake was less than expected (due to poor soil structure, drought, pest damage, etc), and b) over fertilization (due to overestimation of crop yield, failure to credit the N in manure or previous legume crops, greater mineralization than anticipated, etc.). Minimizing the amount of  $\text{NO}_3\text{-N}$  left in the fall not only reduces the potential for losses to ground and surface water, but it may also increase farm income by avoiding over fertilization. Therefore, monitoring the soil  $\text{NO}_3\text{-N}$  levels under six cropping systems has been an important activity of the WICST.

In 1990, 1991, and 1992 soil samples were collected in 1-foot increments to a depth of 3-ft with a 1.5" diameter probe. Five cores were taken per plot and bulked by depth. A more complete discussion of this monitoring activity is found in the Second Annual Technical Report (pages 52-59). In 1993, the number of cores per plot was increased to six after summer sampling in treatments 1, 8, and 14 to determine the variance components for experimental error and sampling error. In 1994, soil samples were collected to 3-ft in two replications and to only 2-ft in the other two replications. A prediction equation developed based on 1990-93 data for both sites was used to estimate the 3rd foot nitrate level in the two replications that were sampled to 2-ft depth.

The prediction equations used were:

$$\text{ARS : } Y = 2.81 + 0.754x, n=103 \text{ and } r^2 = 0.70$$

$$\text{LAC : } Y = 0.66 + 0.829x, n=106 \text{ and } r^2 = 0.77$$

where Y is 3rd foot  $\text{NO}_3\text{-N}$  content and x is the 2nd foot  $\text{NO}_3\text{-N}$  content (both in lb/A)

The treatment means are given by site and year in the accompanying table 3. In 1992 and 1993 the fall soil  $\text{NO}_3\text{-N}$  levels under most of the treatments were only slightly above the 50 lb  $\text{NO}_3\text{-N/A}$ , which is considered as the background level (Bundy et al., 1992). Thus, most of the rotation phases have not resulted in  $\text{NO}_3\text{-N}$  accumulation that would create a large leaching potential. The possible exceptions were the corn phases of the systems receiving commercial nitrogen fertilizer or dairy manure. As seen in 1994, fall nitrates were highest for corn grown after plowing down 3 year old alfalfa plus 20 t/A of dairy manure (R4) as well as corn following 2 years of alfalfa plus 15 t/A of manure (R5). Fall nitrates were lowest for corn after wheat/red clover without any inorganic fertilizer N additions. These results suggest that the amount of fall nitrates increase as the frequency of corn increases in a rotation and that plowed down alfalfa and manure application results in a surplus of N for the corn and may result in leaching losses.

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\* Former graduate student, currently Postdoctoral Research Associate, Southern Experiment Station, Waseca, MN.

\*\* Project manager, interim Project Coordinator and Project Statistician, and Project Coordinator, respectively.

**APPENDIX VI. Table a. Fall Nitrates in the top 3 ft of the soil at the Arlington Research Station and Lakeland Agricultural Complex sites: 1990-1994\***

| System/Crop              | Arlington Research Station |      |      |      |      | Lakeland Agri Complex |      |      |      |      |
|--------------------------|----------------------------|------|------|------|------|-----------------------|------|------|------|------|
|                          | 1990                       | 1991 | 1992 | 1993 | 1994 | 1990                  | 1991 | 1992 | 1993 | 1994 |
| ----- lb/A -----         |                            |      |      |      |      |                       |      |      |      |      |
| <b>Corn:</b>             |                            |      |      |      |      |                       |      |      |      |      |
| R1 Continuous Corn       | 87                         | 48   | 97   | 102  | 160  | 198                   | 132  | 86   | 134  | 129  |
| R2 Corn after Soybeans   | -                          | 41   | 105  | 105  | 172  | -                     | 125  | 78   | 57   | 81   |
| R3 Corn after Red Clover | -                          | -    | 67   | 83   | 102  | -                     | -    | 62   | 59   | 119  |
| R4 Corn after Alfalfa    | -                          | -    | -    | 142  | 170  | -                     | -    | -    | 122  | 215  |
| R5 Corn after Alfalfa    | -                          | -    | 101  | 118  | 156  | -                     | -    | 81   | 80   | 183  |
| <b>Soybean:</b>          |                            |      |      |      |      |                       |      |      |      |      |
| R2 Narrow-row Soybeans   | 78                         | 42   | 74   | 100  | 85   | 55                    | 76   | 86   | 86   | 79   |
| R3 Wide-row Soybeans     | 75                         | 25   | 66   | 89   | 72   | 49                    | 34   | 63   | 86   | 67   |
| <b>Wheat:</b>            |                            |      |      |      |      |                       |      |      |      |      |
| R3 Wheat/Red Clover      | -                          | 26   | 48   | 65   | 48   | -                     | 49   | 45   | 56   | 61   |
| <b>Alfalfa:</b>          |                            |      |      |      |      |                       |      |      |      |      |
| R4 DS Alfalfa            | 46                         | 32   | 61   | 80   | 77   | 34                    | 67   | 41   | 78   | 97   |
| R4 Alfalfa Hay I         | -                          | 27   | 49   | 55   | 47   | -                     | 71   | 54   | 71   | 84   |
| R4 Alfalfa Hay II        | -                          | -    | 60   | 69   | 46   | -                     | -    | 63   | 60   | 91   |
| R5 Alfalfa with Oats     | -                          | -    | -    | 103  | 68   | -                     | -    | -    | 53   | 73   |
| R5 Alfalfa               | -                          | -    | -    | 84   | 69   | -                     | -    | -    | 78   | 77   |
| <b>Pasture:</b>          |                            |      |      |      |      |                       |      |      |      |      |
| R6                       | -                          | -    | -    | 91   | 59   | -                     | -    | -    | 66   | 108  |

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

#### References

- Bundy, L.G., M.A. Schmitt, and G.W. Randall. 1992. Predicting N fertilizer needs for corn in humid regions: Advances in the upper midwest. pp73-89. In B.R. Brock and K.R. Kelly (eds.) Predicting fertilizer needs for corn in humid regions. Bull Y-226. National Fertilizer and Environmental Research Center, Tennessee Valley Authority, Muscle Shoals, AL 35660.
- Magdoff, F. 1991. Managing nitrogen for sustainable corn systems: problems and possibilities. Amer. J. Alter. Agric. 6(1):3-8.

APPENDIX VII. Energy Use and Output/Input Ratios for the Six WICST Cropping Systems 1990-1994.<sup>1/</sup>

| Rotation | Crop                             | Crops or<br>completed rotations<br>-- # -- | Mean 1990 - 1994 |      |                   |      |
|----------|----------------------------------|--------------------------------------------|------------------|------|-------------------|------|
|          |                                  |                                            | Energy input/yr  |      | Output/input avq. |      |
|          |                                  |                                            | ARS              | LAC  | ARS               | LAC  |
|          |                                  |                                            | -- Mcal/A --     |      | - ratio -         |      |
| 1        | Corn                             | 5                                          | 2686             | 1979 | 5.5               | 6.6  |
| 2        | Soybean                          | 5                                          | 565              | 505  | 11.6              | 14.1 |
|          | Corn                             | 4                                          | 2619             | 2013 | 6.0               | 6.6  |
|          | System average <sup>2/</sup>     | 4                                          | 1615             | 1262 | 6.8               | 8.0  |
| 3        | Soybean/Wheat                    | 5                                          | 507              | 528  | 11.5              | 11.0 |
|          | Wheat/Red Clover                 | 4                                          | 874              | 865  | 9.5               | 8.1  |
|          | Corn                             | 3                                          | 2059             | 1267 | 5.8               | 8.3  |
|          | System average                   | 3                                          | 1199             | 915  | 7.1               | 8.6  |
| 4        | Direct Seeded Alfalfa            | 5                                          | 1715             | 1477 | 8.6               | 2.3  |
|          | Alfalfa I                        | 4                                          | 737              | 702  | 22.9              | 19.9 |
|          | Alfalfa II                       | 3                                          | 945              | 775  | 14.8              | 16.9 |
|          | Corn                             | 2                                          | 1894             | 1286 | 9.1               | 7.9  |
|          | System average                   | 2                                          | 1317             | 1094 | 11.1              | 7.2  |
| 5        | Oats/Alfalfa                     | 5                                          | 1039             | 1007 | 11.1              | 8.2  |
|          | Alfalfa I                        | 4                                          | 709              | 786  | 28.5              | 17.3 |
|          | Corn                             | 3                                          | 2689             | 1426 | 5.1               | 8.5  |
|          | System average                   | 3                                          | 1464             | 1077 | 10.5              | 10.3 |
| 6        | Rotational Grazing <sup>3/</sup> | 5                                          | 629              | 649  | 23.0              | 19.2 |

<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> Forage harvested mechanically until animals began grazing in 1992 at LAC and 1993 at ARS; with grazing animals, energy output calculated using forage production, either harvested mechanically or an estimation of forage consumed by grazing animals.

## APPENDIX VIII.A. ARLINGTON AGRICULTURAL RESEARCH STATION WICST INPUT/OUTPUT DATA - 1994

Corn Treatments

| Crop-94<br>Prev Crop<br>Rotation<br>Treatment | Cont. Corn<br>Corn<br>R1<br>1                                                                                                                             | Corn<br>Soybean<br>R2<br>2                                                                                         | Corn<br>Wheat/RC<br>R3<br>4             | Corn<br>Alfalfa II<br>R4<br>8                      | Corn<br>Alfalfa I<br>R5<br>13                      |
|-----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|-----------------------------------------|----------------------------------------------------|----------------------------------------------------|
| Primary<br>Tillage                            | Chisel Plow<br>11/9/93                                                                                                                                    | No-till                                                                                                            | Chisel Plow<br>Sweeps<br>11/9/93        | Chisel Plow<br>Sweeps<br>11/9/93                   | Chisel Plow<br>Sweeps<br>11/9/93                   |
| Secondary<br>Tillage                          | Disk 4/25/94<br>Soil Finisher<br>4/26/94                                                                                                                  | None                                                                                                               | Disk 4/25/94<br>Soil Finisher<br>5/5/94 | Disk 4/25/94<br>Soil Finisher<br>4/26/94           | Disk 4/25/94<br>Soil Finisher<br>5/5/94            |
| Planted<br>Variety<br>Rate                    | 4/26/94<br>Pioneer 3563<br>31,500                                                                                                                         | 4/26/94<br>Pioneer 3563<br>31,500                                                                                  | 5/5/94<br>Pioneer 3751<br>34,000        | 4/26/94<br>Pioneer 3563<br>31,500                  | 5/5/94<br>Pioneer 3751<br>34,000                   |
| Fertilizer<br>Starter                         | 100 lb<br>6-24-24                                                                                                                                         | 100 lb<br>6-24-24                                                                                                  | None                                    | 100 lb<br>6-24-24                                  | None                                               |
| Nitrogen                                      | 118 lb N/a <sup>1/</sup><br>as 82-0-0<br>6/23/94                                                                                                          | 120 lb N/a<br>as 82-0-0<br>6/23/94                                                                                 | None                                    | None                                               | None                                               |
| Manure                                        | None                                                                                                                                                      | None                                                                                                               | None                                    | 20 Ton/a<br>11/7/93                                | 15 Ton/a<br>11/7/93                                |
| Pesticides                                    | pre 5/5/94<br>Dual 2 pt/a<br>postmerge<br>Buctril 1 pt/a<br>6/1/94<br>post spot trt<br>Stinger .5 pt/a<br>6/8/94<br>Counter 15G<br>9 lb/a<br>with planter | pre 5/5/94<br>Dual 1.3 pt/a<br>postmerge<br>Buctril 1 pt/a<br>6/1/94<br>post spot trt<br>Stinger .5 pt/a<br>6/8/94 | None                                    | Buctril 1 pt/a<br>6/1/94<br>postmerge              | None                                               |
| Rotary Hoe                                    | None                                                                                                                                                      | None                                                                                                               | #1 5/14/94<br>#2 5/19/94                | None                                               | #1 5/14/94<br>#2 5/19/94                           |
| Cultivation<br>S-tine                         | 6/11/94                                                                                                                                                   | 7/5/94                                                                                                             | 5/27/94<br>6/4/94<br>6/11/94            | 6/11/94                                            | 5/27/94<br>6/4/94<br>6/11/94                       |
| No-till                                       | 6/18/94                                                                                                                                                   | 6/18/94                                                                                                            | 6/18/94                                 | 6/18/94                                            | 6/18/94                                            |
| Harvest                                       | 10/21/94                                                                                                                                                  | 10/21/94                                                                                                           | 10/21/94                                | 10/21/94                                           | 10/21/94                                           |
| Yield                                         | 178 bu/a                                                                                                                                                  | 190 bu/a                                                                                                           | 188 bu/a                                | 197 bu/a                                           | 199 bu/a                                           |
| Fall<br>Practices                             | Chisel Plow<br>11/7/94                                                                                                                                    | None                                                                                                               | Chisel Plow<br>11/7/94                  | 20 T/a manure<br>11/3/94<br>Chisel Plow<br>11/7/94 | 15 T/a manure<br>11/3/94<br>Chisel Plow<br>11/7/94 |
| Crop-95                                       | Corn                                                                                                                                                      | NR Soybean                                                                                                         | WR Soybean                              | D.S. Alfalfa                                       | Oats/Alfalfa                                       |

<sup>1/</sup> average of four reps - ranged from 80 to 150 lb/a.

APPENDIX VIII.B. ARLINGTON AGRICULTURAL RESEARCH STATION WICST INPUT/OUTPUT DATA - 1994  
Soybean and Wheat Treatments

|                      |                                                                                                                                          |                                                                           |                                                         |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------------------|
| Crop-94              | NR Soybean <sup>1/</sup>                                                                                                                 | WR Soybean/<br>Wheat                                                      | Wheat/<br>Red Clover                                    |
| Prev. Crop           | Corn                                                                                                                                     | Corn                                                                      | Soybean/Wheat                                           |
| Rotation             | R2                                                                                                                                       | R3                                                                        | R3                                                      |
| Treatment            | 3                                                                                                                                        | 6                                                                         | 5                                                       |
| Primary<br>Tillage   | No-till                                                                                                                                  | Chisel Plow<br>11/9/93                                                    | None                                                    |
| Secondary<br>Tillage | Chisel 6/15/94<br>Chisel 6/15/94<br>Mulcher 6/15/94                                                                                      | Disk 5/5/94                                                               | Disk 7/28/94<br>Soil Finish 2X 7/29/94                  |
| Planting<br>Date     | 5/3/94<br>6/15/94                                                                                                                        | 5/5/94                                                                    | 10/13/93 Wheat<br>4/2/94 Rd Clov<br>7/29/95 Hairy Vetch |
| Rate/Variety         | 235,000 s/a Kalt. 241                                                                                                                    | 175,000 s/a NK 1990                                                       | 180 lb/a Merrimac Wh                                    |
| Rate/Variety         | 235,000 s/a Kalt. 142                                                                                                                    |                                                                           | 20 lb/a Arlington RC                                    |
| Rate/Variety         |                                                                                                                                          |                                                                           | 30 lb/a Hairy Vetch                                     |
| Fertilizer           | None                                                                                                                                     | None                                                                      | None                                                    |
| Pesticides           | postemerge<br>4 oz/a Pursuit + surf.<br>5/31/94<br>.12 oz/a Pinnacle + surf.<br>2 qt/A 28%<br>6/2/94<br>1 pt/a Reflex + surf.<br>7/12/94 | None                                                                      | None                                                    |
| Rotary Hoe           | None                                                                                                                                     | #1 5/21/94<br>#2 6/5/94                                                   | None                                                    |
| Cultivation          | None                                                                                                                                     |                                                                           | None                                                    |
| S-tine               |                                                                                                                                          | 5/27,6/4, 6/22/94                                                         |                                                         |
| No-till              |                                                                                                                                          | 6/18/94                                                                   |                                                         |
| Harvest              | 10/13/94                                                                                                                                 | 10/13/94                                                                  | 7/19/94                                                 |
| Yield                | 43 bu/a                                                                                                                                  | 44 bu/a                                                                   | 61 bu/a wheat<br>1.43 T/a straw                         |
| Fall<br>Practices    | None                                                                                                                                     | Disk 10/14/94<br>No-till drill<br>Glacier w.wheat<br>180 lb/a<br>10/14/94 | Chisel plow (sweeps)<br>11/8/94                         |
| Crop-95              | Corn                                                                                                                                     | Wheat/Red Clover                                                          | Corn                                                    |

<sup>1/</sup> Soybeans tilled and replanted due to severe herbicide damage to soybean plants.

APPENDIX VIII.C. ARLINGTON AGRICULTURAL RESEARCH STATION WICST INPUT/OUTPUT DATA - 1994  
Forage Treatments

|                      |                                                       |                                                                        |                                                                |                                          |                                                                        |                                                                        |
|----------------------|-------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------|------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|
| Crop-94              | D. Seeded<br>Alfalfa                                  | Estab.<br>Alfalfa I                                                    | Estab.<br>Alfalfa II                                           | Oats/<br>Alfalfa                         | Estab.<br>Alfalfa I                                                    | Pasture                                                                |
| Prev. Crop           | Corn                                                  | D.S. Alf.                                                              | Alfalfa I                                                      | Corn                                     | Oats/Alf.                                                              | Pasture                                                                |
| Rotation             | R4                                                    | R4                                                                     | R4                                                             | R5                                       | R5                                                                     | R6                                                                     |
| Treatment            | 7                                                     | 10                                                                     | 9                                                              | 12                                       | 11                                                                     | 14                                                                     |
| Primary<br>Tillage   | Chisel Plow<br>11/9/93                                |                                                                        |                                                                | Chisel Plow<br>11/9/93                   |                                                                        |                                                                        |
| Secondary<br>Tillage | Disk 4/18/94<br>Soil Finisher<br>4/18/94              |                                                                        |                                                                | Disk 4/18/94<br>Soil Finisher<br>4/18/94 |                                                                        |                                                                        |
| Planting<br>Date     | 4/18/94                                               | 5/1/93                                                                 | 4/7/92<br>4/28/93 <sup>1/</sup>                                | 4/18/94                                  | 5/1/93                                                                 | 4/23/90 C,T,B<br>4/30/92 O,B,T<br>7/31/92 O<br>4/9/93 C <sup>2/</sup>  |
| Variety              | Magnum III                                            | Magnum III                                                             | Magnum III                                                     | Prairie-oats<br>Magnum III-alf.          | Magnum III                                                             | Timothy-Toro<br>Brome-Badger<br>Arl Rd Clov                            |
| Planting<br>Rate     | 15 lb/a                                               |                                                                        |                                                                | 64 lb/a oats<br>15 lb/a alfalfa          |                                                                        | 6 lb/a O gr<br>12 lb/a Br<br>6 lb/a Tim<br>4.5 lb/a O gr<br>12 lb/a RC |
| Fertilizer<br>Manure | 20 ton/a<br>11/7/92                                   | None                                                                   | None                                                           | 15 ton/a<br>11/7/92                      | None                                                                   | grazing                                                                |
| Pesticides           | Eptam 2 qt/a<br>ppi 4/18/94                           | None                                                                   | Roundup 2 qt/a<br>Sufactant 1 pt/a<br>10/10/94                 | None                                     | None                                                                   | None                                                                   |
| Harvest              | 6/25/94 haylage<br>7/26/94 haylage<br>8/30/94 haylage | 6/1/94 haylage<br>6/26/94 haylage<br>8/2/94 haylage<br>8/30/94 haylage | 6/1/94 haylage<br>6/26/94 haylage<br>8/2/94 haylage<br>8/30/94 | 6/17/94 oatlage<br>7/26/94 haylage       | 6/1/94 haylage<br>6/25/94 haylage<br>8/2/94 haylage<br>9/30/94 haylage | grazing<br>5/2 - 8/31/94<br>5/31/94 hylg<br>10/21/94 hylg              |
| Yield                | 3.21 tDM/a                                            | 4.56 tDM/a                                                             | 3.68 tDM/a                                                     | 3.37 tDM/a                               | 5.30 tDM/a                                                             | 2.15 tDM/a<br>549 lb gain/a                                            |
| Fall<br>Practices    | None                                                  | None                                                                   | 20 T/a manure<br>11/3/94                                       | None                                     | Roundup 2 qt/a<br>Surf. 1 pt/a<br>10/10/94<br>15 T/a manure<br>11/3/94 | None                                                                   |
| Crop-95              | Alfalfa I                                             | Alfalfa II                                                             | Corn                                                           | Alfalfa I                                | Corn                                                                   | Pasture                                                                |

<sup>1/</sup> No-till drill

T9 105 - whole plot 5 lb/a perennial rye, 203, 308, 406 - whole plots 5 lb/a perennial rye + 8 lb/a Magnum alfalfa

<sup>2/</sup> Seeding with hand operated cyclone seeder.

## APPENDIX IX.A. LAKELAND AGRICULTURAL COMPLEX WICST INPUT/OUTPUT DATA - 1994

Corn Treatments

| Crop-93<br>Prev Crop<br>Rotation<br>Treatment | Cont. Corn<br>Corn<br>R1<br>1                                                                                                                                                                                                                         | Corn<br>Soybean<br>R2<br>2                                         | Corn<br>Wheat/RC<br>R3<br>4       | Corn<br>Alfalfa II<br>R4<br>8                                                                        | Corn<br>Alfalfa I<br>R5<br>13                        |
|-----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|-----------------------------------|------------------------------------------------------------------------------------------------------|------------------------------------------------------|
| Primary<br>Tillage                            | Chisel Plow<br>11/8/93                                                                                                                                                                                                                                | No-till                                                            | Mulchmaster<br>Sweeps<br>11/11/93 | Chisel Plow<br>Sweeps<br>11/11/93                                                                    | Mulchmaster<br>Sweeps<br>11/11/93                    |
| Secondary<br>Tillage                          | Mulchmaster<br>5/3,5/4/94                                                                                                                                                                                                                             | None                                                               | Mulchmaster<br>4/20,5/3,5/4/94    | Mulchmaster<br>5/3,5/4/94                                                                            | Mulchmaster<br>4/20,5/3,5/4/94                       |
| Planted<br>Variety<br>Rate                    | 5/4/94<br>Pioneer 3563<br>32,000                                                                                                                                                                                                                      | 5/4/94<br>Pioneer 3563<br>32,000                                   | 5/4/94<br>Pioneer 3571<br>35,000  | 5/4/94<br>Pioneer 3563<br>32,000                                                                     | 5/4/94<br>Pioneer 3751<br>35,000                     |
| Fertilizer<br>Starter                         | 132 lb/a<br>4-10-10                                                                                                                                                                                                                                   | 132 lb/a<br>4-10-10                                                | None                              | 300 lb/a<br>4-10-10                                                                                  | None                                                 |
| Nitrogen                                      | 46.5 lb N/a<br>5/4/94<br>23.8 lb N/a<br>5/17/94<br>as 28%                                                                                                                                                                                             | 46.5 lb N/a<br>5/4/94<br>59.6 lb N/a<br>5/17/94<br>as 28%          | None                              |                                                                                                      | None                                                 |
| Manure                                        | None                                                                                                                                                                                                                                                  | None                                                               | None                              | 20 Ton/a<br>11/9/93                                                                                  | 15 Ton/a<br>11/9/93                                  |
| Pesticides                                    | pre 5/15/94<br>Extrazine IIDF<br>2.5 lb/a<br>Dual 8E 2.5 pt/a<br>post spot trt 6/1/94<br>Stinger 5.5 oz/a<br>postemerg 6/10/94<br>Accent .67oz/a<br>Buctril 1.5 pt/a<br>Surf. .4 qt/a<br>Amm Sulf 2.5 lb/a<br>Counter 15G 6.5 lb/a<br>7" planter band | pre 5/13/94<br>Roundup 1 qt/a<br>Dual 8E 1.3 pt/a<br>Surf. .4 qt/a | None                              | pre 5/15/94<br>Dual 8E 1.3 pt/a<br>6/10/94<br>postemerg 6/10/94<br>Buctril 1.5 pt/a<br>surf. .4 qt/a | None                                                 |
| Rotary Hoe                                    | None                                                                                                                                                                                                                                                  | None                                                               | #1 5/16/94<br>#2 5/20/94          | None                                                                                                 | #1 5/16/94                                           |
| Cult.<br>S-tine<br>No-till                    | 6/15/94                                                                                                                                                                                                                                               | 6/21/94                                                            | 6/9/94<br>6/21/94                 | 6/15/94                                                                                              | 6/9/94<br>6/21/94                                    |
| Harvest                                       | 11/2/94                                                                                                                                                                                                                                               | 11/2/94                                                            | 11/2/94                           | 11/2/94                                                                                              | 11/2/94                                              |
| Yield                                         | 177 bu/a                                                                                                                                                                                                                                              | 184 bu/a                                                           | 187 bu/a                          | 211 bu/a                                                                                             | 198 bu/a                                             |
| Fall<br>Practices                             | Chisel plow<br>11/17/94                                                                                                                                                                                                                               | None                                                               | Chisel plow<br>11/17/94           | 20 T/a manure<br>11/11/94<br>Chisel plow<br>11/17/94                                                 | 15 T/a manure<br>11/11/94<br>Chisel plow<br>11/17/94 |
| Crop-95                                       | Corn                                                                                                                                                                                                                                                  | NR Soybean                                                         | WR Soybean                        | D.S. Alfalfa                                                                                         | Oats/Alfalfa                                         |

## APPENDIX IX.B. LAKELAND AGRICULTURAL COMPLEX WICST INPUT/OUTPUT DATA - 1994

Soybean and Wheat Treatments

|                      |                                                                                                                                            |                                                                                    |                                                 |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------|
| Crop-94              | Narrow Row<br>Soybean                                                                                                                      | Wide Row<br>Soybean                                                                | Wheat/<br>Red Clover                            |
| Prev. Crop           | Corn                                                                                                                                       | Corn                                                                               | Soybean                                         |
| Rotation             | R2                                                                                                                                         | R3                                                                                 | R3                                              |
| Treatment            | 3                                                                                                                                          | 6                                                                                  | 5                                               |
| Primary              | No-till                                                                                                                                    | Chisel Plow<br>11/8/93                                                             | None                                            |
| Secondary<br>Tillage | None                                                                                                                                       | Mulchmaster<br>5/5,5/6/94                                                          | None                                            |
| Planting<br>Date     | 5/6/94                                                                                                                                     | 5/6/94                                                                             | 10/8/93 Wheat<br>3/19/94 Rd Clov <sup>1/</sup>  |
| Rate/Variety         | 230,000 s/a Kalt. 241                                                                                                                      | 175,000 s/a NK 1990                                                                | 150 lb/a Merrimac Wh<br>23.7 lb/a Medium RC     |
| Fertilizer           | None                                                                                                                                       | None                                                                               | None                                            |
| Pesticides           | pre 5/13/94<br>Roundup 1 qt/a<br>Surf. .4 qt/a<br>post 6/13/94<br>Pinnacle .25 oz/a<br>Assure II 10 oz/a<br>COC .8 qt/a<br>Amm Sulf 2 lb/a | None                                                                               | None                                            |
| Rotary Hoe           | None                                                                                                                                       | #1 5/16/94<br>#2 5/20/94<br>#3 5/31/94                                             | None                                            |
| Cultivation          | None                                                                                                                                       | No-till 6/9/94<br>No-till 6/30/94<br>No-till 7/13/94                               | None                                            |
| Harvest              | 10/13/94                                                                                                                                   | 10/13/94                                                                           | 7/28/94                                         |
| Yield                | 63 bu/a                                                                                                                                    | 47 bu/a                                                                            | 51 bu/a wheat<br>1.86 T/a straw<br>.38 tDM/a RC |
| Fall<br>Practices    | None                                                                                                                                       | Tilloll 2X<br>10/16/94<br>No-till drill<br>Glacier w.wheat<br>175 lb/a<br>10/17/94 | Chisel plow (sweeps)<br>11/18/94                |
| Crop-95              | Corn                                                                                                                                       | Wheat/Red Clover                                                                   | Corn                                            |

<sup>1/</sup> Seeded with cyclone seeder on ATV.

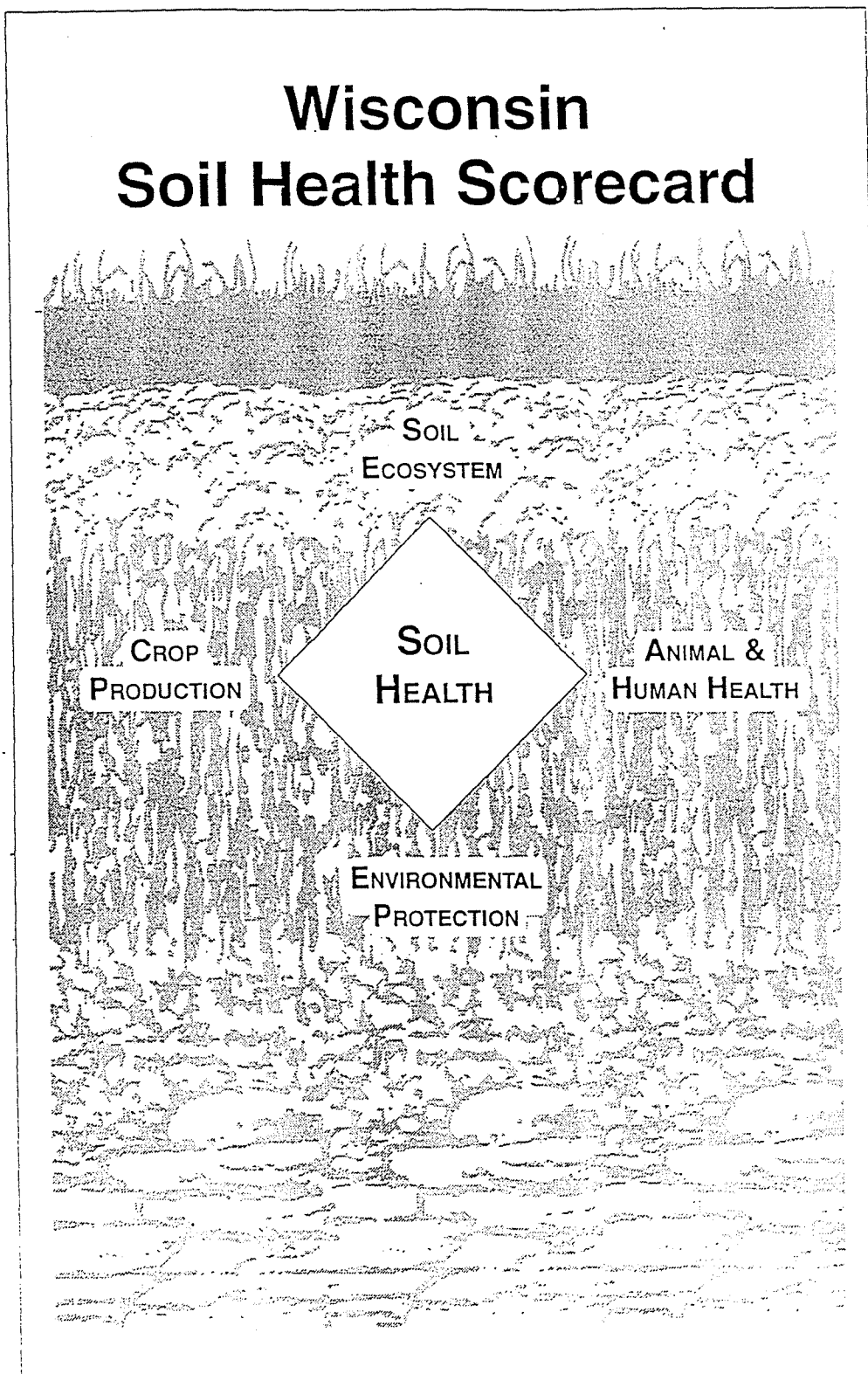
## APPENDIX IX.C. LAKELAND AGRICULTURAL COMPLEX WICST INPUT/OUTPUT DATA - 1994

Forage Treatments

|                       |                                |                                                 |                                                     |                                              |                                                 |                                             |
|-----------------------|--------------------------------|-------------------------------------------------|-----------------------------------------------------|----------------------------------------------|-------------------------------------------------|---------------------------------------------|
| Crop-94               | D. Seeded<br>Alfalfa           | Estab.<br>Alfalfa I                             | Estab.<br>Alfalfa II                                | Oats/<br>Alfalfa                             | Estab.<br>Alfalfa I                             | Pasture                                     |
| Prev. Crop            | Corn                           | D.S. Alf.                                       | Alfalfa I                                           | Corn                                         | Oats/Alf.                                       | Pasture                                     |
| Rotation              | R4                             | R4                                              | R4                                                  | R5                                           | R5                                              | R6                                          |
| Treatment             | 7                              | 10                                              | 9                                                   | 12                                           | 11                                              | 14                                          |
| Primary<br>Tillage    | Chisel Plow<br>11/8/93         |                                                 |                                                     | Chisel Plow<br>12/19/92                      |                                                 |                                             |
| Secondary<br>Tillage  | Mulchmaster<br>4/7, 4/10/94    |                                                 | 5/9, 5/10/94                                        | Mulchmaster                                  |                                                 |                                             |
| Planting<br>Date      | 4/11/94                        | 5/20/93 <sup>1/</sup>                           | 5/4/92<br>5/8/93 <sup>2/</sup>                      | 4/11/94                                      | 5/11/93                                         | 5/30/90<br>4/7/94 <sup>3/</sup>             |
| Variety               | Magnum III                     | Magnum III                                      | Magnum III                                          | Pioneer-oats<br>Magnum III-alf.              | Magnum III                                      | Timothy-Toro<br>Brome-Badger<br>RC-Marathon |
| Planting<br>Rate      | 21.6 lb/a                      |                                                 |                                                     | 80 lb/a oats<br>18 lb/a alf                  |                                                 | 20 lb/a Arl RC                              |
| Fertilizer<br>Manure  | 20 ton/a<br>11/9/93            | None                                            | None                                                | 15 ton/a<br>11/9/93                          | None                                            | grazing                                     |
| Pesticides            | Eptam 2.75 qt/a<br>ppi 4/10/94 | None                                            | None                                                | None                                         | None                                            | None                                        |
| Harvest <sup>4/</sup> | 7/6/94 haylage<br>9/19/94 hay  | 6/2/94 haylage<br>7/6/94 haylage<br>9/19/94 hay | 6/2/94 haylage<br>7/6/94 haylage<br>9/19/94 haylage | 8/15/94 oatlage <sup>5/</sup><br>9/19/94 hay | 6/2/94 haylage<br>7/6/94 haylage<br>9/19/94 hay | began grazing<br>4/26/94                    |
| Yield                 | 2.37tDM/a                      | 4.13 tDM/a                                      | 4.04 tDM/a                                          | 2.96 tDM/a oat.<br>0.53 tDM/a hay.           | 3.82 tDM/a                                      | 850 lbt gain/a                              |
| Fall<br>Practices     | None                           | None                                            | 20 T/a manure<br>11/11/94                           | None                                         | 15 T/a manure<br>11/11/94                       | None                                        |
| Crop-94               | Alfalfa I                      | Alfalfa II                                      | Corn                                                | Alfalfa I                                    | Corn                                            | Pasture                                     |

<sup>1/</sup> Replanted areas where alfalfa was damaged by wet spring weather.<sup>2/</sup> No-till drilled into alfalfa plots with 12 lb/a Medium red clover, 3 lb/a annual rye grass.<sup>3/</sup> Seeded with cyclone seeder on ATV.<sup>4/</sup> Third cutting damaged by rain and chopped back onto field.<sup>5/</sup> Harvested as oatlage when weed growth following wet weather prevented combining for grain.

## APPENDIX XI. Wisconsin Soil Health Scorecard



Romig, D.E., M.J. Garlynd, and R.F. Harris. 1996. Farmer-based assessment of soil quality: A soil health scorecard. In J.W. Doran and A.J. Jones (ed.) Handbook of methods for assessment of soil quality. In press.

## SCORECARD INSTRUCTIONS

The Wisconsin Soil Health Scorecard assesses a soil's health as a function of soil, plant, animal and water properties identified by farmers. The scorecard is a field tool to monitor and improve soil health based on field experience and a working knowledge of a soil.

- The scorecard is best completed near or just following harvest. Periodic and seasonally expressed properties (soil smell, seed germination, infiltration, etc.) should be recorded during the growing season to increase its effectiveness. When scoring your soil's health, please:

1. **Read each question completely. Focus only on the property being graded.**
2. **Choose the answer that best describes the property and enter score between 0 and 4 in the box provided. The scale corresponds to healthy (3-4 pts.), impaired (1.5-2.5), and unhealthy (0-1).**
3. **Answer as many questions as possible to ensure an accurate evaluation of your soil's health.**
4. **Enter NA (not answered) if a question does not apply to your farm, and go to the next question.**

The scorecard was developed by the University of Wisconsin's Soil Health Program<sup>1</sup> from structured interviews with 28 farmers in conjunction with the Wisconsin Integrated Cropping System Trial<sup>2</sup>. Superscript numbers indicate the relative importance and rank of the property. Farmers who were interviewed operated conventional and low-input cash grain and dairy farms typical of southeast Wisconsin. Typical soils are formed in silt over glacial till or outwash. Applying this scorecard to other locations should be done with caution. Modification of the scorecard for other cropping systems and other regions requires structured input from additional farmers.

<sup>1</sup> Supported by the UW Center for Integrated Agricultural Systems, and Agricultural Technology and Family Farm Institute; the WI Department of Agriculture, Trade, and Consumer Protection's Sustainable Agriculture Program; the WI Fertilizer Research Council; the WI Liming Materials Research Council; and the Kellogg Foundation through the Wisconsin Integrated Cropping System Trial.

<sup>2</sup> D. E. Romig, M. J. Garlynd, and R. F. Harris. 1994. Farmer-based soil health scorecard. p. 288. Agronomy abstracts. ASA, Madison, WI.

Please go to next page >>>

**SOIL** - Questions refer primarily to the plow layer

**Descriptive Properties**
**SCORE**
**1. EARTHWORMS<sup>3</sup>**

- 0 Little sign of worm activity
- 2 Few worm holes or castings
- 4 Worm holes and castings numerous

**2. EROSION<sup>4</sup>**

- 0 Severe erosion, considerable topsoil moved, gullies formed
- 2 Moderate erosion, signs of sheet and rill erosion, some topsoil blows
- 4 Little erosion evident, topsoil resists erosion by water or wind

**3. TILLAGE EASE<sup>5</sup>**

- 0 Plow scours hard, soil never works down
- 2 Soil grabs plow, difficult to work, needs extra passes
- 4 Plow field in higher gear, soil flows & falls apart, mellow

**4. SOIL STRUCTURE<sup>7</sup>**

- 0 Soil is cloddy with big chunks, or dusty and powdery
- 2 Soil is lumpy or does not hold together
- 4 Soil is crumbly, granular

**5. COLOR (MOIST)<sup>13</sup>**

- 0 Soil color is tan, light yellow, orange, or light gray
- 2 Soil color is brown, gray, or reddish
- 4 Soil color is black, dark brown, or dark gray

**6. COMPACTION<sup>11</sup>**

- 0 Soil is tight & compacted, cannot get into it, thick hardpan
- 2 Soil packs down, thin hardpan or plow layer
- 4 Soil stays loose, does not pack, no hardpan

**7. INFILTRATION<sup>12</sup>**

- 0 Water does not soak in, sits on top or runs off
- 2 Water soaks in slowly, some runoff or puddling after a heavy rain
- 4 Water soaks right in, soil is spongy, no ponding

Please go to next page &gt;&gt;&gt;

**SOIL** - Questions refer primarily to the plow layer

**Descriptive Properties**
**SCORE**
**8. DRAINAGE<sup>6</sup>**

- 0 Poor drainage, soil is often waterlogged or oversaturated  
 2 Soil drains slowly, slow to dry out  
 4 Soil drains at good rate for crops, water moves through

**9. WATER RETENTION<sup>14</sup>**

- 0 Soil dries out too fast, droughty  
 2 Soil is drought prone in dry weather  
 4 Soil holds moisture well, gives and takes water easily

**10. DECOMPOSITION<sup>16</sup>**

- 0 Residues and manures do not break down in soil  
 2 Slow rotting of residues and manures  
 4 Rapid rotting of residue and manures

**11. SOIL FERTILITY<sup>20</sup>**

- 0 Poor fertility, nutrients do not move, potential is very low  
 2 Fertility not balanced, needs help  
 4 Fertility is balanced, nutrients available, potential is high

**12. FEEL<sup>21</sup>**

- 0 Soil is mucky, greasy, or sticky  
 2 Soil is smooth or grainy, compresses when squeezed  
 4 Soil is loose, fluffy, opens up after being squeezed

**13. SURFACE CRUST<sup>24</sup>**

- 0 Soil surface is hard, cracked when dry, compacted  
 2 Surface is smooth with few holes, thin crust  
 4 Surface does not crust, porous, digs easily with hand

**14. SURFACE COVER<sup>23</sup>**

- 0 Soil surface is clean, bare, residue removed or buried following harvest  
 2 Surface has little residue, mostly buried  
 4 Surface is trashy, lots of mulch left on top or cover crop used

Please go to next page &gt;&gt;&gt;

**SOIL** - Questions refer primarily to the plow layer

**Descriptive Properties**
**SCORE**
**15. HARDNESS<sup>28</sup>**

- 0 Soil is hard, dense or solid, will not break between two fingers
- 2 Soil is firm, breaks up between fingers under moderate pressure
- 4 Soil is soft, crumbles easily under light pressure

**16. SMELL<sup>25</sup>**

- 0 Soil has a sour, putrid or chemical smell
- 2 Soil has no odor or a mineral smell
- 4 Soil has an earthy, sweet, fresh smell

**17. SOIL TEXTURE<sup>31</sup>**

- 0 Texture is a problem, extremely sandy, clayey or rocky
- 2 Texture is too heavy or too light, but presents no problem
- 4 Texture is loamy

**18. AERATION<sup>35</sup>**

- 0 Soil is tight, closed, almost no pores
- 2 Soil is dense, has a few pores
- 4 Soil is open, porous, breaths

**19. BIOLOGICAL ACTIVITY<sup>36</sup>**

- 0 Soil shows little biological activity, no signs of soil microbes
- 2 Moderate biological activity, some wormlike threads, moss, algae
- 4 Biological activity high, white wormlike threads, moss, algae plentiful

**20. TOPSOIL DEPTH<sup>38</sup>**

- 0 Subsoil is exposed or near surface
- 2 Topsoil is shallow
- 4 Topsoil is deep

Please go to next page &gt;&gt;&gt;

**SOIL** - Questions refer primarily to the plow layer

*Analytical properties*
**SCORE**

Values are for typical soils of southeast Wisconsin

**21. ORGANIC MATTER<sup>1</sup>**

- 0 Organic matter less than 2% or greater than 8%
- 2 Organic matter 2 to 4% or 6 to 8%
- 4 Organic matter between 4 and 6%

**22. pH<sup>8</sup>**

- 0 Soil pH less than 6.4 or greater than 7.2
- 2 Soil pH 6.4 to 6.7 or 7.0 to 7.2
- 4 Soil pH between 6.7 and 7.0

**23. SOIL TEST - N, P & K<sup>9</sup>**

- 0 Two or more nutrient levels very low, law of minimum at work
- 2 Soil test values are below recommended levels, need extra inputs
- 4 All nutrient levels at recommended levels

**24. MICRONUTRIENTS<sup>30</sup>**

- 0 Severe shortages of trace minerals (magnesium, zinc, sulfur, boron, etc.)
- 2 Micronutrients at a minimal level or not balanced
- 4 Levels of micronutrients high and balanced

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**PLANTS** - Questions concern typical years with adequate rainfall and temperatures

Descriptive Properties

SCORE

**25. CROP APPEARANCE<sup>2</sup>**

- 0 Overall crop is poor, stunted, discolored, in an uneven stand
- 2 Overall crop is light green, small, in a thin stand
- 4 Overall crop is dark green, large, tall, in a dense stand

**26. NUTRIENT DEFICIENCY<sup>15</sup>**

- 0 Crop shows signs of severe deficiencies (blighted, streaky, spotty, discolored, leaves dry up)
- 2 Crop falls off or discolors as season progresses
- 4 Crop has what it needs, shows little signs of deficiencies

**27. SEED GERMINATION<sup>34</sup>**

- 0 Seed germination is poor, hard for crop to come out of ground
- 2 Germination is uneven, seed must be planted deeper
- 4 Seed comes up right away, good emergence

**28. GROWTH RATE<sup>19</sup>**

- 0 Crop slow to get started, never seems to mature
- 2 Uneven growth, late to mature
- 4 Rapid, even growth, matures on time

**29. ROOTS<sup>17</sup>**

- 0 Plant roots appear unhealthy (brown, diseased, spotted), poorly developed, balled up
- 2 Plant roots are shallow, at hard angles, development limited, few fine roots
- 4 Plant roots are deep, fully developed with lots of fine root hairs

**30. STEMS<sup>40</sup>**

- 0 Stems are short, spindly, lodging often a problem
- 2 Stems are thin, leaning to one side
- 4 Stems are thick, tall, standing, straight

Please go to next page >>>

**PLANTS** - Questions concern typical years with adequate rainfall and temperatures

*Descriptive properties*

**SCORE**

**31. LEAVES<sup>33</sup>**

- 0 Leaves are yellow, discolored, few in number
- 2 Leaves are small, narrow, light green
- 4 Leaves are full, lush, dark green

☐

**32. RESISTS DROUGHT<sup>27</sup>**

- 0 Plants dry out quickly, never completely recover
- 2 Plants suffer in dry weather, slow to recover
- 4 Plants withstand dry weather, fast to recover

☐

**33. RESISTS PESTS AND DISEASE<sup>29</sup>**

- 0 Plants damaged severely by diseases & insects
- 2 Plants stressed by diseases & insects
- 4 Plants tolerate pests & disease well

☐

**34. MATURE CROP<sup>18</sup>**

- 0 Seedhead or pod misshapened, grain is not ripe, shrivelled, poor color
- 2 Seedhead small, unfilled, grain slow to ripen
- 4 Seedhead large, grain full, ripe, with good color

☐

*Analytical Properties*

Values are typical for soils of southeast Wisconsin

**35. YIELD<sup>10</sup>**

- 0 Corn: less than 85 bushel/acre, Alfalfa: less than 2 ton/acre
- 2 Corn: 85 to 130 bushel/acre, Alfalfa: 2 to 6 ton/acre
- 4 Corn: greater than 130 bushel/acre, Alfalfa: greater than 6 ton/acre

☐

**36. FEED VALUE<sup>41</sup>**

- 0 Feed has poor nutritional value (energy, protein, minerals), supplements must be used
- 2 Feed is unbalanced in energy, protein, or minerals, may require supplements
- 4 Feed is balanced, high in nutritional value, supplements used infrequently

☐

Please go to next page >>>

**PLANTS** - Questions concern typical years with adequate rainfall and temperatures

*Analytical Properties*

SCORE

**37. TEST WEIGHT<sup>32</sup>**

- 0 Grain test weight is low, takes a deduction
- 2 Grain test weight is average
- 4 Grain test weight is high

**38. COST OF PRODUCTION AND PROFIT<sup>26</sup>**

- 0 Production and input costs high yet profits are low
- 2 Profits are variable, yields maintained with high input costs
- 4 Profits are dependable, high, yields maintained with low input costs

**ANIMALS** - Questions should not relate to improper housing, poor water or inclement weather.

*Descriptive Properties*

SCORE

**39. HUMAN HEALTH<sup>37</sup>**

- 0 Human health is poor, recurrent health problems, recovery is difficult and long
- 2 Occasional health problems, slow recovery time
- 4 Human health is excellent, resists diseases, long life, quick recovery time

**40. ANIMAL HEALTH<sup>42</sup>**

- 0 Continuous animal health problems, poor performance and production
- 2 Occasional animal health problems, performance average
- 4 Animal health excellent, exceptional performance and production

**41. WILDLIFE<sup>43</sup>**

- 0 Signs of wildlife rare, animals do not appear healthy
- 2 Infrequent signs of wildlife; songbirds, deer, turkey, etc. uncommon
- 4 Wildlife is abundant, gulls behind plow, songbirds, deer, turkey, etc. are common

**WATER***Analytical Properties***SCORE****42. CHEMICALS IN GROUNDWATER<sup>22</sup>**

- 0 Chemicals found in groundwater above allowable levels
- 2 Chemicals found in groundwater below allowable levels
- 4 No chemicals present in groundwater

*Descriptive Properties***43. SURFACE WATER<sup>39</sup>** (open water flowing from fields - lakes, marshes, streams, etc.)

- 0 Surface water is very muddy or slimy
- 2 Surface water is brownish with dirt and silt
- 4 Surface water is clear and clean

Please go to next page &gt;&gt;&gt;

### INTERPRETING THE SOIL HEALTH SCORECARD'S RESULTS

Review the scorecard and tally the number of indicator properties that reside within the three categories of health listed below. Divide the number in each health category by the total number of questions answered (a maximum of 43) and multiply by 100% for the percentage within each category.

| HEALTH<br>CATEGORY                      | NUMBER               | %                    |
|-----------------------------------------|----------------------|----------------------|
| <b>HEALTHY</b><br>(SCORE OF 3 - 4)      | <input type="text"/> | <input type="text"/> |
| <b>IMPAIRED</b><br>(SCORE OF 1.5 - 2.5) | <input type="text"/> | <input type="text"/> |
| <b>UNHEALTHY</b><br>(SCORE OF 0 - 1)    | <input type="text"/> | <input type="text"/> |
| <b>TOTAL</b>                            | <input type="text"/> | <b>100%</b>          |

Scorecard users should examine the distribution of indicator properties within the three categories of health. Ideally, one would prefer to see all of the properties score in the *healthy* category. Even if 90% or more of the indicators you scored are *healthy*, your soil may still have serious problems with the remaining properties. For indicators either in the *impaired* and *unhealthy* categories, careful consideration is necessary to identify what caused the property to be in a less-than-optimum condition. *Impaired* indicator properties should be closely monitored over time to determine whether they are deteriorating or improving. *Unhealthy* properties need immediate attention and corrective action. You may also wish to give higher priority to those properties farmers considered more important as indicated by their relative rank in superscript.

# APPENDIX XI.A. WICST Partial Budgets - Corn (R1 and R2) Arlington - 1994

Rotation: 1 (Continuous Corn)

Crop: Corn

Year: 1994

Site:

Arlington Research Station

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) : |       |      |        |                  |
|------------------------------|-------|------|--------|------------------|
| Product                      | Yield | Unit | Price  | Dollars per acre |
| Corn                         | 178.1 | Bu   | \$1.90 | 338.44           |
| Total                        |       |      |        | \$338.44         |

| II. Direct Costs (\$/Acre) : |        |      |                 |                  |
|------------------------------|--------|------|-----------------|------------------|
| Input                        | Amount | Unit | Price or Factor | Dollars per acre |
| Seed (P3563)                 | 0.39   | Bag  | 76.480          | 30.11            |
| Anhydrous                    | 143.29 | Lb   | 0.102           | 14.54            |
| Starter (6-24-24)            | 100.00 | Lb   | 0.078           | 7.80             |
| Dual                         | 2.00   | Pt   | 7.013           | 14.03            |
| Buctril                      | 1.00   | Pt   | 5.975           | 5.98             |
| Stinger                      | 0.06   | Oz   | 2.828           | 0.17             |
| Counter                      | 9.00   | Lb   | 1.600           | 14.40            |
| Drying (2¢/pt/bu to 15.5%)   | 178.13 | Bu   | 26.45 %         | 38.90            |
| Fuel                         | 8.48   | Gal. | 0.60            | 5.09             |
| Repairs                      | 1.00   | \$   | 16.38           | 16.38            |
| Interest                     | 144.77 | \$   | 0.060           | 8.69             |
| Total                        |        |      |                 | \$156.24         |

III. Gross Margin (\$/Acre) : **\$182.20**

Rotation: 2 (Corn-Soybeans)

Crop: Corn

Year: 1994

Site:

Arlington Research Station

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) : |       |      |        |                  |
|------------------------------|-------|------|--------|------------------|
| Product                      | Yield | Unit | Price  | Dollars per acre |
| Corn                         | 190.2 | Bu   | \$1.90 | 361.29           |
| Total                        |       |      |        | \$361.29         |

| II. Direct Costs (\$/Acre) : |        |      |                 |                  |
|------------------------------|--------|------|-----------------|------------------|
| Input                        | Amount | Unit | Price or Factor | Dollars per acre |
| Seed (P3563)                 | 0.39   | Bag  | 76.480          | 30.11            |
| Anhydrous                    | 146.34 | Lb   | 0.102           | 14.85            |
| Starter                      | 100.00 | Lb   | 0.078           | 7.80             |
| Dual                         | 1.30   | Pt   | 7.013           | 9.12             |
| Buctril                      | 1.00   | Pt   | 5.975           | 5.98             |
| Stinger                      | 0.04   | Oz   | 2.828           | 0.12             |
| Drying (2¢/pt/bu to 15.5%)   | 190.15 | Bu   | 27.91 %         | 47.15            |
| Fuel                         | 4.96   | Gal. | 0.60            | 2.98             |
| Repairs                      | 1.00   | \$   | 14.28           | 14.28            |
| Interest                     | 132.39 | \$   | 0.060           | 7.94             |
| Total                        |        |      |                 | \$140.33         |

III. Gross Margin (\$/Acre) : **\$220.95**

# APPENDIX XI.A. WICST Partial Budgets - Soybeans(R2 and R3) Arlington - 1994

Rotation: 2 (Corn-Soybeans)

Crop: Soybeans (NR)

Year: 1994

Site: Arlington Research Station

Plots: Average across 4 plots

| I. Gross Returns (\$/Acre) : |       |      |        | Dollars  |
|------------------------------|-------|------|--------|----------|
| Product                      | Yield | Unit | Price  | per acre |
| Soybeans                     | 42.7  | Bu   | \$5.05 | 215.76   |
| Total                        |       |      |        | \$215.76 |

| II. Direct Costs (\$/Acre) : |        |      |                 | Dollars  |
|------------------------------|--------|------|-----------------|----------|
| Input                        | Amount | Unit | Price or Factor | per acre |
| Seed (KB241)                 | 100.00 | Lb   | 0.330           | 33.00    |
| Seed(KB142)                  | 85.00  | Lb   | 0.310           | 26.35    |
| Pinnacle                     | 0.13   | Oz   | 26.540          | 3.32     |
| Pursuit                      | 4.00   | Oz   | 4.750           | 19.00    |
| Reflex                       | 1.00   | Pt   | 8.250           | 8.25     |
| Surfactant                   | 2.00   | Pt   | 0.484           | 0.97     |
| Innoculum                    | 0.72   | Pkt  | 2.050           | 1.48     |
| 28%                          | 0.50   | Gal  | 0.580           | 0.29     |
| Fuel                         | 7.56   | Gal. | 0.60            | 4.54     |
| Repairs                      | 1.00   | \$   | 13.43           | 13.43    |
| Interest                     | 110.62 | \$   | 0.060           | 6.64     |
| Total                        |        |      |                 | \$117.25 |

III. Gross Margin (\$/Acre) : \$98.51

Rotation: 3 (Corn/Soybeans/Wheat)

Crop: Soybeans/WRow

Year: 1994

Site: Arlington Research Station

Plots: Average across 4 plots

| I. Gross Returns (\$/Acre) : |       |      |        | Dollars  |
|------------------------------|-------|------|--------|----------|
| Product                      | Yield | Unit | Price  | per acre |
| Soybeans                     | 44.43 | Bu   | \$5.05 | 224.35   |
| Total                        |       |      |        | \$224.35 |

| II. Direct Costs (\$/Acre) : |        |      |                 | Dollars  |
|------------------------------|--------|------|-----------------|----------|
| Input                        | Amount | Unit | Price or Factor | per acre |
| Seed (NK1990)                | 110.00 | Lb   | 0.31            | 34.54    |
| Innoculum                    | 1.00   | Bu   | 0.55            | 0.55     |
| Fuel                         | 7.36   | Gal. | 0.60            | 4.42     |
| Repairs                      | 1.00   | \$   | 12.84           | 12.84    |
| Interest                     | 52.35  | \$   | 0.060           | 3.14     |
| Total                        |        |      |                 | \$55.49  |

III. Gross Margin (\$/Acre) : \$168.86

## APPENDIX XI.A. WICST Partial Budgets - Wheat/Red Clover ( R3) and Corn (R3) Arlington - 1994

|                                  |        |        |                            |          |
|----------------------------------|--------|--------|----------------------------|----------|
| Rotation:3 (Corn/Soybeans/Wheat) |        | Site:  | Arlington Research Station |          |
| Crop: Wheat/Clover               |        | Plots: | Average across 4 plots     |          |
| Year:1994                        |        |        |                            |          |
|                                  |        |        |                            |          |
| I. Gross Returns (\$/Acre) :     |        |        |                            | Dollars  |
| Product                          | Yield  | Unit   | Price                      | per acre |
| Wheat @13%                       | 60.95  | Bu     | \$2.93                     | 178.58   |
| Straw                            | 1.44   | T      | \$62.50                    | 89.69    |
|                                  |        |        |                            |          |
| Total                            |        |        |                            | \$268.27 |
|                                  |        |        |                            |          |
| II. Direct Costs (\$/Acre) :     |        |        | Price or                   | Dollars  |
| Input                            | Amount | Unit   | Factor                     | per acre |
| Wheat Seed (Merrimac)            | 2.50   | Bu     | 7.00                       | 17.50    |
| RedClover (Arlington)            | 12.00  | Lb     | 1.33                       | 15.94    |
| Harry Vetch                      | 30.00  | Lb     | 0.70                       | 21.00    |
| Fuel                             | 9.84   | Gal.   | 0.60                       | 5.90     |
| Repairs                          | 1.00   | \$     | 15.40                      | 15.40    |
| Interest                         | 75.74  | \$     | 0.060                      | 4.54     |
|                                  |        |        |                            |          |
| Total                            |        |        |                            | \$80.29  |
|                                  |        |        |                            |          |
| III. Gross Margin (\$/Acre) :    |        |        |                            | \$187.98 |

|                                  |        |        |          |                            |  |
|----------------------------------|--------|--------|----------|----------------------------|--|
| Rotation:3 (Corn/Soybeans/Wheat) |        | Site:  |          | Arlington Research Station |  |
| Crop: Corn                       |        | Plots: |          | Average across 4 plots     |  |
| Year:1994                        |        |        |          |                            |  |
|                                  |        |        |          |                            |  |
| I. Gross Returns (\$/Acre) :     |        |        |          | Dollars                    |  |
| Product                          | Yield  | Unit   | Price    | per acre                   |  |
| Corn @15.5%                      | 188.40 | Bu     | \$1.90   | 357.96                     |  |
| Total                            |        |        |          | \$357.96                   |  |
|                                  |        |        |          |                            |  |
| II. Direct Costs (\$/Acre) :     |        |        | Price or | Dollars                    |  |
| Input                            | Amount | Unit   | Factor   | per acre                   |  |
| Seed (Pioneer 3751-970)          | 0.43   | bag    | 70.730   | 30.06                      |  |
| Stinger                          | 0.08   | Oz     | 2.828    | 0.22                       |  |
| Drying (2¢/pt/bu to 15.5%)       | 188.40 | Bu     | 27.19 %  | 44.04                      |  |
| Fuel                             | 9.41   | Gal.   | 0.60     | 5.64                       |  |
| Repairs                          | 1.00   | \$     | 15.73    | 15.73                      |  |
| Interest                         | 95.69  | \$     | 0.060    | 5.74                       |  |
| Total                            |        |        |          | \$101.43                   |  |
|                                  |        |        |          |                            |  |
| III. Gross Margin (\$/Acre) :    |        |        |          | \$256.53                   |  |

## APPENDIX XI.A. WICST Partial Budgets - D.S. Alfalfa (R4) and Alfalfa I (R4) Arlington - 1994

|                               |        |        |          |                            |
|-------------------------------|--------|--------|----------|----------------------------|
| Rotation:4 (Alf/Alf/Alf/Corn) |        | Site:  |          | Arlington Research Station |
| Crop: Direct Seed Alfalfa     |        | Plots: |          | Average across 4 plots     |
| Year:1994                     |        |        |          |                            |
|                               |        |        |          |                            |
| I. Gross Returns (\$/Acre) :  |        |        |          | Dollars                    |
| Product                       | Yield  | Unit   | Price    | per acre                   |
| Haylage                       | 1.23   | Tdm    | \$25.50  | 31.37                      |
| Haylage                       | 1.30   | Tdm    | \$40.50  | 52.75                      |
| Haylage                       | 0.67   | Tdm    | \$28.25  | 19.00                      |
|                               |        |        |          |                            |
| Total                         | 3.205  |        |          | \$103.11                   |
|                               |        |        |          |                            |
| II. Direct Costs (\$/Acre) :  |        |        | Price or | Dollars                    |
| Input                         | Amount | Unit   | Factor   | per acre                   |
| Alfalfa Seed (MagnumIII)      | 15.00  | Lb     | \$2.30   | 34.50                      |
| Eptam                         | 2.00   | Qt     | \$6.13   | 12.26                      |
| Fuel                          | 17.30  | Gal.   | 0.60     | 10.38                      |
| Repairs                       | 1.00   | \$     | 17.58    | 17.58                      |
| Interest                      | 74.72  | \$     | 0.060    | 4.48                       |
|                               |        |        |          |                            |
| Total                         |        |        |          | \$79.20                    |
|                               |        |        |          |                            |
| III. Gross Margin (\$/Acre) : |        |        |          | \$23.91                    |

|                               |        |                                  |          |          |
|-------------------------------|--------|----------------------------------|----------|----------|
| Rotation:4 (Alf/Alf/Alf/Corn) |        | Site: Arlington Research Station |          |          |
| Crop Alfalfa I                |        | Plots: Average across 4 plots    |          |          |
| Year:1994                     |        |                                  |          |          |
|                               |        |                                  |          |          |
| I. Gross Returns (\$/Acre) :  |        |                                  |          | Dollars  |
| Product                       | Yield  | Unit                             | Price    | per acre |
| Haylage                       | 1.87   | Tdm                              | \$49.50  | 92.69    |
| Haylage                       | 1.46   | Tdm                              | \$45.75  | 66.80    |
| Haylage                       | 0.66   | Tdm                              | \$74.00  | 48.84    |
| Haylage                       | 0.57   | Tdm                              | \$31.50  | 17.96    |
|                               |        |                                  |          |          |
| Total                         | 4.5625 |                                  |          | \$226.28 |
|                               |        |                                  |          |          |
| II. Direct Costs (\$/Acre) :  |        |                                  | Price or | Dollars  |
| Input                         | Amount | Unit                             | Factor   | per acre |
| Fuel                          | 18.44  | Gal.                             | 0.60     | 11.06    |
| Repairs                       | 1.00   | \$                               | 19.52    | 19.52    |
| Interest                      | 30.58  | \$                               | 0.060    | 1.84     |
|                               |        |                                  |          |          |
| Total                         |        |                                  |          | \$32.42  |
|                               |        |                                  |          |          |
| III. Gross Margin (\$/Acre) : |        |                                  |          | \$193.86 |



## APPENDIX XI.A. WICST Partial Budgets - Oats/Alfalfa (R5) and Alfalfa I (R5) Arlington - 1994

Rotation:5 (Corn/Oats-Alf/Alf)

Crop: Oats/A

Year:1994

Site:

Arlington Research Station

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) :  |        |      |                 |                  |
|-------------------------------|--------|------|-----------------|------------------|
| Product                       | Yield  | Unit | Price           | Dollars per acre |
| Oatlage                       | 1.8    | Ton  | \$17.50         | 32.20            |
| Alfalfa                       | 1.5    | Ton  | \$30.25         | 46.36            |
| Total                         |        |      |                 | \$78.56          |
| II. Direct Costs (\$/Acre) :  |        |      |                 |                  |
| Input                         | Amount | Unit | Price or Factor | Dollars per acre |
| Prairie Oat Seed              | 64.00  | Lb   | 0.203           | 12.99            |
| Magnum III (alfalfa)          | 15.00  | Lb   | 3.440           | 51.60            |
| Fuel                          | 13.33  | Gal. | 0.60            | 8.00             |
| Repairs                       | 1.00   | \$   | 14.03           | 14.03            |
| Interest                      | 86.62  | \$   | 0.060           | 5.20             |
| Total                         |        |      |                 | \$91.82          |
| III. Gross Margin (\$/Acre) : |        |      |                 | (\$13.26)        |

Rotation:5 (Corn/Oats-Alf/Alf)

Crop: Alfa I

Year:1994

Site:

Arlington Research Station

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) :  |        |      |                 |                  |
|-------------------------------|--------|------|-----------------|------------------|
| Product                       | Yield  | Unit | Price           | Dollars per acre |
| Haylage                       | 2.19   | Tdm  | \$52.75         | 115.65           |
| Haylage                       | 0.71   | Tdm  | \$37.25         | 26.45            |
| Haylage                       | 1.11   | Tdm  | \$69.75         | 77.25            |
| Haylage                       | 1.29   | Tdm  | \$45.00         | 58.16            |
| Total                         |        |      |                 | \$277.51         |
| II. Direct Costs (\$/Acre) :  |        |      |                 |                  |
| Input                         | Amount | Unit | Price or Factor | Dollars per acre |
| Manure                        | 15.00  | Ton  | \$0.00          | 0.00             |
| Fuel                          | 19.58  | Gal. | 0.60            | 11.75            |
| Repairs                       | 1.00   | \$   | 20.90           | 20.90            |
| Interest                      | 32.65  | \$   | 0.060           | 1.96             |
| Total                         |        |      |                 | \$34.61          |
| III. Gross Margin (\$/Acre) : |        |      |                 | \$242.91         |

## APPENDIX XI.A. WICST Partial Budgets - Corn (R5) Arlington - 1994

Rotation:5 (Corn/Oats-Alf/Alf)

Crop: Corn

Year:1994

Site:

Arlington Research Station

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) :  |         |      |                 |                  |
|-------------------------------|---------|------|-----------------|------------------|
| Product                       | Yield   | Unit | Price           | Dollars per acre |
| Corn @15.5%                   | 198.83  | Bu   | \$1.90          | 377.77           |
| Total -                       |         |      |                 | \$377.77         |
| II. Direct Costs (\$/Acre) :  |         |      |                 |                  |
| Input                         | Amount  | Unit | Price or Factor | Dollars per acre |
| Seed (Pioneer 3751-970)       | 0.43    | Bag  | 70.73           | 30.06            |
| Manure                        | 15.00   | Ton  | 0.00            | 0.00             |
| Drying (2¢/pt/bu to 15.5%)    | 198.825 | Bu   | 26.65 %         | 44.29            |
| Fuel                          | 10.72   | Gal. | 0.60            | 6.43             |
| Repairs                       | 1.00    | \$   | 19.42           | 19.42            |
| Interest                      | 100.21  | \$   | 0.060           | 6.01             |
| Total                         |         |      |                 | \$106.22         |
| III. Gross Margin (\$/Acre) : |         |      |                 | \$271.55         |

# APPENDIX XI.B. WICST Partial Budgets - Corn (R1 and R2) Lakeland - 1994

Rotation: 1 (Continuous Corn)

Crop: Corn

Year: 1994

Site:

Lakeland Ag Complex

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) : |        |      |        | Dollars  |
|------------------------------|--------|------|--------|----------|
| Product                      | Yield  | Unit | Price  | per acre |
| Corn @ 15.5%                 | 177.04 | Bu   | \$1.95 | 345.23   |
| Total                        |        |      |        | \$345.23 |

| II. Direct Costs (\$/Acre) : |        |      |                 | Dollars  |
|------------------------------|--------|------|-----------------|----------|
| Input                        | Amount | Unit | Price or Factor | per acre |
| Seed (Pioneer 3563)          | 0.40   | Bag  | \$76.480        | 30.59    |
| 28%                          | 166.00 | Lb   | \$0.073         | 12.12    |
| 28%                          | 8.00   | Gal  | \$0.780         | 6.24     |
| Starter (4-10-10)            | 132.00 | Lb   | \$0.056         | 7.39     |
| Counter                      | 6.50   | Lb   | \$2.540         | 16.51    |
| Extrazine II DF              | 2.50   | Lb   | \$3.920         | 9.80     |
| Dual 8E                      | 2.50   | Pt   | \$7.190         | 17.98    |
| Buctril                      | 1.50   | Pt   | \$6.110         | 9.17     |
| Accent                       | 0.67   | Oz   | \$27.710        | 18.57    |
| Stinger                      | 0.31   | Oz   | \$2.830         | 0.87     |
| Preference                   | 0.40   | Qt   | \$3.780         | 1.51     |
| Ammonium Sulfate             | 2.50   | Lb   | \$0.350         | 0.88     |
| Drying (2¢/pt/bu to 15.5%)   | 177.04 | Bu   | 18.63 %         | 11.11    |
| Fuel                         | 7.74   | Gal. | 0.83            | 6.44     |
| Repairs                      | 1.00   | \$   | 16.13           | 16.13    |
| Interest                     | 165.28 | \$   | 0.060           | 9.92     |
| Total                        |        |      |                 | \$175.20 |

III. Gross Margin (\$/Acre) : \$170.03

Rotation: 2 (Corn-Soybeans)

Crop: Corn

Year: 1994

Site:

Lakeland Ag Complex

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) : |        |      |        | Dollars  |
|------------------------------|--------|------|--------|----------|
| Product                      | Yield  | Unit | Price  | per acre |
| Corn @ 15.5%                 | 184.39 | Bu   | \$1.95 | 359.56   |
| Total                        |        |      |        | \$359.56 |

| II. Direct Costs (\$/Acre) : |        |      |                 | Dollars  |
|------------------------------|--------|------|-----------------|----------|
| Input                        | Amount | Unit | Price or Factor | per acre |
| Seed (Pioneer 3563)          | 0.40   | Bag  | 76.480          | 30.69    |
| 28% Nitrogen                 | 166.00 | Lb   | 0.073           | 12.12    |
| Starter (4-10-10)            | 132.00 | Lb   | 0.056           | 7.39     |
| Roundup                      | 1.00   | Qt   | 12.700          | 12.70    |
| Surfactant                   | 0.40   | Qt   | 1.083           | 0.43     |
| Dual                         | 1.30   | Pt   | 7.190           | 9.35     |
| 28%                          | 20.00  | Gal  | 0.780           | 15.60    |
| Drying (2¢/pt/bu to 15.5%)   | 184.39 | Bu   | 19.30           | 13.95    |
| Fuel                         | 4.21   | Gal. | 0.83            | 3.50     |
| Repairs                      | 1.00   | \$   | 13.22           | 13.22    |
| Interest                     | 118.95 | \$   | 0.060           | 7.14     |
| Total                        |        |      |                 | \$126.09 |

III. Gross Margin (\$/Acre) : \$233.47

## APPENDIX XI.B. WICST Partial Budgets - Soybeans(R2 and R3) Lakeland - 1994

Rotation: 2 (Corn-Soybeans)

Crop: Soybeans (NR)

Year: 1994

Site:

Plots:

Lakeland Ag Complex

Average across 4 plots

| I. Gross Returns (\$/Acre) : |       |      |        | Dollars  |
|------------------------------|-------|------|--------|----------|
| Product                      | Yield | Unit | Price  | per acre |
| Soybeans @ 13%               | 63.09 | Bu   | \$5.39 | 340.04   |
| Total                        |       |      |        | \$340.04 |

| II. Direct Costs (\$/Acre) : |         |      |                 | Dollars  |
|------------------------------|---------|------|-----------------|----------|
| Input                        | Amount  | Unit | Price or Factor | per acre |
| Seed (Kaltenberg 241)        | 100.000 | Lb   | 0.297           | 29.74    |
| Assure II                    | 10.00   | Oz   | 1.013           | 10.13    |
| Pinnacle                     | 0.25    | Oz   | 27.290          | 6.82     |
| Classic                      | 0.25    | Oz   | 16.490          | 4.12     |
| Roundup                      | 1.00    | Qt   | 12.700          | 12.70    |
| Crop Oil                     | 1.20    | Qt   | 1.083           | 1.30     |
| Innoculum                    | 1.00    |      | 1.500           | 1.50     |
| Ammonium Sulfate             | 2.00    | Lb   | 0.350           | 0.70     |
| Fuel                         | 3.06    | Gal. | 0.83            | 2.55     |
| Repairs                      | 1.00    | \$   | 12.11           | 12.11    |
| Interest                     | 81.67   | \$   | 0.060           | 4.90     |
| Total                        |         |      |                 | \$86.57  |

III. Gross Margin (\$/Acre) :

~~\$253.47~~

Rotation: 3 (Corn/Soybeans/Wheat)

Crop: Soybeans/WRow

Year: 1994

Site:

Plots:

Lakeland Ag Complex

Average across 4 plots

| I. Gross Returns (\$/Acre) : |       |      |        | Dollars  |
|------------------------------|-------|------|--------|----------|
| Product                      | Yield | Unit | Price  | per acre |
| Soybeans @ 13.0%             | 47.4  | Bu   | \$5.39 | 255.32   |
| Total                        |       |      |        | \$255.32 |

| II. Direct Costs (\$/Acre) : |        |      |                 | Dollars  |
|------------------------------|--------|------|-----------------|----------|
| Input                        | Amount | Unit | Price or Factor | per acre |
| Seed NK 1990                 | 80.0   | Seed | 0.31            | 25.12    |
| Innoculum                    | 1.0    | Bu   | 1.14            | 1.14     |
| Fuel                         | 7.18   | Gal. | 0.83            | 5.97     |
| Repairs                      | 1.00   | \$   | 17.20           | 17.20    |
| Interest                     | 49.44  | \$   | 0.060           | 2.97     |
| Total                        |        |      |                 | \$52.40  |

III. Gross Margin (\$/Acre) :

\$202.92

## APPENDIX XI.B. WICST Partial Budgets - Wheat/Red Clover ( R3) and Corn (R3) Lakeland - 1994

Rotation:3 (Corn/Soybeans/Wheat)

Crop: Wheat/Clover

Year:1994

Site:

Lakeland Ag Complex

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) : |       |      |         | Dollars  |
|------------------------------|-------|------|---------|----------|
| Product                      | Yield | Unit | Price   | per acre |
| Wheat @13%                   | 50.86 | Bu   | \$2.97  | 151.04   |
| Straw                        | 1.87  | Ton  | \$60.00 | 111.90   |
| Red Clover                   | 0.38  | Ton  | \$96.25 | 36.33    |
| Total                        |       |      |         | \$299.27 |

| II. Direct Costs (\$/Acre) : |        |      |                 | Dollars  |
|------------------------------|--------|------|-----------------|----------|
| Input                        | Amount | Unit | Price or Factor | per acre |
| Wheat Seed (Merrimac)        | 2.50   | Bu   | 7.00            | 17.50    |
| RedClover (Medium)           | 23.70  | Lb   | 1.44            | 34.13    |
| Fuel                         | 9.41   | Gal. | 0.83            | 7.83     |
| Repairs                      | 1.00   | \$   | 18.39           | 18.39    |
| Interest                     | 77.85  | \$   | 0.060           | 4.67     |
| Total                        |        |      |                 | \$82.52  |

III. Gross Margin (\$/Acre) : \$216.76

Rotation: 3 (Corn/Soybeans/Wheat)

Crop: Corn

Year:1994

Site:

Lakeland Ag Complex

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) : |        |      |        | Dollars  |
|------------------------------|--------|------|--------|----------|
| Product                      | Yield  | Unit | Price  | per acre |
| Corn @ 15.5%                 | 187.01 | Bu   | \$1.95 | 364.66   |
| Total                        |        |      |        | \$364.66 |

| II. Direct Costs (\$/Acre) : |        |      |                 | Dollars  |
|------------------------------|--------|------|-----------------|----------|
| Input                        | Amount | Unit | Price or Factor | per acre |
| Seed (Pioneer 3751)          | 0.44   | Bag  | 70.73           | 30.94    |
| Stinger                      | 1.16   | Oz   | 2.83            | 3.29     |
| Drying (2¢/pt/bu to 15.5%)   | 187.01 | Bu   | 17.85 %         | 8.81     |
| Fuel                         | 9.98   | Gal. | 0.83            | 8.30     |
| Repairs                      | 1.00   | \$   | 17.58           | 17.58    |
| Interest                     | 68.92  | \$   | 0.060           | 4.14     |
| Total                        |        |      |                 | \$73.06  |

III. Gross Margin (\$/Acre) : \$291.60

## APPENDIX XI.B. WICST Partial Budgets - D.S. Alfalfa (R4) and Alfalfa I (R4) Lakeland - 1994

Rotation:4 (Alfalfa(A-A-A)/Corn)

Crop: Direct Seeded

Year:1994

Site:

Lakeland Ag Complex

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) :  |        |      |                 |                  |
|-------------------------------|--------|------|-----------------|------------------|
| Product                       | Yield  | Unit | Price           | Dollars per acre |
| Haylage                       | 1.64   | Tdm  | \$40.25         | 66.01            |
| Alfalfa Bales                 | 0.73   | Tdm  | \$92.75         | 67.48            |
| <hr/>                         |        |      |                 |                  |
| Total                         | 2.37   |      |                 | \$133.49         |
| <hr/>                         |        |      |                 |                  |
| II. Direct Costs (\$/Acre) :  |        |      |                 |                  |
| Input                         | Amount | Unit | Price or Factor | Dollars per acre |
| Alfa Seed (Magnum III)        | 21.60  | Lb   | 3.44            | 74.30            |
| Eptam 7E                      | 2.75   | Qt   | 6.38            | 17.55            |
| Fuel                          | 13.90  | Gal. | 0.83            | 11.56            |
| Repairs                       | 1.00   | \$   | 14.99           | 14.99            |
| Interest                      | 118.39 | \$   | 0.060           | 7.10             |
| <hr/>                         |        |      |                 |                  |
| Total                         |        |      |                 | \$125.50         |
| <hr/>                         |        |      |                 |                  |
| III. Gross Margin (\$/Acre) : |        |      |                 | \$7.99           |

Rotation:4 (Alfalfa(A-A-A)/Corn)

Crop: Alfa I

Year:1994

Site:

Lakeland Ag Complex

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) :  |        |      |                 |                  |
|-------------------------------|--------|------|-----------------|------------------|
| Product                       | Yield  | Unit | Price           | Dollars per acre |
| Haylage                       | 1.94   | Tdm  | \$51.25         | 99.30            |
| Haylage                       | 1.51   | Tdm  | \$52.00         | 78.52            |
| Haylage                       | 0.68   | Tdm  | \$94.00         | 63.69            |
| <hr/>                         |        |      |                 |                  |
| Total                         | 4.13   |      |                 | \$241.50         |
| <hr/>                         |        |      |                 |                  |
| II. Direct Costs (\$/Acre) :  |        |      |                 |                  |
| Input                         | Amount | Unit | Price or Factor | Dollars per acre |
| Fuel                          | 15.12  | Gal. | 0.83            | 12.58            |
| Repairs                       | 1.00   | \$   | 16.54           | 16.54            |
| Interest                      | 29.12  | \$   | 0.060           | 1.75             |
| <hr/>                         |        |      |                 |                  |
| Total                         |        |      |                 | \$30.87          |
| <hr/>                         |        |      |                 |                  |
| III. Gross Margin (\$/Acre) : |        |      |                 | \$210.63         |

# APPENDIX XI.B. WICST Partial Budgets - Alfalfa II (R4) and Corn (R4) Lakeland - 1994

Rotation:4 (Alfalfa(A-A-A)/Corn)

Crop: Alfa 2

Year:1994

Site:

Lakeland Ag Complex

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) : |       |      |         |                  |
|------------------------------|-------|------|---------|------------------|
| Product                      | Yield | Unit | Price   | Dollars per acre |
| Haylage                      | 2.23  | Tdm  | \$44.00 | 98.12            |
| Haylage                      | 1.35  | Tdm  | \$45.75 | 61.76            |
| Haylage                      | 0.47  | Tdm  | \$94.25 | 44.06            |
| Total                        | 4.05  |      |         | \$203.94         |

| II. Direct Costs (\$/Acre) : |        |      |                 |                  |
|------------------------------|--------|------|-----------------|------------------|
| Input                        | Amount | Unit | Price or Factor | Dollars per acre |
| Manure                       | 19.83  | Ton  | 0.00            | 0.00             |
| Fuel                         | 17.96  | Gal. | 0.83            | 14.94            |
| Repairs                      | 1.00   | \$   | 19.00           | 19.00            |
| Interest                     | 33.94  | \$   | 0.060           | 2.04             |
| Total                        |        |      |                 | \$35.98          |

III. Gross Margin (\$/Acre) : **\$167.97**

Rotation:4 (Alfalfa(A-A-A)/Corn)

Crop: Corn

Year:1994

Site:

Lakeland Ag Complex

Plots:

Average across 4 plots

| I. Gross Returns (\$/Acre) : |        |      |        |                  |
|------------------------------|--------|------|--------|------------------|
| Product                      | Yield  | Unit | Price  | Dollars per acre |
| Corn @ 15.5%                 | 211.35 | Bu   | \$1.95 | 412.12           |
| Total                        |        |      |        | \$412.12         |

| II. Direct Costs (\$/Acre) : |        |      |                 |                  |
|------------------------------|--------|------|-----------------|------------------|
| Input                        | Amount | Unit | Price or Factor | Dollars per acre |
| Seed (Pioneer 3563)          | 0.40   | Bag  | 76.480          | 30.69            |
| Starter (4-10-10)            | 300.00 | Lb   | 0.056           | 16.80            |
| Dual 8E                      | 1.30   | Pt   | 7.190           | 9.35             |
| Buctril                      | 1.50   | Pt   | 6.110           | 9.17             |
| Manure                       | 20.75  | Ton  | 0.000           | 0.00             |
| Preference                   | 0.40   | Qt   | 3.780           | 1.51             |
| Stinger                      | 0.09   | Oz   | 2.830           | 0.24             |
| Drying (2¢/pt/bu to 15.5%)   | 211.35 | Bu   | 18.40 %         | 12.24            |
| Fuel                         | 9.03   | Gal. | 0.83            | 7.51             |
| Repairs                      | 1.00   | \$   | 17.41           | 17.41            |
| Interest                     | 104.91 | \$   | 0.060           | 6.29             |
| Total                        |        |      |                 | \$111.20         |

III. Gross Margin (\$/Acre) : **\$300.92**

## APPENDIX XI.B. WICST Partial Budgets - Oats/Alfalfa (R5) and Alfalfa I (R5) Lakeland - 1994

Rotation:5 (Corn/Oats-Alf/Alf)

Crop: Oats/A

Year:1994

Site:

Plots:

Lakeland Ag Complex

Average across 4 plots

| I. Gross Returns (\$/Acre) : |     |       |      |         | Dollars  |
|------------------------------|-----|-------|------|---------|----------|
| Product                      | RFV | Yield | Unit | Price   | per acre |
| Oatlage                      |     | 3.0   | Ton  | \$35.00 | 103.51   |
| Alfalfa Bales                | 171 | 0.5   | Ton  | \$92.00 | 48.76    |
| Total                        |     |       |      |         | \$152.27 |

| II. Direct Costs (\$/Acre) : |        |      |          |        | Dollars  |
|------------------------------|--------|------|----------|--------|----------|
| Input                        | Amount | Unit | Price or | Factor | per acre |
| Prairie Oat Seed             | 56.25  | Lb   | 0.203    |        | 11.42    |
| Magnum III (alfalfa)         | 21.60  | Lb   | 3.440    |        | 74.30    |
| Fuel                         | 9.52   | Gal. | 0.83     |        | 7.92     |
| Repairs                      | 1.00   | \$   | 10.52    |        | 10.52    |
| Interest                     | 104.16 | \$   | 0.060    |        | 6.25     |
| Total                        |        |      |          |        | \$110.41 |

III. Gross Margin (\$/Acre) : \$41.86

Rotation:5 (Corn/Oats-Alf/Alf)

Crop: Alfa I

Year:1994

Site:

Plots:

Lakeland Ag Complex

Average across 4 plots

| I. Gross Returns (\$/Acre) : |     |       |      |         | Dollars  |
|------------------------------|-----|-------|------|---------|----------|
| Product                      | RFV | Yield | Unit | Price   | per acre |
| Haylage                      | 170 | 2.06  | Tdm  | \$41.50 | 85.28    |
| Haylage                      | 164 | 1.38  | Tdm  | \$46.50 | 64.29    |
| Alfalfa Bales                | 155 | 0.39  | Tdm  | \$97.50 | 38.03    |
|                              |     | 3.83  |      |         |          |
| Total                        |     |       |      |         | \$187.59 |

| II. Direct Costs (\$/Acre) : |        |      |          |        | Dollars  |
|------------------------------|--------|------|----------|--------|----------|
| Input                        | Amount | Unit | Price or | Factor | per acre |
| Manure                       | 17.25  | Ton  | \$0.00   |        | 0.00     |
| Fuel                         | 17.96  | Gal. | 0.83     |        | 14.94    |
| Repairs                      | 1.00   | \$   | 19.00    |        | 19.00    |
| Interest                     | 33.94  | \$   | 0.060    |        | 2.04     |
| Total                        |        |      |          |        | \$35.98  |

III. Gross Margin (\$/Acre) : \$151.61

## APPENDIX XI.B. WICST Partial Budgets - Corn (R5) Lakeland - 1994

Rotation:5 (Corn/Oats-Alf/Alf)

Crop: Corn

Year:1994

Site:

LAC

Plots:

Average across 4 plots

## I. Gross Returns (\$/Acre) :

| Product     | Yield  | Unit | Price  | Dollars<br>per acre |
|-------------|--------|------|--------|---------------------|
| Corn @15.5% | 198.25 | Bu   | \$1.95 | 386.59              |
| Total       |        |      |        | \$386.59            |

## II. Direct Costs (\$/Acre) :

| Input                      | Amount | Unit | Price or<br>Factor | Dollars<br>per acre |
|----------------------------|--------|------|--------------------|---------------------|
| Seed (Pioneer P3751)       | 0.438  | Bag  | 70.730             | 30.94               |
| Stinger                    | 0.470  | Oz   | 2.830              | 1.33                |
| Manure                     | 15.100 | Ton  | 0.000              | 0.00                |
| Drying (2¢/pt/bu to 15.5%) | 198.25 | Bu   | 16.90 %            | 5.50                |
| Fuel                       | 10.35  | Gal. | 0.83               | 8.61                |
| Repairs                    | 1.00   | \$   | 20.16              | 20.16               |
| Interest                   | 66.55  | \$   | 0.060              | 3.99                |
| Total                      |        |      |                    | \$70.54             |

## III. Gross Margin (\$/Acre) :

\$316.05

## APPENDIX XII. WICST Corn and Soybean Populations - 1991-1994

## A. Arlington Agricultural Research Station

| <u>Year</u>              | <u>1991</u>             | <u>1992</u> | <u>1993</u> | <u>1994</u> |
|--------------------------|-------------------------|-------------|-------------|-------------|
|                          | ----- plants/acre ----- |             |             |             |
| Corn R1 <sup>1/</sup>    | 27,150                  | 27,750      | 30,850      | 26,950      |
| Corn R2                  | 26,555                  | 28,650      | 30,800      | 27,300      |
| Corn R3                  |                         | 24,700      | 20,800      | 28,050      |
| Corn R4                  |                         |             | 32,300      | 26,000      |
| Corn R5                  |                         |             | 27,500      | 28,000      |
| Soybean R2 <sup>2/</sup> | 132,741                 | 118,547     | 179,823     | 187,488     |
| Soybean R3 <sup>3/</sup> | 98,746                  | 70,350      | 135,250     | 151,091     |

<sup>1/</sup> Corn - all planted at 32,100 seeds/a in 1991 and 1992, and 32,500 seeds/a in 1993; R1,R2 and R4 at 31,500 and R3 and R5 at 34,000 seeds/a in 1994..

<sup>2/</sup> Narrow row soybean - planted at 235,000 seeds/a.

<sup>3/</sup> Wide row soybean - planted at 156,000 seeds/a in 1991 - 1993 and 175,000 seeds/a in 1994.

## B. Lakeland Agricultural Complex

| <u>Year</u>              | <u>1991</u>             | <u>1992</u> | <u>1993</u> | <u>1994</u> |
|--------------------------|-------------------------|-------------|-------------|-------------|
|                          | ----- plants/acre ----- |             |             |             |
| Corn R1 <sup>4/</sup>    | 30,700                  | 29,050      | 30,150      | 28,200      |
| Corn R2                  | 29,500                  | 24,550      | 29,900      | 27,900      |
| Corn R3                  |                         | 24,250      | 21,100      | 30,350      |
| Corn R4                  |                         |             | 31,250      | 30,050      |
| Corn R5                  |                         |             | 21,400      | 30,850      |
| Soybean R2 <sup>4/</sup> | 116,553                 | 97,000      | 139,228     | 143,278     |
| Soybean R3 <sup>6/</sup> | 117,633                 | 122,952     | 86,950      | 113,050     |

<sup>4/</sup> Corn - all planted at 32,000 seeds/a; R3 and R5 at 35,000 seeds/a in 1994.

<sup>5/</sup> Narrow row soybean - planted at 220,000, 196,000, 222,000 and 230,000 seeds/a in 1991, 1992, 1993, and 1994, respectively.

<sup>6/</sup> Wide row soybean - planted at 140,000, 155,000, 156,000, and 175,000 seeds/a in 1991, 1992, 1993, and 1994, respectively.

# APPENDIX XIII. WICST Fall Legume Nitrogen for following Corn Crop - 1991-1994.

## A. Arlington Agricultural Research Station

| 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            | 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> | 1867       | 2.91   | 1233       | 3.36   | 94        |
| 1993               | 5        | Alfalfa <sup>1/</sup> | 1614       | 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        |

## 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        |

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

<sup>2/</sup> 1994 - R3 - Hairy vetch planted after wheat harvest because of thin stand of red clover, R4 - Aug 30 harvest, Oct 10 Roundup application, R5 - Sept 30 harvest.

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

