The Wisconsin Integrated Cropping Systems Trial
Tenth Report - 2003 & 2004

Compiled by Janet Hedtcke and Josh Posner, December 2005
http://www.cias.wisc.edu/wicst/

TABLE OF CONTENTS

List of Tables and Figures iv
Prologue ix
Introduction x
Weather tables . . . . . A
Yield Table C

MAIN SYSTEMS TRIAL 2003 and 2004

✓ Arlington Agricultural Research Station 2003 Agronomic Report
J. Hedtcke, D. Mueller and P. Bergum 1
✓ Arlington Agricultural Research Station 2004 Agronomic Report
J. Hedtcke, D. Mueller and P. Bergum 3
✓ Gross Margins of the WICST cash-grain systems 2003/2004
J. Hedtcke and J. Posner. 5
✓ WICST forage system comparison: production, milk model, gross margins
J. Hedtcke, J. Baldock, and J. Posner. 12
✓ Rotational grazing with dairy heifers on WICST
J. Hedtcke and J. Posner. 19
✓ Benefits of diversifying the c/sb rotation
J. Hedtcke, J. Posner, and J. Baldock 27
✓ Does increased diversity reduce fall nitrates: Data from WICST
J. Posner, J. Hedtcke, and J. Baldock. 31
✓ Evaluation of the Illinois soil nitrogen test for corn production in Wisconsin
J. Osterhaus, L. Bundy and T. Andraski 35
✓ Vertical distribution of phosphorus under long-term cropping trials
J. Meyer and P. Barak. 45
✓ Soil Acidification Processes in Agroecosystems at WICST
M. Avila, J. Posner, D. Laird and P. Barak. 56
✓ WICST Educational Outreach 2003 and 2004
J. Hedtcke 64
✓ The Wisconsin Integrated Cropping Systems Trials: Yields, Yield Variability, And Yield Trends 1990-2002.
J. Posner, J. Baldock, and J. Hedtcke. 66
✓ Weed Seedbank Community Changes on WICST: 1992-2004
H. Kummel, J. Doll, J. Posner, J. Hedtcke, A. Cook. 95
✓ A Note on SOC, SON, and POM on WICST plots
J. Posner L. Cooperband, A. Wells, J. Hedtcke 119

OFF-STATION GRAZING RESEARCH

- ✓ Forage value of midstory shrubs found in degraded oak savannas
  J. Hedtcke, J. Posner, K. Albrecht, M. Rosemeyer. 136
- ✓ Using cattle to reduce oak savanna understory shrub abundance: stocking rates and weight gains
  J. Hedtcke, J. Posner, M. Rosemeyer 148
- ✓ Monitoring cattle performance on pasture at the Krusenbaum farm
  J. Hedtcke, J. Posner, and A. Krusenbaum 155

RECYCLING MANURE NUTRIENTS

LINKING FARMS

- ✓ Production results and nutrient budgets from 2003 and 2004
  A. Cook, J. Posner, J. Hall, J. Hedtcke, G. Sanford. 161
- ✓ Reconnecting dairy and cash-grain farms through shared manure management:
- ✓ Assessing weed pressure from manure applications on corn grain fields
  A. Cook, J. Posner, J. Hall, J. Hedtcke, G. Sanford. 178
- ✓ Manure management on a township scale
  T. Wagner and J. Posner 188

GRASS LEY

- ✓ The grass ley: an alternative forage system for improved manure management
  A. Cook, J. Hedtcke, J. Posner, J. Hall, R. Walgenbach 203

NEW RESEARCH

- ✓ Certified organic grain strips 2004 at ARS and MFAI
  J. Hedtcke, J. Posner, J. Hall, D. Mueller, R. Doetch 223
- ✓ Reintegrating a former dairy farm as a new agricultural enterprise: The Quinney Farm
  J. Hall, J. Posner, J. Hedtcke, J. Lumkuler, R.Jackson, D.Undersander, and G.Brink 234
- ✓ Manure in cash-grain systems: Compaction Studies
  G. Sanford, J. Posner, J. Hedtcke, J. Baldock, A. Cook. 242
- ✓ Using Food Sprays as a supplemental food source for *Harmonia axyridis* (Multicolored Asian Lady Beetle) to enhance suppression of *Aphis glycines* (Soybean Aphid) in soybeans
  H. Kraiss and E. Cullen. 248

APPENDIX

		Page #
I.	WICST Input/Output data at Arlington Research Station (ARS)	
	a. 2003	251
	b. 2004	255
II.	WICST soil test (0-6" depth) at ARS	259
III.	WICST soil depth test results (0-6, 6-12, 12-24, 24-36") at ARS	
	a. Phosphorus	260
	b. Potassium	261
IV.	Corn seeding rate and plant population	
	a. Arlington Research Station	262
	b. Lakeland Ag Complex	262
V.	Soybean seeding rate and plant population	
	a. Arlington Research Station	263
	b. Lakeland Ag Complex	263
VI.	WICST fall legume Nitrogen from crop preceding corn phase at ARS	264
VII.	WICST N additions as purchased fertilizers and cattle manure (1991-2004)	265
VIII.	Fall nitrates in the top 3-ft of soil at ARS (1991-2004)	266
IX.	Weighted relative feed value on WICST forage systems (1992-2004)	267
X.	Total nutrient composition of manure applied to CS4 and CS5 (1990-2004)	268
XI.	List of publications involving WICST project over the duration of the trial	269

LIST OF TABLES & FIGURES

PREFACE

Introduction

Figure 1a Outline of major Land Resource Area 95B and two sites of the WICST. . xi
Figure 1b Schematic drawing of cropping systems in the WICST xi

Table i. Productivity, Economic, and Environmental Comparisons Between Rotations, WICST, 1990. xii
Table 1. Growing season rainfall (in.) at WICST at Arlington . . . . . A
Figure 2. Rainfall (in.) graph from Arlington 2003 and 2004 vs. the long-term norm. . A
Figure 3. Growing Degree Days at Arlington (2004 vs. norm). . . . . B
Figure 4. Growing Degree Days at Arlington (2003 vs. norm). . . . . B
Table 2. Yields from WICST at Arlington Agric. Research Station, 1992-2004. . . . C

MAIN SYSTEMS TRIAL 2003-2004

Table 1. Price comparison: Conventional (CBOT) and organic feed-grade prices. . . 6
Gross Margin Analysis
Table 2. Field worker wage ($/hr) across years in the Lake Region of the Midwest . . 6
Table 3. Owner/Operator labor for cash grain systems. 7
Table 4. Crop yields from WICST cash-grain systems. 8
Table 5. Variable costs of the cash-grain cropping systems on WICST, 2003 & 2004. . 9
Figure 1. Gross Margins of the cash grain systems, 2003-04 10
Table 6. Organic prices for crops sold directly from the field -feed grade for c, sb, w. .10

WICST Forage Systems
Table 1. Seeding year hay yield and quality at ARL 2003 and 2004. 14
Table 2. Established year hay yield and quality at ARL 2003 and 2004. 14
Table 3. Milk 2000 model for WICST forage systems at ARL (2003, 2004). 15
Table 4. Milk91 linear contrasts for WICST forage systems at both sites. 15
Figure 1. 2003 & 2004 forage systems gross margins vs. 10-yr trial average. . . . 16
Table 5. Effect of 'days on pasture' on gross margins. Staring date: May 1. 16
Table 6. Effect of grain supplementation* on GM. 17

WICST Intensive Rotational Grazing
Table 1 WICST pasture seeding dates and rates. 20
Fig. 1. Dry matter production on pasture plots at Arlington from 1993-98 (first 6 yrs) vs. 1999-04 (last 6 yrs). 21
Fig 2. Pasture forage availability at Arlington over the duration of the trial (the line is the mean for each sample period with 90% confidence interval around each mean) . 23
Fig 3. Pasture forage availability at Lakeland during the first four years of the trial (the line is the mean for each sample period with 90% CI around each mean). . . . 23
Table 2. Mechanical hay harvested on pasture plots over the course of the trial at ARS. 24
Table 3. Mechanical hay harvested on pasture plots over the course of the trial at LAC. 24
Fig 4. Pasture crude protein at Arlington over the duration of the trial (the line is the mean for each sample period with 90% confidence interval around each mean). . . . 25
Fig. 5. Pasture crude protein at Lakeland during the first four years of the trial (the line is the mean for each sample period with 90% CI around each mean). 25
Fig 6. Heifer performance under managed grazing compared to confinement with 90% confidence interval around each mean. 26

Benefits of Diversification
Figure 1. Corn and soybean yield comparison across systems with 95% CI (95-03). . 28
Figure 2. Net returns on each system ($/a/yr) over 9 years. 28
Figure 2a Number of endogeic earthworms from the spring soil core sampling in
Figure 3. Fall soil nitrates in top 3-ft of soil in each system (95-03) 29
Fig. 4. Predicted soil loss by RUSLE2 on the 3 systems at varying slope steepness and lengths. 29

Figure 1. Cropping system fall nitrates – mean and 90% CI at Arl (93-03) 32
Figure 2. Cropping system fall nitrates – mean and 90% CI at LAC (93-96) 32
Figure 3. Crop phase fall nitrates – mean and 90% CI at Arl (93-03) 33
Figure 4. Crop phase fall nitrates – mean and 90% CI at Arl (93-96) 33

ISNT

Table 1. Effect of previous crop on preplant (April) soil profile NO_3-N levels. . . . 40
Table 2. Effect of previous crop on preplant (April) soil profile NO_3-N levels. . . . 40
Table 3. Preplant ISNT values. 40
Table 4. Economic optimum N rate for corn silage yield following corn and soybean, Arlington 2003. 41
Table 5. Economic optimum N rate for corn silage yield following corn and soybean, Arlington 2004. 41
Table 6. Economic optimum N rate for corn grain yield following corn and soybean, Arlington 2003 42
Table 7. Economic optimum N rate for corn grain yield following corn and soybean, Arlington 2004. 42
Table 8. Effect of previous crop and corn N rate on end-of-season (October) soil NO_3-N levels (0 to 3 ft) following corn, Arlington 2003. 43
Table 9. Effect of previous crop and corn N rate on end-of-season (October) soil NO_3-N levels (0 to 3 ft) following corn, Arlington 2004. 43
Table 10. Summary of EONR compared to UW recommendations and soil nitrate tests. 44

Vertical P distribution

Table 1. Mean Bray P-1 at three combined depths with the values having been mathematically averaged. 48
Table 2. Average Bray P-1 values for three different depth intervals commonly sampled for soil test phosphorus. Max/Min is equal to the maximum P concentration from 0 to 5 cm and minimum equals the lowest concentration from 26 to 30 cm. Mean denotes the average of the plow layer (0 to 15 cm). 49
Table 3. Fitted and calculated parameters using the Langmuir equation for P sorption data for CS1, plot 109. 51

Soil Acidification

Table 1: Acid/base balance of CS1, CS2, and CS4 at the WICST. 63

Outreach

Table 1. Outreach activities involving the WICST project in 2003 and 2004. 65

Yield Variability

Table 1. Description of the six cropping systems. 85
Table 2. Example of staggered start and cycles for the soybean-corn rotation in CS2. . 86
Table 3a. Means squares for analyses of grain crops over sites. 86
Table 3b. Means squares for analyses of forage crop dry matter yields over sites. . . 86
Table 3c. Mean square for the variance components for analyses of grain and forage crops over sites. 86
Table 4a. Mean corn yields and variability of the annual mean yield at Arlington 1993-2002. 87
Table 4b. Mean corn yields and variability of the annual mean yield at Lakeland 1993-1998. 87
Table 4c. Mean soybean yields and variability of the annual mean yield. 87
Table 4d. Mean winter wheat yields and variability of the annual mean yield. 88
Table 4e. Mean forage yields and variability of the annual mean yield at Arlington. . . 88
Table 4f. Mean forage yields and variability of the annual mean yield at Lakeland. . . 88
Table 4g. Forage quality and estimated milk yield at Arlington. 89
Table 4h. Forage quality and estimated milk yield at Lakeland. 89
Fig. 1a. Mean yields of corn and soybeans by site and system. 90
Fig. 1b. Mean forage yields by site and system. 90

Fig. 2. Lakeland Ag Complex, WI, May plus June Growing Degree Days (GDD, base 50°F) and May plus June rainfall, as a percentage of the 1971-2002 norms 91
Fig. 3. Arlington, WI, May plus June Growing Degree Days (GDD, base 50°F) and May plus June rainfall, as a percentage of the 1971-2002 norms. 91
Fig. 4. Trend of corn yields for CS1 and CS2 over cycles at Arlington (n=8). 92
Fig. 5. Corn yield trends for CS1, CS3, and CS5 over cycles (n=12 for Cycles 1-3 and n=8 for Cycle 4). 92
Fig. 6. Corn yields for CS1 and CS4 over cycles (n=16 for Cycles 1-2, n=8 for Cycle 3). 93
Fig. 7. Trend of soybean yields for CS2 (n=8) and CS3 (n=12) over cycles. 93
Fig. 8. Trend of mean wheat yields for CS3 over cycle (n=12). 94
Fig. 9. Trend of mean 1st year alfalfa yields for CS4 (n=16, except Cycle 2 n=15) and for CS5 (n=12) over cycles. 94

Weed Seed

Table 1- Cropping weed and nutrient management summary by system. 104
Table 2a - Mean of total weed seed/m2 in the spring following corn (n=4). 105
Table 2b – Total weed seed ANOVA of 6 systems initially and in 2004. 105
Table 3 – Percentage of broadleaf to grass of total weed seed per system. 105
Table 4- Linear Contrasts. 106
Figure 1 – CS3 and CS5 total weed seed density divided into grass and brdleaf species. 107
Appendix I- Summary of linear contrasts to determine the influence of agricultural management practices on weed seedbank (1991/92 - 2004). 110
Appendix IIa - Weed community analysis for CS1 from 1991 to 2004. 112
Appendix IIb. Weed community analysis for CS2 from 1992 to 2004. 113
Appendix IIc. Weed community analysis for CS3 from 1992 to 2004. 114
Appendix IId. Weed community analysis for CS4 from 1992 to 2004 115
Appendix IIe. Weed community analysis for CS5 from 1992 to 2004. 116
Appendix IIf. Weed community analysis for CS6 from 1991 to 2004. 117
Appendix III- Weed seedbank changes in WICST at ARL from 1990 to 2004. 118

POM

Fig. 1. Schematic drawing of cropping systems in the WICST. Numbers within circles represent year of rotation. 124
Figure 2a. Arlington Research Station (ARS) Site Map. Location of initial plots. . . 125
Figure 2b. Lakeland Agricultural Complex (LAC) Site Map. Location of initial plots. 125
Table 1. Combined Soil Organic Matter Analysis of WICST Cropping Systems. . . 126
Figure 3a. POM-C Site x System interaction (0-5 cm). 127
Figure 3b. POM-C Site x System interaction (5-10 cm). 127
Table 2. Combined site analysis of systems 1-4 and 6. 128
Figure 4a. POM-N Site by System Interaction (0-5 cm). 129
Figure 4b. POM-N site by system Interaction (5-10 cm). 129
Table 3. SOC, POM and Total N analysis at Arlington (ARS). 130
Table 4. SOC, POM and Total N analysis at Lakeland (LAC). 131
Table 5a. Linear contrasts comparing dairy-based vs. grain based systems effects on soil organic matter characteristics. 132
Table 5b. Linear contrasts comparing the effect of tillage vs no-tillage on soil organic matter characteristics. 133
Table 5c. Linear contrasts comparing the effect of high crop diversity vs. low crop diversity on soil organic matter characteristics. 134
Table 5d. Linear Contrasts comparing the effect of high crop diversity vs low crop diversity on soil organic matter within dairy and grain systems. 135

OFF-STATION GRAZING RESEARCH

Oak savanna

Table 1. Baseline routine soil tests to 15-cm depth from the three study sites. . . . 146
Table 2. Quality of various shrub species from on-farm and YLWA averaged

across replicates and years plus alfalfa checks for comparison. 146
Fig. 1. Percent of time cattle spent grazing various components of degraded oak savanna. 147

Table 1. Baseline routine soil tests to 6-inch (15-cm) depth from the three study sites. 153
Table 2. Cattle rotation schedule at the 3 sites. 153
Table 3. Stocking densities in lbs/a (with number of animals in parenthesis) at the 3 sites. 154
Table 4. Cattle weight gain or loss on treatment and control plots. 154

Krusenbaum Animal Performance

Table 1. Replacement heifers and steers in the study. 156
Table 2. Weighing dates. 156
Table 3. Average daily weight gain as a function of gender. 157
Table 4. Bred heifer body weights—winter weight gains. 158
Table 5. Young heifers body weights—winter weight gains. 158
Table 6. Average daily weight gain of bred and yearling heifers. 158
Table 7. Seasonal effect on weight gain (lb/d) on 2003 and 2004 young stock (including steers). 159

RECYCLING MANURE NUTRIENTS

Linking Farms Production

Table 1. Characterization of 2004 and 2005 On-Farm Sites. 168
Table 2. 2004 and 2005 Season Slurry Manure Analyses, Estimated 1st Year Available Nutrients. 168
Table 3. 2004 and 2005 Season Solid Manure Analyses, Estimated 1st Year Available Nutrients. 169
Table 4. 2004 On-Farm Nitrogen Credits Prior to Pre-Sidedress Nitrate Test (PSNT) and PSNT recommendations. 169
Table 5. 2004 On-Farm Nitrogen Budgets. 169
Table 6. 2004 On-Farm Phosphorus Budgets. 170
Table 7. 2004 On-Farm Potassium Budgets. 170
Table 8. 2003—2004 WICST Slurry Manure Analyses, 1st year Available Nutrients 170
Table 9. 2003-2004 WICST Ncredits prior to nitrate test and nitrate test recs 171
Table 10. 2003 and 2004 WICST N Budgets (lbs/acre) On-Farm Nitrogen Budgets . 171
Table 11. 2003 and 2004 WICST N Budgets (lbs/acre) On-Farm Nitrogen Budgets . 172
Table 12. 2003 and 2004 WICST Phosphorus Budgets. 172
Figure 1. 2003 and 2004 Fall Nitrate Levels (lbs NO_3/3-foot depth). 173
Figure 2. 2004 On-Farm Mean Corn Grain Yields 173
Figure 3. 2004 On-Farm Crude Protein Percentages. 174
Figure 4. 2004 On-Farm Post-Harvest Fall Nitrate Levels. 174
Figure 5 and 5b: 2003 and 2004 WICST Mean Corn Yields. 175
Figures 6a and 6b: 2003 and 2004 WICST Mean Crude Protein Percentages. . . . 175
Figure 7a and 7b: 2003 and 2004 WICST Fall Nitrate Levels (lbs NO_3/3-foot depth). 176

Linking Farms Weeds

Table 1. On-farm Site Information: Manure application and weed control practices. . 183
Table 2. Weed density of baseline quadrats (No Manure, No Weed Control); Pass 2 (~ 46 DAP, weeds m^{-2}). 183
Table 3. Early Emergence, at approximately 18 DAP (Total weeds m^{-2}). 184
Table 4. Weed Density at approximately 46 DAP (Total weeds m^{-2}). 184
Table 5. Weed Biomass at approximately 68 DAP (aboveground DM grams m^{-2}). . .184
Table 6. Species Richness and Diversity at approximately 46 DAP. 185
Table 7: Weed species occurring only in one of the two manure treatments. 186
Figure 1: Typical layout, one repetition (not to scale). 186

Linking Farms GIS

Figure 1 Location and Overview of the Study Site. 195
Table 1 Hypothetical 100 Cow Diary Herd Profile. 196
Table 2 Animal Unit (AU) Calculation chart. 197
Figure 2. Town of West Point land cover data layer, 2003. 198
Figure 3. Livestock Farms of West Point and Suburban Developments. 199
Figure 4. Spreading, grazing and no-spreading zones, Town of West Point. 200
Figure 5. Schematic presentation of land evaluation steps resulting in priority spreading, cautionary spreading, grazing and no spreading areas. 201
Figure 6. Land Evaluation categories and livestock farms in the Town of West. . . 202

Grass Ley

Table 1. Initial Assumptions of Crop Off-take and Manure Nutrient Additions, Three-Year Rotation. 210
Table 2. 2004 Agronomic Input/Output Data, Dairy Forage Research Center Site I. . 211
Table 3. 2004 Agronomic Input/Output Data, Michael Fields Site I. 212
Table 4. Baseline Routine Soil Fertility Results (0-6"), Fall 2003, Sites I. 212
Table 5. Baseline Soil Nitrate Results, 3-foot depth. 213
Table 6. Grass ley Manure Analyses, Dairy Forage Research Center Site I. 214
Table 7. Grass Ley Manure analyses, Michael Fields Site I. 214
Table 8. Orchardgrass Yield and Quality, 2004. 215
Table 9. Grass Ley Nitrogen Budget (lbs N/a), 2004. 215
Table 10. Grass Ley Phosphorus Budget (lbs P_2O_5/a), 2004. 215
Table 11. Grass ley Potassium Budget (lbs K_2O/a) 2004. 216
Figure 1: Map of the DFRC Research Plots and Feeding Trials, Sites I and II. 216
Figure 2: Map of MF Plots, Sites I and II. 217
Figures 3a and 3b: Orchardgrass and corn silage rotation schematic. 218
Figure 4: 2004 Orchardgrass Yields (dry matter tons/acre). 219
Figure 5: 2004 Corn Silage Yields (dry matter tons/acre). 219
Figure 6: Post-season Nitrate levels, by Crop treatment, 2004. 220
Appendix A: 2004 Agronomic Inputs/Outputs of DFRC Feeding Trial Fields, Site I. .221

NEW RESEARCH

Certified Organic Strips

Table 1a. Cropping sequence at ARS. 224
Table 1b. Cropping sequence at MFAI. 225
Table 2. Grain yields on organic 'production' strips in 2004. 227
Table 3. Organic corn variety trial yields at ARS. 228
Table 4. Organic soybean variety trial yields at ARS and MFAI. 229
Appendix I. Map 1a. ARS Organic strips plot layout 2004. 230
Appendix I. Map 1b. MFAI organic strips 2004 230
Appendix 2a. Baseline soil fertility (Fall 2004) at ARS. 231
Appendix 2b. Baseline soil fertility (Spring 2005) at MFAI. 231
Appendix 3. 2004 weed seed bank at ARS (greenhouse germination). 231
Appendix 4a. Agronomic input/outputs for production strips at ARS. 232
Appendix 4b. Agronomic input/outputs for production strips at MFAI. 233

Quinney Farm

Figure 1. Quinney farm location in Walworth County. 237
Figure 2. Sugar Creek township with Quinney farm and Turtle Valley shown. . . . 238
Figure 3. Aerial view of Quinney farm. 239
Figure 4. Map of soil types on Quinney farm. 240
Figure 5. Map of ecological units across Quinney farm. 241

Soil Compaction From Manure Applic. Equipment

Table 1. Weight comparison of common farm machinery. 245
Figure 1. Site Setup: Arlington Compaction Study. 246
Figure 2. Plot Layout: On-Farm Compaction Study. 247

PROLOGUE

This is the tenth 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 thirteen production years (1990 – 2002). In this report, we discuss the results of the 2003 & 2004 growing seasons. This is the twelfth time all the phases of the six rotations have run concurrently, permitting us to again compare all the systems. By the end of the growing season in 2004, all the treatments of the Cropping Systems had completed at least three full cycles of their respective rotations. Also included in this report are research results of satellite trials conducted both on-farm and adjacent to the WICST core trials.

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

Summer 2003 & 2004 Collaborators

Josh Posner	UW-Agronomy Dept
John Hall	Michael Fields Agricultural Institute
Dwight Mueller	Superintendent, Arlington Agricultural Research Station
Janet Hedtcke	UW-Agronomy Dept
Jon Baldock	President, AgStat
Bill Stangel	Soil Solutions Consulting
Peg Reedy	UW-Extension, Walworth County
Laura Paine	UW-Extension, Columbia County
Walter Goldstein	Michael Fields Agricultural Institute
Ron Doetch	Marketing, Quality Traders Inc.
Jerry Doll	UW-Agronomy Dept.
Phil Barak	UW-Soil Science Dept.
Katie Simonsen	Graduate student, UW-Landscape Arch. Dept
Mauricio Avila	Graduate student, UW-Soil Science Dept.
Trish Wagner	Graduate student, Land Resources
Amy Cook	Graduate student, Agronomy
Gregg Sanford	Graduate student, Agronomy

We also acknowledge with many thanks, the contributions to this project of those who assisted at the research stations in managing the crops and animals –Darwin Frye, Paul Bergum, and Tim Patchin at Arlington.

INTRODUCTION

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

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

The selection of cropping systems provoked a great deal of discussion within the group. Ultimately, a factorial array of rotations was selected. It was observed that within southern Wisconsin there were two principal types of farm enterprises: cash-grain and forage-based systems, each with its own production requirements. At the level of production strategy, our hypothesis stated that as systems became more complex, they would require less and less external inputs to remain productive. As a result, production strategies with a high, medium, and low level of complexity were designed. Put in an inverse fashion, systems that required a high, medium, and low level of purchased inputs were put into practice. The six rotations are schematically represented in Figure 1b. Some of the anticipated differences between the rotations are outlined in Table i.

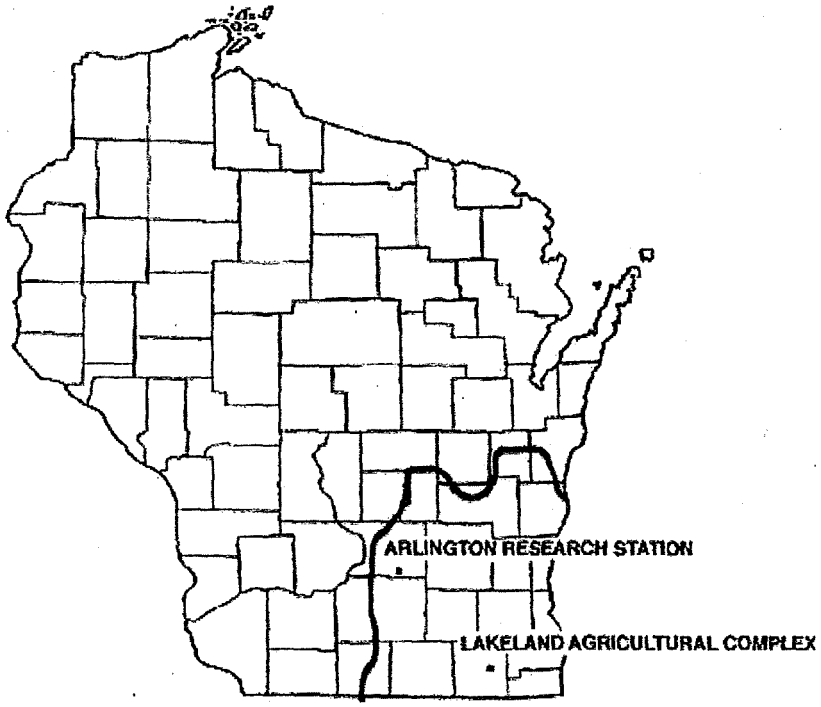


Figure 1a. Outline of major Land Resource Area 95B and the two sites of the Wisconsin Integrated Cropping Systems Trial.

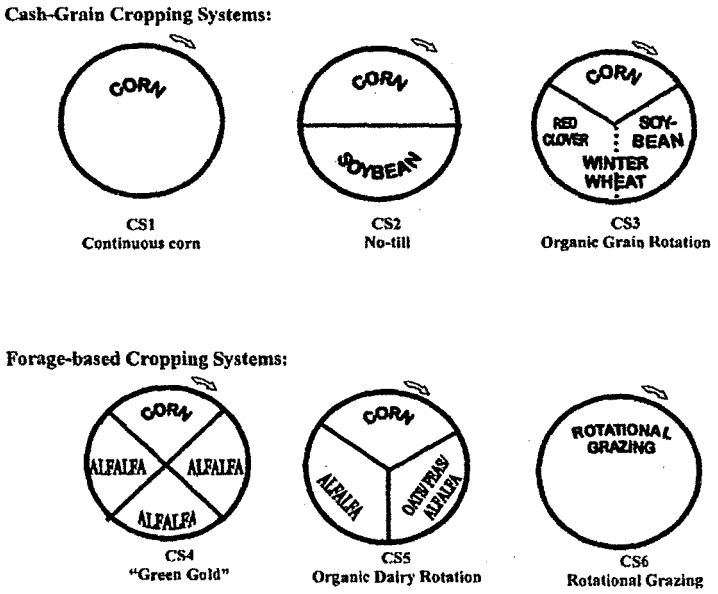


Figure 1b. Schematic diagram of the cropping systems of the WICST experiment.

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

Rotation	Predicted Yield/acre	Mean above ground productivity[1]	Mean energy input[2]	Energy output/input[3]	Variable costs[4]	Chemical inputs			Erosion[5]
						N Fertilizer on corn	Herbicide	Insecticide	
		Lb/a/yr	Mcal/a/yr	ratio	$/a/yr	lb/a	AI/a	AI/a	t/a/yr
R_1									
Continuous Corn	150 bu	15,780	2369	6.0	140	150	Atrazine 2 lb Alachlor 2 lb	Counter 1.4 lb	4.1
R_2									
Drilled Soybean	55 bu	12,510	1788	6.9	104	110	Bladex 2.5 lb Alachlor 2.5 lb Sencor 0.5 lb Treflan 1.5 lb	0	4.0
Corn	160 bu								
R_3									
Row soybean	40 bu	10,010	763	12.6	50	0	0	0	2.9
Wheat	60 bu/2t straw								
Corn	120 bu								
R_4									
Seeding alfalfa	3t dm	10,710	1188	13.7	110	10	Eptam 2.9 lb Bladex 2.0 lb Alachlor 2.5 lb	Lorsban 1.0 lb	1.9
Hay I	5t dm								
Hay II	5t dm								
Corn	160 bu								
R_5									
Oats/alfalfa	60 bu/2t dm	9,440	811	18.2	45	10	0	0	1.6
Hay I	4t dm								
Corn	120 bu								
R_6									
Rotational Grazing	4t dm	8,000	129	104.3	16	na	0	0	0.5

[1] Mean above ground productivity: dry matter biomass production per acre per year. Calculated based on the following harvest indices: Corn .45; soybean .35; wheat .42; oat .45.
[2] Mean energy input includes only seed, fertilizer, lime, pesticides, and fuel. Based on Pimentel, D. 1980 Handbook of Energy Utilization in Agriculture, CRS Press Inc.
[3] Ratio of energy value of agricultural output to energy consumption
[4] Variable costs include seed, fertilizer, pesticides, drying, fuel, and labor. Costs based on 1988 Wisconsin Crop Budgets. R. Klemme and L. Gillespie.
[5] Erosion estimates were made using the USLE for a 4% slope, 200 feet long with a silt loam soil and contour planting.

Table 1. Growing season rainfall (inches) at the Wisconsin Integrated Cropping Systems Trial site at Arlington.[1]

Month	2004	(*)	2003	(*)	30-year average 1971 - 2000
April	1.92	-1.32	2.06	-1.18	3.24
May	10.36	6.93	3.85	0.42	3.43
June	4.11	0.07	3.36	-0.68	4.04
July	4.35	0.49	3.26	-0.6	3.86
August	3.12	-1.12	1.85	-2.39	4.24
September	0.56	-3.08	4.00	0.36	3.64
October	3.32	0.89	1.35	-1.08	2.43
Growing Season Total	27.74		19.73		24.88
Yearly Total	35.75		29.09		32.80

* Deviation from 30-year average

Figure 2. Rainfall graph from Arlington 2003 and 2004 vs. the long-term norm.

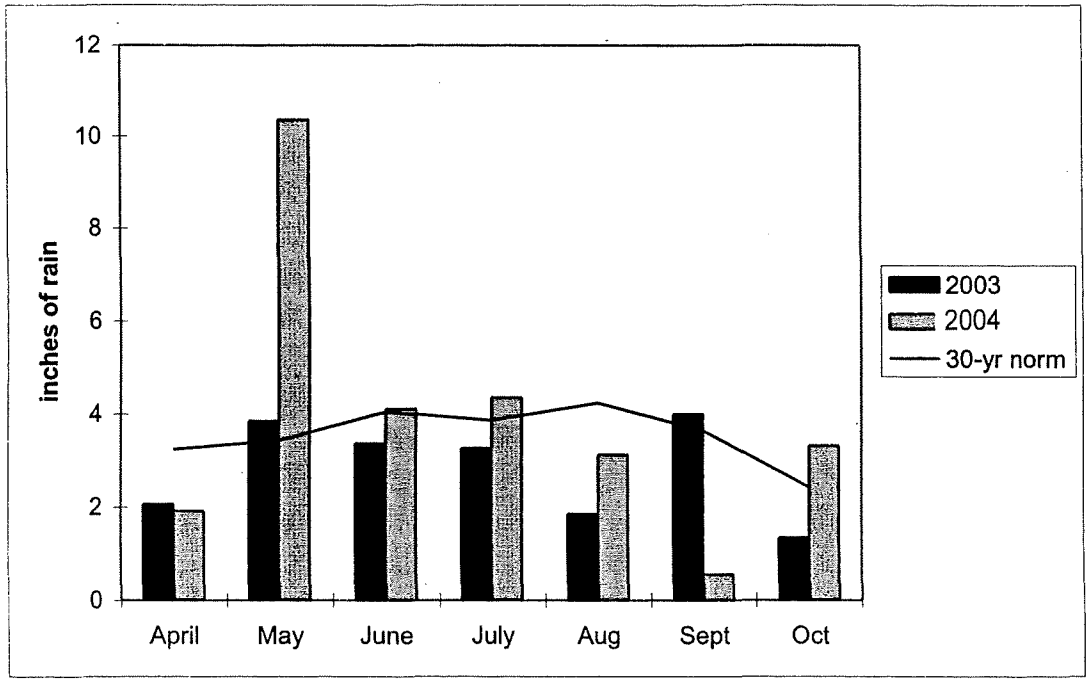


Figure 3. Growing Degree Days at Arlington (2004 vs. norm)

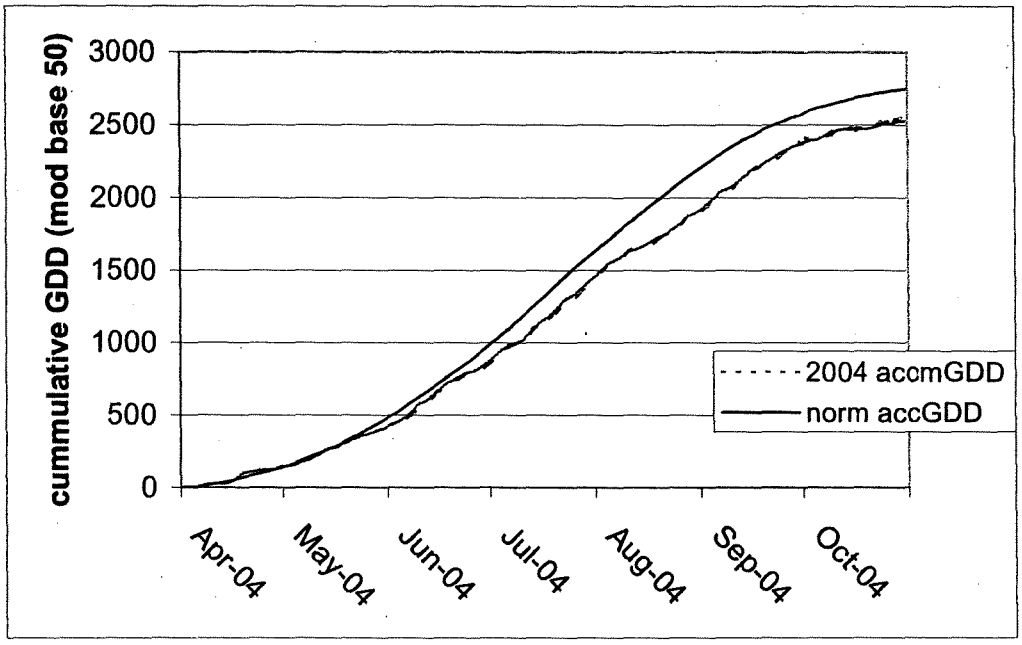


Figure 4. Growing Degree Days at Arlington (2003 vs. norm).

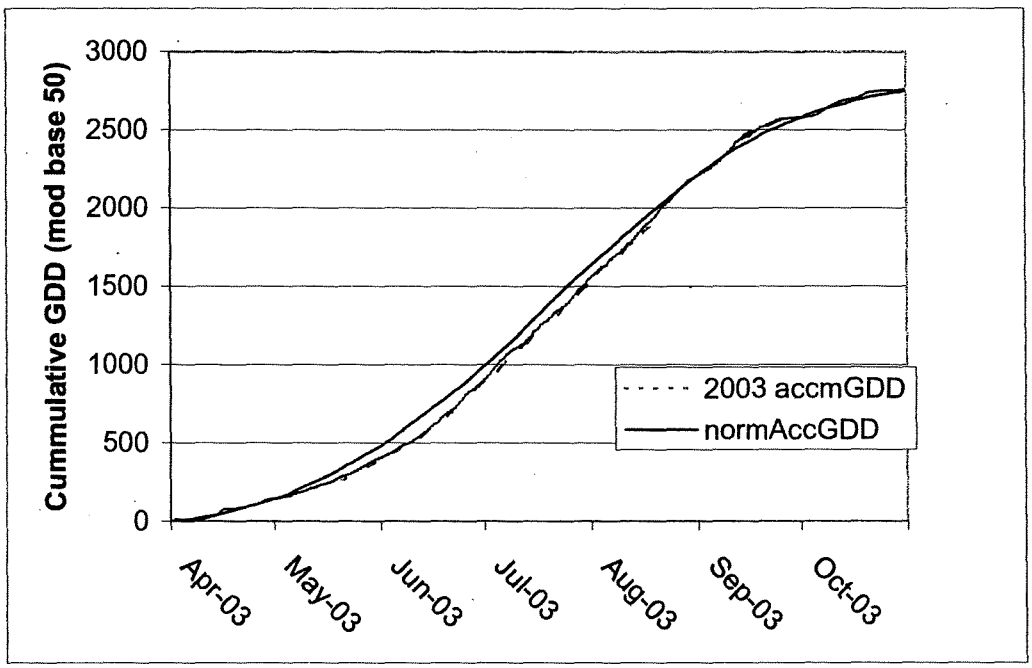


Table 2. Yields from WICST at Arlington Agric. Research Station, 1992-2004.

	Corn	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
		bu/acre												
CS_1	Continous corn	144.0	123.7	178.1	143.1	131.5	128.6	196.2	170.4	161.6	193.6	192.2	175.0	193.9
CS_2	After sb (No Till)	150.1	129.8	190.2	167.7	140.0	157.4	212.6	162.9	162.9	207.7	159.0[1]	176.5	189.0
CS_3	Org. 3-crop	99.2	87.1	188.4	155.6	83.4	147.6	197.8	155.6	132.8	155.5	157.8	110.0	-[2]
CS_4	After 3-yrs alf	-	165.1	196.5	167.5	151.2	159.1	226.8	189.7	179.4	227.8	186.6	190.6	212.7
CS_5	After 2-yrs alf (org)	112.0	119.1	198.8	157.1	153.6	155.3	205.1	181.9	135.2	181.2	174.1	149.7	-[2]
LSD (P<0.05)		*12.6*	*7.4*	*12.6*	*11.6*	*16.0*	*10.0*	*12.3*	*14.7*	*24.5*	*18.3*	*21.1*	*18.0*	*5.1*
	Soybeans	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
		bu/acre												
CS_2	Drilled – No till	30.1	52.8	42.7[3]	58.1	53.7	51.9	63.6	59.2	56.3	51.6	54.5	35.6	49.8
CS_3	Org. 3-crop	38.0	53.3	44.4	63.3	60.2	48.8	51.9	31.0	40.9	35.4	51.0[1]	32.5	33.6
LSD (P<0.05)		*NS*	*NS*	*NS*	*2.20*	*NS*	*NS*	*NS*	*1.5*	*4.5*	*15.6*	*NS*	*1.6*	*10.47*
	Wheat	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
CS_3	Grain (bu/a)	45.2	28.6	60.9	68.1	45.4	54.4	57.7	56.9	41.7	54.8	70.5	53.6	34.9
CS_3	Straw (ton DM/a)	0.34	1.44	1.44	1.22	1.55	0.97	0.58	0.63	0.83	0.71	1.43	0.40	0.54
	Seeding yr. Forage	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
		ton DM/acre												
CS_4	Direct seeded	3.59	3.27	3.21	3.19	1.57	3.56	2.63	2.27	2.59	3.21	2.96	2.91	1.85
CS_5	Oats/peas/alf	2.60	NA	3.37	3.21	2.68	4.66	5.67	4.69	4.14	4.53	3.56	2.30	4.35
LSD (P<0.05)		*0.49*	*0.51*	*NS*	*NS*	*0.90*	*NS*	*0.67*	*0.34*	*0.24*	*1.27*	*NS*	*NS*	*1.06*
	Estab'd Forage	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
		ton DM/acre												
CS_4	Hay I	3.46	3.93	4.56	4.02	4.16	5.08	4.30	4.49	5.44	5.89	5.18	4.83	5.08
CS_5	Hay I	5.17	4.65	5.30	4.89	4.42	4.99	4.47	5.49	5.86	5.29	5.10	5.94	4.88
CS_4	Hay II	3.99	3.25	3.68	2.24	3.77	4.50	4.13	4.06	5.31	5.53	4.50	3.37[4]	5.15
CS6	Pasture[5]	2.81	-	-	-	-	-	-	-	-	-	-	-	5.48
LSD (P<0.05)		*1.20*	*1.15*	*0.42*	*0.36*	*0.59*	*NS*	*NS*	*0.35*	*0.32*	*0.52*	*0.50*	*0.86*	*0.69*

[1] 3-plot average. Severe ground squirrel damage in plot 206 corn and intensive/expensive hand weeding in 411 beans led to their omission.
[2] Due to poor stand and late replanting date, corn did not make blacklayer before end of season and was harvested as snaplage (cob+husk+ear) yielding 1.07 and 1.36 ton DM/a for CS3 and CS5, respectively.
[3] Soybeans replanted 6/15 due to severe herbicide damage to soybeans and poor weed control.
[4] Only 3 cuts taken on CS4 Hay II (4 cuts taken on CS4 Hay I and CS5 Hay I).
[5] Hay was mechanically harvested as a comparison with CS4 and CS5.

Org = organically managed

Arlington Agricultural Research Station – 2003 Report

Janet Hedtcke, Dwight Mueller, and Paul Bergum

The 2003 season's soil moisture started well below normal due to low precipitation during previous fall and winter. Rain plus snow from November through April was only 50% of the longterm average. May and June rainfall was about average but then the summer became very dry with only a total of 2" from July 15-Sept 10. Finally, rain came in November and December totally more than 7 inches.

In 2003, 2 different trials were superimposed on the border rows of the grain systems. On the western 6 rows of the corn phase of CS1 and CS2, Larry Bundy set out a study to compare the amino sugar N test with the pre-sidedress N test. On the eastern 6 rows of the corn phase of CS1, CS2, and CS3, 11,000 gal/a of slurry was applied in the spring (April 21st) as part of graduate student, Amy Cook's, research project of importing manure from dairy to cash grain systems.

Corn Phase

Corn in CS1, CS2, and CS4 were all planted on April 29th at 32,000 seeds/A with a 105-day corn, Pioneer 35R58 Bt. The organically managed corn (CS3, CS5) was planted into a stale seedbed that had been worked with a field digger in late April and again just before planting on May 23rd at 34,500 seed/A with a 101-day corn, NC+ 100A2. Deep nitrate soil tests (PPNT) were taken for the CS1 and CS2 plots. As a result of the tests, a side-dress application of 80-120 lbs N/a was applied on CS1 plots and 80 lbs N/a on CS2 plots on June 19th. Legume and manure credits were taken in the other systems and no additional synthetic fertilizer was needed on the manured grain plots (eastern 6 rows of cs1 and cs2). Starter fertilizer (5-14-42) was used on CS1, CS2, and CS4 at 100 lb/a.

Weed control worked well with the high-input corn, although there was some quackgrass creeping in on the border rows. The border rows were treated with Accent but this expenditure was not 'charged' against CS1. The organically managed systems had medium-to-heavy weed pressure. We continue to struggle to find the appropriate tool for shallow tillage in preparing the stale seedbed. In addition, we didn't succeed in allowing flushes of weeds to germinate between seedbed preparation and planting. Once planted, two rotary hoeing were done followed by 3 cultivations in CS3. Still, CS3 had heavy foxtail pressure but broadleaf weeds were moderately well controlled. No hand labor was spent on pulling weeds because it would have been too costly.

Ground squirrels are still causing severe problems in CS2. Areas of two plots (303, 401) were so destroyed that they had to be replanted with the planter using Renk 232 (85 d) corn. Hand baiting of zinc phosphide pellets was done but after the damage was done. We will try adding this poison in-furrow next year at planting. Plant population and yield data don't however, reflect the ground squirrel damage caused in CS2 vs. CS1.

Corn yields averaged 181 bu/a for the high input systems, above average from the trial average of 171 bu/a. Corn yields were more variable in the low input systems from 110 on CS3 to 150 on CS5, both lower than the trial mean. Corn on CS3 had very heavy weed pressure and looked N deficient, especially when comparing it to the eastern 6 rows which had received 11,000 gal/a slurry this spring. CS1 and CS2 yields were very similar at 175 and 177 bu/a respectively, vs.

191 bu/a on CS4. This demonstrates the significant benefit of rotating corn with leguminous crops and manure.

Soybean Phase

Asgrow 2001 (RR) was planted at 250,000 seeds/A in 7" rows for the CS2, no-till rotation on May 22nd. A food-grade variety (IA2053) was planted at 190,000 seeds/A in 30" rows for the CS3 rotation on May 23rd. The CS2 soybeans were no tilled into high residue cover (approximately 75% cover) with a John Deere no-till drill. For CS2, a burndown treatment of Round Up Weathermax helped control early weeds. A second application of Round-up Weathermax on the round-up ready beans took care of the post-planting weeds. Weed control for the rest of the growing season was excellent in the CS2 rotation. Narrow-row beans were sprayed for aphids in early August.

The organically managed beans were planted into a seedbed that had been worked with a field digger in late April and again just before planting. After planting, two rotary hoeings and 3 cultivations were done on CS3 beans. Hand weeding of the organic bean plots was done on July 2, spending about 2 man-hours/acre. Yields of both systems were only about 70% of the trial average because of the summer drought conditions. CS3 beans were taken to DeLong for grading; cleanout (splits, off-color, off-shape) was minimal (~ 5%).

Wheat/Red Clover Phase

Wheat (var, 'Kaskaskia') had been planted on October 10th, 2002 following soybean harvest tillage at a seeding rate of 180 lbs/a. The wheat hardly got out of the ground (~1") before a cold November set in. Winterkill was a concern, but eventually the stand started to greenup in late April. There was a moderate weed population of yellow foxtail and lambsquarter beneath the wheat canopy. The wheat yield averaged 54 bu/a, right on pace with the trial average but straw yields were low at 0.40 tons DM/a, partly due to the high cutting height to avoid weeds and red clover. Red Clover was seeded on April 2, 2003 at 12 lbs/a, with a John Deere no-till drill. Wheat stubble and weeds were clipped/removed in early September to prevent weeds from setting seed. The stand of red clover was doing well under the wheat but yields were rather poor with less tan half a ton DM at the end of the growing season because of no rain for most of the summer.

Forage Phases

The new seedings in CS4 and CS5 systems were planted with Magnum V on April 14th. CS5 was planted with a mix of alfalfa, bay oats, and Trapper field peas to help with forage yield and quality and weed control. CS5 seeding was taken off as silage on June 27th but the second crop was all weeds so it was clipped and blown back on the field. CS4 alfalfa seeding established well and was harvested 3x during the season. All the established plots were harvested 4 times during the season except plowdown phase of CS4, which was sprayed out. July cuttings got rained on for all phases of each system. Seasonal yields were very comparable to the trial average. Relative feed value was similar to past years and was highest on CS4 and lowest on oats/peas/alfalfa phase of CS5. CS5 established plots had a lot of quackgrass present.
Pasture (CS 6) was quite productive until mid-August when rain deficit reduced growth and hay had to be supplemented to the heifers for the remainder of the season.

Arlington Agricultural Research Station – 2004 Report

Janet Hedtcke, Dwight Mueller, and Paul Bergum

2004 will be remembered as a very cool season with ample moisture. Although the winter and early spring were again below average in precipitation, rainfall in May was record breaking (3x the norm at 10.3"). The weather conditions were difficult on crop establishment (there was standing water on the Northeast end of the trial well into June), but once established most crops yielded well. Growing degree units were well below normal, particularly in July and August (see Fig. 3), which impacted corn maturity in some cases but fortunately the weather was abnormally warm in September.

The 2 superimposed trials on the border rows of the grain systems continued this season. On the western 6 rows of CS1 and CS2, Larry Bundy and graduate student Jeff Osterhaus continued to monitor corn yields and soil nitrates to improve their amino sugar N test. On the eastern 6 rows of CS1, CS2, and CS3, ~ 11,000 gal/a of slurry was applied the previous fall (November 2nd) with the 'Calumet' tanker as part of graduate student Amy Cook's research project of importing manure from dairy to cash grain systems. Manure was incorporated (with the chisel plow) on CS1 and CS3 and surface applied on CS2.

Corn Phase

Corn in CS1, CS2, and CS4 were all planted on May 5th at 32,000 seeds/A with a 105-day corn, LG2533. Starter fertilizer (5-14-42) was used on CS1, CS2, and CS4 at 100 lb/a. Potash was applied on some of the plots in CS4 and CS2. In June PSNT samples were taken from both manured and non-manured plots in CS1, 2, and 3. As a result of the test, the recommended full rate of N fertilizer (160 lb N/a) was applied on CS1 and CS2 corn on June 21th. The PSNT did not pick up the approximately 100 (?) pounds of N added in the 11,000 gals/a of slurry added to the manured strips.

Although it never reached 90 °F during the season, corn yields in the conventional systems were excellent reaching a max of 224 bu/a (i.e. Chemlite). However, corn moistures were high, still in the upper 20's in mid-November. In recent years, CS2 yields advantage over CS1 has been diminishing. This year, CS1 corn yield was significantly higher that CS2 by 5 bu/a. One possible reason for the general convergence of yields is the problem with ground squirrels in CS2. They have caused considerable stand damage in some plots. However, yearly stand counts have not been statistically different between the systems. Although we hand bated 'Prozap' (zinc phosphide) pellets, some areas were replanted. New insecticide boxes have been purchased that are split so regular insecticide can be put on one side and the prozap on the other. This will allow better calibration/effectiveness in 2005. It is also likely that the cool, wet conditions this spring delayed emergence in the no-till system more so that in CS1, and thus reduced CS2 yields.

There were more challenges than usual this year with corn in the chemfree systems (CS3 and CS5). Plots had a lot of volunteer alfalfa, quackgrass and red clover from last fall's plowdown. The first spring tillage didn't occur until mid-May when plots were disked and field dug but then a wet period delayed any further seed bed preparation and planting until late May. For reasons unclear to us, the corn on the WICST plots had a very poor stand when it emerged but the same variety planted the same day on the 403 plots has an excellent stand. Corn was replanted to an 85-day variety (Brunner OR8403) on June 16th, but, the GDD units were way below average and the corn did not develop fully. By the first killing frost (Oct 5), the CS3 and CS5 corn had not

dented. Because the corn was too wet for grain harvest, but we did not want the field full of volunteer corn next year, and harvesting as silage would markedly affect the long term nutrient budgets, snaplage (kernels+husk+cob) was harvested using a custom chopper.

It is interesting to look at the corn yield trends from the first 6 years (1993-1998) compared to the last 6 years (1999-2004). Among the high-input systems, the largest increase has been in CS1 with a 31 bu increase, followed by CS4 with a 20 bu increase, and lastly CS2 with a 10 bu/a increase. Both low-input systems had lost 1 bu in the latter period, with CS3 and CS5 averaging 142 and 164 bu/a, respectively, in the last 6 years. The increase in the high input is attributed to improved varieties. The lack of change in the low-input systems may be a combination of improved variety but offset by increasing weed pressure. The weed seed bank continues to build up in the CS3 and CS5 plots, particularly giant foxtail and quackgrass, respectively. In April, we collected soil samples from each system and grew them out in the greenhouse. Later in the season, as part of Amy Cook's weed id study, we counted and id'd weeds in all corn phases of each system using 1-m^2 quadrats.

Soybean Phase

Soybeans were planted on May 17 and May 27 for CS2 and CS3 respectively. A Roundup Ready (RR) variety was used on CS2 (KB241) and an organically grown food-grade variety was planted in CS3 (NC+1F61). We used a non-RR variety for Chemlite (Latham 250). Another result of the cool weather was reduced aphid pressure; so much so that beans did not need to be treated with insecticide. Beans were dry in time for wheat planting by October 5th. Yields were modest for CS2 at 50 bu/a and markedly lower in CS3 due to heavy giant foxtail pressure. Even after 2 rotary hoeings and 3 row cultivations, giant foxtail was still severe in the CS3 beans. We spent about 8 man-hr/acre hand weeding broadleaf weeds from the chemfree soybean plots.

Wheat/Red Clover Phase

Growing conditions in the fall of 2003 allowed good wheat stands and there was little to no winterkill on the plots. However, the cool wet weather of May and June also set the stage for head scab on wheat all across Wisconsin. The WICST plots were no exception where both 'Patriot' and 'Pioneer 35R37' had significant damage (20-30%) and heavy dockage at the elevator. To improve the quality, combines were set to blow light kernels out the back so volunteer wheat was very common. Hence, yields were about half the average at 35 bu/a.

Forage Phases

The new seedings in CS4 and CS5 systems were planted with Magnum V on April 4th. CS5 was planted with a mix of alfalfa, 'Forage Plus' oats, and Trapper field peas. Emergence was timely but due to the wet field conditions this spring, the new seedings had reduced vigor. The alfalfa in CS4 was stunted and chlorotic. Post emergence herbicide was delayed until the alfalfa plants recovered. The oats and peas in CS5 seeding seemed to be growing well but the alfalfa underneath was slow to grow. Roots were likely infected with disease. Two cuts were taken from the new seedings and 4 cuts were taken on the established forage in CS4. This year, we set up exclusion areas within each pasture and mechanically harvested from the area throughout the season. Yields and quality were comparable to the established alfalfa systems. Heifer performance was excellent averaging 1.92 lb/head/day. We plan to continue monitoring pasture productivity mechanically and with weekly hand sampling.

GROSS MARGINS OF THE WICST CASH-GRAIN SYSTEMS: 2003 and 2004

Janet Hedtcke[1] and Josh Posner2

INTRODUCTION

Profitability is one of the key factors that drive management decisions. Farming is no exception. Successful commodity farming, i.e. cash-grain production, is dependent upon producing and marketing large volumes of grain as efficiently as possible. Large acreage, large machinery, and large debts are all part of the business. However, growing interest in organic production uses another strategy: producing food/feed in an ecologically balanced way and usually on a smaller scale. In this approach, the idea is to promote natural or biological synergies that exist in crop rotations and through a combination of lower input costs and price premiums, more than compensate for reduced returns from lower yields, lower volume and higher labor inputs[2]. The economics of producing corn and soybeans under 3 different cropping system will be addressed in this paper.

MATERIALS AND METHODS

The WICST cash-grain systems are compared in this paper. The WICST forage system analyses can be found in 'WICST Forage Systems Comparison: Production, Milk Models and Gross Margins' of this technical report. To review, cropping system 1 (CS1) is continuous corn with a high input level. Cropping system 2 (CS2) is a no-till corn-soybean rotation with medium inputs. Cropping system 3 (CS3) is a 3-yr rotation of corn-soybean-winter wheat/red clover with low inputs (chemical free). Although managed organically, it is not 'certified organic' due to constraints of the trial. CS1 and CS2 are scaled up from 0.7-acre plot size to 1200-acre farms while CS3, being managed without chemicals, has been scaled up from 0.7-acre plots to 600-acre farm size. Reducing the size of a farm in the CS3 rotation was based on an informal survey of organic farmers and inspectors who reported few single-family organic grain farms surpassed 600 acres. The primary reason for this was that mechanical tillage sets an upper limit on the size of a farm entirely in row/annual crops, unless most of the work can be custom hired.

Gross margins were calculated using Agriculture Budgeting Calculation Software, (ABCS; Frank and Gregory, 2000). Gross margins represent the dollars available to cover the overhead costs of capital, land, labor and management. The way to interpret the adequacy of the gross margin is to estimate the amount of dollars needed per acre to cover those overhead costs. Project economists estimate that a cash grain farmer would need approximately $35-$40 per acre to cover labor and management, $80 to $140 per acre for rent, and approximately $40-$60 per acre to cover the depreciation and interest cost associated with machinery and drying facilities owned on the farm. This adds up to approximately $155 to $240 per acre (or on average ~ $200/acre) to be covered by gross margins. Therefore, we are considering the break-even point as ~ $200/acre.

Input and output prices for each system were recorded each year. Commodity corn and soybean prices for conventional grains are taken from WI Ag Statistical Service October price. To not

[1] Research Specialist, UW-Madison, Agronomy Dept. E-mail: jlrieste@wisc.edu
[1] Professor, UW-Madison, Agronomy Dept. Email: jlposner@facstaff.wisc.edu
[2] repeated mechanical tillage and hand weeding

inflate the potential premiums for the organic grains, organic feed grade prices were collected from various elevators marketing organic grains (Table 1) to livestock producers. Since WI Ag Statistics Service no longer tracks wheat prices, cash price at time of harvest was used. No storage or futures options are included in the analysis; grain is sold 'right off the combine'. Trucking was charged against CS1 and CS2 at $0.04/bu and against CS3 at $0.11/bu per 100 miles and because commodity grain elevators are closer and more widespread than organic grain elevators. Corn drying costs were at $0.03/point/bu down to 15% moisture.

Table 1. Price comparison: Conventional (CBOT) and organic feed-grade prices.*

	Conventional $/bu		Organic feed grade $/bu	
	2003	2004	2003	2004
corn	2.08	2.25	3.75	4.00
soybean	6.50	5.71	8.75	12.50
wheat	3.13	1.52	3.75	3.50

* organic prices quoted from Delong, Cashton, Sunrich, Clarkson, Peavy, Didion, American Health & Nutrition

In addition to grain prices, labor requirements are an important issue when comparing conventional and organic production systems. Table 2 shows the wage for a field worker according to National Agricultural Statistic Service's Lake Region (includes Wisconsin, Minnesota and Michigan) averaging April and October rates for the course of the trial. Labor costs were included for such things as handling/hauling grain in both conventional systems and hand weeding the organic soybeans, and other miscellaneous tasks. In the 8th WICST Technical Report (1999-2000) it was determined that CS3 had labor requirements (planting, rotary hoeing, cultivating, harvesting) in both the spring and fall that would make it very difficult for a family to manage a 1200-acre farm. As a result, we decided to reduced farm size to 600 acres, and to lessen the spring workload, we assigned rotary hoeing (after two hoeings) and cultivation (after one cultivation) to be custom hired. Since farm size was reduced from 1200 to 600 acres, it was decided that the operator could harvest soybeans and plant wheat himself instead of custom hiring it done. Neither 2003 nor 2004 actually used any custom hire because rotary hoeing and cultivation were minimal. Custom rates are typically based on survey results compiled by USDA WI Ag Stats 'Wisconsin's 200X Custom Rate Guide'.

Table 2. Field worker wage ($/hr) across years in the Lake Region of the Midwest.

1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
5.35	6.01	5.94	6.47	6.64	7.29	7.35	7.43	7.84	8.21	9.28	9.28	9.17

Still, gross margin analysis is a blunt tool to compare systems with different labor requirements because owner/operator labor is not charged as a production cost, but rather must be recovered in the gross margin. Table 3 shows the estimated labor/acre that is done by the operator himself or family member, and not covered in hired labor.

Table 3. Owner/Operator labor for cash grain systems.		
	2003	2004
System	Number of hours per acre	
CS1	**1.38**	**1.30**
CS2 corn	0.91	0.91
CS2 soybean	0.45	0.45
CS2 mean	**0.68**	**0.68**
CS3 corn	1.62	1.25
CS3 soybean	1.63	2.03
CS3 wheat	0.76	0.76
CS3 mean	**1.34**	**1.35**

RESULTS

Yields

Yields from the cash-grain systems are in Table 4. In 2003, corn yields were not different between CS1 and CS2 ($p<0.05$); however, CS3 corn yields were lower because they suffered from heavy weed competition as well as a later planting date. Soybean yields were slightly higher in CS2 ($p<0.05$) but both systems suffered from the dry summer weather that year. Heavy giant foxtail pressure in CS3 limited soybean yields to 33 bu/a. Wheat grain in 2003 was comparable with the trial average but straw yields were particularly low, partly due to the high cutting height to avoid contamination by the tall red clover beneath.

In 2004, CS1 and CS2 yields were not significantly different, both yielding very well in a cold growing season. However, CS3 corn was considered a failure. System 3 was replanted in mid-June because of poor initial emergence, but due to a cold growing season, grain did not reach blacklayer by the killing frost. It was decided to custom harvest as snaplage (ear + husk) because corn silage removal would result in an unusually heavy nutrient removal and no harvest would result in heavy infestation of volunteer corn in next year's soybeans. Soybean yields were also much better in CS2 vs. CS3 due to heavy weed pressure in CS3. And finally, the scab in wheat hurt yields and quality as the infected kernels were blown out the back of the combine. Straw yields continue to be very low.

Table 4. Crop yields from WICST cash-grain systems.		
	2003	**2004**
Corn (bu/acre)		
Continuous corn (CS1)	175.0	193.9
After sb (No-till system) (CS2)	176.5	189.0
Org. 3-crop (CS3)	110.0	-[2]
LSD (0.05)	*17.3*	*6.9*
Soybean (bu/acre)		
After corn (No-till system) (CS2)	35.6	49.8
Org. 3-crop system (CS3)	32.5	33.6
LSD (0.05)	*1.6*	*10.5*
Wheat		
Org. 3-crop (CS3) grain (bu/acre)	53.6	34.9
Org. 3-crop (CS3) straw (tons DM/a)	0.40	0.54

[2] Corn harvested as snaplage valued at $37/ton 'as fed' yielding on average 3.3 tons/acre, 'as fed'

Production Costs

The largest variable expenses incurred by the grain farmer are fertilizer, seed, pesticides and corn drying costs (Table 5). Continuous corn (CS1) incurs higher fertilizer costs than CS2 because of annual starter and nitrogen fertilizer inputs necessary for the production of corn; CS2 corn also enjoys legume credits from the soybean phase, which results in less N input needed. Furthermore, CS1's drying costs are higher than the other two systems since 100% of its acres are in corn vs. half or a third of the farm acreage in CS2 or CS3. For example, in 2003, CS1 farm wide drying costs averaged $54/a vs. $30/a for CS2 and only $11 for CS3. In 2004, corn moisture was very high at harvest, and with the high price of natural gas, drying costs were quite extraordinary at nearly $90/a for CS1. Although no pesticides are used in CS3, hand weeding is charged to the soybean phase and capped at $50/acre. The organic system (CS3) does incur higher trucking costs because organic markets are generally not as close as commodity markets and organic grain requires special tracking to maintain their identity. Diesel fuel usage serves as a proxy of operator labor. During the last two years, fuel has been highest for CS1 at around $14/acre. , Fuel costs are slightly higher for CS3 than CS2 because of repeated tillage in the former and no tillage in the latter but both are about half the cost of CS1. It is interesting to find that fuel cost isn't higher for CS3 with its heavy demand on mechanical weed control, but rotary hoeing and cultivation don't use as much horsepower than say, chisel plowing. Also, during the wheat phase, fuel costs are reduced significantly lowering the system average. The inputs costs for growing organic corn and beans are about half that of conventional corn and beans so even though organic yields are not as high as conventional ones, lower input costs result in similar or better gross margins. For example, in both 2003 and 2004, CS3 variable expenses were less than half that of CS1 and about 33% less than CS2.

Table 5. Variable costs of the cash-grain cropping systems on WICST, 2003 & 2004.							
Year	**Crop Phase**	**Fertilizer**	**Seed**	**Corn Drying**	**Herbicide & Insect.**	**Diesel fuel**	**Total Var. Expenses[1]**
		$/acre					
2003	**CS1 – corn**	**29.65**	**54.00**	**54.06**	**31.13**	**13.89**	**227.42**
	CS2- corn	32.94	54.00	59.54	32.07	9.68	235.82
	CS2-sb	0	45.00	0	15.55	5.84	95.21
	CS2-average	**16.47**	**49.50**	**29.77**	**23.81**	**7.76**	**165.52**
	CS3- corn	0	47.30	33.78	0	9.70	136.78
	CS3-sb	0	24.81	0	0	9.94	72.48
	CS3-wheat/rc	0	72.24	0	0	4.30	106.34
	CS3-average	**0**	**48.11**	**11.26**	**0**	**7.98**	**105.20**
2004	**CS1 – corn**	**47.88**	**48.60**	**88.54**	**28.25**	**15.81**	**276.84**
	CS2- corn	55.85	48.60	91.71	16.35	11.16	272.98
	CS2-sb	0	30.00	0	15.22	6.73	78.97
	CS2-average	**27.93**	**39.30**	**45.86**	**15.79**	**8.95**	**175.98**
	CS3- corn	0	80.41	--[2]	0	10.40	165.60
	CS3-sb	0	33.27	0	0	13.56	125.35
	CS3-wheat/rc	0	54.64	0	0	5.19	79.10
	CS3-average	**0**	**56.11**	**0**	**0**	**9.72**	**123.35**

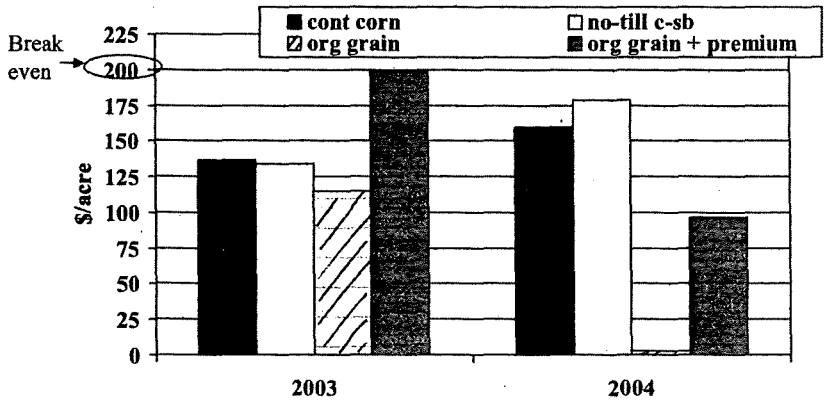
[1] Total variable expenses includes other items than just those in the table (e.g., scouting, trucking, repair & maintenance, etc.)
[2] Corn harvested as snaplage

Gross Margins

Gross margins without government payment were all below the break-even mark of $200/acre in both 2003 and 2004 (Fig. 1). Low commodity prices and mediocre soybean yields due to mid-summer drought were to blame in 2003. However, adding an organic feed grade premium in 2003 to CS3 boosted profits up to the break-even level. Custom rates for snaplage processing in 2004 were quite high at $52/acre. As the Fig. 1 shows, the failed corn stand along with scab problems on the wheat severely impacted gross margins for CS3. No organic premium was given to the snaplage and the already low yielding wheat was heavily docked for damaged kernels. 2004 was the first time in the history of the trial that the corn crop has failed and the

wheat was a disaster in CS3. On a real farm, an alternative crop would likely have been planted instead of replanting corn in late June of such a cold and wet spring.

Fig. 1. Gross margins of the cash-grain systems 2003 and 2004



. *Government payments not included in analysis

Organic feed grade premiums have been holding steady for the last 6 years (Table 6) and look to stay there as organic dairy farms increase the market for organic feed.

Table 6. Organic prices for crops sold directly from the field -feed grade for c, sb, w.

Year	corn	soybean	wheat
		$/bu	
1999	3.75	9.00	5.00
2000	3.67	8.00	4.50
2001	3.67	7.50	4.50
2002	3.67	7.50	4.50
2003	3.75	8.75	3.75
2004	4.00	12.50	3.50

prices quoted by Delong, Cashton, Sunrich, Clarkson, Peavy, Didion, American Health & Nutrition

CONCLUSIONS

Generally speaking, 2003 and 2004 were difficult years for profitable grain production. While production was high for conventional systems, especially in 2004, prices were low and variable costs were high. In the organic grain system, production was modest in 2003 and largely a failure in 2004, but low input prices and feed premiums resulted in the system having highest gross margins in 2003 and modest margins in 2004. In appears due to the expansion of the organic livestock market in the upper Midwest, that feed grade premiums will remain good for the near future and the harder to attain food grade premiums will be excellent. This coupled with

lower costs, will make organic grain production competitive with conventional production. However, improved weed control will be necessary to maintain good yields and increase gross margins.

CITATIONS

Frank, G., and R. Gregory. 2000. ABCS CD, v. 7.1. Center for Dairy Profitability, Dairy Sci. Dept. UW-Madison.

National Agricultural Statistic Service's Lake Region

WI Agricultural Statistics 2004. USDA.

WICST FORAGE SYSTEMS COMPARISON:

a. Production, Milk Models and Gross Margins

Janet Hedtcke[1], Jon Baldock[2] and Josh Posner[3]

INTRODUCTION

Forages play a major role in Wisconsin agriculture. Over 3 million acres of Wisconsin cropland are in alfalfa, grass and clover hay and pasture, similar to the acreage in corn production (WI Ag Stats, 2004). They play a major role in dairy and beef rations as well has horse diets, providing 50 to 100% of the dry matter intake. Furthermore, cropping systems that include forages and manure result in better corn yields vs. strictly cash-grain systems (WICST data not shown). Additional benefits come from the perennial characteristic of forages such as permanent ground cover and thus little soil erosion, expanded wildlife habitat, and aesthetic beauty of a varied landscape. This paper summarizes the three forage systems of WICST comparing forage yield and quality, milk production and gross margins.

MATERIALS AND METHODS

Historical trial data are presented from both the Arlington Research Station (ARL) and Lakeland Ag Complex (LAC) through 2002. There is no data beyond 2002 for LAC as WICST was no longer conducted at that site. System four (CS4) is a high input forage ration with 3 years of alfalfa followed by one year of corn. The alfalfa is sole seeded and herbicides are used to control weeds. Dairy manure is applied with a slinger spreader at the rate of 20 tons/acre before and after the corn phase. During the alfalfa phases, the established alfalfa is on an intensive cutting schedule with 4 cuts to be taken before Sept 15. System five (CS5) is a chemical free system of alfalfa seeded with oats and peas, a production year of alfalfa, followed by a year of corn. Dairy manure is spread at a rate of 15 tons/acre before and after the corn phase. The last cut of the plowdown alfalfa in CS5 is taken during late September to promote winterkill. The pasture (CS6) is a management-intensive rotational grazing system using dairy heifers to harvest their forage and spread their manure. Starting in 2004, exclusion areas (10' x 20') were set up in each pasture plot and mechanically harvested on a haying schedule for a yield comparison to the mechanically harvested alfalfa plots in CS4 and CS5. For more details on the grazing system, see 'Rotational Grazing with Dairy Heifers on WICST: b. Pasture and Heifer Productivity' in this report.

Forage quality was analyzed by UW Soil and Plant Analysis Lab using NIRS technology. In the last few years, relative forage quality (RFQ) has been used, which more accurately reflects the feeding value than relative feed value (RFV) when the forage contains a lot of grass that has a more readily digestible fiber fraction. Milk91 (Howard et al, 1991) was used to summarize 1992-2002 data and Milk2000 (Shaver et al, 2000) was used for 2003 and 2004 where digestibility values were included in the forage analysis reports. MILK91 uses the forage analysis (crude protein, acid detergent fiber (ADF), and neutral detergent fiber (NDF)) to calculate an approximation of a balanced ration using National Research Council (NRC) values. MILK2000 uses forage analyses (crude protein, NDF, *in vitro* NDF digestibility, starch, and non-

[1] Research Specialist, UW-Madison, Agronomy Dept. E-mail: jlrieste@facstaff.wisc.edu
[2] Statistician/consultant, AGSTAT, Verona, WI E-mail: agstat@tds.net
[3] Professor, UW-Madison, Agronomy Dept. Email: jlposner@facstaff.wisc.edu

fiber carbohydrate) to estimate energy content and DM intake to predict milk production per ton of forage DM.

The economic analysis is based on the concept of gross margins. Gross margins equal the dollars available to cover the costs of capital, land, and the operator's labor and management once the variable cost of production (seed, fertilizer, chemical, fuel, repairs, etc.) have been paid.. Gross margins were calculated using Agriculture Budgeting Calculation Software (ABCS) (Frank, 2000). We would estimate that a dairy farmer would need approximately $35-$40 per acre to cover labor and management, $80 to $140 per acre for rent, and approximately $40-$60 per acre to cover the depreciation and interest cost associated with machinery and drying facilities owned on the farm. This adds up to approximately $155 to $240 per acre (or on average ~ $200/acre) to be covered by gross margins. Therefore, our hypothetical the break-even point is ~ $200/acre. However, $200/acre is probably an over estimate for CS6 because of the less capital, depreciation, labor, etc. associated with this system vs. the mechanically harvested systems.

Gross revenue for CS4 and CS5 is based on the actual yield and market price based on forage quality or Relative Feed Value (RFV) during the forage phases, and grain prices during the corn phase. For example, RFV of 140 is used as the base since it is the minimal quality necessary for early lactation, high producing dairy cows (Undersander et al., 1992). This 140 RFV was assigned a price of $80 per ton of dry matter and any deviations in RFV from 140 were used to adjust the forage price by adding or subtracting $1 per RFV point. Each cutting from each plot were summed to give an annual gross margin estimate. The machinery complement was dimensioned for a 150-acre farm for both systems

The Stocker Enterprise Budgets for Grass-based Systems (Schuster et al 2001) was used as a model to estimate gross margins for the pasture system (CS6). An informal survey and recent newspaper articles revealed that custom grazing heifer raisers are getting from $0.85 to $1.50 per head per day (Agriview, Aug. 18, 2005). The price differential reflects who pays for supplemental feeding, breeding and vet costs. In our analysis, heifer income was based on a rate of $1.18/hd/d (average of $0.85 and $1.50) because we charged supplemental feed to the system but not vet or breeding costs. Farm size was fixed at 150 acres. Heifer expenses (supplemental feed, minerals, labor) and pasture expenses (reseeding, fertilizer, fuel, custom haying, etc.) were then deducted from heifer income. Stocking density was about 1.2 Animal Units/acre for the grazing months (i.e. average heifer weight over season was ~ 650 lbs * 5 head; grazing area of 2.8 acres; 1000 lbs live weight = 1 Animal Unit). It should be realized that the gross margins analysis for CS6 only pertain to the time spent on pasture and not during the off-season when cattle must be fed stored feed. Three difference scenarios are presented to show the effect on grazing GMs when days on pasture, cost of grain supplement, and amount of grain fed are varied.

RESULTS

HAY PRODUCTION

New Seeding. Forage production in the new seedings has differed between systems and years. In 2003, direct seeded alfalfa phase of CS4 produced significantly higher yields and quality than the oat-pea-alfalfa seeding in CS5 (Table 1). This can be explained because 3 cuts were taken from CS4 vs. just 1 cut taken in CS5. Weeds were a problem in that year in CS5 seeding and the

later cuts were mostly weeds and therefore removed and disposed of. Although lower quality than CS4, forage from the seeding year of CS5 produced forage suitable for many classes of livestock including far-off dry cows, unbred heifers, beef cows, horses and other livestock at maintenance nutritional requirements. Due to high potassium in the CS5 forage, particularly the oatlage, it has limited value as a sole-source forage for the transition diet of dry cows because of problems such as milk fever associated with high potassium diets.

Unlike 2003, in 2004, CS4 alfalfa seeding produced significantly less yield (albeit higher quality forage) than the CS5 oat-pea-alfalfa seeding (Table 1). Both systems were harvested two times but record rainfall (3x the norm for May) likely reduced seedling vigor by hastening root disease in the sole-seeded alfalfa. At the same time, the oats and peas in CS5 responded favorably to high moisture and produced over 2 ton/acre of forage. Pasture forage was not compared since there is not a newly seeded phase in that system.

Table 1. Seeding year hay yield and quality at ARL 2003 and 2004.

	System	Yield (T dm/a)	RFV	RFQ	Protein %
2003	CS4 (c-**a**-a-a)	2.91a*	186a	208a	22.4a
	CS5 (c-**o/p/a**-a)	2.30a	112b	147b	16.7b
2004	CS4 (c-**a**-a-a)	1.85y	166y	172y	21.0y
	CS5 (c-**o/p/a**-a)	4.35z	107z	145z	13.9z

*Different letters within column for each year are statistically different at $p<0.01$

Established Alfalfa. In 2003, alfalfa yield produced in CS4 was significantly lower than in CS5 (Table 2). Though, CS5 alfalfa was lower in forage quality than CS4 alfalfa, it was still very good quality even for high producing dairy cows. Protein levels were all above the minimum of 16.5% recommended for lactating dairy cows (NRC of dairy, 2001).

In 2004, forage yields were similar across systems (Table 2). With plenty of rainfall and soil moisture this spring, established forages thrived. Four cuts were taken from CS4 and 3 cuts from CS5 and the pasture. Impressively, pasture quality was better than the alfalfa in CS5 and it could have been higher if it were harvested on a grazing vs. a haying schedule.

Table 2. Established year hay yield and quality at ARL 2003 and 2004.

	System	Yield (T dm/a)	RFV	RFQ	Protein %
2003‡	CS4 (c-a-**a**-a) A1	4.83b*	166a	186a	21.1a
	CS4 (c-a-a-**a**) A2	3.37c	162a	181ab	19.8b
	CS5 (c-o/p/a-**a**) A1	5.94a	150c	173b	19.6b
2004§	CS4 (c-a-**a**-a) A1	5.08z	157a	175a	22.5a
	CS4 (c-a-a-**a**) A2	5.15z	155a	173a	21.9a
	CS5 (c-o/p/a-**a**) A1	4.88z	110c	127c	17.2c
	CS6 (pasture)	5.48z	132b	156b	19.4b

*Different letters within column for each year are statistically different at $p<0.01$

‡ CS4 2nd yr hay was only cut 3 times vs. other systems which were cut 4 times.

ESTIMATED MILK PRODUCTION

Estimated milk production is a function of dry matter production and quality. Milk production in 2003 was higher for CS4 seeding vs. CS5 seeding due to higher yield and quality (Table 3). In the established plots, milk production was similar between systems except that the final year of CS4 alfalfa was lower because only 3 cuts were taken vs 4 cuts in the other plots.

In 2004, greater yield with average quality produced 2.5 times more milk from CS5 oats-peas-alf than the pure alfalfa seeding in CS4 (Table 3). In the established phases, one less cut in CS5 resulted in lower milk production compared to CS4. Excellent pasture quality and yields produced abundant milk.

Table 3. Milk 2000 model for WICST forage systems at ARL (2003, 2004).

	2003	2004
	Milk production (lb/acre)	Milk production (lb/acre)
CS4 new alf seeding	9,162x	5,444z
CS5 oat/alf seeding	7,052y	13,809y
CS4 1st prod yr of hay	14,093a	15,543 a
CS4 2nd prod yr of hay	10,368b	15,803 a
CS5 1st prod yr of hay	17,378a	13,599 b
CS6 12th yr of pasture	N/a‡	16,752a

*Different letters within column for each year are statistically different at $p<0.01$

‡No hay exclosure data in 2003.

Looking at the forage data over the course of the trial, results from the MILK91 analysis showed no significant differences between systems within each site (Table 4).

Table 4. Milk91 linear contrasts for WICST forage systems at both sites.

	Milk production (lb/acre)	
	ARL (through 2002)	LAC (through 1998)
CS4 direct seeded alfalfa	6,150	4,740
CS5 oats/peas/alfalfa‡	6,200 NS*	4,350 NS
CS4 Hay 1 vs.	9,740	8,380
CS5 Hay 1§	10,460 NS	8,810 NS
CS4 Hay 1	9,590	8,390
CS4 Hay 2¶	8,860 NS	8,470 NS

*NS= not significant at $p<0.10$; linear contrasts are for each site (LSMeans)

‡ 1990 first year of data; no data for 1991 and 1993 because oats were harvested as grain.

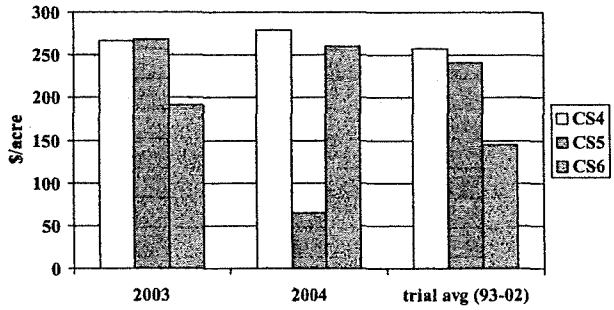
§ 1991-first year of data.

¶ 1992- first year of data.

GROSS MARGINS

Integrating forage yield and quality not only serves to estimate milk production, but it also is the basis to determine gross revenue and therefore gross margins. Figure 1 shows the gross margins in 2003 and 2004 and the trial average for the 3 forage systems. In 2003, gross margins were about equal between CS4 and CS5 averaging $267/acre. However, due to the droughty summer of 2003, supplemental hay had to be fed to heifers for about a month thus reducing CS6 gross margin to $191/acre. However, all three systems were at or above the long-term trial mean in 2003. In 2004, the failure of replanted corn stand in CS5 reduced gross margins to just over $50/acre. The pasture was as profitable as the high-input alfalfa system of CS4 since less capital (machinery, interest, depreciation, etc.) and labor are required in the grazing system. For more information on the calculation of the pasture gross margins, see the WICST 9th Technical Report (2003) on page 35.

Fig. 1. 2003 & 2004 forage system gross margins vs. 10-yr trial mean at ARL



SCENARIOS THAT EFFECT GM OF GRAZING

Days on Pasture. The average number of days on pasture at Arlington is 135, well short of a full growing season. Table 5 shows the effect on GM by keeping the heifers on pasture for more days of the year. A producer can make about $1.70/day for each day beyond 140 days. Maximizing days on pasture reduces overall yearly feeding costs and manure handling. However, wind and rain protection should be provided if heifers are going to be out on pasture in April or late October when cold, driving rain can negatively impact heifer performance. Further, shade should be available to help alleviate heat stress in the summer.

Table 5. Effect of 'days on pasture' on gross margins. Staring date: May 1

# days on pasture	Removal date	Gross margin per acre
140	Sept 17	$182
150	Sept 27	$199
160	Oct 7	$216
170	Oct 17	$233
180	Oct 27	$250

assumptions: $1.18/hd/d, 2 # grain/hd/d @ $0.087/lb, 1 hr labor/d @ $10/hr, no hay fed

Cost of grain. Another factor that affects GM is the cost of supplemental grain. Grain cost can vary depending on the source of corn. If a grazier has access to corn at close to the costs of production, then the concentrate and mineral mix (including mill charge) is about $0.087/lb. However, if the corn must be purchased, then the cost of grain mix increases to $0.15 to 0.20/lb, depending on market price. In WICST Technical Report #9 (2000 and 2001), the annual purchase price for corn was used for the years 1992-2002. If we assume 170 days on pasture, $1.18/hd/d income, 1 hr labor/d @ $10/hr, and 2 lbs grain fed per hd per day using $0.087/lb and $0.175/lb, gross margins increase from $180 to $233/acre by using the less expensive grain. It would be hard to justify paying higher grain rates if the income was less than $1.18/hd/day. If cheaper corn could not be found, then the grower might think about reducing the amount fed by focusing on feeding at times of high energy needs such as early spring when the weather can be cold and wet.

Amount of grain fed. Table 6 shows the effect of reducing the amount of grain fed from 100%, which is 2 lb/hd/day all season. For example, assuming 170 days on pasture, the 50% reduction rate would equal feeding 2 lb/hd/d for all of May and June and 25 days in October, the most obvious times that heifers would need supplemental energy.

Table 6. Effect of grain supplementation* on GM.

Grain fed	Gross margin (per acre)
100%	$233
75%	$246
50%*	$259
25%	$273

* grain held at $0.087/pound

CONCLUSION

Forages are an important component of dairy based agriculture. WICST data has shown that both chemical free forage production (CS5), as well as rotational grazing (CS6) are both highly productive systems with suitable quality forage for many classes of livestock. The alternative systems on WICST could successfully be included on any livestock farm as milk production was shown to be very similar between systems. Good productivity and reduced inputs have made these alternative systems economically competitive with the high input, pure alfalfa system (CS4). Comparing scenarios shows the importance of keeping the animals on the paddocks for a full 170 days and assuring a source of inexpensive corn. Reducing the amount or timing of corn fed to the animals will become a priority if heifer weight gains begin to surpass the target 1.8 lbs/day.

CITATIONS

Agri-view Newspaper. Aug. 18, 2005. 'Dairy' section. "Jaeger happy Raising Replacement Heifers on Grass. By Ron Johnson. Vol. 31 No. 33.

Frank, G., and R. Gregory. 2000. ABCS, v. 7.1. Center for Dairy Profitability, Dairy Sci. Dept. UW-Madison.

Hedtcke, J., and J. Posner (eds). 2003. WICST 9th Technical Report, 2001& 2002.

Howard T., R. Shaver, and D. Undersander. 1991. Milk91 for Combining Forage Yield and Quality into a Single Term. http://www.uwex.edu/ces/forage/pubs/milkac.htm

Nutrient Requirements of Dairy Cattle, 2001. National Academy Press. Washington D.C.

Shaver R., D. Undersander, E. Schwab, P. Hoffman, J. Lauer, D. Combs, and J. Coors. 2000. MILK2000: Combining Yield and Quality into a Single Term. http://www.uwex.edu/ces/forage/pubs/milk2000.htm

Schuster, D., D. Undersander, D. Schaefer, R. Klemme, M. Siemens and L. Smith. 2001. Stocker Enterprise Budgets for Grass-based Systems UW-Extension publication A3718

Undersander, D., R. Hintz, T. Howard, M. Hutjens, L. Kilmer, J. Linn, N. Martin, and R. Shaver. 1992. Alfalfa for dairy animals: Revised edition. Produced by Certified Alfalfa Seed Council, Inc, Davis, CA.

WI Agricultural Statistic Service (DATCP, USDA), 2004.

ROTATIONAL GRAZING WITH DAIRY HEIFERS ON WICST:

a. Pasture and Heifer Productivity

Janet Hedtcke[1] and Josh Posner[2]

INTRODUCTION

Whereas more and more of the milk stream is coming from large dairies with more than 1000 animal units (1 AU=1000 lb cow), managed (rotational) grazing is an increasingly important part of the landscape. In a recent study by PATS, researchers reported that managed grazing farms consistently generated more farm income and had lower costs than confinement farms in spite of less milk per cow produced (Krigel and McNair, 2005). Managed grazing is now practiced on 22% of the states' farms with another 21% of dairy farms using some pasture for the milk cow ration. Farmers in the driftless area of Wisconsin have the highest use of grazing (49-74%), primarily on marginal land and south-central WI also has a significant number of dairymen using managed grazing at 26-35% (Kriegl and McNair, 2005). Average farm size for dairy farms using managed grazing in Wisconsin is 245 acres. In this report, we look at the productivity of the grazed paddocks between 1993 to 2004 at Arlington, and 1992-1995 at Lakeland.

MATERIALS AND METHODS

Background

Pastures were established at the Lakeland Agricultural Complex (LAC) and the Arlington Agricultural Research Station (ARS) in 1990. Initially, species included red clover (*Trifolium pratense*), smooth bromegrass (*Bromus inermis*) and timothy (*Phleum pratense*); later, orchardgrass (*Dactylis glomerata*), perennial ryegrass (*Lolium perenne*) and reed canarygrass (*Phalaris arundinacea*) were also included (see Table 1 for seeding dates and rates). At LAC, the forage was mechanically harvested in 1991 and grazing began in 1992. At ARS, severe winterkill of the grasses required reseeding in 1992. Slow establishment due to drought delayed grazing there until the spring of 1993. Red clover was seeded (frost seeded at LAC and drilled at ARS) into the pastures on alternative years through 1995. Thereafter, red clover was seeded at a reduced rate when deemed necessary. Two of the paddocks at LAC (reps 1 and 4) were tilled and reseeded in August of 1996 to repair severe trampling damage, which occurred during the wet weather earlier that summer. The fall seeding of 1996 there failed and there was more reseeding in the fall of 1997. As a result, no grazing or mechanical harvest occurred on the plots at LAC in 1997. The WICST trial ended at LAC after the 2002 growing season.

[1] Research Specialist, UW-Madison, Agronomy Dept. E-mail: jlrieste@facstaff.wisc.edu
[2] Professor, UW-Madison, Agronomy Dept. Email: jlposner@facstaff.wisc.edu

Table 1. WICST pasture seeding dates and rates.

	Arlington Ag Research Station			Lakeland Agricultural Complex		
Year	Date	Species	(lb/acre)	Date	Species	(lb/acre)
1990	23-Apr	'Marathon' red clover	7.0	30-May	'Marathon' red clover	6.1
		'Badger' smooth bromegrass	8.0		'Badger' smooth bromegrass	3.0
		'Toro' timothy	4.0		'Toro' timothy	3.5
1992	30-Apr	Orchardgrass (early)	6.0	-	-	-
		'Badger' smooth bromegrass	12.0			
		'Toro' timothy	6.0			
	31-Jul	Orchardgrass (early)	4.5			
1993	09-Apr	'Arlington' red clover	12.0	07-Apr	'Arlington' red clover	20.0
1995	17-Mar	'Arlington' red clover	15.0	24-Mar	'Arlington' red clover	18.0
1996	26-Apr	'Arlington' red clover	6.0	09-Mar	'Arlington' red clover*	18.0
				22-Aug	'Arlington' red clover**	6.0
					timothy	4.0
					perennial ryegrass	3.0
1997	05-Apr	'Arlington' red clover	6.0	21-Aug	reed canarygrass	8.0
					Orchardgrass (early)	3.0
					'Arlington' red clover	8.0
1998	-	-	-	30-Mar	'Arlington' red clover***	15.0
2001	13-April	'Arlington' red clover	12.0	26-Mar	Arlington' red clover	6.0
2003	02-April	'Arlington' red clover	8.0	-	-	-

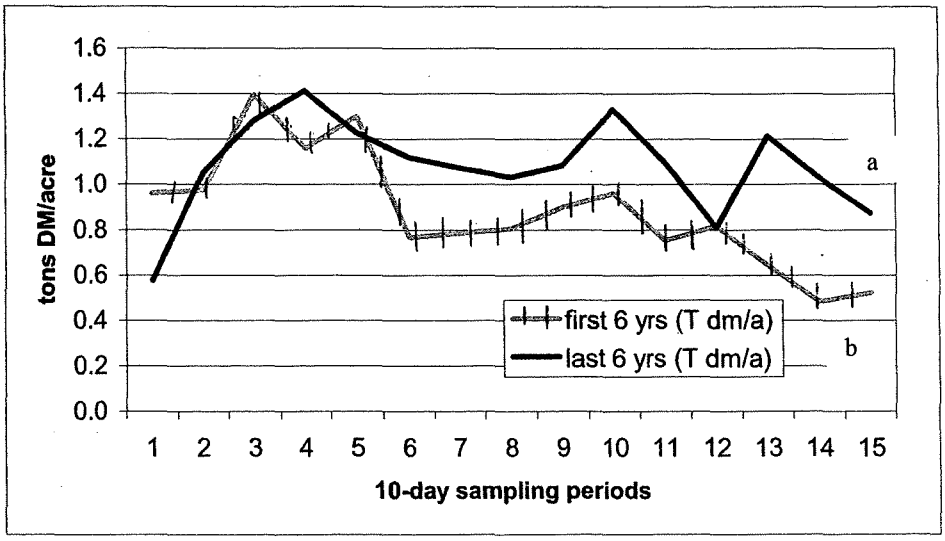
* Seeded with no-till drill; otherwise broadcast seeded except for drilling with 1990 establishment.

* * reps 1 and 2 *** Heavy seeding due to poor pasture conditions

Pasture Management

Throughout the history of the trial, dairy heifers were cycled 5-6 times per season through the four pasture plots at each site. Three grazing management strategies have been used over the 15 years of WICST (see WICST 9th Report, p. 21). The most recent, effective and practical was stocking four-to-five heifers on the plots and treating them as a cohort. This has resulted in some haying in the early spring, but the paddocks appear to be in better health (Fig. 1). Grazing pressure is adjusted throughout the season as the rate of forage growth changes. For example, in the hot, dry summer months, when forage regrowth has slowed, heifers will be given a larger area or moved through the paddock at an increased rate to maintain intake and body condition. If necessary, supplemental hay will be fed to allow adequate pasture rest and regrowth. The disadvantage of this "cohort" system is that there are not 4 replicate plots per year, each with its individual forage productivity and animal weight gain, but instead, a single result. However, years (1993-2004) replace replicates in the analysis of variance of heifer performance.

Fig. 1. Dry matter production on pasture plots at Arlington from 1993-98 (first 6 yrs) vs. 1999-04 (last 6 yrs).



In both 2003 and 2004, 5 heifers at approximately 500# each were placed on the 2.8 acres of pasture for a stocking rate of 1.8 animals/acre. Heifers moved through each paddock in about a-week-to-9 days, allowing each paddock to recover for about 24 days. Since the initiation of the trial pasture *yield* or more correctly *available forage or herbage mass* has been estimated approximately weekly from three to four random quadrats ($0.25m^2$) placed in the next area that animals would be moved to, clipped to ground level (i.e. 1 to 2-in. stubble). This information was graphed by pooling the harvest quadrat data from the 11 years at Arlington. Each point represents the mean of 4-12 sampling dates that fell within the indicated 10-day period across the season. In 2004, we initiated a second measure of productivity, by establishing an exclusion area in each pasture plot, which we mechanically harvested based on a haying schedule (data found in the paper '*WICST Forage Systems Comparison: Milk Models and Economics*' within this technical report).

Forage was dried (in 60°C oven for at least 48 hr) and forage availability is expressed on a dry matter basis. Samples were sent to the UW Soil and Plant Analysis Lab (SPAL) for quality analysis where NIRS was used to estimate crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF). Relative feed value (RFV) was calculated from NDF and ADF for each sample. Recently available from SPAL is RFQ (relative forage quality), which more accurately predicts quality than RFV because it uses fiber digestibility as an indicator verses just the amount of fiber present. This improvement is especially important for graziers as their paddocks are primarily grasses that have a higher digestible fiber than many legumes.

Herbicide. The plots are regularly scouted and spot-sprayed for thistle (Canada and bull) using stinger in a backpack sprayer (7ml of stinger/gal water). In 2003 about 0.25 gallons were used in the four plots (2.8a). In 2004 about twice that quantity of spray was used (0.5 gallons). Typically, thistles have been found along the fenceline where the mower can't reach.

Clipping. Since 2000, the heifer stocking density has remained constant and therefore excess

spring forage growth has been mechanically harvested as hay, which on a real farm would be used for winter feed or during forage shortages during the growing season. Generally, 2 plots each season are harvested as hay of mediocre forage quality; occasionally a good fall (1994, 1995) allowed an additional hay harvest from one of the paddocks (Tables 2 & 3). Mechanical clipping with a rotary mower (to about 4" stubble height) following a grazing episode has frequently been done through mid-July to remove seed heads and keep weeds in check thus improving the pasture stand and quality.

Nutrient management. Nitrogen fertilizer was not added in either 2003 or 2004. It was very dry in 2003 and timing fertilizer application with rainfall proved to be impossible. In 2004, there was so much rainfall and thus lush pasture growth that N fertilizer was unnecessary. Early spring applications of 50 lb N/a were administered at Arlington in 1993, 1994, 1996, and 2000, and in 1993 at Lakeland. In 2004, soil test P and K levels in replicates # 1 and 2 are still 'excessively high'. Rep 2 (plot 207) has historically tested excessively high in STK (388 ppm), probably due to its proximity to the old field road from the dairy barn. However, in replicates #3 and 4, STK is drawing near the replacement category (STK=115) and should start receiving K fertilizer to maintain levels.

Heifer Management

Grazing details for years prior to 2003 have been reported in each of the previous WICST technical reports (2nd-9th).

2003. Five heifers were shrunk, weighed and placed on pasture from May 7th and removed September 24th (139 days on pasture). Five control animals of similar size were weighed at the same time and remained in confinement. Due to a drought during the summer months, pasture grass growth was minimal in August so supplemental hay was fed for 33 days for a total of 1020 lbs (*as fed).* The cattle were removed earlier than normal from the plots due to lack of feed. Two pounds of grain was fed each day to each heifer.

2004. Five heifers were shrunk, weighed and placed on pasture from April 27th until October 11th (167 days on pasture). Another 5 control animals (confinement) were weighed (recently moved and housed at Marshfield). Heifers cycled through the plots 5 times this season. Ample rainfall, excellent water holding capacity of the soil, and cooler than average temperatures all contributed to excellent forage production. No supplemental hay was fed, but grain was again fed at 2 lb/hd/day throughout the season.

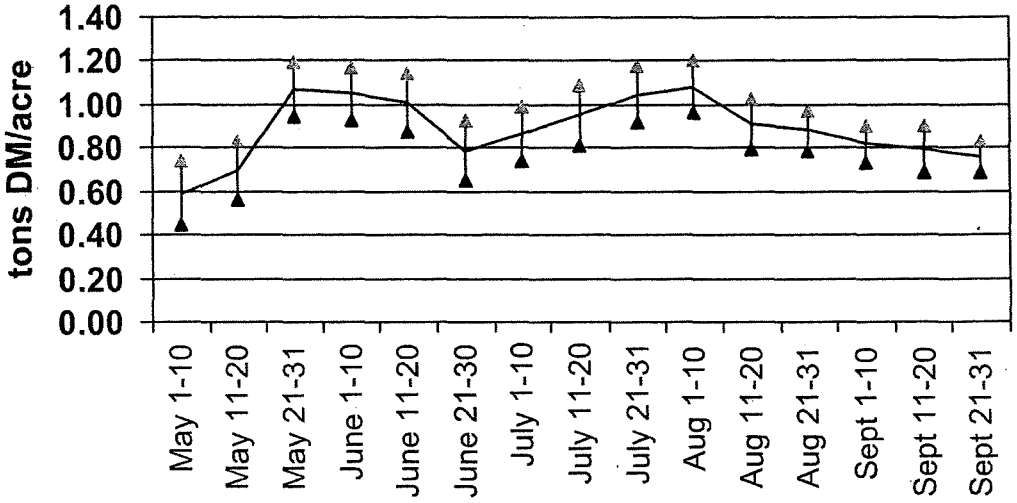
RESULTS AND DISCUSSION

Long-term Productivity.

Since the pasture plots were established, they have produced well with about 0.8 to 1.0 tons of available dry matter/acre at Arlington as the heifers moved to new grass, and 0.6 to 1.0 tons at Lakeland (Fig. 2 & 3). The growth curves at each site suggest that our stocking rate is about right so that a relatively constant supply of forage is available in each cycle. At ARS, the growth distribution was a bit more even than at LAC although both sites experienced the 'summer slump', or reduced forage production in late June and July. The flat lay of the paddocks at ARS allows most of the rainfall to infiltrate instead of running off and the excellent water holding

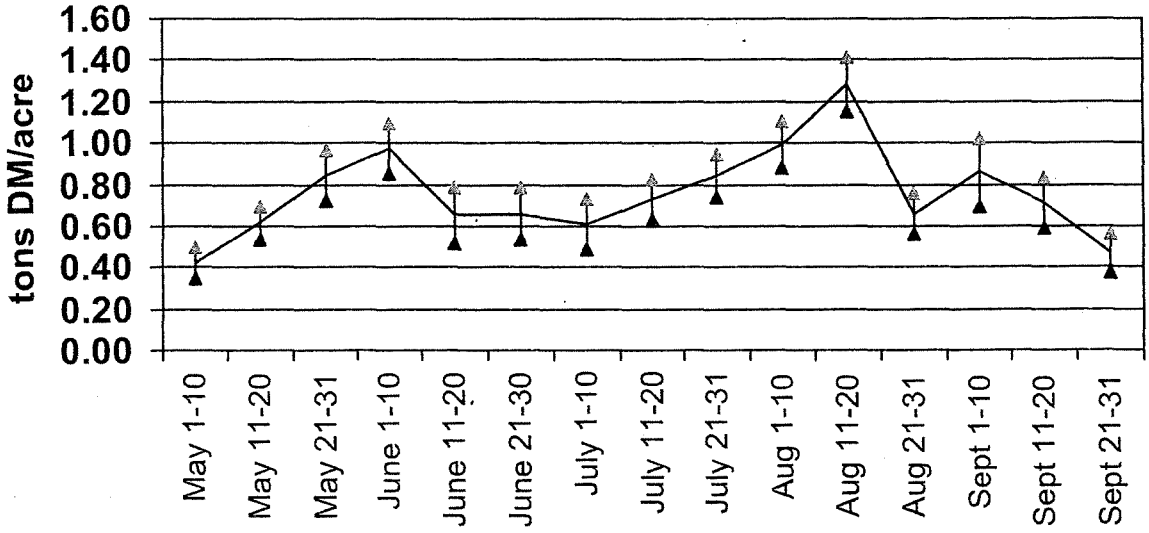
capacity of the soil are partial explanations for the sustained production during the dry summer months. At LAC, reduced summer yields were, in large part due to the fact that the paddocks are on some slope, the soils have slower infiltration rates and during several years, there has been hotter, drier summer weather at this site.

Fig 2. Pasture forage availability at Arlington over the duration of the trial (the line is the mean for each sample period with 90% confidence interval around each mean).



1 Data from 1993-2004 except no yield data for 1996.

Fig 3. Pasture forage availability at Lakeland during the first four years of the trial (the line is the mean for each sample period with 90% confidence interval around each mean).



1 Data from 1992-1995.

Table 2. Mechanical hay harvested on pasture plots over the course of the trial at ARS.

Year[1]	Date	Yield (tons DM/a)	Plot #	Crude Protein (%)	RFV
1993	June 11	0.54	112,302,405	13.8	90
1994	May 31	1.08	All 4 plots[2]	13.3	103
	October 21	1.10	All 4 plots[2]	16.7	125
1995	June 5	0.38	All 4 plots[2]	12.1	101
	October 9	0.99	All 4 plots[2]	16.9	93
1997	June 14	1.43	405	-	-
1998	May 12	1.68	302	19.4	145
2000	May 16	1.15	207	18.1	120
	June 6	1.68	302	9.6	82
2001	May 25	1.52	207	-	-
	June 30	1.04	405	10.7	89
2002	May 6	1.20	207	-	-
	May 16	0.94	405	18.7	132
	June 11	0.23	405	15.5	108
2003	June 24	2.15	405	12.9	102
2004	May 25	1.75	302	14.0	115

[1] No hay harvested in 1996 or 1999. [2] Only partial plot was taken as hay while the rest was grazed.

Table 3. Mechanical hay harvested on pasture plots over the course of the trial at LAC.

Year[1]	Date	Yield (tons DM/a)	Plot #	Crude Protein (% of DM)	RFV[2]
1992	May 30	1.43	104,314,408	16.5	136
1994	June 16	0.39	All 4 plots[2]	12.1	99
1995	May 31	0.28	All 4 plots[2]	11.6	79
	June 23	0.32	104, 314	15.4	90
2000	June 20	1.59	408	16.6	-
2001	July 9	0.75	408	6.6	84
2002	June 9	1.28	408	13.9	102

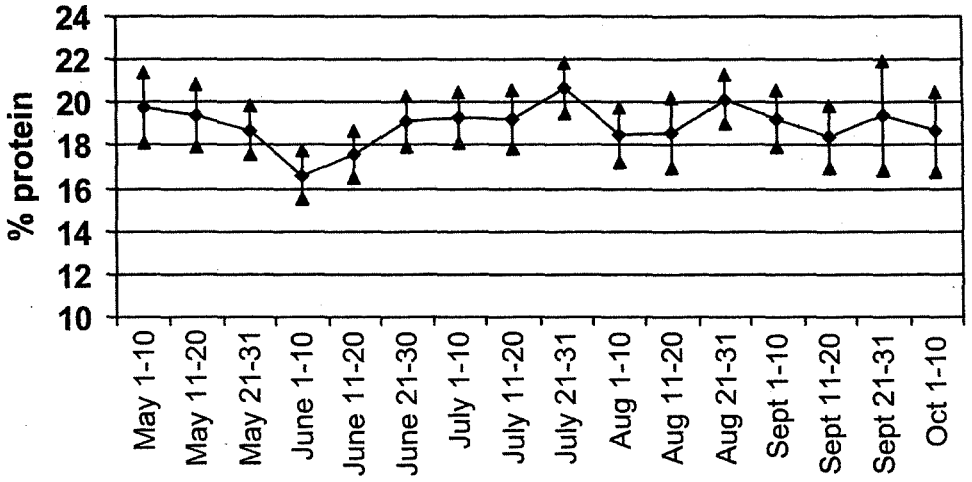
[1] No hay harvested in 1993, 1996-1999. [2] Only partial plot was taken as hay while the rest was grazed.
[2] RFV of 100 = full bloom alfalfa

Long-term Quality

Forage quality has been very good with protein levels fairly steady within the season. Average crude protein was 18.4% across sites and peaked at 21% when grass regrowth was leafy and legumes were prevalent (Figs. 4 and 5). Generally, protein levels dropped as low as 14% during mid-June as grasses matured. The forage quality in the first week on June is significantly lower than in early May or later in the summer when the grasses are predominately leaves.

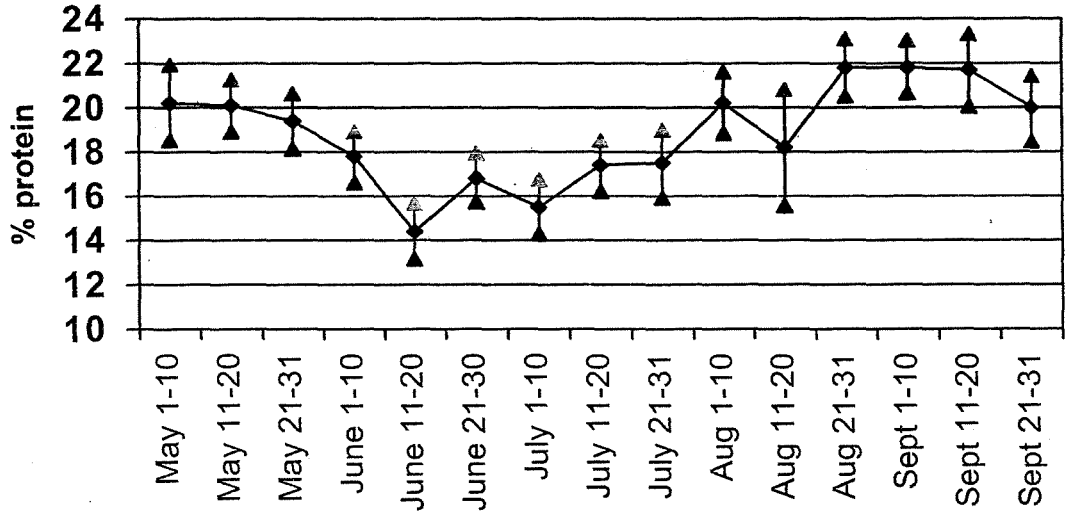
Relative feed value, averaged 123 across sites and years ranging from 100 to 160 (data not shown). (This number underestimates the quality of grass-based forage and in the future the RFQ analysis will be used). Arlington tended to have higher quality grass than LAC at most sampling points perhaps due to a more favorable environment at ARS or better plot management. A RFV between 115 and 130 is considered appropriate for growing heifers between 12 and 18 months like those used in the study.

Fig 4. Pasture crude protein at Arlington over the duration of the trial (the line is the mean for each sample period with 90% confidence interval around each mean).



1 Data from 1993-2004 except no yield data for 1996.

Fig. 5. Pasture crude protein at Lakeland during the first four years of the trial (the line is the mean for each sample period with 90% confidence interval around each mean).



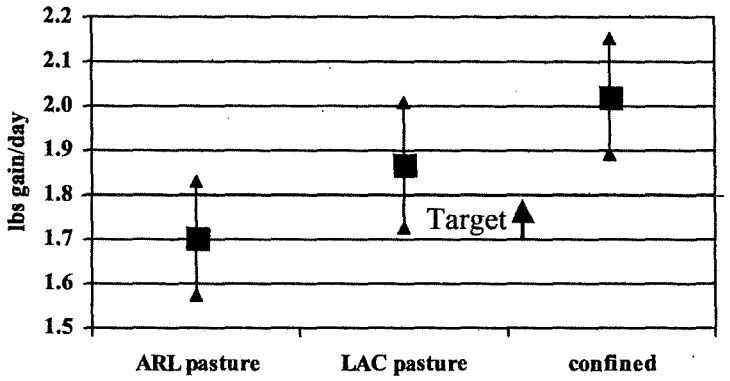
1 Data from 1992-1995.

Heifer performance

Using years as our replication factor for heifer performance, we had 69 animals on the grazing treatment and 65 animals on the confinement treatment at ARL (12 years of data). Fifty-four animals were on pasture at LAC over the duration of the trial (7 years of data). Using 1.8 lb/day weight gain target, grazing at both sites was not statistically different from the goal as shown by the 90% confidence intervals in Fig. 6. However, the mean of 1.7 lb/hd/d is at the low end of performance and it seems that our minimal grain supplementation will continue to be necessary to provide energy. There was a difference between the confinement group and the pasture group

at ARL with the confinement group having significantly more body condition. This can be explained by their high-energy ration and less exercise compared to the pasture group. In general, confinement animals gained 2.2 lb/d or about 20% faster rate than the heifers on pasture. This is in agreement with a study by Tobert and Linn (2002) who found that feedlot heifers gained 23% more weight per day than pastured heifers. The daily ration fed to the confinement group on per heifer basis is typically 11 # alfalfa haylage (18% CP, 63% DM), 5 # corn silage (7% CP, 38% DM) and 5 # of corn-soybean meal-oat mix (16% CP, 90% DM).

Fig 6. Heifer performance under managed grazing compared to confinement with 90% confidence interval around each mean.



CONCLUSION

On the excellent soils at Arlington and good soils at Lakeland, intensive rotational grazing with modest corn supplementation permits dairy heifers to gain weight at close to the recommended 1.8 lbs/head/day. The economics of the conventional alfalfa based hay vs. rotational grazing is presented in the paper '*WICST Forage Systems Comparison: Milk Models and Economics*' within this technical report. Pastured heifers, harvesting their own forage and spreading their manure can substantially reduce labor and feeding costs compared to confinement. However, one must remember that heifers are only on pasture 6 months of the year, which means stored feed must be on hand for winter feeding and extra labor must be added for manure management and some type of housing or shelter should be available against wind and rain.

LITERATURE CITED

Kriegl, T., and R. McNair. 2005. Pastures of plenty: Financial performance of Wisconsin grazing dairy farms. PATS. UW-Madison, February 2005.

Tobert and Linn. Agri-view newspaper article, June 12, 2003.

BENEFITS OF DIVERSIFYING THE CORN-SOYBEAN ROTATION: Data from WICST 1995-2003

Janet Hedtcke[1], Josh Posner[2], and Jon Baldock[3]

INTRODUCTION

Since the mid-20th century, farmers have become more specialized, resulting in less diverse and higher input cropping systems. However, marginal profits, increasing pest pressure, and growing concern for pollution hazard have renewed interest in diversifying cash-grain rotations. As part of the Wisconsin Integrated Cropping Systems Trial (WICST), we compared 3 cash-grain systems with different levels of crop diversity and inputs for 9 years and compared them in terms of production, profitability and environmental impact.

MATERIALS AND METHODS

Based on early results from the WICST, which began in 1989, a 'Chemlite' system was initiated in 1995 for comparison to the existing cash grain systems of continuous corn (c-c-c), and a no-till corn-soybean system (c-sb). Chemlite is a corn-soybean-winter wheat with red clover system (c-sb-w/rc) with half the N fertilizer and pesticide inputs as the other systems. The soybeans were drilled in narrow rows in the no-till system and planted in wide rows in Chemlite to allow row cultivation. Red clover was drilled in the wheat in early spring. All plots were 0.7 acre and field-sized equipment was used. Management inputs and outputs, and commodity prices have been recorded each year. Soil fertility levels and soil nitrates were monitored from annual fall soil sampling.

The experiment was set up with two replicates in a randomized complete block. Each phase of each system existed each year during the 9-yr trial to encompass different environments and weather. All effects in the model are fixed except year and replicate, which are random. To compare corn and soybean phases, 95% confidence intervals were calculated.

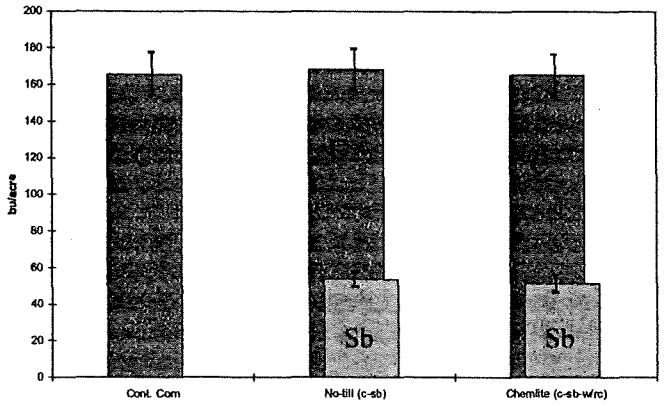
The Crop Rotations Options Program (CROP) software (Baldock et al., 1998) was used to determine net returns (to labor, capital, and management). Net returns were calculated on a system basis. A 1000-acre farm was used in CROP and yearly input prices (seed, fertilizer, herbicide etc.), yields, and commodity prices (including straw sales) were entered for each system. Harvest-time commodity price (October price without storage option [WI Ag Stats, 2004]) was used across systems without any governmental price supports. We used RUSLE2 at various slope steepness and lengths to compare each system's predicted soil erosion.

RESULTS

There were no YEAR X SYSTEM interactions for crop yield so system means are presented. Corn and soybean yields were not significantly different among the systems averaging 166.9 and 52.5 bu/a, respectively (Fig. 1). Wheat grain and straw yields in Chemlite were above the local county average (data not shown).

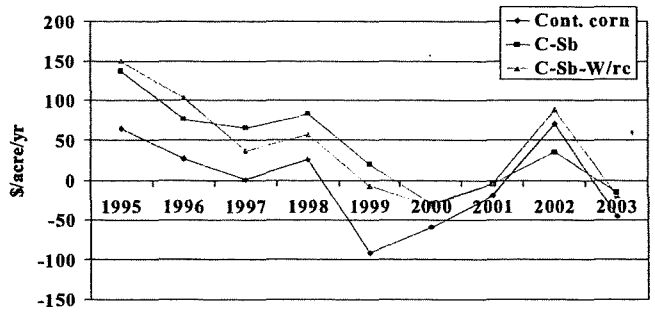
[1] Research Specialist, UW-Madison, Agronomy Dept. jlrieste@wisc.edu
[2] Professor, UW-Madison, Agronomy Dept., jlposner@wisc.edu
[3] AGSTAT, Verona, WI agstat@tds.net

Fig. 1. Corn and soybean yield comparison across systems with 95% confidence interval (1995-2003 avg.)



The 9-yr. average net return was very similar between no-till c-sb ($45/a/yr) and Chemlite ($41/a/yr), both significantly higher than continuous corn ($3/a/yr). Note the precipitous trend in net returns for all systems, which was mainly due to declining commodity prices during the time of the study (Fig. 2).

Fig. 2. Net Returns ($/a/yr) on each system over 9 years.



Due to the annual use of starter fertilizer, the continuous corn plots had higher STP values (89 ppm) than the other systems (58 ppm). Fall soil nitrates, which could potentially leach into the ground water, were always highest under continuous corn, over twice that of typical

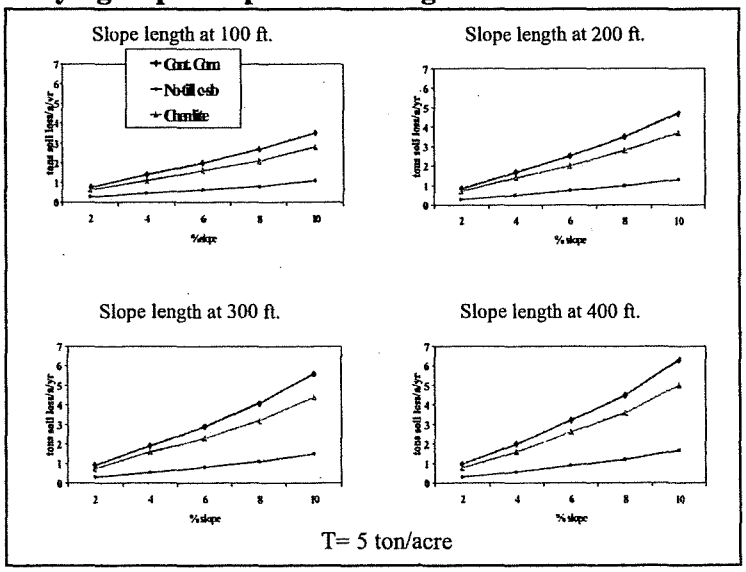
'background' nitrate levels of 50 lb/a to a 3-ft. depth. Chemlite was 41 and 23% lower than continuous corn and no-till c-sb, respectively (Fig. 3). The wheat phase in the fall and winter on a third of the farm helps to hold the nitrate in place. Furthermore, the red clover green manure reduces the use of chemical fertilizer in the following corn phase.

Fig. 3. Fall soil nitrates in top 3 ft. of soil in each system (1999-2003 avg.)

System	lb NO_3^-N/a	95% CI
Continuous corn	107.4	89.6 to 125.2
No-till corn-soy	82.5	65.2 to 99.8
Chemlite corn-soy-wheat/red clover	63.8	46.0 to 81.6

Soil loss was well under 'T' (T=5 T/a/yr) for the no-till c-sb on all 'farmable' slopes (Fig. 4). However, due to repeated annual tillage, the conventionally tilled systems should not be done on steep slopes longer than 300 ft. because soil loss approaches or exceeds 'T'. The continuous corn system had higher soil loss than Chemlite in all scenarios tested because the wheat and red clover cover crop provided soil protection in a third of the system. No-till methods can be added to Chemlite to further reduce soil erosion on steep slopes.

Fig. 4. Predicted soil loss by RUSLE2 on the 3 systems at varying slope steepness and lengths.



CONCLUSIONS

This research shows that expanding grain rotations beyond monocropping corn is advantageous from economic and environmental perspectives. Net returns were lowest for continuous corn. Soil test P remains excessively high under continuous corn. Soil loss was always CS1>Chemlite>CS2. Increasing from two crops to three also has certain environmental advantages such as reduced nitrates and it is still economically competitive.

CITATIONS

Baldock, J.O., J. L. Posner, D. Fisher. 1998. Crop Rotations Options Program. Software University of WI, Madison, WI.

RUSLE2. http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm

WI Agricultural Statistic Service (DATCP, USDA), 2004.

DOES DIVERSIFICATIONS REDUCE FALL NITRATES: Data from WICST

Josh Posner[1], Janet Hedtcke[2] and Jon Baldock[3]

INTRODUCTION

Fall soil nitrate-N levels are an indirect measure of the synchrony between nitrogen availability during the growing season and crop nitrogen uptake in agricultural fields. Also, between late fall and the following spring these nitrates can leach below the rooting zone and be lost to the agricultural system. As a result, fall monitoring of soil nitrates is one measure of potential environmental impact of alternative production systems. For this reason we monitored nitrate-N on all 14 phases of the six cropping systems in the Wisconsin Integrated Cropping Systems Trials (WICST) at two locations in southern Wisconsin.

MATERIALS AND METHODS

In 1990, the trial was initiated at Arlington and Elkhorn, Wisconsin on silt loam soils developed under prairie vegetation. The trial compares three cash-grain systems and three forage based systems. Plots are 0.7 acres in size, all phases are present every year and each system is replicated four times at both locations. In late October/early November, we sampled the plots for fall nitrates. Each sample consisted of six cores that were taken as 3-paired samples across the plot and bulked at 0-12 inches, 13 to 24 inches and 25-36 in depths. Initially (1990-1996) sampling was done by hand with a 1-in. diameter probe and subsequently (1997-2003) with a truck mounted 1.25-in. diameter hydraulic probe. Each year samples were taken from adjacent land to serve as non-agricultural, background checks.

All phases of the six systems were up and running by 1993, and until 1998, the treatments were equivalent at both sites. Shortly thereafter the Elkhorn site was terminated and the trial continues at the Arlington site. Nitrate-N was extracted from the top 3 feet of soil using a 2M KCl extractant and analyzed with a Lachet Flow Injection Analyzer. The SAS ProcMix model was used for this analysis, where year and block where considered random variables.

RESULTS

When averaged over rotation phases, the ranking of the systems fall soil nitrate-N levels were nearly the same at both locations. Continuous corn (CS1) had the highest levels at both sites, and the rotationally grazed paddocks (CS6) had the lowest levels at Arlington, while the chemical free grain system (CS3) was lowest at Elkhorn **(Fig. 1 and 2)**. Somewhat surprisingly, the no-till corn soybean system (CS2) operated under Best Management Practices was very similar in fall nitrates to the two dairy rotations amended with manure (CS4 and CS5). The chemical free grain system (CS3) and the rotational grazing (CS6) were among the lowest at both sites and not significantly different from each other. All six cropping systems left nitrate-N levels that were significantly above the standard background level in Wisconsin of 50 lbs nitrate-N/3 feet (Bundy, 1994).

[1] Professor, UW-Madison, Agronomy Dept. jlposner@wisc.edu
[2] Research specialist, UW-Madison, Agronomy Dept. jlrieste@wisc.edu
[3] AGSTAT, Verona, WI agstat@tds.net

Fig. 1. Cropping Systems Fall Nitrates
Mean and 90% Confidence Intervals
Arlington (1993-2003)

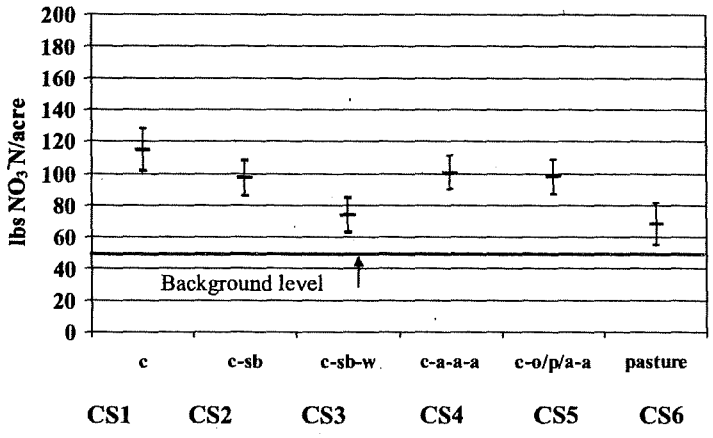
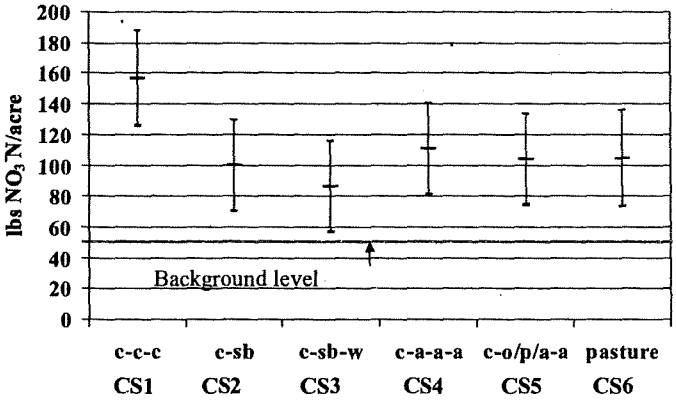


Fig. 2. Cropping Systems Fall Nitrates
Mean and 90% Confidence Intervals
Elkhorn (1993-1996)



Corn was the "hot" phase in the dairy rotations due to the combination of legume credits plus manure **(Fig. 3 and 4)**. In the grain rotations, continuous corn had the highest nitrate-N levels, but the corn and soybean phases of systems CS2 and CS3 were nearly equivalent. The wheat/red clover phase in the chemical free system (CS3) had the lowest mean nitrate-N levels at both sites and it was the only phase that was not significantly different from the background level at both sites. This was probably due to the production of wheat with only soil organic matter mineralization and soybean legume credits and then the vigorous growth of red clover that was only undercut, not incorporated in the late fall. In this system wheat yields averaged 54 bu/a and corn yields were 146 bu/a. (WICST Technical Report, 2003).

Fig. 3. Crop Phase Fall Nitrates
Mean and 90% Confidence Intervals
Arlington (1993-2003)

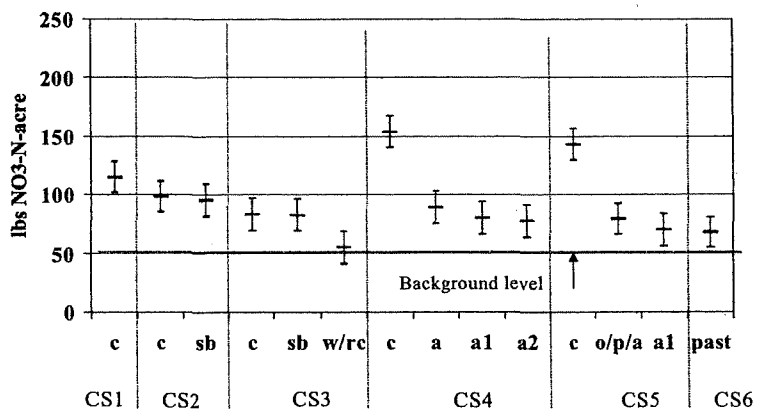
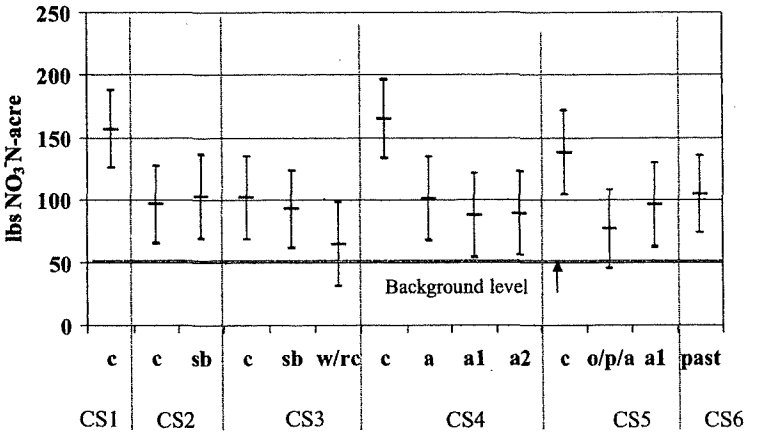


Fig. 4. Crop Phase Fall Nitrates
Mean and 90% Confidence Intervals
Elkhorn (1993-1996)



CONCLUSIONS

This work suggests that all the agricultural systems studied did have significantly higher levels of fall nitrates than the background level of 50 lbs nitrate-N/3 feet. Also, both the forage based and grain based systems resulted, on average, in equally high levels of fall nitrate-N. The most benign systems were the chemical free grain (CS3) and rotational grazing forage (CS6) systems. The highest fall soil nitrate-N levels were associated with corn production especially when corn received both legume-N and manure-N. With both the grain and forage systems, the lowest fall nitrate-N levels were associated with the most diversified cropping systems.

CITATIONS

Bundy, L. 1994. Soil nitrate test for Wisconsin cropping systems. UW Extension Bulletin A3624. University of Wisconsin Madison, WI.

WICST 9th Technical Report. 2003. Wisconsin Integrated Cropping Systems Trial Ninth Technical Report 2001, 2002 Agronomy Department mimeo University of Wisconsin Madison, WI.

EVALUATION OF THE ILLINOIS SOIL NITROGEN TEST FOR CORN PRODUCTION IN WISCONSIN

J.T. Osterhaus, L.G. Bundy, and T.W. Andraski

JUSTIFICATION AND STATEMENT OF PROBLEM

Improved nitrogen (N) management in corn production is needed to optimize economic returns to farmers and minimize environmental impacts associated with agricultural N use, specifically, nitrate enrichment of groundwater and hypoxia of the Gulf of Mexico. In recent years, improving nitrogen management has been made through the use of soil nitrate testing in Wisconsin (Bundy and Andraski, 1995; Andraski and Bundy, 2002), although additional improvements in predicting crop N requirements on a site-specific basis are needed. A North Central Regional study (Bundy et al., 1999) showed that preplant (PPNT) and presidedress (PSNT) soil nitrate tests could improve identification of sites where corn would not respond to N fertilization, but the use of soil nitrate tests in cropping systems with substantial amounts of organic N mineralization was less promising and indicated a need to better understand and quantify N mineralization in cropping systems (Bundy et al., 1999). A major obstacle to improve N management is the lack of a reliable technique to estimate the N mineralization component of the crop N supply. A recent test based on measuring the amino sugar content of soils (Khan et al., 2001) shows promise for predicting corn N response where variation in N availability is mainly due to differing levels of N provided by N mineralization. Amino sugars are a structural component of the microbes that result in nitrogen mineralization, therefore measuring amino sugars could be an indirect indication of N-mineralization. Research is needed to evaluate this method (Illinois soil nitrogen test) in a range of soil climates and previous management environments to determine its potential for improving N management in Wisconsin and other locations.

OBJECTIVE

Calibrate the amino sugar N test method (Illinois soil nitrogen test – ISNT) for predicting corn nitrogen rates in Wisconsin using established experiments with a range in N availability.

SUMMARY OF PREVIOUS WORK

Amino sugar-N accounts for about 10-15% of the total N in most soils. Recent work in Illinois (Khan et al., 2001; Mulvaney et al., 2001) shows that amino sugar-N content is a good indicator of the need for N fertilization in corn production. In the Illinois research, 11 of 18 corn N response experiments showed no response to additional N fertilizer. Analysis of amino sugar-N in soils from these 18 N response experiments showed a good inverse relationship between the magnitude of corn yield response to N and the amino sugar content of the soil. All of the non-responsive sites had amino sugar-N test values of more than 250 ppm while sites where applied N fertilizer resulted in increased yields test values were less than 250 ppm. These findings indicate that the Illinois soil nitrogen test has the potential to improve N fertilization recommendations for corn on a wide range of soils. This paper will discuss the performance of the Illinois soil nitrogen test alone and in conjunction with soil nitrate-N measurements for predicting corn yield response to N fertilization in southern Wisconsin.

PROCEDURE

The experiments were located on several of the established cropping systems treatments in the Wisconsin Integrated Cropping Systems Trial (WICST) at the Arlington Agricultural Station. Access to the WICST experimental site is provided through the cooperation of Dr. J.L. Posner, University of Wisconsin-Madison, Department of Agronomy.

Research using the Wisconsin Cropping Systems Trial (WICST):

The Wisconsin Integrated Cropping Systems Trial (WICST) at the Arlington Research Station was initiated in 1990 and includes six cropping systems with a range of crop diversity, management intensity, and external or purchased inputs (Griffith and Posner, 2001). The trial features large individual plot size (0.70 acres) and the cropping systems have been managed uniformly for more than ten years. Two systems were of special interest for the evaluation of the amino sugar N test, specifically, fall plowed continuous corn (CC) and no-till soybean-corn rotation (SC). Nitrogen response experiments were established in each of these two cropping systems using a randomized complete block design with four replications. Nitrogen fertilizer treatments were hand broadcast as ammonium nitrate at rates of 0, 60, 90, 120, 150, 180, and 210 lb N/acre soon after corn planting. Individual plots were six rows wide and 30 ft. long. Corn was planted using an adapted hybrid, 30-inch row spacing, and a target plant density of 28,000-30,000 plants/acre. Corn silage yield by harvesting 6 randomly selected plants from the two center rows. Corn grain yields were determined in each plot by harvesting the two center rows with a plot combine. The N rate structure in the corn sequences allowed determination of corn yield response to N and an estimate of the economic optimum N rate (EONR). Regression analysis was used to establish the relationship between (EONR) for corn and soil N tests.

Soil samples were collected before corn planting from each plot according to the following plan: 1) Preplant soil samples (0-3 ft depth in 1-ft increments) for soil nitrate determinations were taken in April; 2) Soil samples for the amino sugar-N analysis were collected at the same time from the 0-6 and 6-12 inch depths; 3) Pre-sidedress soil samples to one foot depth were collected in early June, at approximately the v-6 stage; and 4) at the end of season (November) soil samples were collected after corn grain harvest (0-3 ft depth in 1-ft increments) to see if any residual nitrate-N remained after the growing season. Preplant soil samples were analyzed for nitrate-N (Bundy and Meisinger, 1994) and amino sugar-N analysis was performed as described by Khan et al. (2001). Nitrate analysis for the pre-sidedress and fall nitrate tests were conducted following the preplant sampling method. The second year experiments in the WICST experiment were moved to a new location within the experiment to avoid any residual effects of the N rate treatments from the previous year.

RESULTS AND DISCUSSION

Soil nitrate and amino sugar-N content:

In the 2003 growing season, preplant soil profile (0-3 ft) NO_3-N contents obtained in April were significantly higher in CC (142 lb/a) than in SC (84 lb/a) and about one-half of this was in the top one foot (Table 1). Pre-sidedress soil NO_3-N contents (0-1 ft) obtained in June were not significantly different between previous crops (57 lb/a in CC and 40 lb/a in SC.

During the 2004 growing season, preplant soil profile (0-3 ft) NO_3-N contents obtained in April were nearly equal in both CC (44 lb/a) and SC (53 lb/a) resulting in no credit in the CC rotation and only 3 lb/a N-credit in the SC rotation (Table 2). Pre-sidedress soil NO_3-N contents (0-1 ft) obtained in June were not significantly different between previous crops (33 lb/a in CC and 26 lb/a in SC),

The preplant samples were also analyzed using the ISNT. The values also show that in both years only the CS rotation in 2003 would have responded to additional N fertilizer based on the critical value of 235 ppm determined by Khan and Mulvaney (Khan et al., 2001). However, this is not the N response that was observed in the field.

In both 2003 and 2004, soil samples were also obtained in approximately 7-day increments from two depths (0-6 and 6-12 in.) from one replication for each of the two previous crops throughout the growing season. In general, little change in ISNT values was apparent over the course of the growing season and the apparent differences over time are likely due to spatial variability. This suggests that the ISNT is measuring a more constant and stable fraction of the soil N pool instead of a variable and plant available N pool.

Corn silage and grain yield:

Corn Silage Analysis:

The 2003 corn silage yield averaged across N rates for CC and SC was 8.95 and 9.03 tons DM/acre, respectively, and was not significantly different. Silage yield without N fertilizer was 6.90 and 5.90 tons DM/acre for CC and SC, respectively. Regression analysis of the N response data resulted in an economic optimum N rate (EONR) of 175 lb/acre for CC and 156 lb/acre for SC (Table 4). Silage yields at the EONR were 9.70 tons/acre for CC and 9.81 tons/acre for SC.

The 2004 corn silage yield averaged across N rates for CC and SC was 6.60 and 7.26 tons DM/acre, respectively, and was not significantly different. Silage yield without N fertilizer was 5.51 and 5.66 tons DM/acre for CC and SC, respectively. Regression analysis of the N response data resulted in an economic optimum N rate (EONR) of 63 lb/acre for CC and 109 lb/acre for SC (Table 5). Silage yields at the EONR were 5.98 tons DM/acre for CC and 7.64 tons/acre for SC.

Corn Grain Analysis:

In 2003, the effect of previous crop on corn grain yield was not significant. Grain yields without N fertilizer were 119 bu/acre for CC and 109 bu/acre for SC. A significant grain yield response to N fertilizer occurred with yield increases of about 55% for CC and 90% for SC at the non-limiting N rate. Similar to silage, grain yield responded to slightly higher N rates in CC compared with SC (Table 6). The EONR for CC was 196 lb/acre resulting in a yield of 184 bu/acre compared with SC which had an EONR of 160 lb/acre with a corresponding yield of 206 bu/acre.

During 2004, the effect of previous crop on corn grain yield was not significant. Grain yields without N fertilizer were 144 bu/acre for CC and 146 bu/acre for SC. A significant grain yield response to N fertilizer occurred with yield increases of about 33% for CC and 36% for SC at the non-limiting N rate. Similar to silage, grain yield responded to slightly higher N rates in CC

compared with SC (Table 7). The EONR for CC was 109 lb/acre resulting in a yield of 188 bu/acre compared with SC which had an EONR of 100 lb/acre with a corresponding yield of 191 bu/acre.

End-of-season soil nitrate:

In 2003, soil profile (0-3 ft) NO_3-N contents at the end of the growing season were significantly higher in CC than in SC at all N rates (Table 8). A linear relationship between N rate and soil NO_3-N content was apparent for both previous crops. For CC, soil NO_3-N values ranged from 21 to 120 lb/acre at the 0 to 210 lb/acre N rate. For the full range of N rates in SC, NO_3-N values ranged from 7 to 106 lb/acre.

The 2004 growing season soil profile (0-3 ft) NO_3-N contents at the end of the growing season were not significantly different in either rotation all N rates (Table 9). A linear relationship between N rate and soil NO_3-N content was apparent for both previous crops. For CC, soil NO_3-N values ranged from 33 to 70 lb/acre at the 0 to 210 lb/acre N rate. For the full range of N rates in SC, NO_3-N values ranged from 22 to 119 lb/acre.

SUMMARY

The amino sugar-N content of soil based on the results of the ISNT is not adequate to correctly determine crop N need. The N recommendation based on the ISNT results given the critical value of 235 ppm would have resulted in no additional N application in both 2003 and 2004 except in the 2003 CS rotation, resulting in under application of N.

The 2003 and 2004 growing seasons resulted in very different N recommendations for each year and for each crop rotations. The ISNT values differed very little from one growing season to the next and throughout each of the growing seasons. This shows that the ISNT is measuring a more constant and stable fraction of the soil N pool instead of a variable and plant available N pool.

Nitrogen rate recommendations based on the preplant soil nitrate test (PPNT) would have resulted in below optimum N rates for both CC and SC in 2003, while in 2004 over-application would have resulted in both cropping rotations. Nitrogen rate recommendations based on the presidedress soil nitrate test (PSNT) for the 2003 season underestimated the EONR for both rotations. In 2004, the PSNT resulted in a slight over-application of N fertilizer in both the CC and SC rotation (about 20-30 lb. over-application). Table 10 summarizes the EONR compared UW recommendations and soil nitrate tests. Further research will evaluate whether a combination of soil N tests (i.e. PPNT or PSNT and ISNT) will improve site-specific N rate recommendations.

REFERENCES:

Andraski, T.W., and L.G. Bundy. 2002. Using the PSNT and organic N crediting to improve corn nitrogen recommendations. Agron. J. 94:1411-1418.

Bundy, L.G., and T.W. Andraski. 1993. Soil and plant nitrogen availability tests for corn following alfalfa. J. Prod. Agric. 6:200-206.

Bundy, L.G., and T.W. Andraski. 1995. Soil yield potential effects on performance of soil nitrate tests. J. Prod. Agric. 8:561-568.

Bundy, L.G., D.T. Walters, and A.E. Olness. 1999. Evaluation of soil nitrate tests for predicting corn nitrogen response in the North Central Region. NC Regional Res. Pub. No. 342. Univ. of Wis., Madison, WI.

Bundy, L.G., and J.J. Meisinger. 1994. Nitrogen availability indices. p. 951-984. In R.W. Weaver et al. (ed.) Methods of soil analysis. Part 2. Microbiological and biochemical properties SSSA book series no. 5. SSSA, Madison, WI.

Griffith, K., and J.L. Posner. 2001. Comparing Upper Midwestern farming systems: Results from the first 10 years of the Wisconsin Integrated Cropping Systems Trial (WICST), 36 p. Dept. of Agronomy, Univ. of Wisconsin, Madison, WI..

Kahn, S.A., R.L. Mulvaney, and R.G. Hoeft. 2001. A simple soil test for detecting sites that are nonresponsive to nitrogen fertilization. Soil Sci. Soc. Am. J. 65:1751-1760.
Mulvaney, R.L., S.A. Khan, R.G. Hoeft, and H.M. Brown. 2001. A soil organic nitrogen fraction that reduces the need for nitrogen fertilization. Soil Sci. Soc. Am. J. 65:1164-1172.

Vanotti, M.B., and L.G. Bundy. 1995. Soybean effects on soil nitrogen availability in crop rotations. Agron. J. 87:676-680.

Vanotti, M.B., L.G. Bundy, and A.E. Peterson. 1997. Nitrogen fertilizer and legume-cereal rotation effects on soil productivity and organic matter dynamics in Wisconsin. p. 105-119. In E.A. Paul et al. (ed.) Soil organic matter in temperate agroecosystems: Longterm experiments in North America. CRC Press, Inc., Boca Raton, FL.

Table 1. Effect of previous crop on preplant (April) soil profile NO_3-N levels, Arlington 2003.

	Previous crop †	
Soil depth	Corn	Soybean
	---------- soil NO_3-N, lb/acre ----------	
0 - 1	69	36
1 - 2	49	32
2 - 3	24	16
0 - 3	142	84

† Previous crop (0-3 ft) $p>f = 0.01$.

Table 2. Effect of previous crop on preplant (April) soil profile NO_3-N levels, Arlington 2004

	Previous crop †	
Soil depth	Corn	Soybean
	---------- soil NO_3-N, lb/acre ----------	
0 - 1	18	20
1 - 2	14	16
2 - 3	12	17
0 - 3	44	53

† Previous crop (0-3 ft) $p>f = 0.25$.

Table 3. Preplant ISNT values

Crop Rotation	Sample Depth (ft)	Average ISNT Value (ppm)	
		2003	2004
Cont. Corn (CS1)	0-1	291	252
Soybean Corn (CS2)	0-1	207	259

Table 4. Economic optimum N rate for corn silage yield following corn and soybean, Arlington 2003.

Previous crop	n ‡	Model	R^2	EONR †	Yield at EONR
				lb/acre	ton/acre
Corn	27	$y = 6.98 + 0.029x - 0.000077x^2$	0.42	175	9.70
Soybean	20	$y = 5.83 + 0.049x - 0.00015x^2$	0.58	156	9.81

† Based on $0.15/lb N fertilizer and $20/ton corn silage at 70% moisture.
‡ n = 27 and 20 due to the removal of some plots from the experiment due to heavy weed, insect, and rodent damage.

Table 5. Economic optimum N rate for corn silage yield following corn and soybean, Arlington 2004.

Previous crop	n ‡	Model	R^2	EONR †	Yield at EONR
				lb/acre	ton/acre
Corn	27	$y = 5.5443 + 0.00998x - 0.0000492x^2$	0.37	63	5.98
Soybean	20	$y = 5.6875 + 0.0321x - 0.00013x^2$	0.26	109	7.64

† Based on $0.25/lb N fertilizer and $20/ton corn silage at 70% moisture.
‡ n = 27 and 20 due to the removal of some plots from the experiment due to heavy weed, insect, and rodent damage

Table 6. Economic optimum N rate for corn grain yield following corn and soybean, Arlington 2003.

Previous crop	n ‡	Model	R^2	EONR †	Yield at EONR
				lb/acre	bu/acre
Corn	27	$y = 120 + 0.60x - 0.0014x^2$	0.64	196	184
Soybean	20	$y = 108 + 1.17x - 0.0035x^2$	0.63	160	206

† Based on $0.15/lb N fertilizer and $2.50/bu corn grain.
‡ n = 27 and 20 due to the removal of some plots from the experiment due to heavy weed, insect, and rodent damage

Table 7. Economic optimum N rate for corn grain yield following corn and soybean, Arlington 2004.

Previous crop	n ‡	Model	R^2	EONR †	Yield at EONR
				lb/acre	bu/acre
Corn	27	$y = 144 + 0.705 - 0.00278x^2$	0.84	109	188
Soybean	20	$y = 147 + 0.781x - 0.0034x^2$	0.81	100	191

† Based on $0.25/lb N fertilizer and $2.50/bu corn grain.
‡ n = 27 and 20 due to the removal of some plots from the experiment due to heavy weed, insect, and rodent damage

Table 8. Effect of previous crop and corn N rate on end-of-season (October) soil NO_3-N levels (0 to 3 ft) following corn, Arlington 2003.

Previous crop	N rate, lb/acre 0	60	90	120	150	180	210	Mean †
	soil NO_3-N, lb/acre							
Corn	21	41	55	79	93	103	120	72 a §
Soybean	7	19	37	34	66	87	106	51 b
Mean ‡	16 e	32 de	46 cde	59 bcd	84 abc	94 ab	115 a	

† Previous crop $p>f = 0.03$.
‡ N rate $p>f = <0.01$. Previous crop x N rate $p>f = 0.97$. CV = 56%.
§ Mean values followed by the same letter are not significantly different at the 0.05 probability level.

Table 9. Effect of previous crop and corn N rate on end-of-season (October) soil NO_3-N levels (0 to 3 ft) following corn, Arlington 2004.

Previous crop	N rate, lb/acre 0	60	90	120	150	180	210	Mean †
	soil NO_3-N, lb/acre							
Corn	34	33	36	40	47	46	70	44
Soybean	22	26	23	33	33	119	68	46
Mean ‡	28 b §	29 b	30 b	36 b	40 b	82 ab	69 ab	

† Previous crop $p>f = 0.86$.
‡ N rate $p>f = 0.03$. Previous crop x N rate $p>f = 0.23$.
§ Mean values followed by the same letter are not significantly different at the 0.05 probability level.

Table 10. Summary of EONR compared to UW recommendations and soil nitrate tests.

Growing Season	2003		2004	
Previous Crop	Sb	C	Sb	C
EONR †	160	196	100	109
UW Recommendation	120	160	120	160
PPNT ‡	86	68	117	160
PSNT §	103	120	134	127

† Economic optimum nitrogen rate (lb/a).
‡ Preplant soil nitrate test recommendation (lb/a).
§ Pre-sidedress soil nitrate test recommendation (lb/a).

VERTICAL DISTRIBUTION OF PHOSPHORUS UNDER LONG-TERM CROPPING TRIALS

Juliane M. Meyer and Phillip Barak

INTRODUCTION

Historically, due to its high soil fixation rates and low solubility, phosphorus has not been considered an environmental menace, but years of over-application and the shift in American agriculture from small family farms to large corporate enterprises (McDowell et al., 2001; Sharpley et al., 2001) has led to phosphorus buildup and leaching in many soil types (Eghball et al., 1996; Lucero et al., 1995; Novak et al., 2000; Whalen and Chang, 2001). In addition, phosphorus accumulation in the upper soil profile can be exacerbated by conservation tillage with significant vertical stratification of nutrients occurring (Cruse et al., 1983; Holanda et al., 1998; Howard et al., 1999; Robbins and Voss, 1991; Scheiner and Lavado, 1998; Shear and Moschler, 1969). Because of these issues, the objective of this research was to examine the vertical distribution of phosphorus under the well-managed cropping systems established at the Wisconsin Integrated Cropping Systems Trials (WICST) in an attempt to determine the location of labile phosphorus and assess the potential negative environmental impacts based on the placement of the phosphorus.

SITE HISTORY

Prior to the establishment of the Arlington Agricultural Research Station in Arlington, Wisconsin, the 28 ha of land that is now the site of the WICST plots was privately held and farmed. Farmsteads were located at various sites near the current day location of the WICST site, but one farmhouse and the accompanying outbuildings occupied the easternmost portion of the site, next to US-51. Research station records for these fields began in 1961, and at that time the acreage was all farmed as alfalfa hay. Over the ensuing years, the land was divided into three fields and planted in a variety of crops including oats, alfalfa, and corn with various phosphorus applications ranging from 0 to 82 kg P ha^{-1}. The site also has a history of heavy manure application due to its close proximity to local dairies; however, because manure has often been considered a waste product and not a nutrient source, the application rates were not recorded. The WICST trial was initiated in 1990.

HYPOTHESES

***Bray-1 phosphorus soil test levels*:** The soil test phosphorus (STP) levels on all the plots were excessively high at the initiation of the trial and one goal in Best Management Practices was to bring these levels to optimum. It was hypothesized that the alfalfa-corn system (CS4) would have the highest levels of STP after 12 years of cropping due to the additions of manure and fertilizer, followed by the continuous corn treatment (CS1) since starter fertilizer, high in phosphorus, was applied annually. The corn-soybean rotation (CS2) would follow since P fertilizer was only added to the corn phase. It was anticipated that the rotational grazing (CS6) would follow due to the lack of added fertilizer, and simple recycling of the grazing and subsequent manure deposition. The rotation with lowest STP values would be CS3, which had no P fertilizer or manure additions, but annual removal of corn, soybeans and wheat + straw. (CS4>CS1>CS2>CS6>CS3).

Vertical stratification: It was anticipated that two factors would be important in P-stratification: tillage and crop harvest. Considering primarily tillage, the greatest stratification would occur in the no-till systems (CS2 and CS6), followed by the high input, conventional tillage systems (CS1 and CS4) and then the low input conventionally tilled CS3. Looking at harvest management, it was thought that the removal of the forage in CS6 would lessen phytocycling compared to leaving the corn and soybean residue on the surface in CS2. By the same token, the alfalfa harvest would reduce P-enrichment of the soil surface compared to CS1 where corn stover was left on the field. (CS2>CS6>CS1>CS4>CS3)

Soil sorption isotherms: It is thought that soils with high levels of STP, or having received high amounts of P inputs, would have lower sorption capabilities and greater soil solution phosphorus, presenting a situation where P leaching could potentially occur. Because of this, the cropping systems that still receive phosphorus inputs (either mineral or manure) would have a greater chance of exhibiting vertical P movement.

MATERIALS AND METHODS

Field Sampling: Duplicate soil cores, 45-mm in diameter (1 ¾") and 1-m depth, were obtained from each plot in five of six cropping systems in the fall of 2002 and again in the springs of 2003 and 2004 in repetitions 1 and 2. The systems sampled include: continuous corn, CS1; corn-soybean, CS2; corn-soybean-winter wheat-red clover, CS3; corn-alfalfa-alfalfa-alfalfa, CS4; and, pasture, CS6. The sampled plots were in the corn phase of each rotation in 2002, with the exception the rotational grazing system, and each followed their rotation sequence in 2003 and 2004. All the plots had been in their respective rotation for 12 years prior to sampling. Two sets of control cores were removed from center of the grass alleyways between plots 112 and 113 in repetition I and plots 206 and 207 in repetition II.

After removal, cores were stored intact in plastic capped liners (Giddings Machine Company Inc., Windsor, Colorado; www.soilsample.com) at 4° C until processing. Cores were processed individually by sectioning into 1-cm intervals for the first 40 cm and then 5-cm intervals for the next 40 cm. The remaining 20 cm of the core were not analyzed. Samples were air-dried and hand-ground for analysis. This resulted in forty-eight samples from each core.

Laboratory Experiments: Labile phosphorus was extracted by the Bray P-1 dilute acid extraction (Bray and Kurtz, 1945) as modified by Avila-Segura et al. (2004) for use with a microplate reader and analyzed by the ascorbic acid method (Avila-Segura et al., 2004; Murphy and Riley, 1962).

Soil sorption isotherms were created using the techniques of Graetz and Nair (2000) as modified for a microplate reader by Avila-Segura et al. (2004). Specific samples were chosen by using profiles of the Bray P-1 with depth. Solutions were analyzed by the ascorbic acid method (Murphy and Riley, 1962) and plotted using the Langmuir equation. As soil sorption is nonlinear, the data were fit to this equation using the nonlinear optimizing routine "Solver" (Microsoft Excel 2000) to minimize the sum of squares of the residuals (Barrow, 1978). The fitted data were graphed and inspected to assure that local minima were avoided. Equilibrium P concentration and the P buffer capacity were analytically calculated from the fitted parameters.

RESULTS AND DISCUSSION

Three or four cores from each plot of the five cropping systems in repetitions 1 and 2, plus a control set were analyzed (i.e., approximately one core per plot per year). The mean P-levels and standard error bars per plot are shown in Figures 1 and 2. The control cores were too dissimilar to simply average, so all four cores are represented in Figure 2b. Because all the samples were analyzed in 1-cm and 5-cm increments, the analytical results were also mathematically combined and then averaged to create "bulk samples". This allowed us to compare cores in a manner consistent with current soil testing procedures, (i.e., samples taken in 15-cm increments).

Cropping System Cores: The phosphorus profiles for the various cropping systems (Figures 1 and 2) suggest chromatography columns, with considerable vertical stratification. There is a general trend of high surface phosphorus content decreasing with depth to low mid-range concentrations and then increasing concentration at depths of 40-cm and greater. Initial surface soil (0 to 1-cm depth) P levels range from 35 mg P kg^{-1} soil to 155 mg P kg^{-1} soil and the results from the 15-cm depth range from 20 mg P kg^{-1} soil to 147 mg P kg^{-1} soil.

Control Cores: The WICST organizers neither set aside a location for a control nor did they archive sufficient samples to depth at the onset of the trial in 1989, because the intent of the research was to compare cropping systems and not to explicitly track soil changes from their start point in time. In an effort to determine a background phosphorus profile, it was decided that the 2.4-m alleyways between the existing plots were the best potential locations. These grass alleyways are not used for vehicular traffic and spillage of fertilizer is minimal. In order to further reduce edge effects, the chosen locations were adjacent to the pasture plots that only receive depositional manure from the grazing heifers.

Four cores were removed from each of the two locations. Unfortunately, due to the inherent heterogeneity of the site, these profiles were not entirely comparable (Figure 2b); controls B and C had similar profiles that started with approximately 140 mg P kg^{-1} and average plow layer Bray P-1 values from 110 to 140 mg P kg^{-1}. Controls A and D had very similar profiles, with surface Bray P-1 levels near 90 mg P kg^{-1} and average plow layer values of approximately 50 mg P kg^{-1} soil. Although the initial P levels differ, both sets of cores have surface phosphorus values that are approximately 30 mg P kg^{-1} greater than the mean of the entire 15 cm plow layer. This type of heterogeneity has been shown to be common in heavily manured fields.

Bray P-1 Concentrations to Depth

Because current soil testing methods composite soil cores over a greater area with lesser resolution, the values obtained for this study were mathematically averaged to provide a comparison. Table 1 shows the results of the current research for the combined samples (0 to 15 cm, 16 to 30 cm, and 31 to 60 cm) for each cropping system and the difference from the controls. For simplicity, the similar controls were averaged (i.e., A & D and B & C) and the results are shown accordingly.

For the current research, in the 0 to 15 cm plow layer, the mean Bray P-1 levels of all cropping system cores are vary when compared to the control cores with most showing some

drawdown of P. The actual ranking of soil test levels did not exactly match our hypothetical ranking, as there was one difference. Cropping system 4, the corn-alfalfa system, has the highest average phosphorus value (due to heavy manuring), followed by CS1 (continuous corn with high-P starter fertilizer every year), followed by the fertilizer-free CS6 (pasture), CS2 (corn-soybean with high-P fertilizer every other year), and CS3 (corn-soybean-winter wheat-red clover). It was hypothesized that CS2 would be ranked higher than CS6, but that was not the case. It is possible that less phosphorus is removed from the pasture system then the corn-soybean system causing a greater amount of phosphorus to remain in the soil profile.

In the zone below the plow layer, 16 to 30 cm, average P values are still high to excessively high when compared to soil test recommendations for Wisconsin in every system except CS3. In the 31 to 60 cm zone, all soil test phosphorus levels are lower than in the upper profile. The highest value was found in CS2, 35.7 mg kg^{-1}, with the control B & C following having a P concentration of 29.7 mg kg^{-1}. The level of phosphorus in control A & D at this depth is similar with the other plots, but the P level in control B & C is higher than the remaining systems suggesting that the crop rooting system is extracting P from these depths more consistently than in those check plots.

The second half of Table 1 shows the difference in Bray P-1 concentrations between each system and two controls, with negative values denoting depletion of soil phosphorus. As shown, P levels have been lowered in the upper 15 cm for all five cropping systems studied. This decrease is greatest for CS3, which does not receive any fertilizer and lowest for CS4, which receives manure additions twice throughout each four year rotation. The subsoils (16 to 30 cm) also have been depleted of soil P with the greatest removal again in CS3.

Table 1. Mean Bray P-1 at three combined depths with the values having been mathematically averaged.

Soil Depth	CS1	CS2	CS3	CS4	CS6	Control	
Plot Number	*109 & 204*	*108 & 206*	*102 & 212*	*113 & 210*	*112 & 207*	*A & D*	*B & C*
cm			—— mg P kg^{-1} ——				
0-15	60.6	31.3	29.1	77.1	42.1	50.5	122
16-30	57.7	37.8	28.9	50.7	45.0	38.8	149
31-60	13.6	20.2	14.2	16.8	13.7	10.6	29.7
Difference from controls A & D							
0-15	10.1	-19.3	-21.4	26.5	-8.4	–	–
16-30	18.8	-1.0	-9.9	11.9	6.2	–	–
31-60	3.0	9.5	3.6	6.2	3.0	–	–
Difference from controls B & C							
0-15	-61.6	-90.9	-93.1	-45.1	-80.1	–	–
16-30	-91.1	-111	-120	-98.1	-104	–	–
31-60	-16.0	-9.5	-15.5	-12.9	-16.0	–	–

Vertical Stratification in the Root Zone

The range of phosphorus concentrations with depth, from high to low to high again, reveals that vertical stratification is present in the majority of cropping systems at the WICST at Arlington. Figure 3 shows the Bray P-1 phosphorus distribution in the upper 30 cm of each plot and Table 2 shows the average concentration of Bray P-1 phosphorus over three different depth

intervals commonly sampled for soil testing for agriculture and environmental purposes. Of the plots sampled, 109 (continuous corn), 113 (corn-alfalfa), 210 (corn-alfalfa), and 112 (pasture) have the greatest stratification, with their surface P concentrations ranging from approximately 75 to 125 mg P kg^{-1} soil and the phosphorus concentrations at 30 cm depth between 15 and 20 mg P kg^{-1} soil. Cropping system one, plot 204 and CS6, plot 207 show stratification to a lesser degree, with surface concentrations between 55 and 70 mg P kg^{-1} soil and the deeper depths again around 15 to 20 mg P kg^{-1} soil. CS6-207 shows most of the stratification for its profile in the upper five centimeters, whereas the other profiles have a more gradual decline in phosphorus levels from the surface to 30-cm deep. Of the stratified systems, CS3 (corn-soybean-winter wheat-red clover) has the least stratification, with the surface soil for both plots containing approximately 35 to 40 mg P kg^{-1} soil and the 30-cm soil containing about 15 mg P kg^{-1} soil. Cropping system 2 (corn-soybean) did not show stratification in the top 20 cm most likely because it was conventionally tilled for the first four years of production. Although not directly associated with vertical stratification, all of the systems show a slight increase of phosphorus between 12 and 14 cm, which is likely a mechanical effect from the old plow layer.

The actual estimates of stratification did not match the hypothetical ranking. It was thought that the no-till systems 2 (corn and soybeans) and 6 (pasture) would have the greatest stratification and the more frequently tilled systems 1 (continuous corn), 4 (corn and alfalfa) and 3 (organic grain) would have the least stratification. In this study when comparing the average stratification for each cropping system using the 0 to 5/5 to 15 cm ratio, the greatest stratification occurred in CS6 followed by CS3, CS4, CS1, and CS2. It is likely that CS2 has the least amount of stratification due to modest P additions and high P off take as corn and soybean grain. This net removal of phosphorous has masked the natural tendency for this no-till system to create a stratified P profile in the soil.

Table 2. Average Bray P-1 values for three different depth intervals commonly sampled for soil test phosphorus. Max/Min is equal to the maximum P concentration from 0 to 5 cm and minimum equals the lowest concentration from 26 to 30 cm. Mean denotes the average of the plow layer (0 to 15 cm).

Core	CS1		CS2		CS3		CS4		CS6	
Interval	109	204	108	206D	102	212	113	210	112	207
cm	mg kg^{-1}									
0 – 5	82.0	54.9	33.1	27.1	38.0	36.4	90.3	96.6	79.0	42.3
5 – 15	73.6	39.7	34.3	29.3	25.1	25.1	55.3	82.4	41.8	23.8
15 – 30	32.6	18.8	14.5	18.7	14.4	11.7	22.5	22.2	21.8	19.8
Max/Min	5.6	4.3	4.0	3.9	4.3	4.9	10.3	7.5	8.4	4.5
Max/Mean	1.1	1.3	1.1	1.2	1.4	1.3	1.5	1.2	1.7	2.3
0–5/5–15	1.1	1.4	0.97	0.92	1.5	1.4	1.6	1.2	1.9	1.8

There are likely causes for the stratification shown in this research: first, the systems are minimally tilled and so P inputs from fertilizer and manure are left to slowly infiltrate the soil profile, and second, these systems leave copious amounts of plant tissue as crop residue on the soil surface after harvest. Upon decomposition, this plant matter releases phosphorus (that was mined from deeper in the soil profile) back into the soil at the surface and so this phytocycling of nutrients will cause greater stratification.

Because this site was under conservation management prior to the beginning of the WICST and vertical stratification was found in the untilled control, this is assumed to be the starting condition. Twelve years of tillage and nutrient extractions have not only maintained the vertical stratification but somewhat amplified it. The original goals of the Wisconsin Integrated Cropping Systems Trials included intentional drawdown of high phosphorus concentrations and reduction of erosion using conventional tillage methods. According to current Wisconsin soil test recommendations, the P levels for the plow layer in each of the cropping systems are still excessively high for corn, alfalfa, wheat, and managed pasture (>30 ppm P) as well as soybeans (>20 ppm P) and red clover (>25 ppm P) (Kelling et al., 1998). These values are based on bulk soil samples for the plow layer, but phosphorus levels in conservation tillage systems are known to become stratified with depth due to the lack of mixing (Cruse et al., 1983; Holanda et al., 1998; Howard et al., 1999; Robbins and Voss, 1991; Scheiner and Lavado, 1998; Shear and Moschler, 1969). It is difficult to compare stratified systems with recommendations based on conventional soil testing methods because the act of taking composite soil samples from a soil that does not display P homogeneity means that the values obtained are highly dependent upon the depth of sampling. In essence, composite sampling on a stratified system gives a weighted average that only truly represents the phosphorus level at one soil depth within the entire sampling zone. In stratified systems, the greatest amount of soil P is at the most vulnerable location for loss by soil erosion and the true P value for crop requirements is not determined. This shows that new testing methods are needed for these systems, to determine both plant nutritional needs and runoff potential.

Soil Sorption Isotherms

Phosphorus sorption research was conducted on a subset of soil samples from the larger collection of cores with the depths selected based on inflection points from the Bray P-1 to depth curves (Figures 1-2). Results of the phosphorus sorption/desorption protocol (Avila-Segura et al., 2004; Nair et al., 1984) were fit to a form of the Langmuir equation written as:

$$S - S_0 = k_l S_{\max} \frac{C}{1 + k_l C},$$

where S is the sorbed P, S_0 is the initial sorbed P, k_l is the Langmuir constant, C is the soil solution concentration, and S_{max} is the P sorption maximum. Figure 4 and Table 3 show the isotherms and the fitted and calculated parameters for each interval of a selected core from CS1, plot 109. The data for the remaining cores are not presented here.

Values for S_{max} varied among plots (data not shown), but within a core (Table 3), tended to be similar or increase with depth, which is consistent with the findings of Mozaffari and Sims (1994). The largest sorption maximums were located at the deepest soil intervals, for multiple reasons: first, there are more sorption sites in this zone due to lower phosphorus levels; second, clay content is higher in the subsoil and sorption is correlated with the clay content (Mozaffari and Sims, 1994); third, the fitted functions were less precise due to the steepness of slope; and fourth, S_{max} is an extrapolation of the data beyond the range of data points toward a saturating concentration of phosphorus. It is important to note that there was little correlation between the S_{max} values and Bray P-1 phosphorus concentrations, a finding that agrees with results from Eghball et al. (1996), who found no correlation between adsorption maximums and available phosphorus concentrations at different soil depths.

Table 3. Fitted and calculated parameters using the Langmuir equation for P sorption data for CS1, plot 109.

Cropping System	Depth	SSE	k_l	S_{max}	S_0	pH	C_0	$dS/dC\|_{C=C_0}$	r^2
	cm			mg P kg^{-1}			mg P L^{-1}		
CS1 – 109	6	4.78	0.50	201	-34.2	6.00	0.407	69.7	0.998
	12	5.23	0.48	189	-28.4	5.33	0.367	65.7	0.997
	19	69.0	1.14	203	-31.9	6.00	0.163	165	0.974
	24	139	1.39	205	-28.8	6.32	0.117	212	0.954
	30	857	3.00	244	-41.1	6.32	0.068	506	0.776
	40-45	337	8.32	355	-129	6.20	0.068	1201	0.929
	55-60	488	9.90	384	-136	6.00	0.055	1588	0.899
	70-75	665	4.13	273	-57.2	5.39	0.064	707	0.841

The phosphorus adsorption strength, k_l, tended to increase with depth and the equilibrium phosphorus concentrations, C_0, defined here as the concentration at which no phosphorus is sorbed or desorbed from solution, decrease with depth within a core. Finally, the buffer capacity of the soil, calculated from the fitted sorption isotherm at the equilibrium phosphorus concentration, i.e., dS/dC at C_0, increases with depth within each core, particularly below 20 cm. The highest soil solution P values are associated with soil samples with the lowest buffer capacity and the highest Bray P-1 concentrations. There is the potential for leaching within these systems; however, at this time, the deeper soils are fully capable of sorbing the excess P that may slip below the upper root zone, thereby keeping vertical migration to a minimum.

CONCLUSIONS

The soil profiles presented here all resemble chromatography columns and all the cores within a plot have similar Bray P-1 profiles to depth. These results show the intentional drawdown of phosphorus, starting in 1989, has been successful and continued management will bring the phosphorus levels to optimum for Wisconsin soils (between 10 and 25 mg kg^{-1}). The majority of the soil profiles presented did not show phosphorus leaching to depth, but the soil sorption data shows that the potential exists. Phosphorus added at the soil surface, through both fertilizer additions and crop residue decomposition, will slowly infiltrate and migrate downward through the nutrient-rich surface soil, which has limited sorption sites, to the more nutrient-poor soil below where sorption sites are abundant, thereby limiting the leaching potential. Further analysis of these samples using the Hydrus 1-D modeling program will shed more light on the movement of P through both leaching and phytocycling.

Finally, vertical stratification is present in these systems, including the control cores, and the current management practices are amplifying this stratification by adding nutrients at the soil surface without incorporation by tillage. This practice is localizing high concentrations of phosphorus at the soil surface; the area most susceptible to runoff. Because current soil sampling methods composite soil from multiple cores to a depth of 15-cm, a stratified system would give a value for runoff potential that would be lower than the actual P concentration at the surface and so new soil sampling techniques are needed for systems that exhibit vertical stratification.

REFERENCES

Avila-Segura, M., J.W. Lyne, J.M. Meyer, and P. Barak. 2004. Rapid spectrophotometric analysis of soil phosphorus with a microplate reader. Commun. Soil Sci. Plant Anal. 35:547-557.

Barrow, N.J. 1978. The description of phosphate adsorption curves. J. Soil Sci. 29:447-462.

Bray, R.H., and L.T. Kurtz. 1945. Determination of total, organic, and available forms of phosphorus in soils. Soil Sci. 59:39-45.

Cruse, R.M., G.A. Yakle, T.C. Colvin, D.R. Timmons, and A.L. Musselman. 1983. Tillage effects on corn and soybean production in farmer-managed, university-monitored field plots. J. Soil Water Conserv. 38:512-514.

Eghball, B., E.D. Binford, and D.D. Baltensperger. 1996. Phosphorus movement and adsorption in a soil receiving long-term manure and fertilizer application. J. Environ. Qual. 25:1339-1343.

Graetz, D.A., and V.D. Nair. 2000. Phosphorus sorption isotherm determination, p. 102, *In* G. M. Pierzynski, ed. Methods for P analysis for soils, sediments, residuals, and waters, 396 ed. North Carolina State University.

Holanda, F.S.R., D.B. Mengel, M.B. Paula, J.G. Carvaho, and J.C. Bertoni. 1998. Influence of crop rotations and tillage systems on phosphorus and potassium stratification and root distribution in the soil profile. Commun. Soil Sci. Plant Anal. 29:2383-2394.

Howard, D.D., M.E. Essington, and D.D. Tyler. 1999. Vertical phosphorus and potassium stratification in no-till cotton soils. Agron. J. 91:266-269.

Kelling, K.A., E.E. Schulte, L.G. Bundy, S.M. Combs, and J.B. Peters. 1998. Soil test recommendations for field, vegetable, and fruit crops. Ser. Bull. No. A2809.

Lucero, D.W., D.C. Martens, J.R. McKenna, and D.E. Starner. 1995. Accumulation and movement of phosphorus from poultry litter application on a starr clay loam. Commun. Soil Sci. Plant Anal. 26:1709-1718.

McDowell, R.W., A.N. Sharpley, D.B. Beegle, and J.L. Weld. 2001. Comparing phosphorus management strategies at a watershed scale. J. Soil Water Conserv. 56:306-315.

Mozaffari, M., and J.T. Sims. 1994. Phosphorus availability and sorption in an Atlantic Coastal Plain watershed dominated by animal-based agriculture. Soil Sci. 157:97-106.

Murphy, J., and J.P. Riley. 1962. A modified single solution method for the determination fo phosphate in natural waters. Anal. Chim. Acta. 27:31-36.

Nair, P.S., T.J. Logan, A.N. Sharpley, L.E. Sommers, M.A. Tabatabai, and T.L. Yuan. 1984. Interlaboratory comparison of a standardized phosphorus adsorption procedure. J. Environ. Qual. 13:591-595.

Novak, J.M., D.W. Watts, P.G. Hunt, and K.C. Stone. 2000. Phosphorus movement through a Coastal Plain soil after a decade of intensive swine manure application. J. Environ. Qual. 29:1310-1315.

Robbins, S.G., and R.D. Voss. 1991. Phosphorus and potassium stratification in conservation tillage systems. J. Soil Water Conserv. 46:298-300.

Scheiner, J.D., and R.S. Lavado. 1998. The role of fertilization on phosphorus stratification in no-till soils. Commun. Soil Sci. Plant Anal. 29:2705-2711.

Sharpley, A.N., R.W. McDowell, and P.J.A. Kleinman. 2001. Phosphorus loss from land to water: integrating agricultural and environmental management. Plant Soil 237:287-307.

Shear, G.M., and W.W. Moschler. 1969. Continuous corn by the no-tillage and conventional tillage methods: a six-year comparison. Agron. J. 61:524-526.

Whalen, J.K., and C. Chang. 2001. Phosphorus accumulation in cultivated soils from long-term annual applications of cattle feedlot manure. J. Environ. Qual. 30:229-237.

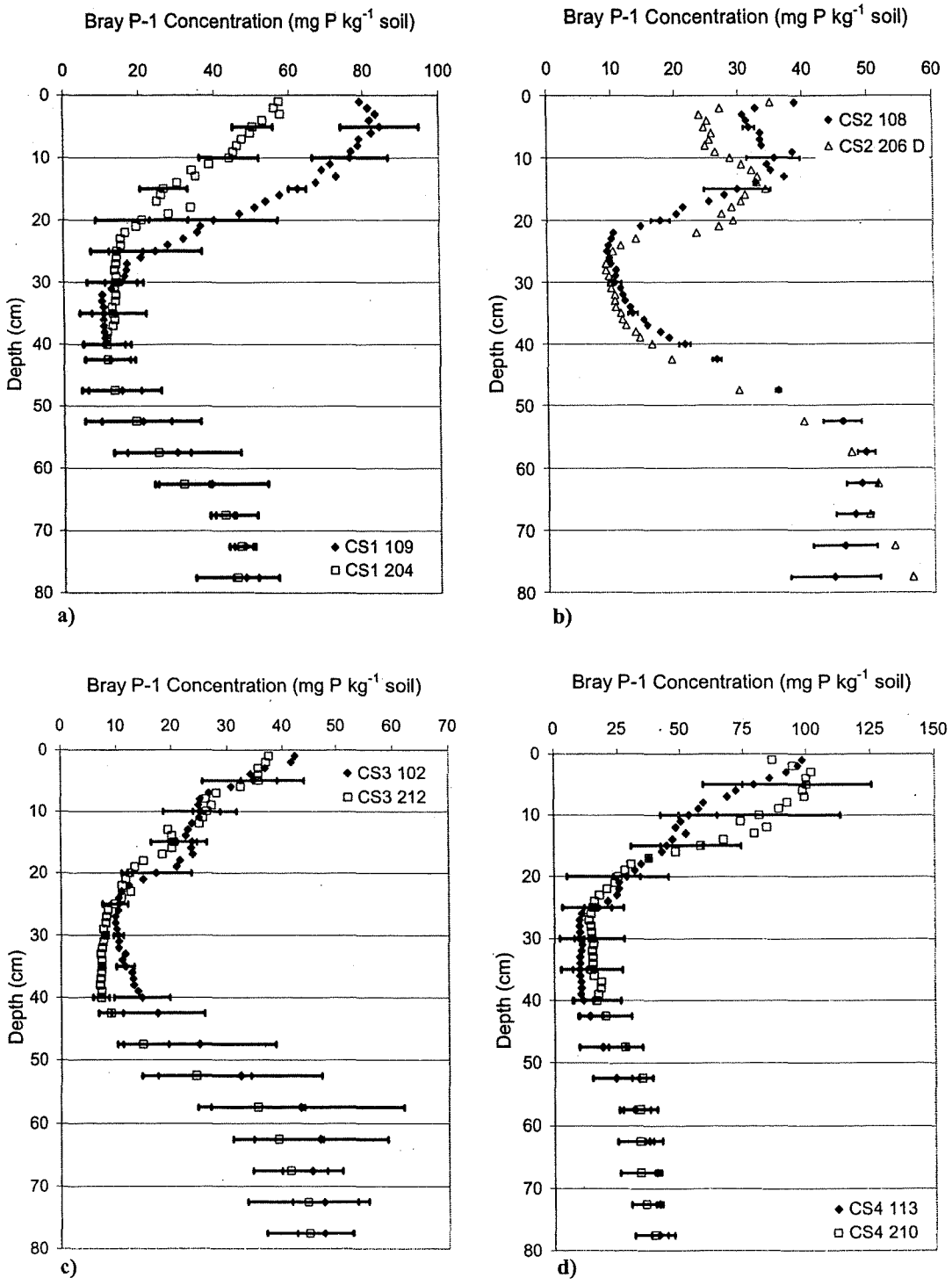


Figure 1. Average concentrations of Bray P-1 (mg P kg^{-1}) to depth for four cropping systems at the WICST Arlington, Wisconsin site: a) CS1, plots 109 and 204; b) CS2, plots 108 and 206; c) CS3, plots 102 and 212; d) CS4, plots 113 and 210. Standard error bars represent the standard deviation from the average of the three cores evaluated for each plot.

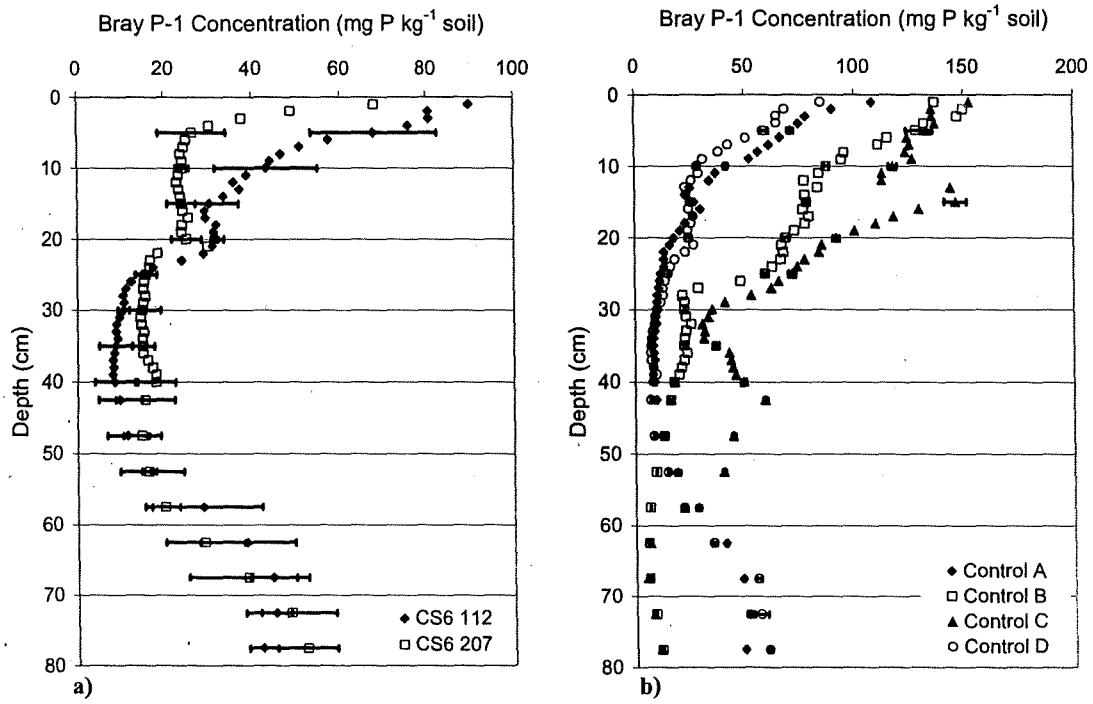


Figure 2. Average concentrations of Bray P-1 (mg P kg^{-1}) to depth for one cropping system and hypothetical control plots at the WICST Arlington, Wisconsin site: a) CS6, plots 112 and 207; b) four control cores removed from the alleyway between existing plots. Standard error bars represent the standard deviation from the average of the three cores evaluated for each plot.

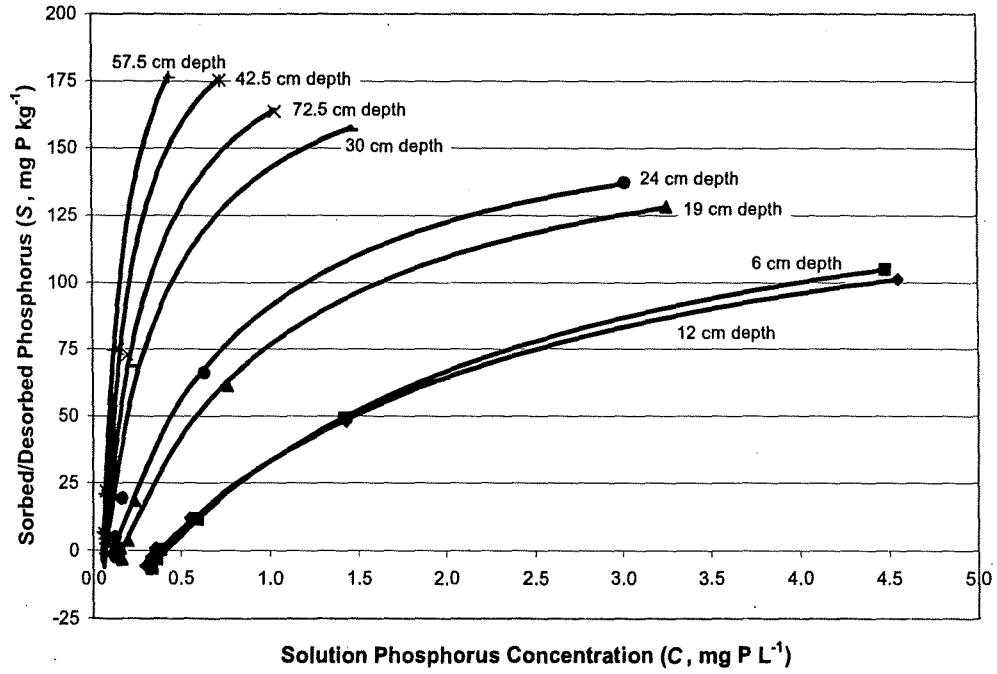


Figure 3. Langmuir sorption isotherms for CS1, plot 109 at eight depth intervals.

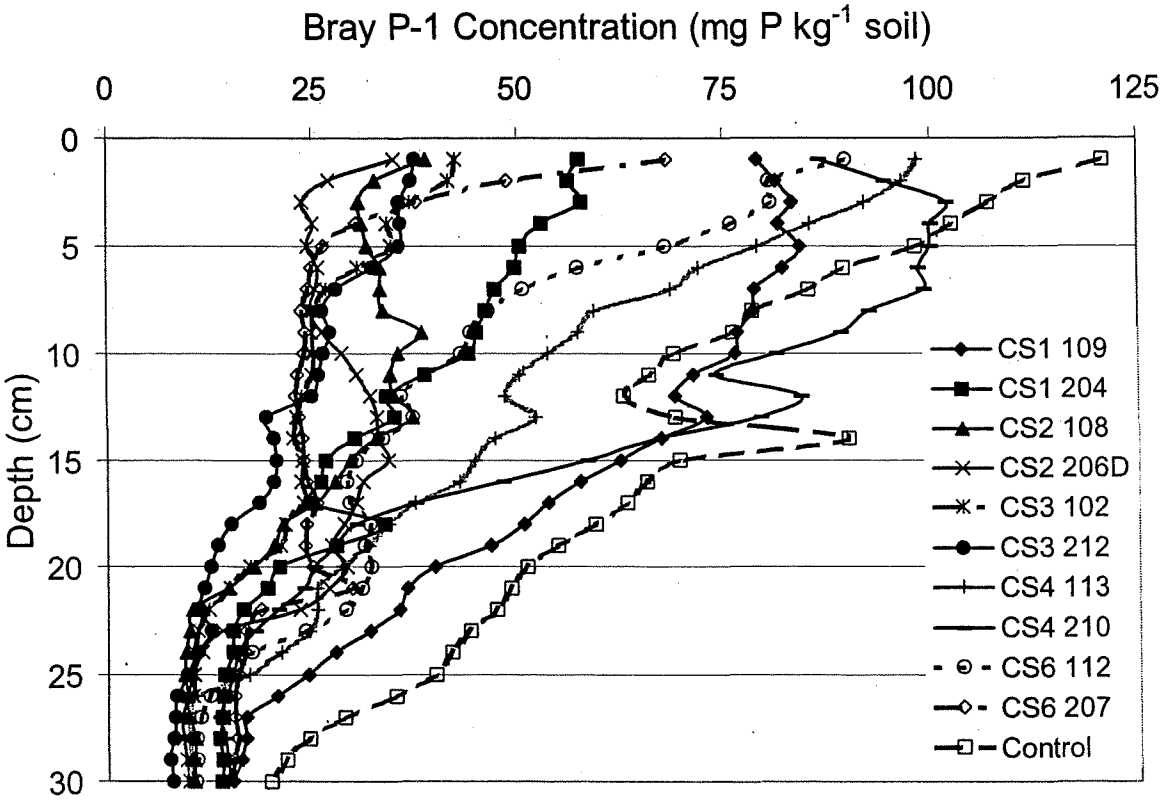


Figure 4. Vertical phosphorus stratification at the Wisconsin Integrated Cropping Systems Trial as shown by the Bray P-1 concentrations (mg P kg^{-1} soil) to depth.

SOIL ACIDIFICATION PROCESSES IN AGROECOSYSTEMS AT WISCONSIN INTEGRATED CROPPING SYSTEM TRIALS

Mauricio Avila[1], Joshua L. Posner[2], David A. Laird[3], and Phillip Barak[1]

July 2005

ABSTRACT

Soil acidification associated with nitrogen inputs, both as acid-forming fertilizers and biological nitrogen fixation, has been noted in a variety of agroecosystems. Previously reported acidification rates range from 1.1 to 11.4 kmol ha^{-1} yr^{-1}, largely associated with crop productivity and nitrate leaching losses. The objective of this research was to determine acidification rates at the Arlington site of the Wisconsin Integrated Cropping System Trials (WICST) for several cropping systems that represent major agroecosystems of the Upper MidWest: continuous corn (CS1), corn/soybean rotation (CS2), and corn/alfalfa/alfalfa/alfalfa rotation (CS4). Average annual acidification rates for these rotations at WICST were 0.8, 1.3, and 6.5 kmol ha^{-1}, respectively. The legume phases of CS2 and CS4 were particularly associated with strongly acidifying processes. At WICST, however, 'best management practices' reduced annual acidification rates in continuous corn by the use of pre-plant nitrate tests (PPNT) to judiciously apply nitrogen fertilizer by as much as 5.2 kmol ha^{-1} and by stover return by 3.7 kmol ha^{-1}. The use of manure, which also returns plant alkalinity to soil, in CS4 reduced soil acidification rates by as much as 6.0 kmol ha^{-1} yr^{-1}.

INTRODUCTION

It has long been known, since the pioneering work of W.H. Pierre in the 1930s, that use of ammoniacal N fertilizers in excess of crop uptake and removal induces acidification in agricultural soils. This knowledge has been broadened to include legume-derived nitrogen as well. In recent years, estimates of soil acidification rates have been established for various agricultural systems. Legume-based pastures in New Zealand showed acidity inputs of 1.1 to 11.4 kmol ha^{-1} yr^{-1} that were correlated to the rate of biological N_2 fixation (BNF; Bolan et al., 1991). Wheat and barley in Canada, fertilized with 90 and 180 kg N ha^{-1} yr^{-1}, showed acidity inputs of 1.3 and 5.6 kmol ha^{-1} yr^{-1} (Bouman et al., 1995). In Wisconsin, continuous corn receiving 56, 112 and 168 kg N ha^{-1} yr^{-1} as ammonium nitrate or urea showed net acidity inputs of 1.5, 4.2 and 8.9 kmol ha^{-1} yr^{-1} (Barak et al., 1997). Soil acidification associated with nitrogen inputs has been shown to trigger loss of base cations (Ca and Mg; Bolan et al., 1991; Barak et al., 1997) and manganese toxicities in crops. With acidification, there is also loss of cation exchange capacity and evidence of accelerated soil weathering (Barak et al., 1997).

The Wisconsin Integrated Cropping Systems Trial (WICST), a long-term study with measured nutrient fluxes and archived soil samples, provides an attractive test site for measuring acidity fluxes in Midwestern agroecosystems because of its well-managed, highly productive fields. Of the six cropping systems at the WICST, continuous corn (CS1), corn-soybeans (CS2), and alfalfa-alfalfa-alfalfa-corn (CS4) were studied in this project because of their predominant roles in Wisconsin agriculture and their representation of extremes of cultural practices, ranging

[1] UW-Madison, Soil Science Dept.
[2] UW-Madison, Agronomy Dept.
[3] National Soil Tilth Laboratory, Ames, IA

from monoculture relying on N fertilizer (CS1) to legume-based rotations that rely heavily on biological N_2 fixation (BNF; CS2 and CS4). (The WICST nomenclature, i.e., CS1, CS2 and CS4, is used here to facilitate use of our data in the context of current and future research efforts at the WICST.) Furthermore, some of the current practices at WICST have reasonable alternatives, such as harvesting corn stover for biomass instead of returning residue to soil surface for conservation tillage to reduce erosion (as in CS1, CS2, and CS4) or forgoing the use of dairy manure in the corn/alfalfa rotation (CS4); careful analysis of the fluxes of acidity will allow evaluation of these practices in terms of soil acidification without separate long-term experiments.

MATERIALS AND METHODS

The WICST fields at Arlington (WI) Agricultural Research Station are on a Plano silt loam (fine-silty, mixed, superactive, mesic Typic Argiudoll), with adequate drainage. Denitrification potential of similar plots in the area is limited (Brye et al., 2001). The experimental design of WICST has four replicates in the field combined with cropping sequences that allow for each phase of the rotation to be grown each year in each block of the trial. Thus, continuous corn has one sequence, corn-soybean has two, and corn-alfalfa-alfalfa-alfalfa has four. Full acidity budgets were prepared for each of the rotations selected and for 1997 through 2002.

Plant tissue sampling and analysis:

Corn, soybean, and alfalfa tissue samples were taken from the field and dried at 60°C; harvest indices were estimated for the corn and soybean crops in the rotations to supplement the grain and bean harvest data collected by the WICST team. After drying, plant materials were ground and sent to the Soil and Plant Analysis Laboratory (SPAL; Madison, WI) for total elemental analysis. Total macronutrients (Ca, Mg, K, Na, total-N, total-S, and P) were determined for grain, stover and cobs (corn), beans and straw (soybean), and whole tissue (alfalfa hay). Soluble SO_4^{2-}, NH_4^+, and NO_3^- were measured in some tissue samples in order to estimate accumulation of N and S as inorganic anions that can affect the cation/anion balance calculations. Organic N and S were estimated as the difference between total tissue content and soluble forms. Grain and stover/straw yields were estimated based on the harvest index; nutrient concentrations of all tissues sampled were determined at the University of Wisconsin Soil and Plant Analysis Laboratory (SPAL).

Acidity/alkalinity inputs:

The inputs of acidity in agricultural systems are primarily due to chemically-reduced N (Helyar, 1976; Johnston et al., 1986; Bolan et al., 1991; Barak et al., 1997). The acidity budget therefore relies heavily on the knowledge of the reduced-N inputs as a source of potential acidity upon nitrification and permanent acidification upon nitrate leaching. The main sources of acidity associated with N inputs in the cropping systems of the WICST are: fertilizers in CS1 and CS2, dairy cattle manure in CS4, atmospheric NO_x deposition, Fall NO_3^--N measured by the WICST in CS2 and CS4 (assumed to be the result of BNF and subsequent nitrification), soybean credits to corn in CS2, alfalfa plowdown N credits to corn in CS4 (also from BNF), and crop residues (corn stover additions in CS1, CS2, and CS4, as well as soybean stover additions in CS2). In our computations, the N inputs from all sources are converted from lb N per acre or kg N ha^{-1} to kmol ha^{-1} (kilomoles of charge) and summed. This sum is the potential acidity of the reduced-N

inputs, assuming that one mole of reduced-N from any of these sources generates one mole of H^+ during nitrification.

In addition to acidity inputs from reduced N in these sources, alkalinity inputs from manure and H+/alkalinity excretion by the crops were considered. Crop excretion of H+/alkalinity was calculated following the procedure of van Beusichem et al. (1988), which assumes that in the corn crop, all N, S, and P were taken up as nitrate, sulfate, and $H_2PO_4^-$, respectively (see Avila-Segura [2004] for details). Manure alkalinity per unit N was calculated based on ASAE (2003).

Crop potential Acidity:

Organic alkalinity in plant tissue was based on plant tissue analysis of the various aboveground plant parts, following the procedure of van Beusichem et al. (1988). The potential acidity was calculated based on the total N and S composition of the plant material, after considering small corrections for nitrate and sulfate.

Net H+/OH input of the cropping system:

The net effect was calculated by summing the acidity/alkalinity inputs and crop potential acidity components, both for standard harvest and several additional scenarios. When comparing the effect of different crop rotations of different durations on the soil or nutrient fluxes, it is necessary to calculate the "average" annual effect of a particular rotation. Obviously this "average" does not have a statistical meaning for an individual block because the dry matter production or the nutrient fluxes due to harvest of two or more different crops belong to different statistical populations; however, the 'average' annual effect is necessary to compare a system with a one year rotation (continuous corn, CS1) to a two-year rotation (corn-soy, CS2) or a four yr rotation (corn-alfalfa-alfalfa-alfalfa, CS4). More details found in Avila-Segura, 2004. All quantities were tabulated for all replicates of each treatment, where indicated, and analyses of variance were performed using the Statistical Analysis System software with the General Linear Model and the Student-Newman-Kuels test for differences among treatment means.

RESULTS AND DISCUSSION

The calculation of the acid/base balance of a crop or rotation of crops is not a trivial exercise since not only the fluxes of N must be known but also their origin, nature, and chemical formulation (whether nitrate or reduced). In order to calculate the acid/base balance of the rotation it is necessary to estimate and then sum the cation/anion uptake balance of the crops (acidity/alkalinity excretion), total acidity inputs from reduced-N sources, and the alkalinity inputs from manure and crop residues returned to the field at the end of the season. First, the cation uptake is calculated. Second, the total plant N and the uptake of P and S are calculated. The amount of N present in the tissues can have different origin depending upon the crop and the availability of NO_3^- in the soil during the season. Thus, in the case of corn crops, all plant N is considered as NO_3^- uptake. In the case of soybean and alfalfa, of the total N present in the plant only an amount equal to the N inputs to the crop (other than BNF) is considered as taken up in the form of NO_3^-; if the total plant N is greater than the N inputs then the difference is considered to be the result of biological N_2 fixation by soybean or alfalfa. Thus, if the soybean or alfalfa crops extract less N than the NO_3^- available we assume that little or no BNF has taken

place throughout the season and that the crop fulfilled its N needs exclusively through NO_3^- uptake.

Once the NO_3^- uptake is calculated (total plant N in corn; total plant N minus soil available NO_3^--N in soy and alfalfa) then the total anion uptake can be calculated as ($H_2PO_4^-$ + 2 SO_4^{2-} + NO_3^-). Once the cation uptake and the anion uptake are calculated, OH^-/H^+ excretion is calculated as $\Sigma_{cations} - \Sigma_{anions}$. If the total aboveground biomass is harvested, this is the contribution of the crop to the acid/base balance of the cropping system. However, if the corn stover or the soybean straw are returned to the field, the contribution of the stover/straw to the general acid/base balance (normally alkaline) has to be ascertained and explicitly included in the acid/base balance. Furthermore, the alkalinity from manures must be also added to the balance.

Finally, the acid/base balance of the cropping system is calculated by summing the acidity inputs (from reduced-N) plus the OH^-/H^+ excretion, manure alkalinity and the stover/straw alkalinity. This value can also be expressed as the calcium carbonate equivalent (in kg ha^{-1} yr^{-1}) necessary for neutralizing the acidity added the cropping system, based on 50 kg $CaCO_3$ per kmol H^+.

Acidity and alkalinity inputs in CS1, CS2, and CS4 of the WICST

Results of these acidity/alkalinity calculations for WICST at Arlington are shown in Table 1. Examination shows that the total nitrogen fluxes—the sum of BNF and all other N inputs—in the continuous corn (CS1) and corn/soy rotation (CS2) are almost identical, 18.2 and 19.1 kmol N ha^{-1} yr^{-1}, while the corn/alfalfa/alfalfa/alfalfa rotation (CS4) cycles 30.5 kmol N ha^{-1} yr^{-1}, on average. Interestingly, BNF in the direct seeded alfalfa (DSA) phase of CS4 appears to be almost completely suppressed by the addition of manure-N and its mineralization.

Annual acidity inputs to CS1, CS2, and CS4 average 13.0, 10.7, and 17.5 kmol H^+ ha^{-1}, respectively (Table 1) and the means are statistically different in the order CS2 < CS1 < CS4. In CS4, acidity inputs come mainly from the manure applications to corn and DSA and from BNF during the two hay production years of the alfalfa rotation. For CS2, acidity inputs come from N fertilizers applied to the corn phase of the rotation and BNF by the soybean crop. In CS1, the acidity originates mainly from N fertilizers.

On the basis of total acidity inputs, it seems reasonable for CS4 to have greater net acidity input to the soil; however, the effects of manure alkalinity and crop anion excretion must be considered. Manure alkalinity inputs to CS4 average 6.0 kmol OH^- ha^{-1} yr^{-1}, and to a varying degree affect each phase of the rotation. Crop alkalinity excretion averages 3.9, 6.0, and 8.5 kmol OH^- ha^{-1} (negative values denote alkalinity; Table 1) in CS4, CS2, and CS1 and show that continuous corn at the WICST has much greater potential for neutralizing acidity inputs than either corn-soybean or corn-alfalfa (statistically significant in the order CS1 < CS2 < CS4, following sign convention). This is further confirmed by the distribution of the alkalinity excretion among the individual crops of CS2 and CS4 (Table 1). Alkalinity excretion by the corn crops of CS2 and CS4 average 8.6 and 10.0 kmol OH^- ha^{-1}, respectively, and represent the bulk of the alkalinity excretion in both rotations. In CS2, soy alkalinity excretion accounts for only about a third of the anion excretion of the 2-yr rotation. In CS4, anion excretion is lower in the legume phases, particularly A1 and A2, where NO_3^- uptake is replaced by BNF. The 1-yr corn phase in CS4 excretes more than 60% of the alkalinity excreted in the 4-yr rotation, and DSA excretes most of the rest, with the production phases contributing only minor amounts of alkalinity (A1) or acidity (A2) as the result of cation/anion uptake balance.

Potential acidity in the crop:

The harvested portions of these agroecosystems, whether corn, beans, or alfalfa hay, are major sources of potential acidity (Table 1), primarily by virtue of the reduced N as protein, stored in the harvest and the generally low quantities of organic alkalinity in the harvest. By contrast, corn stover and soy straw contain considerable organic alkalinity in the leaves, which offsets the potential acidity associated with the residual protein and gives a net alkaline value for these materials.

Net H+/OH input of the cropping systems:

The standard harvest of continuous corn (CS1) at WICST consists of a grain-only harvest (9.0 kmol H^+ ha^{-1}), returning -3.7 kmol H^+ ha^{-1} as stover alkalinity to the soil, thereby offsetting a significant portion of the total acid input, 13.0 kmol H^+ h^{-1}. The net acidification rate for this crop and management practice is 0.8 kmol H^+ ha^{-1} (±0.58), which is virtually zero and considerable lower than that cited by other authors (Bolan, 1991; Bouman et al., 1995; Barak et al., 1997) for other crops and management practices. The cause of this near-zero acidification rate in continuous corn at WICST is related to the both the residue and nitrogen management techniques. The return of corn stover to the soil returns both organic nitrogen, which is potentially acidic, and organic alkalinity. The mineralization of the residue and nitrification to nitrate generates acidity, but the acidity is counterbalanced by the greater amount of stover alkalinity that is added simultaneously. Furthermore, the WICST fertilization strategy is to employ pre-plant nitrate tests (PPNT) to assess residual nitrate in the soil profile and to subtract the amount of preplant nitrate from the total nitrogen added, thereby reducing the amount of acid-forming ammoniacal nitrogen added. This practice has led to application of 90 to 140 kg N ha^{-1} (80 to 120 lb N per acre) at WICST instead of the full recommendation of 180 kg ha^{-1} (160 lb N per acre) as fertilizer N, which is common in Midwestern corn agriculture. The use of PPNT at WICST is therefore likely to have reduced the net acidification of continuous corn by 5.2 kmol H^+ ha^{-1}.

The results for CS1 at WICST can be used to estimate the effect of total removal of corn grain and stover on soil acidification rates, assuming that the nitrogen in the corn stover would be replaced on a one-for-one basis with fertilizer to maintain identical nitrogen supply. Such a practice might be put in place if corn were harvested for silage or stover or biofuel. In such a case, harvest of total aboveground biomass would lead to an annual acidification rate of 4.5 kmol H^+ ha^{-1}, which is significantly higher than that of the current practice that removes grain only and is quite in line with rates reported by Barak et al. (1997) for continuous corn in Wisconsin.

The average annual acidification rate of corn/soybean rotation at WICST (CS2; Table 1) average 1.3 kmol H^+ ha^{-1}. The acidification process is here related entirely to BNF in the soybean phase, but averages out over the two phases to be not significantly different than those of continuous corn. If, on the other hand, crop residues were also removed, e.g., stover for silage or biofuel and soybean straw for animal bedding, then the annual acidification rate would be 4.7 kmol H^+ ha^{-1}, almost identical to that of continuous corn with complete removal of aboveground plant material.

The corn/alfalfa/alfalfa/alfalfa rotation (CS4) as practiced at WICST produced an average annual acidification rate of 6.5 kmol H^+ ha^{-1}, significantly greater than CS1 and CS2 (Table 1). The major acidifying phase of this rotation is A1 and A2, the period of great productivity and active BNF. The potential removal of corn stover would only modestly increase the annual acidification rate of CS4 to 7.6 kmol H^+ ha^{-1}. However, one of the interesting practices at

WICST associated with this cropping system is the use of dairy manure before and after the corn phase. Withholding the manure applications and its associated inputs of alkalinity in favor of enhanced BNF or added ammoniacal fertilizer (for non-legumes), both potentially acid-forming, would add an average of 6.0 kmol H^+ ha^{-1} yr^{-1}, leading to projected total annual acidification rate of 12.5 kmol H^+ ha^{-1}. Such a value is slightly higher than the value reported by Bolan et al. (1991), 11.34 kmol H^+ ha^{-1} yr^{-1}, for a highly productive (16.5 t dry matter ha^{-1} yr^{-1}) rye grass/white clover pasture in a temperature climate with 1600 mm annual rainfall in Waikato, New Zealand; intensive dairy pastures in New Zealand require application of ~2.5 tons of lime per ha every 6 years and Bolan et al. predicted an annual requirement of 550 kg $CaCO_3$ ha^{-1} yr^{-1}. At the WICST trials, the use of manure to return back to the alfalfa fields some of the alkalinity generated by the leafy tissue that was harvested from those fields serves as means to cycle alkalinity in a manner that had been previously considered only for nutrients; in the process, the manure serves as a liming agent and reduces the total lime requirement. Since 50 g $CaCO_3$ neutralizes 1 mole H+, the current CS4 rotation is predicted to generate a requirement for 380 kg $CaCO_3$ ha^{-1} yr^{-1}or 1520 kg over a 4-yr rotation; in local units, the anticipated lime requirement would be 0.68 'English' tons aglime per acre, or 0.80 tons 80-89 aglime per acre, per 4-yr rotation. In the absence of manuring, the anticipated lime requirements per 4-yr rotation would be proportionately higher—2500 kg $CaCO_3$ ha^{-1}, or 1.31 tons 80-89 aglime per acre.

CONCLUSIONS

Of the three cropping systems examined and compared, the total and net acidity inputs ranked CS1<CS2<CS4. When standard harvest practices are implemented, continuous corn (CS1) has net acidity inputs to the soil that average 0.8 kmol H^+ ha^{-1}. In comparison, corn-soybean (CS2) and corn-alfalfa (CS4) average 1.3 and 6.5 kmol H^+ ha^{-1}. Throughout, the legume phases of these systems were more strongly acidifying than the corn phase, even though continuous corn was fertilized by acid-forming ammoniacal fertilizers. This was largely due to lower anion excretion under BNF and nitrification of unutilized chemically-reduced N at the end of the season.

These acidification rates reported here are somewhat smaller than those reported in the literature for other sites and other agricultural systems (Barak et al., 1997, Bouman et al., 1995; Bolan et al., 1991). Examples of higher acidification rates documented (Barak et al., 1997) are associated with N fertilization rates normally greater (160 kg N ha^{-1} or more) than those of the WICST in combination with total removal of aboveground biomass and no manuring practices. At the WICST fields, 'best management practices' included preplant nitrate tests that substantially reduced the rate of application of acid-forming ammoniacal fertilizers. The use of manure in the corn/alfalfa rotation also cut the potential acidification rate of that rotation in half.

A final observation worthy of mention is that the net acidity inputs in CS1 and CS2 are similar in size to those associated with acid rain in the Upper Midwest, which are ~0.5 kmol H^+ ha^{-1} based on atmospheric N deposition data. However, the total acidity inputs in these three cropping systems—13.0, 10.7, and 17.5 kmol H^+ ha^{-1} in CS1, CS2, and CS4, respectively—are 20 to 35 times greater than those from atmospheric inputs. Therefore, concerns about acidity inputs from acid rain to agricultural soils in the Midwestern United States are irrelevant in comparison to acidity inputs from sources related to agricultural activities.

ACKNOWLEDGMENTS

This research was funded by the USDA National Research Initiative ('Accelerated Soil Weathering due to Nutrient Inputs in Wisconsin Cropping Systems', 1997-2002) and the University of Wisconsin Graduate School.

REFERENCES

American Society of Agricultural Engineers. 2003. Manure production and characteristics. Standard ASAE D384.1 FEB03 [on-line, http://asae.frymulti.com; verified 26 Nov 2003]

Avila-Segura, M. 2004. Soil Acidification Processes in Agroecosystems. Ph. D. Dissertation, University of Wisconsin-Madison. Madison, WI.

Barak, P., B.O. Jobe, A.R. Krueger, L.A. Peterson, and D.A. Laird. 1997. Effects of long-term soil acidification due to nitrogen fertilizer inputs in Wisconsin. Plant Soil 197:61-69.

Bolan, N.S., M.J. Hedley, and R.E. White. 1991. Processes of soil acidification during nitrogen cycling with emphasis on legume based pastures. Plant Soil 134:53-63.

Bouman, O.T., D. Curtin, C.A. Campbell, V.O. Biederbeck, and H. Ukrainetz. 1995. Soil acidification from long-term use of anhydrous ammonia and urea. Soil Sci. Soc. Am. J. 59:1488-1494.

Brye, K.R., J.M. Norman, L.G. Bundy, and S.T. Gower. 2001. Nitrogen and carbon leaching in agroecosystems and their role in denitrification potential. J. Env. Qual. 30:58-70.

Graham, P.H. 1999. Dinitrogen Fixation. p. C139-C148. In M.E. Sumner (ed). Handbook of Soil Science. CRC Press. Washington, D.C.

Helyar, K.R. 1976. Nitrogen cycling and soil acidification. J. Aust. Inst. Agric. Sci. 42:212-221.

Johnston, A.E., K.W.T. Goulding, and P.R. Poulton. 1986. Soil acidification during more than 100 years under permanent grassland and woodland at Rothamsted. Soil Use Manag. 2:3-10.

van Beusichem, M.L., E.A. Kirby, and R. Bass. 1988. Influence of nitrate and ammonium nutrition on the uptake, assimilation, and distribution of nutrients in *Ricinus communis*. Plant Physiol. 86:914-921.

Table 1: Acid/base balance of CS1, CS2, and CS4 at the WICST

	CS1	CS2			CS4					
	corn	**corn**	**soy**	**rotation**	**corn**	**DSA**	**A1**	**A2**	**rotation**	**LSD***
	kmol ha^{-1}									
Nitrogen Inputs										
N input (other than BNF)	**18.2**	16.9	4.5	**10.8**	26.4	20.6	13.3	11.0	**16.1**	
Biological N_2 fixation (BNF)	--	--	16.2	**8.3**	--	1.1	21.4	27.5	**14.4**	
General Acidity and alkalinity inputs†										
Total H^+ input	**13.0b§**	11.3	9.9	**10.7c**	17.9	17.9	15.2	18.1	**17.5a**	1.7
Manure OH^-	**0.0**	0.0	0.0	**0.0**	-6.4	-8.6	-5.4	-3.5	**-6.0**	
Crop H^+/OH^- excretion	**–8.5c**	–8.6	–3.6	**–6.0b**	–10.0	–5.8	–0.6	0.8	**–3.9a**	0.5
Crop potential acidity‡										
grain, beans and hay	**9.0**	9.2	11.8	**10.4**	10.3	5.8	15.0	14.2	**11.5**	
stover stover/straw	**–0.6**	–0.6	–1.3	**–1.0**	–0.3	0	0	0	**–0.1**	
Aboveground	**8.5**	8.6	10.5	**9.5**	10.0	5.8	15.0	14.2	**11.4**	
Net H^+/OH^- input of the cropping system										
Aboveground harvest	**4.5b**	2.7	6.3	**4.7b**	1.5	3.5	9.2	15.4	**7.6a**	0.5
stover/straw H^+/OH^- return to soil	**–3.7b**	–3.8	–3.0	**–3.4b**	–4.3	0	0	0	**–1.0a**	0.2
Standard harvest	**0.8b**	–1.1	3.3	**1.3b**	–2.8	3.5	9.2	15.4	**6.5a**	0.58

* LSD = "Least Significant Difference" of a Duncan test for separation of experimental means, or the first "critical range" in the "Student-Newman-Keuls" multiple range test.

† Total H+ input although dependent on N inputs, is not identical in magnitude to N inputs due to internal recycling of N in the soil-plant system and decoupling between proton production and N uptake by the crop.

§ Means accompanied by different letters in the same row are statistically different at the 0.05 level.

¶ negative signs denote alkalinity and are used for convenience in this table but are not used in the discussion.

‡ The "net potential acidity" of corn aboveground material is identical to the "crop OH^-/H^+ excretion". In soy and alfalfa, however, BNF produces differences between these two quantities.

WICST EDUCATIONAL OUTREACH 2003 and 2004

Janet Hedtcke[1]

WICST continues to serve as an 'outdoor laboratory' for learning about issues of sustainable agriculture such as crop rotation, environmental stewardship, economic sustainability, and bio-diversity. In addition to field tours, we have disseminated WICST results at local and regional events as well as scientific meetings. Table 1 summarizes the outreach and educational activities for WICST in 2003 and 2004. WICST abstracts, theses and publications are listed in Appendix XI.

Several brochures were developed and passed out to UW Extension. They include the following titles: 'Leaching of Agricultural Chemicals to Tile Drains on WICST'; 'Using Pre-Plant Nitrate Test To Reduce N Inputs On Corn: 11-Year History On The WICST Plots'; 'Benefits of diversifying corn grain systems: Data from WICST'; and 'Restoring native prairie at the Arlington Research Station'. Our website (www.cias.wisc.edu/wicst) continues to provide information for a worldwide audience and we frequently receive emails and phone calls generated by the website.

On-station. Field tours were given throughout each year to several groups including extension agents, local farmers, and UW students and foreign visitors. The major outreach activities were the Agronomy/Soil Science Departments' annual field day (140 visitors) in 2003 and Prairies Jubilee in both years, which is co-hosted by the Audubon Society (300 visitors). Two posters were presented at Prairies Jubilee in 2003 and 2004 describing WICST prairie restoration efforts and our work with rotational grazing in degraded oak savannas. A tour was led through the restored prairie plots to show the differences between high and low diversity treatments.

In addition to field days, WICST held its annual winter meeting on February 7, 2003 and February 13, 2004 discussing WICST data to a mixed audience of farmers, USDA staff, UW faculty, UW Extension, Ag consultants, UW students, and MFAI collaborators. Topics included comparison across systems of soil nutrient and physical properties; economic analysis of the WICST systems, including rotational grazing; a discussion on the Conservation Security Program by NRCS officials; and an update from several graduate students on the Linking Farms Project.

Local/Regional Research data from the WICST projects was presented in both oral and poster form at ASA, CSSA, SSSA annual meetings in Denver, CO (Nov. 2-6, 2003) and Seattle, WA (Oct 31-Nov 4, 2004). Posters were displayed at The Natural Areas Conference in Madison, WI (Sept. 26, 2003) and the 2004 North American Prairie Conference in mid-August.

John Hall and Ron Doetch (MFAI) along with local organizations and agency officials developed the SE Wisconsin Resource Conservation and Development District (RC&D) formed to cover 13 counties in SE Wisconsin. Hall represented WICST as chair of the Agriculture Issue Team for the new RC&D, and by serving on the NRCS State Technical Committee. Activities

[1] Research specialist, UW-Madison, Agronomy Dept.

included hosting a farm tour that included the manure linking and organic grain trials at MFAI, and a presentation on "Diversified Farming Systems" at the annual Urban Rural Conference in October. We collaborated with Walworth County Extension and Town & Country RC&D to develop a Grazing Specialists position for the Southeast Wisconsin Grazing Network. The specialist is working with area NRCS conservationists to assist farmers in developing grazing plans that meet USDA program criteria for assistance.

Many face-to-face interviews with farmers, nutrient haulers, extension, ag consultants were conducted by grad students Amy Cook and Gregg Sanford to learn about current manure management strategies and to share with them our research ideas in the Linking Farms project. Interviews will be summarized in Amy and Gregg's theses.

Table 1. Outreach activities involving the WICST project in 2003 and 2004.

	EVENT	LOCATION	DATE	ATTENDANCE
2003				
	Westside Madison Rotary Club	Madison, WI	February 4	45
	WICST Winter Meeting	Madison, WI	February 7	30
	Waunakee 4th grade tour at plots	Arlington, WI	May 6	140
	Agronomy Centennial	Madison, WI	May 22	200
	'Land Use in WI' mini course at plots	Arlington, WI	Early June	20
	VoAg Training Day at plots	Arlington, WI	June 26	11
	Agronomy/Soils Field Day	Arlington, WI	July 9	140
	Natural Areas Conference	Madison, WI	September 24	50
	Prairies Jubilee at plots	Arlington, WI	September 28	100
	Radio Tapes w/ Jeanie Gurnick	Madison, WI	October 2	> 100
	ASA, CSSA, SSSA	Denver, CO	November 2-6	1500
	Soil Mgt Short Course at plots	Arlington, WI	December 9-10	30
2004				
	WICST Winter Meeting	Madison, WI	February 13	35
	DeForest School tour	Arlington, WI	EarlyMay, 2days	100
	Holistic Mgt Grassland Monitoring Fld day	Arlington, WI	May 12	12
	'Land Use in WI' mini course at plots	Arlington, WI	Early June	20
	Tour for Australian scholarship recipient	Arlington, WI	July 29	2
	North American Prairie Conference	Madison, WI	August 8-12	500
	CESA #3 Fall Ag Day (grazing tour)	Arlington, WI	September 22	30
	Prairies Jubilee	Arlington, WI	September 26	100
	ASA, CSSA, SSSA	Seattle, WA	Oct. 31-Nov. 4	1500

THE WISCONSIN INTEGRATED CROPPING SYSTEMS TRIALS: YIELDS, YIELD VARIABILITY, AND YIELD TRENDS 1990-2002.

Joshua Posner[1], Jon Baldock[2], and Janet Hedtcke[1]
Date: Sept 4, 2005

ABSTRACT

In 1990, a large scale, and long-term study entitled the Wisconsin Integrated Cropping Systems Trial (WICST) was initiated at two locations in southern Wisconsin. The purpose of the project was to compare alternative grain and forage-based systems using three performance criteria: 1) productivity; 2) profitability; and, 3) environmental impact.

An obvious initial criterion in comparing alternative agricultural systems is crop productivity. Three fundamental research questions were asked: 1) do the low input, organically managed production systems have lower yields than the high input production systems; 2) do the low input, biologically diverse systems have greater annual yield variability than the high input systems; and 3) do the biologically diverse systems gradually increase in productivity over time.

Our conclusions are the following:

1-The lack of a site × system interaction in three of the four crops and the relatively small crossover in the other crop in spite of the large difference in drainage suggests that these results are widely applicable and could be averaged over sites. We propose that the trial results have a wide area of inference on prairie-derived soils of the upper mid-west.

2-The quasi-organic systems produced 10 to 20% smaller grain yields (corn and soybeans) than the high and medium external input systems during the first 8 to 13 years of the two trials. However, the low external input forage system, CS5, produced up to 10% more alfalfa in the same period. Thus, the size of the deficit production with the low external systems was less than expected by many.

3-Thus far, the data do not support the hypothesis that the low external input systems are more variable in an absolute or a relative sense than the higher external systems. In fact, the only significant difference between variabilities found that the low-external input system, CS5, had lower variability for first-year, established alfalfa than the high-external input system, CS4, at Arlington.

4-There were significant yield trends in the four crops examined (corn, soybeans, wheat, and alfalfa). These trends differed among the cropping systems. With a few exceptions, there were increasing trends with the high- and medium-external input systems, but steady to decreasing trends with the low-external input systems.

[1] UW-Madison, Agronomy Dept.
[2] AGSTAT, Verona, WI

5-Overall we conclude from these trials that differences in productivity, yield trends, and yield variability between the low external input systems and the higher external do exist. However, the differences are small enough and inconsistent enough that other factors; such as such as profitability, environmental impact, and life-style preferences; will often be the determinate in the selection of a cropping system.

J. Posner and J. Hedtcke, Dep. of Agronomy, Univ. of Wisconsin, Madison, WI 53706, J. Baldock, Agstat, Verona, WI 53593. *Corresponding author (jlposner@wisc.edu).

Acknowledgements

This paper would not have been possible without the efforts of the entire WICST team, especially John Hall, Jim Stute, Tom Mulder, and Dwight Mueller.

INTRODUCTION AND OBJECTIVES

Southern Wisconsin and much of the upper Midwest was home to mixed grain and livestock production systems from the 1880's to the early 1960's (Felstehausen, 1986). Since that time however, with the introduction of herbicides and chemical fertilizers, farms have tended to become primarily focused on either livestock or annual grain production. At the same time that this trend in specialized rather than mixed farming has been taking place, there has been increased criticism of farms as sources of non-point pollution. In 1990, in response to growing public concern about the environmental impact of this changing agricultural model, a large scale, and long-term study entitled the Wisconsin Integrated Cropping Systems Trial (WICST) was initiated at two locations in southern Wisconsin. The purpose of the project was to compare alternative grain and forage-based systems using three performance criteria: 1) productivity; 2) profitability; and, 3) environmental impact.

The systems were designed to test the agroecological hypothesis that with increased biological complexity, agricultural systems would remain highly productive but with less reliance on external inputs (Altieri, 1987; Harwood, 1985). As a result, WICST is a nested factorial with two enterprise types (annual grain production or forage-based livestock production) and within each, three production strategies: a) low crop diversity with high inputs; b) medium crop diversity and medium inputs; and, c) high crop diversity and low inputs. These latter systems were designed to be managed organically. To adequately test this cropping diversity hypothesis, it was not possible to either; 1) fix cropping sequence and only vary input levels (an input management trial); nor, 2) fix input levels and only vary cropping sequence (a crop rotation trial). In this study, *production management strategies* are being compared, so the two factors, sequence and input level, are fixed simultaneously to represent realistic *cropping systems*.

An obvious initial criterion in comparing alternative agricultural systems is crop productivity. Three fundamental research questions were asked: 1) do the low input, organically managed production systems have lower yields than the high input production systems; 2) do the low input, biologically diverse systems have greater annual yield variability than the high input systems; and 3) do the biologically diverse systems gradually increase in productivity over time. The last objective is particularly important in view of the expectation that cropping systems, especially those that are organically managed, have a period of transition before reaching higher and more stable output levels (Liebhart et al., 1989; Dabbert and Madden, 1986) Also, it would be counterproductive to calculate and discuss simple means of crop yields averaged over time if time trends existed showing increasing or decreasing yields.

LITERATURE REVIEW

Most of the work on the impact of crop diversity on crop yield has been conducted within high input crop rotation trials. A number of researchers have found shown that corn and soybeans yields, for example, increase often by 10 to 15% when not planted in a monoculture (Lund et al, 1991; Porter et al, 1997). It has also been shown that including a leguminous forage crop like alfalfa in a rotation can have a large impact on the following corn or soybean crop yield (Baldock and Musgrave, 1980; Baldock et al, 1981). However, relatively few studies have looked at the impact of crop diversity within a context of reduced chemical inputs. What work had been done has primarily compared conventional and organically managed

systems. At the time the WICST trial began, most of the literature suggested that organically managed cropping systems would be less productive than the higher input systems (Berardi, 1978; Crosson and Ostrov, 1990; Helmers et al., 1986; Klepper et al, 1977). A survey conducted in Ohio in 1990 indicated that the certified organic field crop producers (n=19) had yields equivalent to 72% for corn, 80% for soybeans, 70% for wheat and 68% for hay of their conventional farming counterparts in the Ohio Farm Household Longitudinal Survey (n=960) (Batte et al, 1993). By the mid-90's, this argument was being used by some (Avery and Avery, 1996) to justify that the agricultural research focus must be kept on high input agriculture, as shifting to organic agriculture would result in both a massive expansion of area cropped, and food shortfalls in the future. Some studies were available however, indicating that organic yields were nearly equivalent to conventional yields (Lockeretz et al, 1978; Lockeretz et al., 1981; Cacek and Langner, 1986).

There is less information available about the impact of crop diversity or rotations on yield stability. In one study however, it was reported that organic systems did not show increased variability in net returns (Helmers et al., 1986). Porter et al (1997a) in looking at approximately 10 years of data at four locations has shown that the rotation effect with corn and soybeans is greater in years with low average yields than in years with high average yields in the case of corn. Nevertheless, discussions with growers indicated that they were particularly concerned about the potential for increased weed pressure and reduced nutrient availability in the organically managed systems, resulting in economic losses in some years.

And, there was a general consensus that shifting to organic systems would require a period of transition before yields would rise. Initial analyses on the Rodale Conversion Trial (1981-1985) indicated that corn yields were only 75% of conventional yields during the first four years of the study (Liebhardt et al., 1989). Duffy and colleagues (1989) did an economic study of the alternative "starting points" of the organic rotation and concluded that these systems needed to start with low input crops (small grains) or nitrogen fixing crops (legumes) that would subsequently "set the stage" for high N demanding crops.

MATERIALS AND METHODS

Cropping System Trials and Terminology

Definitions of the terms: crop rotation, crop sequence, phase, cycle and test crop; are consistent with those originated by Cochran (1947) and Yates (1954). Cady (1991) provides a more recent statement of them. By "cropping system" we mean the combination of a crop rotation and a management philosophy. Our use of cropping system is more general than the definition in Cady that a cropping system is the combination of a crop rotation and a set of specific management practices. Substitution of a management philosophy for specific practices allows the flexibility to adjust the practices to the needs of each crop rotation and keep up with rapidly changing technologies such as changes in varieties, weed control, and tillage. We used a panel of farmers and researchers to guide such changes and ensure that they were consistent with the overall philosophy of each system (Posner et al. 1995). Cropping system trials such as these may be viewed as fractions of the full factorial combinations of crop rotations by cultural practices discussed in Patterson and Lowe (1970) and Cady (1991). By choosing only the treatment combinations that are appropriate for each crop rotation, every cropping system is compared near its optimal level and the problem of impractically large, full-factorials trials that Cady warned of

are avoided. This flexibility and efficiency in cropping systems trials comes at a price; that is, the ability to identify specific causes of differences among systems is mostly lost.

Experimental Design and Establishment

The WICST study consists of six cropping systems, replicated four times, at each of two sites in southern Wisconsin. Three cash grain systems and three forage systems were selected for study (**Table 1**). Although there were at least eight criteria in the selection and design process (Posner et al. 1995), the two key criteria were crop diversity and level of external inputs. Table 1 summarizes the key differences in cultural practices among the rotations. Since nearly the inception of the trial, CS3 and CS5, the organic grain and organic forage systems have meet the USDA requirements for a *certified* organic system (http://www.ams.usda.gov/nop/NOP/standards.html), except for the lack of twenty-five foot buffer zone around each plot, the use of certified organic seed prior to the 2003 season and, the cleaning and purging of equipment coming from conventionally managed fields. Thus, these are quasi-organic systems.

The trials were established in 1989 with all 60 acres at each site planted to corn to improve the uniformity of crop history and allow baseline measurements to be taken. Some of the baseline variables, especially yield, were used to block the trial into four blocks of 14 plots (0.75 acre per plot) for the 14 total phases in the six cropping systems.

Except during the staggered start, which was completed by 1993 (**Table 2**; Posner et al, 1995), every phase was present every year for all the crop rotations in the RCBD, thus meeting a core requirement of a crop rotation trial (Cady, 1991). The staggered start was used to replicate each phase of the crop rotations in time as well as space, thus providing a more powerful analysis of time trends by cycle than could be accomplished with an even start of all possible crop sequences for a crop rotation.

Plots were tilled, planted, and harvested with field equipment. Grain and dry matter yields were estimated by running the harvest wagons across a farm scale. Grab samples were taken for quality analysis. Grain crops samples were analyzed for moisture and protein levels; while forage samples (both hay and pasture) were tested with NIR to determine Relative Feed Value (RFV) (Rohweder et al, 1978; Rohweder, 1984). In the rotational grazing system, randomly selected samples (4 x 0.5 m^2) were hand-cut each week with a shears at ground level just prior to grazing by the heifers (Marten, 1989). Additional details on the design and conduct of the WISCT trial are provided in Posner et al (1995).

Sites

Both sites are in Major Land Resource Area 95B, which covers most of south central and southeastern Wisconsin. (U.S. Dept. of Agric., 1981). Soils in this land resource area are primarily prairie-derived soils (Mollisols) and vary along two gradients, the depth of silt loam loess cap over glacial till, and internal soil drainage. One site is the somewhat poorly drained Lakeland Agricultural Complex (LAC) on the Walworth County Farm near Elkhorn, WI (42 39'N; 88 29'W). The dominant soil types at this site are a Pella (fine-silty, mixed, mesic Typic Haplaquoll) and a mottled variant of Griswold (fine-silty, mixed, mesic Typic Argiudoll). The other is a well-drained site at the University of Wisconsin Arlington Research Station (ARS) (43 18'N; 89 21'W) and is located on a Plano soil type (fine-silty, mixed, mesic Typic Argiudoll).

For the most part, both sites had been in a dairy-forage cropping system of corn and alfalfa with manure for the 20 years prior to establishing the trial. As a result, both sites initially had high organic matter levels (4.7 and 5.2% at ARS and LAC respectively), medium soil pH levels (6.5 and 6.3), high soil test phosphorus (108 and 58 ppm Bray I), and high soil test potassium (255 and 188 ppm exchangeable K).

Statistical Analyses

Yields. To conduct the statistical analysis, we fit the crop yields and quality data to a linear, additive model using the Restricted Maximum Likelihood (REML) facility of SAS PROC MIXED (SAS Institute Inc., 1999). The model we fit for the preliminary analyses over locations and years was:

$$Z_{ijkl} = \mu + L_i + Y_j + LY_{ij} + B_j(L) + YB_{jk}(L) + S_l + LS_{il} + YS_{jl} + LYS_{ijl} + \varepsilon_{ijkl},$$

where

Z_{ijkl}	=	observed yield or quality measurement for the ijkl-th case,
μ	=	overall mean yield,
L_i	=	effect of location i,
Y_j	=	effect of year j,
LY_{ij}	=	interaction effect of location i with year j,
$B_k(L)$	=	effect of block k nested within location,
$YBj_k(L)$	=	interaction of effect of year j with block k within location,
S_l	=	effect of cropping system l,
LS_{il}	=	interaction effect of location i with cropping system l,
YS_{jl}	=	interaction of year j with cropping system l,
LYS_{ijl}	=	interaction of location i with year j and cropping system l,
ε_{ijkl}	=	residual error,

i = 1, 2;
j = 1, ..., x depending on crop and location;
k = 1, ..., 4;
l = 1, ...6 depending on crop and location

We also analyzed the data within sites using the above model without the terms involving locations because the LAC site data only ran from 1993 to 1998, while at ARS the data set continued to 2002. Both the full model and the reduce model disregard the different cycle lengths for the cropping systems and consider the year effect to be a whole plot factor as opposed to a subplot (or split-plot-in-time) factor. We believe this is the better choice because the weather aspects of years were larger than the time aspects of years (i.e., the number of years since the trial began). A separate analysis over cycles of the crop rotations (see below) not only provided a better way to investigate possible time trends, but also a more appropriate way to address the potential correlations of measurements on the same plot inherent in crop rotation studies (Cady, 1991). We regarded years, blocks, and interactions as random factors so the inference space extends beyond the particular levels in these trials. To help answer some questions, we calculated the 90% confidence interval or LSD at the 10% significance level from the standard error and degrees-of-freedom reported by the appropriate ESTIMATE statement in SAS PROC MIXED.

Yield variability. We compared the variances of the annual mean yields (averaged over replications within a year) as a measure of the absolute yield variability of the systems with an F-test for two systems or with Barlett's test for more than two systems (Snedecor and Cochran, 1967). Both of these tests assume a normal distribution and Barlett's test is especially sensitive to minor departures from the normal distribution (Bonett and Seier, 2003). Consequently, we also examined the variability among systems with the mean absolute deviation from the median, which is a distribution-free method that is less affected by extreme values (Bonett and Seier, 2003). However, even if there are no differences in the absolute variability, there may be differences in the relative variability as measured by the coefficient of variation (CV). The computations to compare CVs statistically are formidable; however, Verrill (2003) developed a procedure and published a web-based program to do them.

Yield trends over time. Cady (1991) described four methods for determining the existence of yield trends overtime: 1) univariate split-plot analyses where the subplot is time, 2) multivariate repeated measures analyses, 3) analyzing estimated polynomials coefficients for each plot, and 4) modeling approaches; e.g., using the Mitscherlich equation. He also discussed the need to quantify the correlation between errors in measurements necessarily made on the same plots over time in crop rotation studies. Recent advances in REML models add a fifth method to estimate trends over time that is related to the repeated measures analysis and has the capability to simultaneously estimate the correlation of observations (Singh and Jones, 2002). We used the REML models as implemented in the SAS PROC MIXED to first determine how best to describe the possible correlation and heterogeneity of errors as described in Wolfinger (1996) and then test for time trends using the sequence of models outlined in the analysis of covariance chapter in Little et al. (1996). In these analyses, we used cycle number of the crop rotation as the unit of time instead of years that provided a direct measure of the number of times the plot had been through the corresponding rotation. Furthermore, cycles afford replication over time, as well as space, when the staggered-start is used and every phase of every rotation is grown in each year **(Table 2)**. Initial runs estimated the block, block by cycle interaction, and individual plot effects to be negligible when plots were used as the subjects. Thus, these effects were not included in the analyses for time trends. We investigated yield trends at ARS and not LAC because changes in rotations and management in 1999 at LAC reduced the number of cycles to the point few of the REML analyses would converge to a solution.

RESULTS AND DISCUSSION

Crop Yields Over Locations

Table 3 (a & b) and **Fig. 1 (a & b)** summarize the preliminary analyses of crop yields over sites for the four crops that appeared in more than one cropping system. The effect of cropping systems was statistically significant for corn, soybeans, and first-year alfalfa yields; but not for seeding-year forage yields. Corn yields in the forage systems averaged 13 bushels/acre more than in the cash grain systems ($P<0.01$). In the cash grain systems, the quasi-organic system yielded 91% as much corn than as the average of the two higher external input systems ($P=0.04$). In the forage systems, the quasi-organic system, CS5, produced 88% as much corn as the high

external input system CS4 (P=0.01). For soybean, the quasi-organic system, CS3, generated 96% as much yield as the high external input system, C2 (P=0.09), but there was a site × system interaction (see below). The quasi-organic system, CS5, produced 105% as much dry matter as the high external input system, CS4, in the first hay year of alfalfa (P=0.03); however, the difference between the two systems in the seeding year yields was not statistically significant due to greater variability and fewer years of data.

The effect of site was statistically significant for corn and the two forage crop phases with the well-drained ARS soils providing higher yields than the poorly drained LAC soils for all crops and systems except CS2 soybeans. In the three crops where sites were significantly different, the site × system interaction was not significant. The nearly parallel results over sites shown in **Fig. 1a and 1b**, corroborated the lack of a site × system interaction for the three crops. In soybean, however, the effect of site was not significant, but the site × system interaction was significant, which was confirmed by the crossover pattern for soybean in **Fig 1a**. The lack of a site × system interaction in three of the four crops and the relatively small crossover in the other crop, in spite of the large difference in drainage, suggests that these results are widely applicable in the upper Midwest on prairie derived soils. However, we decided to re-run the analysis by site for three reasons;

- As can be seen in **Table 3c**, there is a large variance component for year × site (the only variance component larger than the residual in all four crops;
- There was greater variability of the data from LAC than ARS; and,
- There were a greater number of years of data at ARS than LAC.

Crop Yields Within Locations

Corn. When we analyzed all the corn data after the staggered start for all five systems at ARS (1993-2002), the effect of system was significant (P<0.01) and the ranking of the cropping system mean yields did not change from the ranking obtained from the analysis over sites: CS4>CS2>CS5>CS1>CS3 (**Table 4a**). When we analyzed the data for wetter LAC (1993-1998), the effect of systems was again significant (P=0.05). However, the order of CS1 and CS5 reversed (**Table 4b**) putting the two quasi-organic systems at the low end of the list. These analyses confirmed the residual variance of corn yields at LAC was larger than at ARS. In fact, the variance at LAC was over twice as large as it was at ARS, which was statistically significant (P<0.01).

Weed competition in the quasi-organic systems was one of the major causes of yield differences between years. Poor weed control in the quasi-organic systems as a result of wet spring weather occurred in 1993 and 1998 at LAC. Corn yields for these two years averaged 120 bushels/acre compared to 160 bushels for the three years (1994, 1995, and 1997) with drier springs and better mechanical weed control. We omitted 1996 from this set of analyses because the spring was so wet that it was not possible to plant the corn until late June. Consequently, very low corn yields and good weed control were obtained with all five systems in that year. When we investigated the weather records it was clear that May plus June rainfall in excess of 10 inches (140% of the norm) fit our set of problem years perfectly (**Fig 2**).

Similarly, we noted incomplete weed control in the quasi-organic systems impacted the comparison with the higher-external input systems in 1993, 1996, 2000, and 2001 at ARS. As

was the case at LAC, these years had May plus June rainfall in excess of 140% of the norm **(Fig. 3)**. In these four years, the corn grain yields in the quasi-organic grain system, CS3, averaged only 76% of the mean for the higher-external input systems, CS1 and CS2. In contrast to LAC, two other years (1994 and 1998) also had excessive rain in the spring, but these two years also had slightly above normal Growing Degree Days (GDD) for that period **(Fig. 3)**. Thus, on the better-drained soils at ARS, it appears that both wet and cold weather are necessary to inhibit the effectiveness of mechanical weed control in corn. However, in the six years with more favorable spring weather, quasi-organic grain system (167 bu/a) averaged 96% of the two conventional systems. Likewise in the forage systems at ARS, the quasi-organic system, CS5, yielded 83% as well as CS4 in the four unfavorable years; but it yielded 94% as well in the six favorable years. Porter et al (2003) working in Minnesota also found that wet springs reduced the efficacy of mechanical weed control and adversely affected organic corn and soybean yields.

These differences in cropping system corn yields between years with springs favorable versus unfavorable for mechanical weed control account for most of the large year × system variance component in **Table 3c**. It is also likely however, that the colder, wet weather would have also limited nitrogen mineralization in the quasi-organic systems (CS 3 & CS 5) (Andraski and Bundy, 2002) reducing the competitiveness of the corn with weeds, further resulting in the lower yields). Regardless of whether one or both factors caused the lower yield, it is clear the performance of the quasi-organic systems relative to the higher-external input systems during years with wet springs at LAC (61 to 77%) or cold wet springs at ARS (76 to 83%) was comparable to that Batte et al, (1993) reported (72%). However, their relative corn yields in years with drier springs at both sites (94 to 97%) was much better than expected from that report.

In addition to the low versus high external input comparison, the corn yields in the forage systems were significantly greater than those in the cash grain systems for the 10-year analysis at ARS ($P<0.01$) and for the years with a dry spring at LAC. ($P=0.02$). A key component of this linear contrast is the comparison of continuous corn to corn grown after any other crop when adequate N has been supplied. Baldock et al. (1981) found this rotation effect to be 17.0 to 18.0 bu/a following two years of alfalfa and Porter et al. (1997b) reported it was 23.3 to 27.1 bu/a following one year of alfalfa. In the WICST, the rotation effect was 23.1 ± 10.1 bu/a at ARS and 21.4 ± 16.2 bu/a for the three, dry-spring years at LAC, which is consistent with the prior research. However, the smaller, nonsignificant, estimate of 14.3 bushels/acre for the three wet-spring years at LAC is contrary to Porter et al. (2003) where the rotation effect was larger in low yielding years. Also, the estimated rotation effect for corn following soybean; i.e. the comparison of CS1 to CS2 corn, at both WICST locations was smaller (six to nine bushels/a) and nonsignificant **(Tables 4a and 4b)**.

Soybeans. Similar to corn, soybean yields in the quasi-organic system, CS3, averaged 10% less than those in the high-external input system, CS2, at ARS for 1990 through 2002. **(Table 4c)**. As was the case with corn, we had difficulty controlling weeds mechanically in CS3 in some years; specifically in 1992, 1994, 1999, 2000, and 2001 at ARS. In those five years the CS3 soybean yields averaged 38 bushels/acre, which was 79% of the CS2 soybean yields for the same years. But in the other eight years CS3 soybean yields averaged 48 bushels/acre, which was 96% of those in CS2 over the same years. We obtained a similar result at LAC. Over all nine years of data, soybean CS3 produced only 85% as well as in CS2 and the difference was

statistically significant (P=0.04). However, our notes indicate problems controlling weeds in 1993, 1994 and 1998. In those years CS3 soybean production averaged 69% of that in CS2; but in the five years with good mechanical weed control, CS3 soybean production averaged 96% of that in CS2. The years of poor weed control fit well with the value of 80% Batte et al. (1993) reported. However, in the majority of years in which we obtained good weed control mechanically the performance of soybean in CS3 relative to that in CS2 was much better (96%) at both sites.

Wheat. The 90% confidence interval for the CS3 wheat yields at ARS was 54.0 ± 6.2 bushels/acre over the period 1991 through 2002 (**see Table 4d**). This was approximately 6% less than the county average yield for the same period, 57.3 bushels/acre (http://www.nass.usda.gov/wi/annbull/). For Lakeland, the 90% confidence interval for CS3 wheat yields was 43.6 ± 12.9 bushels/acre for the years 1991 through 1998 (omitting 1996 when the wheat winterkilled, not only at this site, but over most of southern Wisconsin). This was 20% less than the county average for the same years, 54.4 bushels/acre. These yield losses associated with organic production were nevertheless, smaller than the 30% reduction reported in the Batte et al. (1993) survey.

Forages. **Tables 4e and 4f** show that the quasi-organic system, CS5, produced 7 to 42% more forage dry matter than the high external system, CS4. In the seeding year at ARS (**Table 4e**), the difference between the companion seeding with oats and field peas and sole seeding was barely statistically significant (P=0.10); and at LAC **(Table 4f)** the difference was not quite statistically significant (P=0.13). In both systems the first year forage production was significantly greater than during the establishment year. During the first year after seeding, the advantage of CS5 over CS4 was significant at ARS (P=0.04), but not at LAC (P=0.33). At ARS there was a significant decline in the forage produced in second hay year of alfalfa compared to the first hay year in CS4 (P=0.01). Although there was a similar decline between the alfalfa phases at Lakeland, the difference was not statistically significant.

After the pastures were established we rotationally grazed them with approximately 500 lb heifer calves. We tried several methods of rotational grazing and settled on using a cohort technique in which we moved all the animals together from plot to plot. We have hand sampled forage yield and quality data from this pasture system for 1997 through 2002 at ARS, where the overall mean forage yield was 4.98 ± 0.96 tons dm/acre. Because this 90% confidence interval encloses the established alfalfa yields in CS4 and CS5, the CS6 forage yields were not significantly different from them (**Table 4e**).

Because animal production in the form of meat or milk is the ultimate goal of forage production, forage quality is as important as dry matter yield. We determined relative feed value (RFV) as a measure of forage quality and estimated milk production with MILK91 (Undersander et al. 1993). **Tables 4g and 4h** show the results of these observations. Not surprisingly, there was a 23 (ARS) to 35 (LAC) point RFV advantage between forage that was primarily composed of alfalfa versus the companion-seeded option (oats/peas) in the establishment year. The RFV of

the pasture samples was 120 ± 10, which was also significantly lower than for alfalfa in CS4, but not for alfalfa in CS5. However, the differences in RFV were offset by larger dry matter yields so there were no significant differences in estimated milk production between the two systems. Similar offsets occurred, but to a lesser extent, in the other comparisons so there were no significant differences in milk production in any of the comparisons at ARS or LAC.

Crop Yield Variability Over Years Within Locations

Although the primary concern of the farmers and researchers on the WICST advisory panels was on long-term mean productivity, they were also very concerned about variation in yields from year-to-year, especially in the quasi-organic systems. The above results appear to validate that concern. Both corn and soybean yields in the quasi-organic systems showed substantial variability over years depending primarily on the favorability for mechanical weed control.

Corn. **Table 4a and 4b** give the standard deviations and the CVs of the annual mean corn yields for each system at ARS and LAC. There is a hint of greater variation with the quasi-organic systems, CS3 at ARS and CS5 at LAC; however, the differences are too small to be statistically significant at either site with Bartlett's test (P=0.8 at ARS and P=0.9 at LAC). In addition, there were no differences among the systems using the mean absolute deviation from the median (data not shown). On the other hand, the systems with the greatest variability are also those with some of the lower yields. Thus, even though there were no significant differences in the absolute variabilities, there may be significant differences in the relative variabilities (i.e., the ratio of the standard deviations to the mean, which is the Coefficient of Variation (CV). At ARS, the 90% confidence intervals for the CV of all the systems except the quasi-organic system, CS3, could be approximated by the interval [0.1, 0.3]. Although the 90% confidence interval for the CV in CS3 was shifted up approximately by 0.1 to [0.2, 0.4], there was still substantial overlap between it and the interval for the other systems. Similarly at LAC, the 90% confidence interval for the CV in CS1 through CS4 were within the interval [0.1, 0.8], but the 90% confidence interval for the CV in the quasi-organic system, CS5, was about 0.2 units higher. Again there was substantial overlap between the 90% confidence intervals for all the systems, including CS5, so there were no significant differences. Therefore, in spite of the hint of greater variability of annual mean corn yields section for the quasi-organic systems, CS3 and CS5, in the previous section; there were no significant differences between these systems and the conventional systems in absolute or relative variability at either location.

Soybeans. **Table 4c** states the variability statistics for the annual mean soybean yields at both sites. The F-test of the variance ratio for CS3 to CS2 was not statistically significant at ARS (P=0.35) or at LAC (P=0.31). Furthermore, the mean absolute deviations from the median were not different stastistically (data not shown). The relative variabilities, i.e., the CVs, were not significantly different at either site. Although the previous section found substantial year-to-year variability for soybean yields in the quasi-organic system, this variability was not significantly greater than that in the conventional system.

Wheat. **Table 4d** presents the variability information for annual mean wheat yields in the quasi-organic system, CS3. The standard deviation for CS3 was actually smaller than those calculated for the same time period from the Wisconsin Department of Agriculture statistics (http://www.nass.usda.gov/wi/annbull/) for Columbia County (the location of the ARS), so the

difference was not statistically significant. In CS3 at LAC, the standard deviation of the annual mean wheat yields for 1991 through 1998, including 1996 when the wheat crop failed, was 22.45 bushels/acre. If 1996 was omitted, then the standard deviation was 17.62 bushels/acre. In either case, the WICST results had a larger standard deviation than those for Walworth County, but the differences were not statistically significant.

Alfalfa. The variability statistics for forages are given in **Tables 4e and 4f.** In the seeding year there were no significant differences in absolute or relative variation in annual mean yields between the high external input system (CS4) and the low external input system (CS5) at either site. However, in the first established year of alfalfa at ARS, the variance of the annual mean forage yields from CS4 was significantly larger than that for CS5 using the F test (P=0.06). In addition, the mean absolute deviations from the median for the two systems were significant at the 10% level (data not shown). At Lakeland, the variance for CS4 was also significantly greater than that for CS5 (P= 0.06). However, the mean absolute deviations from the median values, were not significantly different at the 10% level (data not shown). The CVs for CS4 were approximately 1.8 times those for CS5, but the CVs were not significantly different at either site.

Thus, the only evidence of greater variability we found was that the high external input system, CS4, had more variable alfalfa yields in the year after establishment than the quasi-organic system, CS5, at both locations. There are two causes of this result, which is counter to the expectations of many. First, the quasi-organic systems are less variable than anticipated. And second, with all the focus on the organic systems, many have forgotten how variable the high input systems are. For example, in the established alfalfa the high input system, CS4, had much greater winterkill than CS5 and it had to be reseeded with red clover and ryegrass in 1992, which led to 2 tons dm/acre yield differential. We attributed this difference to the more aggressive cutting schedule weakening the stand. Also, during 1999, dry weather reduced CS4 established yields more than in CS5, probably for the same reason. CS1 has succumbed to whatever constitutes the "rotation effect" (see above) compared to the other systems in some years more than others. In CS2, rodent problems have plagued the notill corn phase and herbicide injury was so severe in the very cold, dry spring of 1992 **(Fig. 3)** that the soybean crop had to be replanted. Thus, each system has its unique challenges as well as those that are similar across systems; consequently, except for first-year alfalfa where the high input system was more variable, the yield variabilities were not statistically different.

Crop Yield Trends at Arlington

While the mean yields of a long-term study are very important parameters, it is also essential to determine if the yields are stable over time, or if trends have developed that could eventually change the differences among the cropping systems.

Corn. **Fig. 4** shows the corn yields trends for continuous corn, CS1, and corn in the soybean-corn system, CS2, over 6 cycles. Initially CS2 yields were greater than those in CS1, however in the last two cycles, CS1 performed better than CS2. This difference plus the decrease in yields during Cycles 2 and 3 (due largely to the cold, wet weather in May and June 1992 and 1993, **Fig**

3) led to a separate quadratic equation for the two systems being the best fitting model. From the low at Cycle 3 to the high at Cycle 6, the yields in CS1 increased 50.7 bushels/acre, thus the average annual increase was 8.5 bushels/acre. In CS2 the yield increase over this period was 20.4 bushels/acre making the average annual increase only 3.4 bushels/acre.

Fig. 5 illustrates the trend in corn yields for the high external input, continuous system, CS1, compared the trends for corn yields in the quasi-organic systems, CS3 and CS5 over cycles. Although the data look as if the quadratic model would provide a good fit as it did for CS1 and CS2, none of the terms in the quadratic model were statistically different from zero. Also, the linear slope term for CS3 was not statistically significant. That leaves the overall mean corn yield in CS3, 142 bu/a, as the best estimate of the corn yields in this system. (Jon, how important is this next sentence. Can we drop it ?) In this analysis, regrouping the CS1 data as if it had 3 phases had little effect on the rate of yield increase compared to the 2-year cycle grouping in **Fig. 4** over the last several cycles. In other words, there was an increase of 23.7 bushel/acres per cycle in **Fig. 4**, which translates into an improvement of 7.9 bushel/acre per year, which is very close to that calculated for CS1 above. As a result of the increasing corn yields for CS1 and the flat yields for CS3 these data project an increasing advantage for CS1 over CS3. The forage based, quasi-organic system, CS5, had a significantly positive slope showing corn yields rising at a rate of 11.1 bu/a per cycle (3.7 bu/a/year). Thus, it too had an increasing advantage over CS3, but its rate of increase was less than half of that in CS1.

We also found significant linear trends in slopes in the comparison of CS1 and CS4 corn yields (**Fig. 6**). The regression equations estimate a 37 bushel/acre advantage for CS4 during Cycle 1. However, they also estimate the advantage will switch to CS1 by Cycle 5 (i.e., 2010 in this trial) due to the significantly larger slope for CS1. The slope of CS1 suggests an increase of 29.7 bushels/acre per cycle, or 7.4 bushels/acre per year, *which is very close to the rate estimated with the 2- and 3-year cycles discussed above.* In the CS4, the comparable estimates are 18.6 bushels/acre per cycle, which equates to 4.7 bushels/acre per year.

Thus, corn yields in four of the five cropping systems at ARS had significantly positive yield trends over the first twelve years of the WICST. If these slope trends continue at the rates observed, CS1>CS4>CS5>CS2 and CS3=0 (assuming the linearization of the trend for CS2 estimated above), then the corn yield rankings will eventually follow that order, which is substantially different from the one observed over the first thirteen years (see above). The most astounding of these forecasts is for the continuous corn system, CS1, to go from next-to-last to first. While it is not unprecedented for continuous corn to yield as well as corn in a rotation (i.e. have a rotation effect of zero, Shrader et al., 1966; Baldock and Musgrave, 1980), we are unaware of any reports in refereed journals that continuous corn produced greater grain yields than corn in a rotation. On the other hand, there are such reports in the trade press. For example, Reichenberger (2004) reported that the record yields in the National Corn Growers Association yield contest have been obtained in fields that have been in corn for over 20 years and that continuous corn has performed better than a corn-soybean rotation after the initial three to four years. Consequently, the next 10-year of the WICST should help answer some key questions in regard to corn yields. Will the continuous corn system continue to have the most rapid increase to become the top corn producing system? Will the rates level off so its yields equal those of the

longer rotations? Or, are the current rates an aberration that will be corrected so that continuous corn resumes a position near the bottom of the order?

Soybeans. The cycle lengths of CS2 and CS3 are not the same, which causes missing cell problems for conducting an analysis of covariance for soybean yields like we did with corn. However, even without applying statistical tests, the trends for the two systems are clearly different (**Fig. 7**). The saw-tooth oscillations in soybean yields in CS2 resulted in a slightly negative yield trend of 0.6 bushels/acre per year. In CS3, soybean yields followed a concave quadratic trend. The estimated slope at Cycle 4 was a negative 8.0 bushels/acre per year. If these trends continue, then the gap between CS2 and CS3 soybean yields will be much wider than the 5 bushels/acre we reported above. But in the yield section above, we also identified cold, wet spring weather as having caused a problem with weed control in several years in the last two cycles of CS3. If this was the major reason for the steep decline observed, then it is likely that the weather would return to a more normal pattern and the CS3 yield would again approach the smaller 5 bushel/acre difference compared to CS2, especially if more aggressive weed control measures are implemented in this quasi-organic system. This will be another interesting question to follow to see which interpretation is born out.

Wheat. **Fig. 8** illustrates the trend in wheat yields. After an increase from the first to the second cycle, the trend has been down. The resulting quadratic trend predicts yields are now falling at 1.9 bushels/acre per year. It may be that decreasing soil fertility levels and increasing weed pressure in this quasi-organic system that, although not pronounced, are causing lower yields. On the other hand, the yields could also be responding to variations in weather patterns, in which case the trend might reverse once the weather improves. However, a statistically significant, linear increase in county average yields of 3.4 bushels/acre per year over the same period argues against the latter alternative. So once again, additional years of data are necessary to distinguish between these alternatives.

Alfalfa. Amongst the forage crops, the possible trends in the first year of established alfalfa yields are most interesting because two systems, CS4 and CS5, can be compared. The yields in both systems have followed a quadratic trend with the better yields in the early and later cycles (**Fig. 9**). During Cycle 3, CS4 yields have been increasing by 0.325 tons dm/acre per year, while during its last cycle CS5 yields have been increasing at 0.226 tons/acre per year. The nearly 50% faster increase in CS4 yields suggests that the first 13-year results (see above) showing that CS5 yields exceeded CS4 yields by nearly 0.5 ton dm/acre may be reversed in several more cycles.

Thus, statistically significant yield trends occurred over the first 13 years in the four major crops of the WICST at ARS. As a result, the mean yields presented in the yield section cannot be regarded as the final outcome of these trials. Some might put the emphasis on the overall means, while other might emphasize the yield trends. However, we agree with Singh and Jones (2002) that a system must have both a high overall yield level as well as a positive yield trend to have sustainable production. For example, continuous corn, CS1, has the most rapidly increasing yields, but it cannot be deemed to have the most sustainable productivity of the systems in the WICST because it was next-to-last in overall yield. Also, CS2 is not the second most sustainable system although its overall all mean corn yield was second only to CS4 because it had the next-

to-the-lowest rate of corn yield increase and the trend in soybean yields was negative. Consequently, some way needs to be found to combine these two facets of yield sustainability

If the yield trends eventually reached an equilibrium level, then there would not be a conflict between the overall means and the yield trends. Cady, (1991) argued that yield trends in long-term studies are the result of the cumulative effects of crop rotations or other treatments on soils that would change rapidly at first, then slow and eventually level off at an equilibrium. That may be true of long-term trials with fixed treatments, but the problem with such trials are that by the time the trend and the equilibrium point are identified the treatments may be obsolete. The advantage of a cropping system trial with philosophical goals such as reported here is that the treatments are adjusted to keep up with technology. For example, superior cultivars, such as herbicide resistant soybean varieties, are selected as they are identified; more effective herbicides are applied when they have been proven; and more effective equipment, such as better drills and rotary hoes, are used when they are developed. As a consequence, it is doubtful that an equilibrium level will ever be reached. The best we can hope is that the rate of change approaches that of the overall technology rate.

One cropping system had the lowest overall yields and yield trends below the rate of technological advances for all crops in the system; namely, CS3, which is the quasi-organic, cash-grain system. Thus, this system may not be sustainable as we designed it. We knew from the beginning that this was a marginally sustainable system because it is a very "tight rotation with 4 crops in three years, no forage phase, and because it does not include a complete source of plant nutrients such as animal manure or compost. But it serves as a reference point for cash grain producers. The fact that the crop yields in CS3 has done so well for so long (88 to 94% of conventional system yields for 13 years at ARS and 80 to 90% for 9 years at LAC) bodes well for the quasi-organic in the long run. In fact, we believe the primary conclusion of the WICST to this point is that the differences in the overall yields, variability in yields, and yield trends among systems (including quasi-organic and conventional) are small enough that other factors; such as profitability, environmental impact, and life-style preferences; will often be the determinate in the selection of a cropping system.

CONCLUSIONS

1-The lack of a site × system interaction in three of the four crops and the relatively small crossover in the other crop in spite of the large difference in drainage suggests that these results are widely applicable and could be averaged over sites. This suggests that the trial results have a wide area of inference on prairie-derived soils of the upper mid-west.

2-The quasi-organic systems produced 10 to 20% smaller grain yields than the high and medium external input systems during the first 8 to 13 years of the two trials. However, the low external input forage system, CS5, produced up to 10% more alfalfa in the same period. Thus, the size of the deficit production with the low external systems was less than expected by many.

3-Thus far, the data do not support the hypothesis that the low external input systems are more variable in an absolute or a relative sense than the higher external systems. In fact, the

only significant difference between variabilities found that the low-external input system, CS5, had lower variability for first-year, established alfalfa than the high-external input system, CS4, at Arlington.

4-There were significant yield trends in the four crops examined (corn, soybeans, wheat, and alfalfa). These trends differed among the cropping systems. With a few exceptions, there were increasing trends with the high- and medium-external input systems, but steady to decreasing trends with the low-external input systems.

5-Overall we conclude from these trials that differences in productivity, yield trends, and yield variability between the low external input systems and the higher external do exist. However, the differences are small enough and inconsistent enough that other factors; such as such as profitability, environmental impact, and life-style preferences; will often be the determinate in the selection of a cropping system.

LITERATURE CITED

Altieri, Miguel. 1987. Agroecology: The scientific basis of alternative agriculture. Westview Press. Bolder Colorado 224pp

Andraski, T.W. and L.G. Bundy. 2002. Using the presidedress soil nitrte test and organic nitrogen crediting to improve corn nitrogen recommendations. 94:1411-18.

Avery, D.T., and A. Avery. 1996. Farming to sustain the environment. Hudson Briefing Paper No. 190. Hudson Institute. Indianapolis, Indiana 19pp

Baldock, J.O. and R.B. Musgrave. 1980. Manure and mineral fertilizer effects in continuous and rotational crop sequences in central New York. Agron. J. 72: 511-518.

Baldock, J.O., R.L. Higgs, W.H. Paulson, J.A. Jackobs, and W.D. Shrader. 1981. Legume and mineral N effects on crop yields in several crop sequences in the upper Mississippi Valley. Agron. J. 73:886-890.

Batte, M.T., D.L. Forster, and F.J. Hitzhusen. 1993. Organic agriculture in Ohio: An economic perspective. J. Prod. Agric. 6:4:536-542

Berardi, G.M. 1978. Organic and conventional wheat production: Examination of energy and economics Agro-Ecosystems 4:367-376

Bonett, Douglas. G. and Edith Seier. 2003. Confidence intervals for mean absolute deviations. The Am. Statistician. 57:233-236.

Cady, Foster B. 1991. Experimental design and data management of rotation experiments. Agron. J. 83:50-56.

Cacek, T. and L. Langner. 1986. The economic implications of organic farming. Am. J of Alt. Agic. 1:1:25-29

Cochran, W.G. 1947. Some consequences when the assumptions for the analysis of variance are not satisfied. Biometrics 3:22-38.

Crosson, Pierre and Janet Ostrov. 1990. Sorting out the environmental benefits of alternative agriculture. J. of Soil and Water Conservation 45:1:34-41

Dabbert, Stephan, and Patrick Madden. 1986. The transition to organic agriculture: A multi-year simulation model of a Pennsylvania farm. Am. J. Alt. Agric. 1:99-107.

Duffy, Michael, R. Ginder, and S., Nicholson. 1989. An economic analysis of the Rodale Conversion Project: Overview. Dept of Economics Staff. Paper no 212. Iowa State University. Ames, Iowa

Felstehausen, H. 1986. Decline of farming in Wisconsin. Wisconsin Academy Review. 33:1:44-50

Harwood, Richard R. 1985. The integration efficiencies of cropping systems pg 64-75. In T.C. Edens, C. Fridgen and S.L. Battenfield (ed) Sustainable agriculture and integrated framing systems: Conference Proceedings. 1984. Michigan State Univ. Press, East Lansing MI

Helmers, G.A., M.R. Langemeier, and J. Atwood. 1986. An economic analysis of alternative cropping systems for east-central Nebraska. Am J. of Alt Agric. 1:4:153-158

Klepper, R.W., W. Lockeretz, B. Commoner, M.Gertler, S.Fast, D. O'Leary, and R. Blobaum. 1977. Economic performance and energy intensiveness on organic and conventional farms in the Corn Belt: A preliminary comparison. Am. J. Agric. Econ. 59:1-12

Liebhardt, W.C., R.W. Andrews, M.N. Culik, R.R. Harwood, R.R. Janke, J.K. Radke, and S.L. Rieger-Schwartz. 1989. Crop production during conversion from conventional to low-input methods. Agron. J. 81:150-159.

Little, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS system for mixed models. SAS Institute Inc. Cary, NC.

Lockeretz, William, G. Shearer, R. Klepper, and S. Sweeney. 1978. Field crop production on organic farms in the Midwest. J. of Soil and Water Conservation 33:130-134

Lockeretz, William, Georgia Shearer, and Daniel H Kohl. 1981. Organic farming in the Corn Belt. Science. 211:540-546.

Marten G.C. (ed) 1989. Grazing Research: Design, Methodology and Analysis. CSSA Special Publications Number 16. CSSA/ASA Madison WI.

Patterson, H.D., and B. I. Lowe. 1970. The errors of long-term experiments. J. Agric. Sci. Camb. 74:53-60

Porter, P. M., J. G. Lauer, W. E. Lueschen, J. H. Ford, T. R. Hoverstad, E. S. Oplinger, and R. K. Crookston. 1997a. Environment affects the corn soybean rotation effect. Agron J. 89:441-448

Porter, P.M., R.K. Crookston, J.H. Ford, D.R. Huggins, and W.E. Lueschen. 1997b. Interrupting yield depression in monoculture corn: comparative effectiveness of grasses and dicots. Agron. J. 89:247-250.

Porter, P.M., D. R. Huggins, C.A. Perillo, S. R. Quiring, and R.K. Crookston. 2003. Organic and other management strategies with two and four year crop rotations in Minnesota. Agron J. 95:233-244

Posner, J.L., M.D. Casler, and J.O.Baldock. 1995. The Wisconsin integrated cropping system trial: Combining agro-ecology with production agronomy. Am. J. Alt Agric. 10:98-107.

Reichenberger, L. 2004. High-yield challenge. The Furrow. March pp 10-13.

Rohweder, D.A., R.R. Barnes, and N. Jorgensen. 1978. Proposed hay grading standards based on laboratory analysis for evaluating quality. J. Anim. Sci. 47:747-759

Rohweder, D.A. 1984. Estimating Forage Hay Quality. In National Alfalfa Hay Quality Testing Workshop. Chicago, IL. March 22-23, 1984 pp 31-37

SAS Institute Inc. 1999. SAS Online, Version 8. SAS Institute, Inc. Cary, NC.

Shrader, W.D., W.A. Fuller, and F.B. Cady. 1966. Estimation of a common N response function for corn (Zea mays) in different crop rotations. Agron. J. 58:397-401.

Singh, Murari, and Michael J. Jones. 2002. Modeling yield sustainability for different rotations in long-term barley trials. J. Agric. Biological, and Environ. Statistics. 7:525-535.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods. 6th ed. Iowa State Univ. Press. Ames, IA. 593 p.

U.S. Dept of Agric. 1981. Land Resource Regions and major Land Resource Areas of the United States. Handbook 296. Washington D.C

Verrill, Steve. 2003. Confidence Bounds for Normal and Lognormal Distribution Coefficients of Variation. Research Paper FPL-RP-609. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 13p. http://www1.fpl.fs.fed.us/covnorm.html

Undersander, D.J., T.H. Howard, and R. Shaver. 1993 Milk per acres spreadsheet for combining yield and quality into a single term. J. Prod. Agric. 6:231-5.

Wolfinger, Russell D. 1996. Heterogeneous variance-covariance structures for repeated measures. J. Agricultural, Biological, and Environmental Statistics. 1:205-230.

Yates, F. 1954. The analysis of experiments containing different crop rotations. Biometrics 10:324-246

Table 1. **Description of the six cropping systems.**

System Code	Enterprise	Phase	Crop†	Use of External Inputs	Key cultural practices					
					Primary Tillage	Starter Fertilizer	Fertilizer rates for N-P-K	Manure rate, tons/a (1)	Weed Control	Soil Insectide
CS1	Grain	1	C	High	Chisel plow	Yes	Soil tests	0	Herbicides	Yes
CS2	Grain	1	Sb	Medium	No-till drill§	None	Soil tests	0	Herbicides	None
		2	C		No-till	Yes	Soil tests	0	Herbicides	None
CS3	Grain	1	Sb	Low	Chisel plow¶	None	0	0	Mechanical	None
		2	Wrc‡		Field cultivate	None	0	0	None	None
		3	C		Chisel plow	None	0	0	Mechanical	None
CS4	Forage	1	A‡	High	Chisel plow	None	Soil tests	20	Herbicides	None
		2	A		None	None	Soil tests	0	Herbicides	None
		3	A		None	None	Soil tests	0	Herbicides	None
		4	C		Chisel plow	Yes	Soil tests	20	Herbicides	None
CS5	Forage	1	Op‡	Low	Chisel plow	None	0	15	None	None
		2	A		None	None	0	0	None	None
		3	C		Chisel plow	None	0	15	Mechanical	None
CS6	Forage	1	RC/T/B	Low	None	None	None	As deposited	None	None

(1) Manure application calculated in the forage systems CS4 & CS5 at the rate of 10 t/a/yr. Manure applied in the fall of the year prior to planting

† Corn (*Zea mays*) = C; soybean (*Glycine max*) = Sb; winter wheat (*Triticum aestivum*) with frost seeded red clover (*Trifolium pratense*) = Wrc; alfalfa (*Medicago sativa*) = A; oat (*Avena sativa*) and pea (*Pisum sativum*) mix = Op; mixture of red clover, timothy (*Phleum pratense*), and brome (*Bromis inermis*) for rotational grazing = RC/T/B.

‡ The red clover was frost seeded into the winter wheat, the alfalfa in phase one of CS4 was sole seeded, and the alfalfa in phase 1 of CS5 was companion seeded with the oat-pea mix.

§ Prior to 1994 at Lakeland and 1995 at Arlington, conventional tillage and drilling were used. After that the system was entirely no-till

¶ Soybeans planted in 30-inch rows.

WICST 10th Technical Report

Table 2. Example of staggered start and cycles for the soybean-corn rotation in CS2†.

System	Plot	Year					
		1989	1990	1991	1992	1993	1994
CS2	101	F	Sb_1	C_1	Sb_2	C_2	Sb_3
	108	F	F	Sb_1	C_1	Sb_2	C_2

† F, background or filler corn; Sb soybeans; C, corn; and the subscripts denote the cycle.

Table 3a. Means squares for analyses of grain crops over sites.

Source	Corn 1993-1998			Soybeans 1990-1998		
	Num. df	Denom df	MS	Num. df	Denom df	MS
Site	1	5	816†	1	6	2 NS
System	4	20	923 **	1	8	88†
Site x system	4	20	137 NS	1	8	145*

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

Table 3b. Means squares for analyses of forage crop dry matter yields over sites.

Source	Establishment year forage, 1994-1998‡			First-year alfalfa, 1991-1998		
	Num. df	Denom df	MS	Num. df	Denom df	MS
Site	1	4	2.96*	1	14	2.27*
System	1	8	0.71 NS	1	14	2.64*
Site x system	1	8	0.00 NS	1	14	0.39 NS

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.
† Significant at the 0.10 probability level.
‡ 1996 omitted because oat companion crops were harvested as grain.

Table 3c. **Mean square for the variance components for analyses of grain and forage crops over sites.**

Source	Corn 1993-1998	Soybeans 1990-1998	Seeding year 90-98	Alfalfa 1991-1998
Year, Y	1191	0	0.07	0
Block (Site), B(S)	12	1	0	0
Y x B(S)	4	4	0.03	0
Y x Site	511	54	0.29	0.40
Y x System	52	14	0	0
Y x Site x System	145	15	0.61	0.12
Residual	150	25	0.13	0.31

Table 4a. Mean corn yields and variability of the annual mean yield at Arlington 1993-2002.

System	Overall mean (Bu/a)	S†	CV†; 90% confidence interval
	bushels/acre		
CS1	162	28.5	0.18; 0.13, 0.30
CS2	168	27.4	0.16; 0.12, 0.27
CS3	146	37.2	0.25; 0.18, 0.44
CS4	185	26.4	0.14; 0.10, 0.24
CS5	166	27.2	0.16; 0.12, 0.27
Mean	165		
LSD(10%)	23.5		

† S, standard deviation; CV, coefficient of variation.

Table 4b. Mean corn yields and variability of the annual mean yield at Lakeland 1993-1998.

System	Overall mean (Bu/a)	S†	CV†; 90% confidence interval
	bushels/acre		
CS1	125	33.6	0.24; 0.15, 0.61
CS2	134	31.8	0.21; 0.13, 0.53
CS3	117	38.7	0.29; 0.18, 0.78
CS4	146	35.3	0.22; 0.14, 0.55
CS5	121	47.6	0.36; 0.22, 1.01
Mean	128		
LSD(10%)	53.0		

† Omitting 1996, n=5; S, standard deviation; CV, coefficient of variation.

Table 4c. Mean soybean yields and variability of the annual mean yield†.

Site, System	Overall mean (Bu/a)	S‡	CV‡; 90% confidence interval
	bushels/acre		
ARS, CS2	53.0	8.5	0.16; 0.12, 0.25
ARS, CS3	47.9	9.5	0.20; 0.15, 0.31
Mean	50.5		
LSD(10%)	6.3		
LAC, CS2	54.5	8.6	0.16; 0.11, 0.27
LAC, CS3	46.4	10.3	0.22; 0.16, 0.39
Mean	50.4		
LSD(10%)	8.0		

† ARS = Arlington Research Station, 1990-2002; LAC = Lakeland Agricultural Complex, 1990-1998.

‡ S, standard deviation; CV, coefficient of variation.

Table 4d. Mean winter wheat yields and variability of the annual mean yield[†].

Site, System	Overall mean (bu/a)	S[‡]	CV[‡]; 90% confidence interval
	----------bushels/acre----------		
ARS, CS3	54.0	12.0	0.22; 0.16, 0.35
LAC, CS3	43.6	17.6	0.40; 0.27, 0.89

[†] ARS = Arlington Research Station, 1991-2002; LAC = Lakeland Agricultural Complex, 1991-1998 (1996 omitted at LAC due to winter kill).
[‡] S, standard deviation; CV, coefficient of variation.

Table 4e. Mean forage yields and variability of the annual mean yield at Arlington.

System	Overall mean (Tdm/a)	S[†]	CV[†]; 90% confidence interval
	----------tons dm/acre----------		
CS4, sole seeded alfalfa[‡]	3.17	0.853	0.27; 0.20, 0.42
CS4, first-year alfalfa[§]	4.70	0.784	0.17; 0.12, 0.26
CS4, second year alfalfa[¶]	4.09	0.910	0.22; 0.16, 0.37
CS5, companion seeded[‡]	3.82	0.943	0.25; 0.18, 0.41
CS5, first-year alfalfa§	5.12	0.479	0.09; 0.07, 0.15
CS6, hay 1990-1992	3.85	Xxyy	ssyy
CS6, rotational pasture[††]	4.92		

[†] S, standard deviation, CV, coefficient of variation.
[‡] 1990-2002, except no data for CS5 in 1991 and 1993 because oats were harvested as grain.
[§] 1991-2002.
[¶] 1992-2002.
[††] Based on nine years of data.

Table 4f. Mean forage yields and variability of the annual mean yield at Lakeland.

System	Overall mean (Tdm/a)	S[†]	CV[†]; 90% confidence interval
	----------tons dm/acre----------		
CS4, sole seeded alfalfa[‡]	1.30 (1.55)[††]	0.905	0.58; 0.39, 1.36
CS4, first-year alfalfa[§]	3.64	1.08	0.30; 0.20, 0.57
CS4, second year alfalfa[¶]	3.54	0.547	0.15; 0.11, 0.30
CS5, companion seeded alfalfa[‡]	1.74 (2.04)[††]	0.995	0.49; 0.31, 1.31
CS5, first-year alfalfa§	3.88	0.657	0.17; 0.12, 0.31
CS6, hay 1991	3.39	-	Insufficient data
CS6, rotational pasture[‡‡]	3.98		

[†] S, standard deviation; CV, coefficient of variation.
[‡] 1990-1998, except no data for CS5 in 1991, 1992 and 1996 because oats were harvested as grain
[§] 1991-1998.
[¶] 1992-1998.
[††] The overall mean annual mean yield in parentheses differs from the REML value because of missing plots. (Do we need this nuance Jon?)
[‡‡] Based on four years of data.

Table 4g. Forage quality and estimated milk yield at Arlington.

System, comparison	Relative feed value	Milk production(1), Cwt/acre
CS4-sole seeded alfalfa, vs. CS5-companion seeded alfalfa‡	143 120**	61.5 62.0 NS†
CS4-first-year alfalfa, vs. CS5-first-year alfalfa§	142 138 NS	97.4 104.6 NS
CS4-first-year alfalfa, vs. CS4, second year alfalfa¶	143 149 NS	95.9 88.6 NS

Estimated using MILK91 (Undersander et al. 1993)

*,** Significant at the 0.05 and 0.01 probability levels, respectively.
† NS, not significant at the 0.1 probability level.
‡ 1990-2002, except no data for 1991 and 1993 because oats were harvested as grain.
§ 1991-2002.
¶ 1992-2002.

Table 4h. Forage quality and estimated milk yield at Lakeland.

System, comparison	Relative feed value	Milk production (1), Cwt/acre
CS4-sole seeded alfalfa, vs. CS5-companion seeded alfalfa‡	149 114**	47.4 43.5 NS†
CS4-first-year alfalfa, vs. CS5-first-year alfalfa§	146 143 NS	83.8 88.1 NS
CS4-first-year alfalfa, vs. CS4, second year alfalfa¶	148 152 NS	83.9 84.7 NS

Estimated using MILK91 (Undersander et al, 1993)

*,** Significant at the 0.05 and 0.01 probability levels, respectively.
† NS, not significant at the 0.1 probability level.
‡ 1993-1998, except no data for 1996.
§ 1991-1998.
¶ 1992-1998.

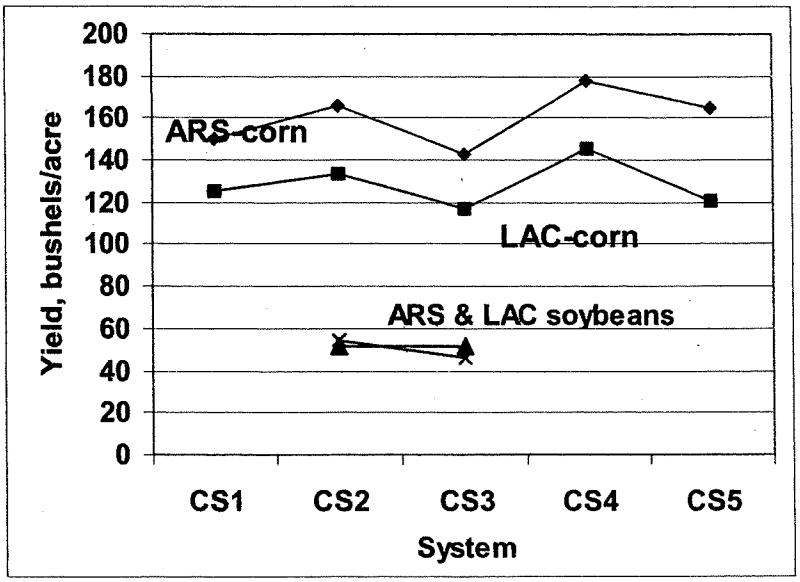


Fig. 1a. Mean yields of corn and soybeans by site and system.
ARS =Arlington Research Station; LAC = Lakeland Agricultural Complex

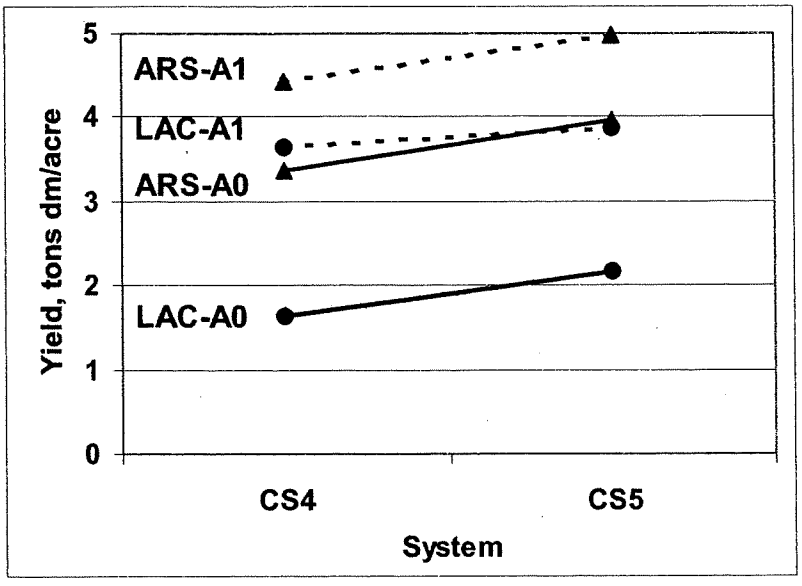


Fig. 1b. Mean forage yields by site and system.
ARS=Arlington Research Station; LAC= Lakeland Agricultural Complex
A1=alfalfa hay year I; A0=alfalfa seeding year

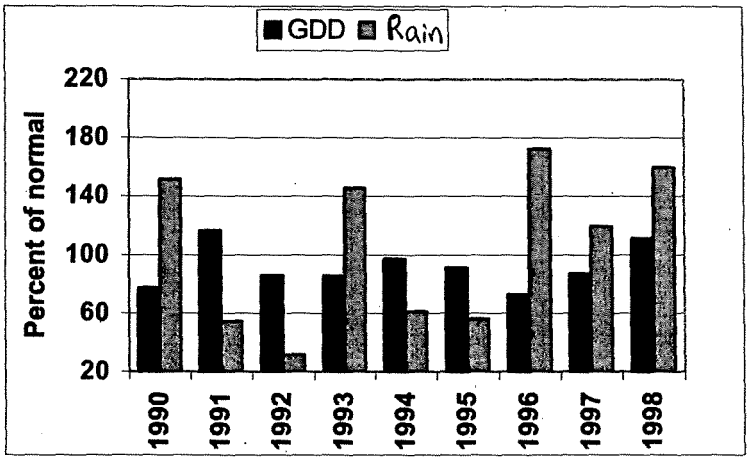


Fig. 2. Lakeland Ag Complex, WI, May plus June Growing Degree Days (GDD, base 50°F) and May plus June rainfall, as a percentage of the 1971-2002 norms.

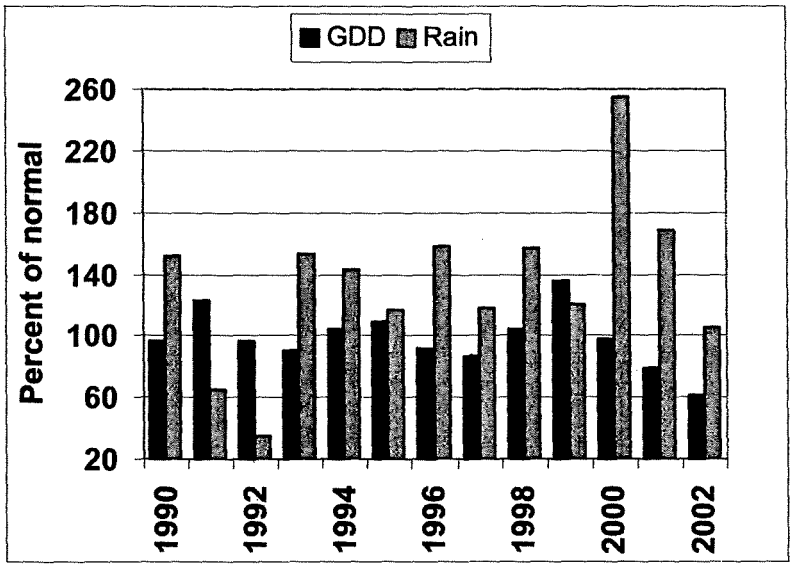


Fig. 3. Arlington, WI, May plus June Growing Degree Days (GDD, base 50°F) and May plus June rainfall, as a percentage of the 1971-2002 norms.

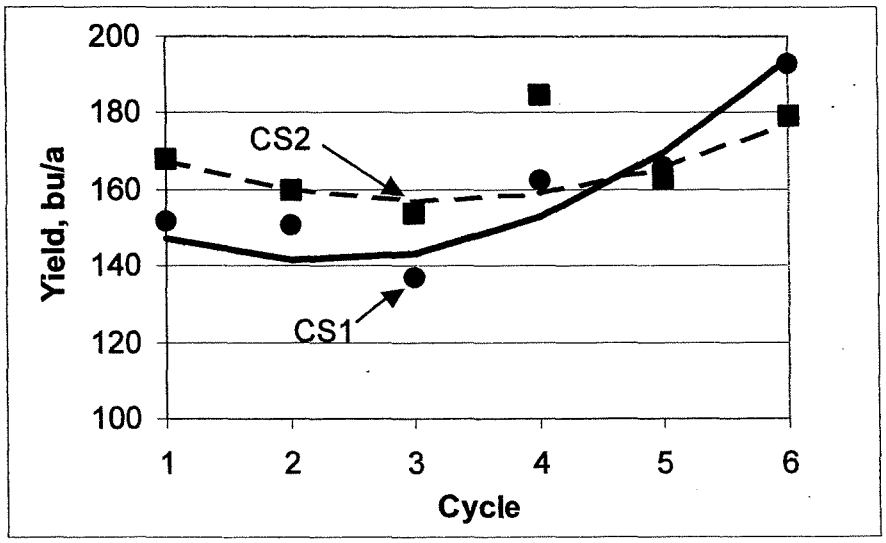


Fig. 4. Trend of corn yields for CS1 and CS2 over cycles at Arlington (n=8). The regression:equation are CS1: Yield = 160.7 – 17.2*Cycle + 3.8*Cycle^2; and CS2: Yield = 180.0 – 14.9*Cycle + 2.4* Cycle^2. Each term in these models is significant at the 10% level or better.

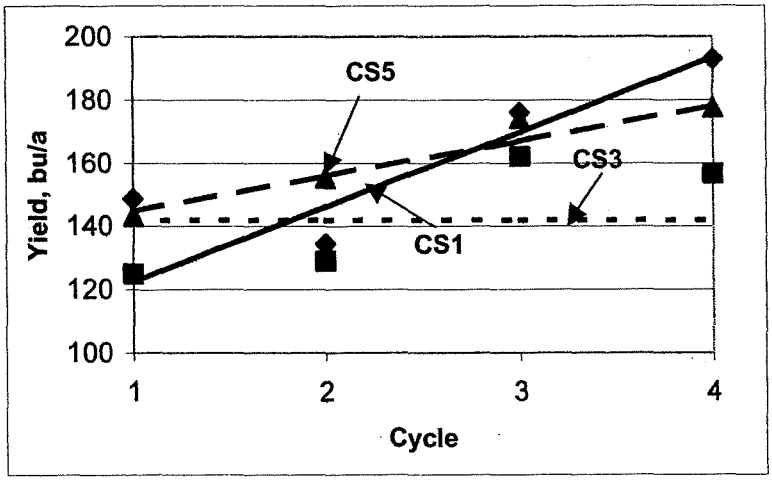


Fig. 5. Corn yield trends for CS1, CS3, and CS5 over cycles (n=12 for Cycles 1-3 and n=8 for Cycle 4). The regression equations are CS1: Yield = 98.7 + 23.7*Cycle; CS3: Yield = 141.9; and CS5: Yield = 133.7 + 11.1*Cycle. Each term in these models is significant at the 1% level.

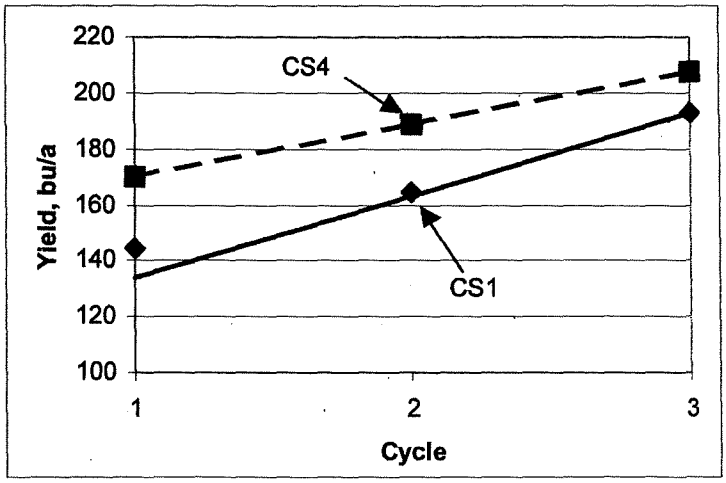


Fig. 6. Corn yields for CS1 and CS4 over cycles (n=16 for Cycles 1-2, n=8 for Cycle 3). The regression equations are CS1: Yield = 103.9 + 29.7*Cycle and CS4: Yield = 151.5 + 18.6*Cycle, each term in the models is statistically significant at the 2% level.

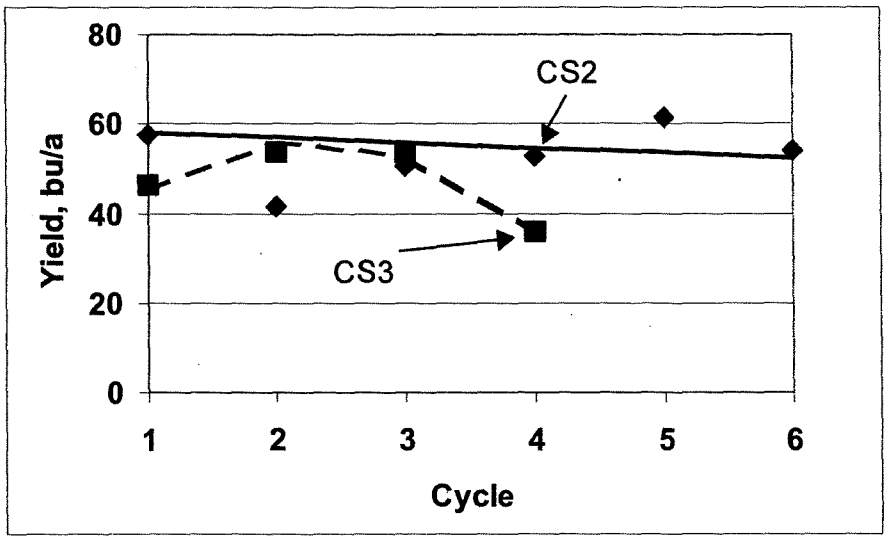


Fig. 7. Trend of soybean yields for CS2 (n=8) and CS3 (n=12) over cycles. The regression equations are CS2: Yield = 59.180 – 1.150*Cycle and CS3: Yield = 20.52 + 31.58*Cycle – 6.94*Cycle^2. The coefficients in both equations are statistically significant at the 1% level.

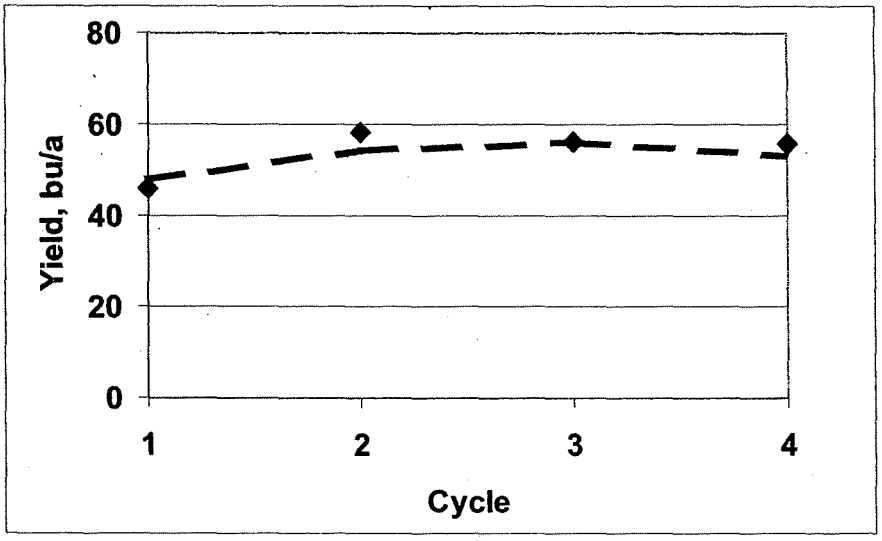


Fig. 8. **Trend of mean wheat yields for CS3 over cycle (n=12).** The regression equation is Yield = 36.46 + 13.87*Cycle – 2.43*Cycle^2. The coefficients are statistically significant at the 5% level.

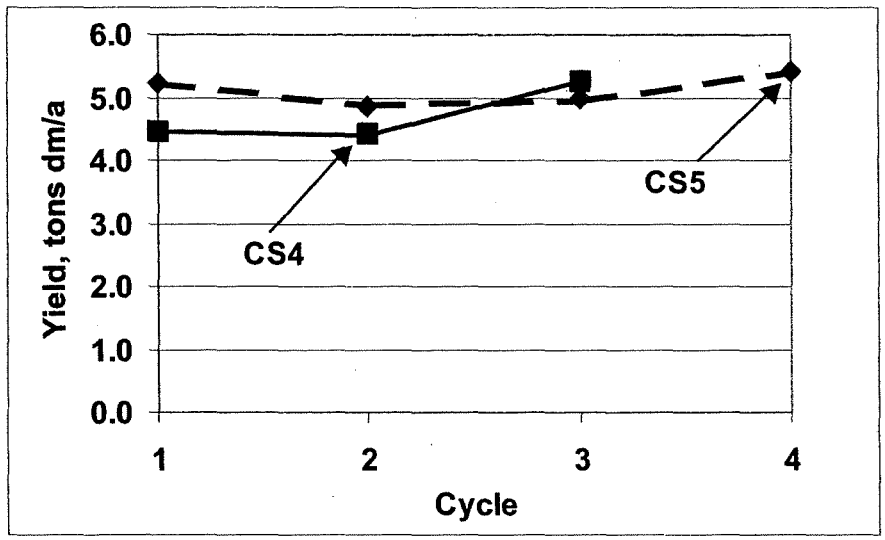


Fig. 9. **Trend of mean 1st year alfalfa yields for CS4 (n=16, except Cycle 2 n=15) and for CS5 (n=12) over cycles.** The regression equation is CS4: Yield = 5.41 –1.40*Cycle + 0.45*Cycle^2. and CS5: Yield = 5.99 – 0.96*Cycle + 0.2049* Cycle^2. The coefficients for both equations are statistically significant at the 10% level.

WEED SEEDBANK COMMUNITY CHANGES ON THE WISCONSIN INTEGRATED CROPPING SYSTEMS TRIAL (WICST): 1992-2004.

H. Kümmel[1], J. Doll[2], J. Posner[2], J. Hedtcke[3], A. Cook[4]

INTRODUCTION

Weed seedbanks are the viable seeds present in the soil, and its surface. Seedbanks consist of both recent and older seeds shed; so, the soil weed seedbank can be regarded as the 'memory' of a weed community. The seedbank influences both the weed populations that occur in a field and the success of weed management strategies (Iowa State university 1996). Changes in weed community and weed seedbank size occur as time passes. Dekker (1999) explains that species once present may be replaced, or reduced due to the arrival of more competitive intra-specific variants, variable weather and crop management practices. He emphasizes however, that changes in the environment (especially wet or dry seasons that reduce weed control efficacy), and agricultural activities are the two most important factors influencing multiple year changes in the soil seedbank. A number of authors have shown for example, that crop rotation alone (Buhler et al. 2001; Forcella et al. 1988; Hill 1989; Schreiber 1992), tillage systems alone (Cardina et al. 1991; Mulugeta and Stoltenberg 1997), cultivations (Roberts and Dawkins 1967), crop rotation *and* tillage (Cardina et al. 2002), cropping systems (Davis et al. 2005), and weed management (Roberts and Chancellor 1986) are all important practices impacting seedbanks on arable land.

With agronomic systems, the seedbank itself is the primary source of annual weeds (Dekker 1999). Therefore, tracking the changes in weed seedbank composition can help one understand and evaluate the long-term effects of alternative cropping systems. Iowa State University's study of agricultural fields found that the weed seedbank density in the north central Corn Belt ranges from 2,100 to 580,000 seeds/m^2 (Iowa State University 1996). Forcella et al. (1992) in a study centered on Minnesota and Wisconsin found that the range in seed bank density in crop fields was between 1,500 seed/m^2 to 22,000 seed/m^2. These weed seedbanks are composed of many species, but 70 to 90% of the total seeds are from few dominant species. A second group comprising 10 to 20% of the total seedbank is generally made of species adapted to the geographic area, but not to current production practices. A final small percentage of the total seeds include recalcitrant seeds from previous seedbanks, newly introduced species, and seeds of previous crops (Buhler 1997).

Long-term studies of weed seedbanks are necessary however, to understand cropping management effects on seedbanks. This is because, for example, tillage systems require from 4 to 10 years to reach equilibrium in yield, weed populations, and soil characteristics (cited in Cardina et al. 1991). In addition, Roberts and Dawkins (1967) found that improvements in estimating seed bank could be achieved by sampling the same time of the year in successive years (cited in Dekker 1996).

Seedbanks have been estimated using: 1) seedling emergence, also called tray method (Forcella et al. 1992, 1997; Hill et al. 1989; Roberts and Dawkins 1997; Mulugeta and Stoltenberg 1997a, 1997b); 2) direct extraction from the soil called as extraction method (Buhler et al. 2001; Schreiber 1992); and 3) seedling emergence from undisturbed cores called core

[1] Undergraduate student, independent project (699), UW-Madison, Agronomy Dept.
[2] Professor, UW-Madison, Agronomy Dept.
[3] Research specialist, UW-Madison, Agronomy Dept.
[4] Graduate student, UW-Madison, Agronomy Dept.

method (Forcella and Sparrow 1996). All three approaches have its pros and cons. While, seedling emergence may under estimate the weed seed density due to unknown quantities of dormant seeds remaining in the soil, extraction of seeds directly from the soil may over estimate the weed seed density due to the difficulty in judging seeds viability and fitness (Dekker 1999). There have been also some studies conducted to evaluate and/or compare methods to predict weed seedling populations from the soil seedbank. Forcella and Sparrow (1996) found that the three methods (extraction, trays germination and core methods) were essentially equivalent in variability and in predictability of seedling populations. They report that the main difference between methods was the time and effort required to complete the procedure. While the seed extraction method required the most effort, and the core method over the standard tray method required minimum sample manipulation. However, in general Forcella and Sparrow found that the emergence percentage was lower from the core method that from the tray method (Forcella and Sparrow 1996). A second issue in estimating weed seed density is how to soil sample. Kropac (1966) and Roberts (1970) each reported that it is better to take large numbers of smaller soil samples rather than relatively smaller numbers of lager samples (cited in Dekker 1996).

The goal of this study was to compare the effect of six different cropping systems over a 14-year period on:

- Weed seed density;
- The weed seed community; and,
- To statistically test the hypothesis developed at the onset of the Wisconsin Cropping Systems Trial (WICST) at ARL UW- Research Station trial in 1990.

MATERIAL AND METHODS

The Wisconsin Cropping Systems Trial (WICST) started in 1989 and consists of three grain, and three forage cropping systems. (See **Table 1**) The fields were in a dairy rotation (a-a-c) with manure for the previous 20 years. The weed seedbank at the trial has been monitored annually since 1989 by counting weed seedlings that germinate in soil collected from selected plots early in the spring. Seeds include seeds (fertilized ripened ovule of a flowering plant) and fruits, but not vegetative propagules or spores.

Dr Jerry Doll initially conducted the sampling protocol and data collection and the results are available in an earlier WICST report (WICST Technical Report #8 1997-1998). Initially (1989-1992) three subsamples of soil per plot, each consisting of ten 0.75in. diameter cores and 6 in. deep were taken. In 1994 six subsamples of ten 0.75in. diameter cores and 6 in. deep were taken. Since 1995 four subsamples of soil per plot, each consisting of eight 0.75in. diameter cores and 6 in. deep are taken. This results in approximately 1.0 to 1.3 lb of soil per subsample. The soil is then mixed with an equal weight of silica sand, placed in 8 X 12-in. plastic trays with small holes in the bottom (giving a 0.75- to 1-inch soil depth). Trays are then placed on capillary mat on a greenhouse bench and subirrigated every other day, or daily when necessary. As seeds germinate, the seedlings are identified, counted and removed. After the first flush of seedlings is counted, the soil is let to dry completely, remixed and returned to the trays for another germination cycle. Three cycles of weed seed germination are conducted from May to September, and when all germination observations are completed, the number of seedlings per square meter is calculated for each system as follow:

$\leq$ 1995 when tray sample was made of 10 cores: # plants / tray * 350.849 = weed seed /m^2

$\geq$1997 when tray sample was made of 8 cores: # plants / tray * 438.56 = weed seed /m^2.

Currently, the sampling strategy is to sample all plots in the spring following the corn phase because this helps to standardize the results since corn is a common crop in 5 of the 6 systems. The permanent pasture and continuous corn system are sampled every year. For this report the weed seedbank density results from 2004 for the 6 cropping systems were compared to the baseline data from 1991 for CS1 and CS6, and 1992 for the other four systems. The plots were sampled on March , 2004. The design of the trial is a randomized complete block with four replications for each of the six systems. In total, there are 14 plots per repetition to cover each phase of the 6 cropping systems and the individual plots are 0.73 acres in size. Each sampled plot had 3 subsamples (germination trays) for the baseline years and 4 subsamples (germination trays) for 2004. The data was analyzed with PROC MIXED (SAS 8.2). Analysis of variance and test for normality were performed on the total weed density data. Years and repetitions were considered random, and cropping systems as fixed effects. In addition to PROC MIXED, which gives a preliminary test of the average effect of the sources of variation (i.e. system, block, block (sample)), linear comparisons were used to provide a more detailed assessment of the factors influencing weed seed density.

RESULTS AND DISCUSSION

I) Evolution of weed seed numbers

Viable seeds of 9 broadleaf weed species were found, and they were: red root pigweed (Rrpw), common lambsquarter (Colq), velvetleaf (Vele), shepard's purse (Shpu), smartweed (Smwe), eastern black nightshade (Blns), broadleaf plantain (BdPlntn), dandelion (Dali), white cockle (Whco), and others (O_Bdlf). The viable seeds of grass weeds found were giant foxtail (Gift), green foxtail (Grft), yellow foxtail (Yeft), fall panicum (Fapa), barnyard grass (Bygr), large crabgrass (Lacg), and others (O_Grs). In all six systems, the total weed seedbank density decreased since 1992. (See **Table 2a**) Except for the rotational grazing plots, the reserves of viable seed in the soil are typically dominated by one or two species in each system. Total viable seedbank densities found ranged from 2,000 to 13,000 seed /m² in the earlier years of 1991-92 and 600 to 10,000 seed /m² in 2004. These numbers are toward the lower range found in the Iowa State studies (1996) and are similar to Forcella et al. (1992) findings in Wisconsin and Minnesota. Weed seedbanks densities are categorized into population categories: **low** (< 4,300 seeds/m²), **moderate** (4,301- 8,600 seeds/m²), **high** (8,601 – 12,900 seeds /m²), and **severe** (> 12,901 seeds/m²) (WICST Report #8).

In the continuous corn cropping system (**CS1**), which receives conventional rates of herbicides and tillage, the weed seedbank decreased 66% since 1991 (currently 600 seeds/m²). The plots sampled and analyzed in 2004 were established in a low to moderate weed seed density area to begin with (WICST Uniformity Year Report 1989). The 2004 data shows that the weed seed density in this high input, low diversity system is considerably less than when the system was last sampled in 1998. Completion of the data analysis from the 2005 sampling on these plots will allow us confirm this reduction in weed seed load. Cardina et al. (1991) compared weed seed density in three locations following 25-26 years of continuous corn and found that the weed seed density under minimum tillage (chisel plow) ranged from 4,800 to 400 seeds/m², similar to our findings.

The weed seedbank in the no-till (**CS2**) cropping system had decreased by 60% since 1992 (2,400 seeds/m²). The weed seed density is low, and even though the total weed seed

density is quite variable from year to year, it has been decreasing over time. Weed seed density declined sharply from 5,838 seed/m² in 1998 to 2412 seed/m² in 2004. The decline may be due to changes in weed management. In 1998 we switched from Asgrow 1900 using glyphosate only as a pre emergence herbicide to Asgrow 2301 using glyphosate pre and post emergence.

The organically managed grain system **CS3** has the lowest decrease in weed seedbank density over time among all the systems in WICST. The weed seed density was high in 1992 and after 13 years it decreased 18% maintaining high weed seed density (9,300 seeds/m²). Total weed seed density decreased by 55% from 1992 to 1995. However, the total weed seed density is increasing steadily since 1995.

In the conventional forage system **CS4** the weed seedbank density is low and it has been steadily decreasing over time (1,650 seeds/m²). The use of herbicide in the corn and alfalfa establishment phase's plus intensive management of the forage phases has proved effective again weed encroachment. The major weak link in this system is the openings in the sod, created by winterkill. The total weed seed density in this forage system decreased 74% since 1992.

The weed seedbank density in the organic forage **CS5** decreased 77% since 1992 (3,000 seeds/m²) changing from moderate to low. However, visual observations show that quack grass, which is not counted in the germination trays, is building up in CS5.

The weed seedbank density at the rotational grazing plots (**CS6**) is low, and decreased 60% since 1991 to 1,700 seeds.m². Reducing the stocking rate on the paddocks plus a timely schedule of clipping and hay making in early spring and late fall has increased the competitiveness of the pastures to weed development since 1996.

The weed management regime in the high input, low diversity systems (CS1) and (CS4), seems to successfully hold steady or even decrease the total weed seed density over time. Meanwhile, it appears that weed control is more challenging in the low input, high diversity systems, especially CS3. Still, our findings are optimistic. For instance, when studying weed seedbank dynamics in three organic farming cropping systems, Teasdale et al. (2004) found that seedbank populations in different organic cropping systems tended to "fluctuate within a range that was considerably higher than the initial levels." Their study compared the weed seedbank of a 2 yr corn-soybean, 3 yr corn-soybean-wheat/fallow and a 4yr corn-soybean-wheat-red clover/orchard grass hay rotations using the tray method sampling the systems following the corn phase also.

Davis et al. (2005) analyzed the effects of cropping systems in the weed seedbank in four systems: conventional (CONV), no-till (NT), reduced input (RI) and organic (ORG). The long-term project started in 1990 at Michigan State University's Biological Station and from 1990 to 1993 the CONV and NT systems were in corn-soybean crop sequence and RI and ORG systems were in corn-soybean- wheat/underseed with red clover crop sequence. After 1993 CONV and NT were switched to the same rotation as RI and ORG. The moldboard plow was used as primary tillage for CONV, RI and ORG systems. The seed densities found in ARL are well bellow the ones found in their study. He reports that the weed seed density after 12 years were 22,600, 21,780, 29,350, and 18,540 seed/m² in CONV, NT, RI, ORG respectively. Similarly to our findings, they found that high input systems (CONV, NT) and low input systems (RI, ORG) changed in similar manner over time. Although, they found that the weed seed density in the ORG system was slightly lower than the other systems (Davis et al. 2005).

In the early years of 91 and 92, system as a fixed effect did not significantly effect weed seed density. This was expected because all the plots were managed similarly for the 10 years

before 1989. However, the test shows that cropping system significantly affects the total weed seedbank density after 13 years (see **Table 2b**).

II) Changes in weed community

Ratio of broadleaves to grasses

As can be seen in **Table 3**, the proportion of broadleaf to grasses was fairly constant in continuous corn (CS1), green gold alfalfa (CS4), and the rotational grazing (CS6). Whereas the proportion of broadleaves grew in importance in the no-till corn/soybean rotation (CS2), the proportion of grasses increased in the two organic rotations (CS3 & CS5).

Tillage effects weed seedbank due to several factors as depth distribution, abundance, and species composition of seeds in soil (Cardina et al. 2002). However, seed depth in the soil seems to be the most important factor (Buhler 1995). No-till systems favors emergences of small-seeded annual broadleaf and annual grasses that are adapted to germinate well near the surface (Buhler 1995). In no-tillage systems over 60% of all the weed seeds are located in the upper 1–4 cm of soil where most germination occurs and establishment is favored (Buhler 1995; Buhler 1997; Mulugeta and Stoltenberg 1997). In the wet spring years of 1996, 1998, 2000 and 2001 the moisture level on the soil surface may had favored broadleaf seed germination and the number of broadleaf weeds established, consequently the number of escape seeds increased.

It appears that grass control is more challenging in the organic systems, especially CS3. Our hypothesis is that in CS3 the grass seedbank started to increase heavily in wet spring years especially in the corn phase (WICST 7th report). WICST data has shown that when May and June rainfall exceeds 10 inches, organic corn yields are severely impacted due poor mechanical weed control resulting in heavy weed pressure (Baldock et al in press). Indeed, the climate data shows that there were wet springs in 1996, 1998, 2000 and 2001 reducing mechanical weed control performance and providing ideal conditions for late emergence and consequent weed seed production (WICST Report #7). Likewise, Teasdale et al. (2004) found that seedbanks in organic systems tend to rise the following years when a high abundance of weeds generated high seed inputs.

Weed Community Analysis

In continuous corn (**CS1**), redroot pigweed and common lambsquarters dominated the broadleaf seed bank (74%) and fall panicum (60% of the grasses species), and foxtails were the predominant grasses. The 2004 data reveals that common lambsquarters still composes 34% of the broadleaf weed seed community, but pigweed seeds decreased its percentage among broadleaves from 34% to 12%. Curiously, the winter annual shepherd's purse which was present in 1991 at 12% of the broadleaf weed seeds wasn't detected in 2004, and the summer annual eastern black nightshade increased from 2% in 91 to 24% of the broadleaves weed seed community in 2004. The data in 2004 showed species not found in 91 like large crabgrass, and barnyard. Fall panicum wasn't found in 2004 samples; however, 40% of the grass seedlings were not identified due to a hot weekend when they wilted and died before identification. Maybe, fall panicum seedlings, which aren't as drought tolerant as large crabgrass and barnyard, were the first to die. (See **Appendix II**)

Even though the plots sampled in 2004 for **CS2** were initially located in moderate to high grass weeds areas, the grass weed seedbank density decreased from composing 22% of the seedbank in 1992 to 7% in 2004. The grass weed community changed from a diverse and

proportional mixture of foxtails, fall panicum, barnyard and large crabgrass to a seedbank composed primarily of large crabgrass (49%). Among the broadleaf seeds community, common lambsquarters was the dominant specie, and still is. (More than 50% of the broadleaf seeds detected in the soil weed seedbank. Broadleaves composed 78% of the seedbank in 1992 and in 2004, represented 93% of the seed bank. (See **Appendix II**)

The organic grain system (**CS3**) broadleaf seed community doesn't show any major changes in its composition. Common lambsquarters represents 70% of the broadleaf weed seed community just as it did in 1992. Other summer annuals such as redroot pigweed and eastern black nightshade still comprise relatively the same percentage of the broadleaf seedbank compared to the 1992 baseline data. However, there is a clear shift from broadleaf weeds to grass weeds in the seedbank after 1995. (See **Figure 1**) The grass community was composed of 50% of fall panicum and 41% of a mix of yellow, green and giant foxtails. Today, 72% of the grass community is composed by giant foxtail. (See **Appendix II**) Indeed, Buhler and Daniel (1988); Buhler and Oplinger (1990) and Johnson et al. (1989) reported that the most troublesome change in annual weed populations is the increase in summer annual grasses such as giant foxtail (cited in Buhler, 1995).

There may be several reasons for such a shift in the weed seed community in cropping system 3. First, as mentioned above the climate data shows that there were wet springs in 1996, 1998, 2000 and 2001 reducing mechanical weed control performance and providing ideal conditions for late emergence and consequent weed seed production (WICST Report #7). Second, in addition to the weather, the tillage system used in CS3 and CS5 (chisel plow) may be giving the weeds a higher chance to succeed. It had been reported by Buhler (1995) and Mulugeta and Stoltenberg (1997) that giant foxtail density is greater under reduced chisel plow than under moldboard plow. Thirdly, we have found that wheat and red clover "sod" phase hasn't been very effective for weed control, allowing many foxtail plants to go to seed. Lastly, it has been observed in the past seasons that the giant foxtail escapes from poor past weed control is vigorously growing in the soybean phase and the within-row weeds do not get buried by the cultivator and go to seed.

Many researchers observed that indeed, the seedbank can increase rapidly following a year of poor weed control because many weed species are prolific seed producers (Iowa State University 1996). In addition, a species that produces seed population with individuals that each has different germination requirements is even more likely to succeed (Dekker 1996). Giant foxtail according to Dekker, possess a very wide range of germination requirements when shed from the parent plant, and this heterogeneity arises from many sources in an individual plant, including the type of tiller the panicle appears on, the position of the seed in the panicle, and the position of the seed on the fascicle in the panicle (Dekker 1996). While it is true that weed seed densities can rapidly increase if plants are allowed to produce seeds, weed seed densities can also greatly be reduced if seed production is eliminated by a few years.

The conventional forage system (**CS4**) maintained the proportion of 90% broadleaves to 10% grasses comparing 1992 to 2004 data. The only change in the weed seed community since 1992 is the presence of initially not detected white cockle seeds. (Currently it composes 20% of the broadleaf community). White cockle is commonly found in alfalfa and probably it got in the field with the manure applied. (See **Appendix II**)

The weed seedbank in **CS5**, the other organically managed system, is 77% lower than it was in 1992. However, grass weed seeds represent a higher percentage of the total weed seeds than it did in 1992. Initially, the system weed seeds were composed of 86% of broadleaves and

14% of grasses. Currently, grasses represent 40% of the total weed seeds in the soil seedbank. The broadleaf weed seed community became much more diverse. There were four detected broadleaves species in 1992 against nine species detected in 2004. The broadleaves community is dominated by common lambsquarters and redroot pigweed by 73%, but also contains yellow wood sorrel, dandelion, velvetleaf, shepherd's purse, black nightshade and smartweed. This is probably due to the use of manure in this system. (See **Appendix II)**

Comparing the two organically managed cropping systems we find that CS3 is presenting a much more problematic weed control. Because they are managed similarly (chemical free, chisel plow as primary tillage, cultivation as the main weed control, and delayed planting of the row crops into a "stale seedbed"), it seems likely that the longer alfalfa rotation in CS5 is providing a better "sod" phase to smother weeds than is the wheat/red clover phase in CS3. Foxtail is emerging throughout summer and setting seed with the onset of the fall.

The weed seedbank density at the rotational grazing plots (**CS6**) is low and the proportion of broadleaf weed seeds to grass weed seeds in 2004 is still basically the same. The broadleaf weed community, which was dominated by common lambsquarter and redroot pigweed, is now more diverse and balanced. This isn't surprising since constantly disturbed agricultural sites are normally dominated by a few species in contrast to not disturbed sites like grasslands. To our advantage, one of the broadleaf weed specie to increase its presence from 1% to 10% at the CS6 sites was dandelion, which is considered palatable forage. Another change in the weed seed community is the increase in white cockle seeds, which is a common weed of pastures. All the weed community changes in CS6 have been positive so far. For example, eastern black nightshade seed density has decreased since 1991. Eastern black nightshade contains glycoalkaloid solanine and can cause gastrointestinal irritation and its vegetative parts and fruit can poison all classes of livestock (Stubbendieck et al. 2003). (see **Appendix II)**

III) Hypothesis testing with linear contrasts

We have been collecting the density and diversity of weed species to be able to compare the effects of cropping systems in weed seedbank and species shifts hoping to test the following hypotheses:

Cash Grain Systems

Ho: Weed seed numbers: with herbicides as part of the program, there will be fewer escapes and weed seed numbers will decrease more rapidly in the high input grain systems than in mechanical weed control systems (CS1&CS2 < CS3).

Results: As can be seen in **Table 4,** although total weed seed number was not different among the three systems at the beginning of the trial, by spring 2004 CS3 had significantly more weed seeds than CS1 and CS2. Thus our hypothesis was confirmed and there is better weed control in the chemical systems than in the organic grain system.

Ho: Weed shifts: annual grasses will increase in proportion under continuous corn (CS1) in comparison to more diverse CS2 and CS3.

Results: Annual grasses increased in proportion under continuous corn (CS1), organic grain (CS3), organic forage (CS5), and rotational grazing (CS6). However, CS3 and CS5 had a greater increase in the proportion of annual grasses than CS1. (See Table 3)

Forage Systems

Ho: Weed seed numbers**:** due to the longer sod phase, more intensive forage harvesting schedule, and use of herbicides on the corn, weed seed numbers will be lower in CS4 than CS5.

Results: As can be seen in **Table 4**, similar to the cash grain contrasts, the high input CS4 had fewer weed seeds than the organic CS5 system. However, the difference was not as marked (only at 10% probability) as with the cash grain comparison (.01 % probability) CS4 and CS5 didn't present any difference in total weed seedbank density in 1992. In contrast, CS4 < CS5 regarding grasses seedbank density in 2004. (See **Table4**)

Cash Grain and Hay Systems vs. Rotational Grazing

Ho: Weed seed numbers: due to the grazing clipping regime and no-tillage, it is expected that the rotational grazing (CS6) system will have the lower weed seed numbers that the systems including annual crops (CS1 thru CS5 > CS6).

Results: As can be seen in **Table 4,** CS6 has indeed a lower total weed seed density when compared to the average of the other five systems. It is surprising to note that agronomically CS1 is almost the complete opposite of CS6, and yet CS1 has the lowest actual weed seed density (603 vs. 1,727 seeds/m^2) among all the systems in 2004. (See **Table 4**).

CONCLUSION

The long-term cropping systems trial (WICST), conducted in the UW-research station at in Arlington, Wisconsin shows that cropping systems significantly affect weed seed density over time. The results show that in all six systems, for the plots sampled in 2004, the total weed seed density decreased over time. Initially weed seed densities ranged from 2,000 seed /m^2 to 13,000 seed /m^2 in, while recent data reveals weed seed densities ranging from 600 seed /m^2 to 10,000 seed /m^2. Except for CS3, all the other cropping systems show low weed seed density (< 4,300 seeds/ m^2). Shifts in the ratio of broadleaves to grasses were only important in the two organic systems (increased proportion of grasses in CS3 and CS5) and in the no-till corn-soybean rotation (increased proportion of broadleaves).

It is observed that CS3 weed community clearly shifted from a system dominated by broadleaf weeds to a system dominated by grass weeds. The community shift may have occurred due to environmental, tillage and crop rotation effects. Wet springs in 1996, 1998, 2000 and 2001 made cultivation challenging and weeds had a chance to shed seeds, especially in the corn phase of the rotation. Also, the chisel plow may not be aggressive enough to bury the weed seeds under the favorable germination increasing weed emergence. Consequently, more weeds have a change to succeed and boost the weed seedbank. Furthermore, the forage rotation in CS3 may not be long enough to smother the weeds and avoid new seeds to enter the seedbank. Thus, organic grain farmers may choose to use the moldboard plow instead of chisel plow if erosion is not a problem in their land and/or have a longer hay crop into the organic corn and soybean rotations in order to minimize opportunities for rapid buildup of the seedbank.

On the whole, the hypothesis that over the years the weed seed density in CS1 and CS2 would be lower than CS3 due to herbicide usage is supported by the linear contrast among the systems. Also the hypothesis that over time CS4 would have a lower weed seed density than CS5 due to the fact that CS4 has not only a longer forage rotation phase, but also uses herbicides is supported by our data. The other hypothesis that ultimately CS6 would have the lowest weed seed density of all systems is not supported by the data yet. However, CS6 presents a more balanced broadleaf community than it did back in 1991. The weed seed community in CS6 isn't categorized by a few dominant species, but by various proportionally represented species. With fewer disturbances than the other systems, CS6 doesn't present as much space for opportunistic annual weeds to get established. In addition, annual weeds do not have the chance to go to seed because of the frequent grazing by the heifers.

The trends over time of the weed seedbank due to differences in cropping systems will be strengthened when 2005 data is analyzed and the plots in a different phase of the rotation will be compared to their baseline data.

Table 1- Cropping weed and nutrient management summary by system.

Cropping System	Weed management	Nutrient management
(CS1) Conventional corn "Continuous corn" *corn*	*conventional rates of herbicides *cultivation when needed *conventional tillage[1]	*Recommended rates of fertilizers
(CS2) No-till "No-till corn" *corn – soybeans*	*reduced rates of herbicides in corn followed by cultivation *conventional rates of herbicides in soybean phase until 1998 when glyphosate- resistant soybeans were adopted	*Recommended rates of fertilizers in the corn phase.
(CS3) Organically managed "Organic grain" *corn – soybeans – winter wheat/red clover*	*primary[1] and secondary tillage [2] *delayed planting *rotary hoeing and cultivation * no herbicides	*green manure plowed down before corn planting
(CS4) Conventional forage "Green gold alfalfa" *corn – alf – alf – alf*	*full rates of herbicides and cultivation in the corn phase Recommended rates of herbicide with alfalfa seeding *last alfalfa crop is killed with fall-applied glyphosate *conventional tillage[1]	*cattle manure application 20t/a in fall prior to corn planting and again before the alfalfa seeding phase
(CS5) Organically managed "Organic forage" *corn – oats/peas/alf – alf*	*delayed planting *rotary hoeing and cultivation *last alfalfa crop is chisel plowed *no herbicides	*green manure *cattle manure 15t/a prior to the corn and oat/pea/alf phases
(CS6) Rotational grazing "Rotational grazing"	*intensive rotational grazing by dairy heifers *spot herbicide application for thistles	*cattle manure deposited directly on the paddocks

[1] shank, disc chisel

[2] mulch master, field digger, soil finisher, cultivator and/or disc.

Table 2a - Mean of total weed seed/m2 in the spring following corn (n=4).

	91	92	93	94	95	96	97	98	04
CS1	1,784	2,222	2,866	1,842		3,860	2,686	3,947	603
CS2	5,162	6,140		11,373		2,916		5,838	2,412
CS3		11,257			5,087			6,387	9,319
CS4		6,286				2,149			1,645
CS5		12,894			3,004			2,357	2,988
CS6	4,356				4,144	6,513			1,727

Table 2b – Total weed seed ANOVA of 6 systems initially and in 2004.

Effect	Num DF	F Value	Pr > F
System initially (91-92)	5	11.01	0.2247
System in 2004	5	31.17	<. 0001

Table 3 – Percentage of broadleaf to grass of total weed seed per system.

	1991-1992	2004	From 1991-2 to 2004
Cropping System	**% Broadleaf / %Grass**	**%Broadleaf / %Grass**	**% Grass**
CS1	84 / 16	77 / 23	From 16% to 23% = 7%
CS2	78 / 22	93 / 7	
CS3	88 / 12	18 / 82	From 12% to 82% = 70%
CS4	90 / 10	90 / 10	
CS5	86 / 14	60 / 40	From 14% to 40% = 26%
CS6	75 / 25	68 / 32	From 25% to 32% = 7%

Table 4- Linear Contrasts

Ho: CS1&CS2<CS3

	Baseline 91/92			2004		
Total seeds	**df**	**p>F**	**Means**	**df**	**p>F**	**Means**
2) CS1, 2 (conv. grains) vs.			4,181			1,508
CS3 (org grain)	1	0.1338	11,256	1	<.0001	9,319

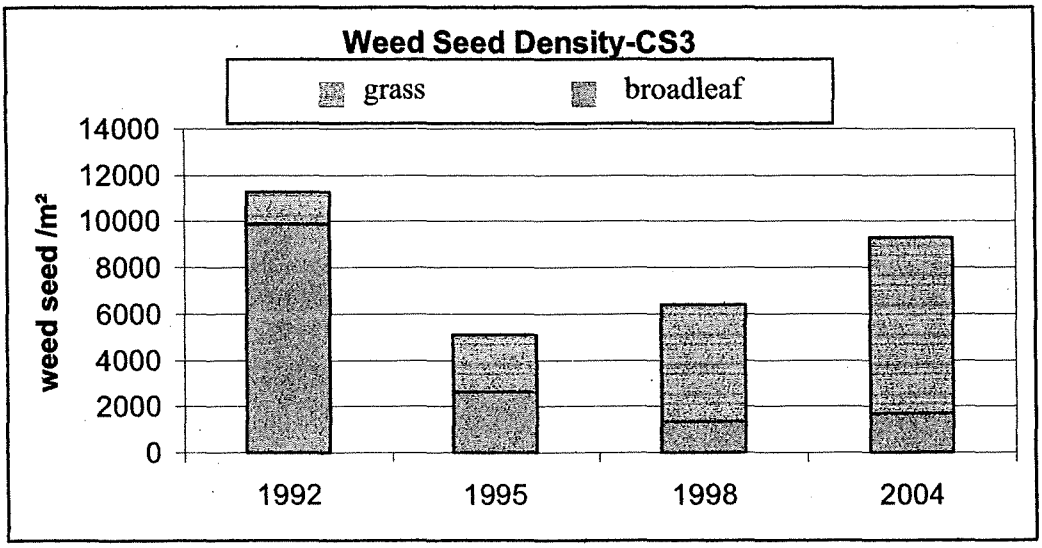
Ho: Total weed seed in CS4 < CS5

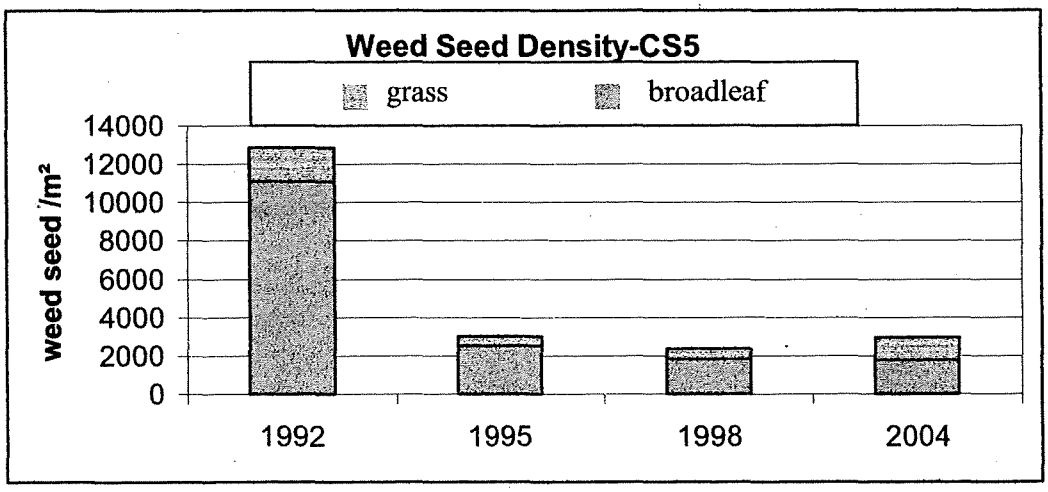
Total seeds	**df**	**p>F**	**Means**	**df**	**p>F**	**Means**
4) CS4 (forage) vs. CS5			6,286			1,645
(org forage)	1	0.1642	12,894	1	0.0952	2,988

Ho: Total weed seed in CS1 thru CS5 > CS6

Total seeds	**df**	**p>F**	**Means**	**df**	**p>F**	**Means**
2) CS1,5 (sys w/ Corn) vs.			7,760			3,393
CS6 (sys w/out Corn)	1	0.2405	4,356	1	0.0082	1,727

Figure 1 – CS3 and CS5 total weed seed density divided into grass and broadleaf species.





CITATIONS

Buhler, D. et al. 2001. Weed Seed Bank Dynamics During a Five-Year Crop Rotation. Weed Technology. 15: 170-176.

Buhler, D. et al. 1997. Implications of Weed Seedbank Dynamics to Weed Management. Weed Science. 45: 329-336.

Buhler, D. 1995. Influence of Tillage Systems on Weed Population Dynamics and Management in Corn and Soybean in the Central USA. Crop Science. 35: 1247-1258.

Cardina, J. and Denise Sparrow. 1996. A Comparison of Methods to Predict Weed Seedling Populations From the Soil Seed Bank. Weed Science. 44: 46-51.

Cardina, J. et al. 2002. Crop Rotation and Tillage System Effects on Weed Seedbanks. Weed Science. 50: 448-460.

Cardina, J. et al. 1991. Long-term Tillage Effects on Seed Banks in Three Ohio Soils. Weed Science. 39: 186-194.

Davis, A. et al. 2005. Weed Seedbank and Community Shifts in a Long-Term Cropping Systems Experiment. Weed Science. 52: 296-306.

Dekker, Jack. 1999. Soil Weed Seed Banks and Weed Management. Journal of Crop Production. 2: 139-166.

Forcella, F. et al. 1997. Weed Seed Bank Emergence Across the Corn Belt. Weed Science. 45: 67-76.

Forcella, F. et al. 1992. Weed Seedbanks of the US Corn Belt: Magnitude, Variation, Emergence, and Application. Weed Science. 40: 636-644.

Hill, N. M. et al. 1989. Weed Seed Bank and Vegetation at the Beginning and End of the First Cycle of a 4-Course Crop Rotation with Minimal Weed Control. Journal of Applied Ecology. 26: 233-246.

Mulugeta, D. and David E. Stoltenberg. 1997. Increased Weed Emergence and Seed Bank Depletion by Soil Disturbance in a No-till System. Weed Science. 45: 234-241.

Mulugeta, D. and David E. Stoltenberg. 1997a. Weed and Seedbank Management with Integrated Methods as Influenced by Tillage. Weed Science. 45: 706-715.

Roberts, H. A. and R.J. Chancellor. Seed Banks of Arable Soils in the English Midlands. Weed Research. 26: 251-257.

Roberts, H. A. and Patricia A. Dawkins. 1967. Effect of Cultivation on the Numbers of Viable Weed Seed in Soil. Weed Research. 7: 290-301

Schreiber, Marvin M. 1992. Influence of Tillage, Crop Rotation, and Weed Management on Giant Foxtail (*Setaria faberi*) Population Dynamics and Corn Yield. Weed Science. 40: 645-653.

Stubbendieck, James, Mitchell Coffin, and L.M. Landholt. Weeds of the Great Plains. Lincoln: Nebraska Department of Agriculture, 2003.

Teasdale, J. et al. 2004. Weed Seedbank Dynamics in Three Organic Farming Crop Rotations. Agronomy Journal. 96: 1429-1435.

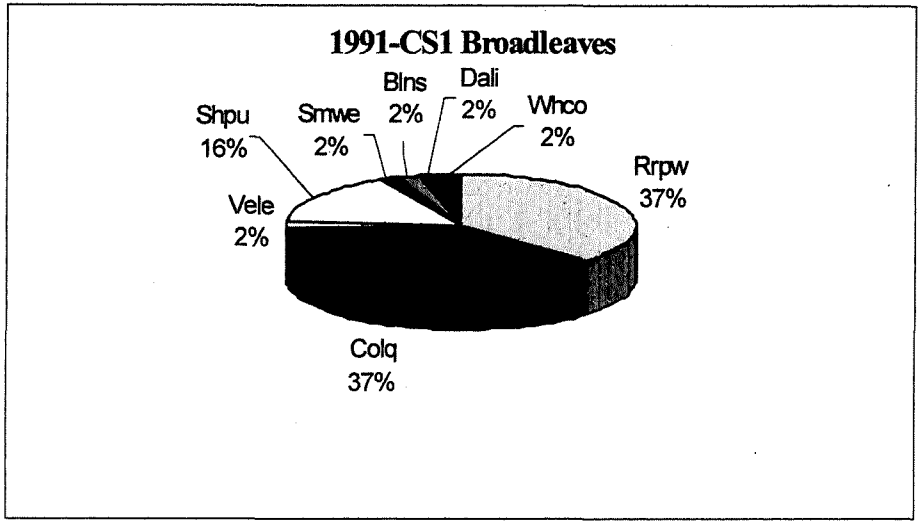
Appendix I- Summary of linear contrasts to determine the influence of agricultural management practices on weed seedbank (1991/92 - 2004)

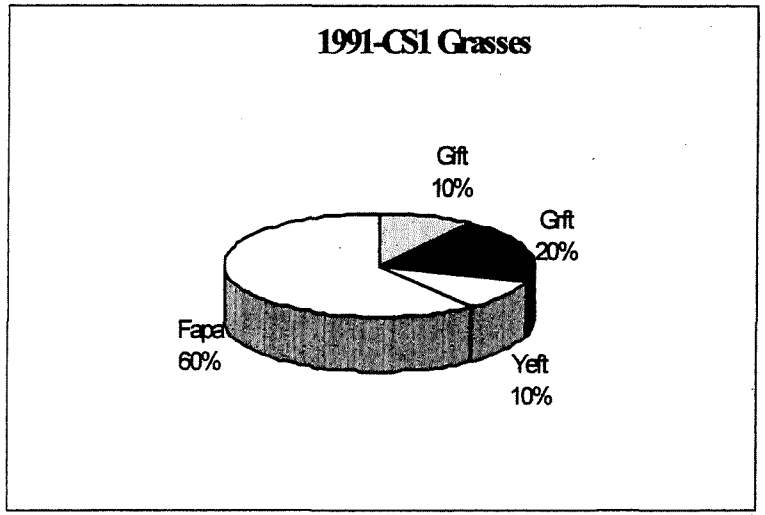
	Baseline 91/92			2004		
Total seeds	**df**	**p>F**	**Means**	**df**	**p>F**	**Means**
1) CS3 (org grain) vs. CS5			11,256			9,319
(org forage)	1	0.5200	12,894	1	<.0001	2,988
2) CS1,5 (sys w/ Corn) vs.			7,760			3,393
CS6 (sys w/out Corn)	1	0.2405	4,356	1	0.0082	1,727
3) CS4, 5 (hay forages) vs.			9,590			2,316
CS6 (pasture)	1	0.1788	4,356	1	0.3952	1,727
4) CS4 (forage) vs.			6,286			1,645
CS5 (org forage)	1	0.1642	12,894	1	0.0952	2,988
5) CS1 (C corn) vs.			2,222			603
CS2 (no-till Corn)	1	0.2665	6,140	1	0.0255	2,412
6) CS2 (no-till grain) vs.			6,140			2,412
CS6 (no-till forage)	1	0.4928	4,356	1	0.3919	1,727
7) CS1, 3 (grains) vs.			6,539			4,111
CS4, 5 (forages)	1	0.2250	9,590	1	0.0007	2,316
8) CS1, 2 (grains) vs.			4,181			1,508
CS3 (org grain)	1	0.1338	11,256	1	<.0001	9,319

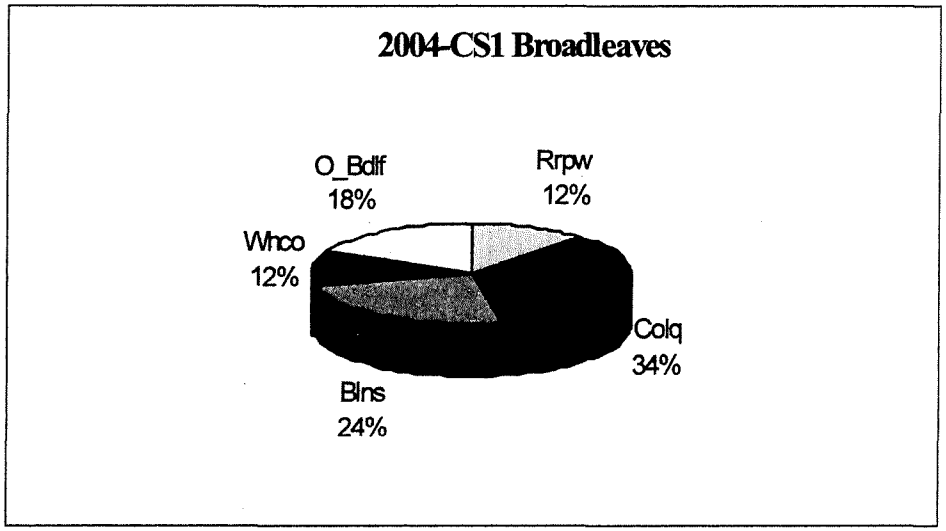
	Baseline 91/92			2004		
Broadleaf seeds	**df**	**p>F**	**Means**	**df**	**p>F**	**Means**
1) CS3 (org grain) vs. CS5 (org forage)	1	0.6078	9,911.50 11,052	1	0.8223	1,672.06 1,781.63
2) CS1,5 (sys w/ Corn) vs. CS6 (sys w/out Corn)	1	0.2244	6,666.15 3,274.50	1	0.3548	1,529.53 1,178.81
3) CS4, 5 (hay forages) vs. CS6 (pasture)	1	0.1708	8,347.33 3,274.50	1	0.2864	1,630.97 1,178.81
4) CS4 (forage) vs. CS5 (org forage)	1	0.1842	5,642.92 11,052	1	0.5374	1,480.31 1,781.63
5) CS1 (C corn) vs. CS2 (no-till Corn)	1	0.3260	1,929 4,795	1	0.0005	466.06 2,247.56
6) CS2 (no-till grain) vs. CS6 (no-till forage)	1	0.5183	4,795 3,274.5	1	0.0310	2,247.56 1,178.81
7) CS1, 3 (grains) vs. CS4, 5 (forages)	1	0.2262	5,545.13 8,347.33	1	0.5917	1,461.89 1,630.97
8) CS1, 2 (grains) vs. CS3 (org grain)	1	0.1336	3,362.29 9,911.5	1	0.4564	1,356.81 1,672.06

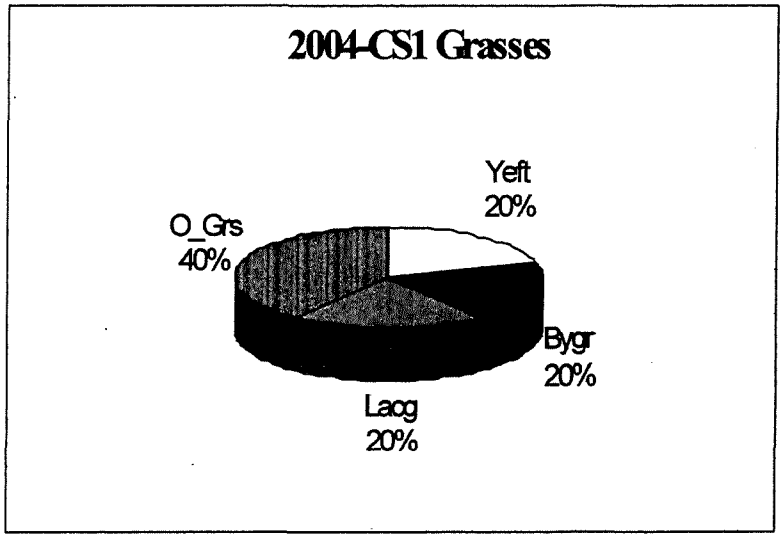
Grass seeds	**df**	**p>F**	**Means**	**df**	**p>F**	**Means**
1) CS3 (org grain) vs. CS5 (org forage)	1	0.3329	1,345 1,842.17	1	<.0001	7,647.38 1,206.00
2) CS1,5 (sys w/ Corn) vs. CS6 (sys w/out Corn)	1	0.9764	1,093.55 1,081.83	1	0.0059	1,863.93 548.31
3) CS4, 5 (hay forages) vs. CS6 (pasture)	1	0.7165	1,242.71 1,081.83	1	0.7935	685.28 548.31
4) CS4 (forage) vs. CS5 (org forage)	1	0.0221	643.25 1,842.17	1	0.0873	164.56 1,206.00
5) CS1 (C corn) vs. CS2 (no-till Corn)	1	0.0433	292.42 1,344.92	1	0.9638	137.13 164.56
6) CS2 (no-till grain) vs. CS6 (no-till forage)	1	0.6073	1,344.92 1,081.83	1	0.5258	164.56 548.31
7) CS1, 3 (grains) vs. CS4, 5 (forages)	1	0.4524	994.12 1,242.71	1	<.0001	2,649.69 685.28
8) CS1, 2 (grains) vs. CS3 (org grain)	1	0.2375	818.67 1,345.00	1	<.0001	150.84 7,647.38

Appendix II - Weed community analysis for CS1 from 1991 to 2004.

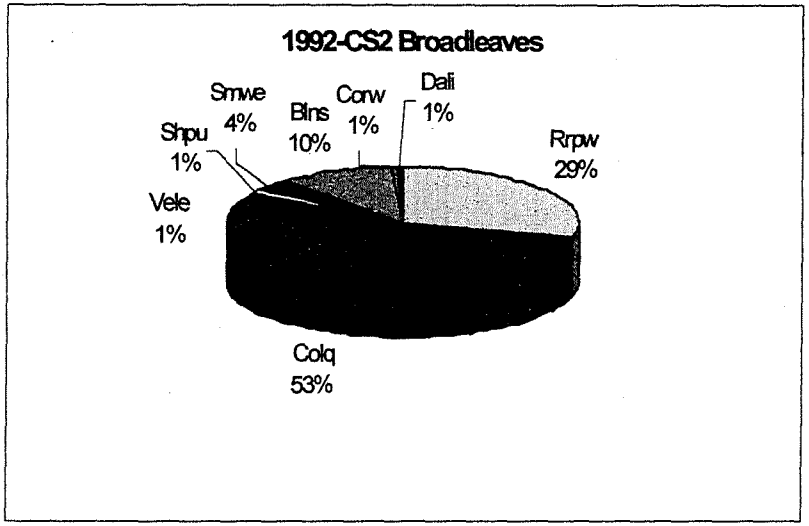


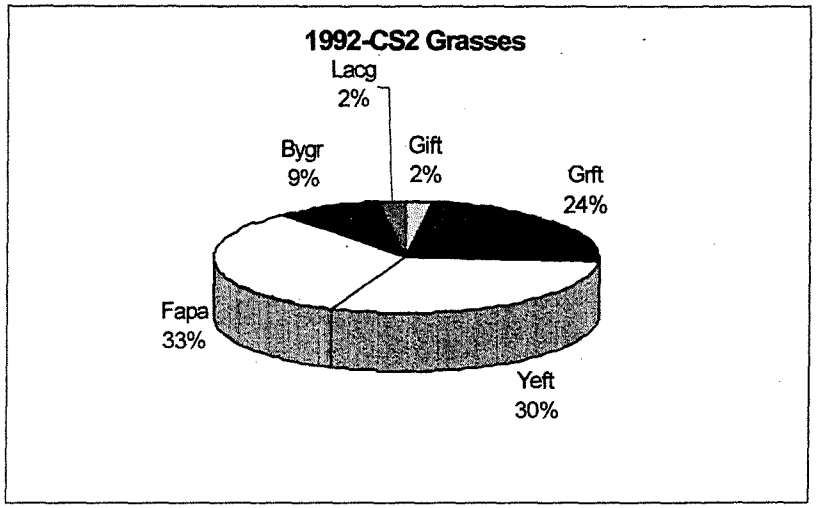


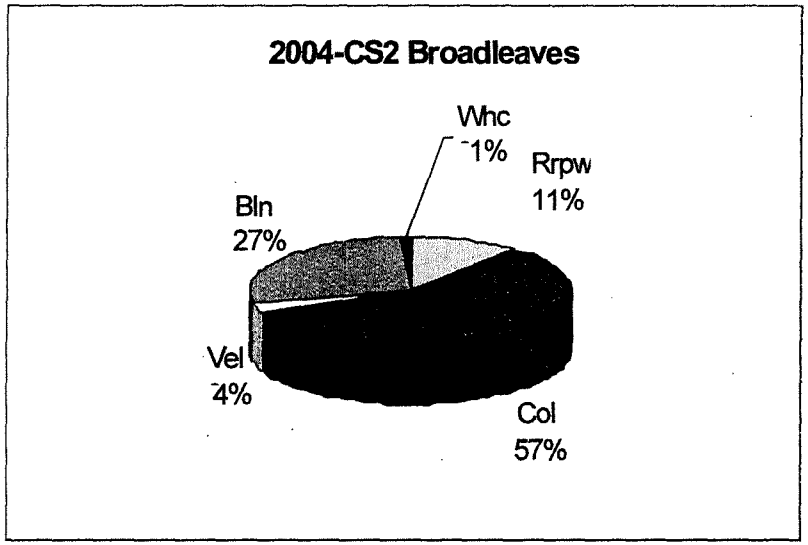


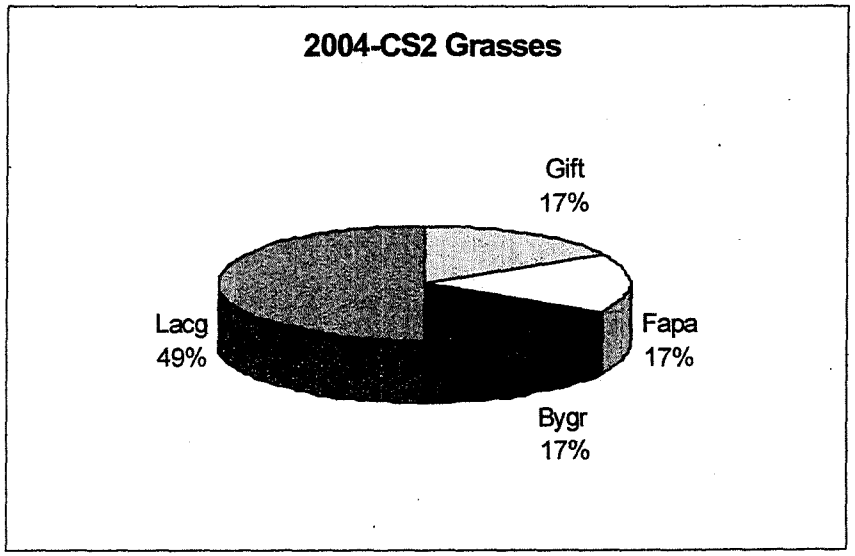


Weed community analysis for CS2 from 1992 to 2004.

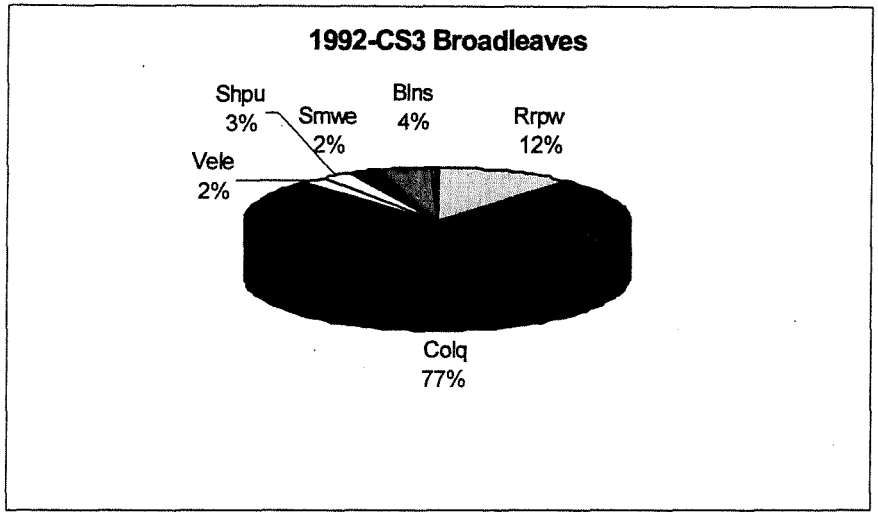


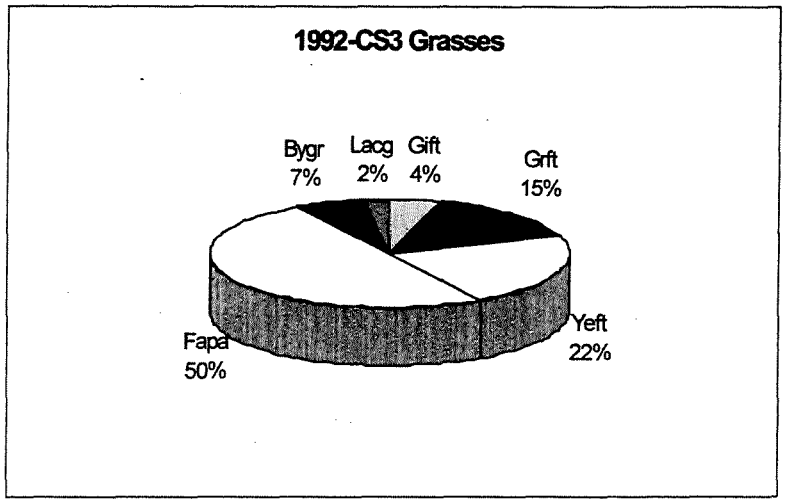


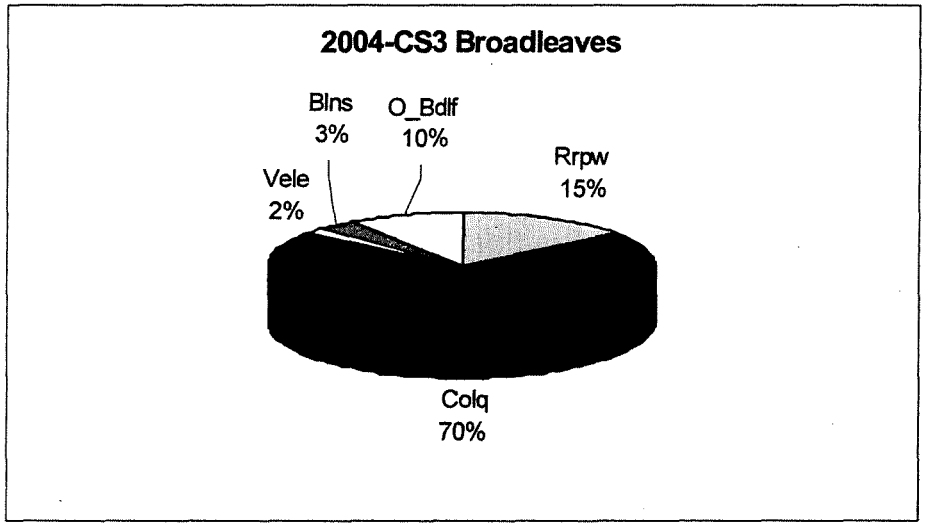


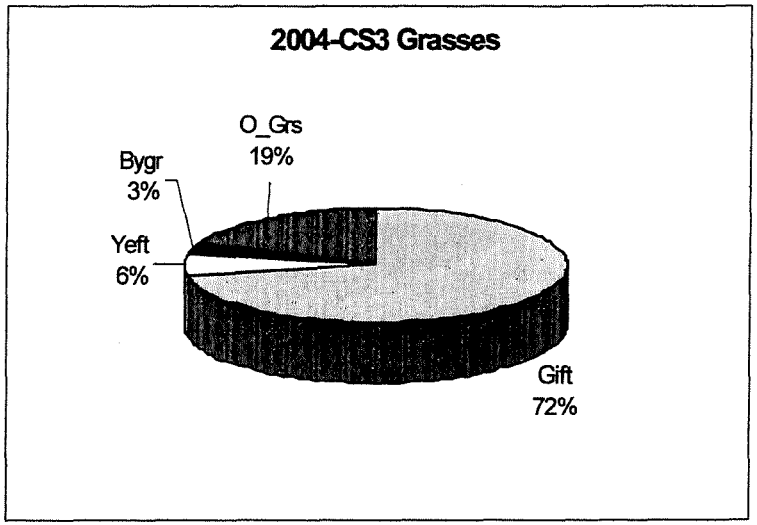


Weed community analysis for CS3 from 1992 to 2004.

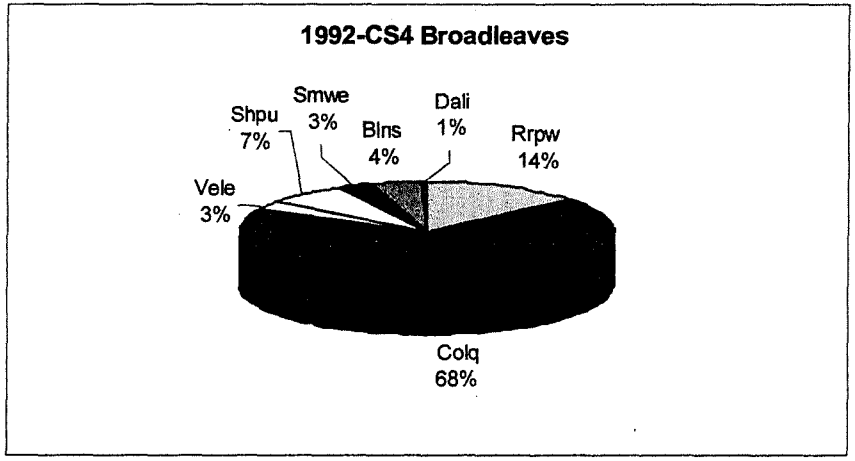


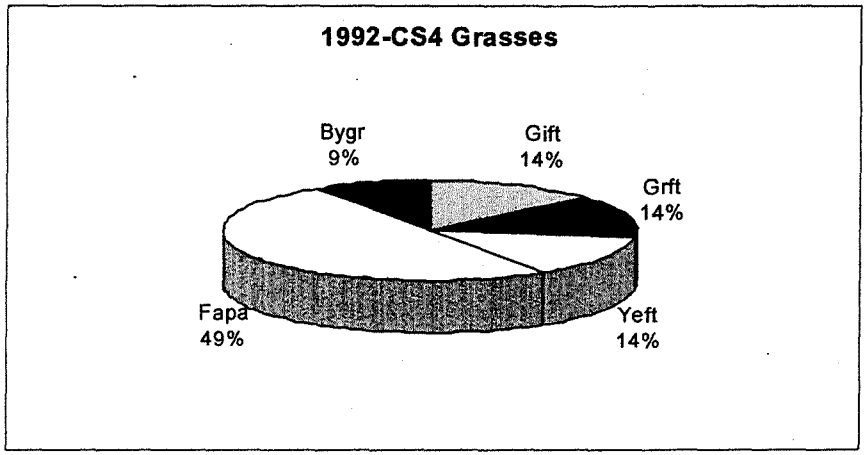


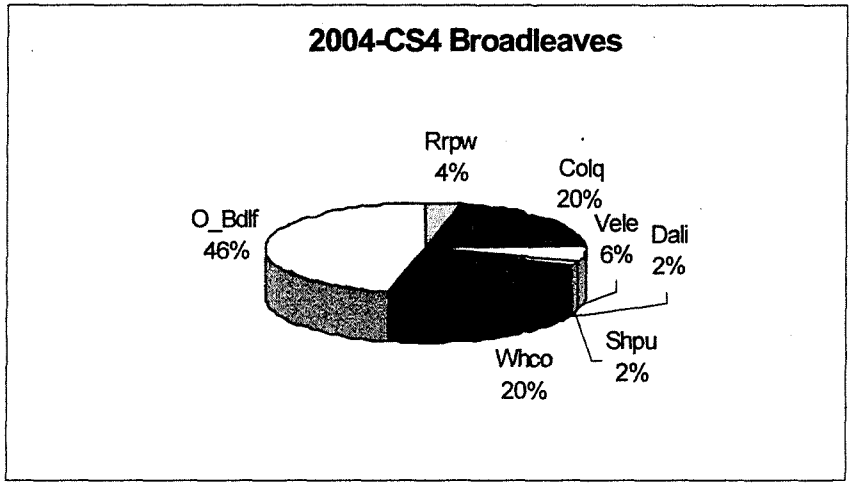


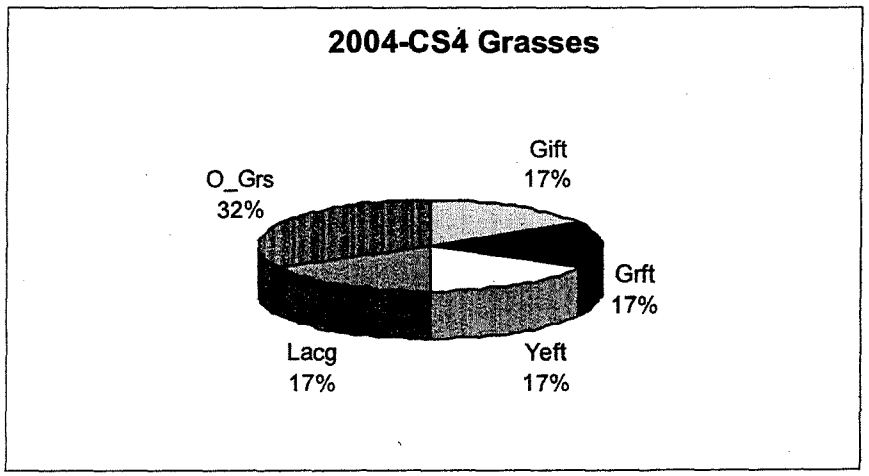


Weed community analysis for CS4 from 1992 to 2004.

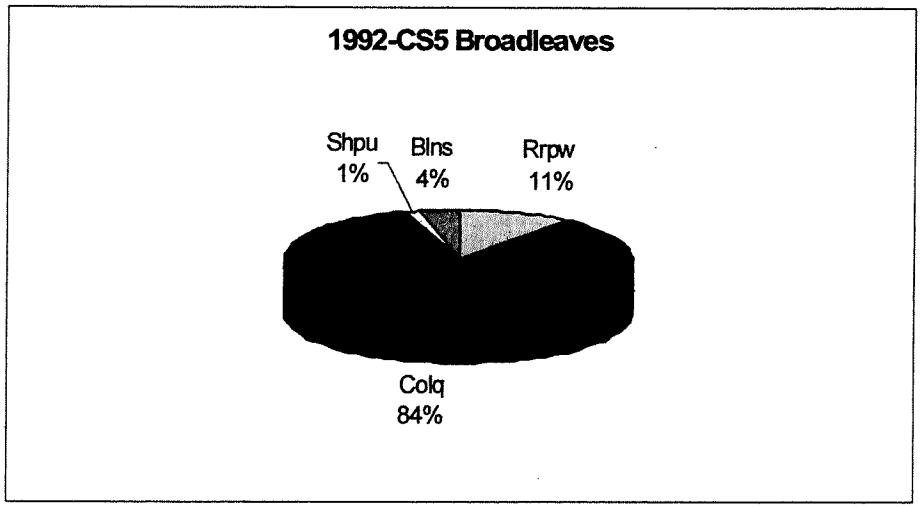


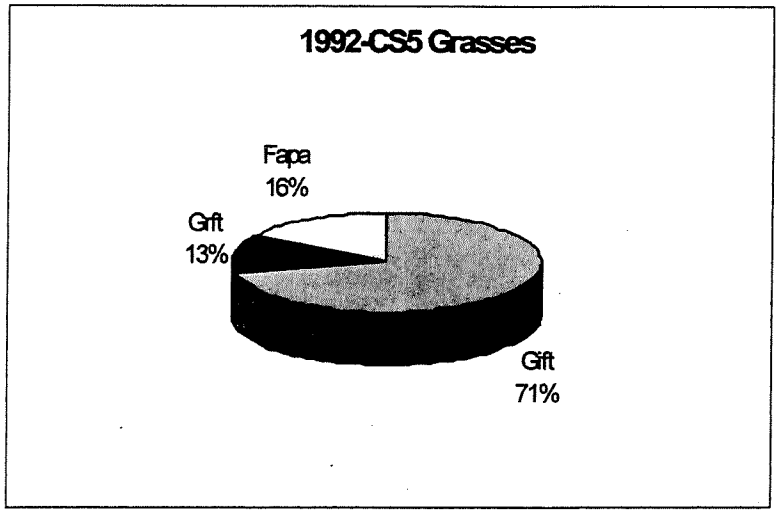


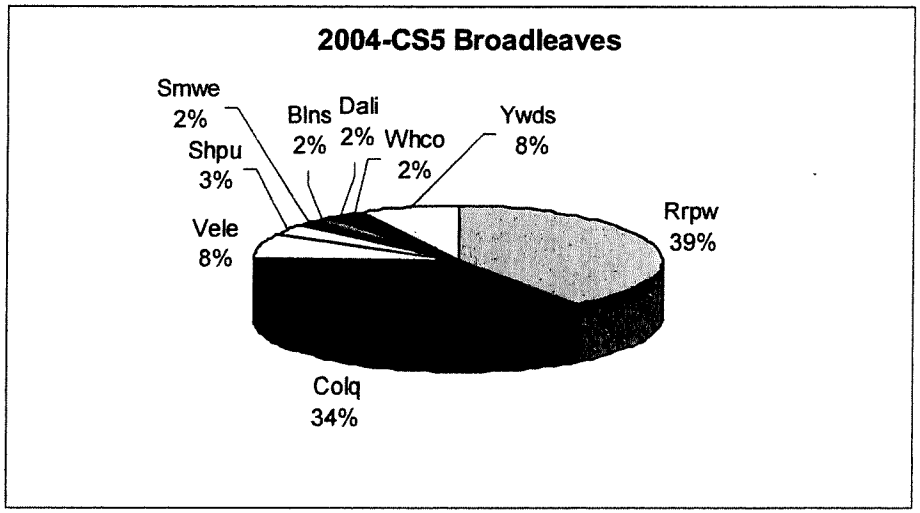


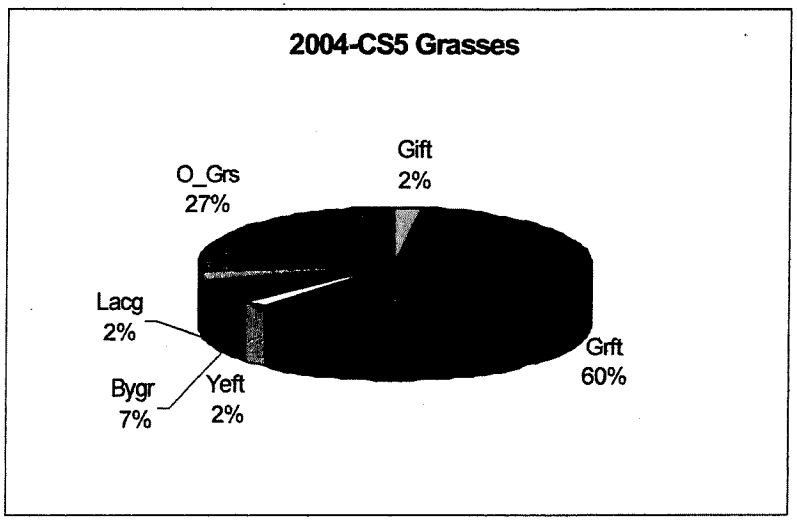


Weed community analysis for CS5 from 1992 to 2004.

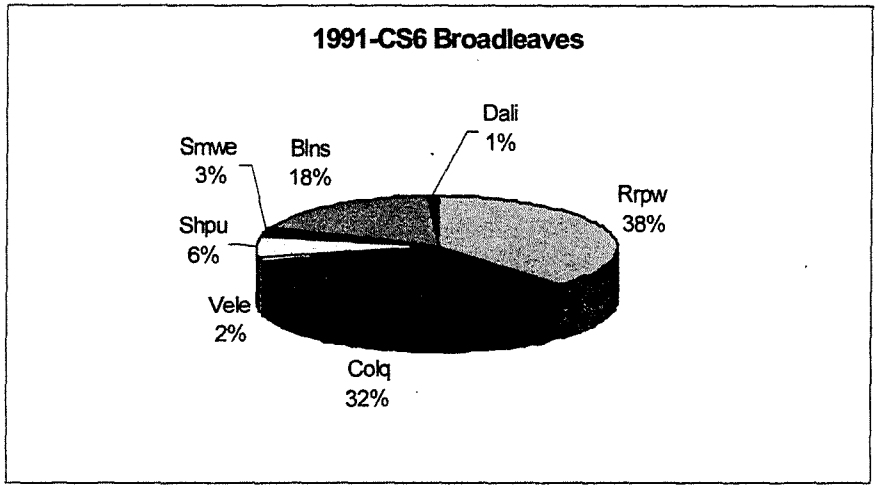


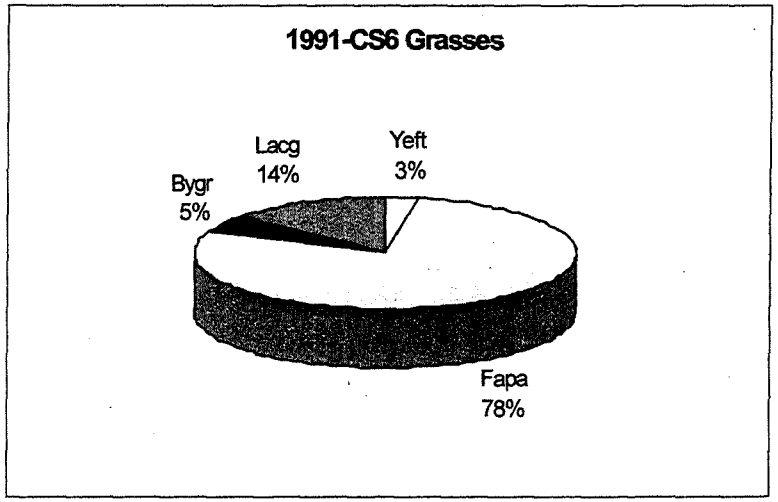


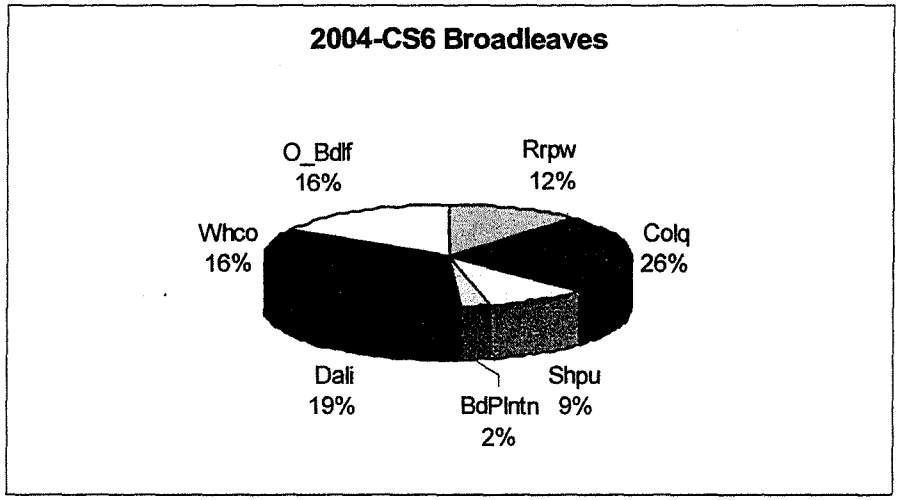


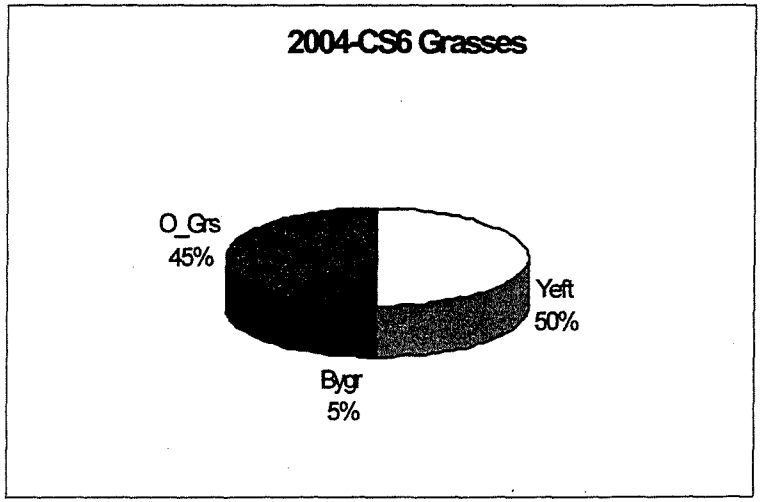


Weed community analysis for CS6 from 1991 to 2004.









Appendix III- Weed seedbank changes in WICST at ARL from 1990 to 2004.

trt		90	91	92	93	94	95	96	97	98	.....	04
1	Seeds/m^2	C 4,823	C 1,787	C 2,218	C 2,864	C 1,841	C	C 3,827	C 2,821	C 3,951		C 603
	% brdlf	86	84	87	86	81	--	92	97	79	.....	77
	% grass	14	16	13	14	49	--	8	3	21		23
2	Seeds/m^2	FC	S 1,548	C	S 2,312	C	S 3,043	C	S 2,247	C		C
	% brdlf	--	70	--	86	--	93	--	95	--	.....	--
	% grass	--	30	--	14	--	7	--	5	--		--
3	Seeds/m^2	S 4,613	C 5,162	S 6,140	C	S 11,366	C	S 2,871	C	S 5,828		S 2,409
	% brdlf	75	73	78	--	88	--	96	--	88	.....	93
	% grass	25	27	22	--	12	--	4	--	12		7
4	Seeds/m^2	FC	FC	S 11,247	W/Rc	C 7,677	S5,130	W/Rc	C	S 6,376		Sb 9,312
	% brdlf	--	--	88	--	64	51	--	--	21	.....	18
	% grass	--	--	12	--	36	49	--	--	79		82
5	Seeds/m^2	S 2,215	W 2,935	C 9,613	S 9,140	W	C	S 3,645	W	C		C
	% brdlf	68	80	85	83	--	--	95	--	--	.....	--
	% grass	32	20	15	17	--	--	5	--	--		--
6	Seeds/m^2	FC	S 7,559	W	C 11,602	S 10,807	W	C	S 13,990	W		W
	% brdlf	--	88	-	67	43	--	--	13	--	.....	--
	% grass	--	12	--	33	57	--	--	87	--		--
7	Seeds/m^2	A 5,075	A 2,839	A	C	A 2,570	A	A	C	A 3,258		A
	% brdlf	82	81	--	--	93	--	--	--	57	.....	
	% grass	18	19	--	--	7	--	--	--	43		
8	Seeds/m^2	FC	A 3,097	A	A	C 12,301	A 3,720	A	A	C		A
	% brdlf	--	59	--	--	99	96	--	--	--	.....	--
	% grass	--	41	--	--	1	4	--	--	--		--
9	Seeds/m^2	FC	FC	A 6,280	A	A	C 2,925	A 2,258	A	A		A 1,645
	% brdlf	--	--	90	--	--	94	83	--	--	.....	90
	% grass	--	--	10	--	--	6	17	--	--		10
10	Seeds/m^2	FC	FC	FC 7,742	A 2,892	A	A	C 4,011	A 1,893	A		C
	% brdlf	--	--	93	88	--	--	60	86	--	.....	--
	% grass	--	--	7	12	--	--	40	14	--		--
11	Seeds/m^2	Oa 4,774	A 8,118	C 7,441	Oa 3,645	A	C 4,205 77	Oa 2,301	A	C		C
	% brdlf	82	64	91	95	--	23	63	--	--	.....	--
	% grass	18	36	9	5	--		37	--	--		--
12	Seeds/ft^2	FC	Oa 5,871	A	C 5,441	Oa 4,968	A	C 6,355	Oa 4,269	A		A
	% brdlf	--	82	--	88	86	--	57	58	--	.....	--
	% grass	--	18	--	12	14	--	43	42	--		--
13	Seeds/ft^2	FC	FC	Oa12,882	A	C 3,452	Oa 3,000	A	C	Oa 2,355		Oa 2,990
	% brdlf	--	--	86	--	90	83	--	--	77	.....	60
	% grass	--	--	14	--	10	17	--	--	23		40
14	Seeds/ft^2	P 4,151	P 4,312	P	P	P	P 4,118	P 6,462	P	P		P 1,720
	% brdlf	82	75	--	--	--	89	73	--	--	.....	68
	% grass	18	25	--	--	--	11	27	--	--		32

A NOTE ON SOIL ORGANIC CARBON, SOIL ORGANIC NITROGEN, AND PARTICULATE ORGANIC MATTER ON THE WICST PLOTS

Joshua Posner[1], Leslie Cooperband[2], Ana Wells[3], and Janet Hedtcke[1]

INTRODUCTION

Soil organic matter is one of the most important attributes of a soil because it affects nutrient cycling, soil structure, and water availability. Maintaining, or better yet, increasing soil organic carbon (SOC) content is an important measure of the sustainability of a cropping system. In fact, the USDA has developed a Soil Conditioning Index (SCI) that is a tool that can predict the consequence of cropping systems and tillage practices on the trend of soil organic matter accumulation (USDA, 2002). A positive index is the first criteria used in the Conservation Security Program (CSP) for advancement from Tier I to Tier II stewardship payments (USDA, 2004). Overall, management practices that contribute to increasing SOC levels include those that add more organic carbon to the soil than the amount removed from the system (e.g. crop residues), increase the diversity of organic materials added (e.g. cover crops, manure), or decrease the rate of organic matter loss (e.g. reduced tillage, reduced erosion) (Magdoff, and Weil, 2004).

Soil organic carbon can be usefully envisioned as consisting of three pools: an active rapid-turnover pool (0-5 years); a moderate to slow turnover pool (6-25 years); and a recalcitrant pool that may have a half-life of several hundred years (Paustian et al., 1992). According to Wander (2004), the active fraction of organic matter (usually considered as organic material of recent origin) is most closely associated with soil biological activity, materials of intermediate age contribute to soil physical structure and the carbon with the longest residence time in the soil has its greatest influence on the physicochemical reactivity of the soil. The labile, or active fraction of soil organic matter can be assessed by characterizing the Particulate Organic Matter (POM), which is composed primarily of plant-derived remains and includes fungal spores, hyphae and in some cases, charcoal. (Wander, 2004). POM's primary value is as an indicator of early trends of changes in soil organic matter characteristics.

Soil organic matter and POM were measured on the Wisconsin Integrated Cropping Systems Trial (WICST) plots at the Arlington Research Station (ARS) and the Lakeland Agricultural Complex (LAC). These plots were established in 1990 to compare alternative cropping systems and their impact on productivity, profitability and the environment. Three of the rotations are cash grain based [CS1-continous corn (CC); CS2-no-till corn-soybeans (NT CSb); CS3- Organic Grain (OG) corn-soybeans-wheat/red clover] and three forage based systems [CS4- Conventional Forage (CF) alfalfa-alfalfa-alfalfa-corn with manure; CS5- Organic Forage (OF) oats/peas/alfalfa -alfalfa-corn with manure; and, CS6-rotational grazing (RG)]. **(see Figure 1)**

These systems are common to Upper Midwestern farms and vary in the intensity of tillage, amount and type of biomass amendments, and crop diversity.

[1] UW-Madison, Agronomy Dept.
[2] University of Illinois – Human and Community Development Dept.
[3] UW-Madison, Soil Science Dept.

Our initial hypotheses were:
H1: The dairy rotations, due to the inclusion of manure and leguminous forage crops would have higher levels of soil organic carbon (SOC), particulate organic matter (POM), and POM would represent a higher percentage of total SOC than in the grain based systems (CS4 + CS5 + CS6 > CS1 + CS2 + CS3);

H2: Since tillage and cultivation promote organic matter oxidation, it was hypothesized that the systems with these interventions would result in lower levels of SOC, lower levels of readily oxidizable organic matter and POM would represent a lower percentage of SOC than in the no-till systems (CS1 + CS3 + CS4 + CS5 < CS2 + CS6).

H3: The systems with higher biological diversity would have higher levels of soil organic carbon (SOC), particulate organic matter (POM), and POM would represent a higher percentage of total SOC than the lower crop diversity systems (CS3 + CS6 > CS1 + CS4);

In addition, we anticipated that within the grain-based systems and the forage-based systems, the more diverse rotations would have higher levels of soil organic carbon (SOC), particulate organic matter (POM), and POM would represent a higher percentage of total SOC than the less diverse rotations (CS3>CS1; CS6>CS4).

METHODS

Soils were sampled from the Arlington site (ARS) on April 11, 2003 and from the Lakeland site (LAC) on April 12, 2003. This was 13 years after the plots had been established. Only the initial 6 plots/replicate that were established in 1990 (T1, T3, T5, T7, T11 and T14) were sampled at Arlington. In addition, the newly established (1999) prairie plots (high diversity) and the companion continuous corn plots were sampled. At Lakeland, the initial plots established in 1990 were also sampled, however, due to the change in cropping pattern in Cropping System 5, there were only 5 plots/replicate (T1, T3, T5, T7, T14). At each site there were four replicates (**see Figure 2a and b**). Three sub samples, from the north, center and south ends of each plot, each constituted by bulking six cores that were in near proximity to each other (3/4" dia. probe), were collected. Soil was sampled to 3 depths: 0 to 5 cm, 5 to 10 cm, and 10 to 20 cm.

Soil samples were air dried on the lab bench and then sieved through a 2-mm screen to remove rocks and plant debris. 50g of soil were ground to pass a 10-μm sieve for Total C and Total N. To determine the particulate organic matter or POM fraction of whole soil, a 20-g sub sample was place in a 250 ml Nalgene bottle with 100 ml of dionized water and 10 6-mm glass beads, and shaken for 16 hours at 180 cycles per min (Cambardella and Elliot, 1992; Chantigny et al., 1999). Then the soil was passed through a 53-μm sieve. The material retained in the sieve was oven dried at 50° C and ground to pass a 10 -μm sieve. Total soil C and N were determined by dry combustion (LECO CNS-2000, Leco Corp., St. Joseph, MI).

We are reporting the coarse POM fraction including loose and occluded fractions. The occluded fraction refers to aggregated and protected soil organic matter and the loose fraction refers to non-aggregated soil organic matter (Wander, 2004).

Bulk density samples (2 per plot) were taken concurrently from 0-10-cm depth.

RESULTS & DISCUSSION

Combined Analysis

Soil Organic Carbon and Total Nitrogen

Initially the data was analyzed across both sites for the five common production systems. The probability of significant differences is summarized in **Table 1**. Total SOC was highly significantly different between sites at all three depths (e.g.; 0-5 cm, LAC=36.47 g C/kg of soil; ARS=30.12 g C/kg of soil). And by the same token, Total N was also highly significantly different at all three depths (e.g. 0-5, LAC= 3.23 g N/kg of soil; ARS= 2.58 g N/kg of soil). This is primarily due to the more poorly drained status of the soils at the Lakeland Agricultural Complex (Griswold and Pella series). Cropping systems SOC and total N were also significantly different at 0-5 and 5-10 cm, but not at 10-20 cm depth. At both sites, the pasture plots were the highest in SOC and total N (see **Table 2**). For SOC and total N, there was no interaction between site and cropping systems (**Table 1**).

POM-Carbon, POM-Nitrogen and % POM-C and % POM-N

POM-C and POM-N were significantly different between sites at all three depths (LAC > ARS) but not the % POM-C or % POM-N. This suggests that like total organic matter, the g POM/kg of soil was also higher at the more poorly drained Lakeland site, but the "quality" or % POM was not different- on average between sites. Not surprisingly, cropping systems POM-C and POM-N were significantly different, as were their proportion in the organic matter (% POM-C, % POM-N) at all three depths. The range in % POM-C by systems across sites (0-5 cm) was 22.4 % for the rotational grazing to 15.2% in the no-till system and 18 % to 11.8 % for total N. This indicates that quality of the organic matter, assuming that more POM indicates a more biologically active organic matter component did change with cropping system.

An interesting anomaly in the data is the interaction at 0-5 and 5-10 cm depth between cropping systems and site for POM-C, POM-N and their percent of the total SOC content. Most of the interaction at 0-5 cm is due to the organic grain system (CS3) that actually was lower in POM-C at Lakeland than it was at Arlington (**Figure 3a**). The other four systems produced higher POM-C at Lakeland, although the increase was very modest in CS1 (continuous corn) and CS2 (no-till corn/soybean). At 5-10 cm depth (**Figure 3b**), POM-C in CS3 was again lower at Lakeland and CS1 was nearly constant. It is surprising that although there was no interaction at 10-20 cm depth—all five systems had higher POM-C at Lakeland and the arithmetically highest was CS3 (data not shown). The same pattern was found for POM-N (**Figure 4a & b**).

Site Analysis

Total SOC, POM-C, and %POM-C were generally highest in the rotationally grazed plots (CS6) at both locations (see **Table 3 & 4**). The same was the case for total N, POM-N and % POM-N. Surprisingly, the system with the lowest levels of SOC, POM-C and %POM-C at Arlington was the no-till corn and soybean system (CS2). The trend was the same for total N, POM-N and % POM-N. At Lakeland, it was more difficult to distinguish a trend other than that the three grain systems (CS1, CS2, CS3) were generally lower in both the carbon and nitrogen variables than the forage systems (CS4 and CS6).

Prairie vs. Continuous corn

The prairie and continuous corn plots were initiated at Arlington in 1999, so this analysis was conducted after only four years. SOC and total N were not yet different between the two systems but the amount of POM-C in the surface horizon (0-5 cm) was significantly higher in the prairie plots (**see Table 3**).

Hypothesis testing

Linear contrasts were used to test the hypotheses set out in the introduction

H1: The dairy systems with manure and forage legumes would have increased levels of soil organic matter (SOC), levels of POM, and that POM would represent a larger percentage of total carbon. Table 5a summarizes the results from the contrasts between the dairy (CS6, CS5, CS4) systems and the grain (CS3, CS2, CS1) systems. Not surprisingly, the combined analyses, as well as the individual site contrasts showed that the dairy systems tended to have higher SOC levels and higher POM-C levels as well as a greater percentage of their total carbon in the active POM fraction.

H2: The systems with tillage would have lower levels of soil organic carbon (SOC), lower levels of POM, and that POM would represent a lower percentage of total SOC than the systems without tillage. The results of the contrasts between the systems with tillage (CS1, CS3, CS4, CS5) and the systems without tillage (CS2, CS6) are presented in **Table 5b**. In the combined and individual site analyses, the systems with tillage had lower SOC levels, lower POM-C levels, as well as a lower percentage of their total carbon in the active POM fraction. This contrast is not consistent at Arlington, where the no-till pasture was much higher, in SOC than the other systems, while the no-till corn and soybean system was actually the lowest of the six. Nonetheless, on average, SOC and POM were significantly higher in non-tilled systems than the other four systems with tillage. In contrast, at Lakeland, both no-till systems were among the highest in SOC.

H3: The systems with higher biological diversity would have higher levels of soil organic carbon (SOC), particulate organic matter (POM), and POM would represent a higher percentage of total SOC than the lower crop diversity systems. These contrasts are summarized on **Table 5c**. This is the hypothesis that is least supported by the data. Generally the contrasts were non-significant at the 5-10 cm depth for most of the analyses, nor were they significant at Lakeland. At Arlington, there was a clear tendency to find higher SOC, higher POM-C and a higher percentage of SOC that was POM when comparing the more diverse organic grain (CS3) and pasture systems (CS6) versus the less diverse conventional forage (CS4) and continuous corn (CS1) plots.

When we looked within the dairy systems (**Table 5d**), for SOC, POM-C, and % POM-C, the more diverse grazing system (CS6) generally had higher values than the less diverse conventional forage system (CS4) at both sites. Within the grain systems (Table 5d), the picture was less clear due to anomalous behavior of CS3. We noted earlier that although for the carbon and nitrogen variables, all the systems showed higher values at LAC than ARS, the organic grain system (CS3) was an exception. As a result, at Arlington the more diverse CS3 had significantly

higher SOC, POM-C and % POM-C than continuous corn (CS1), but this was not the case at Lakeland.

CONCLUSION

Cropping systems, after a relatively modest time after establishment (13 years), do alter soil carbon and nitrogen characteristics. This is particularly the case in the surface soil depths: 0 to 5 and 5 to 10 cm. Below 10 cm depth, few significant differences were observed. In this case the research was conducted on prairie derived silt loam soils at two locations, a somewhat poorly drained site (Lakeland Agricultural Complex) and at a well drained site (Arlington Research Station).

As might be expected, soil organic carbon, particulate organic matter, and the percentage of organic matter as POM were higher in the dairy-based systems than the grain-based systems. Intensity of tillage also modified organic matter characteristics, and systems without tillage had higher levels of SOC than those with tillage. It is more difficult to argue that the more diverse systems promoted higher levels of SOC, POM or % POM-C.

LITERATURE CITED:

Cambardella C.A., Elliott E.T. 1992. Particulate soil organic-matter changes across a grassland cultivation sequence. Soil Sci. Soc. Am. J. 56:777-783.

Chantigny, Angers, and Beauchamp. 1999. Aggregation and Organic Matter Decomposition in Soils Amended with De-Inking Paper Sludge. Soil Sci. Soc. Am. J. 63:1214-1221

Magdoff, F. and R. Weil. 2004. Soil organic matter management strategies. In (Eds) F. Magdoff and R. Weil. Soil Organic Matter in Sustainable Agriculture. CRC Press Boca Raton. 45-66pp

Paustian, K., W.J.Parton, and J.Persson. 1992. Modeling soil organic matter in organic-amended and nitrogen-fertilized long-term plots. Soil Sci. Soc. Am. J. 56:476-488.

Wander, M. 2004. Soil organic matter fractions and their relevance to soil function. In (Eds) F. Magdoff and R. Weil. Soil Organic Matter in Sustainable Agriculture. CRC Press Boca Raton, Florida. 67-102pp

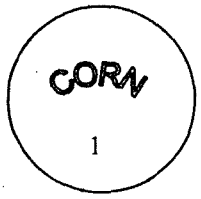
USDA-NRCS. 2002. National Agronomy Manual. Part 508-Soils

USDA-NRCS. 2004. Conservation Security Program. Federal Register. Vol 69:118:34533-34535

Fig. 1. Schematic drawing of cropping systems in the Wisconsin Integrated Cropping Systems Trial. Numbers within circles represent year of rotation.

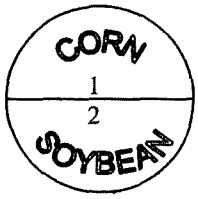
Cash Grain Cropping Systems:

CS1



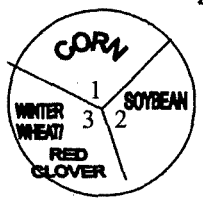
Continuous corn

CS2



No-till corn & soybeans

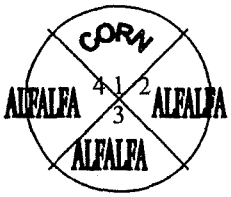
CS3



Organic grain rotation

Forage-based Cropping Systems:

CS4



"Green gold" alfalfa

CS5

Organic dairy rotation

CS6

Rotational Grazing

Figure 2a. Arlington Research Station (ARS) Site Map. Location of initial plots (1990)

414	CS4	T8	DS Alfalfa	408	CS2	T2	NR Soybeans
413	CS5	T11	Est. Alfalfa I	407	CS3	T6	WR Soybeans
412	CS1	T1	Continuous Corn	406	CS4	T9	Corn
411	CS3	T5	Wheat/red clover	405	CS6	T14	Pasture
410	CS5	T12	Oat/pea/alfalfa	404	CS4	T10	Est. Alfalfa II
409	CS4	T7	Est. Alfalfa I	403	CS5	T13	Corn
Restored prairie				402	CS3	T4	Corn
				401	CS2	T3	No-till Corn
				309	CS4	T10	Est. Alfalfa II
				308	CS4	T9	Corn
314	CS5	T12	Oat/pea/alfalfa	307	CS3	T5	Wheat/red clover
313	CS3	T6	WR Soybeans	306	CS1	T1	Continuous Corn
Restored prairie				305	CS4	T7	Est. Alfalfa I
				304	CS5	T11	Est. Alfalfa I
312	CS5	T13	Corn	303	CS2	T3	No-till Corn
311	CS4	T8	DS Alfalfa	302	CS6	T14	Pasture
310	CS2	T2	NR Soybean	301	CS3	T4	Corn
114	CS5	T13	Corn	214	CS2	T3	No-till Corn
113	CS4	T8	DS Alfalfa	213	CS5	T12	Oat/pea/alfalfa
112	CS6	T14	Pasture	212	CS3	T6	WR Soybeans
111	CS4	T7	Est. Alfalfa I	211	CS5	T13	Corn
110	CS5	T11	Est. Alfalfa I	210	CS4	T8	DS Alfalfa
109	CS1	T1	Continuous Corn	209	CS4	T7	Est. Alfalfa I
108	CS2	T2	NR Soybean	208	CS5	T11	Est. Alfalfa I
107	CS4	T10	Est. Alfalfa II	207	CS6	T14	Pasture
106	CS3	T5	Wheat/red clover	206	CS2	T2	NR Soybeans
105	CS4	T9	Corn	205	CS4	T10	Est. Alfalfa II
104	CS3	T4	Corn	204	CS1	T1	Continuous Corn
103	CS5	T12	Oat/pea/alfalfa	203	CS4	T9	Corn
102	CS3	T6	WR Soybeans	202	CS3	T5	Wheat/red clover
101	CS2	T3	No-till Corn	201	CS3	T4	Corn
A	CS3	50#N	Wheat/Red Clover	D	CS3	50#N	Corn w/starter
B	CS3		WR Soybeans	E	CS3	50#N	Wheat/Red Clover
C	CS3	50#N	Corn w/starter	F	CS3		WR Soybeans

Figure 2b. Lakeland Agricultural Complex (LAC) Site Map. Location of initial plots (1990)

101 CS1 T1	201 CS5 T23	301 CS4 T20	401 CS1 T1
102 CS15 18	202 CS4 T7	302 CS14 T19	402 CS15 T18
103 CS4 T7	203 CS2 T2	303 CS1 T1	403 CS4 T20
104 CS6 T14	204 CS3 T4	304 CS2 T2	404 CS3 T4
105 CS15 T22	205 CS3 T5	305 CS15 T18	405 CS5 T23
106 CS15 T21	206 CS2 T3	306 CS3 T6	406 CS3 T5
107 CS3 T5	207 CS15 T22	307 CS3 T5	407 CS3 T6
108 CS2 T2	208 CS3 T6	308 CS3 T4	408 CS6 T14
109 CS3 T4	209 CS15 T18	309 CS15 T22	409 CS2 T2
110 CS14 T19	210 CS1 T1	310 CS4 T7	410 CS2 T3
111 CS3 T6	211 CS15 T21	311 CS2 T3	411 CS4 T7
112 CS4 T20	212 CS14 T19	312 CS15 T21	412 CS15 T22
113 CS2 T3	213 CS6 T14	313 CS5 T23	413 CS15 T21
114 CS5 T23	214 CS4 T20	314 CS6 T14	414 CS14 T19

Table 1. Combined Soil Organic Matter Analysis of WICST Cropping Systems (4/2003). Probability that the F-test is significant

A. Main effect of Site (Arlington & Lakeland)

depth	Total SOC	Total N	POM C	POM N	% POM C	% POM N
0-5 cm	0.0210	0.0077	0.0017	0.0012	0.8966	0.6674
5-10 cm	0.0165	0.0044	0.0025	0.0001	0.4155	0.1458
10-20 cm	0.0021	0.0037	0.0216	0.0007	0.8548	0.4227

B. Main effect of Cropping System (Systems 1-4 & 6)

depth	Total SOC	Total N	POM C	POM N	% POM C	% POM N
0-5 cm	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001
5-10 cm	0.0633	0.0194	0.0001	0.0001	0.0001	0.0001
10-20 cm	0.5294	0.4229	0.0135	0.0038	0.0051	0.0007

C. Interaction of Site x System

depth	Total SOC	Total N	POM C	POM N	% POM C	% POM N
0-5 cm	0.2197	0.0743	0.0001	0.0001	0.0001	0.0001
5-10 cm	0.4610	0.1201	0.0043	0.0160	0.0070	0.0001
10-20 cm	0.8884	0.5256	0.9291	0.8145	0.9656	0.0766

Figure 3a. POM-C Site x System interaction (0-5 cm)

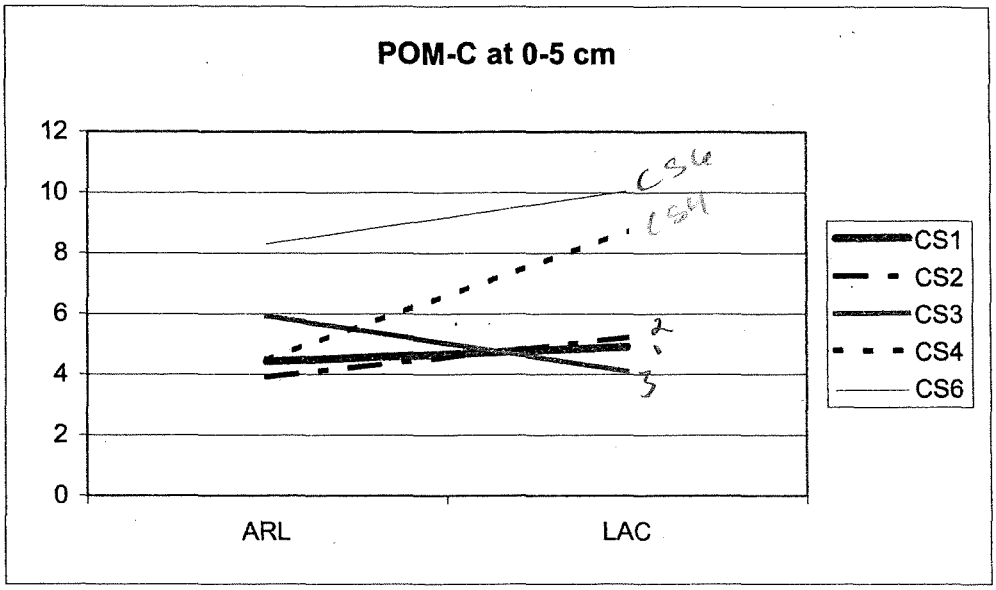


Figure 3b. POM-C Site x System interaction (5-10 cm)

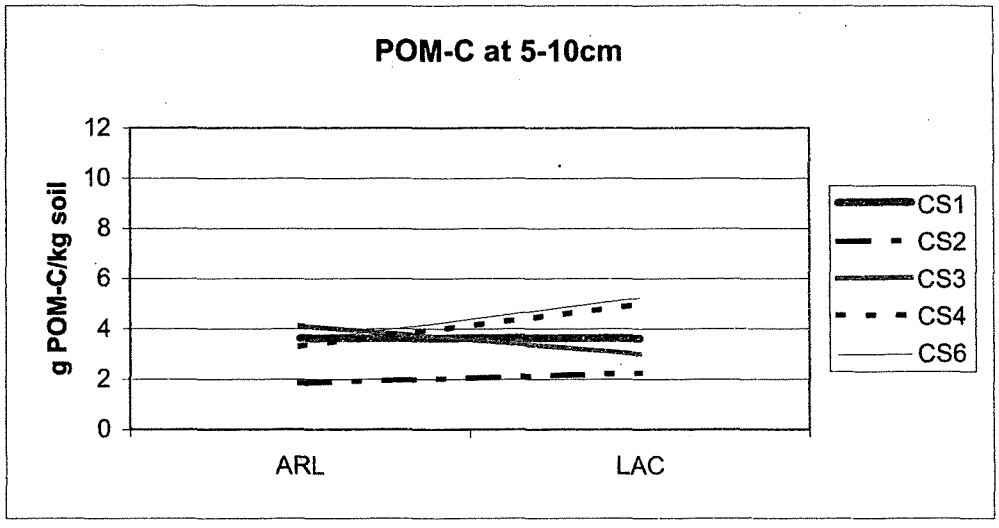


Table 2. Combined site analysis of systems 1-4 and 6
Means across sites *

System	Total g SOC/kg soil 0-5cm		5-10cm		10-20cm ns	g POM-C /kg soil 0-5cm		5-10cm		10-20cm		% POM C 0-5cm		5-10cm		10-20cm	
1.Cont. corn	29.54	c	27.98	b	24.93	4.67	c	3.63	ab	2.02	a	0.159	c	0.131	a	0.079	a
2. No-till Csb	30.05	bc	26.24	b	24.33	4.57	c	2.05	c	1.38	b	0.152	c	0.079	b	0.058	b
3. C-sb/w-w/rcl	30.48	bc	28.88	ab	26.39	5.02	c	3.56	b	2.33	a	0.165	c	0.125	a	0.088	a
4. A-A-A-C	34.70	b	31.17	ab	26.33	6.61	b	4.14	ab	1.95	a	0.187	b	0.134	a	0.075	a
6. Rot. graze	41.69	a	33.33	a	28.47	9.17	a	4.39	a	2.33	a	0.224	a	0.134	a	0.086	a

System	Total g N/kg/soil 0-5cm		5-10cm		10-20cm ns	g POM-N/kg of soil 0-5cm		5-10cm		10-20cm		% POM N 0-5cm		5-10cm		10-20cm	
1. Cont. corn	2.59	c	2.49	bc	2.25	0.301	c	0.234	b	0.136	a	0.118	c	0.095	b	0.061	b
2. No-till Csb	2.57	c	2.31	c	2.13	0.304	c	0.148	c	0.098	b	0.118	c	0.064	c	0.047	c
3. C-sb/w-w/rcl	2.64	c	2.55	bc	2.33	0.304	c	0.242	b	0.165	a	0.119	c	0.099	ab	0.072	a
4. A-A-A-C	3.06	b	2.79	ab	2.36	0.486	b	0.311	a	0.150	a	0.156	b	0.111	a	0.063	ab
6. Rot graze	3.68	a	2.97	a	2.50	0.640	a	0.317	a	0.168	a	0.180	a	0.109	a	0.071	ab

*** multiple range test (p=0.05)**

Figure 4a POM-N Site by System Interaction (0-5 cm)

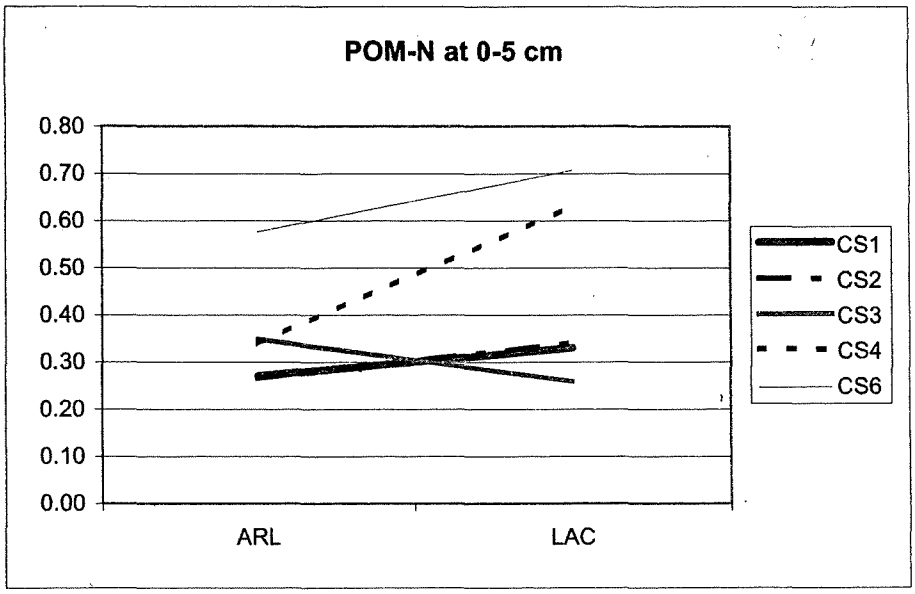


Figure 4b POM-N site by system Interaction (5-10 cm)

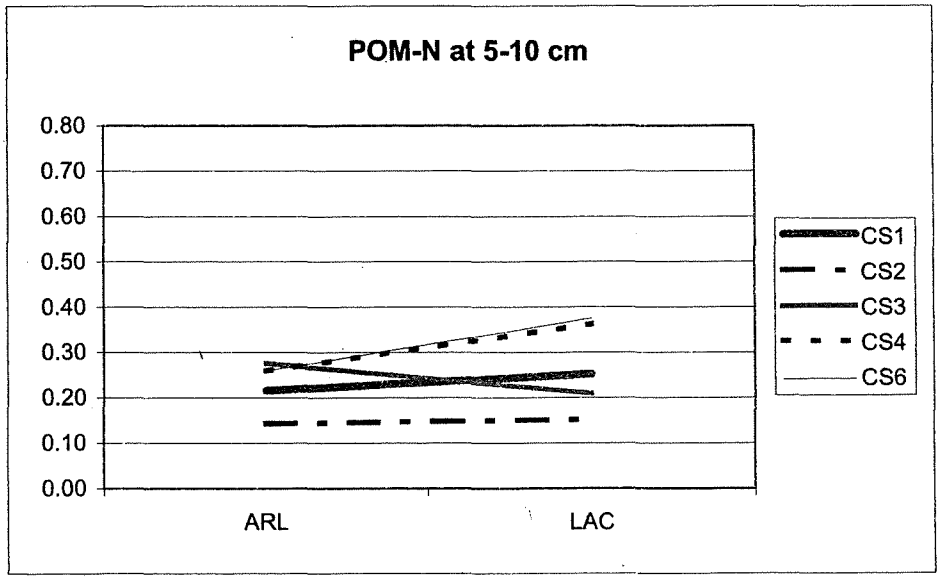


Table 3. SOC, POM and Total N analysis at Arlington (ARS)*

System	Total g SOC/kg soil						g POM-C/kg soil						% POM-C					
	0 to 5 cm		5 to 10 cm		10 to 20 cm		0 to 5 cm		5 to 10 cm		10 to 20 cm		0 to 5 cm		5 to 10 cm		10 to 20 cm	
1. Cont. corn	28.37	bc	26.95	ab	23.03		4.42	d	3.63	ab	1.88		0.158	c	0.139	a	0.079	
2. No-till Csb.	25.76	c	22.25	b	20.29		3.91	d	1.85	c	1.19		0.152	c	0.080	b	0.059	
3. C-sb/w-w/rcl	29.85	bc	27.77	b	23.9		5.94	b	4.13	a	2.01		0.198	b	0.150	a	0.085	
4. A-A-A-C	28.92	bc	26.91	ab	22.75		4.47	d	3.30	b	1.63		0.156	c	0.125	a	0.073	
5. C-o/p/a-A	31.71	b	30.13	a	25.31		5.21	c	3.89	ab	1.94		0.168	c	0.134	a	0.079	
6. Rot. Graze	37.67	a	29.25	a	26.35		8.30	a	3.53	ab	2.18		0.226	a	0.126	a	0.087	
p-value	*0.0010*		*0.0511*		*0.2375*		*0.0001*		*0.0001*		*0.1915*		*0.0001*		*0.0079*		0.2797	
grand mean	30.38		27.21		23.61		5.38		3.39		1.81		0.176		0.126		0.077	
HD prairie	30.02		24.30		20.95		5.92	a	3.13		1.58	a	0.197		0.135		0.080	
prairie corn	25.01		23.31		18.65		4.60	b	2.94		1.46	b	0.184		0.121		0.076	
p-value	*0.1138*		*0.5856*		*0.2874*		*0.0499*		*0.4890*		*0.0218*		*0.1603*		*0.2381*		*0.6142*	

System	Total g N/kg soil						g POM-N/kg soil						% POM-N					
	0 to 5 cm		5 to 10 cm		10 to 20 cm		0 to 5 cm		5 to 10 cm		10 to 20 cm		0 to 5 cm		5 to 10 cm		10 to 20 cm	
1. Cont. corn	2.23	b	2.17	b	1.87		0.271	c	0.215	b	0.119	ab	0.124	c	0.102	b	0.064	ab
2. No-till Csb	2.39	b	2.12	b	1.91		0.266	c	0.143	c	0.091	b	0.111	c	0.068	c	0.048	b
3. C-sb/w-w/rcl	2.37	b	2.22	b	1.93		0.349	b	0.276	a	0.149	a	0.147	b	0.126	a	0.078	a
4. A-A-A-C	2.91	a	2.69	a	2.24		0.349	b	0.259	a	0.123	ab	0.117	c	0.097	b	0.055	b
5. O/p/a-A-C	2.82	a	2.66	a	2.21		0.351	b	0.263	a	0.134	a	0.126	c	0.100	b	0.061	b
6. Rot. Graze	3.02	a	2.35	ab	2.11		0.577	a	0.259	a	0.159	a	0.196	a	0.114	ab	0.078	a
p-value	*0.0006*		*0.0086*		*0.1621*		*0.0001*		*0.0001*		*0.0354*		*0.0001*		*0.0002*		*0.0063*	
grand mean	2.62		2.37		2.05		0.359		0.236		0.129		0.137		0.101		0.064	
HD prairie	2.63		2.14		1.85		0.381		0.205		0.106		0.145		0.100		0.059	
prairie corn	2.18		2.06		1.66		0.285		0.195		0.097		0.130		0.090		0.058	
p-value	*0.0713*		*0.5290*		*0.2636*		*0.0891*		*0.6595*		*0.2570*		*0.1754*		*0.3196*		0.8029	

*** mulitple range test at (p=0.05)**

Table 4. SOC, POM and Total N analysis at Lakeland (LAC)*

	Total g SOC/kg soil					g POM-C/kg soil					% POM-C				
System	**0 to 5 cm**		**5 to 10 cm**		**10 to 20 cm**	**0 to 5 cm**		**5 to 10 cm**		**10 to 20 cm**	**0 to 5 cm**		**5 to 10 cm**		**10 to 20 cm**
1. Cont. corn	30.70	c	29.00		26.83	4.91	b	3.62	bc	2.15	0.161	b	0.123	a	0.078 a
2. No-till Csb	34.33	bc	30.23		28.38	5.23	b	2.26	c	1.58	0.153	bc	0.075	c	0.058 b
3. C-sb/w-w/rcl	31.10	bc	30.00		28.90	4.09	b	2.99	c	2.64	0.132	c	0.100	b	0.092 a
4. A-A-A-C	40.48	ab	35.43		29.90	8.74	a	4.98	ab	2.27	0.218	a	0.143	a	0.078 a
6. Rot. Graze	45.71	a	37.40		30.59	10.04	a	5.24	a	2.47	0.223	a	0.141	a	0.085 a
p-value	*0.0240*		*0.2768*		*0.9243*	*0.0001*		*0.0031*		*0.1153*	*0.0001*		*0.0001*		*0.0113*
grand mean	36.47		32.41		28.91	6.60		3.81		2.22	0.177		0.116		0.078

	Total g N/kg soil					g POM-N/kg soil					% POM-N				
System	**0 to 5 cm**		**5 to 10 cm**		**10 to 20 cm**	**0 to 5 cm**		**5 to 10 cm**		**10 to 20 cm**	**0 to 5 cm**		**5 to 10 cm**		**10 to 20 cm**
1. Cont. corn	2.94	b	2.81	b	2.63	0.331	b	0.252	bc	0.152	0.113	cd	0.088	bc	0.057 ab
2. No-till Csb	2.76	b	2.50	b	2.34	0.342	b	0.152	c	0.106	0.124	c	0.061	d	0.046 b
3. C-sb/w-w/rcl	2.90	b	2.88	ab	2.72	0.259	b	0.209	c	0.181	0.090	d	0.073	cd	0.067 a
4. A-A-A-C	3.22	b	2.90	ab	2.49	0.632	a	0.363	ab	0.176	0.195	a	0.126	a	0.071 a
6. Rot. Graze	4.34	a	3.60	a	2.89	0.708	a	0.375	a	0.176	0.164	b	0.104	b	0.063 a
p-value	*0.0027*		*0.0933*		*0.5929*	*0.0001*		*0.0040*		*0.1173*	*0.0001*		*0.0002*		*0.0313*
grand mean	3.23		2.94		2.61	0.454		0.270		0.158	0.137		0.090		0.061

*** multiple range test (p=0.05)**

Table 5a. Linear contrasts comparing dairy-based vs grain based system effects on soil organic matter characteristics

	Total g SOC/kg of soil					
	Combined analysis		ARS analysis*		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS 4, CS 5* CS6	38.2	0.0001	32.8	0.0001	43.1	0.0001
CS1, CS2, CS3	30		28		32	
5-10 cm depth						
CS4, CS5*, CS6	32.3	0.0010	29.8	0.0025	36.4	0.0001
CS1, CS2, CS3	27.7		25.7		29.7	

	g POM-C/kg of soil					
	Combined analysis		ARS analysis*		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS 4, CS 5* CS6	7.9	0.0001	6.0	0.0001	9.4	0.0001
CS1, CS2, CS3	4.8		4.8		4.7	
5-10 cm depth						
CS4, CS5*, CS6	4.2	0.0001	3.6	0.0090	5.1	0.0001
CS1, CS2, CS3	3.1		3.2		3.2	

	% POM-C					
	Combined analysis		ARS analysis*		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS 4, CS 5* CS6	20.6	0.0001	18.3	0.0160	22.1	0.0001
CS1, CS2, CS3	15.9		16.9		14.9	
5-10 cm depth						
CS4, CS5*, CS6	13.4	0.0001	12.8	0.4800	14.2	0.0001
CS1, CS2, CS3	11.2		12.3		9.9	

*** CS5 was present at ARS, but not LAC so is only included in contrasts at ARS**

Table 5b. Linear contrasts comparing the effect of tillage vs no-tillage on soil organic matter characteristics

	Total g SOC/kg of soil					
	Combined analysis		ARS analysis*		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS1, 3, 4, 5*	31.6	0.0001	29	0.0500	34.1	0.0001
CS2, CS6	35.9		31.7		40	
5-10 cm						
CS1, 3, 4, 5*	29.3	0.6000	27.2	0.0390	31.5	0.1000
CS2, CS6	29.8		25.8		33.8	

	g POM-C/kg of soil					
	Combined analysis		ARS analysis*		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS1, 3, 4, 5*	5.4	0.0001	5	0.0001	5.9	0.0010
CS2, CS6	6.9		6.1		7.6	
5-10 cm						
CS1, 3, 4, 5*	3.8	0.0001	3.7	0.0001	3.9	0.5600
CS2, CS6	3.2		2.7		3.8	

	% POM-C					
	Combined analysis		ARS analysis*		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS1, 3, 4, 5*	17	0.0002	17	0.0023	17	0.0100
CS2, CS6	18.8		18.9		18.8	
5-10 cm						
CS1, 3, 4, 5*	13	0.0001	13.7	0.0001	12.2	0.0010
CS2, CS6	10.6		10.3		10.8	

*** CS5 was present at ARS, but not LAC so is only included in contrasts at ARS**

Table 5c. Linear contrasts comparing the effect of high crop diversity vs. low crop diversity on soil organic matter characteristics

Total g C/kg of soil

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS3, CS6	36.1	0.0001	33.8	0.0001	38.4	0.6500
CS1, CS4	32.1		28.6		35.6	
5-10 cm depth						
CS3, CS6	31.1	0.1060	28.5	0.1900	33.7	0.3400
CS1, CS4	29.6		26.9		32.2	

g POM-C/kg of soil

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS3, CS6	7.1	0.0001	7.1	0.0001	7.1	0.4900
CS1, CS4	5.6		4.4		6.8	
5-10 cm depth						
CS3, CS6	4	0.5400	3.8	0.0300	4.1	0.4100
CS1, CS4	3.9		3.5		4.3	

% POM-C

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS3, CS6	19.5	0.0001	21.2	0.0001	17.8	0.1000
CS1, CS4	17.3		15.7		19	
5-10 cm depth						
CS3, CS6	13	0.4900	13.8	0.4400	12.1	0.0080
CS1, CS4	13.3		13.2		13.3	

Table 5d. Linear Contrasts comparing the effect of high crop diversity vs low crop diversity on soil organic matter within dairy and grain systems

Total g SOC/kg soil in dairy systems

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS6	41.7	0.0001	37.7	0.0001	45.7	0.0170
CS4	34.7		28.9		40.5	

g POM-C/kg of soil in dairy systems

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS6	9.2	0.0001	8.3	0.0010	10.04	0.0120
CS4	6.6		4.5		8.74	

% POM-C in dairy systems

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS6	22.4	0.0001	22.6	0.0001	22.3	0.6300
CS4	18.7		15.6		21.8	

Total g SOC/kg of soil in grain systems

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS3	30.5	0.4700	29.9	0.3700	31.1	0.8500
CS1	29.5		28.4		30.7	

g POM-C/kg of soil in grain systems

	Combined analysis		ARS analysis		LAC analysis	
0-5 cm depth	mean	probability	mean	probability	mean	probability
CS3	5	0.2400	5.94	0.0001	4.09	0.1100
CS1	4.7		4.42		4.91	

% POM-C in grain systems

	Combined analysis		ARS analysis		LAC analysis	
	mean	probability	mean	probability	mean	probability
0-5 cm depth						
CS3	16.5	0.4100	19.8	0.0001	13.2	0.0070
CS1	15.9		15.8		16.1	

FORAGE VALUE OF MIDSTORY SHRUBS FOUND IN DEGRADED OAK SAVANNAS

Janet Hedtcke[1], Joshua Posner[2] and Ken Albrecht[2], and Martha Rosemeyer[3]

Key Index Words: grazing, shrub quality, oak woodland, Scottish Highland cattle

---

Submitted to Rangeland Ecology and Management in September 23, 2005.

Authors are: [1]Research specialist, [2]Professors, Agronomy Dept., University of Wisconsin, Madison, WI 53706; and [3]Professor, Evergreen State College, Olympia, WA, 98505

Research was funded in part by: Multi-Agency Land and Water Education Grant Program/Environmental Quality Incentives Program (USDA-NRCS), Partnership for Wildlife Program (WI DNR), and University of Wisconsin System Consortium Grant Program.

Correspondence: Janet Hedtcke, Agronomy Dept., UW-Madison, Madison, WI 53706. Email: jlrieste@wisc.edu

Manuscript received ----------.

Manuscript accepted ----------.

FORAGE VALUE OF MIDSTORY SHRUBS FOUND IN DEGRADED OAK SAVANNAS

ABSTRACT

Oak (*Quercus* spp.) savanna, once a dominant grassy ecosystem of the southern Wisconsin has become very rare due the clearing of vast areas for agriculture. The absence of grazing and burning along with the arrival of new invasive species has resulted in severe degradation of most of the remaining patches of this ecosystem. Research was undertaken to see if grazing cattle would contribute to restoration of oak savanna structure. In this paper we report on the forage quality of the shrub layer. This study took place at three sites in southwestern Wisconsin. Shrub species included prickly ash (*Xanthoxylem americana* P. Mill), gooseberry (*Ribes* spp.), gray dogwood (*Cornus racemesa* L.), multiflora rose (*Rosa multiflora* Thunb. ex Murr.), berries (*Rubus* spp.) and wild parsnip (*Pastinaca sativa* L.). Leaf biomass was collected pre-grazing in June 2001 and 2002 and analyzed for crude protein (CP), fiber, in vitro total digestibility (IVTD) and minerals (P, K, Ca, Mg). Animals were observed frequently to determine eating and behavior patterns. Cattle chose a diverse diet, equally mixed with shrub leaves, grass, and herbaceous forbs. Prickly ash and *Rubus* spp. were the most frequently browsed shrubs accounting for more than 60% of shrub and tree species eaten. Across years, prickly ash and *Rubus* spp. also had the highest CP (19.0%) while multiflora rose and dogwood had the lowest levels (12.0%). All shrubs had high IVTD when compared to alfalfa (*Medicago sativa* L), with prickly ash and wild parsnip ranking the highest, approaching 85%. Microorganisms collected from the rumen of Scottish Highland (*Bos taurus* spp.) or Angus (*Bos taurus* spp.) cattle had similar capacity to digest the six shrub species evaluated. We found that the invasive shrub layer provides nutritional support for beef cattle under rotational grazing. Continued application of managed grazing and some mechanical thinning would further reduce the shrub layer, possibly releasing the production of native prairie grasses and forbs once present in healthy oak savannas.

INTRODUCTION

Oak savanna, characterized by widely scattered oaks with an understory of herbaceous prairie grass and forb species is now one of Wisconsin's rarest ecosystems with less than 620 acres of intact savanna remaining (Henderson 1995). Grassland ecologists agree that the loss of oak savanna can be attributed to clearing and plowing and cessation of fire and grazing (Henderson 1995; Anderson 1998; Bowles and McBride 1998). Most existing oak savannas are highly degraded with a thick, impenetrable layer of shrubs in the under and mid-story allowing little sunlight penetration. Removing these shrubs and thus increasing light penetration could partially restore these oak savannas, as well as expand the pasture base for some landowners. Further, while the feed production might be modest, an oak savanna or oak woodland can offer livestock protection from harsh weather i.e. shade on the hottest days of summer and windbreak in the winter.

Fire and grazing are two mechanisms that may be used for savanna recovery. Fire is not always successful at reducing dense shrubs (Haney and Apfelbaum 1993) and may subject farmers to serious liability issues. Continuous grazing is problematic in that it causes soil compaction (Van Haveren 1983, Dudley et al. 2002), and promotes erosion (Fleischner 1994, Gifferd et al. 1977). Managed (rotational) grazing, however, has not been thoroughly tested in restoring oak savanna structure and it may be a potential conservation management tool if the initial shrub quantity and quality can maintain animal performance. The overall objective of this study was to determine the effectiveness of rotational grazing and fire on reducing the shrub layer in degraded oak savannas thereby restoring their openness. Anecdotal information suggest that Scottish Highland cattle are good browsers that make them an ideal choice for grazing rough habitat such as the overgrown shrub layer of degraded oak savanna. In this paper, we will describe the shrub quality and diet selection by cattle grazing various shrubs common to degraded oak savannas.

MATERIALS AND METHODS

This study took place at three sites in southern Wisconsin: Yellowstone Lake Wildlife Area (YLWA) in Lafayette County, owned and managed by the Wisconsin Department of Natural Resources (WDNR); Prairie Oaks Farm, also in Lafayette County; and Creag-Is-Daru Farm, in Iowa County. Current conditions at the three sites reflect soil differences and past land use history. Prairie Oaks Farm is a shrub-infested oak woodland, dominated by bur (*Quercus macrocarpa*) and/or white oak (*Quercus alba*). YWLA was once savanna that has been highly degraded by encroaching shrubs and invasive species. Soils (Dubuque silt loam >12% slope) at these two sites are well-drained and shallow. Creag-Is-Daru Farm is the least degraded of all sites with significant oak savanna components present. The soil there (Northfield sandy loam, > 12% slope) is well drained, shallow, and sandy. Each site had remnant prairie patches with species common to historic tall grass prairie-oak savanna regions of southern Wisconsin. The soil test values for each site are reported in Table 1. YLWA and Prairie Oaks Farm are on higher fertility and higher organic matter soils, and were not brought under the plow primarily due to the steep slopes. At Craeg-Is-Daru, the soils are acidic and have lower soil fertility and not conducive to row-crop agriculture.

The field experimental design was a randomized complete block with five replicates at each site. Plots were one acre in size. Grazing with Scottish Highland cattle (*Bos taurus* spp.) for about two days per month with six animal units/a (1 au =1000 lbs) occurred from June to September in

2001 and 2002. Shrub species that were most prevalent at each site were chosen for analysis. The shrub species at YLWA were prickly ash, gooseberry, and gray dogwood. An additional treatment of fire (annually burned in April or not burned) was included at YLWA since prescribed burns are commonly practiced on publicly managed lands. Due to species and treatment differences between YLWA and on-farm, they were analyzed separately. On-farm shrub species were prickly ash, multiflora rose (Prairie Oaks Farm), and berries and wild parsnip (Creag-Is-Daru Farm). Although wild parsnip is not a shrub, it was included because of its notoriety among herbaceous plants, and cattle readily grazed it.

Before grazing occurred, shrub leaves were hand-stripped from the branches in late June each year to determine nutritional content. Samples were taken randomly from the test plots from each replication with an effort to sample that which the cattle were likely to browse (based on observation), avoiding woody stems or canes. Samples were analyzed for CP using macro-Kjeldahl method to determine N, then multiplying N by 6.25 (AOAC 1990). Neutral detergent fiber (NDF) was analyzed according to Goering and Van Soest 1970; Van Soest et al. 1991; Mertens 2002. In-vitro true digestibility (IVTD) was used to measure forage digestibility with adaptations from various methods: Goering and Van Soest 1970; Marten and Barnes 1979; Craig et al. 1984; and Tilley and Terry 1963. Forage samples, including alfalfa lab standards, were simultaneously tested for digestibility using both Scottish Highland and Angus rumen fluid. Forage IVTD was measured only in 2001 due to the complexity and cost associated with the assay and finding no differences between cattle type. Phosphorus (P) was analyzed as dry ash by spectrophotometer; potassium (K), calcium (Ca) and magnesium (Mg) were determined as dry ash by atomic absorption.

Cattle behavior, feeding choice, and location data were recorded throughout the summer within each block at each site in both years. All animals were observed either directly or with binoculars for 5-minute periods with feeding or behavioral data recorded every 15 seconds. Total number of cow and steer observations were 6080 and 13960, respectively. Observations were conducted in the cooler parts of the day (early morning or late afternoon) and primarily during day 1 on the plot when there was the greatest grazing selection.

Data were analyzed with SAS 8.2© using Proc Mixed. Assumptions of normality and homogenous variances were confirmed using PROC UNIVARIATE and PROC PLOT of the residuals vs. predicted values. All effects were fixed except block (replicate). LSMEANS were computed and LSDs ($P < 0.05$) were used to compare differences across means.

RESULTS

Protein and Energy

Shrub quality (CP, NDF, IVTD) ranged from moderately good to excellent and was comparable to alfalfa samples analyzed concurrently (Table 2). Since there was no difference between savanna management treatments (fire vs. control) and there was no interaction with year and species, the combined data is presented in Table 2. Year was significantly different ($P < 0.05$) with CP being higher and NDF lower in 2002 across most species (data not shown). Crude protein level averaged across shrub species was 19.4 and 17.5% on-farm and at YLWA, respectively in 2002 and 12.9 and 12.8% on-farm and at YLWA, respectively in 2001. Neutral

detergent fiber was about 3.5 percentage units lower in 2002 vs. 2001 at each site. Although June precipitation was similar between years and to the 30-yr normal, May of 2002 was dry (2.66" in 2002 vs. 6.16" in 2001) resulting in slower maturing and younger forage at the time of sampling, partially explaining the increased CP and decreased NDF.

On-farm, prickly ash and *Rubus* spp. had the highest CP while multiflora rose had the lowest (Table 2). Prickly ash at YLWA was significantly higher than the other shrubs and gray dogwood ranked the lowest in CP in both years at that site.

Neutral detergent fiber levels of most of the shrubs on-farm and at YLWA were comparable to that of high quality alfalfa with wild parsnip, gray dogwood and gooseberry having the lowest NDF. There is, a minimum amount of fiber needed for proper rumen function and some shrubs, like dogwood, are very low in effective fiber and if the only source of forage, could cause a problem.

Digestible energy, measured as IVTD, was also high across species, averaging 75% and ranging from 64.5% to 84.9% on-farm; prickly ash and wild parsnip (84.2%) were significantly higher than the *Rubus* species and multiflora rose (66.0%). The lower IVTD for *Rubus* spp. might be explained by a higher proportion of stems or juvenile canes mixed in the sample vs. mostly leaves in the sample of the other shrubs. Our observation was that cattle consumed juvenile berry canes but not much stem from other shrubs. At YLWA, IVTD of prickly ash (84.8%) was significantly higher than gooseberry (78.4%). Microorganisms collected from the rumen of Scottish Highland (*Bos taurus* spp.) or Angus (*Bos taurus* spp.) cattle had similar capacity to digest the six shrub species evaluated.

Macro Minerals (P, Ca, K, Mg)

Phosphorus concentration in shrubs was not different between years at either YLWA or on-farm (data not shown). However, shrub species showed considerable variation in P. Wild parsnip, followed by prickly ash ranked highest and *Rubus* spp. and multiflora rose ranked lowest in P on-farm, while prickly ash ranked highest and gray dogwood lowest at YLWA (Table 2). Alfalfa typically has 0.21 to 0.33% P, with higher levels in younger plants (Table 2).

Species at YLWA had significantly higher levels of Ca in 2001 than 2002 but year was not significant for on-farm vegetation. Dogwood, low in P and K, ranked highest in Ca concentration. On the farm with acidic soil and low organic matter, Ca levels were very low in *Rubus* spp. Most of the shrub Ca levels fell in the range of immature and mature alfalfa (Table 2).

Potassium concentrations in shrubs were similar over years ($P < 0.05$). Potassium levels in gooseberry at YLWA were higher in 2001 (3.2%) than 2002 (2.6%) suggesting that this species exhibited luxury consumption in a wet spring resulting in soil solution with high available K. Potassium levels of species ranked similar to P levels on-farm (Table 2). Very low K levels were found in gray dogwood (0.91%) and gooseberry had the highest K at YLWA (Table 2).

Prickly ash ranked lowest of all shrubs in Mg at both on-farm and YLWA. Wild parsnip was particularly high in Mg with less difference between the remaining shrubs and all of the shrubs tested higher in Mg than alfalfa (Table 2).

Cattle Observations

The Scottish Highland cattle spent the majority of their time (>65%) in the wooded area of the plots and less time in the open, grassy area. Trampling and rubbing of trees and shrubs was common among the cows. They seemed to choose a diverse diet of plants including leaves from shrubs and trees, grasses and forbs (Fig. 1). Cows used their horns to knock down small trees and to open up dense shrub groves. Cows were observed to walk down small trees to reach the leaves. Prickly ash and *Rubus* spp. were browsed most frequently, accounting for over 50% of the total shrubs consumed. The cattle ate leaves of most shrubs present, but consumed minimal amounts on multiflora rose, gooseberry and dogwood, all of which ranked lower in quality than prickly ash and *Rubus* spp. Cows preferred the shrub layer more so than the yearling steers (34 vs. 21%); steers preferring more forbs than shrubs (data not shown). Reasons for this are likely the cows' larger body size and bigger horns allowing them at reach or access more leaves of trees and shrubs. Also, the energy requirements of growing steers are greater than mature cows, and the greater sward density of the forbs could provide greater energy intake.

DISCUSSION

According to the Nutrient Requirements of Beef Cattle (1996), growing or finishing cattle gaining over 2 lb/day generally need on average 12 to 13% of CP (on a dry matter basis) in the feed they consume. All shrubs were highly digestible and as long as quantity is not limiting, beef cattle would meet their energy requirement. Crude protein and IVTD levels of shrubs in our study were adequate for many classes of cattle.

Calcium and P, important for bones, teeth, and reproduction are required by beef cattle in concentrations from 0.38 to 0.70 and 0.17 to 0.37 % of DM, respectively, depending on class of animal (Beef NRC 1996). All shrubs in our study test sufficient-to-high in Ca, and P levels were sufficient (Table 2). K is an important cation in intracellular fluid and cell functions and is often abundant in forages, with levels above 2% in alfalfa (Table 2). With the exception of multiflora rose and dogwood, which were low-to-deficient in K, the other shrubs tested sufficient-to-high in K. Magnesium, important for many enzyme function and all biosynthetic processes, is needed at levels of 0.10 to 0.20% of DM, increasing from growing or finishing cattle to lactating cows (Beef NRC 1996) and tested slightly higher than alfalfa.

Not only are these species more than adequate for beef cattle nutrition, they are high compared to most other browse species. Mineral concentrations from 14 browse species in northern Mexico were found to be at their highest levels in spring and summer; however, none of them matched the species sampled in our study (Ramirez 2001). With just one sampling period in our study, it is hard to say how mineral levels would change but it seems safe to assume that mineral levels are at their highest in the late spring when soils are moist and microbial decomposition is active. Assuming this, mineral supplementation would be required if dogwood was a major shrub to be grazed since it has such low P and K concentrations in late spring.

Mitchell and Rodgers (1985) working in Idaho had similar findings to our own, and estimated that cattle preferred to spend more time in July in shrubs vs. pasture (70 vs. 30%). Kirby and Stuth (1982) and Kirby and Parman (1986) however, reported that grasses dominated (>65%) diets across seasons in esophygeally fistulated beef cattle when grazing mixed prairie or brush managed pastures. Likewise, Rutagwenda et al. (1990) found that cattle grazing in semiarid Kenya, favored grasses, irrespective of season, with > 90% of the total feeding time spent on grasses. It is possible that there may exist palatability differences among various shrubs. For example, high tannin levels common in many tropical shrub species have been shown to reduce intake (Barahona et al., 1997). An explanation for the difference between our findings and these other studies may be due to the longhaired cattle used in our study moving to the cooler, shaded areas of the plots where there is less grass and more shrubs present. Although forage digestibility was similar between Scottish Highland and Angus cattle, Scottish Highland cattle may have greater browsing habits than the more common domestic beef cattle such as Angus or Hereford. Our observations support local belief that this breed is an effective browser. It is not known what other cattle breeds or livestock species would consume if put in a similar environment. Similar to our observations, Mitchell and Rodgers (1985) observed cattle walking down branches of willow (*Salix* spp.) plants so the leaves could be reached and consumed. In a sister study to ours, Harrington and Kathol (in press) reported grazing caused significant reduction in stem density for *Corylus Americana* (hazelnut), *Rubus* spp., prickly ash and others but not for gray dogwood or *Ribes* spp. The small leaf-to-stem ratio of *Ribes* spp. and multiflora rose may account for the lack of grazing effect on stem density but gray dogwood, which does not have thorns and has high leaf-to-stem ratio may have anti-quality factors affecting intake.

CONCLUSIONS

With the cessation of fire and grazing, natural succession has led to a degraded state of most of the oak savanna that once existed on so many acres in pre-settlement Wisconsin. Managed grazing in these degraded savannas could serve the dual purpose of providing livestock feed and shelter and at the same time restoring oak savanna structure. Shrub forage quality, sampled in early summer was good-to-excellent for most species tested. With the diversity of species that exist in degraded oak savannas and woodlands and associated pastures, cattle should be able to choose the higher quality species to maximize performance. Our expectation is that with repeated grazing episodes, and perhaps some mechanical thinning, light would penetrate the understory, releasing the native vegetation associated with healthy savannas.

ACKNOWLEDGEMENTS

The authors express appreciation to our collaborators on the project including Ron and Sally Niemann and Peter and Mary Rathbun, cattle and land owners, Bruce Folley, Wis DNR, YLWA land manager, Peggy Compton, UW Extension, Emily Kathol, UW-Madison Graduate student, John Harrington, UW-Madison, Tom Hunt and Marlene Sorenson, UW-Platteville and Ed Bures, UW-Madison, Agronomy Dept.

LITERATURE CITED

Association of Official Analysts and Chemists (AOAC). 1990. Protein (crude) determination in animal feed: copper catalyst Kjeldahl method (98413). Official Methods of Analysis 15th Edition.

Anderson, R.C. 1998. Overview of Midwestern oak savanna. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 86:1-18.

Barahona, R., C. E. Lascano, R. Cochran, J. Morrill and E. C. Titgemeyer. 1997. Intake, digestion, and nitrogen utilization by sheep fed tropical legumes with contrasting tannin concentration and astringency. Journal of Animal Science. 75:1633-1640.

Bowles, M.L., and J.L. McBride. 1998. Vegetation composition, structure, and chronological change in a decadent Midwestern North American savanna remnant. Natural Areas Journal 18:14-27.

Craig, W.M., B.J. Hong, G.A. Broderick, and R.J. Bula. 1984. In vitro inoculum enriched with particle-associated microorganisms for determining rates of fiber digestion and protein degradation. Journal of Dairy Science. 67:2902-2909.

Dudley, D.M., K.W. Tate, N.K. McDougald, and M.R. George. 2002. Factors influencing soil-surface bulk density on oak savanna rangeland in the southern Sierra Nevada foothills. USDA Forest Service General Technical Report PSW-GTR-184.

Gifferd, G.F., R.H. Faust, and G.B. Coltharp. 1977. Measuring soil compaction on rangeland. Journal of Range Management. 30:457-461.

Goering, H.K., and P.J. Van Soest. 1970. Forage Fiber Analysis (Apparatus Reagents, Procedures, and Some Applications). USDA Agr. Handbook No. 379. 20 p.

Gonzalez, C.L. and J.H. Everitt. 1982. Nutrient contents of major food plants eaten by cattle in the south Texas plains. Journal of Range Management. 35:733-736.

Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology. 8:629-644.

Haney, A., and S.I. Apfelbaum. 1993. Characterization of Midwestern oak savanna. In F. Stearns and K. Holland, eds. Proceedings of the Midwest Oak Savanna Conference, Chicago, Illinois. U.S. Environmental Protection Agency.

Harrington, J., and E. Kathol. In press. Responses of shrub midstory and herbaceous layers to grazing and fire in a Wisconsin shrub-infested savanna and prairie landscape. Submitted to Restoration Ecology. August 2005.

Henderson, R. 1995. Oak savanna communities in Wisconsin Biodiversity as a Management Issue: A Report to Department of Natural Resources Managers. Wisconsin Department of Natural Resources, Madison, WI.

Kirby, D.R., and M. Parman. 1986. Botanical composition and diet quality of cattle under a short duration grazing system. Journal of Range Management. 39:509-512.

Kirby, D.R. and J.W. Stuth. 1982. Botanical composition of cattle diets grazing brush managed pastures in east-central Texas. Journal of Range Management. 35:434-436.

Marten, G.C. and R.F. Barnes. 1979. Prediction of energy digestibility of forages with in-vitro rumen fermentation and fungal enzyme systems. P. 61-71 *In* W.J. Pigden et al. (ed.) Proc. Int. Workshop on Standardization Anal. Methodology Feeds, IDRC-134e, Ottawa, Canada. 12-14 Mar. 1979. Unipub, New York.

Mertens, D.R. 2002. Gravimetric determination of amylase-treated neutral detergent fiber in feeds using refluxing in beakers or crucibles: Collaborative study. Journal of the AOAC International. 85:1217-1240.

Mitchell, J.E. and R.T. Rodgers. 1985. Food habits and distribution of cattle on a forest and pasture range in northern Idaho. Journal of Range Management 38:314-220.

National Research Council. 2001. Nutrient Requirements of Dairy Cattle, Seventh Rev. Ed. Washington, D.C.: National Academy Press.

National Research Council. 1996. Nutritional Requirements of Beef Cattle, Seventh Rev. Ed. Washington, DC.: National Academy Press.

Ramirez, R. G., G. F. W. Haenlein, and M. A. Nunez-Gonzalez. 2001. Seasonal variation of macro and trace mineral contents in 14 browse species that grow in northeastern Mexico. Small ruminant research: The Official Journal of the International Goat Association. 39:153-159.

Rutagwenda, T., M. Lechner-Doll, H.J. Schwartz, W. Schultka, and W. von Engelhardt. 1990. Dietary Preference and degradability of forage on a semiarid thornbush savannah by indigenous ruminants, camels and donkeys. Animal Feed Science and Technology. 31:179-192.

Shinde, A. K., S. K. Sankhyan, R. Bhatta, and D. L. Verma. 2000. Seasonal changes in

nutrient intake and its utilization by range goats in a semi-arid region of India. The Journal of Agricultural Science. 135:429-436.

Tilley, J.M. and R.A. Terry. 1963. A two-stage technique for the digestion of forage crops. Journal of British Grassland Society. 18:104-111.

Van Haveren, B.P. 1983. Soil bulk density as influenced by grazing intensity and soil type on a shortgrass prairie site. Journal of Range Management. 36:586-589.

Van Soest, P.J., J.B. Robertson, and B.A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. Journal of Dairy Science. 74:3583-3597.

Table 1. Baseline routine soil tests to 15-cm depth from the three study sites.

Site	Soil Test P (ppm)	Soil Test K (ppm)	Organic matter %	pH
YLWA	20	141	6.0	7.0
Prairie Oaks	33	153	7.6	6.8
Creag-is-Daru	29	71	2.8	4.9

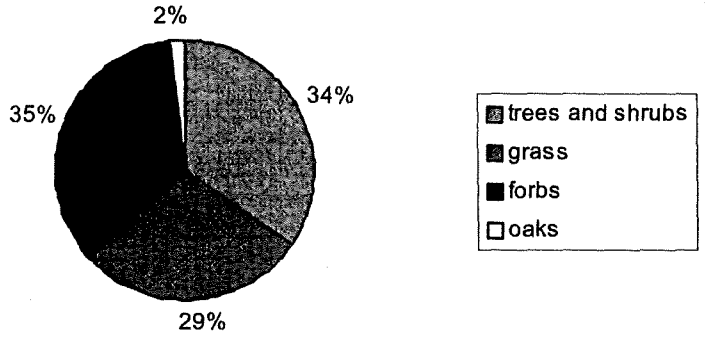
Table 2. Quality of various shrub species from on-farm and YLWA averaged across replicates and years plus alfalfa checks for comparison.

Site	Species	%CP	%NDF	%IVTD	%P	%Ca	%K	%Mg
On-farm								
	Rubus spp.	18.1a	39.6a	67.4b	0.25c	0.80c	1.75c	0.46b
	Multiflora rose	11.7c	40.1a	64.5b	0.25c	1.46a	1.48c	0.35c
	Prickly ash	20.0a	36.7ab	84.9a	0.31b	1.63a	2.27b	0.35c
	Wild parsnip	14.9b	32.5b	83.5a	0.48a	1.28b	2.88a	0.64a
	LSD ($P < 0.05$)	2.7	5.6	4.8	0.05	0.18	0.44	0.03
YLWA								
	Prickly ash	18.8x	38.1x	84.5x	0.28x	1.45z	2.14y	0.28z
	Gray Dogwood	12.3y	24.1z	80.3y	0.21z	1.76x	0.91z	0.41x
	Gooseberry	14.3y	30.8y	78.4y	0.24y	1.59y	2.88x	0.35y
	LSD ($P < 0.05$)	2.0	2.9	3.5	0.02	0.14	0.16	0.04
Alfalfa Checks								
	Immature	23.1	33.3	80.3	0.33	1.50	2.51	0.21
	Mature	16.9	46.9	70.8	0.21	1.18	2.07	0.22

1 Different letters in same column show significant differences at $P < 0.05$

2 Checks pertain to lab standards from K. Albrecht's lab tested frequently over 4 years.

Fig 1. Percent of time cattle spent eating various components of degraded oak savanna.



1

USING CATTLE TO REDUCE OAK SAVANNA UNDERSTORY SHRUB ABUNDANCE: STOCKING RATES AND WEIGHT GAINS

Janet L. Hedtcke*, Joshua L. Posner, and Martha Rosemeyer
Dept. of Agronomy, UW-Madison,
1575 Linden Dr., Madison, WI 53706

Submitted to the 2004 North American Prairie Conference Proceedings (Eds. D. Egan and J. Harrington) on September 29, 2005.

ABSTRACT

Oak (*Quercus* spp.) savanna, characterized by widely scattered oaks with an understory of prairie species is one of the most endangered native ecosystems in North America. The absence of grazing and burning along with the introduction of tillage agriculture are key factors for the loss of this ecosystem. Our objective was to determine the effectiveness of rotational grazing to reduce the shrub layer in degraded oak savannas. This study took place at 3 sites in southwestern Wisconsin. In this paper we will report on the results of the savanna grazing on the cattle. For 2 summers, cow/calf pairs or yearling Scottish Highland cattle (*Bos taurus* spp.) were placed on 1-acre (0.4 ha) treatment sites for about 2-3 days per month with a rest on grass pasture for one day between replicates. Animal weight gain was satisfactory. During the study, cattle generally gained better in 2002 due to adjusted stocking densities from 2001. Cows that calved prior to the study typically maintained body weight similar to controls while late-calving cows in both groups lost some weight. Dry cows, steers and nursing calves also performed similar to the controls. Body condition scores (BCS) for all classes of cattle were similar between the treatment and control groups over the season, hovering around 5 and 6. Managed grazing with 5 to 7 cow/calf pairs or 12 yearlings per acre, for about 2-3 days per month 2 to 4 times per season reduced the shrub layer in oak savanna while permitting adequate weight gains.

KEYWORDS

Oak woodland, managed grazing, Scottish Highland cattle

INTRODUCTION

Oak savanna, characterized by scattered open-grown oak trees, and a groundcover composed of grasses, sedges, wildflowers, and occasionally brush, is the most endangered native ecosystem in North America (Nuzzo 1986, Packard and Mutel 1997). Grassland ecologists attribute the lack of grazing and burning along with the introduction of agriculture as key factors explaining the disappearance of this ecosystem. Restoring oak savanna structure to the remaining fragments of this ecosystem begins with increasing light penetration to the herbaceous ground layer. The overall objective of this study was to determine the effectiveness of rotational cattle grazing to reduce the shrub layer in degraded oak savannas. In this paper we will focus on the impact of grazing oak savanna on the livestock themselves. Shrub forage nutritional value and cattle observation data can be found in Hedtcke et al. (in press). Information on the impact of grazing on the vegetation is presented in a companion paper (Harrington and Kathol, in press).

STUDY AREA AND METHODS

The pre-settlement landscape of southwestern Wisconsin was a mosaic of vegetation types that ranged from prairie to forest. Tallgrass prairie had few-to-no trees and depended on frequent fires to maintain a grassy landscape. Next was oak savanna, which had scattered open-grown trees but also prairie underneath. Then there was oak woodland, which had more trees, but less than 80% canopy cover. And finally, the mixed hardwood forest itself, with little direct sunlight penetration beneath the tree canopy. Critical to maintaining the former two ecologies was grazing.

This study took place at three sites in southern Wisconsin: Yellowstone Lake Wildlife Area (YLWA) in Lafayette County, owned and managed by the Wisconsin Department of Natural Resources (WDNR); Prairie Oaks Farm (hereafter referred to as Farm 1), also in Lafayette County; and Creag-Is-Daru Farm (hereafter referred to as Farm 2), in Iowa County. Current conditions at the three sites reflect primarily soil and slope differences. Farm 1 is a shrub-infested oak woodland, dominated by bur (*Quercus macrocarpa*) and/or white oak (*Quercus alba*). YWLA was once a savanna that has been highly degraded by encroaching shrubs and invasive species. The Dubuque silt loam soils at these two sites are well drained and high in organic matter. Farm 2 is the least degraded of all sites with significant oak savanna components present. Its soil (Northfield sandy loam > 12% slope) is well drained, shallow, and sandy. Each site had remnant prairie patches with species common to historic tallgrass prairie and oak savanna regions of southern Wisconsin. The soil test values for each site are reported in Table 1. YLWA and Farm 1, which are on fertile soils, were not brought under the plow primarily due to the steep slopes. At Farm 2, the steep, shallow, acidic, less fertile soils are not conducive to row-crop agriculture.

The study was done using a Scottish Highland breed of cattle of which there are currently about 20,000 registered plus an unrecorded number of unregistered animals raised for beef in the USA (American Highland Cattle Association, pers. comm. 2002). This breed has a shorter stature than typical beef breeds but they have similar body weights. They are good browsing animals, and they possess large horns frequently used to knock over small trees and brush. Several local grazers considered these traits and their reported ability to thrive in less than ideal pasture circumstances on the Scottish moors, as advantages for grazing in overgrown oak savannas.

Treatments and Design.
At all three sites, the cattle grazed in the oak savanna for about 25 days/month during the summer and were compared to animals grazing only in grass/legume pastures. The design was a randomized complete block design with five replicates at each site. Three-strand high tensile wire fencing was installed around each 1-acre (0.4 ha) plot in the spring of 2001 at all 3 sites. Each plot had an open grassy area at the bottom of the slope with increasingly dense understory beneath the tree canopy upslope.

Grazing occurred during the summer of 2001 and 2002. Cattle were weighed just prior to entering plots in late May and again at the end of the grazing season. Cattle were weighed one at a time using a gated chute set up around a weighing platform under which was a Tru-Test™ load-bar scale with digital readout. Cows and steers were also scored for body condition in 2002 at the beginning and end of the season using a visual BCS system with a scale from 1 to 9, with 1 representing emaciated and 9 meaning obese condition (Whitman, 1975). The same trained cattle handler scored each animal at the time of the weighing.

Cattle Rotation
Cattle 'grazed' the savanna plots in each replicate for 4 days and were then placed in a pasture area for one day between replicates. At the end of the 25-days, cattle were returned where they started in the first replicate (Table 2).

Stocking Rates:
Stocking rates, expressed as AU/acre (1 AU=1000 lbs live cattle weight or 455 kg) were based on our evaluation of existing forage in late May (Table 3). On-farm, cow/calf pairs and dry cows (about 1000 lbs or 455 kg each) were used while 450-lb (205-kg) steers were used at YLWA. At the same time that the grazing animals were selected, a paired control group on grass/legume pasture was identified to be used as a reference for weight and body condition each summer.

RESULTS & DISCUSSION

Cattle Rotation:
At YLWA, the animals were grazed all summer (4 cycles in 2001; 3 cycles in 2002) while on-farm, there were only two grazing cycles each year (Table 2). The July and August cycles of grazing were eliminated due to dry summer weather. In both years, June rainfall stopped by mid-month, and July rainfall was less than half of the 30-year average.

Stocking Rates:
As summarized in Table 3, on Farm 1, 6 cow/calf pairs were rotated through the plots in both years. Based on experience we lowered the stocking rates at the other two sites in the second year. On Farm 2, 6 cow/calf pairs and 3 dry cows were used in 2001 and 4 cow/calf pairs and 2 dry cows were used in 2002. At YLWA, overstocking occurred for cycle 1 of the first year, where we started with 18 steers. Twelve animals were used for the entire 2002 season at YLWA. Our impression is that the 2002 stocking rates (5-7 AU/a) were sustainable and permitted good animal weight gains (Table 4) as well as partial clearing of the shrub layer.

Animal Performance

Cow/calf pairs. Under good grazing conditions, pregnant beef cows generally lose about 100-150 pounds (45-68 kg) during the first few weeks after calving due to heavy energy demands from peak milk production (National Research Council, 1996). During our study, the treatment cows that calved late or during the study lost on average 92 lbs (42 kg) due to calving and peak lactation compared to a 40-lb (18 kg) loss in the control group (Table 4). Cows that calved prior to the study essentially maintained body weight and condition, similar to controls. Initial BCS were slightly higher in the control group (6.2) than the treatment group (5.2) but both groups maintained their condition at the end of the season.

Weight gains of nursing calves were similar between treatment and control groups (Table 4), with both groups doubling or tripling their birth weight by the end of the season. Most of their nutrition was from milk but some foraging of shrubs and forbs was observed as well.

Dry cows and steers. During the 2 seasons, dry cows gained a similar amount of weight on both the oak savanna plots and the control plots. As with the pregnant cows, body scores were similar between the animals grazing in the oak savanna and those on pasture all summer. Final BCS was also similar between groups of 6.6 for the controls and 6.0 for the treatment group. At YLWA, the 12 steers gained weight as well as the controls in 2002 and final BCS was acceptable at 5.3 but the control group gained more condition over the season increasing from 5.0 to 6.5. However, in the first season, due to overstocking and overgrazing on cycle 1, the six steers that remained on the plots only gained 60% of that by the controls (Table 4).

CONCLUSIONS

Our results indicate that grazing with Scottish Highland cattle have the potential to reduce the shrub layer and begin the process of oak savanna structure restoration. We found that using 5 to 7 cow/calf pairs or 12 yearlings per acre, rotated through the paddocks for about 2-3 days per month 2 to 4 times a year resulted in measurable shrub removal. Generally, the weight gains and condition scores of cattle on treatment plots were adequate and similar to that on the control plots. Due to the heterogeneity of forage production within oak savannas and variability in summer rainfall, managers are advised to carefully monitor the vegetation and livestock as actual stocking rates and duration in the savanna will vary. We recommend further evaluation of this system on larger paddocks with more animals and for several years, before promoting its use as a habitat management option.

LITERATURE CITED

Harrington, J., and E. Kathol. In press. Responses of shrub midstory and herbaceous layers to grazing and fire in a Wisconsin shrub-infested savanna and prairie landscape. Submitted to Restoration Ecology. *Submitted August 2005.*

Hedtcke, J., J. Posner, K. Albrecht, and M. Rosemeyer. In press. Forage Value of Midstory Shrubs Found in Degraded Oak Savannas. Submitted to Rangeland Ecology and Management. *Submitted September 2005.*

National Research Council. 1996. Nutritional Requirements of Beef Cattle, Seventh Rev. Ed. Washington, DC: National Academy Press.

Nuzzo, V. 1986. Extent and status of Midwest oak savanna: pre-settlement and 1985. Natural Areas Journal 6;6-36.

Packard, S. and C. Mutel. 1997. The Tallgrass Restoration Handbook for Prairies, Savannas and Woodlands. Island Press, Washington, D.C.

Whitman, R. W. 1975. Weight change, body condition and beef-cow reproduction. Ph.D. Dissertation. Colorado State Univ., Fort Collins.

ACKNOWLEDGEMENTS

The authors would like to thank the other collaborators on the oak savanna project without whose time and expertise we would not have gotten the project running: The cattle owner/land managers, Ron and Sally Niemann of Prairie Oaks Farm, Peter and Mary Rathbun of Creig-is-Daru farm, Bruce Folley and Jackie Curry of YLWA; UW-Madison – John Harrington and Emily Kathol, Devin Biggs, UW-Extension – Peggy Compton, UW-Platteville – Tom Hunt and Marlene Sorenson, DNR – Jerry Bartelt and Dick Bautz, and Evergreen State College – Martha Rosemeyer. Funding sources were EQIP, UW Consortium, and the DNR's Partnerships for Wildlife Program.

TABLES

Table 1. Baseline routine soil tests to 6-inch (15-cm) depth from the three study sites.

Site	Soil Test P (ppm)	Soil Test K (ppm)	Organic matter %	pH
Farm 1	33	153	7.6	6.8
Farm 2	29	71	2.8	4.9
YLWA	20	141	6.0	7.0

Table 2. Cattle rotation schedule at the 3 sites

Site	2001	2002
Farm 1	June 1-June 25	June 1-June 25
	June 26-July 20	Aug 20-Sept 13
	Sept 17-Oct 10	
Farm 2	June 1-June 25	June 1-June 25
	July 1-July 25	Aug 26-Sept 19
	Sept 15-Oct 8	
YLWA	June 1-June 25	June 1-June 25
	June 26-July 20	June 26-July 20
	July 21-Aug 14	July 21-Aug 17
	Aug 18 -Sept 11	

Table 3. Stocking densities in lbs/a (with number of animals in parenthesis) at the 3 sites.

	lbs/acre	
	2001	2002
Farm 1	6717 (6 cow/calf pairs)	7256 (6 cow/calf pairs)
Farm 2	8840 (6 cow/calf pairs + 3 dry cows)	5802 (4 cow/calf pairs + 2 dry cows)
YLWA	8685 (18 yearling steers)[1]	5064 (12 yearling steers)

[1] Stocking density was reduced to 6 steers after first grazing cycle.

Table 4. Cattle weight gain or loss on treatment and control plots.

Site	Class of cattle	Treatment (Degraded savanna)		Control (Grass/legume pasture)
		2001	2002	2-yr average
On-farm		----------lbs/head----------		
	Lactating cows			
	Calved early	-18 (n=9)	50 (n=7)	65 (n=8)
	Calved late	-91 (n=3)	-92 (n=3)	-40 (n=7)
	Baby calves	174 (n=11)	151 (n=7)	170 (n=14)
	Dry cows	91 (n=3)	153 (n=2)	112 (n=8)
YLWA				
	Yearling steers	76 (n=6)[1]	108 (n=12)	127 (n=4)

[1] Initially there were 18 animals on the plots. This was reduced to 6 steers in mid-summer.

MONITORING CATTLE PERFORMANCE ON PASTURE AT THE KRUSENBAUM FARM.

Janet Hedtcke, Josh Posner and Altfrid Krusenbaum

INTRODUCTION

After converting from a conventional dairy to a managed-intensive rotational grazing dairy farm in the early 1990's, the Krusenbaums's ('Krusen Grass' Farm) were interested in further improving their labor efficiency to reduce the cost of production and to allow for some vacation time. They implemented seasonal calving so that the majority of their herd was dry during the winter and calved in the spring. To further lighten their load and to minimize capital costs they decided to outwinter the cows, bred heifers, and young stock on the paddocks.

However, by the winter of 1997/98, they were beginning to make some modifications. Although they aimed to have all the cows dry in February, they were more flexible in drying the cows off according to their due date, depending on labor availability. And secondly, they constructed an outwintering shed for the milking string. The former modification was made for reasons of cash flow and total milk production, and the latter for reasons of herd health, cow comfort and more flexible manure management. They now focused their attention on the impact of their outwintering strategies on the bred heifers and young stock.

More specifically, they were concerned about how their herd management decisions were impacting animal weight gain. Was it necessary to separate steers from heifers due to the different levels of aggressiveness of each during grazing? Did crossbreeding their Holsteins with Jerseys result in improved rates of weight gain? Was it necessary to invest in housing for the young stock if winter weight gains were low?

A study in Sweden on behavioral responses of dairy heifers to climate showed that climate had significant effects on main activity and location of the heifers and that heifers adapted their behavior to reduce energy expenditure by spending more time lying in the wooded areas in very cold or windy conditions (Redbo et al., 2001). Knowing this, it was important to provide some protection from the elements so that animals didn't lose a lot of condition. To help maintain condition and weight gain, the replacement cattle were provided high quality round bales or baleage on the paddocks during the winter months. Water was provided in the lot. In extremely cold or windy conditions, animals were supplemented with corn grain and were provided either natural (trees or valley) or artificial windbreaks set up using 2 layers of large round bales.

We decided to ask three questions:

1) Did steers and heifers gain at the same rate?
2) Did Holstein cattle gain at the same rate as Jersey crossbred cattle?
3) Would winter weight gain equal summer weight gain?

This is a report on the first two years of data collection.

MATERIALS AND METHODS

Bred heifers, weaned calves, and male calves were weighed in late fall at the end of the grazing season and again as the overwintering period ended and the paddocks began to green up (early

Spring). Summer weighing was avoided as to not interfere with conception rates during this delicate phase. The target birthing and breeding schedule for this farm is for the calves to be born in March, pass a first winter as young stock, to be bred in June (at ~14 months) and pass a second winter as bred heifers, and finally give birth and enter the milking string in March (at 23 months). Table 1 summarized the number of animals that entered the study. They are grouped as the calves born in Spring 2002 (only measured over their second winter, ~20 mo.), the calves born in Spring 2003 (weighed over two winter seasons, first as calves (~8 mo.) and then as bred heifers ~20 mo.) and those born in 2004 (at the date of this report, only weighed as calves going through their first winter). Table 2 shows the weighing schedule.

Table 1. Replacement heifers and steers in the study.

Animals born in the spring of:	Holstein heifers	Crossbred heifers	Steers (mixed breeds)	Total Animals
2002	11	12	0*	23
2003	12	22	22	56
2004	26	7	23	56

* steers not weighed

Table 2. Weighing dates.

Fall weighing dates	Early Spring weighing dates
December 12, 2003	March 1, 2004
November 5, 2004	February 22, 2005
August 25, 2005	Late February, 2006 (end of study)

Cattle were brought in off the paddocks the morning they were to be weighed. Supplemental feed was withheld until after weighing. One-by-one, cattle were 'run' across a Tru-Test© load bar scale and loading platform set up beneath a holding chute. Though body condition scoring was not recorded, each animal was observed for problems and thrift while on the platform scale. Using phenotype, breed was assigned to each animal. Because the farm does raise some organic beef, male calves (steers) were included in the second and third cohort.

Data was analyzed with a pair T-test approach for each group using SAS 8.2 Proc Mixed. LSMEANS were used to report the means. There were no gender x season or breed x season interactions so the main effects are averaged across seasons in this report.

RESULTS AND DISCUSSION

Heifer vs. Steer Weight Gain

Looking at the unbred heifers and steers, weight gain of steers, although arithmetically higher, wasn't statistically consistently higher from year to year (Table 3). We would like to get another year of data before basing a decision on separating males and females into different grazing groups.

Table 3. Average daily weight gain as a function of gender.			
Year	Class of cattle	Winter1	Summer2
		lbs/day	
Calf2003	Unbred Heifer	1.37	1.51
	Steer	1.50	1.57
p-value		*0.1043*	*0.3018*
Calf2004	Unbred Heifer	1.22	1.46
	Steer	1.26	1.55
p-value		*0.4946*	*0.1044*

Overwintering period and the effect of breed

Bred Heifers: Bred heifers (Calf2002) were weighed going through their second winter at about 1050 lbs/animal or 75% of their mature weight (Table 4). By the end of their second winter, some bred heifers had already calved and thus were moved to the milking string. Although the Holstein heifers tended to be heavier than the crossbreds there was no effect of breed on average weight.

The following winter (2004-2005), another set of bred heifers (Calf2003) was weighed. Similar to Calf2002 group, breed was not significant factor in average body weight at the start of the winter but by late February the Holstein heifers were heavier. It is interesting to note that this group performed better in a harsher winter of 04/05 (1.82 lb/day) than did Calf2002 during the previous milder winter (1.36 lb/day) ($p<0.0025$). Although the animal weight gain was very different in these two winters prior to calving, DHIA herd records show that the Krusenbaum heifers calve at an average age of 24 months of age, and a median age of 23 months (Nordlund, pers comm. 2005).

Yearling heifers: The young stock at 8-9 months old averaged 475 lbs the first year (Calf2003) and 430 (Calf2004) the second year going into their first winter and came out of winter season (~12 mo. of age) at 584 (Calf2003) and 559 (Calf2004) lbs on average (Table 5). As with the bred heifers there was generally no effect of breed on animal weights going into the winter or coming out of the winter. These animals were small compared to industry standards where the desirable weights at 14 months (breeding age) are between 825-875 lbs for Holstein heifers and 580-600 lbs for Jerseys (Crowley et al., 1991; Hoffman, 1997). Vargas et al (1998) actually found a significant effect of heifer weight at 13 months on age at first calving. They reported that the chance of calving was consistently higher for heifers with higher body weights at 13 months, and it decreased linearly from the top to the lowest quartiles. Although somewhat light, DHIA records show a very high rate of conception for the 1st-calf heifers at nearly one service per conception, exceeding their goal of 1.5 services per conception.

Table 4. Bred heifer body weights—winter weight gains				
	Calf2002		Calf2003	
	Dec. 12, 2003	March 1, 2004	Nov. 5, 2004	Feb. 22, 2005
	Start of 2nd winter	End of 2nd winter	Start of 2nd winter	End of 2nd winter
Breed	----------lbs----------			
Holstein	1058 N=12	1162 N=11	975 N=12	1201 N=10
Jersey Cross	1048 N=17	1173 N=13	937 N=22	1126 N=21
Mean	*1053*	*1168*	*956*	*1163*
p-value	*0.7936*	*0.8410*	*0.1155*	*0.0245*

Table 5. Young heifers body weights—winter weight gains				
	Calf2003		Calf2004	
	Dec. 12, 2003	March 1, 2004	Nov. 5, 2004	Feb. 22, 2005
	Start of 1st winter	End of 1st winter	Start of 1st winter	End of 1st winter
	----------lbs----------			
Holstein	490 N=12	600 N=12	440 N=26	576 N=26
Jersey Cross	461 N=22	568 N=22	420 N=7	541 N=7
Mean	*475*	*584*	*430*	*559*
p-value	*0.0694*	*0.1345*	*0.4420*	*0.2150*

Table 6. Average daily weight gain of bred and yearling heifers						
Group	Class	Season	Holstein	Jersey-Hol. Cross	Mean	Pr > F
			Average daily gain (lb/day)			
Calf2002	Bred heifer	Winter '03-04	1.27	1.45	1.36	0.5343
Calf2003	Bred heifer	Winter '04-05	1.97	1.74	1.82	0.1304
Calf2003	Yearling heifer	Winter '03-04	1.39	1.35	1.37	0.7239
Calf2004	Yearling heifer	Winter '04-05	1.25	1.22	1.24	0.6450
Calf2003	Yearling heifer	Summer '04	1.51	1.51	1.51	0.9887
Calf2004	Yearling heifer	Summer '05	1.51	1.26	---	0.0033

In Table 6 the animal measurements are "standardized" by presenting their average daily weight gain. Industry standards are approximately 1.8 lb/day for pure Holstein heifers and 1.5 lbs/day for pure Jerseys (Crowley et al., 1991). As with total weights, breed was not significant in all but one case (summer '05). The winter weight gain of 2004-2005 for the yearling heifers was low (1.24 lb/day) and worthy of concern (Table 6). During that winter temperature fluctuated above and below freezing allowing for both rain and snow events. Intervals of freezing and thawing cycles created ice sheets and muddy paddocks. In the first week of January 2005, over 2" of rain fell which caused many problems and headaches for the cattle and paddock condition was

damaged. Winterkill of both grass and legume was prevalent. Animals had a hard time walking in the icy conditions, which likely negatively impacted feed and water intake.

Weight gains for the young heifers: 1st winter season vs. 2nd grazing Season

Due to confounding effect of fetus growth with the bred heifer growth, we only looked at differences between seasonal weight gain of the young stock. Since the difference between breeds was not significant (Table 6), they are averaged in the comparison of winter and summer weight gains (Table 7). To further increase the number of observations steers are included since, as a group, they did not gain weight at a different rate than the heifers (see Table 3). Based on the first two years of data, we find that the year of measurement is significant (the rough winter of 2004/5 markedly reduced the growth rates of the young animal), and season is significant with winter gains lower than summer gains. The interaction is one mainly of scale as the stock that suffered in the winter, markedly increased their weight gain in the summer, while the less affected animals from the year before kept more similar growth rates in both seasons. Overall, weight gains in the winter were modest (1.33 lb/day). Across breeds, weight gain during the grazing season averaged 1.51 lb/day but weight gain was below the target of 1.8 lb/day.

Table 7. Seasonal effect on weight gain (lb/d) on 2003 and 2004 young stock (including steers).

	Season		
	Winter1	Summer2	*Mean*
Group	----------lb/day----------		
Calf2003	1.42	1.53	*1.47*
Calf2004	1.24	1.49	*1.36*
Mean	*1.33*	*1.51*	

Group*season interaction $p<0.0207$. Both main effects significant at $p<0.01$

SUMMARY

In this study, the Holstein and Jersey Holstein crosses are gaining weight at the same rate, as are the heifers and steers. At this point, it appears un-necessary to break the young stock out into different groups for summer grazing and winterfeeding. It was found that summer weight gains were higher for young stock (including steers) (1.51 lb/d) than in the two winters already monitored (1.42 and 1.24 lb/d). The heifers in this study were only gaining weight at about 80% of the industry standard of 1.8 lbs/day. Although most research would suggest that these animals would be more difficult to inseminate and calve at a later date, DHIA records indicate that conception rate is above the industry standard of 1.6 and average age at calving is 23 months. From this partial analysis, it appears that the Krusenbaum outwintering strategy permits the young stock, although a bit small to move into the milk string in an orderly fashion. Furthermore, using this outwintering strategy reduces capital investment in housing. However, there is some risk associated with over wintering young stock out on pasture as can be seen from low weight gain of 1.24 lb/d during the winter of 2004-2005. We will continue to monitor the replacement stock performance, which will allow for adapting future management decisions.

CITATIONS

Crowley, J., N. Jorgensen, T. Howard, P. Hoffman and R. Shaver. 1991. Raising Dairy Replacements. Univ. of Wisconsin-Extension, North Central Regional Extension Publications #205. Madison.

Hoffman, P.C. 1997. Optimum body size of Holstein replacement heifers. J. Animal Sci. 75:836.

Redbo, L., A. Ehrlemark, and P. Redbo-Torstensson. 2001. Behavioral responses to climate demands of dairy heifers housed outdoors. Canadian Journal of Animal Sciences. 81(1): 9-15.

Vargas, B., T. van-der Lende, M. Baaijen, J.A.M. van Arendonk. 1998. Event-time analysis of reproductive traits of dairy heifers. J-dairy-sci. 81 (11):2881-2889.

LINKING FARMS: RECONNECTING DAIRY AND CASH-GRAIN FARMS THROUGH SHARED MANURE MANAGEMENT

I. Production results and nutrient budgets from 2003 and 2004

Amy Cook[1], Joshua Posner[2], John Hall[3], Janet Hedtcke[4], Gregg Sanford[1]

INTRODUCTION

Current trends in the Wisconsin dairy sector show that average herd size is increasing, with a growing proportion of the milk stream produced on farms of 500 animal units (AU) or more (one animal unit = 1000 lbs animal live weight, WASS, 2004). In addition, these larger farms have higher stocking rates (PATS, 1997), or animals per acre. This results in having more manure to manage, and relatively less land to manage it on. These industry trends, however, are colliding with stricter regulations on nutrient management, as first nitrogen, and now phosphorus standards are being applied (NRCS, 2004). These new standards currently effect permitted farms (farms with >1000 AUs, or Concentrated Animal Feeding Operations—CAFOs), and are due to go into effect for all Wisconsin farms in 2008 (Porter, 2004). As a result, many Wisconsin dairy farmers must look for places, beyond their farm gate, for spreading manure.

Cash-grain operators, on the other hand, are facing ever-increasing costs of fertilizer. In 2005 nitrogen fertilizer prices are expected to rise between 11% and 15% from 2004 prices (Hergert, 2005). Thus, cash-grain growers have an incentive to use alternative nutrient sources, such as dairy manure. In addition to providing N, P, K, Zn, Mg, and other nutrients, manure also serves as a soil conditioner by improving porosity and water-holding capacity, and when added over long periods of time, has been reported to increase soil organic matter (Motavalli and Miles, 2002; Anderson et al., 1990).

The Linking Farms Project attempts to address these issues, by studying the agronomic effects of including manure from dairy farms into cash-grain rotations. Specifically, the Linking Farms Project is looking at three critical issues:

- The impact of manure additions on corn grain yield and soil test values;
- The impact of manure additions on weed pressure; and,
- The impact of manure spreading on soil compaction;

In this article, we focus on grain yields, nutrient budgets and soil test values. The first section covers the on-farm trials, and in the second section, the research conducted on the Wisconsin Integrated Cropping Systems Trial is described.

[1] Graduate student, UW-Madison, Agronomy Dept.
[2] Professor, UW-Madison, Agronomy Dept.
[3] Agronomist, Michael Fields Institute, East Troy, WI
[4] Research specialist, UW-Madison, Agronomy Dept.

SECTION A: ON-FARM TRIALS

MATERIALS AND METHODS

Fall Plot Layout:

Manure spreading for the on-farm work was initiated at five sites in the fall of 2003 (for the 2004 season), and eleven sites in the fall of 2004 and spring of 2005 (for the 2005 season)—see **Table 1**. Three dairy farms supplied manure to the sites in 2003-2004, and six dairies participated in 2004-2005. Due to poor corn establishment, results from only four of the five sites in 2004 were reported here. The on-farm trials were established using a randomized complete block design, with 3 repetitions at each site. The two treatments tested were manured plots versus non-manured plots. Plots were between 30 and 60 feet wide, and 200 to 500 feet long. Plot sizes were determined according to the farmer-participants' corn planting and harvesting equipment, as well as to the spray or injection width of the manure application trucks. Baseline soil fertility samples (0-6" and 6-12", 5 cores/plot) were taken preceding manure application and analyzed for pH, organic matter (OM), soil test phosphorus and potassium levels at the Soil and Plant Analysis Laboratory (SPAL) in Madison.

Manure was then spread following wheat or soybean harvest. Slurry (10,000-16,000 gal/a) was used at the majority of sites, while solid manure (bedding pack and barnyard scrapings), spread at 18-20 tons/acre, was used at a few sites. In all cases the manure was injected or incorporated within 3 days of application. Samples of manure were taken from each spreading event for analysis at the University of Wisconsin Soil and Forage Analysis Laboratory (SFAL) in Marshfield.

Fall nitrate soil cores were taken (3-foot depth) on those trials where manure had been applied in the late summer, soon after wheat harvest. Three cores per plot were combined for each sample, and analyzed for nitrate nitrogen at the SPAL in Madison.

Spring Procedures:

Corn was planted on the 2004 sites, with seed selection, population, planting date, herbicide, and starter fertilizer decisions left to the farmer-participants. Nitrogen fertilization was discouraged until a pre-sidedress nitrate test (PSNT) could be made

One-foot soil cores were taken when corn was between 6 and 12 inches tall, or between the V4 and V6 stages (Anderson and Urbanowicz). Composite samples were composed of 6 cores per plot. Use of the PSNT allowed the researchers to see how much nitrogen was actually available for plant uptake at the critical V6 stage, and then follow University of Wisconsin Extension's (UWEX) recommendations of how much additional nitrogen should be applied.

Harvest/Post-harvest Procedures:

Corn was harvested in November, and corn quality was assessed at the SFAL in Marshfield using wet chemistry for dry matter, phosphorus, calcium, potassium, and magnesium assays, and NIRS for crude protein. Following harvest, another series of soil samples was taken for routine fertility (0-6" and 6-12") and 3-foot depth fall nitrate levels. Simple nutrient budgets for N, P_2O_5 and K_2O were calculated by summing legume, fertilizer, and manure credits, then subtracting

crop off-take. Crop off-take was calculated by multiplying grain yield by percent N, P, and K. Percent N was estimated by dividing crude protein by 6.25.

Soil fertility, nitrate levels, corn yields, and corn quality were analyzed on an individual-site basis, using PROC means and PROC mixed of SAS software.

RESULTS AND DISCUSSION

Characterization of Site soils:

The experimental sites were on predominantly silt loam soils, with a few cases of loam or sandy loam soils (see **Table 1**). Typical of soils in the area, soil test phosphorus levels were in the mid- to high-ranges; eight of the fifteen sites were below 50 ppm, which according to the newest draft of the Nutrient Management Standard 590, would allow for manure additions up to the next crop's nitrogen requirements (NRCS, 2004). Five of the fifteen sites ranged between 50 and 100 ppm P, qualifying them for manure applications not to exceed total crop P removal in the following four years. Soil test potassium levels were generally high, with 6 sites in the Excessively High range (>140 or 150), 7 sites in the High range (approximately 101—140 ppm) and only 2 sites in the Optimal range (81—100 ppm). These ranges were according to UWEX recommendations (Kelling et al., 1998) for corn/soybean rotations. Thirteen of the sites had organic matter greater than 2.0% on average, and 9 sites had pH levels above 6.3, the level considered optimum for corn/soybean rotations (Kelling et al, 1998).

Manure Analyses:

Results from the manure analyses showed that there was much variation in percent dry matter and nutrient concentration among the samples taken, particularly in the slurry manure. **Tables 2** and **3** display summary data for the combined 2004 and 2005 season manure analysis results for slurry and solid manure, respectively. This heterogeneity was typical for manure analyses and was due to pit agitation, dilution after heavy rains, and variation in bedding materials (e.g. straw vs. sand). Variability of nutrient concentration, especially with slurry, could complicate the task of nutrient crediting of manure by cash-grain operators.

Fall nitrate levels after manure application:

The purpose of fall nitrate sampling was to see if late-summer application of manure at the six sites (2003 + 2004) following wheat harvest increased the risk of nitrate leaching over winter. As shown in **Figure 1**, higher levels of nitrates were found in the manured treatments in every on-farm site, with levels statistically higher in four of the six sites ($\alpha = 0.10$). However, in only three sites were nitrate levels markedly higher than the standard "background" level found in non-agricultural land of 50 lbs NO_3 per acre. The results of the initial fall nitrate tests indicated that early fall applications of manure that had a high concentration of nitrogen (e.g. the manure at JB I and KS I) were particularly likely to raise soil nitrate levels in the late fall.

Pre-Sidedress Nitrate Test Results:

Results of the pre-sidedress nitrate test (PSNT) taken in Spring 2004 indicated that nearly all the manured plots at all sites needed a full rate of 160 pounds nitrogen per acre (**Table 4**). This was unexpected, as N-additions via manure applications in the previous fall ranged from 95 to 160 lbs. The most likely explanation was that nitrogen from the manure did not have enough time to mineralize before the PSNT was taken, due to the cold, wet conditions of Spring 2004. A second explanation was that some nitrate leaching occurred between the time that manure was applied, and the time of the PSNT. Interestingly, technicians at the SPAL who ran the nitrate analyses commented that PSNT results from most of their clients had been very low that year. Dr. Bundy, a UW soil fertility specialist, in fact, advises growers to use anticipated N-credits from the manure in addition to the results of the PSNT analysis when it is a cool spring (Andraski and Bundy, 2002).

Corn grain yields and quality:

Corn grain yields from the on-farm trials in 2004 averaged between 181 and 215 bu/a and were not significantly different between manured and non-manured treatments (see **Figure 2**). This was surprising as the manured plots received manure plus a full rate of sidedressed N fertilizer. This indicates that either something besides nitrogen was limiting yields in the manured plots, or the manure-nitrogen was not available to the corn crop during this first year after application (**Table 5**). The 2004 corn yields demonstrated the potential unavailability of manure nitrogen under wet and cold conditions in the spring.

Corn grain quality analyses were similar to the yield results. While crude protein percentages of the corn grain from the manured plots were arithmetically higher at all on-farm sites, probably due to greater nitrogen additions, no significant differences were detected (**Figure 3**).

Post-Harvest Fall Nitrates and Nitrogen Nutrient Budgets:

As shown in **Figure 4**, post-season nitrate levels were very low at all sites, in both treatments. This event was in stark contrast to the high net balance of nitrogen credits in the manured plots, as calculated in the nitrogen budget (**Table 5**). The combination of low fall nitrates and high net N balance could be a further indication that much of the nitrogen from the manure did not mineralize during the cool 2004 season. There is a good chance, however, that this organic nitrogen will become available in subsequent years through continued mineralization. Another possibility was that the low post-season nitrate levels were an indication of nitrogen losses to the environment, such as ammonia volatilization. Leaching loss seemed unlikely, since it would be highly unusual to see downward movement below the 3-foot depth analyzed in the nitrate test in such a short time span.

Nutrient Budgeting—Phosphorus and Potassium:

Phosphorus (phosphate) and potassium (potash) nutrient budgets are shown in **Tables 6** and **7**, respectively. At all sites, there was a positive phosphate balance and potash balance on the manured plots, and a low or negative balance on the non-manured plots. These results were not surprising, since manure was proportionally higher in phosphorus and potassium, as compared to nitrogen, so typical N-based spreading rates would cause these nutrients to accumulate. Unlike

nitrates and phosphates, high soil potassium levels were not a primary concern for groundwater or surface water contamination.

SECTION B: WICST STUDY

METHODS AND MATERIALS:

Fall Plot Layout:

The experimental design at the WICST site was very similar to that of the on-farm studies. The study however, began in Spring 2003 and has run for two seasons to date (2003 and 2004), with the 2005 season currently in place. Plots were delineated on the corn phases of the three grain-based cropping systems: CS 1 (Continuous Corn), CS 2 (No-till Corn-Soybeans) and CS 3 (Organic Corn-Soybeans-Winter Wheat/Red Clover).

Manured strips were created on the eastern-most 15 feet of each plot going into corn, and were compared against the remaining 45 feet check strips. Between 11,000 and 12,000 gallons of slurry were applied before the corn phase of each season (on 4/28/03, 11/25/03 and 12/03/04). Each system was replicated four times.

The Pre-Plant Nitrate Test (PPNT) was used in the first season at WICST in order to determine fertilizer rates on the non-manured strips. In the case of the manured strips, manure nutrient credits were estimated and subtracted from the total N requirement. The difference in manure nitrogen credits and crop requirements, as well as the PPNT results from the non-manured strips, were both used when figuring the best fertilizer rates on the manured strips. The Pre-Sidedress Nitrate Test (PSNT) was used for both manured and non-manured strips in the 2004 season.

Late replanting of the initially poor stand on the CS3 plots in 2004 resulted in harvesting the corn as snaplage. Thus, the data from this system was not included in this report.

RESULTS AND DISCUSSION

Characterization of Site soils:

Plano silt loam created the base of the WICST plots, and this prairie-derived soil was relatively high in organic matter (ranging from 3.9 to 4.5) and had a neutral pH (between 6.5 and 6.9). Soil test phosphorus levels were rated Excessively High (ranging between 45 ppm and 91 ppm) and STK levels were rated between Optimum and Excessively High (ranging from 95 to 226) (Kelling et al., 1998).

Manure Analyses:

Table 8 displays the analyses of the liquid manure spread prior to corn planting. Variability was slightly less than seen across all on-farm manure analyses. This was not surprising, since the manure for the WICST study came from either the East or Center pits from the on-station Blaine dairy.

Pre-Plant and Pre-Sidedress Nitrate Test Results:

This latter test came back with outcomes very similar to the on-farm trials; namely, little to no credit was gained from the manure (**Table 9**). These results indicated once again that due to the cold, wet spring of 2004, nitrogen in the form of plant-available nitrate was absent due to either slow mineralization, or leaching below the one-foot level.

Corn grain yields and quality:

Manure tended to increase corn yields on the WICST plots. In 2003, systems CS 1 and CS 3 had better yields on the manured plots, whereas CS 2 had poorer yields. It was hypothesized that the spring application of manure (as opposed to a fall spreading) and the high dry matter content of the manure (12%), resulted in a rougher field surface. We believe that due to the inadequate adjustment of the no-till planter, this resulted in a poorer stand in the manured versus non-manured plots in CS 2. In the following season, when manure was fall-spread, manure increased yields in systems CS1 and CS 2 (see **Figures 5a** and **5b**).

Crude protein percentage was significantly higher on the manured plots in CS 1 and CS 3 in 2003. This was not the case in 2004 (**Figures 6a** and **6b**).

These results once again indicated that while adding manure into a grain system could potentially raise crude protein percentage, there was little guarantee that this outcome would occur.

Post-harvest Fall Nitrates and Nitrogen Nutrient Budgets:

In 2003, although the net N balance was higher on the manured plots (**Table 10**), fall nitrate levels were significantly lower than the non-manured plots (**Figure 7**). These surprising results conflict with results from 2004, as well as with the 2004 on-farm data.

Although the 2004 PSNT indicated that full rates of N fertilizer were necessary on CS1 and CS2 in the manured plots, fall nitrate readings suggested that the plots were over-fertilized. Higher levels of nitrates in the top three feet indicated that more nitrogen was available in the system than could be used by the corn crop (**Table 10**). It appeared that more of the manure nitrogen must have mineralized after the PSNT and that adding full fertilizer N rates was probably not necessary on the WICST plots in 2004.

Nutrient Budgeting—Phosphorus and Potassium:

As with the on-farm trials, in both 2003 and 2004, there was a greater phosphorus (**Table 11**) and potassium (**Table 12**) balance on the manured plots than the non-manured plots. Although the phosphate and potash balances in the manured plots appeared high, it was assumed that the crops would draw down P and K accumulation in the soil in subsequent years.

CONCLUSIONS

A number of important issues came to our attention during this first phase of our research:

1. Manure in general, and slurry in particular, is a variable source of nutrients. Farmers are encouraged to take manure samples for lab analysis, as opposed to relying solely on standardized book values.

2. Mineralization of manure may be delayed in cool spring weather making it difficult to anticipate the availability of nitrogen to the corn crop. Thus, a combination of taking manure credits, following recommendations of the Pre-Sidedress Nitrate Test, and common sense is probably the best method of deciding on nitrogen fertilizer rates.

3. The application of manure in early fall (after a small grain) may result in a build up of fall nitrates that could leach during the winter months. Thus, it is recommended to plant a fall cover crop following the small grain harvest in order to trap nitrates for use in the next season.

4. At least initially, soil test P and K will probably increase in the manure-amended soils due to the high concentration of these nutrients. Theoretically, these higher levels would be drawn down by future crop off take.

Table 1: Characterization of 2004 and 2005 On-Farm Sites

Site	Crop Season	County	Soil Series (Predominantly silt loams)	Previous Crop	Manure Type	Manure Application Date
JB I	2004	Dane	St. Charles / Ringwood	Wheat	Slurry	8/15/03
DF I	2004	Walworth	Plano	Wheat	Solid	10/20/03
NH I	2004	Columbia	Virgil	Soybeans	Slurry	10/31/03
RJ I	2004	Columbia	Plano/ Dodge	Wheat	Solid	8/26/03
JB II	2005	Dane	St. Charles silty clay loam	Wheat	Slurry	9/10/04
DF II	2005	Walworth	Plano	Wheat	Solid	10/06/04
NH II	2005	Columbia	Pella silty clay loam	Soybeans	Slurry	11/03/04
RJ II	2005	Columbia	Plano	Wheat	Slurry	11/03/04
TK I	2005	Columbia	Plano	Soybeans	Slurry	10/14/04
TM I	2005	Columbia	Plano	Wheat	Slurry	10/14/04
CP I	2005	Walworth	Kidami silt loam	Corn	Slurry	4/18/05
SS-Alf I	2005	Walworth	Rotamer loam	Alfalfa	Slurry	4/27/05
SS-Sb I	2005	Walworth	Lamartine	Soybeans	Slurry	4/27/05
SS-W I	2005	Walworth	Kidder loam	Wheat	Slurry	10/9/04
KS I	2005	Jefferson	Kidami silt loam	Wheat/Clover/ Alfalfa	Slurry	9/20/04

Table 2: 2004 and 2005 Season Slurry Manure Analyses, Estimated 1st Year Available Nutrients

Site	Season	Dry Matter %	N lbs/1000 gal	P_2O_5 lbs/1000 gal	K_2O lbs/1000 gal
JB I	2004	11.5	12.3	6.8	22.5
NH I	2004	6.2	8.3	5.6	16.3
JB II	2005	9.1	10.2	6.5	20.2
NH II	2005	9.5	13.1	7.1	21.8
RJ II	2005	9.7	14.1	7.3	22.6
TK I	2005	10.1	9.6	5.6	16.3
TM I	2005	14.8	11.0	4.9	17.7
CP I *	2005	8.1	7.8	3.4	15.2
SS-Alf I *	2005	4.2	8.0	3.4	12.5
SS-Sb I *	2005	4.8	8.0	3.9	13.2
SS-W I	2005	6.3	7.8	3.9	15.7
KS I	2005	10.3	12.6	7.2	20.4
Average		*8.7*	*10.2*	*5.5*	*17.9*
Book Values		*6.0*	*10.0*	*5.0*	*16.0*

Notes: All samples were taken at time of spreading, in the fall previous to the stated season. Lightly-shaded cells designate nutrient-poor manure; darker-shaded cells highlight nutrient-rich manure. Site averages and "book values" (standardized ratios determined by UWEX) are at the bottom of the table (Nutrient Management Fast Facts, 2003).

* Manure was spread on these sites in the spring prior to corn planting.

Table 3: 2004 and 2005 Season Solid Manure Analyses, Estimated 1st Year Available Nutrients

Site	Season	Dry Matter %	N lbs/ton	P_2O_5 lbs/ton	K_2O lbs/ton
DF I	2004	27.0	5.9	6.5	21.2
RJ I	2004	35.9	5.2	2.9	15.3
DF II	2005	23.8	4.8	5.6	8.1
Averages		*28.9*	*5.3*	*5.0*	*14.9*
Book Values		*24.0*	*4.0*	*3.0*	*7.0*

Notes: All samples were taken at time of spreading, in the fall previous to the stated season. Shaded cells highlight especially nutrient-rich manure. Site averages and "book values" (standardized ratios determined by UWEX) are at the bottom of the table (Nutrient Management Fast Facts, 2003).

Table 4: 2004 On-Farm Nitrogen Credits Prior to Pre-Sidedress Nitrate Test (PSNT) and PSNT recommendations

Site	Trt.	Manure credit	Fertilizer + legume N credit prior to PSNT	Total N credits prior to PSNT	PSNT recommendations
JB I	M	148	39	187	60
	NM	0	199	199	0
DF I	M	106	19	125	160
	NM	0	19	19	160
NH I	M	96	48	144	160
	NM	0	130	130	160
RJ I	M	160	6	166	160
	NM	0	6	6	150

Notes: M = Manure, NM = No Manure. Manured treatments are shaded. All units in lbs N/acre.

Table 5: 2004 On-Farm Nitrogen Budgets

Sites	Trt.	N Inputs		Estimated Total N Input	N Off-take	Estimated Net N
		Manure + legume credits	Fertilizer			
JB I	M	148	92	240	137	103
	NM	0	199	199	148	52
DF I	M	105	159	265	118	146
	NM	0	159	159	108	51
NH I	M	126	63	189	130	59
	NM	30	145	175	128	47
RJ I	M	160	166	326	145	181
	NM	0	166	166	133	33

Notes: M = Manure, NM = No Manure. Fertilizer = starter + sidedressed N. Manured treatments are shaded. All units in lbs N/acre.

Table 6: 2004 On-Farm Phosphorus Budgets

Sites	Trt.	P_2O_5 Inputs		Total P_2O_5 in	P_2O_5 Off-take	Net P_2O_5
		Manure	Fertilizer			
JB I	M	82	10	92	51	41
	NM	0	10	10	46	-36
DF I	M	116	34	150	43	107
	NM	0	34	34	36	-2
NH I	M	64	46	110	41	68
	NM	0	46	46	42	4
RJ I	M	90	19	109	52	58
	NM	0	19	19	41	-21

Notes: M = Manure; NM = No Manure. Manured treatments are shaded. All units in P_2O_5 lbs/a.

Table 7: 2004 On-farm Potassium Budgets

Sites	Trt.	K_2O Inputs		Total K_2O In	K_2O Off-take	Net K_2O
		Manure	Fertilizer			
JB I	M	270	10	280	43	237
	NM	0	10	10	47	-37
DF I	M	379	115	494	41	453
	NM	0	115	115	39	76
NH I	M	187	60	247	42	205
	NM	0	60	60	40	20
RJ I	M	475	0	475	42	433
	NM	0	0	0	36	-36

Notes: M = Manure; NM = No Manure. Manured treatments are shaded. All units in K_2O lbs/a.

Table 8: 2003—2004 WICST Slurry Manure Analyses, 1st year Available Nutrients

System	Crop Season	Dry Matter %	N lbs/1000 gal	P_2O_5 lbs/1000 gal	K_2O lbs/1000 gal
CS 1 CS 2 CS 3	2003	12.3	13.0	7.6	20.1
CS 1 CS 2	2004	6.1	8.6	5.2	16.2
CS 1	2005	8.4	11.2	6.1	16.9
CS 2	2005	8.7	11.0	6.0	17.2
CS 3	2005	8.6	10.9	6.3	16.7
Book Values		*6.0*	*10.0*	*5.0*	*16.0*

Notes: Book values from Nutrient Management Fast Facts, 2003. Shaded cells highlight especially nutrient-rich manure.

Table 9: 2003 and 2004 WICST Nitrogen Credits prior to Nitrate Tests and Nitrate Test Recommendations (lbs/acre)

System	Season	Trt.	Manure credits	Fertilizer + legume credits prior to sidedressing	Total N credit prior to sidedressing	Nitrate Test Recommendations
CS 1 (1)	2003	M	143	5	148	-
		NM	0	5	5	90
CS 2 (1)	2003	M	143	45	188	-
		NM	0	45	45	90
CS 3 (1)	2003	M	143	118	261	-
		NM	0	118	118	-
CS 1 (2)	2004	M	95	5	100	160
		NM	0	5	5	160
CS 2 (2)	2004	M	95	45	140	160
		NM	0	45	45	160

Notes: M = Manure, NM = No Manure. Manured treatments are shaded.

(1) On NM treatments, Pre-Plant Nitrate Test (PPNT) used for determination of fertilizer rates. On the M treatments, manure credits were subtracted from the total nitrogen requirement (160 lbs/a), and the difference, plus the PPNT results from the NM plots were used to determine fertilizer rates. No nitrate test taken at CS 3 plots.

(2) Pre-Sidedress Nitrate Test used on M and NM treatments to determine fertilizer rates.

Table 10: 2003 and 2004 WICST Nitrogen Budgets (lbs/acre)

System	Season	Trt.	N Inputs		Estimated Total N input	N Off-take	Estimated Net N
			Manure + legume credits	Fertilizer			
CS 1 (1)	2003	M	143	45	188	143	46
		NM	0	105	105	120	-14
CS 2 (1)	2003	M	183	5	188	91	97
		NM	40	85	125	119	6
CS 3 (1)	2003	M	261	0	261	83	178
		NM	118	0	118	68	50
CS 1 (2)	2004	M	95	165	260	154	105
		NM	0	165	165	135	30
CS 2 (2)	2004	M	135	165	300	146	154
		NM	40	165	205	131	74

Notes: M = Manure, NM = No Manure. Manured treatments are shaded. Fertilizer = starter + sidedressed N.

(1) On NM treatments, Pre-Plant Nitrate Test (PPNT) used for determination of fertilizer rates. On the M treatments, manure credits were subtracted from the total nitrogen requirement (160 lbs/a), and the difference, plus the PPNT results from the NM plots were used to determine fertilizer rates.

(2) Pre-Sidedress Nitrate Test used on M and NM treatments to determine fertilizer rates.

Table 11: 2003 and 2004 WICST Phosphorus Budgets

System	Season	Trt.	P_2O_5 Inputs		Total P_2O_5 in	P_2O_5 Off-take	Net P_2O_5
			Manure	Fertilizer			
CS 1	2003	M	84	14	97	47	50
		NM	0	14	14	41	-26
CS 2	2003	M	84	6	90	39	51
		NM	0	6	6	40	-34
CS 3	2003	M	84	0	84	30	54
		NM	0	0	0	25	-25
CS 1	2004	M	57	14	71	51	20
		NM	0	14	14	43	-29
CS 2	2004	M	57	14	71	44	27
		NM	0	14	14	46	-32

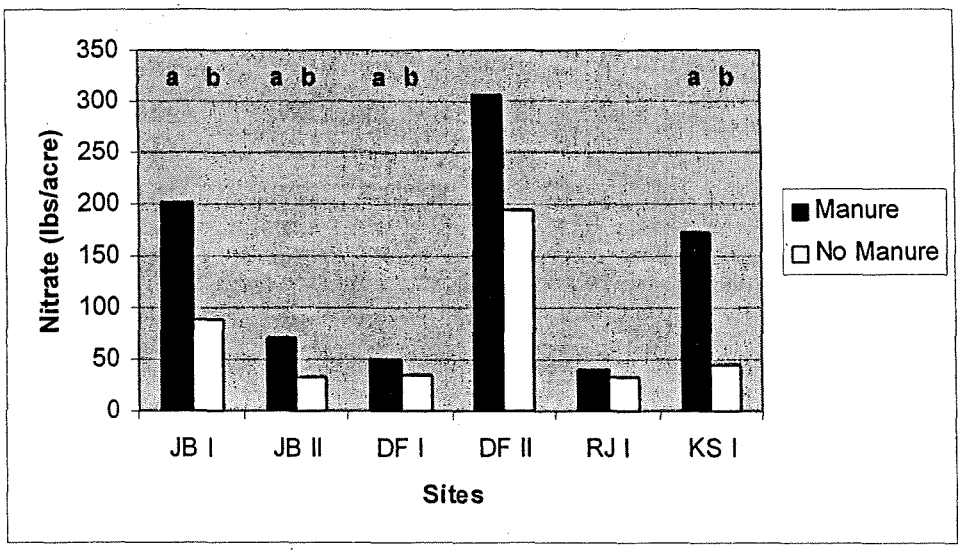
Notes: M = Manure; NM = No Manure. Manured treatments are shaded. All units in P_2O_5 lbs/a

Table 12: 2003 and 2004 WICST Potassium Budgets

System	Season	Trt.	K_2O Inputs		Total K_2O In	K_2O Off-take	Net K_2O
			Manure	Fertilizer			
CS 1	2003	M	221	42	263	40	223
		NM	0	42	42	36	6
CS 2	2003	M	221	68	289	32	257
		NM	0	68	68	36	33
CS 3	2003	M	221	0	221	27	194
		NM	0	0	0	25	-24
CS 1	2004	M	178	42	220	58	162
		NM	0	42	42	51	-9
CS 2	2004	M	178	91	269	55	213
		NM	0	91	91	51	40

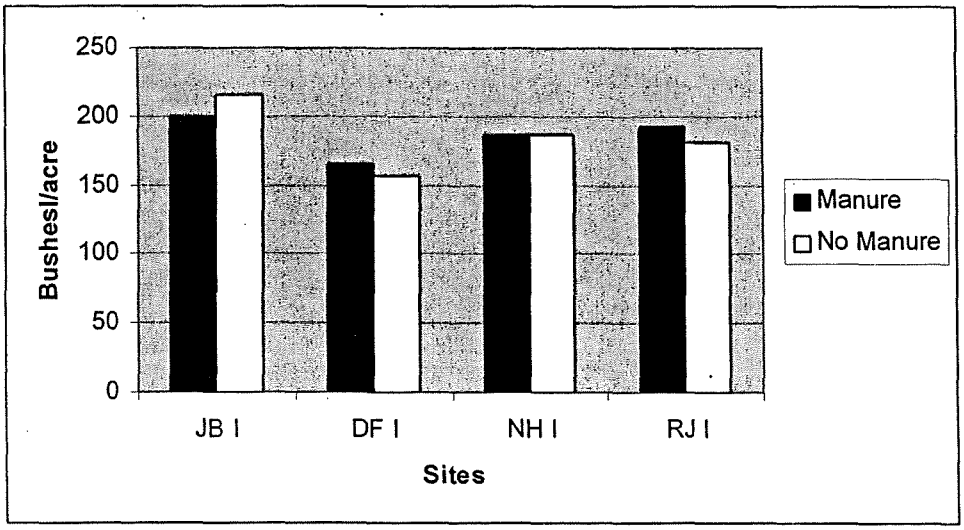
M = Manure; NM = No Manure. Manured treatments are shaded. All units in K_2O lbs/a.

Figure 1: 2003 and 2004 Fall Nitrate Levels (lbs NO_3/3-foot depth)



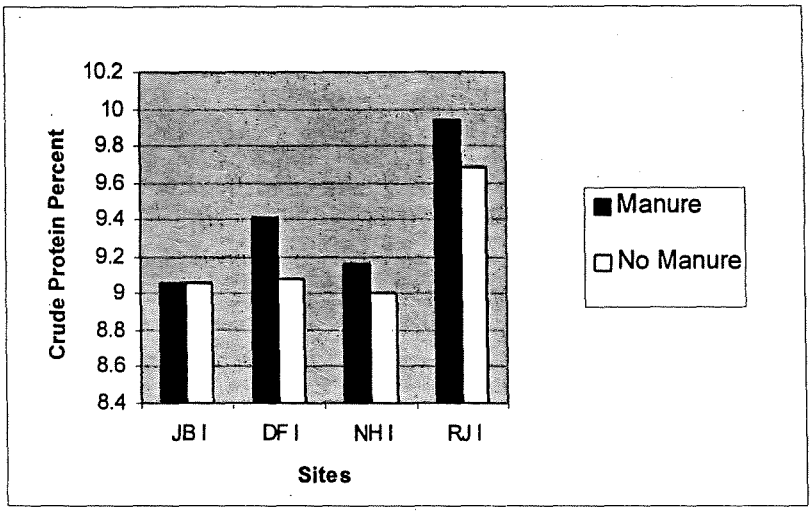
Note: Letters above histogram indicate significant differences ($\alpha = 0.10$).

Figure 2: 2004 On-Farm Mean Corn Grain Yields



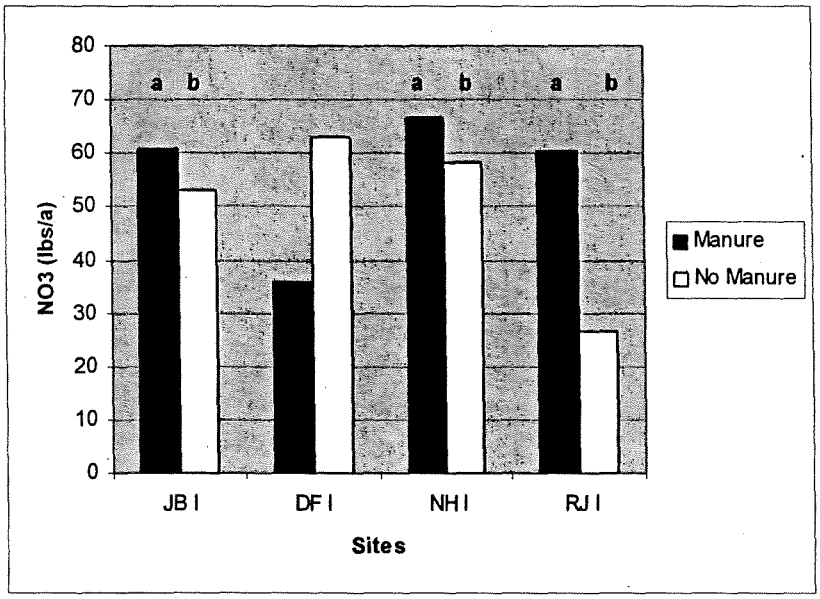
Note: No significant differences found ($\alpha = 0.10$).

Figure 3: 2004 On-Farm Crude Protein Percentages



Note: No significant differences found ($\alpha = 0.10$).

Figure 4: 2004 On-Farm Post-Harvest Fall Nitrate Levels



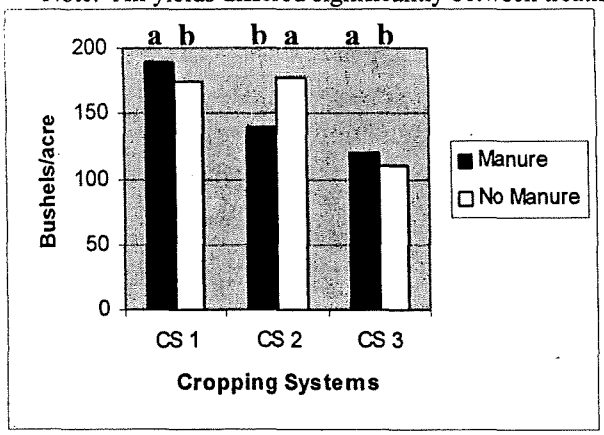
Note: Fall nitrate levels measured in the top 3 feet. Letters above histograms indicate significant differences ($\alpha = 0.10$).

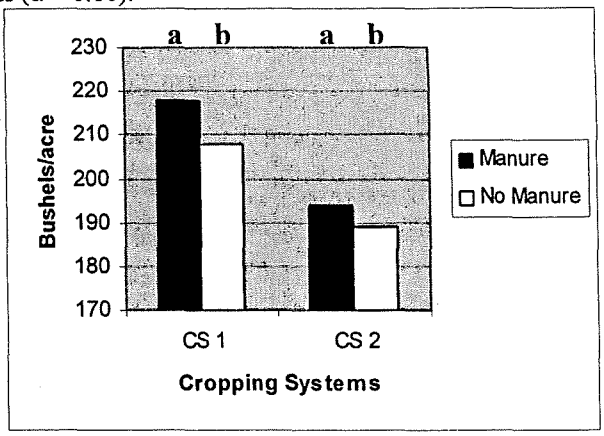
Figures 5a and 5b: 2003 and 2004 WICST Mean Corn Yields

Figure 5a: 2003 Corn Yields

Figure 5b: 2004 Corn Yields

Note: All yields differed significantly between treatments ($\alpha = 0.10$).

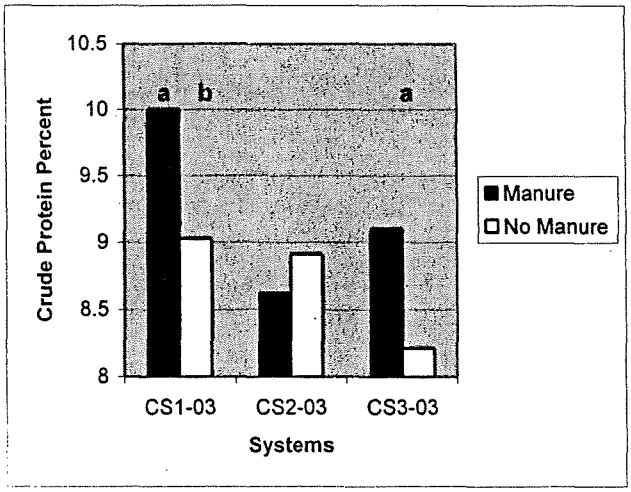


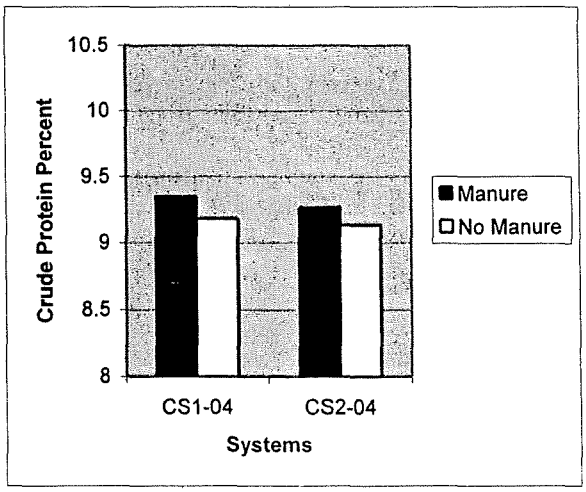


Figures 6a and 6b: 2003 and 2004 WICST Mean Crude Protein Percentages

Figure 6a: 2003 Crude Protein Percentage

Figure 6b: 2004 Crude Protein Percentage





Note: Letters above histogram indicate significant differences ($\alpha = 0.10$).

Figure 7a and 7b: 2003 and 2004 WICST Fall Nitrate Levels (lbs NO_3/3-foot depth)

Figure 7a: 2003 Fall Nitrates

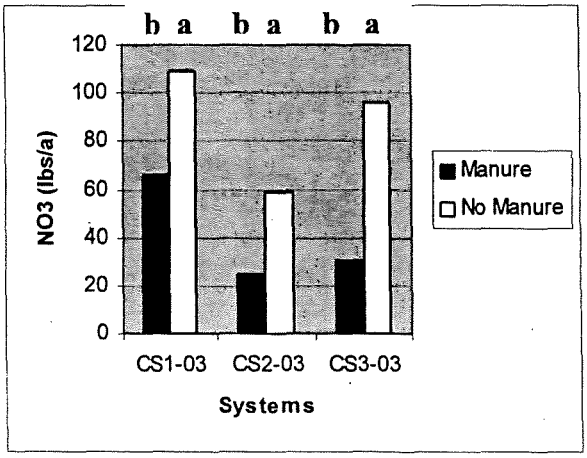
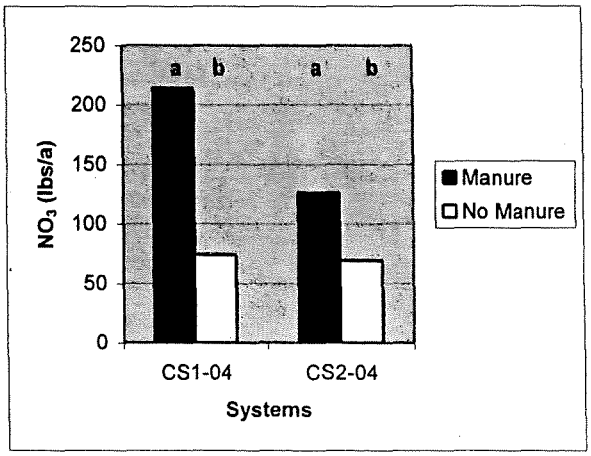


Figure 7b: 2004 Fall Nitrates



Notes: Fall nitrate levels measured in the top 3 feet. Letters above histograms indicate significant differences between nitrate levels ($\alpha = 0.10$).

REFERENCES:

Anderson S.H., C.J. Gantzer, and J.R. Brown. 1990. Soil physical properties after 100 years of continuous cultivation. J. Soil Water Conserv. 45:117—121.

Anderson, S. and B. Urbanowicz. A Summary of University Presidedress Nitrogen Test (PSNT) for Corn. Spectrum Analytic Agronomy Library. http://www.spectrumanalytic.com/support/library/rf/Presidedress_Nitrate_Nitrogen_Test_University_Summary.htm

Andraski, T.W. and L.G. Bundy. 2002. Using the presidedress soil nitrate test and organic nitrogen crediting to improve corn nitrogen recommendations. Agron. J. 94:1411-18.

Hergert G. 2005. Quoted in "Mitigating Nitrogen Sticker Shock" Agri-view, Jan. 20 2005, Crops p. 1,8.

Kelling K.A., L.G. Bundy, S.M. Combs, and J.B. Peters. 1998. Soil test recommendations for field, vegetable, and fruit crops. University of Wisconsin-Extention Publication A2809.

Motavalli P.P. and R.J. Miles. 2002. Soil phosphorus factions after 111 years of animal manure and fertilizer applications. Biol. Fertil. Soils. 36:35—42.

NRCS. 2004. Nutrient Management Code 590, Proposed Final Draft 11-01-04, Article C.2b(1) and (2).

Nutrient Management Fast Facts. 2003. Nutrient and Pest Management Program. University of Wisconsin-Extension.

PATS (Program on Agricultural Technology Studies). 1997. Availability of land for manure spreading on Wisconsin Dariy Farms, by Size of Herd. http://www.pats.wisc.edu/dmanspread.htm

Porter, S. 2004. The Future of Nutrient Management in Wisconsin. Proceedings from the Wisconsin Fertilizer, Aglime, and Pest Management Conference, p. 2. http://www.soils.wisc.edu/extension/FAPM/2004proceedings/Porter.pdf

WASS (Wisconsin Agricultural Statistics Service). 2004 Booklet, p. 51. http://www.nass.usda.gov/wi/annbull/page51.pdf

LINKING FARMS: RECONNECTING DAIRY AND CASH-GRAIN FARMS THROUGH SHARED MANURE MANAGEMENT

II. Assessing weed pressure from manure applications on corn grain fields

Amy Cook[1], Joshua Posner[2], Janet Hedtcke[3], Herika Kummel[4]

INTRODUCTION

Due to higher stocking rates, suburban land development, and stricter nutrient management regulations, Wisconsin dairy farmers are looking beyond their own land for areas to spread manure. One possible alternative is to transport and apply manure to nearby, willing cash-grain farmers' land. However, grain farmers have concerns that adding manure to their fields may increase weed pressure, and cause higher expenses in their weed management programs. Other studies that have examined weed pressure from manure have focused on indirect measurements, such as counting viable seeds extracted from various types of manure storage facilities (Takabayashi et al., 1979; Cudney et al., 1992; Sarapatka et al., 1993), or measuring the viability of weed seeds following animal digestion (Oswald, 1908; Harmon and Keim, 1934; Blackshaw and Rode, 1991). In this study, we took a direct approach of measuring weed pressure (in-field weed counts, species richness and diversity, and biomass) from paired manured and non-manured plots in corn fields. In the first year of the study, 2004, the following questions were studied:

1. Does manure spreading influence early weed germination?
2. Does manure influence overall weed density (number of weeds) or competitiveness (weed biomass), particularly under normal weed control practices?
3. Does manure spreading influence weed communities (species richness and diversity)?
4. Does manure introduce new weed species not already present in the field?

MATERIALS AND METHODS

Five on-farm trials in corn fields were conducted. Main plots were laid out as described in the previous report "Production results and nutrient budgets 2003 and 2004," with manured and non-manured treatments in a randomized complete block design. In **Table 1** the manure application and weed control practices for each site are summarized.

For weed monitoring, six 1-m^2 quadrats were established in each manured and non-manured strip. Three of these six quadrats had no pre- or post-emergent weed control, while the other three quadrats received the same herbicide or mechanical weed control as the rest of the plot. The two manure treatments, Manure (M) and No Manure (NM), and the two weed control treatments, Weed Control (WC) and No Weed Control (NWC), resulted in four total treatments.

[1] Graduate student, UW-Madison, Agronomy Dept. amycook@wisc.edu
[2] Professor, UW-Madison, Agronomy Dept. jlposner@wisc.edu
[3] Research specialist, UW-Madison, Agronomy Dept. jlrieste@wisc.edu
[4] Undergraduate student, UW-Madison, Agronomy Dept. hkummel@wisc.edu

Figure 1 represents one replication from a typical site. Two replications were made at MP and MS, while three replications were made at JB I, NH I, and RJ I.

At the times of pre-emergent and post-emergent herbicide spraying, the NWC quadrats were covered with 1.15 m^2 tarps. In the case of the one organic site, NWC areas were created by having the farmer lift her cultivator bar as she tilled those areas.

A first pass to collect data on early emergence was made at approximately 18 days after planting (DAP), when the corn was between VE and V2. Weeds in all quadrats were counted and designated as broadleaf or narrow leaf (mainly grass) weeds. Due to logistical issues, this count was not made at the MP site.

A second pass to collect data on weed density and species richness was made at approximately 46 DAP (V6 stage in corn). Weeds were counted and identified to species level, primarily, but in the case of highly related species, such as smooth and redroot pigweed, only to the genus level.

A third pass was made at approximately 68 DAP to harvest all aboveground weed biomass that stood over four inches tall. Broadleaf weeds and perennial grasses were separated into individual species, excepting very small or infrequent weeds, which were combined as "miscellaneous." Annual grasses were combined. Weeds were oven-dried for 5 to 7 days and weighed for dry biomass.

A fourth pass was made after corn harvest at most sites to scout the field for exotic weed species not already encountered at the monitoring stations. The areas scouted were approximately 200 feet long and 6 rows wide, or 3000 ft^2. All weeds seen in this swath were identified but not individually counted.

Hill's 2nd Species Diversity Index was used to classify weed communities (Ludwig and Reynolds, 1988). This index was chosen over other diversity indices because it incorporates both species richness (number of species present in the sample) and evenness (the distribution of individuals in each species). Additionally, it is simple to calculate and is used frequently in community ecology research.

The index, based on Shannon's index, H', uses the following equations:

Equation 1 $$H' = -\sum\left[\left(\frac{n_i}{n}\right)\ln\left(\frac{n_i}{n}\right)\right]$$

Equation 2 $$N1 = e^{H'}$$

In **Equation 1**, n_i represents the number of individuals of the ith species, and n represents the total number of individuals in the sample. H' is defined as a measure of "uncertainty" in predicting to what species an individual randomly chosen from a collection of species will belong. H' increases as the number of species increases, and as the distribution of individuals in each species becomes more even. The benefit of Hill's function, N1 (**Equation 2**), is that the units are actually in terms of species, such that N1 represents the number of species that would,

if all species were equally distributed, produce the same H' as the sample. A higher N1 represents a sample that is both more rich and even in species.

The treatment design was a 2-factor factorial of manure (with and without) and weed control (with and without). Due to logistical constraints, the experiment was set up as a split-plot design with 2 or 3 replications, as described above, in which the two manure treatments defined the whole-plots, and the two weed control treatments made up the subplots. Within each replication, three repetitions of each treatment were made (see **Figure 1**). In order to maintain enough degrees of freedom to best approximate error for the analysis of variance (ANOVA) within each location, the whole-plot error, subplot error, and residual error were all pooled. The resulting reduced model was identical to the standard Randomized Complete Block ANOVA, ignoring the split-plot layout. A mixed effects model was used in order to comply with the postulates that the two treatments (manure and weed control) were fixed effects, and site and blocking were random effects. Proc univariate, proc plot normal, and proc mixed of SAS 8.2 software were used in the analysis. Because the data did not adhere to the statistical assumptions of homogenous variance and normality, it was largely log-transformed for the analyses, such that $[y = log(x + 1)]$. Thus, the means reported are the least squares means of the untransformed data, while p-values are from the transformed analyses.

Due to the time-intensive nature of this study, some key changes are being made for the 2005 season. No early emergence pass will be made. All data collection will be made in one combined pass, dated between 6 and 8 weeks after corn planting. Weeds will be identified to species (or genus, in the case of highly related weeds), counted, and harvested for biomass measures. In addition to identifying weeds in the quadrats, scouting passes will be made in each plot to search for introduced weeds that were not present in the quadrats.

RESULTS AND DISCUSSION

A. Baseline Weed Pressure:

In order to interpret the data collected on weed pressure from manure applications, it is useful to understand the potential "weediness" of each field, without manure additions or weed control effects. Results from each site's check quadrats (Pass 2) are recorded in **Table 2**. Also shown in **Table 2** are the average weed density measurements made by Clark Wagner (Wagner, 1992). These averages, taken in 1990 and 1991 at 37 non-treated field corn and 12 non-treated sweet corn sites in southern and central Wisconsin, serve here as "standards" of total weed pressure in non-treated fields, and are used to help categorize the relative weediness of each site. They appear in the last row of the table.

As can be seen from the table, the cooperating farmers previously had good control of grass weeds in their fields, with the exception of MS. Potential broadleaf pressure was more variable. By and large, however, it appears that at most of the sites, historic weed control had been good, and the weed pressure potential prior to applying manure was comparative to or lower than the sites used in the Wagner study.

B. Early Emergence

Results of the analyses of Pass 1 (DAP ~ 18) are displayed in **Table 3**. As can be seen, adding manure did not seem to cause earlier emergence of weeds. It was found that in all 4 sites, with no weed control, weed density was not higher in the manured plots. In the case where the farmers' weed control programs were employed, there was a larger early flush of weeds in the manured treatment at only one site (NH 1) but the numbers were fairly low. When the total weed density was separated into grasses and broadleaves and analyzed again, the results proved similar to the total weed analysis. Thus, in response to the first question of whether manure influenced weeds early on in the season, the results did not point to any predictable effect of manure applications on weed emergence timing.

C. Weed Density and Biomass (Resource Competitiveness)/Weed Control Efficacy

The results of the analyses on total weed density in Pass 2 (approximately 46 DAP) are displayed in **Table 4**. These results show that manure did not cause a significant increase in weed density at any site under the No Weed Control conditions, as well as when weed control was used. At one site in fact, the weeds in the non-manured plots significantly outnumbered the weeds in the manured plots. The individual analyses of grasses and broadleaves (not shown) followed the same pattern as the analysis of total weeds. As might be expected, total aboveground weed biomass also did not increase as a result of manure additions (see **Table 5**). Similar results were found from the individual analyses of grasses and broadleaves (not shown): no significant increase in biomass in the manured plots.

These results indicate that in both the absence and presence of weed control, manure did not cause an increase weed numbers or growth rates. Thus, corn yields should not have been affected by greater weed pressure in the manured plots.

D. Impact on Weed Communities

A number of weed species were identified across the five sites—over 25 broadleaf species, and at least 9 grass species. The most widely seen weeds included common lambsquarters (*Chenopodium album*), various pigweeds (*Amaranthus* spp.), velvetleaf (*Abutilon theophrasti*), dandelion (*Taraxacum officinale*), eastern black nightshade (*Solanum ptycanthm*), giant foxtail (*Setaria faberi*), and yellow foxtail (*Setaria glauca*). In the Wagner study in Wisconsin, common lambsquarters, redroot pigweed, velvetleaf, and giant, yellow, and green foxtail (*Setaria viridis*) were also the most common species counted (Wagner, 1992). Analyses on the prevalence of individual weed species in each treatment were not made for this report for sake of brevity.

Data collected on species richness was analyzed to see whether manure had any effect on the number of species present in the plots. The results, reported in **Table 6a**, show that species richness did not increase with the addition of manure. The only significant difference in species richness was found at RJ I (NWC and WC), where a greater number of species was actually found in the non-manured plots than in the manured plots. Whether weed control was used or not did not greatly affect these results.

Hill's Species Diversity Index #2 (N1) was used with the Pass 2 data in order to determine manure's effect on species diversity (richness and evenness); these results are shown in **Table 6b**. Similar to the species richness results, manure did not increase species diversity by a significant amount in either weed control treatment.

E. Introduced species

Species identifications from Passes 2, 3 and 4 were combined to see if there were any weed species that were unique to only the manured or non-manured plots at each site. These results may be found in **Table 7**. While there are some species at each site that only were found in the manured plots, there are also species identified only in the non-manured plots. Thus, this method of identifying seedlings in both small quadrats and large scouting passes did not seem to be an adequate technique for answering the question of whether new species were introduced or not. More information is needed, such as a detailed historical weed species inventory of all the sites, and more complete scouting that covered a greater percentage of each plot, in order to better address the question of introduction of exotic species.

CONCLUSIONS

With a few exceptions, manure additions did not cause more rapid weed emergence, nor significantly increased weed density, biomass or species diversity. Manure applications also did not seem to influence weed communities, in terms of species richness and evenness in these five on-farm trials. The 2004 results suggest that incorporating manure into a cash-grain rotation is unlikely to cause any difference in weed density, competitiveness, or species richness, and that the weed control strategies already employed by the farmers are as effective on the manured plots as on the non-manured plots. It appears that even without weed control, the addition of manure did not result in much higher weed density or biomass. Thus, adding manure to a cropping system should not cause alterations to a farmer's weed management program, nor subsequent declines in yield as a cause of weed pressure.

TABLES AND FIGURES

Table 1: On-farm Site Information: Manure application and weed control practices

Site	County	Manure Source: Type /Amount	Manure Application Date	Tillage/Mechanical Weed Control	Chemical Weed Control, Application Timing
JB I	Dane	Dairy A: Slurry / ~ 12,000 gal/a	Aug. 15, 2003	Fall chiseled, disked, dragged. Spring field cultivated.	Outlook (1 pt/a), Pre-E Prowl (3 pts/a), Post-E Distinct (6pts/a), Post -E
RJ I	Columbia	Dairy B: Solid / ~ 31 tons/a	Aug. 26, 2003	Fall deep chiseled.	Accent (2/3 oz/a) + Hornet (3 oz/a), Post-E
NH I	Columbia	Dairy B: Slurry / ~ 11,500 gal/a	Oct. 31, 2003	None (Fall strip-tilled with 8" bands)	Dual II Magnum (1.6 pts/a), Pre-E Clarity (0.5 pts/a), Post -E
MP	Outagamie	Dairy C: Solid / ~ 10 tons/a	Early June, 2004	None (Fall zone tilled with 1.5" bands)	Clear Out burndown, Pre-P Callisto (2-5 oz/a) + Atrazine (0.75 lbs/a), Post-E
MS	Brown	Dairy D: Solid / ~ 15 tons/a	Early June, 2004	Spring rotary hoed (1x); Lilliston cultivator (2x)	None (organic farm)

Notes: All chemical weed control products listed above are commercial products. Generic active ingredients are as follows: Accent = nicosulfuron; Buctril = bromoxynil; Callisto = mesotrione; Clear Out = glyphosate; Distinct = dicamba + diflufenzopyr; Dual II Magnum = s-metolachlor + safener; Hornet = flumetsulam + clopyralid; Outlook = dimethenamid-P; Prowl = pendimethalin. Application timing: Pre-E = pre-emergent; Post-E = post-emergent; Pre-P = pre-plant.

Table 2: Weed density of baseline quadrats (No Manure, No Weed Control); Pass 2 (~ 46 DAP, weeds m^{-2})

Site	Grasses	Broadleaves	Total	Relative density
JB I	5	55	60	Low
NH I	0.1	30	30	Very Low
RJ I	20	29	49	Very Low
MP	0.3	121	121	Medium
MS	3542	94	3636	Very High
Wagner's Average	*394*	*115*	*509*	

Notes: Wagner's counts made at 40 DAP (Wagner, 1992).

Table 3: Early Emergence, at approximately 18 DAP (Total weeds m^{-2})

	No Weed Control			With Weed Control		
	Manure	No Manure	Manure Effect	Manure	No Manure	Manure Effect
JB I	29	57	NS	26	44	NS
NH I	27	9	NS	18	3	*
RJ I †	7	13	**	N/A	N/A	N/A
MS I	2199	1939	NS	211	616	***

Notes: With $\alpha = 0.10$: NS = Not Significant; * = 0.05—0.10; ** = 0.01—0.05; *** < 0.01. The least squares means are reported from non-transformed data, and significance is based upon raw p-values from log-transformed data *[y = log(x+1)]*.

†No pre-emergent herbicide sprayed at RJ I, so only No Weed Control data was available.

Table 4: Weed Density at approximately 46 DAP (Total weeds m^{-2})

	No Weed Control			With Weed Control		
	Manure	No Manure	Manure Effect	Manure	No Manure	Manure Effect
JB I	37	60	NS	6	12	NS
NH I	24	30	NS	4	8	NS
RJ I	44	49	NS	14	10	NS
MP I	36	121	***	0.8	4	**
MS I	2806	3636	NS	291	498	NS

Notes: With $\alpha = 0.10$: NS = Not Significant; * = 0.05—0.10; ** = 0.01—0.05; *** < 0.01. The least squares means are reported from non-transformed data, and significance is based upon raw p-values from log-transformed data *[y = log(x+1)]*.

Table 5: Weed Biomass at approximately 68 DAP (aboveground DM grams m^{-2})

	No Weed Control			With Weed Control		
	Manure	No Manure	Manure Effect	Manure	No Manure	Manure Effect
JB I	284.3	440	NS	59.3	1.3	NS
NH I	201.6	72.2	NS	2.5	1.6	NS
RJ I	53.9	37	NS	8.5	1.3	NS
MP I	28	83.4	NS	0.3	11.1	NS
MS I	270.1	253.2	NS	72.6	64.4	NS

Notes: With $\alpha = 0.10$: NS = Not Significant; * = 0.05—0.10; ** = 0.01—0.05; *** < 0.01. The least squares means are reported from non-transformed data, and significance is based upon raw p-values from log-transformed data *[y = log(x+1)]*.

Table 6: Species Richness and Diversity at approximately 46 DAP

Table 6a: Species Richness (number of spp. m^{-2})

	No Weed Control			With Weed Control		
	Manure	No Manure	Manure Effect	Manure	No Manure	Manure Effect
JB I	5.4	5.9	NS	1.8	2.1	NS
NH I	3.6	3	NS	1.6	2.4	NS
RJ I †	5.4	7.2	***	2.1	3.1	*
MP I	3.2	3.5	NS	0.7	1.8	NS
MS I	3.8	4.5	NS	2.2	2	NS

Table 6b: Hill's Species Diversity Index, N1‡

	No Weed Control			With Weed Control		
	Manure	No Manure	Manure Effect	Manure	No Manure	Manure Effect
JB I †	3.4	3.4	NS	1.8	1.9	NS
NH I †	2.3	1.8	NS	1.6	2.2	NS
RJ I	3.4	4.6	**	1.8	2.7	*
MP I	2.0	1.7	NS	1.2	1.8	NS
MS I †	1.3	1.2	NS	1.2	1.2	NS

Notes: With $\alpha = 0.10$: NS = Not Significant; * = 0.05—0.10; ** = 0.01—0.05; *** < 0.01. The least squares means are reported from non-transformed data, and significance is based upon raw p-values from log-transformed data *[y = log(x+1)]*.

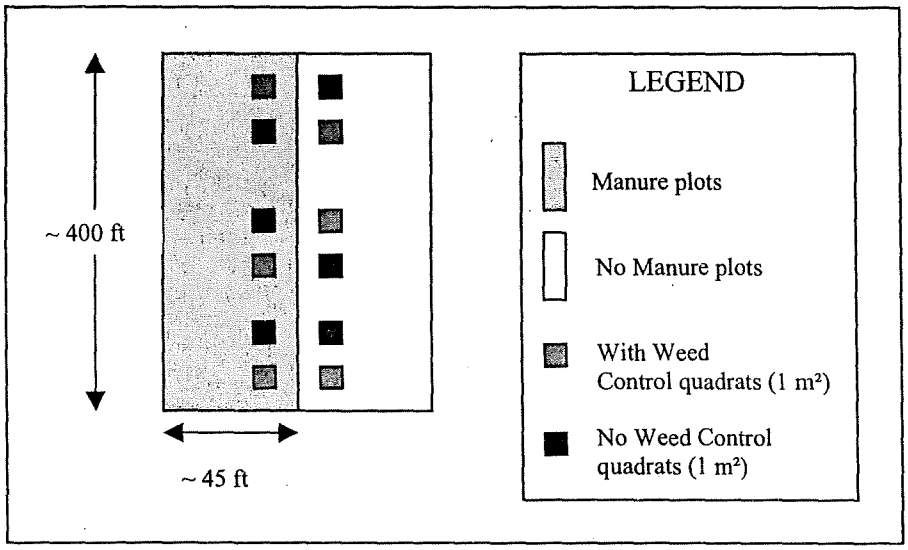
† Raw data set used in analysis (not log-transformed), as the raw data was a better fit to the ANOVA assumptions than the transformed data.

‡ $N1 = e^{H'}$, where $H' = -\sum [(\frac{n_i}{n}) \ln (\frac{n_i}{n})]$

Table 7: Weed species occurring only in one of the two manure treatments

Site	Broadleaves only in Manure Plots	Grasses only in Manure Plots	Broadleaves only in No Manure Plots	Grasses only in No Manure Plots
JB I	Broadleaf Plantain		Purslane, Wild Buckwheat, Prickly Lettuce, Yellow Wood Sorrel, Shepherd's purse, Fleabane, Canada Thistle	Wheat, Quackgrass
NH I	Knotweed, Purslane		Horseweed	Wild Oat
RJ I	Milkweed, Fleabane		Purslane, Yellow Wood Sorrel, Broadleaf Plantain	
MP		Giant Foxtail, Wild Proso Millet	Velvetleaf, Dandelion	Fall Panicum
MS	Broadleaf Plantain	Green Foxtail		Quackgrass

Figure 1: Typical layout, one repetition (not to scale)



REFERENCES

Blackshaw, R. E. and L. M. Rode. 1991. Effect of ensiling and rumen digestion by cattle on weed seed viability. Weed Sci. 39:104-108.

Cudney, D. W., S. D. Wright, T. A. Shultz, and J. S. Reints. 1992. Weed seed in dairy manure depends on collection site. California Agric. 46:31-32.

Harmon, G. W. and F. D. Keim. 1934. The percentage and viability of weed seeds recovered in the feces of farm animals and their longevity when buried in manure. Agron. J. 26:762-767.

Ludwig, J. A., and J. F. Reynolds. 1988. Diversity Indices. p. 85-92 *in* Statistical Ecology: A primer on methods and computing. Wiley Press, New York.

Mt. Pleasant, J. and K. J. Schlather. 1994. Incidence of weed seed in cow (*Bos taurus* spp.) manure and its importance as a weed source for cropland. Weed Tech. 8:304-310.

Sarapatka, B., M. Holub and M. Lhotska. 1993. The effect of farmyard manure anaerobic treatment on weed seed viability. Biol. Agric. Hort. 10:1-8.

Takabayashi, M., T. Kubota, and H. Abe. 1979. Dissemination of weed seeds through cow feces. JARQ. 13:204-207.

Wagner, C. R. 1992. Soil weed seed bank population dynamics and methods for measuring weed seed populations in soil. M.S. Thesis, Agronomy. University of Wisconsin: Madison.

MANURE MANAGEMENT ON A TOWNSHIP SCALE: USING A LAND EVALUATION AND SITE ASSESSMENT (LESA) APPROACH IN WI

Trisha Wagner[1] and Joshua Posner[2]

INTRODUCTION

Properly managing manure is essential to reducing nutrient buildup on farm fields and controlling nutrient runoff into surface waters. One way of promoting sound manure management is by linking the number of animals to the area of land and cropping system available for manure assimilation (Saam et al, 2005). However, due to the recent upswing in the rate of dairy herd expansion, many farmers now have more manure to spread than can be recycled on their own cropland. Herd sizes grew at a relatively constant rate (2 to 3%) from 1960-1990 in Wisconsin and then increased at a rate of 4.6% from 1995-1999 (PATS 2002a). Along with increasing size have come increasing stocking rates. It appears that farms with 25 to 100 cows have 2.2 acres of cropland per animal unit (AU=1,000 lbs of animal weight), farms with 100 to 200 cows have 1.8 acres per AU, while farms with more than 200 dairy cows have an average of only 1.6 cropland acres per animal unit (PATS, 2002b). This increasing stocking rate threatens the ability of Wisconsin livestock producers to adequately recycle manure nutrients back onto crop fields and increases the risk of environmental pollution.

A potential solution to this problem is to envision manure management on a landscape, rather than a single-farm scale. An advantage for Wisconsin and most of the upper Midwest is that the agricultural landscape is a mosaic of livestock and cash-grain farms. From this perspective, livestock farmers could spread manure beyond their farm in order to facilitate more complete manure nutrient recycling by crops.

A Land Evaluation Site Assessment (LESA) model was developed as a tool to facilitate the discussion, at a community level, of the feasibility of this concept. The major components of the LESA model are two analytic processes: 1) a land evaluation and 2) a site assessment (American Farmland Trust, 2004). The land evaluation begins with the acquisition of digital geographical data layers of a particular landscape's physical characteristics while the site assessment portion analyzes a number of other factors that affect agriculture. Examples include social features such as development pressure, traffic patterns or the presence of scenic areas.

Our vision is that land use planners and community members could build a series of maps to examine the geographic proximity of priority manure spreading areas to farms where the manure is being produced, and the social and physical barriers between the two. Such information would be useful for people who want to accommodate both residential growth while maintaining an agricultural landscape and a viable livestock industry. A township in Wisconsin is hypothetically 6 miles by 6 miles (23,040 acres). This is an attractive unit for looking at landscape level manure management as manure is rarely moved more than 3 to 5 miles, and township governments deal with most land use and local road maintenance issues. In this note we describe the application of the LESA model to West Point township in south central Wisconsin.

[1] Graduate Student, UW-Madison, Land Resources
[2] Professor, UW-Madison, Agronomy Dept.

MATERIALS AND METHODS

The geographical data layers chosen for the land evaluation were based on the regulations outlined in the USDA-Natural Resources Conservation Service (NRCS) 590 Nutrient Management Standards (2004a) for applying manure. The key landscape physical features include slope, identification of soils with high nitrogen leaching potential, proximity to surface water, and land cover. Data layers chosen for the site assessment include the location of livestock farms, size of operations and location of suburban development. To test the complexity of using this model to build a set of maps linking manure production with spreading areas, a township with livestock farms, grain farms and a growing suburban population was chosen. The Town of West Point (**Figure 1**) was chosen and is located along the Wisconsin River in Columbia County, Wisconsin. Due to the river truncating the 6-mile x 6-mile township grid, this town includes approximately 18,844 acres. It has a population of 1,634 people, and has seen a 22 percent growth in residents from 1990-2003. This number is expected to increase with the completion of the highway expansion project that links the town to the Madison metropolitan area. Census data also reports a 3.4 percent decrease in the land taxed for agricultural purposes (PATS, 2003). There is, not surprisingly, a growing concern among town officials about how to maintain a viable local agricultural industry while accommodating residential growth.

Land evaluation: slope

A Digital Elevation Model (DEM) data layer was used to measure the percent slope of the landscape. The NRCS 590 nutrient management standard prohibits the application of nutrients on frozen or snow covered soil on slopes greater than 9%, except where conservation practices are implemented e.g. contour strips and grass water ways (USDA-NRCS, 2004a). The DEM was downloaded from the US Geologic Survey website at which time 30 meter data (1:24,000 scale) was available for the study area (USGS 2003). The slope was calculated using ArcGIS 3D Analyst (ESRI, 2004) to represent percent slope of the landscape. In this study we simplified the slope classes to cropland slopes less than 6% were considered adequate for spreading manure, cropland slopes between 6.1-12% was cautionary for spreading manure, and the few acres of cropland above 12% were, according to the 590 standard, not available for spreading.

Land evaluation: soil

Soil survey data was used to evaluate hydrologic constraints such as shallow depth to bedrock (R), perched water table (W), as well as highly permeable soils (A). The NRCS 590 nutrient management standard cautions spreading nutrients on these soils due to the high potential for nitrogen leaching (USDA-NRCS, 2004a). Tabular information regarding the R, W and A soil properties was obtained from soil scientists at the USDA-NRCS and was attached to Columbia County soils data, downloaded from the NRCS website (USDA-NRCS, 2004b). Soil survey data is available for the county at 1:12,000 scale. In this study, the sols with R, W or A constraints were considered cautionary for spreading manure, as they are considered safe against nutrient leaching for only part of the year.

Land evaluation: land cover

According to the NRCS 590 standard, manure can only be applied to land that has a crop taken off of it unless an emergency situation occurs. Satellite imagery of the study area's land cover in 2003 was acquired from the National Agriculture Statistics Service (NASS 2004). The

NASS Cropland Data Layer provides classified yearly imagery of land cover and major crops for Wisconsin, using 30-meter resolution imagery from Landsat satellites 5 and 7. Eight of forty-one possible NASS land cover categories used in all states are present in the portion of the Wisconsin scene used for the study area. Using a satellite imagery processing software, ERDAS Imagine (Leica Geosystems, 2004) the portion of the study was clipped from the Wisconsin scene and a simple nearest neighborhood classifier was utilized to geometrically correct the NASS raster image and resample the raster to avoid frivolous pixilation (ibid).

Land evaluation: hydrology

The NRCS 590 nutrient management standard prohibits the application of nutrients when frozen or snow-covered soils prevent effective incorporation at the time of application, regardless of slope, in Surface Water Quality Management Areas (SWQMAs). For purposes of nutrient management planning, SWQMAs are defined as 1.) "...the area within 1,000 feet from the ordinary high-water mark of navigable waters that consist of a lake, pond or flowage, 2.) ... the area within 300 feet from the ordinary high water mark of navigable waters that consist of a river or stream...". Digital data for the study area's hydrologic features were obtained at the county level from the Columbia County Land Information Office at a scale of 1:20,000.

Site assessment: livestock location and number

In Wisconsin, there are not official lists of livestock operations, numbers of animals and addresses. As an alternative, a list of the location of the livestock farms and animal numbers was developed through consulting with town council officials and farmers. Through these discussions, the number of mature cows on the dairy farms in the study area was obtained. Based on this estimate, a total herd number (dry cows, heifers, calves) was generated using a herd profile estimation table (**Table 1**). The average weight of animals in each age category was used to estimate animal units (AU) (**Table 2**).

In the case of beef operations in West Point, the average number of head fattened per year on beef farms was estimated via the informal survey. The majority of producers bought approximately 500 pound animals in April, fed them on grass for six months until October (750 pounds) and then finished the animals to marketing weight (1,100 pounds) over winter. The AU calculation was estimated in two phases, first during the spring/summer grazing months (April-October) and second during the confinement months (November-March).

There is one "feeder" pig operation in the study area. There are 200 sows on the farm throughout the year. An estimation of two and a half pregnancies per sow per year, with an average of eight piglets, results in 4,000 piglets passing through the farm each year. However, there are only about 1600 piglets on this farm at any time because the piglets are only kept from birth to approximately 65 pounds (about three months).

Site assessment: urban development

Through discussions with town officials and the use of aerial photographs, digital parcel data and the road network, areas of urban development were delineated. The digital data layers were acquired through the Columbia County Land Information Office. When the parcel data is overlaid on the photograph, it is possible to identify the growing suburban developments along the Wisconsin River and local lakes. Other features such as the golf course were also visually identified by this method.

RESULTS AND DISCUSSION

The Town of West Point is predominately rolling hills with about half of the landscape above 6% slope. Steep areas, above 12% slope, are mainly forested bluffs. There is a relatively small area of soils constrained due to hydrologic considerations (725 acres). The majority of these soils are highly permeable soils, which require particular attention to timing of manure applications with expected rapid crop growth and nutrient uptake (figures not shown). As can be seen in the land cover **Figure 2** (NASS scene from 2003), cropping acres (corn, soybeans, alfalfa) cover approximately forty percent of the town and another forty percent of the area is in the broad Pasture/Grassland/Non-Agriculture category.

There are twelve dairy farms, nine beef and one hog farm; ranging from 19 to 582 AU, with a total of nearly 4,000 AU in the study area. As can be seen in **Figure 3**, the livestock farms appear to be evenly distributed throughout the town, and fairly distant from the development along the Wisconsin River. The town's four largest livestock farms (>300AU) also appear to be fairly distant from one another. Areas of urban development are not surprisingly near the scenic areas of the town such as the Wisconsin River and Crystal Lake. Here, a new housing development called Paradise Island is replacing older, smaller cabins resulting in increased traffic and land prices. Roads with significant travel (highway 60 and 113) serve the suburban development areas.

Land Evaluation: identifying priority spreading acres

The goal of this land evaluation was to develop four classes relative to manure management: 1.) Priority spreading; 2.) Cautionary spreading; 3.) Grazing zone; and 4.) No spreading permitted. These classes are based on the data layers used to interpret the recommended practices of the NRCS 590 nutrient management standard.

The base data layer for this application is the NASS Cropland data layer (**Figure 2**). Initially the assumed classes for manure spreading were the cropping acres of corn, alfalfa and soybeans for a total of 7,321 acres. A large portion of the study area (43%) however, is in a mixed category entitled Pasture/Grassland/Non-Agriculture (PGNA) and therefore difficult to classify relative to spreading manure. Upon closer examination, much of the non-agriculture portion of the class coincides with the suburbanized areas of the town and golf course where the spectral signature is reflecting lawn, similar to grasslands but obviously not available for manure spreading. By consulting the aerial photograph, a 1300-foot buffer from the Wisconsin River shoreline and a 300 foot buffer around Crystal Lake tourist area were created. This 1,600 acre area all came from the PGNA category and was identified as non-agriculture and therefore not available for spreading manure.

Further analysis of much of the remaining Pasture/Grassland areas however, appeared to be embedded in cropland, raising the question of possible spectral signature confusion between cropland that was temporarily in alfalfa/grass mixtures and permanent pasture/grassland. A ground-truth survey was conducted in the study area to observe the remaining areas classified as Pasture/Grassland. Fifteen Pasture/Grassland sites were selected in the study area. Five of the fifteen sites visited are misclassified. Four of these five sites were on flat areas and in 2004 were in corn or soybeans -indicating they are part of the cropping rotation. These sites were most likely 3rd or 4th year alfalfa stands in 2003 and had included enough grass in the vegetation to cause a signature similar to pasture/grassland. Of the ten areas that were classified correctly, eight were on steeper terrain (> 6% slope) that was either fenced pasture or open grassland.

Other researchers at NASS have also found that the grassland/pasture category included a certain amount of error. The 2003 NASS Cropland data layer scene for the study area is considered highly accurate (Kappa Coefficient of 90%+) for major crops of alfalfa, corn and soybeans but low for grassland and pasture (59% and 57%) (NASS 2003). A high commission error for pasture (44%) suggests that nearly half of the pixels being classified as Pasture/Grassland actually belong in other categories.

This problem is not exclusive to the NASS Cropland data layer. The Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) produced land cover data for the State of Wisconsin in 1993 based on Thematic Mapper (TM) satellite imagery. In this classification substantial confusion exists among forage crops and grassland in both errors of omission and commission (WDNR 1999). Similar to NASS, of all ground-truthed polygons classified as grassland in WISCLAND, only about half were verified as grassland and the others were in fact forage crops (ibid).

Based on the ground truthing and corroborating studies, it was decided to break the Pasture/Grassland category into two categories; 1) areas below 6% slope were considered alfalfa hay fields (1,991 acres) and added to the cropping acres; and, 2) areas above 6% slope were kept as pasture/grasslands to be used for a grazing zone (4,458 acres).

As is summarized in **Figure 4,** there are 5,522 acres unavailable for spreading manure, 4,458 acres in grazing and a total of 8,884 acres in cropland available for spreading. Approximately 50% of the town is in cropland and the remainder is evenly divided between pasture/grasslands and non-agriculture areas (water, urban, suburban, forest or > 12% slope). Some of these crop acres however, according to the 590 standard are cautionary acres.

Land Evaluation: identifying cautionary spreading acres

Areas are identified for "cautionary spreading" because they require additional attention at some time during the year. The schematic diagram in **Figure 5**, is an outline of how the "possible spreading acres" were dived into priority and cautionary spreading acres. After cautionary acres are identified and removed from priority spreading for slope, soil and SWQMAs, a total of 6,779 acres remain in the study area as priority spreading acres. According to our interpretation of the 590 regulations, approximately 24% of the crop acres are under cautionary spreading rules, requiring farmers to take special caution such as incorporating manure within 72 hours of application or only applying manure in mid-summer when the water table is lowered.

Integrated Assessment

Figure 6 displays the farm locations and their relative size (AU) and the four land evaluation categories. In general, farm location appears to coincide with the land that is available for priority spreading. The farms appear to be evenly distributed in terms of AU size and geographic location. Suburban developments are along the shorelines of the Wisconsin River and Crystal Lake and the major traffic routes are near the developments. Therefore, for the most part, development is not fragmenting the three main valleys used for agriculture.

In addition to the spatial representation, calculating stocking rates (animal units/acre) can also be a useful way to look at the relationship of livestock to spreading acres. It is estimated that there are approximately 3,833 AU exist in the town on a priority spreading land base of 6,779 acres (3,833 AU/6,779 ac.), resulting in a stocking rate of .57 AU/acre. With the additional 2,105 acres in cautionary spreading, the stocking rate drops to .43 AU/acre. These

estimated stocking rates are considered low. Livestock operations with less than .74 AU/acre are considered to have sufficient cropland to assimilate all manure P (Saam et al. 2005).

The estimated stocking rate of .43 AU/acre is actually higher than the actual stocking rate. This is because many of the livestock farmers also graze a portion of their herd for the summer months thus depositing some of the manure not on crop acres, but on the grazing acres. This is particularly the case for the beef operations (18% of the town AU) where the summer manure from the young animals is deposited on grazed acres. By grazing the young animals (April-October), it is estimated that beef farmers in the study reduced the managed manure stream of P2O5 by 43% and K2O by 45%.

Considering the low stocking rates and general distance between suburban developments and the farms, manure management is not a crisis situation in West Point.

CONCLUSION

Using primarily secondary data, relatively easily accessible at the county and state level, a land evaluation site assessment tool was developed to help local land use planners and farmers envision manure management on a landscape scale rather than just confined to the farm. Such information can inform decision makers of the social challenges to manure management that can threaten the ability of livestock farmers to implement new nutrient management regulations. Crucial to the site assessment was the involvement of local officials and farmers who supplied valuable information pertaining to social challenges to manure management and commented on the completed maps.

REFERENCES

American Farmland Trust. 2004. Farmland Information Center Factsheet. Land Evaluation and Site Assessment Model. Farmland Information Center. August. www.farmlandinfo.org

Environmental Systems Research Institute. 2004. GIS and Mapping Software. ArcGIS software. http://www.esri.com/index.html

Leica Geosystems. 2004 ERDAS Imagine Software. Available online: http://www.gis.leica-geosystems.com/Products/Imagine/

National Agriculture Statistics Service. 2003. NASS cropland data layer scene for Wisconsin 2003 growing season metadata file. October 2003. http://www.nass.usda.gov/research/Cropland/SARS1a.htm

National Agriculture Statistics Services. 2004. NASS Cropland Data Layer. Available online: http://www.nass.usda.gov/research/Cropland/SARS1a.htm

Powell, J.M., D. Jackson-Smith, L. Satter, L.G. Bundy. 2002. Whole-Farm Phosphorus Management on Dairy Farms. 2002 Wisconsin Fertilizer, Aglime and Pest Management Conference. Madison, WI. Vol. 41, pp 13-24.

Program on Agriculture Technologies (PATS). 2002a. Estimated number of Wisconsin Dairy Farm Entrants and Exiters, and Net Change in Dairy Farm Numbers per

year 1978-1997. University of Wisconsin-Madison. Available online: http://www.pats.wisc.edu/

Program on Agriculture Technologies (PATS). 2002b. Availability of Land for Manure Spreading on Wisconsin Dairy Farms, By Herd Size, 1997. University of Wisconsin-Madison. Available online:http://www.pats.wisc.edu/

Program on Agriculture Technologies (PATS). 2003. Town Land Use Books, Columbia County, WI. University of Wisconsin-Madison. Available online: http://www.pats.wisc.edu/

Saam, H., J. M. Powell, D. Jackson-Smith, B. Bland and J. Posner. 2005. Use of Animal Density to Estimate Manure Nutrient Recycling ability of Wisconsin Dairy Farms. Agricultural Systems. 84 (2005) 343-357.

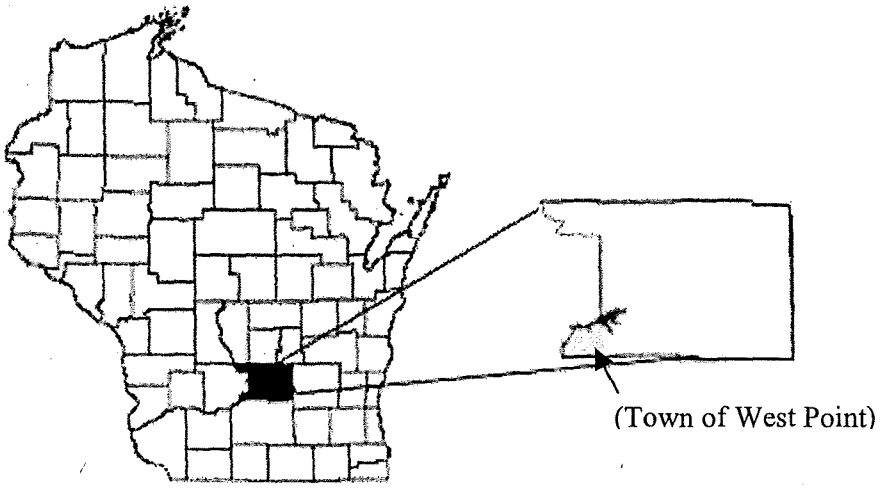
United States Department of Agriculture NRCS, 2004a 590 Nutrient Management Standard. Available online from the Department of Agriculture, Trade and Consumer Protection: http://www.datcp.state.wi.us/index.html

United States Department of Agriculture NRCS. 2004b. Soil Survey Geographic (SSURGO) Database. National Cartography and Geospatial Center. Online: http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/

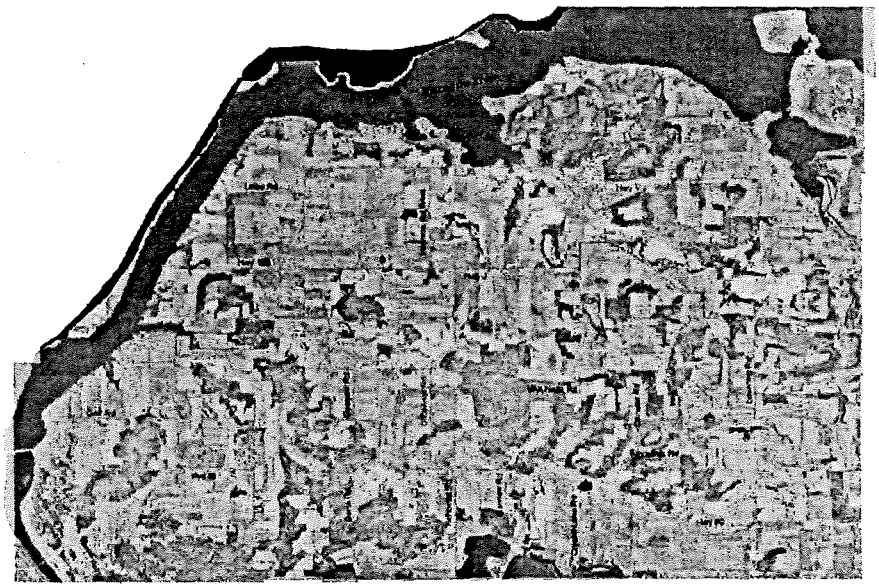
United States Geological Survey. 2003. EROS Data Center. The National Map Seamless Data Distribution System. Available: http://seamless.usgs.gov/

Wisconsin Department of Natural Resources (DNR). 1999. Land Cover of Wisconsin. A User's Guide to WISCLAND Land Cover Data. Wisconsin Dept of Natural Resources. December 9, 1999. available for download: http://www.dnr.state.wi.us/maps/gis/datalandcover.html#overview

Figure 1 Location and Overview of the Study Site



a. Location of Columbia County, Wisconsin and the Town of West Point



b. 2000 Aerial photograph of the Town of West Point[1]

1. Columbia County Land Information Office, 2000

Table 1 Hypothetical 100 Cow Diary Herd Profile[1]

Herd Size = 100 mature animals

Mature Animals (100):		**Number of Animals**			**Average weight (lb)**
Milking Cows		**83**			**1400**
Dry Cows		**17**			**1400**
Young stock (100):	Age range (months)		initial weight (lb)	final weight (lb)	
Calves	birth-6	**25**	125	400	**262**
Yearlings	7-12	**25**	400	725	**562**
Unbred heifers	13-18	**25**	725	1000	**862**
Bred heifers	19-24	**25**	1000	1300	**1150**

1. Adapted from Midwest Plan Service 2000 and David Kammel UW-Madison Biological Systems Engineer 2004.

Table 2 Animal Unit (AU) Calculation chart[1]

Animal Unit (AU) Calculation Chart

Animal Type	Average weight (lbs)	Animal Unit Equivalency Conversion Factor
Dairy Cattle		
milking cow	1400	1.4
dry cow	1400	1.4
calves	262	.262
Yearlings	562	.562
Unbred heifers	862	.862
Bred heifers	1150	1.15
Beef Cattle		
April - October	625	.625
November - March	925	.925
Pigs		
piglets	50	0.05
swine	375	0.375

1. An AU is defined by the NRCS as an average animal body weight equal to 1000 lbs, one mature cow of approximately 1000 pounds (USDA-NRCS, 2004).

Figure 2 Town of West Point land cover data layer, 2003[1]

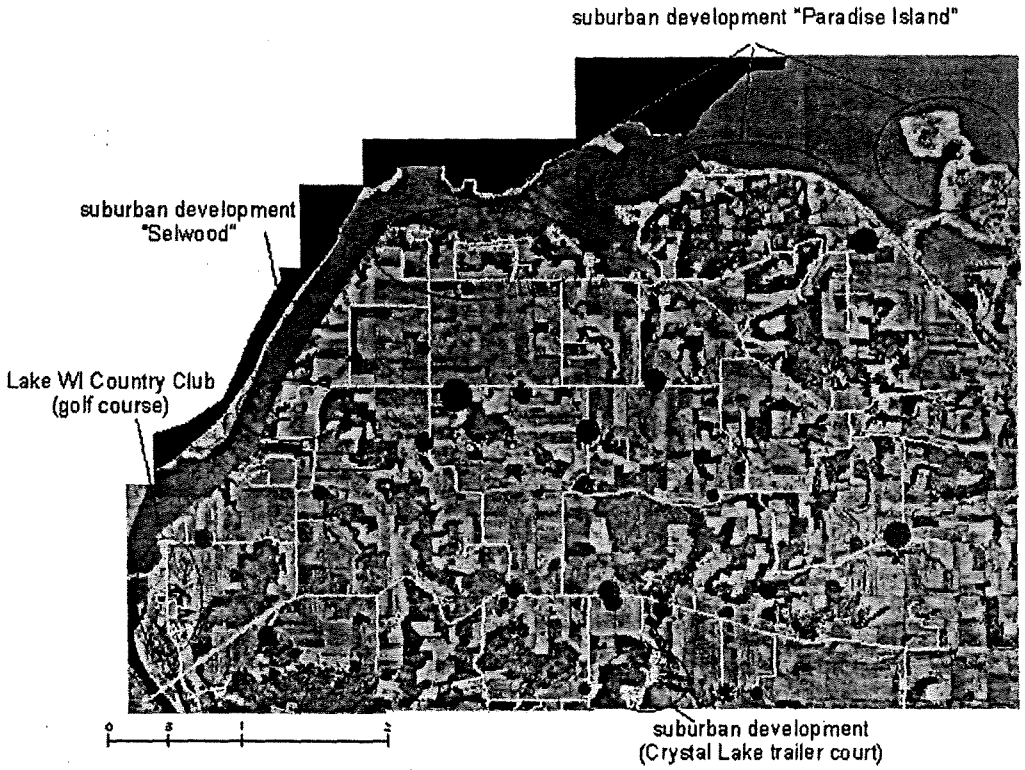
% of landscape*	acres	
25%	4,634	Corn
11%	2,005	Soybean
4%	682	Alfalfa
.5%	103	Fallow/Idle Cropland
43%	8,041	Pasture/Grassland/Non-Agriculture
16%	3,029	Forest
2%	370	Urban
	1,096	Water

* Water not included in tally.

1. National Agriculture Statistics Services, 2004

Figure 3

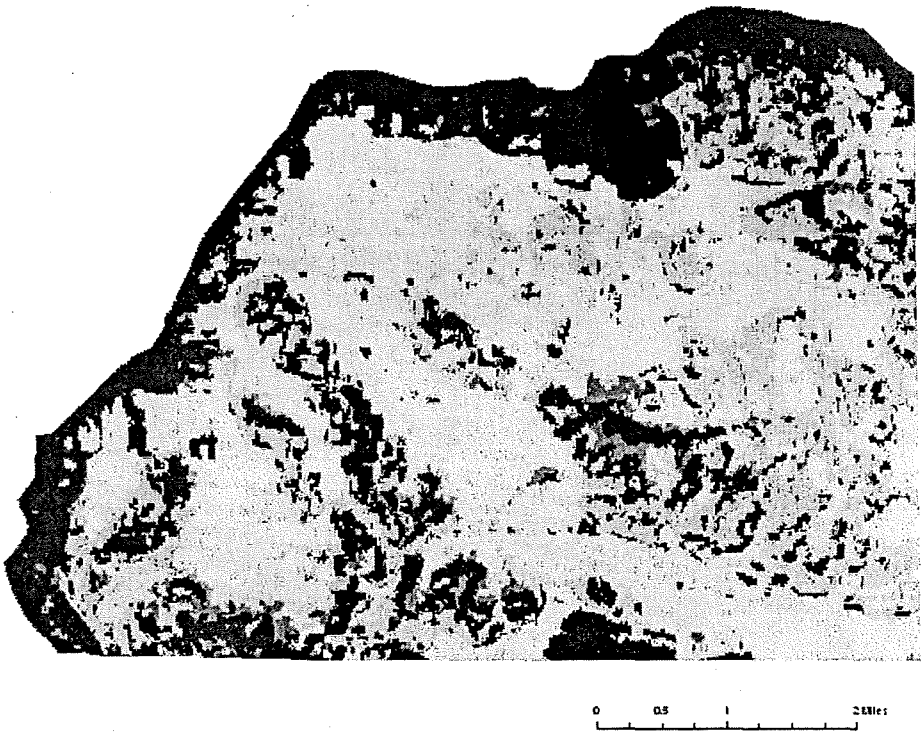
Livestock Farms of West Point and Suburban Developments



Animal Units (1)	# of Farms
< 100	(8)
101-200	(8)
201–300	(2)
301-400	(1)
>400	(3)

(1) AU=454 kg or 1000 lbs animal live weight

Figure 4. Spreading, grazing and no-spreading zones, Town of West Point



Spreading (corn, soybean, alfalfa) 8,884 acres

Grazing (Pasture/Grassland, > 6% slope) 4,458 acres

No spreading: (> 12% slope, urban, suburban and forest) 5,522 acres

Water

6,137 acres

Figure 5 Schematic presentation of land evaluation steps resulting in priority spreading, cautionary spreading, grazing and no spreading areas

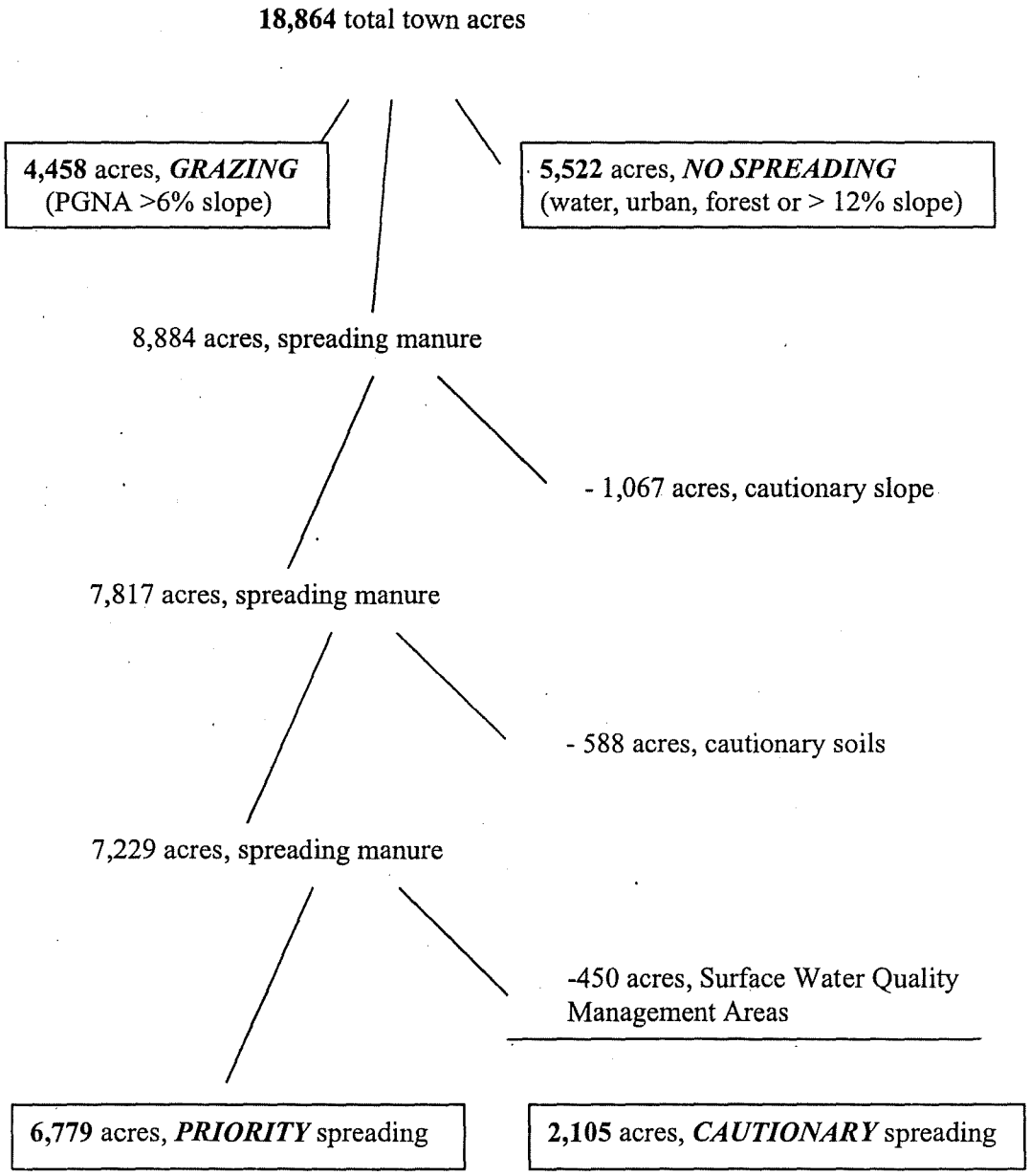
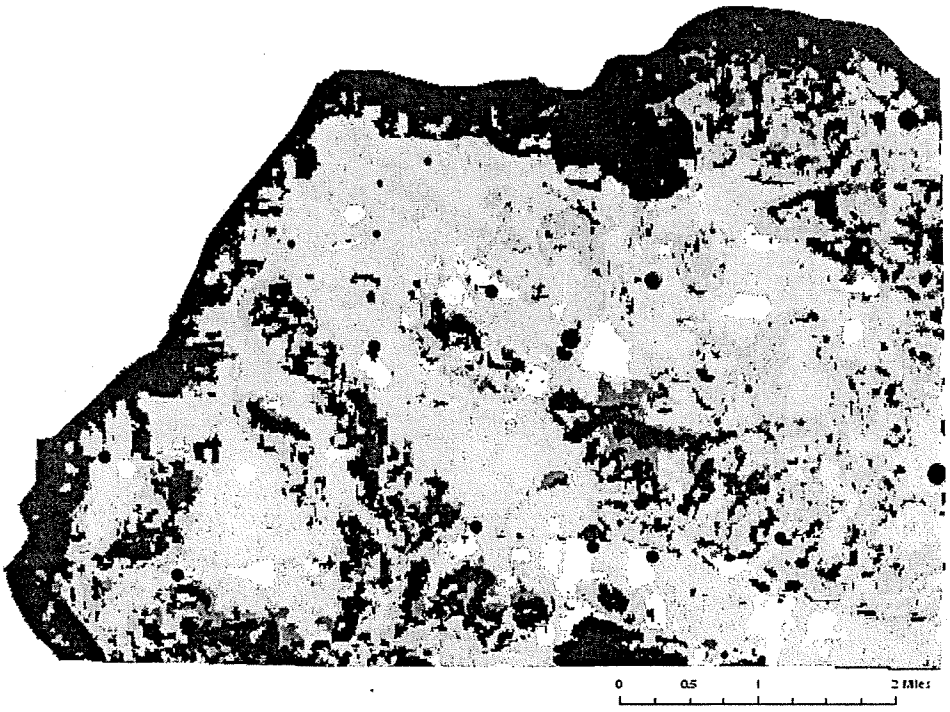


Figure 6. Land Evaluation categories and livestock farms in the Town of West Point



Priority spreading (corn, soybean, alfalfa) 6, 779 acres

Cautionary spreading 2,105 acres

Grazing (Pasture/Grassland, > 6% slope) 4,458 acres

No spreading (> 12% slope, urban, suburban, forest) 5,522 acres

Water

Animal Units	# of farms
< 100	(8)
101-200	(8)
201–300	(2)
301-400	(1)
>400	(3)

THE GRASS LEY: AN ALTERNATIVE FORAGE SYSTEM FOR IMPROVED MANURE MANAGEMENT

Amy Cook, Janet Hedtcke, Joshua Posner, John Hall, Rick Walgenbach

INTRODUCTION

Wisconsin dairy farmers have limited opportunities to spread manure, due to seasonal weather conditions and existing cropping systems. Spring manure spreading is not ideal, since moist soil is more prone to compaction, and may delay corn planting and/or germination due to colder, wetter conditions. The typical crops grown by a dairy farmer (alfalfa and corn) make summer manure spreading difficult. While winter spreading is a necessity for most dairymen, it is restricted in certain areas, and is less desirable due to the potential of manure runoff during thaws.

A grass *ley* is a grass "phase" within a longer-term crop rotation. Usually the forage grass is grown for a few years, and is then followed by several years of annual crops. The grass may be grown for pasture, hay, silage, or green chop. Benefits of the ley system include greater diversity within a rotation, reduced nitrate leaching (Simmelsgaard, 1998), reduced nitrogen and phosphorus runoff due to a more complete ground cover, and better soil structure and rainfall infiltration commonly found under grass sod (Heathwaite et al., 1998).

The goal of this study is to test the effectiveness of a grass ley system in helping dairy farmers expand their options for spreading manure. In particular, the Grass Ley Project focuses on the following objectives:

- To test the efficacy of the grass ley system in recycling manure nutrients, especially nitrogen and phosphorus, as compared to a "typical" forage system featuring corn for silage;
- To produce abundant, good quality forage.
- To gauge rejection of the manured grass in a livestock feeding trial.

The objective of this report is to describe site lay-out in the first two years, 2004 and 2005, and to discuss the results from the first year of the study, 2004.

MATERIALS AND METHODS

Experimental design:

The study was initiated in the fall of 2003 at two locations, the Dairy Forage Research Center (DFRC) in Prairie du Sac and the Michael Fields Agricultural Institute (MF) in East Troy. Site layout was in a randomized complete block design, with four treatments:

1. orchardgrass (*Dactylis glomerata* L.) with manure (OG-M) and fertilizer as needed;
2. orchardgrass without manure (OG-NM), but with fertilizer;
3. corn for silage (*Zea mays* L.) with manure (CS-M) and fertilizer as needed; and,
4. corn for silage without manure (CS-NM) but with fertilizer.

Orchardgrass was chosen for its reputation of fairly easy establishment, decent over-wintering capacity, excellent regrowth after harvest, good nitrogen uptake, and reasonably good forage quality. One replicated site (Site I) was laid out in each location in fall 2003, and a

second site (Site II) was established at each location in fall 2004. The protocol called for a fall seeding of the orchardgrass, followed by two years of hay, and a final year of soybeans. The corn silage rotation consisted of two years of silage, then a year of soybeans. Plot size at DFRC was 20' by 30' and at MF was 24' by 50'. See **Figures 1 and 2** for maps of the DFRC and MF sites, respectively.

At DFRC, both sites followed a mid-summer harvest of wheat, and consisted of five replications each. DFRC is a conventionally managed dairy farm, where manure is stored as slurry. A Nuhn plot-size liquid manure spreader was used to apply the slurry to the surface. It was fitted with hoses spaced approximately 1.5 feet that released manure at ground level. The field was not tilled, and no-till equipment was used at seeding.

In contrast, the site at MF is a reduced-input system where no pesticides are used. Therefore, mechanical tillage was used to control weeds and incorporate manure prior to orchardgrass planting, and in the corn silage plots. Semi-composted solid bedding pack manure from a neighboring organic dairy farm was applied with a box-spreader. There were six replications in Site I (following barley harvest) and five reps (following oats) in Site II. Thus, the two study locations represent different types of dairy systems.

The nutrient management goal of this project was to make manure additions at several times during the season that would be sufficient to stimulate orchardgrass growth, but not lead to animal rejection, nor soil build-up of nutrients, especially phosphorus. In the case of corn silage, summer windows were not possible, but the goal was still to meet crop needs without resulting in phosphorus accumulation. With an estimated yield of 5.5 tons of dry matter per acre of orchardgrass, 20 tons/acre fresh weight of corn silage and 50 bu/acre of soybeans, it was possible to calculate expected N, P and K removal of the hypothetical crop rotation. Then using standard manure content values, it was possible to estimate manure additions to meet the three-year expected phosphorus removals. The focus was on P-budgeting because it was assumed that the fields on typical dairy farms had high soil test P, and needed to be managed to prevent phosphorus build-up. These assumptions are laid out in **Tables 1a** and **1b**. At each manure-spreading event, samples were taken and analyzed at the Soil and Forage Analysis Laboratory in Marshfield.

In the case of the orchardgrass rotation, with the application of 63,000 gallons of slurry or 105 tons of manure, no more P is added than would be removed by the crop. Using the same approach, it is possible to apply 35,000 gallons of slurry or 59 tons of manure in the corn silage-based system. **Figure 3** is a schematic drawing of the original plan for manure applications. In the orchardgrass rotation, the idea was to apply 8,000 gallons/acre or 13 tons/acre during 8 passes, and 12,000 gals or 20 tons/a during the three "openings" in the corn silage rotation. Both treatments of the corn silage plots received University recommended rates of nitrogen fertilizer, and the non-manured orchardgrass received 50 lbs N after each cutting.

Soil samples for routine fertility (0-6") were taken prior to fall manure applications, samples of the manure were taken at the time of each spreading, and soil samples for nitrate (0-3') were taken in the late fall, after the final harvests and manure applications. All soil samples were analyzed at the Soil and Plant Analysis Laboratory in Madison.

Summaries of the agronomic inputs and outputs from each site are shown in **Tables 2** and **3**. These summaries reflect actual field practices, as opposed to the original protocols.

Orchardgrass management:

Seeding:

The orchardgrass plots at both locations were seeded (10-12 lbs/a) in the late summer of 2003, (DFRC 9/11/03; MF 9/20/03). However, at DFRC, rainfall was approximately 6 inches between August 1 and October 31, which was only 60% of the 30-year average of approximately 10.17 inches (MRCC, 2005, Prairie du Sac and Baraboo Stations). Near the MF site, only 4.8 inches fell in this time period in 2003, or 45% of the 30-year average (MRCC, 2005, Whitewater and Burlington Weather Stations). Due to the dry fall and competition from weeds and volunteer wheat, grass establishment was poor. As a result, both locations were re-seeded the following spring (DFRC 4/29/04; MF 4/14/04). Poor establishment of the 2004 late summer seeding (DFRC 8/13/04; MF 9/18/04) also occurred due to somewhat dry weather (64% of normal rainfall from August to October at DFRC, and 56% of normal rainfall near MF). Again, the orchardgrass plots at both sites were re-seeded in spring 2005 (DFRC 4/27/05; MF 4/3/05). Starting with the 2005 season seedings, 20 lbs of N/acre were applied at or soon after planting on the non-manured orchardgrass plots at DFRC and on both orchardgrass treatments at MF to help ensure rapid emergence and establishment.

Harvesting:

First cuts of orchardgrass were taken when the crop had reached 10-14" in height (6/30/04 at MF; 7/29/04 at DFRC). Second cuts were taken when the grass grew back to approximately the same height (9/3/04 at both locations). Only two cuts were taken from each site in the first year. Sample swaths of a known area were cut with a sickle-bar mower set at approximately the 3" height, and then the harvested grass was immediately weighed fresh. Small "grab" samples were taken from each plot, weighed fresh, and then were dried and weighed again in order to calculate dry matter percent and a dry matter tons/acre yield for each plot. The grab samples were then ground through a Wiley hammer mill fitted with a 1mm screen and sent to the University of Wisconsin Soil and Forage Analysis Laboratory for quality analysis, using NIR and wet chemistry techniques.

Corn silage management:

Planting:

Corn plots were planted at DFRC on 5/17/04 using treated seed in a no-till planter, on 30" rows. One hundred lbs starter (5:14:42) was applied at planting. Due to heavy rainfall, planting was delayed at MF until 6/9/04. Untreated seed was planted on 36" rows, with no starter fertilizer. Target population was 29,000 at MF and 34,000 plants per acre at DFRC.

Manure/Fertilizer Schedule; Pre-Sidedress Nitrate Testing:

Manure was applied to the corn plots with manure (CS-M) in the fall, prior to planting. Corn fertilizer rates for the CS-M plots and the corn plots without manure (CS-NM) were determined by using the recommendations from the Pre-Sidedress Nitrate Test (PSNT), as opposed to using manure nutrient crediting. Soil samples for the PSNT were composed of two pairs of cores (one in the row, one in-between rows) taken at one-foot in depth, when the corn was at approximately the V6 stage. Soil samples were analyzed at the Soil and Plant Analysis Laboratory. Ammonium nitrate or UAN were side-dressed with a drop-spreader at DFRC, and by hand at MF.

Harvesting:
Corn was harvested as silage in 2004 when kernel milk-line reached approximately half-way (9/23/04 at DFRC; 9/30/04 at MF). Two rows of corn from each plot were harvested with a Hege 2-row plot harvester (Kemper 'Champion 1200 head) at DFRC, which chops the stalks and ears, then weighs the mixture. Since machinery for making silage was not available at MF, plant population was counted in each plot, and then fifteen stalks were hand-cut and transported to the West Madison Research Station to be chopped into silage with a plot combine. Yields were then back-calculated, based upon the plant population of each plot. Grab samples were collected and dried in order to calculate dry matter percent and tonnage, as well as for quality analysis. However, while in the dryer, the samples molded. Dry matter yields were still calculated, based upon the amount of matter present, but samples were not sent to the lab for quality analysis.

Statistical Procedures:
Nutrient budgets were made by summing nutrient input from manure and fertilizer, then subtracting nutrient off-take by each crop. Nutrient off-take on the ley plots was calculated from the orchardgrass quality results, and from standardized values on the corn plots (NRC, 1989). Analysis of variance procedures using proc mixed, proc univariate, and proc means of SAS 8.2 software were used to analyze orchardgrass and corn yields, orchardgrass quality, and pre-season and post-season fall nitrates. Statistical analyses were made on both an individual-location and a combined-location basis; the individual-location analyses are reported here.

Future Procedures:
In anticipation of conducting a feeding trial using heifers at DFRC, production-size fields of manured and non-manured orchardgrass were seeded at the DFRC location in the fall of 2003 and 2004. The grass has been harvested as hay, baled, and stored for use in this future feeding trial. See **Appendix A** for the agronomic inputs and outputs from the first year's feeding trial fields.

RESULTS AND DISCUSSION

Baseline Soil Data:
The two sites were comparable in baseline soil characteristics, as displayed in **Table 4**. The average Soil Test Phosphorus (STP) at MF was 53 ppm, placing it in the Excessively High category for corn and orchardgrass, according to UW Extension (Kelling et al., 1998). Soil Test Potassium (STK) averaged at 66 ppm, (Low category for both corn and orchardgrass). The DFRC site's STP was slightly lower than at MF, with an average of 40 ppm (Excessively High category), while STK levels were higher, at 138 ppm (High category).

In addition to routine fertility, initial fall nitrate soil samples were taken 2—3 months after the very first manure applications were made at each new site in August and September. Results from fall 2003, Sites I are showed in **Table 5a**, and from fall 2004, Sites II are in **Table 5b**. In 2003 at the DFRC, there was a slight overall effect of manure (p-value = 0.07), with higher nitrate levels in the manured plots than the non-manured. However, as the reported means show, the differences in nitrate levels between the manure treatments were fairly small. While nitrate levels were arithmetically higher on the manured plots at MF, there was no significant difference

between the manured and non-manured plots. There was also no effect of crop type on nitrate levels at either location. In 2004, nitrate levels in the manured plots were significantly higher than those in the the non-manured treatment (p-value = 0.04), but no other statistical differences were seen. These results indicate that while manure may cause somewhat increased initial nitrate levels regardless of crop type, this is not necessarily the case.

Manure Analyses:
The two locations of the study utilized very different dairy manure, both in terms of type (slurry and solid bedding pack) and nutrient content (dilute and concentrated). The manure from DFRC was generally very watery and nutrient-poor, often containing only 50% of the expected nutrient load. This lower concentration led to higher actual rates of manure used at DFRC, as well as extra applications on the corn silage plots (See **Table 2**). On the other hand, the semi-composted manure at MF had average dry matter content and average to high nutrient concentration. **Tables 6** and **7** display the results of the manure analyses from the first year's applications at DFRC and MF, respectively. The slurry manure from DFRC is stored in a large cement pit that is open to rainwater and the surrounding area's runoff, which explains its dilute nature. Furthermore, the pit design does not allow complete agitation when full, so solids settle to the bottom, leaving nutrient-poor "dirty water" on top. The bedding pack from MF is generally stored in windrows, which once crusted over may shed rainfall, thus helping to retain nutrients.

Pre-Sidedress Nitrate Test Results:
In 2004, very low levels of residual and/or mineralized nitrate were detected in the spring in all the corn plots, both nutrient treatments, and so the full rates of 160 lbs nitrogen/acre were applied to every plot at DFRC, and in all but one plot at MF, which received 125 lbs N/acre. As with the on-farm Linking Farms manure project (Cook et al., 2005), the cold, wet spring of 2004 presumably caused slow mineralization of manure nitrogen, and/or leaching of available nitrate.

Orchardgrass Yields and Quality:
Only two cuts, instead of the planned three, were made at both locations, due to the late establishment of the spring-seeded orchardgrass. The fewer number of cuts caused lower yields than expected, and thus, less phosphorus off-take (**Table 2**), as well as fewer windows for spreading manure. The DFRC OG-M plots yielded significantly higher ($\alpha = 0.10$) than the OG-NM plots, while there was no significant difference between OG-M and OG-NM at MF. See **Figure 4** for yield data of the 2004 season (sum of Cuts 1 and 2). One possible explanation for these mixed results could be made by examining the differences in manure used at the two locations. Although more nutrient-poor, the slurry at DFRC was better able to quickly infiltrate into the soil. On the other hand, the solid manure at MF mainly sat on the surface of the ley, and took a long time to decompose and become available to the plants. It is thus possible that a large proportion of manure N at MF was lost to the atmosphere through volatilization, since manure N has been shown to volatilize the most in the first few hours after application when left unincorporated (Sanderson and Jones, 1997). Additionally, researchers observed areas at MF where large manure clods smothered orchardgrass regrowth.

Individual-location analyses on forage quality detected few significant differences between OG-M and OG-NM (see **Table 8** for quality data). In general, OG-M in Cut 2 at DFRC was significantly higher in Relative Forage Quality (RFQ) and had greater N and K accumulation than OG-NM ($\alpha = 0.10$). In contrast, Cut 2 at MF had significantly reduced N accumulation in

the manured plots. These results again indicate that the unincorporated slurry manure at DFRC may have better-delivered nutrients into the soil than unincorporated solid manure, thus making them more available for mineralization and plant up-take.

Corn Silage Yields:
There was no significant difference at either site between the corn plots that received manure and fertilizer, and those that only received fertilizer. The yield data is shown in **Figure 5**. These results are similar to a past study of comparing yields of fertilized, manured corn to corn plots that were only fertilized (Jokela, 1992). One possible reason for these results may be the low levels of nitrogen mineralization in spring 2004. Since there was no apparent nitrogen credit from the manure, according to the PSNT results, the manured and non-manured plots had the same apparent amount of available N—only the 160 lbs of sidedressed N fertilizer.

Nutrient Budgets:
Nutrient budgets for N, P_2O_5, and K_2O were constructed for each treatment at both locations (See **Tables 9, 10,** and **11**). The site at DFRC, where manure was more dilute in nutrient content, gave lower net balances of nutrients than the site at MF, in the cases of both the orchardgrass and corn plots. In general, the manured plots resulted in positive net balances of nutrients, whereas the non-manured plots were mainly negative or only slightly positive values. Because this is the first year of a three-year study, it is too early to confirm whether nutrient-loading is taking place in the manured plots, as future draw-down is expected.

Post-season Nitrate Tests:
Although the N-budgets at both sites (see **Table 9**) were always more positive for the manured treatments, there was no significant difference in fall nitrate levels between the manured and non-manured treatments. However, there was a significant overall difference between the two forage crops (see **Figure 6**). Nitrate levels were far lower in the orchardgrass plots than in the corn plots, most likely due to the fact that the orchardgrass was still photosynthesizing and utilizing nitrogen into the late fall.

These conclusions are supported by other studies that tested nitrate leaching on grass/sod crops. Eriksen et al (1999) tested nitrate leaching in four cropping systems where manure was applied, and found the lowest level of leaching occurred in the first year of a grass/clover system. A second group had similar results, with the second-lowest leaching losses in their cropping system experiment from a perennial ryegrass ley (Thomsen et al., 1993). A Cornell team found that following annual manure applications, orchardgrass recovered large quantities of liquid manure and solid manure N (Kanneganti and Klausner, 1994).

CONCLUSIONS

Yields were modest during the 2004 season. This was due to the failed summer seeding of the orchardgrass in 2003 and the wet and cold spring of 2004 that delayed planting and subsequently the mineralization of manure N. Nevertheless, the orchardgrass plots did open two summer windows for manure spreading and we are expecting that improved production will reduce nutrient loading in subsequent years.

There were a number of "lessons learned" in the first year of the project, which when followed, will hopefully 1) improve orchardgrass establishment, and 2) improve production of the already-established orchardgrass plots. Since the orchardgrass was planted fairly late (late August or early September) in both years, and a poor stand resulted, it is evident that seeding earlier in August would be a good strategy, and that seeding should also include some starter fertilizer. In order to improve the established plots' production, plans for 2005 and 2006 include a 50 lbs N fertilizer application on all orchardgrass plots following the last harvest, and another 25 lbs N early in the spring, to help develop the first flush of grass.

Although our 2004 results were not that positive, we think including a grass ley in their cropping system could be a useful strategy for dairy farmers in search of both a productive forage crop, as well as summer windows to spread manure. The 2005 and 2006 seasons of this project will help to determine the efficacy and reliability of this cropping system.

TABLES AND FIGURES

Table 1: Initial Assumptions of Crop Off-take and Manure Nutrient Additions, Three-Year Rotation

Table 1a: Orchardgrass rotation

Year: Crop	Yield	N (lbs/a) (2)	P_2O_5 (2) (lbs/a)	K_2O (2) (lbs/a)
1: Orchardgrass(1)	11,000 dm lbs/a	324	135	474
2: Orchardgrass	11,000 dm lbs/a	324	135	474
3: Soybeans	50 bu/a		44	66
Total Nutrient Off-take		648	314	1014
Manure Type	**Manure Nutrient Content (3)**	**To Meet N**	**To Meet P_2O_5**	**To Meet K_2O**
Slurry Manure	7-5-16 lbs/1000 gal	93,000 gal/a	63,000 gal/a	63,000 gal/a
Solid Manure	3-3-7 lbs/ton	216 tons/a	105 tons/a	145 tons/a

(1) Assuming 5.5 tons DM of orchard grass in three cuttings following previous fall seeding.
(2) Crop off-take amounts based upon nutrient removal rates from NRC, 1989.
(3) Manure nutrient content = lbs N-P_2O_5-K_2O, respectively (Nutrient Management Fast Facts, 2003).

Table 1b: Corn Silage rotation

Year: Crop	Yield	N (lbs/a) (2)	P_2O_5 (2) (lbs/a)	K_2O (2) (lbs/a)
1: Corn Silage (1)	13,200 dm lbs/a	171	66	153
2: Corn Silage	13,200 dm lbs/a	171	66	153
3: Soybeans	50 bu/a		44	66
Total Nutrient Off-take		342	176	372
Manure Type	**Manure Nutrient Content (3)**	**To Meet N**	**To Meet P_2O_5**	**To Meet K_2O**
Slurry Manure	7 (10)-5-16 lbs/1000 gal	48,000 (34,000) gal/a	35,000 gal/a	23,000 gal/a
Solid Manure	3 (4)-3-7 lbs/ton	114 (86) tons/a	59 tons/a	53 tons/a

(1) Assuming 20t/a silage production.
(2) Crop off-take amounts based upon nutrient removal rates from NRC, 1989.
(3) Values in parentheses represent values for incorporated manure. Manure nutrient content = lbs N-P_2O_5-K_2O, respectively. (Nutrient Management Fast Facts, 2003).

Table 2: 2004 Agronomic Input/Output Data, Dairy Forage Research Center Site I

	OG-M	OG-NM	CS-M	CS-NM
Plot #s	104, 204, 301, 402, 504	102, 203, 303, 403, 502	101, 201, 302, 401, 501	103, 202, 304, 404, 503
Primary Tillage	None	None	None	None
Secondary Tillage	None	None	None	None
Variety	Elsie	Elsie	Croplan Genetics 364 RR, 95 day maturity	Croplan Genetics 364 RR, 95 day maturity
Planting Date/Rate	9/11/03; replanted 4/29/04: 10-12 lbs/a	9/11/03; replanted 4/29/04: 10-12 lbs/a	5/17/04: 34,000 ppa	5/17/04: 34,000 ppa
Starter	None	None	100 lbs 5:14:42	100 lbs 5:14:42
Fertilizer	0	8/3/04: 50 lbs N/a 9/15/04: 50 lbs N/a Total: 100 lbs N/a (Ammonium nitrate)	6/25/04: 160 lbs N/a –PSNT. (Ammonium nitrate)	6/25/04: 160 lbs N/a—PSNT. (Ammonium nitrate)
Manure	8/29/03: 8,000 gal/a 8/3/04: 16,000 gal/a 9/14/04: 16,000 gal/a Total: 40,000 gal/a; 78 lbs P_2O_5/a	0	8/29/03: 12,000 gal/a 4/27/04: 8,000 gal/a Total: 20,000 gal/a; 51 lbs P_2O_5/a	0
Pesticides	4/27/04: Round-up burndown. 6/16/04 2, 4-D	4/27/04: Round-up burndown 6/16/04 2, 4-D	4/27/04: Round-up burndown 6/16/04 2, 4-D	4/27/04: Round-up burndown 6/16/04 2, 4-D
Rotary hoe/ Cultivation	None	None	None	None
Harvests	1st: 7/29/04; 2nd: 9/3/04	1st: 7/29/04; 2nd: 9/3/04	9/23/04	9/23/04
Yield	2.06 tons/a	1.57 tons/a	9.35 tons/a	8.58 tons/a
Fall Practices	Manure spread following final OG harvest. New site (Site II) set up, and manure applied	New site set up.	Manure spread following CS harvest. New site set up and manure applied.	New site set up.

Note: The trial was set up on Field #4450 of the Dairy Forage Research Center's land in the Badger Ammunitions Plant near Prairie du Sac, Wisconsin.

Table 3: 2004 Agronomic Input/Output Data, Michael Fields Site I

	OG-M	OG-NM	CS-M	CS-NM
Plot #s	104, 201, 304, 403, 501, 603	103, 202, 302, 402, 503, 604	101, 204, 303, 404, 504, 601	102, 203, 301, 401, 502, 602
Primary Tillage	9/19/03: Rotovated	9/19/03: Rotovated	5/5/04: Rotovated	5/5/04: Rotovated
Secondary Tillage	9/20/03: Cultipacked	9/20/03: Cultipacked	6/09/04: Field cultivated	6/09/04: Field cultivated
Variety	Elsie	Elsie	NC+48F37	NC+48F37
Planting Date/Rate	9/20/03; 4/14/04: 10-12 lbs/a	9/20/03; 4/14/04: 10-12 lbs/a	6/9/04: 29,000 ppa	6/9/04: 29,000 ppa
Starter	None	None	None	None
Fertilizer	0	100 lbs total N (Ammonium nitrate)	8/2/04: 160 lbs N-PSNT (Ammonium nitrate)	8/2/04: 160 lbs N PSNT (Ammonium nitrate)
Total Manure	9/20/03 16 ton/a 7/9/04 16 ton/a 9/3/04 20 ton/a Total: 52 ton/a; 240 lbs lbs P_2O_5/a.	0	9/20/03 16 ton/a 4/18/04 16 ton/a Total: 32 ton/a; 125 lbs lbs P_2O_5/a.	0
Pesticides	None	None	None	None
Rotary hoe/ Tine Weed/ Cultivation	None	None	6/16/04 6/26/04 7/09/04	6/16/04 6/26/04 7/09/04
Harvests	1st: 6/30/04 2nd: 9/3/04	1st: 6/30/04 2nd: 9/3/04	9/30/04	9/30/04
Yield	2.84 tons/a	2.87 tons/a	5.46 tons/a	4.93 tons/a
Fall Practices	Manure spread following final OG harvest. New site set up, and manure applied.	New site set up	New site set up, and manure applied.	New site set up.

* Plot 301 received only 125 lbs N, as according to UW recommendations based on the PSNT.

Table 4: Baseline Routine Soil Fertility Results (0-6"), Fall 2003, Sites I

Site	Soil Type	Soil Test Phosphorus	Soil Test Potassium	Organic Matter %	pH
DFRC	St. Charles/ Richwood silt loams	40 ppm	138 ppm	3.6	7.1
MF	Fox silt loam	53 ppm	66 ppm	2.7	6.2

Table 5: Baseline Soil Nitrate Results, 3-foot depth

Table 5a: Fall 2003, Sites I

Site	Treatment	Manure Rate prior to sampling	Nitrate (lbs/a)
DFRC	OG-M	8,000 gal/a	114
	OG-NM	0	86
	CS-M	12,000 gal/a	128
	CS-NM	0	102
MF	OG-M	16 ton/a	77
	OG-NM	0	63
	CS-M	16 ton/a	74
	CS-NM	0	51

Notes: No N fertilizer was used on the orchardgrass plots prior to fall nitrate sampling in 2003. OG-M = orchardgrass with manure; OG-NM = orchardgrass, no manure; CS-M = corn silage with manure; CS-NM = corn silage, no manure.

Table 5b: Fall 2004, Sites II

Site	Treatment	Manure Rate prior to sampling	Fertilizer Rate prior to sampling	Nitrate (lbs/a)
DFRC	OG-M	16,000 gal/a	20 lbs N/a	48
	OG-NM	0	20 lbs N/a	38
	CS-M	16,000 gal/a	0	50
	CS-NM	0	0	52
MF	OG-M	20 ton/a	20 lbs N/a	70 a
	OG-NM	0	20 lbs N/a	50 b
	CS-M	30 ton/a	0	61
	CS-NM	0	0	60

Notes: a,b = Significant difference at orchardgrass plots between manure and no-manure treatments ($\alpha = 0.05$). OG-M = orchardgrass with manure; OG-NM = orchardgrass, no manure; CS-M = corn silage with manure; CS-NM = corn silage, no manure.

Table 6: Grass ley Manure Analyses, Dairy Forage Research Center Site I

Description	Date	Manure Rate (gal/a)	Dry Matter %	N	P_2O_5	K_2O
Initial plot lay-out	8/29/03	8,000 on OG-M 12,000 on CS-M	2.1	4.3	2.0	12.6
Applied before planting corn	4/27/04	8,000 on CS-M	3.6	6.0	3.4	10.4
After orchardgrass Cut 1	8/3/04	16,000 on OG-M	1.7	2.7	1.8	8.1
After orchardgrass Cut 2	9/14/04	16,000 on OG-M	1.7	4.2	2.1	10.4
After corn harvest	11/17/04	12,000 on CS-M	3.2	5.9	3.7	11.7
Average			2.5	4.6	2.6	10.6
Book Values			6.0	7.0	5.0	16.0

Notes: Nutrients are 1st-year available credits in lbs/1000 gallons manure. Book values of dry matter from Peters, 2002; Book values of nutrient content from Nutrient Management Fast Facts, 2003.

Table 7: Grass Ley Manure analyses, Michael Fields Site I

Description	Date	Manure rate (tons/a)	Dry Matter %	N	P_2O_5	K_2O
Initial plot layout	9/20/03	16 on CS-M 16 on OG-M	27.1	6.9	3.6	12.1
Applied before planting corn	4/18/04	16 on CS-M	18.9	3.6	4.3	7.1
After orchardgrass Cut 1	7/9/04	16 on OG-M	24.3	2.4	6.5	7.9
After orchardgrass Cut 2	9/2/04	20 on OG-M	23.6	3.6	3.9	11.7
After corn harvest	11/17/04	30 on CS-M	20.2	3.3	2.8	6.3
Average			22.8	3.4	4.2	9.0
Book Values			24.0	3.0	3.0	7.0

Notes: OG-M = orchardgrass with manure. Nutrients are 1st-year available credits in lbs/ton manure. Book values of dry matter from Peters, 2002; Book values of nutrient content from Nutrient Management Fast Facts, 2003.

Table 8: Orchardgrass Yield and Quality, 2004

Location	Cut	Treatment	Yield ton/a	RFQ (1)	CP% (2)	P% (3)	K% (4)
DFRC	1	Manure	1.2	139.1	13.1	0.37	3.4
		No Manure	0.92	136.2	12.7	0.39	3.2
	2	Manure	0.86	174.2 a	18.5 a	0.43	4.0 a
		No Manure	0.65	159.6 b	16.3 b	0.44	3.4 b
MF	1	Manure	2.01	135.7	10.9	0.43	2.8
		No Manure	1.64	131.8	10.2	0.40	2.6
	2	Manure	0.83	123.3	12.8 b	0.21	1.4
		No Manure	1.23	131.7	15.6 a	0.18	1.3

(1) Relative Forage Quality; (2) Crude Protein %; (3) Phosphorus %; (4) Potassium %
a,b = significant differences between Manure and No Manure treatments ($\alpha = 0.10$).
Yields measured in dry matter tons.

Table 9: Grass Ley Nitrogen Budget (lbs N/a), 2004

Loc.	Treatment	Total Manure	Manure N	Fertilizer N	Total N Input	Yield (tons DM/a)	N Off-take	Net N
DFRC	OG-M	40,000 (gal/a)	144	0	144	2.1	91	53
DFRC	OG-NM	0	0	100	100	1.6	65	35
DFRC	CS-M	20,000 (gal/a)	100	165	265	9.4	244*	21
DFRC	CS-NM	0	0	165	165	8.6	222*	-57
MF	OG-M	52 (t/a)	220	0	220	2.8	105	115
MF	OG-NM	0	0	100	100	2.9	114	-13
MF	CS-M	32 (t/a)	169	160	329	5.5	141*	188
MF	CS-NM	0	0	154	154	4.9	128*	26

Notes: OG-M = orchardgrass with manure; OG-NM = orchardgrass, no manure; CS-M = corn silage with manure; CS-NM = corn silage, no manure. Manured treatments are shaded.
N off-take estimated as 6.25% of crude protein.
* Due to moldy CS samples, crude protein was estimated to be 8.1% of dry corn silage biomass (NRC, 1989).

Table 10: Grass Ley Phosphorus Budget (lbs P_2O_5/a), 2004

Loc.	Treatment	Total Manure	Manure P_2O_5	Fertilizer P_2O_5	Total P_2O_5 Input	Yield (tons DM/a)	P_2O_5 Off-take	Net P_2O_5
DFRC	OG-M	40,000 (gal/a)	78	0	78	2.1	33	45
DFRC	OG-NM	0	0	0	0	1.6	27	-27
DFRC	CS-M	20,000 (gal/a)	51	14	65	9.4	94*	-29
DFRC	CS-NM	0	0	14	14	8.6	86*	-72
MF	OG-M	52 (t/a)	240	0	240	2.8	55	185
MF	OG-NM	0	0	0	0	2.9	50	-50
MF	CS-M	32 (t/a)	125	0	125	5.5	55*	70
MF	CS-NM	0	0	0	0	4.9	49*	-49

Notes: OG-M = orchardgrass with manure; OG-NM = orchardgrass, no manure; CS-M = corn silage with manure; CS-NM = corn silage, no manure. Manured treatments are shaded.
* Due to moldy CS samples, P estimated to be 0.22% of dry corn silage biomass, (NRC, 1989).

Table 11: Grass ley Potassium Budget (lbs K_2O/a) 2004

Loc.	Treatment	Total Manure	Manure K_2O	Fertilizer K_2O	Total K_2O Input	Yield (tons DM/a)	K_2O Off-take	Net K_2O
DFRC	OG-M	40,000 (gal/a)	396	0	396	2.06	161	235
DFRC	OG-NM	0	0	0	0	1.57	112	-112
DFRC	CS-M	20,000 (gal/a)	234	42	276	9.35	218*	58
DFRC	CS-NM	0	0	42	42	8.58	199*	-157
MF	OG-M	52 (t/a)	555	0	555	2.84	192	363
MF	OG-NM	0	0	0	0	2.87	191	-191
MF	CS-M	32 (t/a)	308	0	308	5.46	126*	182
MF	CS-NM	0	0	0	0	4.93	114*	-114

Notes: OG-M = orchardgrass with manure; OG-NM = orchardgrass, no manure; CS-M = corn silage with manure; CS-NM = corn silage, no manure. Manured treatments are shaded.
* Due to moldy CS samples, K estimated to be 0.96% of dry corn silage biomass (NRC, 1989).

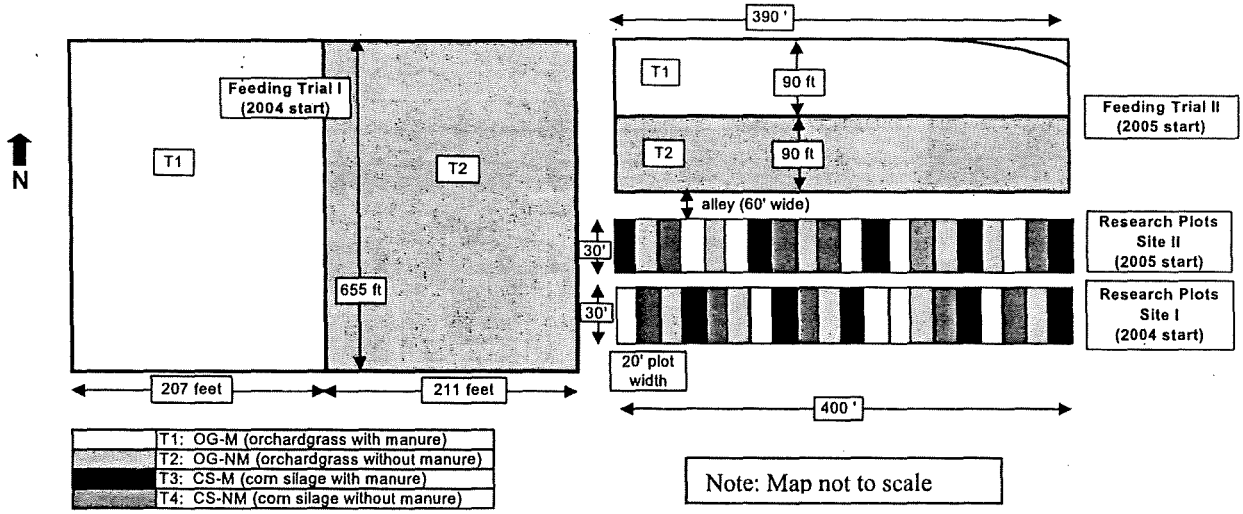


Figure 1: Map of the DFRC Research Plots and Feeding Trials, Sites I and II

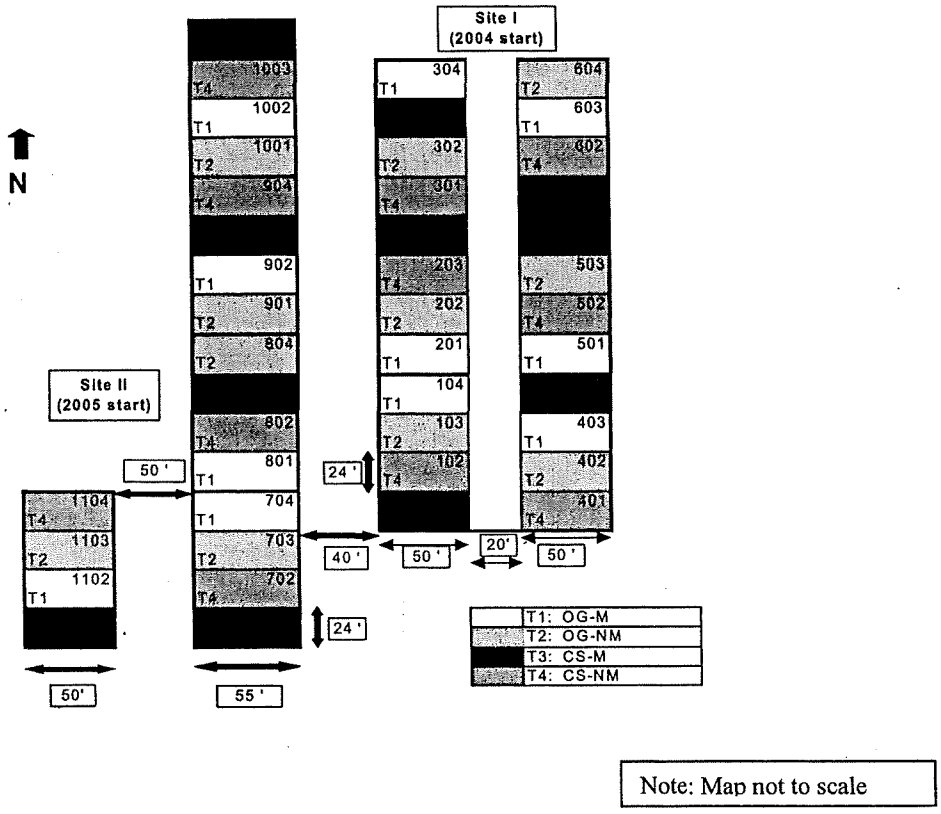


Figure 2: Map of MF Plots, Sites I and II

Figure 3a: Orchardgrass Rotation

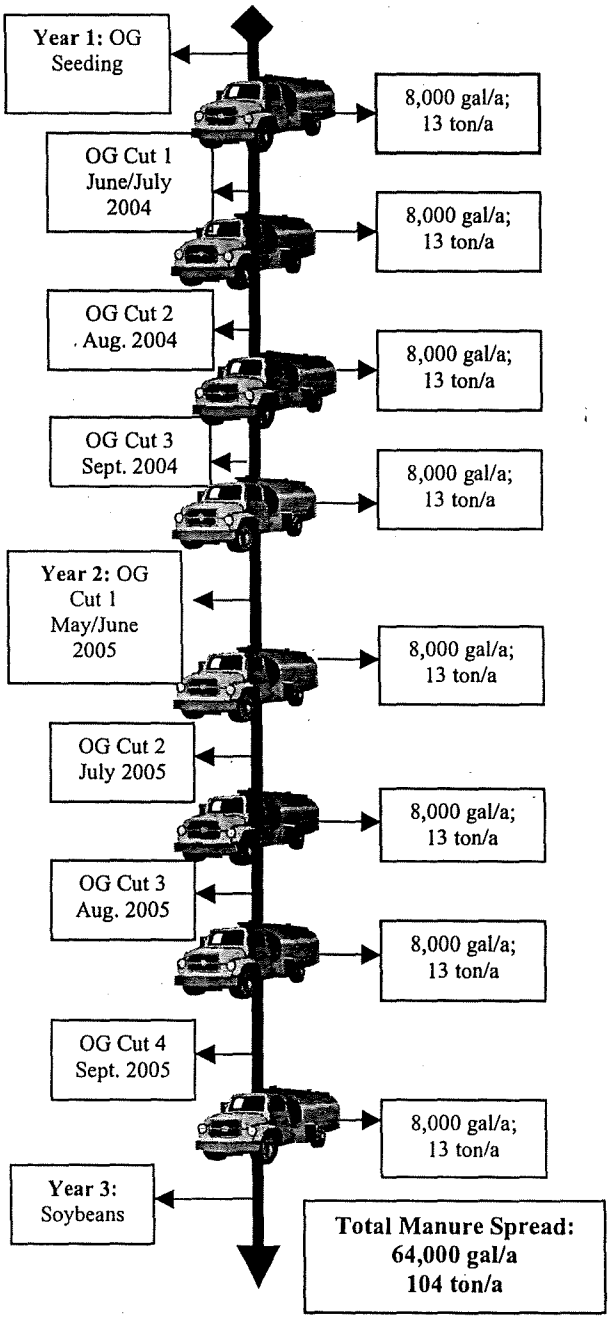


Figure 3b: Corn Silage Rotation

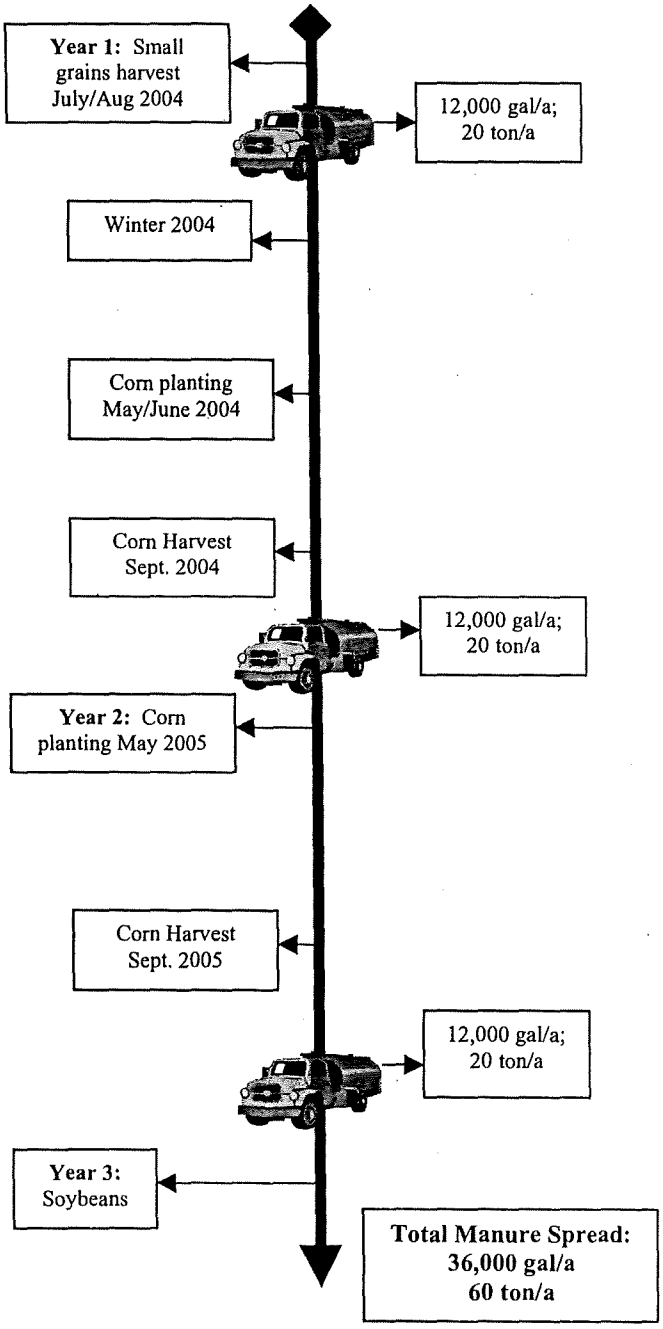


Figure 3: Theoretical Timelines of Phosphorus-Based Manure Applications on Orchardgrass and Corn Silage Rotations over a 3-year cycle.

Notes: Manure truck icon = manure application made. Gal/a refers to rates at DFRC; ton/a refers to rates at MF.

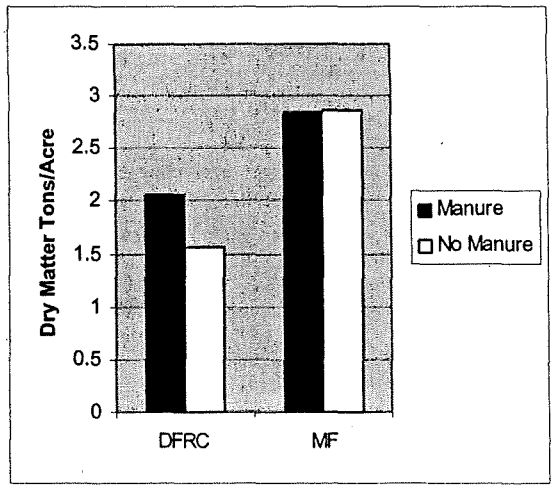


Figure 4: 2004 Orchardgrass Yields (dry matter tons/acre)
No significant differences found between treatments at either location.

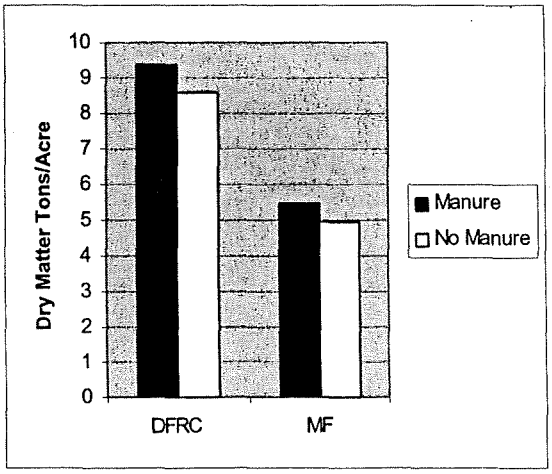


Figure 5: 2004 Corn Silage Yields (dry matter tons/acre)
Note: No significant differences found between treatments at either location.

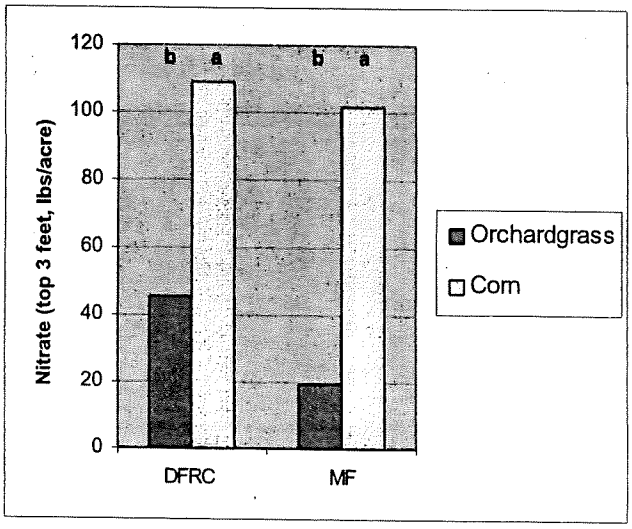


Figure 6: Post-season Nitrate levels, by Crop treatment, 2004
Note: No significant differences found between locations.

Appendix A: 2004 Agronomic Inputs/Outputs of DFRC Feeding Trial Fields, Site I

	OG-M	OG-NM
Plots	West	East
Primary Tillage	None—No till field	None—No till field
Variety	Elsie	Elsie
Planting Dates; Rate	9/11/03 10-12 lbs/a; 4/29/04 10-12 lbs/a	9/11/03 10-12 lbs/a; 4/29/04 10-12 lbs/a
Starter	None	None
Fertilizer	None	8/23/04 50 lbs N/a; 10/7/04 50 lbs N/a
Total Manure	9/11/03 8,000 gal/a 8/9/04 16,000 gal/a 9/17/04 16,000 gal/a Total: 40,000 gal/a	0
Pesticides	None	None
Harvest (2 cuts)	1st: 8/4/04 2nd: 9/27/04	1st: 8/4/04 2nd: 9/27/04
Yield†	1st: Approx. 1.3 DM tons/acre	
	2nd: 0.78 DM tons/acre	2nd: 0.55 DM tons/acre
Fall Practices: Site II lay-out	OG seeded 8/13/04. 16,000 gal manure/a spread 9/17/04.	OG seeded 8/13/04. 20 lbs N/a spread on 10/7/04.

The manured and non-manured portions of the field in cut 1were combined to serve as acclimation feed at the start of the feeding trial.

REFERENCES

Cook, A., J.L. Posner, J. Hall, J.L. Hedtcke, G. Sanford. 2005. Linking Farms: Reconnecting dairy and cash-grain farms through shared manure management, I. Production results and nutrient budgets from 2003 and 2004. *in* The Wisconsin Integrated Cropping Systems Trial 10th Report The University of Wisconsin—Madison.

Eriksen, J., M. Askegaard, and K. Kristensen. 1999. Nitrate leaching in an organic dairy/crop rotation as affected by organic manure type, livestock density and crop. Soil Use and Management. 15:176-182.

Heathwaite, A.L. P. Griffiths, and R.J. Parkinson. 1998. Nitrogen and phosphorus in runoff from grassland with buffer strips following application of fertilizers and manures. Soil Use and Management. 14:142-148.

Jokela, W.E. 1992. Nitrogen fertilizer and dairy manure effects on corn yield and soil nitrate. Soil Sci. Soc. Am. J. 56:148-154.

Kanneganti, V.R. and S. D. Klausner. 1994. Nitrogen recovery by orchardgrass from dairy manure applied with or without fertilizer nitrogen. Commun. Soil Sci. Plant Anal. 25:2771-2783.

Kelling K.A., L.G. Bundy, S.M. Combs, and J.B. Peters. 1998. Soil test recommendations for field, vegetable, and fruit crops. University of Wisconsin-Extention Publication A2809.

Midwest Regional Climate Center. 2005.
Whitewater Station: http://mcc.sws.uiuc.edu/Precip/WI/479190_psum.html;
Burlington Station: http://mcc.sws.uiuc.edu/Precip/WI/471205_psum.html.
Baraboo Station: http://sisyphus.sws.uiuc.edu/climate_midwest/historical/precip/wi/470516_psum.html
Prairie du Sac Station: http://sisyphus.sws.uiuc.edu/climate_midwest/historical/precip/wi/476838_psum.html

National Research Council. Nutrient Requirements of Dairy Cattle, 6th Revised Ed., Update 1989. National Academy Press, Washington D.C. 1988. p. 96.

Nutrient Management Fast Facts. 2003. Nutrient and Pest Management Program. University of Wisconsin-Extension.

Peters, John. Personal communication 8/16/05. Average dry matter content from 805 solid dairy manure samples and 959 liquid dairy manure samples between 1998—2001, Soil and Forage Analysis Lab, Marshfield, WI.

Sanderson, M.A. and R.M. Jones. 1997. Forage yields, nutrient uptake, soil chemical changes, and nitrogen volatilization from bermudagrass treated with dairy manure. J. Prod. Agric. 10:266-270.

Simmelsgaard, S.E. 1998. The effect of crop, N-level, soil type and drainage on nitrate leaching from Danish soil. Soil Use and Management. 14:30-36.

Sutton, A.L., D.W. Nelson, N.J. Moeller, and D.L. Hill. 1979. Applying liquid dairy waste to silt loam soils cropped to corn and alfalfa-orchardgrass. J. Environ. Qual. 8:515-519.

Thomsen, I.K., J.F. Hansen, V. Kjellerup and B.T. Christensen. 1993. Effects of cropping system and rates of nitrogen in animal slurry and mineral fertilizer on nitrate leaching from a sandy loam. Soil Use and Management. 9:53-58.

CERTIFIED ORGANIC GRAIN STRIPS 2004

Janet Hedtcke[1], Josh Posner[2], John Hall[3], Dwight Mueller[4], and Ron Doetch[3]

INTRODUCTION

Since the early 90's, organic production has been gaining momentum in the upper Midwest. By 2000, Wisconsin ranked first in the nation for organic dairy cows and other livestock and third in the nation for number of certified organic farms, corn, soybean and small grain acres (USDA ERS, 2001). With the implementation of the USDA's National Organic Program in October 2002, organic farming gained further momentum. In order to meet the informational needs of this growing clientele, it was decided to certify some land for organic research at the ARS Research Station and to conduct similar trials on the Michael Fields Agricultural Institute organic farm. The goal of this project is to do research for those producers that want to grow and market organic grain. In addition to field research, our goal was to learn about the certification process (how difficult is it) and, to learn about organic grain marketing.

BACKGROUND

Arlington Research Station (ARS):

In the winter of 2002, discussions were initiated between WICST team members and the corn, soybeans and small grains programs about developing a new site at ARS that would become a certified organic field. At the same time, a "key informant" survey of organic grain farmers and their consultants was initiated to ascertain what were their key problems and most common rotations. It appears that most growers have either a 3-year (corn-soybean-small grain/red clover green manure) or 4-year (corn-soybean-small grain/forage seeding-forage) system and many use winter rye as a cover crop. In both, if the soybeans come off in late September, winter wheat can be planted, or if soybean harvest is delayed, spring oats are planted the following year. The red clover green manure is frost seeded into the wheat in March of the 3rd year, or if it is spring oats, hairy vetch can be seeded following small grain harvest. In the longer rotation, after the wheat or oats are harvested for grain, alfalfa is planted (mid-August) and kept in for a hay year. The respondents to the telephone interviews spoke primarily about the problems of weed control and variety selection. Most of the growers had access to manure, which was applied prior to corn planting, so they made relatively little mention of soil fertility problems.

Two adjacent fields that are classified as plano silt loams (3-6% slope) were identified that had been planted to alfalfa in 2001 and 2002. This area had been managed as part of a turkey rearing facility for the past 30 years. The general rotation was a year of alfalfa seeding, a second year as a turkey pasture and then one or two years of corn. In addition to the turkeys grazing, prior to corn planting the field was manured with either turkey or dairy manure. The Turkey Research Center was closed in 2001 and since that time the area has been seeded down to alfalfa. By joining the two fields, the last chemical applications had been in 2001 (leaf hopper control 7/19/01) and the field could be legally certified for the 2004 harvest (the treated alfalfa seed

[1] Research Specialist, UW-Madison, Agronomy Dept., jlrieste@wisc.edu
[2]Professor, UW-Madison, Agronomy Dept., jlposner@wisc.edu
[3] Agronomist, Michael Fields Ag Institute; jhall@michaelfieldsaginst.org Executive Director, rdoetch@michaelfieldsaginst.org
[4] Superintendent, UW-Madison, ARS Ag Research Station

planted in April of 2002 was grandfathered in to meet organic compliance by the fall of 2004). It was decided to go ahead with a 4-year rotation, and the plots were established in the spring of 2003 (See **Appendix I,** Map 1a). Each phase of the rotation has two plots, one that will be used for research and one that will be used for production. The research and production plots will be switched each year, so that research plots will not be superimposed on previous research plots, and the production year will help to homogenize the area. Also, the grass waterway that cut through strip 3 was leveled out and seeded to alfalfa. In 2003 then, two strips remained in alfalfa, while one strip was planted to corn, and the other to soybeans so that in 2004 the entire rotation could begin simultaneously (see **Table 1a**). The baseline fertility data are summarized in **Appendix II**. Generally speaking the soils at the site have 4% organic matter, are excessively high in STP (>60 ppm), potassium levels are optimum to low (STK<100), and pH levels are near neutral. Baseline soil bank weed seed numbers are summarized in **Appendix II**. The weediest strip is #3, which has a recently leveled waterway running through it. The major broadleaves are galinsoga, pigweed, lambsquarter as well as some white cockle in strip #1. Barnyard grass, large crabgrass, and foxtails are the primary grassy weeds.

Michael Fields Agricultural Institute (MFAI):
The MFAI has a 400-acre research and production farm in East Troy, Wisconsin. The site of the trial has been certified organic since 1998, has both Warsaw silt loam and Matherton silt loam soils, and has followed a rotation of soybeans, corn, winter wheat and alfalfa. It was decided in early 2004 to include this as a second site for the organic rotation work. The field layout can be seen in **Appendix I,** Map 1b. The field had been planted to winter wheat in the fall of 2003, following the harvest of corn for silage, so the wheat was plowed under in the early spring of 2004 on two of the strips for corn and soybean planting. The recent cropping history and crop rotation is outlined on **Table 1b** and initial soil test results are in **Appendix II**. In general, the eastern side of the trial (strips I & II) is lower in fertility than the western half and all plots could benefit from the addition of manure and lime. Potassium fertilizer (mined K_2SO_4) should also be added to Strips 3 and 4 as it is testing 'Low' in K.

Table 1a. Cropping sequence at ARS.

	2002	2003	2004	2005	2006	2007
STRIP 1	Alfalfa filler	soybeans/ small grain	small grain/forage mix	forage mix	corn	soybeans/ small grain
STRIP 2	Alfalfa filler	corn	soybean/ small grain	small grain/forage mix	forage mix	corn
STRIP 3	Alfalfa filler	Alfalfa filler	Alfalfa filler	corn	soybean/ small grain	small grain/forage mix
STRIP 4	Alfalfa filler	Alfalfa filler	corn	soybean/ small grain	small grain/forage mix	forage mix

Table 1b. Cropping sequence at MFAI						
	2002	2003	2004	2005	2006	2007
STRIP 1	soybean	Corn/ winter wheat	Wheat	Corn	Soybean	Small grain
STRIP 2	soybean	Corn/ winter wheat	Wheat/ alfalfa, grass mix	Alfalfa, grass mix	Corn	Soybean
STRIP 3	soybean	Corn/ wheat cover	Corn	Soybean	Small grain/forage	Forage
STRIP 4	soybean	Corn/ wheat cover	Soybean	Wheat/ alfalfa, grass mix	Alfalfa, grass mix	Corn

MACHINERY MANAGEMENT STRATEGY

Machinery contamination is a concern for producers who have both organic and conventional grain production but only one set of machinery. Equipment like planters, combines, and grain wagons must not have any conventional seed, chemical residues, or harvested grain in them when they go into an organic field. To keep the organic plots free of contamination from non-organic fields at Arlington, a special protocol using the WICST plots was established. In addition to cleaning the equipment with power washers, all the equipment going on the organic strips, was first used on the WICST chemical free grain rotation (CS3). The same corn, soybean and wheat varieties on CS3 were also used on the organic production strips so all field operations on the organic strips immediately followed those on CS3. In a commercial operation, a farmer would, in addition to cleaning the equipment, have to sacrifice part of the field (6 to 12 rows by 200-300 feet) where he first planted, first used his cultivator, and first entered the field to combine. The grain from this area would not be considered organic, just the area where the equipment was purged to assure that contamination did not take place, and would have to be sold as conventional grain. Machinery contamination was not a problem at the MFAI farm as it is a certified organic farm.

ORGANIC CERTIFICATION PROCESS

Organic certification to MOSA (Midwest Organic Services Association) was applied for in the spring of 2004. A farm plan questionnaire was submitted which included detailed information on the recent (3-year) crop & soil history of the area to be certified. A one-time fee of $50 was needed for first-time applicants that covered the cost for a manual that included useful rules and directories etc. Also, a $150 fee was paid as the base certification fee. Finally a $200 inspection deposit (based on average farm inspection) was added for a total of $400. The actual inspection fee is based on inspector's time and mileage. After our inspection, due to the small size of our area, we received a $30 credit to apply towards next year's fees (or sales) because the actual inspection fee ended up being only $170.

During the season, one is required to record daily activities on each plot by maintaining a logbook, as well as keeping invoices and seed tickets on the varieties used to document organic or untreated seed sources. Field crew report activities to the ARS office and details are recorded as they happen.

In late August, a MOSA inspector visited the site and looked at our records and paper work. The visit lasted about 4 hours. Record keeping was considered adequate as field workers and researchers were very good at reporting any field activities in the logbook. One concern was the lack of documentation from the variety trials as several companies submitted crude labels (i.e. hand written, pail of corn, missing altogether, etc.). MOSA requested that we provide better documentation to show that the entries were organic or untreated.

To maintain organic certification, a field update packet must be submitted to MOSA in the early spring each season. This allows one to update the field plans from the initial farm questionnaire. Annual fees consist of the annual $150 for the base certification maintenance plus $200 for the yearly inspection. Depending on the time spent on the inspection, a fee adjustment may be given. Further, if crops are sold, MOSA gets 0.75% of the gross sales. As with the machinery strategy, the certification process at MFAI was much simpler since the field was inspected as certified organic as part of the annual farm inspection.

PRODUCTION STRIPS IN 2004

Corn: The planting date for corn was late (May 27) due to heavy rains and cool temperatures. This caused some problem at harvest at ARS with the production plots not reaching maturity before the killing frost and therefore, having a high moisture at harvest (25%, Dec. 1, 2004). Grass weed pressure was also rather high, particularly in the variety trial (plot H) at ARS where there was a lot of barnyardgrass. Average plant population was about 28,000 plants/acre and the yield was 133 bu/a. (See table 2)

Corn stand at MFAI was unfortunately uneven and the crop most likely suffered from N deficiency, initially caused by N-immobilization early in the season due to the incorporation of the wheat crop just prior to planting, and the subsequent reduced mineralization of organic N due to the cool and wet soils during much of the summer. The stand was not harvested and considered a failure.

Decisions made for corn planting for the 2005 season included: 1) initiation of tillage and "stale seedbed" rotary hoeing in mid-April to ensure reduced weed pressure on the crop; 2) target an earlier planting date based on accumulated heat units and 7-day weather forecast (aim for week of May 10th); and, 3) increase seeding rate from 33 to 40,000 seeds/acre to compensate for stand loss due to mechanical weed control. At MFAI, due to the recent history of wheat cultivation and not alfalfa, manure will be added before seeding the corn phase. On April, 26, 2005, 22 tons/acre of manure from a bedding pack was applied to Strip I in preparation for the corn crop.

Soybeans: The production plots yielded well (62 bu/a) at ARS even though the target planting date of May 15th was missed due to heavy and frequent rain. Beans in the production plot were harvested October 16th, 2004 and yielded 62 bu/a. However, the soybean variety trial, which contained longer maturity beans was not harvested until November 6th, thus, oats will be planted in this plot in the spring of 2005. Weed control was also excellent--only 4 man-hours/acre hand weeding broadleaf weeds was done in early July.

Yields were more modest at MFAI (30 bu/a) because of a poor stand due to poor initial germination/emergence from wet compacted soils and only partial success of replanting over existing stand (June 23rd). Rotary hoeing however, when beans were 4" tall was effective at reducing in-row weeds.

Wheat: The wheat production block was planted on October 8th, 2003 at ARS. We noticed some volunteer rye in the wheat plot. It was hand pulled before seed heads matured. Like most other wheat in 2004, the hard red variety ('Patriot') suffered from scab and yields were low at 43 bu/a. In addition, it was docked significantly at the elevator (34% damaged kernels). As a side note, no wheat production block (scheduled to be planted following the harvest of the soybean variety trial) was planted at ARS due to the late harvest (November 6) of the soybeans. The plan is to plant oats in the spring of 2005.

The production plots at MFAI yielded 72 bu/a and had less incidence of scab and straw yields of 1.4 tons DM/a.

Alfalfa: The strategy is to plant a variety of alfalfa that produces a lot of tonnage even if winter survival is only modest, since there will be only one hay year. The alfalfa is mixed with orchard grass to ensure good ground cover as this phase has the two objectives of increasing N availability for the subsequent corn crop, as well as suppressing weeds during the three-grain production phases. However, there remains the concern that the N credits from a 1.5 yr old alfalfa stand will be limiting for corn production. Adding dairy manure remains an option to help meet the rotation N-requirement and to maintain STK. Two other possible sources of nutrients that are approved for use in organic systems include 'Cinagro' (crumbled chicken manure) and Potassium Sulfate (mined source, not processed).

An alfalfa/orchardgrass mix was planted after wheat harvest in mid-August (8/18/04) at ARS. Scouting showed good establishment but there was also a flush of annual weeds, particularly shepherd's purse. At MFAI, an alfalfa/orchard grass mix was planted on September 8 following the application of 20 tons/a of pen manure. The stand establishment was less successful at MFAI due to very dry conditions. Alfalfa was reseeded in strip II on April 3, 2005.

Table 2. Grain yields on organic 'production' strips in 2004.

	ARS	MFAI
CORN (bu/a)[1]	**133**	**0**
SOYBEANS (bu/a)[2]	**62**	**30**
WHEAT Grain (bu/a)	**43**	**72**
WHEAT Straw (tons DM/a)	**No data recorded**	**1.4**

[1] corn stand was abandoned at MFAI due to poor stand

[2] ARS variety was NC+1F61 and MFAI variety was Vinton, both food-grade varieties

ORGANIC VARIETY TRIALS IN 2004

Corn, soybean, and wheat variety trials were planted at both locations by UW Corn and Soybean & Small Grains programs (Lauer, Flannery and Kohn, and Borges, Gaska and Martinka). The price for entries was $360 for 3 sites with soybeans, $250 for the 2 sites with corn, and gratis for the 2 Sites with wheat. We received seed and ultimately planted 14, 17, and 10 entries of corn, soybeans, and wheat for the 2004 season, at ARS and MFAI.

At ARS, the corn variety trial was planted June 3, following tillage to smooth out some gully erosion that cut across the plot; it was rotary hoed on 6-11 & 6-16-04 and cultivated 3x: 6-29-04, 7-9-04, 7-13-04. The soybean variety trial was planted May 28th and cultivated, not rotary hoed, on June 16th. Both corn and soybeans received light hand weeding. A winter wheat variety trial was planted on October 14, 2004 on plot C. Variety trial yields are found in Tables 3 and 4.

At MFAI, the corn variety trial was planted June 4, and rotary hoed twice on 6-12 and 6-16. It was cultivated on 6-27 and again on 7-8. The soybean variety trial was planted on May 28, rotary hoed on 6-8. The plots were tine weeded twice on 6-15 and 6-27, and cultivated once on 7-8. Both corn and beans were hand weeded for broadleaf weeds, which averaged about 2 hours/a hand labor. The winter wheat variety trial was planted on October 14, 2004 in plot H.

Table 3. Organic corn variety trial yields at ARS

Brand	Hybrid	Relative Maturity	Yield (bu/a)
Brunner	OR8702	87	144
Prairie Hybrid	0383	92	141
NC+	34C17	93	150
Brown	3020	94	150
Gold Country	9401	94	154
NC+	41F00	97	122
Brunner	OR9802	98	139
NC+	42A32	98	166*
Brown	5335	101	135
Prairie Hybrid	1673	102	154
NC+	48f37	102	144
Merit Seeds	0535	103	139
NC+	53F37	104	139
Brunner	OR1053	105	121
Mean			143
LSD			11

* = yields not statistically different (P<0.05) than the highest yielding variety.
http://corn.agronomy.wisc.edu/HT/2004/Organic.pdf

Table 4. Organic soybean variety trial yields at ARS and MFAI				
Brand	**Hybrid**	**Maturity Group**	**ARS Yield (bu/a)**	**MFAI Yield (bu/a)**
Iowa	IA1006	1.6	53	31
Iowa	IA1008	1.7	54	35
Iowa	IA2017	2.0	49	37
Iowa	IA2041	2.3	40	28
Iowa	IA2053	2.1	56	39
Iowa	HP204	1.9	43	35
Iowa	Vinton81	2.0	43	33
Gold Country	6024FG	2.4	56	23
Kaltenberg	KC201FG	2.0	53	28
Kaltenberg	KC243FG	2.4	56	31
Kaltenberg	KC263FG	2.6	41	26
Latham (check)	280 Brand	1.7	61*	32
NC+	1F44	1.4	46	28
NC+	1F61	1.6	61*	32
NC+	2F11	2.1	57	45*
Viking	0.1832	1.8	60*	30
Viking	0.2022	2.0	64*	38
Mean			52	32
LSD (0.10)			4	5

= yields not statistically different (P<0.10) than the highest yielding variety.
http://soybean.uwex.edu/soytrials/printable/documents/04_organic_soy_results.pdf.

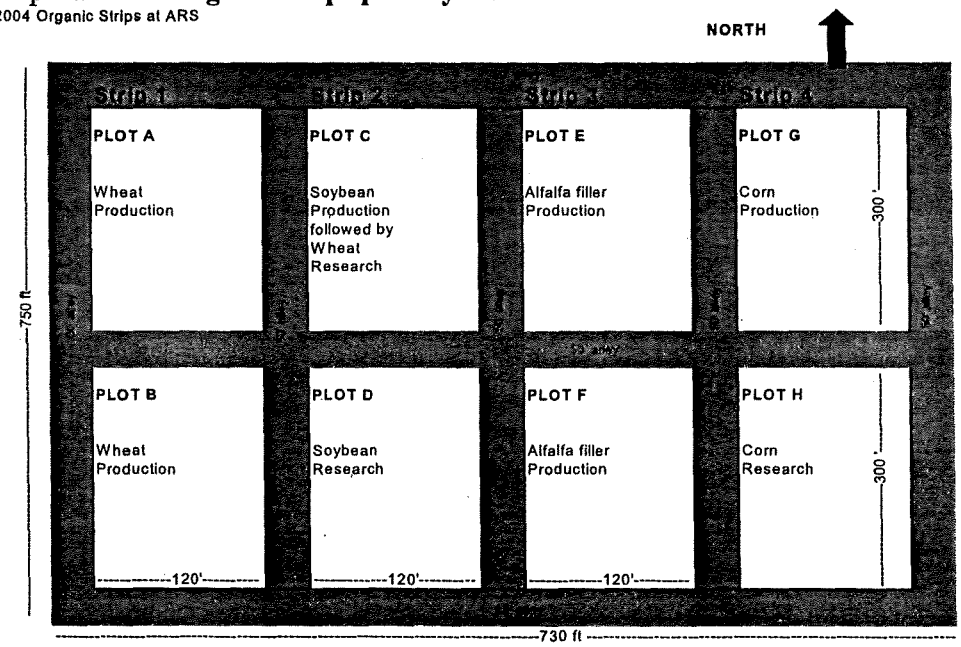
OUTREACH

The Center for Integrated Agricultural Systems (CIAS) distributed the 2004 variety trial data at their booth at the 2005 Upper Midwest Organic Conference on February 25th and 26th. Also, the data and additional discussion of the variety trials can be found online at http://corn.agronomy.wisc.edu/HT/2004/Organic.pdf and http://soybean.uwex.edu/soytrials/printable/documents/04_organic_soy_results.pdf and at the WICST site http://www.cias.wisc.edu/wicst/pubs/index.htm.

APPENDIX I

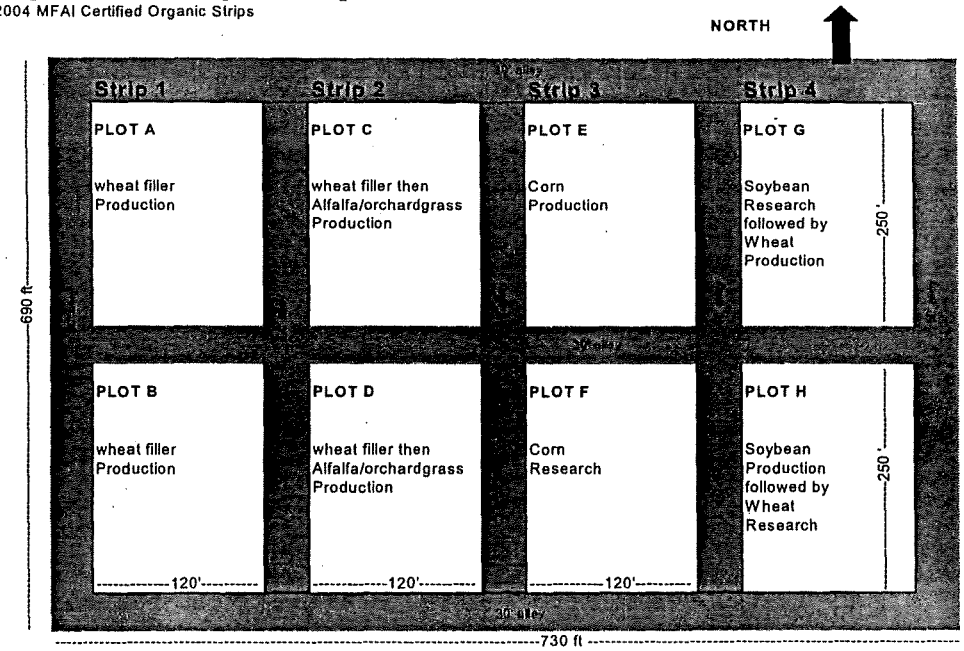
Map 1a. **ARS Organic strips plot layout 2004.**

2004 Organic Strips at ARS



Map 1b. **MFAI organic strips 2004**

2004 MFAI Certified Organic Strips



APPENDIX II

Table 2a. Baseline soil fertility (Fall 2004) at ARS.				
	STP (ppm)	STK (ppm)	OM %	pH
Strip 1 plot A	74	98	4.0	7.3
Strip 1 plot B	65	100	3.8	7.3
Strip 2 plot C	58	78	4.2	7.3
Strip 2 plot D	102	104	4.5	7.2
Strip 3 plot E	55	107	3.9	6.8
Strip 3 plot F	68	129	4.4	6.8
Strip 4 plot G	67	108	3.7	6.8
Strip 4 plot H	101	125	4.0	6.7

Table 2b. Baseline soil fertility (Spring 2005) at MFAI				
	STP (ppm)	STK (ppm)	OM %	pH
Strip 1 plot A	124	176	2.3	6.1
Strip 1 plot B	94	114	2.5	5.7
Strip 2 plot C	112	153	2.6	6.2
Strip 2 plot D	84	123	4.1	5.8
Strip 3 plot E	51	87	4.7	5.8
Strip 3 plot F	48	77	3.6	5.8
Strip 4 plot G	41	50	3.4	6.3
Strip 4 plot H	37	60	3.8	6.1

Table 3. 2004 weed seed bank at ARS (greenhouse germination)				
Strip #	**B'leaf/m2**	**B'leaf Species**	**Grasses/m2**	**Grass species**
#1	2138	56% white cockle, 23% galinsoga; pigweed, lambsquarter	55	"Unknown species"
#2	2028	46% galinsoga, pigweed, lambsquarter, velvetleaf	110	"Unknown species"
#3	4989	78% galinsoga, 11% pigweed + lambsquarter	3289	30% barnyard grass, 33% large crabgrass 18% foxtails
#4	403	64% lambsquarter	1425	38% barnyard grass

APPENDIX III

Table 4a. 2004 Agronomic Inputs/Outputs on the Organic Grain Strips – Production Plots ARS

STRIP # CROP-2004	STRIP 1 WHEAT then ORCHARDGRASS/ ALFALFA MIX	STRIP 2 SOYBEANS then WINTER WHEAT	STRIP 3 ALFALFA	STRIP 4 CORN
Plot	A,B	C, D	E,F	G, H
Primary Tillage	NONE other than field digger prior to wheat planting last fall	Chisel plow w/twisted shank Nov. 14, 2003	NONE	Moldboard plow Nov. 13, 2003
Secondary Tillage	NONE	Field cultivated May 17 (1x), May 26 (2x)	NONE	Field cultivated May 17 (1x), May 26 (2x)
Planting Date Variety Rate	October 8, 2003 'Patriot' wheat (HR) 2.5 bu/a	May 27, 2004 NC+1F61 (food grade) 170,000 seeds/acre	April 14, 2003 Magnum V 12 lb/a	May 27, 2004 NC+34C17 34,500 seeds/acre
Manure	NONE	NONE	NONE	NONE
Rotary Hoe	NONE	2x: 6/11/04, 6/16/04	NONE	2x: 6/11/04, 6/16/04
Cultivation	NONE	3x: 6/26/04, 7/2/04, 7/13/04	NONE	2x: 6/26/04, 7/2/04
Hand weed/scout	1x to pull vol. rye in early July	1x (July) pulled broadleaf weeds ~ 4 man hrs/a	Note: old waterway very grassy	1x (July) barnyardgrass and broadleaf weeds ~ 8 man hrs/a
Harvest	July 27, 2004 43 bu/a	October 6, 2004 2600 lb/plot=62 bu/a	6-6-04 1.69 T DM/a 7-13-04 2.66 T DM/a	December 1, 2004 132.5 bu/a
Fall Practices	Seeded orchardgrass/alfalfa mix August 18, 2004 M/L maturing 'Potomoc' orchgrass at 4 lb/a, and 'Hardy' alf at 8 lb/a	Wheat variety trial planted in plot C October 14, 2004 In plot D, Oats to be planted Spring 2005due to delayed soybean variety trial harvest	Chisel plowed with sweeps after 2nd cut (late July) to work on killing quackgrass; planted oat covercrop September 22,2004 @ 2bu/a	Chisel plow with twisted shanks after stalk chopping December 6, 2004.
Crop 2005	**ORCHARDGRASS/ALFALFA MIX**	**WHEAT then ORCHARDGRASS/ALFALFA MIX**	**CORN**	**SOYBEANS**

Corn variety trial was planted June 3, following tillage to smooth out some gully erosion that cut across the plot; it was rotary hoed 2x on 6-16-04 and cultivated 3x: 6-29-04, 7-9-04, 7-13-04. Soybean variety trial was planted May 28th and cultivated, not rotary hoed, on June 16th. Both corn and soybeans received hand weeding.
Alfalfa alleys were tilled out in late July and planted to organic winter rye. Soil samples (0 to 6") taken for routine fert 11/29/04 from each plot.
Soybean variety trial was not harvested until November 6th so no winter wheat was planted in plot D. No fall tillage on plot D.

Table 4b. 2004 Agronomic Inputs/Outputs on the Organic Grain Strips – Production Plots at MFAI.

STRIP # CROP-2004	STRIP 1 WHEAT FILLER	STRIP 2 WHEAT then ALFALFA-ORCHARDGRASS	STRIP 3 CORN	STRIP 4 SOYBEAN then WHEAT
Plot	A,B	C, D	E, F	G, H
Primary Tillage	Chisel plowed	Chisel plowed for both crops	Rotovated the wheat cover (2x)	Rotovated (2x) for soybeans and chisel plowed for wheat
Secondary Tillage	Field cultivator	Field cultivator	Field cultivated (2x)	Field cultivated (2x) for soybeans and again for wheat
Planting Date Variety Rate	September 23, 2003 Patriot winter wheat 3bu/a	September 23, 2003 Patriot wheat, 3bu/a September 8, 2004 for alfalfa/orchardgrass	June, 7, 2004 NC+ 41F00 28,000 plants/a	June 4, 2004, Vinton 81 soybeans, 175,000 plants/a Oct. 14, 2004, Patroit wheat, 3bu/a
Manure	None	20t/a applied September 4, 2004	None	None
Rotary Hoe	None	None	Rotary hoed twice	Rotary hoed once Tine weeded twice
Cultivation	None	None	Cultivated twice	Cultivated once
Hand weed/scout	None	None	yes	yes
Harvest/yield	July 20,2004 67 bu/a	July 20, 2004 72 bu/a	0 bu/a (stand plowed under)	October 6, 2004 30 bu/a
Fall Practices	Chisel plowed September 5, 2004	Chisel plowed Sept. 5, and field cultivated and drilled alfalfa/orchardgrass September 8, 2004	Chisel plowed	Chisel plowed and field cultivated October 13, 2004 Planted wheat October 14, 2004
Crop 2005	**CORN**	**ALFALFA/ ORCHARDGRASS**	**SOYBEANS**	**WHEAT**

REINTEGRATING A FORMER DAIRY FARM AS A NEW AGRICULTURAL ENTERPRISE: THE QUINNEY FARM

John Hall, Josh Posner, Janet Hedtcke, Randy Jackson , Jeff Lumkuler, Dan Undersander, and Geoffrey Brink

The Challenge:

The majority of the farmland in Southern Wisconsin is still owned in relatively smallholdings of 160 to 250 acres. Much of this land however, is no longer farmed as integrated landscapes but rented to neighbors, put in government conservation reserve programs, or left unmanaged. However, the recent and rapidly growing demand for differentiated agricultural products (natural, grass fed, organic, locally grown) has made it more likely that smaller, market savvy operations will develop that could re-integrate these farms, creating a more vibrant farming sector. Also, as an integrated, working landscape, it is more likely that good farm planning focusing on water management, biodiversity management, wild life habitat and aesthetics would be successful and eligible for government programs. The overall challenge to our team is "Can we take a 160 acre former dairy farm and develop a management system that will re-articulate the farm into a working landscape and meet the two goals of generating enough income to partially sustain a family, as well as meeting a higher standard of land stewardship". This project will contribute to the long-term outcome of increasing farm numbers, increasing farm profitability and improving land stewardship in the Upper Mid-west.

The Approach:

The strength of case studies is that they illuminate links within the farming system, marketing system, community and environment. The weakness of case studies is that they don't indicate the relative importance or universality of these links. To enjoy the benefits and minimize the shortfalls of case studies, the project team will work at three levels: First, baseline biophysical inventories on the farm will be conducted and a farm plan designed; Secondly, companion studies placing the farm within its watershed, community, marketing networks, and county will be undertaken; and finally, an outreach program will be designed aimed at a target population of landowners and operators in SE Wisconsin and young couples with an interest in going into farming.

Baseline survey: To start this project we are focusing on four initial baseline surveys: a soil survey, a vegetation survey, a wildlife survey, and a water quality survey. These will help to: 1) characterize the natural resource baseline; 2) identify key monitoring sites for quantifying, over time, the impact of changes in landscape management; and 3) as input in fine tuning the design of the farm plan.

Developing a farm plan: In order to define potential land uses on the rolling 160-acre Quinney farm, we have made the following choices:

1. Initially we will focus on a forage-based land use system. Animal production (replacement dairy heifers, beef cattle) will be the primary thread that will knit the various ecological niches into a working landscape;
2. As we compare options, we will keep capital investment to a minimum. This will oblige the team to design systems where relatively little machinery is required, and when

machinery is needed, a first effort will be to have the work done by custom operations; and,

3. Landscape management options will be studied that simultaneously meet the objectives of forage productivity and conservation-- breaking the current paradigm of managing some acres for maximum production and others solely for conservation payments

Progress:

Monitoring biophysical parameters:

The Quinney farm was established in 1868. **Figure 1** (Walworth Co townships.pdf) shows the location of the Sugar Creek Township within Walworth County in SE Wisconsin and **Figure 2** (Township and turtle valley.pdf) outlines the farm and shows its close proximity to the Turtle Valley Wildlife area. **Figure 3** (Map of Quinney farm 21304.ppt) is an aerial photo from April 1992.

Figure 4 (NRCS Soil map.pdf). is the soils map of the farm downloaded from the web (http//SoilDataMart.nrcs.usda.gov/), based on the soil survey of 1971. The farm consists of three landscape positions: a flat area of productive silt-loam crop land; an area of relatively steeply sloping land (6-20% slope eroded)-more apt for perennial forages, pasture and woodlands; and, a pond and reed canary grass wetland. An ecological units map was developed after walking the farm (**Figure 5**) (Ecological units & sampling stations 62405.pdf). There are approximately 102 acres of cropland of which 73a are apt for annual cropping (fields 2,3,5,7 and 8) and 29a are apt for cropping perennials or pasture (fields 4, and 6). There are three small areas of oak savanna (5.4a), two of dry mesic oak woodland (7.7a), a pond (0.5a), a wetland (9.2a) and some land in the Conservation Reserve Program (17 acres including field 9)

Figure 5 also shows the location of the soil sampling stations. The fields that had been rented out for soybean and corn production (2, 3, 7, 8) over the past 30 years have STP and STK values in the optimum to high range (STP>30 ppm, STK>120 ppm), while the fields that are small (5) or very rolling (4 & 6) and have been primarily planted to forages and small grains now have relatively low soil test values (STP= 15-20 ppm; STK< 100 ppm). The natural areas (woodland, oak savanna, wetland) all have, not surprisingly even lower soil test P and K values

Water quality, vegetation, weed seed bank and wildlife surveys are being undertaken during the summer of 2005.

Developing a farm plan

Due to the range of ecological units on the farm we are focusing on developing a low input forage-based feeding system that utilizes a combination of high quality intensively managed pastures, grazing woodlands, CRP and wetlands, as well as the production of some forages as alternative early spring, mid-summer, late fall and winter feed. Our target animals will be either custom raised dairy heifers or beef cattle. We see this mixed system of grazing and forage production as the most effective way to generate income on the farm, productively link the entire farm landscape, and meet our stewardship objectives. Although annual cropping in the rotation will require some machinery, it will allow the farm to ensure greater forage production for the animals, an opportunity to market any excess, as well as open the opportunity to manure the fields.

We intend to employ a range of strategies:

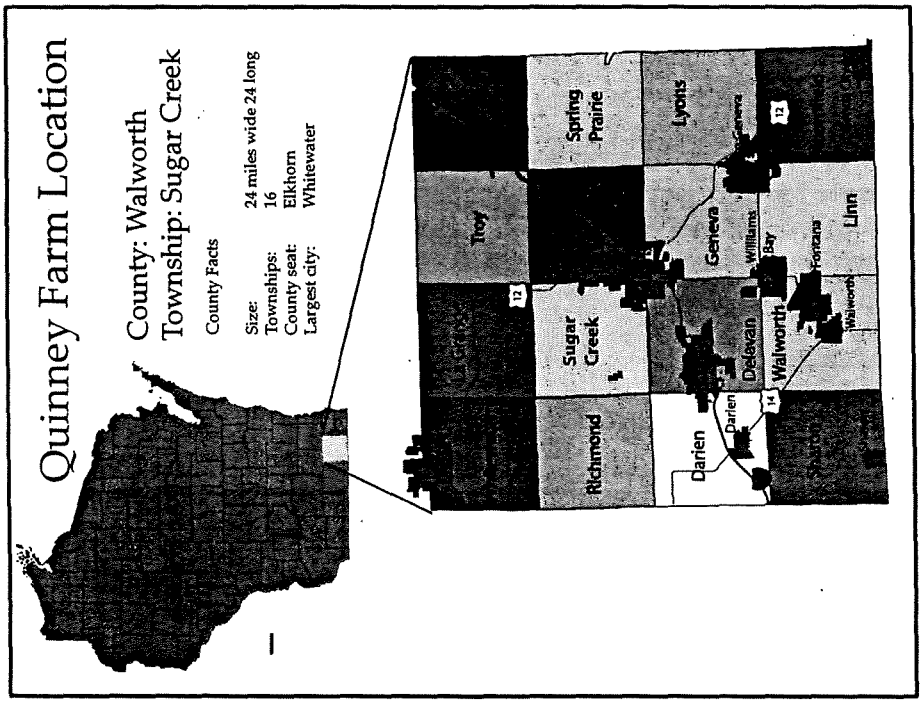
- The fields that have been cropped in the past, but are more steeply sloped will be seeded to perennial forage mixtures for rotational grazing and hay production. These areas will be treated as semi- permanent improved pastures where we will explore various strategies for combating the decline in pasture productivity that many graziers are encountering when former hay fields are converted to permanent pastures. This will include comparisons of renovation techniques such as frost seeding to more aggressive mechanical disturbance, reestablishment and fertility management approaches.

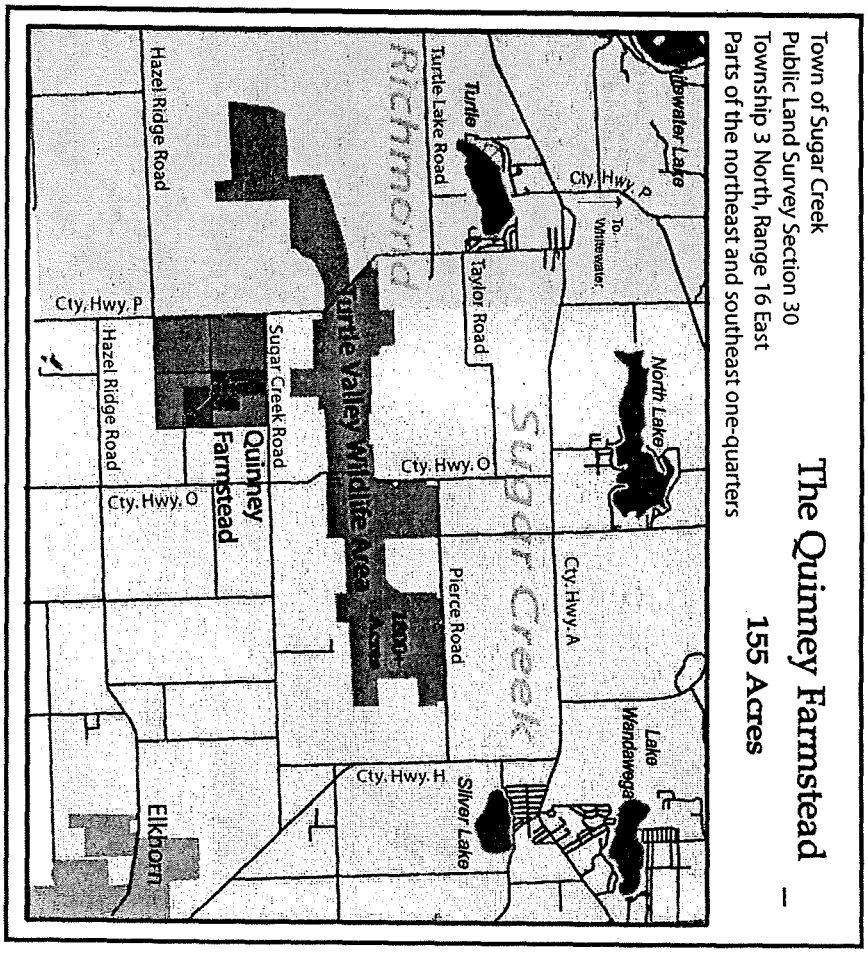
- On the flatter fields we will establish mixed crop rotations. These long rotation fields will include production of winter feed (corn grain, corn silage, oats, triticale), supplementing the grazing paddocks with early spring grazing on winter annuals such as rye and triticale, mid-summer grazing and harvesting of warm season annuals such as sorghum-sudangrass, and late fall production with forage brassicas (turnip, rape, kale). The pasture/hay phase of mixed crop rotations will include the use of short-term forage mixtures such as ryegrass and clover that offer the opportunity of increased forage production and/or quality in the seeding year compared to alfalfa based systems (Peterson, 2003); and

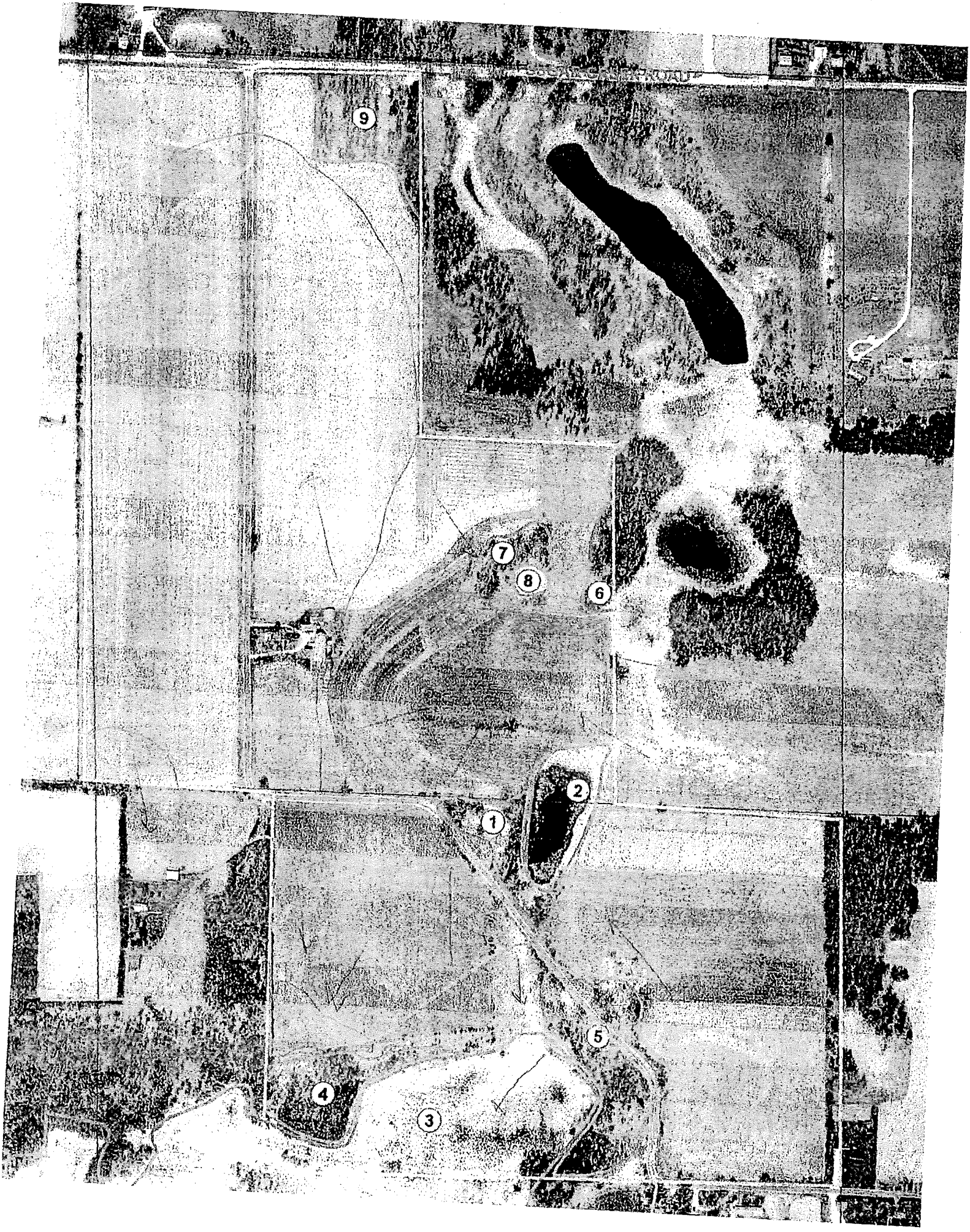
- We will explore the potential for grazing in areas that have not been part of the crop land but were formerly grazed when the farm was operating as a dairy. The goal will be to use grazing management in suitable areas to improve wildlife habitat while realizing some production for livestock.

Companion research themes

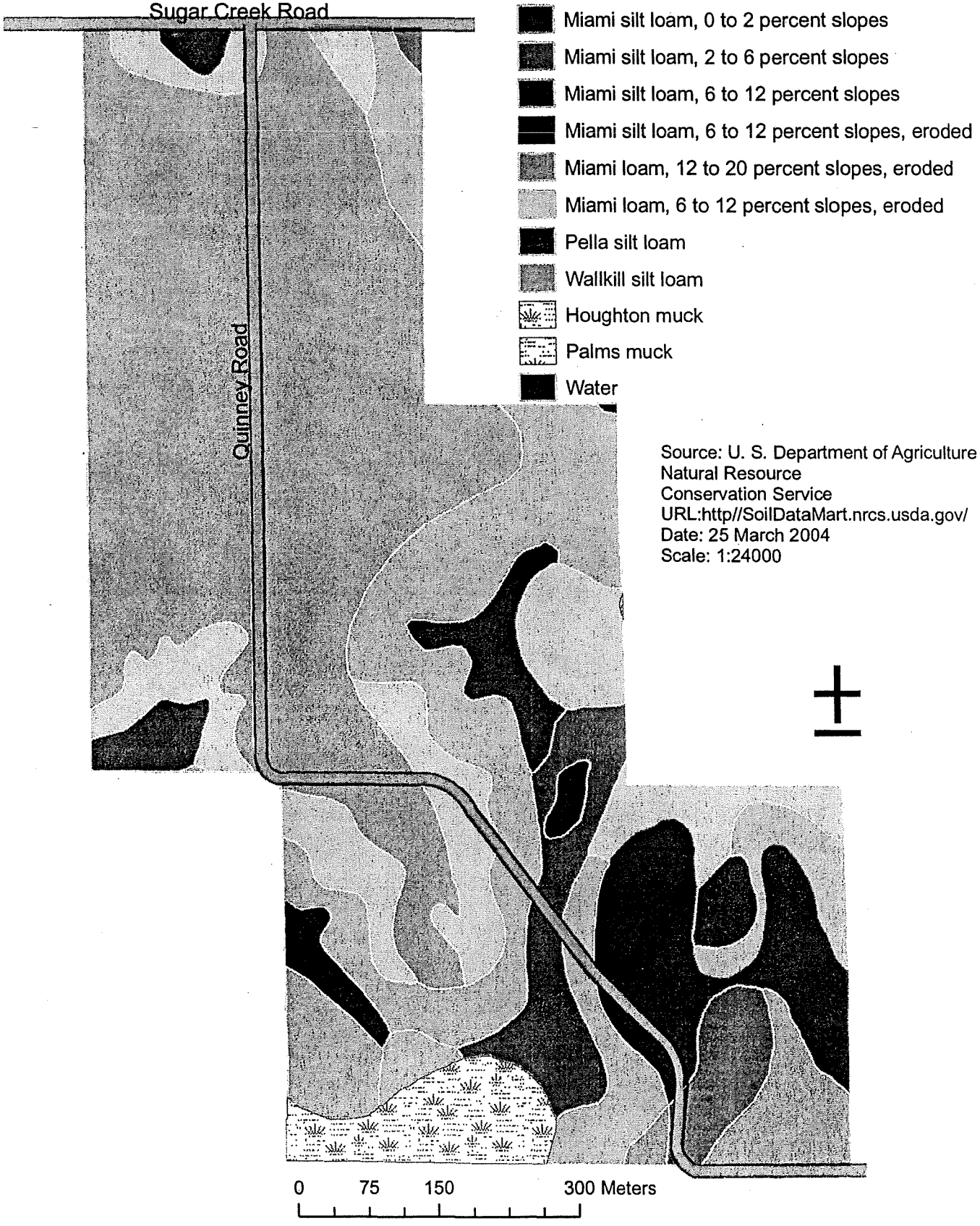
- Alternative approaches to restoring a reed canary grass wetlands to a more productive and biodiverse wetlands;
- Oak savanna grazing management options;
- Pond management for wildlife and livestock use
- Changes in wildlife abundance and distribution;
- Carbon and nitrogen retention and loss under various management schemes;
- Invasive plant trajectories;
- Grazing of native prairie in CRP;

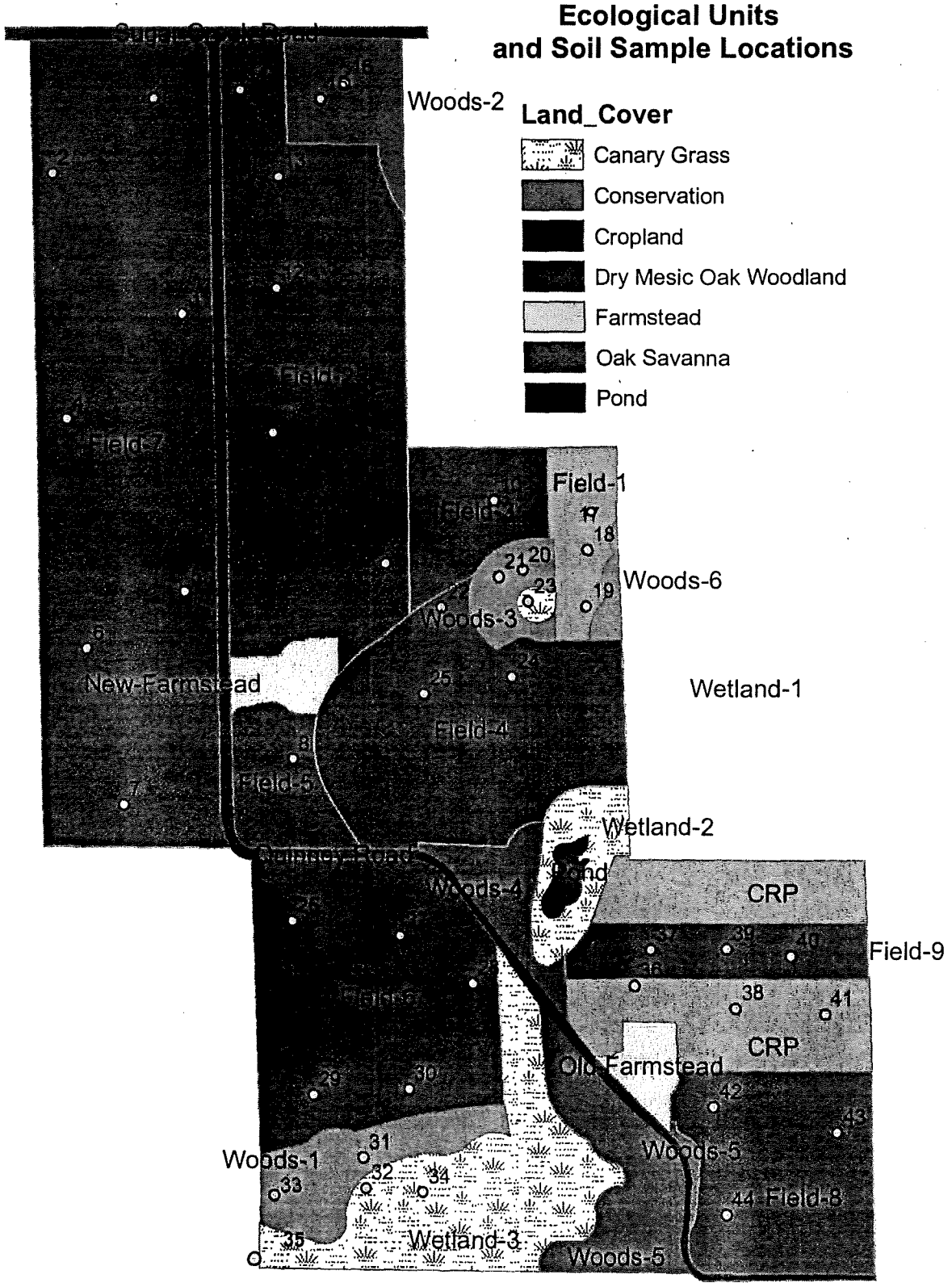

Quinney Farm Location
County: Walworth
Township: Sugar Creek
County Facts
Size: 24 miles wide 24 long
Townships: 16
County seat: Elkhorn
Largest city: Whitewater
Troy
Spring Prairie
Sugar Creek
Lyons
Geneva
Williams Bay
Linn
Richmond
Darien
Delavan
Walworth
Fontana
Walworth


The Quinney Farmstead
155 Acres
Town of Sugar Creek
Public Land Survey Section 30
Township 3 North, Range 16 East
Parts of the northeast and southeast one-quarters
Sugar Creek
Richmond
Cty. Hwy. P
To Whitewater
Turtle Lake
Turtle Lake Road
Taylor Road
North Lake
Cty. Hwy. A
Cty. Hwy. O
Pierce Road
Lake Wandawega
Silver Lake
Cty. Hwy. H
Turtle Valley Wildlife Area
100+ Acres
Quinney Farmstead
Sugar Creek Road
Hazel Ridge Road
Cty. Hwy. P
Hazel Ridge Road
Cty. Hwy. O
Elkhorn


9
7
8
6
2
1
5
4
3

The Quinney Farm




Ecological Units
and Soil Sample Locations
Land_Cover
Canary Grass
Conservation
Cropland
Dry Mesic Oak Woodland
Farmstead
Oak Savanna
Pond
Woods-2
Field-1
Field-2
Field-3
Field-4
Field-5
Field-6
Field-7
Field-8
Field-9
Woods-1
Woods-3
Woods-4
Woods-5
Woods-6
Wetland-1
Wetland-2
Wetland-3
New-Farmstead
Old-Farmstead
Pond
CRP
CRP
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44

MANURE IN CASH-GRAIN SYSTEMS COMPACTION STUDIES

Gregg Sanford[1], Josh Posner[2], Janet Hedtcke[3], Jon Baldock[4], Amy Cook[1]

INTRODUCTION

Despite the nutrient content of manure many grain farmers are hesitant to bring slurry onto their land due to concerns regarding compaction. In the winter of 2004 we conducted several interviews with grain farmers who all cited compaction as a concern with incorporating manure into their rotations. Their concerns are not unfounded as manure tankers commonly range from 3,000 to 7,500 gallons capacity and can weigh from 20,000 to 45,000 pounds per axle. These weights exceed the 20,000 lb/axle benchmark. Axle weights greater than 20,000 lbs have been shown to contribute to subsoil compaction that is generally not alleviated by freeze/thaw cycles or tillage (Håkansson et al., 1987, Lowery and Schuler, 1991, 1994,). The purpose of these studies is to better estimate the impact of manure spreading on soil compaction and crop yield. Our question is, do the benefits associated with manure (plant nutrients, increased porosity, water infiltration, nutrient uptake, increased OM and biological activity) compensate for the potential negatives caused by the use of manure tankers on arable land?

This research will consist of three components: 1) an analysis of axle weights of typical cash grain and manure spreading equipment; 2) an on-station trial looking at alternative traffic patterns for manure spreading and their impact on individual plant yields; and 3) on-farm trials comparing compaction and yield in plots with and without manure.

MACHINERY SCORECARD

In order to place in context the potential compaction associated with manure spreading, a comparison will be made between typical cash grain production equipment and manure spreading equipment (with various configurations) for axle weights. For example a 500 bu grain cart on one axle has an axle weight of approximately 31,000 lbs full, and a combine with a hopper capacity of 250 bu can weigh over 22,000 lbs/axle when loaded with corn at 20% moisture. These axle weights are comparable or greater than those associated with a Balzer 4200 gallon slurry tanker on two axles (see Table 1).

ARLINGTON RESEARCH STATION STUDY

We will be conducting this study on a field that has been in a no-till corn/soy rotation for the past 5 years. Our study will be set up as an augmented 2X2 factorial in a randomized complete block design with four replications. Factor 1 will be the nutrient source for a plot: manured versus non-manured, and Factor 2 will be traffic pattern: 1 pass versus 6 passes with a loaded manure tanker. Traffic pattern will be restricted to the original tire tracks. This will allow us to assess the extent of the area around a tire track in which corn yield is affected. A check plot (*augment*) will also be set up that will not receive manure or heavy machinery traffic. Normal field traffic from planting and harvesting will be considered the baseline.

[1] Graduate Students, UW-Madison, Agronomy Dept.
[2] Professor, UW-Madison, Agronomy Dept.
[3] Research Specialist, UW-Madison, Agronomy Dept.
[4] AGSTAT, Consultant, Verona Wisconsin

In all compacted plots, tire tracks will be clearly marked allowing us to re-locate them over the course of a year. We will be using Arlington's *Waste Handlers* 4,600 gal manure tanker on our compaction plots. This tanker has an approximate full weight of 49,220 lbs and an approximate axle weight of 25,000 lbs or 12.5 tons. The impact of compaction on the soil will be evaluated with a data logging hand-held penetrometer (courtesy of Ron Schuler, UW, Biosystems Eng.), as well as by soil bulk density readings. Impact on corn yields will be estimated by hand sampling and by overall plot yields.

In each plot, three "sampling stations" will be randomly assigned but evenly distributed over the length of a treatment. These stations will begin in the center of a tire track and extend 10' or 120" (*corresponding to ~5 corn rows*) away from a track toward the plot edge in alternating directions. Penetrometer readings will be taken every 15" beginning in the center of the tire track for a total of 9 points (*~ 4 inter-row points, and ~5 within-row points*). At each point where the sampling station intersects with a corn row, a 5' length of corn perpendicular to the sampling station will be hand harvested (see Fig 1). These harvests coupled with our penetrometer readings will allow us to analyze the effects of compaction with and without manure and under one or many traffic passes on corn grain yields. In addition it will allow us to determine the extent to which compaction affects plants outside of the direct tire-contact area. We will also use total plot yields to assess the corn yield response under our five treatments.

ON-FARM STUDY

The objective of this study will be to assess the negative impacts of manure spreader induced compaction on crop yield under varied on-farm conditions. Data will be collected at all on-farm sites and will include corn yield and quality, soil nutrient levels, and penetrometer readings. Treatments will include manure with compaction, no-manure with compaction, and a check plot (no-manure/no-compaction). This study is set up as a randomized complete block design with 3 replications per on-farm site. Traffic patterns on compaction treatments will differ depending on the manure spreader or slurry tanker being used (see Fig 2). These differences will be taken into consideration when analyzing site-specific differences in penetrometer readings and corn yield.

Because of the difficulty of reconstructing traffic pattern at our on-farm sites we will try to quantify compaction more broadly. In each plot two 15' sampling stations will be set up, randomly assigned but evenly distributed over the length of the treatment. These stations will begin at the center line of the plot and move toward the plot edges in opposite directions (perpendicular to the tire tracks). In each station penetrometer readings will be taken every 12" beginning at the center line for a total of 16 reading per station or 32 readings per plot. By taking penetrometer readings from a total of 30' across a plot we will attempt to capture any traffic-induced compaction. Analysis will involve comparing corn yields over our three treatments and relating them to penetrometer readings.

OUTCOMES

The benefits of adding manure to grain rotations extend beyond its nutrient content. Research has show that repeated manure applications to agricultural land increase soil porosity, water infiltration, aggregate stability, biological activity and organic matter (Aoyama et al. 1999, Marianari et al, 2000, Peacock et al., 2001,). Combined, these increase nutrient availability to plants (Wolkowski, 1990), decrease the negative impacts associated with tillage, and can lead to

healthier soils (Bissonette et al., 2001). By addressing the issue of compaction coupled with the application of manure we will be better able to answer a key question: Do the negative effects associated with heavy farm equipment override the many benefits derived from manure? We will also be able to assess the extent to which compaction affects crop yield as plants move away from the wheel track and thus be able to calculate the value/impact of manure over an entire field. This study may facilitate farm links by addressing concerns regarding compaction and by orienting farmers to the relative weights commonly brought onto cropland in the course of a season.

REFERENCES

Aoyama, M., Angers, D.A., N'Dayegamiye, A., and Bissonnette, N. 1999. Protected organic matter in water-stable aggregates as affected by mineral fertilizer and manure applications. Canadian Journal of Soil Science. 79: 419-425.

Bissonette, N., Angers, D.A., Simard, R.R., and Laford, J. 2001. Interactive effects of Management practices on water-stable aggregation and organic matter of a Humic Gleysol. Canadian Journal of Soil Science. 81: 545-551.

Håkansson, I., Voorhees, W.B., and Riley, H., 1987. Vehicle and wheel factors influencing soil compaction and crop response in different traffic regimes. Soil & Tillage Research. 11: 239-282.

Lowery, B., and Schuler, R.T. 1991. Temporal effects of subsoil compaction on soil strength and plant growth. Soil Sci. Soc. Am. J. 55: 216-223.

Lowery, B., and Schulter, R.T. 1994. Duration and effects of compaction on soil and plant growth in Wisconsin. Soil & Tillage Research. 29: 205-210.

Marianari, S., Masciandaro, G., Ceccanti, B., and Grego, S. 2000. Influence of organic and Mineral fertilizers on soil biological and physical properties. Bioresource Technology. 72: 9-17.

Peacock, A.D., Mullen, M.D., Ringelberg, D.B., Tyler, D.D., Hedrick, D.B., Gale, P.M., and White, D.C. 2001. Soil microbial community responses to dairy manure or ammonium nitrate applications. Soil Biology and Biochemistry. 33: 1011-1019.

Wolkowski, R.P. 1990. Relationship between wheel-traffic-induced soil compaction, nutrient availability, and crop growth: a review. Journal of Production Agriculture. 3(4): 460-469.

Table 1. Weight comparison of common farm machinery.

Weight Comparison of Common Farm Machinery[6]						
Combines						
Make	**Model/hp**	**Grain Cap.**	**Empty Wt. lb lh**	**Full Wt. Corn[3]**	**# of Axles (fuel)**	**axle wt. full + fuel[4]**
CASE IH	2366/250	180	25,000	34,090	2 (130)	17,487
CASE IH	2388/280	210	26,500	37,105	2 (180)	19,164
JD	9660/305	250	29,813	42,438	2 (250)	22,069
Grain Boxes						
Make	**Model**	**Cap. Bu.**	**Empty Wt. lb**	**Full Wt. Corn[3]**	**# of Axles**	**Axle/wt. Corn**
Killbros	390	400	3,111	23,311	2	11,656
Grain Carts						
Make	**Model**	**Cap. bu.**	**Empty Wt. lb**	**Full Wt. Corn[3]**	**# of Axles**	**Axle/wt. Corn**
Killbros	1150	500	6,100	31,350	1	31,350
Killbros	1160	600	6,300	36,600	1	36,600
Balzer	1000	1000	22,350	72,850	3	24,283
Balzer	1500	1500	23,350	99,100	3	33,033
Slinger Spreaders						
Make	**Model**	**Cap. Bu.**	**Empty Wt. lb.**	**Full Wt. lb.[2]**	**# of Axles**	**Axle/wt.**
Frontier	MS1223	235	2,890	21,103	1	21,103
Frontier	MS1231	310	4,190	28,215	2	14,108
Frontier	MS1243	430	5,220	38,545	2	19,273
Frontier	MS1256	560	8,140	51,540	2	25,770
Frontier	MS1266	660	9,600	60,750	2	30,375
Slurry Tankers - pull behind						
Make	**Model**	**Cap. gal.**	**Empty Wt. lb.**	**Full Wt. lb.[1]**	**# of Axles**	**Axle/wt.**
Balzer	4200 HD	4200	11,600	47,720	2	23,860
Balzer	5700 HD	5700	14,600	63,620	2	31,810
Better-Bilt	6600	6600	19,500	76,260	3	25,420
Balzer	7500 HD	7500	23,100	87,600	3	29,200
Slurry Tankers - truck mounted						
Make	**Model**	**Cap. gal.**	**Empty Wt. lb.**	**Full Wt. lb.[7]**	**# of Axles**	**Axle/wt.**
Husky		4000	26,100	59,440	3	19,813
Sprayers - self propelled						
Make	**Model**	**Cap. gal.**	**Empty Wt. lb.**	**Full Wt. lb.[8]**	**# of Axles (fuel)**	**axle wt. full + fuel[4]**
John Deere	4720	800	22,700 (80ft. boom)	31,180	2 (95)	15,913
Tractors						
Make	**Model/hp**	**Fuel Cap.**	**op.wt.MFWD lb.[5]**	**axle/wt.**	**axle(s)**	**axle wt. full + fuel[4]**
CASE IH	MX210/170	130	19,700	9,850	2	10,292
CASE IH	MX285/240	160	20,200	10,100	2	10,644

[1] calculated @8.6lb./gal slurry - Calc. from Schluter and Obriend Farms.

[2] calculated at 77.5lb./bu.

[3] corn @ 20% moisture - 50.5lb./bu.- data from Univ. of Nebraska http://ianrpubs.unl.edu/farmmgt/g518.htm#sfc

[4] 1 gallon of diesel ~ 6.8lb

[5] wt. unballasted

[6] all numbers based on manufacturers specs.

[7] calculation made on truck full weights.

[8] weight based on application of UAN (28%) at 10.6 lbs/gal.

Fig.1. Site Setup: Arlington Compaction Study

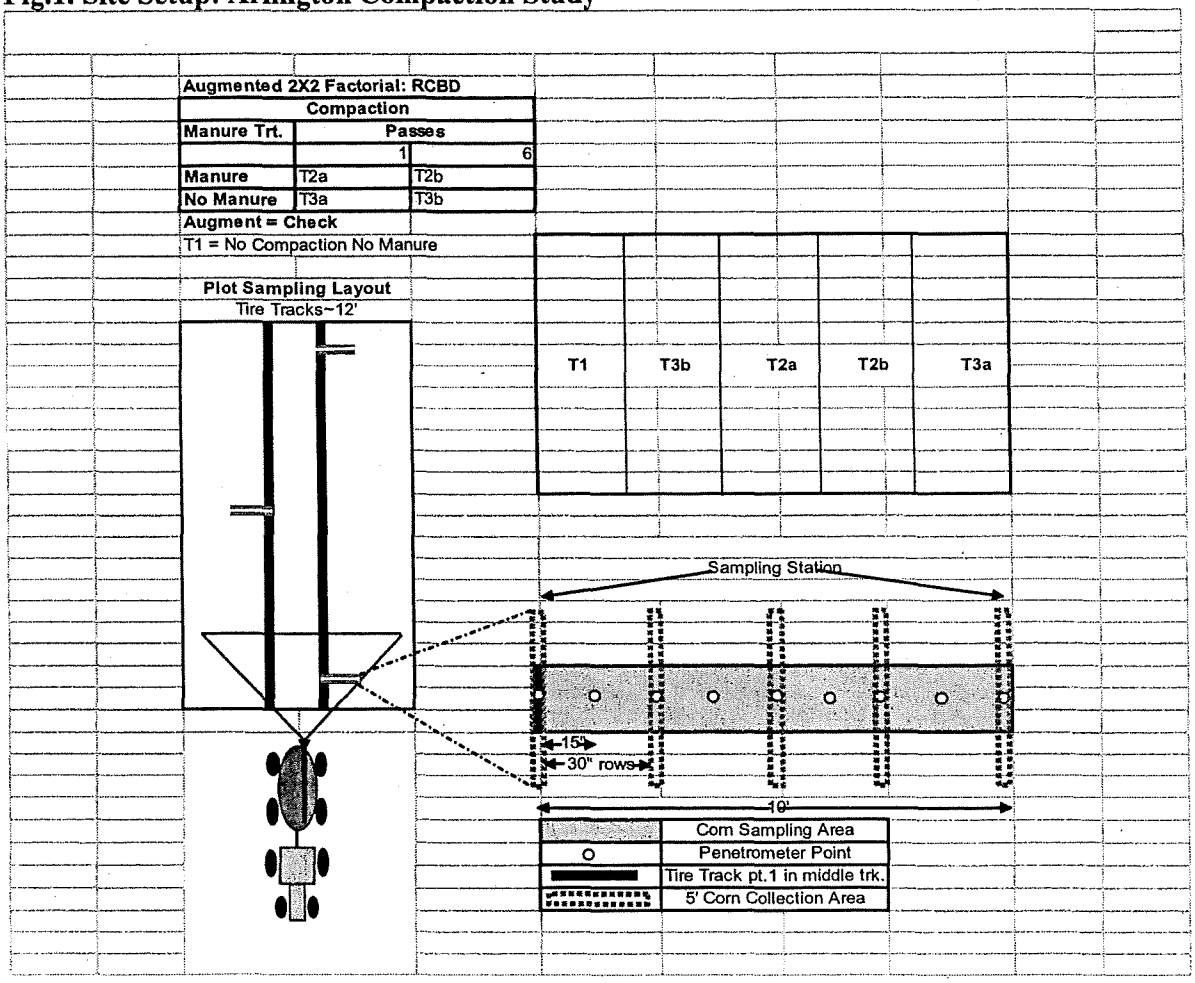
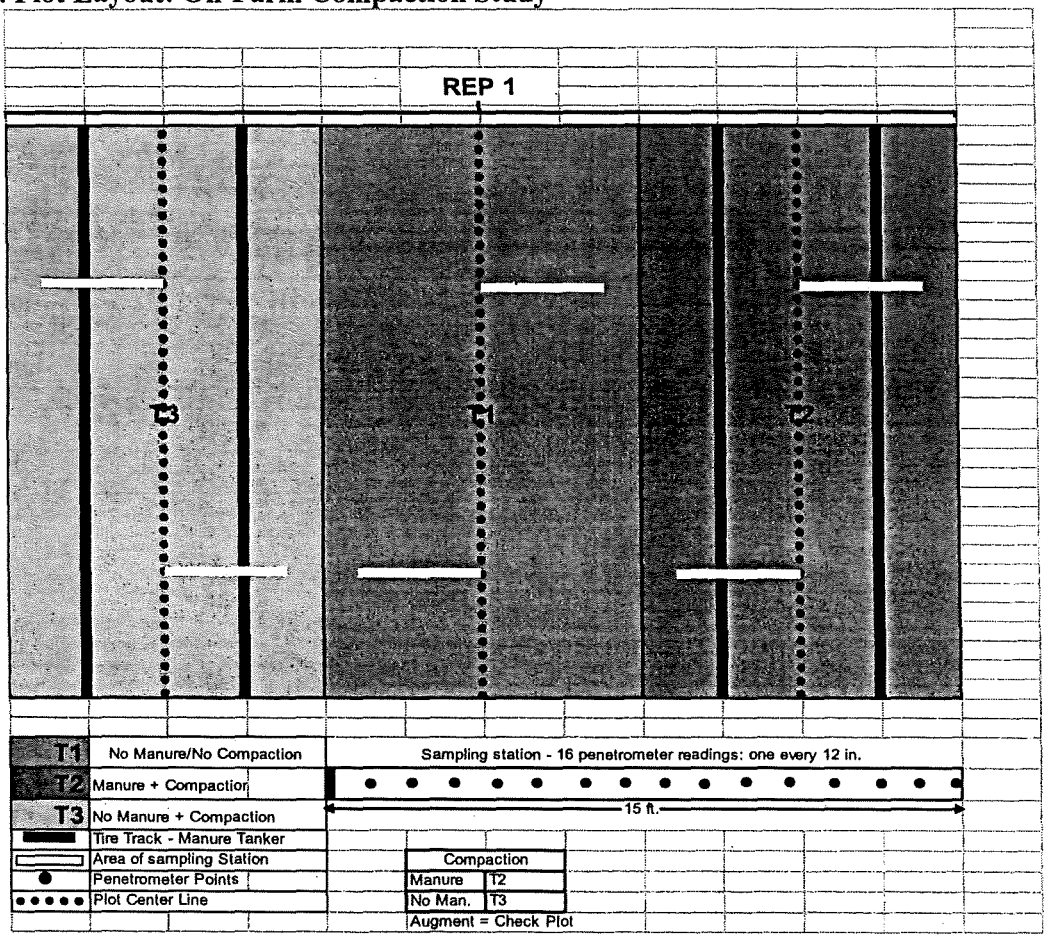


Fig.2. Plot Layout: On-Farm Compaction Study



Using Food Sprays as a supplemental food source for *Harmonia axyridis* (Multicolored Asian Lady Beetle) to enhance suppression of *Aphis glycines* (Soybean Aphid) in soybeans

Heidi Kraiss and Eileen Cullen

INTRODUCTION

Soybean aphid, *Aphis glycines* Matsumura, a species native to eastern Asia, was first identified on soybeans in Wisconsin in July 2000 (Ragsdale 2004) and reached densities of thousands per plant in many locations throughout the state by the summer of 2001 (Ostlie 2001). Direct effects of soybean aphid feeding include reduced pod set, smaller seed production (Fujan 2004), and reduction of photosynthetic rate (Macedo 2003). Indirect effects include soybean viruses spread by aphids (Grau 2003). Soybean aphid had a significant economic impact during a recent outbreak with crop losses totaling 336 million bushels, or $1.7 billion, for all 12 North Central states combined in 2003 (Fujan 2004).

As an exotic invasive pest, *A. glycines* interacts with both native and naturalized predators that were present in North American soybean ecosystems before its arrival. Understanding the role of existing predator communities with regard to *A. glycines* population dynamics is a critical step in the development of effective management systems for this new pest (Fox 2004). Soybean aphid rarely reaches economically damaging population densities in Japan and it believed to be effectively suppressed by natural enemies (Rutledge 2004). There is researcher and farmer interest in minimizing the use of broad-spectrum insecticides for soybean aphid so that they do not diminish the potential for natural control. Fox et al. (2004) showed that predators found in the soybean agroecosystem are able to suppress *A. glycines* population density and concluded that more research is needed in this area. Fox et al. (2004) also stated that in the United States, as in China, the Multicolored Asian Lady Beetle, *Harmonia axyridis* Pallas, is the one of the most common predators of the soybean aphid.

H. axyridis, is a species of the infamous family of beetles, Coccinellidae (Lady Beetles). Coccinellids have been intentionally introduced for classical biological control many times over the last century, beginning with the Vedalia beetle for cottony cushion scale (Doutt 1964) due to their predaceous appetite. *H. axyridis* was also introduced in 1916 in North America to control various types of scale and aphids (Koch 2003). An established colony was first detected in Louisiana in 1988. It is thought it was the result of an accidental seaport introduction (Day, 1994). Soon after, *H. axyridis* spread quickly across the rest of North America (Koch 2003). *H. axyridis* was already present in Wisconsin before the arrival of the soybean aphid but has quickly adjusted to using *A. glycines* as a food source.

The challenge with *H. axyridis* is a lack of reproductive response to *A. glycines* unless the aphid is at a density of more than 100 per plant (Rutledge 2004). This is thought to be due to the fact that they will not oviposit in fields that cannot provide a sufficient food source for their aphidophagous larvae. At higher densities, *H. axyridis* begin to suppress the aphid population. However the threshold of this suppressive effect may not reduce *A. glycines* densities to a level that would prevent economic yield loss. Macedo et al (2003) showed that even at the low aphid density of 50 per plant, there was significant reduction in the soybean plant's photosynthetic rate

and several other vital plant functions. This suggests the need to attract and retain *H. axyridis* earlier in the season to start suppression of *A. glycines* sooner.

Landis et al. (2000) discusses "altering the habitat to improve the availability of the resources required by natural enemies for optimal performance." This can involve providing alternative resources for the natural enemies to attract and retain them until the time when the pest insect prey densities build. Because available prey are continuously changing in crop systems, predators can be faced with periods of food shortages (Rutledge 2004). If predators are able to use other food items, such as plant sap, pollen and fungal spores, it would enable them to maintain their presence in the field (Rutledge 2004).

Research has documented that the addition of food sprays can provide a sufficient alternative food source for predators in agricultural settings. Food sprays in these studies have consisted of honey, sucrose, and different types of yeast in a variety of mixtures. Hagen et al. (1971) found that coccinellids were more concentrated in areas where yeast hydrolysate and sugar dissolved in water had been sprayed, although some aphid prey were required to induce oviposition by the beetles. Schiefelbein and Chiang (1965) found that coccinellid numbers increased in corn when sucrose was sprayed on the crop. Higher coccinellid numbers also correlated with lower aphid numbers.

Results from these and several other studies with food sprays suggest that food sprays can provide a viable option to increase *H. axyridis* population in soybeans when aphid numbers are still low. The goal of this study is to determine whether food spray applications would attract and retain *H. axyridis* in the field to keep the soybean aphid below economically damaging levels. This would provide soybean farmers with alternatives to insecticides for the control of soybean aphid. This would be especially relevant to organic soybean farmers who are not permitted to use conventional insecticides as a management option.

Research Objectives

The purpose of this study is to see if oviposition can be triggered if *H. axyridis* is provided alternative foods in the field when the aphid density is low. We chose three substances to be used as food supplements in this study: honey, wheast (yeast that feeds on whey), and sucrose. Wheast was chosen due to its proven effectiveness in other food spray studies with coccinellids (Nichols and Neels, 1977).

The treatments will consist of each of these supplements alone, all combinations of the supplements and an untreated check. Effectiveness is to be determined by counting beetles present in the field before and after the application of the sprays. Adult, larvae and eggs of *H. axyridis* will all be counted to determine immediate and longer-term effects of the food sprays. Aphid numbers will also be monitored to determine whether the beetles are having an impact on soybean aphid density.

Bibliography

Doutt, R.L. and L.E. Caltigirone. 1989. The History of the Vedalia beetle importation to California and its impact on Biological Control. Annual Review of Entomology 34:1-16.

Fox, T.B., D.A. Landis, F.F. Cardoso, and C.D. Difonzo. 2004. Predators suppress *Aphis glycines* Matsumura population growth in soybean. Environmental Entomolgy. 33(3) 608-618.

Fujan, G. 2004. Soybean Aphid Research Update. North Central Soybean Research Program. http://www.planthealth.ingo/aphidinsert/aphidinser.htm

Grau, C. 2003. Insect-Soybean-Virus Complex in Wisconsin http://www.plantpath.wisc.edu/soyhealth/virus.htm

Hagen, K.S., E.F. Sawall, R.L. Tassan. 1971. The use of food sprays to increase effectiveness of entomophagous insects. Proceedings Tall Timbers Conference on Ecological Animal Control by Habitat Management. 59-81.

Koch, R.L. 2003. The multicolored Asian lady beetle, *Harmonia axyridis*: A review of its biology, uses in biological control, and non-target impacts. Journal of Insect Science. 3:32

Landis, D., S.D. Wratten, and G. Gurr. 2000. Habitat manipulation to conserve natural enemies of arthropod pests in agriculture. Annual Review of Entomology. 47:173-199.

Macedo, T.B., C.S. Bastos, L.G. Higley, K.R. Ostlie and S. Madhavan. 2003. Photosynthetic responses of soybean to soybean aphid (Homoptera:Aphididae) injury. Journal of Economic Entomology. 96:188-193

Nichols, P.R. and W.W. Neels. 1977. The use of Food Wheast as a supplemental food for Coleomegilla maculata (DeGeer) (Coleoptera: Coccinellidae) in the field. Southwestern Entomologist. 2(3) 102-105.

Ostlie, K. 2001. Population dynamics of soybean aphid. University of Minnesota, St. Paul, MN. http://www.soybeans.umn.edu/crop/insects/aphid/aphid_population.htm

Ragsdale, D.W., D.J. Voegtlin, and R.J.O'Neil. 2004. Soybean Aphid Biology in North America. Annual Entomological Society of America. 97(2) 204-208.

Rutledge, C.E., R.J. O'Neil, T.B. Fox, and D.A. Landis. 2004. Soybean aphid predators and their use in integrated pest management. Annals of the Entomological Society of America. 97:240-248.

Appendix I-A. 2003 WICST Input/Output Data - Arlington Research Station

Corn rotations

CROP-03	**CORN**	**CORN**	**CORN**	**CORN**	**CORN**
Rotation	**CS1**	**CS2**	**CS3**	**CS4**	**CS5**
Treatment #	**1**	**3**	**4**	**9**	**13**
Plot #'s	109, 204, 306, 412	101, 214, 303, 401	104, 201, 301, 402	105, 203, 308, 406	114, 211, 312, 403
Primary Tillage	Chisel plow w/twisted shank 11/21/02	None (No-till)	Chisel plow w/sweeps 11/21/02	Chisel plow w/twisted shank 11/21/03	Chisel plow w/sweeps 11/21/02
Secondary Tillage	Field Digger 4/23/03, 4/29/03	None	Field Digger 4/23/03, 5/23/03	Field Digger 4/23/03, 4/29/03	Field Digger 4/23/03, 5/22/03
Planting Date	4/29/03	4/29/03	5/23/03	4/29/03	5/23/03
Variety	Pion. 35R58 Bt	Pion. 35R58 Bt	NC+ 100A2	Pion. 35R58 Bt	NC+ 100A2
Rate	32,000 seeds/a	32,000 seeds/a	34,500 seeds/a	32,000 seeds/a	34,500 seeds/a
Starter Fertilizer	100 lb product 5-14-42	100 lb product 5-14-42	None	100 lb product 5-14-42	None
Fertilizer	80 and 120 lb N/a[1] 82-0-0 sidedressed 6/19/03	80 lb N/a 82-0-0 sidedressed 6/19/03 120 lb/a 0-0-60 (101, 401)	None	None	None
Manure	None	None	None	20 ton/a 11/13/02	15 ton/a 11/13/02
Pesticides	Counter 5 lb/a 4-29-03 Pre-emrg: 5/3/03 Dual II Magnum 1.3 pt/a Post-emrg: 6/9/03 Buctril 1 pt/a	Pre-emrg: 5/2/03 Roundup Weathermax 13 oz/a, Dual II Magnum 1.5 pt/a AMS 3 lb/a Post-emrg: 6/9/03 Buctril 1 pt/a, 6/23/03 Resource 6 oz/a w/ CropOil	None	Pre-emrg: none Post-emrg: 6/9/03 Buctril 1 pt/a	None
Rotary Hoe	None	None	5/31/03	None	5/31/03
Cultivation	6/17/03	None	6/17/03, 6/23/03, 7/1/03	6/17/03, 6/23/03	6/17/03, 6/23/03
Harvest	10/17/03	10/17/03	10/17/03	10/17/03	10/17/03
Yield	175.0 bu/a	176.5 bu/a	110.0 bu/a	190.6 bu/a	149.7 bu/a
Fall Practices	Chop stalks 10/30/03 Chisel plow w/twisted shank 11/11/03	Chop stalks 10/30/03 No fall tillage	Chop stalks 10/30/03 Chisel plow w/twisted shank 11/11/03	Chop stalks 10/30/03 Manure 20 t/a 11/6/03 Chisel plow w/twisted shank 11/11/03	Chop stalks 10/30/03 Manure 15 t/a 11/6/03 Chisel plow w/twisted shank 11/11/03
Crop 2004	**Corn**	**Soybean**	**Soybean**	**D.S. Alfalfa**	**Oats/Alfalfa**

1 Plots 204 and 412 received 80 lb N/a and plots 109 and 306 received 120 lb N/a

Appendix I-A (cont'd). 2003 WICST Input/Output Data - Arlington Research Station

Soybean and Wheat Rotations

CROP-03	**NR Soybean**	**WR Soybean/Wheat**	**Wheat/Red Clover**
Rotation	**CS2**	**CS3**	**CS3**
Treatment #	**2**	**6**	**5**
Plot #'s	108, 206, 310, 408	102, 212, 313, 407	106, 202, 307, 411
Primary Tillage	No-till	Chisel plow w/twisted shank 11/20/02	Field digger 10/11/02
Secondary Tillage	None	Field digger 4/23/03, 5/22/03	None
Planting Date	5/22/03	SB: 5/23/03 WW: 10/8/03	Red clover: 4/2/03 WW: 10/11/02
Variety **Rate**	Asgrow 2001 225,000 seeds/a	IA2053 170,000 seed/a Pioneer 25R37 125 lb/a	Arlington red clover: 12 lb/a Kaskaskia wheat: 180 lb/a
Fertilizer	None	None	None
Pesticides	5/27/03 Roundup Weathermax 11 oz/a 6/23/03 Roundup WM 16 oz/a (Both w/3 lb/a AMS) 8/4/03 Warrior 2.5 oz/a	None	None
Rotary Hoe	None	5/31/03	None
Cultivation	None	6/17/03, 6/23/03, 7/1/03	None
Harvest	10/11/03	10/7/03	Grain: 7/29/03 Straw: 7/31/03
Yield	35.6 bu/a	32.5 bu/a	Grain: 53.6 bu/a Straw: 0.40 ton/a
Fall Practices	None	Field digger 10/8/03 Plant wheat w/roller behind drill 10/8/03	Chisel plow w/sweeps 11/12/03
Crop 2004	**Corn**	**Wheat / Red Clover**	**Corn**

Appendix I-A (cont'd). 2003 WICST Input/Output Data - Arlington Research Station

Forage rotations

CROP-03 Rotation Treatment #	**D.S. Alfalfa CS4 8**	**Estab. Alfalfa I CS4 7**	**Estab. Alfalfa II CS4 10**	**Oats/Alfalfa CS5 12**	**Estab. Alfalfa I CS5 11**	**Pasture CS6 14**
Plot #'s	113, 210, 311, 414	111, 209, 305, 409	107, 205, 309, 404	103, 213, 314, 410	110, 208, 304, 413	112, 207, 302, 405
Primary Tillage	Chisel plow 11/20/02	None	None	Chisel plow 11/21/02	None	None
Secondary Tillage	Field digger 4/4/03, 4/13/03	None	None	Field digger 4/4/03, 4/13/03	None	None
Planting Date	4/14/03	4/9/02	4/17/01	4/14/03	4/9/02	4/2/03
Variety	Magnum V	Magnum V	Magnum V	Bay Oats Trapper peas Magnum V	Bay Oats Trapper peas Magnum V	Arlington Red Clover
Rate	12 lb/a	12 lb/a	12 lb/a	50 lb/a, 50 lb/a 12 lb/a	Alf -12 lb/a Oats – 50 lb/a Peas – 50 lb/a	8 lb/a
Fertilizer	None	170-340 lb/a 0-0-60 (all plots)	340-400 lb/a 0-0-60 (all but plot 205)	None	None	None
Manure	20 ton/a 11/13/02	None	None	15 ton/a 11/13/02	None	~ 5.5 ton/a from 5-500 lb heifers
Pesticides	5/29/03 Raptor 4 oz/a w/NIS, AMS 6/18/03 Pounce 3.2ec 4 oz/a 7/28/03 Pounce 3.2ec 6 oz/a	None	10/22/03 RoundupWeather max 30 oz/a w/AMS 3 lb/a	None	None	Stinger ~ 1.25 gal sln. spot sprayed on 2.8-acre area (used 9 ml of stinger)
Harvest	7/14/03, 8/19/03, 10/21/03	5/31/03, 7/8/03, 8/6/03, 10/21/03	5/31/03, 7/8/03, 8/6/03 4th cut not taken	Oatlage: 6/27/03 2nd cut clipped & discarded	6/4/03, 7/14/03, 9/3/03, 10/21/03	Rotational Grazing/ clipping, 139d of grazing
Yield	2.91 T DM/a	4.83 T DM/a	3.37 T DM/a	2.30 T DM/a	5.94 T DM/a	
Fall Practices	None	None	Manure 20 t/a 11/6/03 Chisel plow w/twisted shank 11/11/03	None	Manure 15 t/a 11/6/03 Chisel plow w/sweeps 11/11/03	None (heifers supplemented with a total of 1020 lb hay in late summer)
Crop 2004	**Alf I**	**Alf II**	**Corn**	**Alf I**	**Corn**	**Pasture**

Appendix I-A. 2003 WICST Input/Output Data - Arlington Research Station

Satellite plots – Chemlite of Cropping System 3

CROP-03	**Corn**	**WR Soybean/Wheat**	**Wheat/Red Clover**
Rotation	**CS3**	**CS3**	**CS3**
Treatment #	**Sat C,D**	**Sat B, F**	**Sat A, E**
Primary Tillage	Chisel plow w/sweeps 11/20/02	Chisel plow w/twisted shank 11/21/03	Field Digger 10/11/02
Secondary Tillage	Field digger 4/23/03, 5/22/03	Field digger 4/23/03, 5/22/03	None
Planting Date	5/23/03	SB: 5/23/03 WW: 10/8/03	Red clover: 4/2/03 WW: 10/11/02
Variety **Rate**	NC+ 100A2 34,500 seeds/a	IA2053 170,000 seeds/a Pioneer 25R37 125 lb/a	Arlington red clover: 12 lb/a Kaskaskia wheat: 180 lb/a
Fertilizer	80 lb N/a 82-0-0 sidedressed	None	4/9/03 50 lb N/a 46-0-0
Pesticides	6/13/03 Accent Gold 0.33 oz/a 6/13/03 Buctril 0.75 pt/a	6/25/03 Raptor 3 oz/a with NIS, AMS	8/12/03 Select 8 oz/a for grass weeds
Rotary Hoe	None	None	None
Cultivation	6/23/03	6/23/03	None
Harvest	10/17/03	10/7/03	Grain: 7/29/03 Straw: 7/31/03
Yield	155.1 bu/a	23.5 bu/a *beans damaged by tank contaminate - puckered	Grain: 67.1 bu/a Straw: 0.40 T DM/a
Fall Practices	Chop stalks 10/30/03 Chisel plow -twisted shank 11/11/03	Field digger 10/8/03 Plant wheat w/roller 10/8/03	9/4/03 clipped for weed control Chisel plow w/sweeps 11/12/03
Crop 2004	**Soybean**	**Wheat / Red Clover**	**Corn**

Appendix I-B. 2004 WICST Input/Output Data - Arlington Research Station

	Corn rotations				
CROP-2004	**CORN**	**CORN**	**CORN**	**CORN**	**CORN**
Rotation	**CS1 + prairie**	**CS2**	**CS3**	**CS4**	**CS5**
Treatment #	**1**	**2**	**5**	**10**	**11**
Plot #'s	109, 204, 306, 412, 501, 504, 508	108, 206, 310, 408	106, 202, 307, 411	107, 205, 309, 404	110, 208, 304, 413
Primary Tillage	Chisel plowed 11-11-03	None	Chisel plowed w/sweeps 11-12-03	Chisel plowed 11-11-03	Chisel plow w/sweeps 11-11-03
Secondary Tillage	Field digger 2x 5-4-04	None	Chisel plow 5-17 Soil finisher 5-26 Field digger 6-16	Field digger 2x 5-4-04	Disk 5-17-04 Soil finisher 5-26 Field digger 6-16
Variety **Planting Date** **Rate**	LG 2533 5-4-04 32,000 seeds/a (Poncho 250 seed trt)	LG 2533 5-4-04 32,000 seeds/a (Poncho 250 seed trt)	NC+ 34C17 5-27-04 Replant[1] Brunner OR8403 6-16-04 34,500 s/a	LG 2533 5-4-04 32,000 seeds/a (Poncho 250 seed trt)	NC+ 34C17 5-27-04 Replant[1] Brunner OR8403 6-16-04
Starter Fertilizer	100 lb 5-14-42	100 lb 5-14-42	None	100 lb 5-14-42	None
Fertilizer	160 lb N/a (82-0-0) 6-21-04	160 lb N/a (82-0-0), 6-21-04 100 lb/a potash - plot 310 and 170 lb/a potash -plot 108, 11-7-03	None	None	None
Manure	None	None	None	20 ton/a 11-10-03	15 ton/a 11-10-03
Pesticides/ Herbicides	In planter box Counter (5 lb/a) Post-emerge: 6-14-04 Buctril 1.5 pt/a	In planter box Prozap zinc phosphide 6 lb/a Post-emerge: 6-14-04 Buctril 1.5 pt/a	None	Post-emerge: 6-14-04 Buctril 1.5 pt/a	None
Rotary Hoe	None	None	6-4-04, 7-2-04	None	6-4-04, 7-2-04
Cultivation	None	None	7-12-04	None	7-12-04
Harvest/Yield	10/25/04 193.9 bu/a	10/25/04 189.0 bu/a	10/26/04 1.07 ton DM/a	10/25/04 212.7 bu/a	10/26/04 1.36 ton DM/a
Fall Practices	Chop stalks 11/9/04 Chisel plow 11/16/04	11/9/04	Chop stalks 11/9/04 Chisel plow 11/16/04	Chop stalks 11/9/04 Manure 20 t/a 11/11/04 Chisel plow 11/16/04	Chop stalks 11/9/04 Manure 15 t/a 11/11/04 Chisel plow 11/16/04
Crop 2005	**Corn**	**Soybean**	**Soybean**	**D.S. Alfalfa**	**Oats/Alfalfa**

[1] CS3 and CS5 corn was replanted with 85 d corn due to very poor stand. Corn never reached black layer by end of season. Used custom chopper/processor to remove whole ear (with husk and cob = snaplage).

Appendix I-B (cont'd). 2004 WICST Input/Output data - Arlington Research Station

Soybean and Wheat Rotations			
CROP-2004	**NR Soybean**	**WR Soybean/Wheat**	**Wheat/Red Clover**
Rotation	**CS2**	**CS3**	**CS3**
Treatment #	**3**	**4**	**6**
Plot #'s	101, 214, 303, 401	104, 201, 301, 402	102, 212, 313, 407
Primary Tillage	None	Chisel plowed 11-12-03	Field digger 1x 10/8/03
Secondary Tillage	None	Disk 5-17-07 Soil finisher 5-26-04	None
Planting Date	May 17, 2004	SB: May 27, 2004 WW: Oct 7, 2004	WW: Oct 8, 2003 Red clover: 4-3-04, NT drill
Variety Rate	Kaltenberg KB241 (RR) 225,000 seeds/a	Sb: NC+1F61 (food grade) 180,000 seeds/a WW: Patriot (Hard Red) 3 bu/a	Pioneer 25R37: 3.0 bu/a Arlington red clover: 12 lb/a
Fertilizer	None	None	None
Pesticides/ Herbicides	Post-emerg: 5-28-04 Roundup-WMax (21 oz/a) + AMS (3 lb/a) 6-30-04 Roundup-WMax (21 oz/a) + AMS (3 lb/a)	None	None[1]
Rotary Hoe	None	6-4-04, 6-16-04 (2x)	None
Cultivation	None	6-26-04, 6-30-04, 7-12-04	None
Harvest/Yield	10/6/04 49.8 bu/a	10/6/04 33.6 bu/a	Wheat[2]: 8-5-04 34.9 bu/a Straw[3]: 8-9-04 0.54 ton DM/a
Fall Practices	None	Disk, Field digger 10/6/04 Drill wheat 10/7/04	Stalk chopper for red clover Chisel plow w/sweeps 11/16/04
Crop 2005	**Corn**	**Wheat / Red Clover**	**Corn**

[1] Spent 7.6 man-hours/acre weeding the CS3 soybeans.
[2] Wheat yields very low due to Scab disease...a lot of light kernels blown out the back of the combine.
[3] Straw yields low due to tall red clover.

Appendix I-B (cont'd). 2004 WICST Input/Output Data - Arlington Research Station

	Forage rotations					
CROP-2004	**D.S. Alfalfa**	**Estab. Alfalfa I**	**Estab. Alfalfa II**	**Oats/Alfalfa**	**Estab. Alfalfa I**	**Pasture**
Rotation	**CS4**	**CS4**	**CS4**	**CS5**	**CS5**	**CS6**
Treatment #	**9**	**8**	**7**	**13**	**12**	**14**
Plot #'s	105, 203, 308, 406	113, 210, 311, 414	111, 209 305, 409	114, 211, 312, 403	103, 213, 314, 410	112, 207, 302, 405
Primary Tillage	Chisel plow 11/11/03	None	None	Chisel plow 11/11/03	None	None
Secondary Tillage	Field digger 2x 4-5-04	None	None	Field Digger 2x 4-5-04	None	None
Planting Date	4-6-04	*4/14/03*	*4/9/02*	4-6-04	*4/14/03*	
Variety	'Magnum V'	*'Magnum V'*	*'Magnum V'*	'Magnum V', 'ForagePlus', Trapper peas	*Magnum V, Bay oats, trapper peas*	
Rate	12 lb/a			Alf - 12 lb/a oats 50 lb/a Peas – 50 lb/a		
Fertilizer	None	None	None	None	None	None
Manure	20 ton/a 11/6/03	None	None	15 ton/a 11/6/03	None	Grazing
Pesticides/ Herbicides	**Herbicide** Post-emerge: 6-15-04 Raptor w/NIS + 28% (4 oz/a) **Insecticide** 6-16-04 Warrior (3 oz/a)	**Insecticide** 7-19-04 Lorsban 4E (0.75 pt/a)	**Insecticide** 7-19-04 Lorsban 4E (0.75 pt/a) **Herbicide** 10-11-04 Express XP (0.125 oz/a), 2,4-D (16 oz/a) Rndup Wmax (21 oz/a) +AMS (3 lb/a)	None	None	Spot sprayed -used about 0.5 gal/a solution (3.5 mls stinger on 2 acres)
Harvest	7-18-04 9-8-04	6-3-04 6-28-04 8-4-04 9-8-04	6-3-04 6-28-04 8-4-04 9-8-04	Oatlage: 6-28-04 Haylage: 9-8-04	6-3-04 7-10-04 9-20-04	5-18-04 7-13-04 8-27-04
Yields	1.85 T DM/a	5.07 T DM/a	5.15 T DM/a	2.73 T DM/a 1.63 T DM/a	4.88 T DM/a	5.48 t DM/a[1]
Fall Practices	None	None	Manure 20 t/a 11/11/04 Chisel plow 11/16/04	None	Manure 15 t/a 11/11/04 Chisel plow w/sweeps 11/16/04	None
Crop 2005	**Alf I**	**Alf II**	**Corn**	**Alf I**	**Corn**	**Pasture**

[1] **CS6 was mechanically harvested from a 50 sq ft area (exclusion) in each plot to determine hay yield.**

Appendix I-B (cont'd). 2004 WICST Input/Output Data - Arlington Research Station

Satellite – Chemlite plots

CROP-2004 Rotation Treatment #	Corn (cs3 w/chemical inputs)	WR Soybean/Wheat (cs3 w/chemical inputs)	Wheat/Red Clover (cs3 w/chemical inputs)
Plot #'s	SAT A, E	SAT C, D	SAT B, F
Primary Tillage	Chisel plowed w/sweeps 11/12/03	Chisel plowed 11/12/03	Field digger 1x 10/8/03
Secondary Tillage	Field digger 2x May 4, 2004	Disc 5-17-04, Soil finisher 5-26-04	None
Planting Date	May 4, 2004	SB: May 27, 2004 WW: Oct. 6, 2004	WW: Oct 8, 2003 Red clover: April 3, 2004
Variety Rate	LG 2533 32,000 seeds/a Poncho 250 seed trt	SB: Latham 280 170,000 seeds/a WW: Pioneer 25R47 150 bu/a	Pioneer 25R37: 180 bu/a Arlington red clover: 12 lb/a
Starter Fertilizer	100 lb 9-23-30	None	None
Fertilizer	80 lbs N/a (82-0-0) 6-21-04	None	50 lb N/a (46-0-0) April 7, 2004
Pesticides/ Herbicides	Post emerge: 6-14-04 Accent (0.67 oz/a) 6-25-04 Buctril (1.5 pt/a)	Post emerge: 6-25-04 Raptor 5 oz/a + NIS	
Rotary Hoe	None	6-4-04, 6-16-04	None
Cultivation	6-30-04	6-30-04	None
Harvest/Yield	10/25/04 223.84 bu/a	10/6/04 47.5 bu/a	Wheat[1]: 8/5/04 38.45 bu/a Straw[2]: 8/9/04 0.48 tons DM/a
Fall Practices	Chop stalks 11/9/04 chisel plow 11/16/04	Disk, Field digger 10/6/04 Drill wheat 10/6/04	Chisel plow w/sweeps 11/16/04
Crop 2005	**WR Soybeans**	**Wheat / Red Clover**	**Corn**

[1] Wheat yields very low due to Scab disease…a lot of light kernels blown out the back of the combine.
[2] Straw yields low due to tall red clover.

Appendix II. Soil test P and K (0-6" depth) at Arlington Ag. Research Station (1992-2004).

	SOIL TEST PHOSPHORUS (ppm)													SOIL TEST POTASSIUM (ppm)											
System/plot#	92	93	94	95	96	97	98	99	00	01	02	03	04	92	93	94	95	96	97	98	99	00	01	02	03	04
CS1 trt 1 109,204,306,412	93	84	91	88	91	83	82	80	76	85	91	79	83	219	295	228	241	257	254	229	217	203	194	202	225	227
CS2 trt 2 108,206,310,408	79	65	68	67	66	61	59	75	69	70	77	63	77	239	229	183	182	214	178	184	197	169	153	179	172	177
CS2 trt 3 101,214,303,401	89	78	89	72	83	72	75	62	53	57	59	52	55	198	264	214	208	230	224	212	164	128	126	131	138	154
CS3 trt 4 104,201,301,402	69	64	68	65	66	55	55	46	43	48	45	36	48	189	251	182	175	209	166	180	124	104	109	95	102	125
CS3 trt 5 106,202,307,411	--	57	63	52	57	56	47	67	49	55	64	49	61	---	226	171	164	191	172	150	174	145	136	140	152	154
CS3 trt 6 102,212,313,407	--	53	57	49	49	48	45	52	51	51	59	54	51	---	201	142	149	155	136	131	149	130	110	133	132	125
CS4 trt 7 111,209,305,409	94	85	99	84	90	90	90	81	80	95	111	85	93	175	216	171	157	180	212	200	168	116	127	146	131	122
CS4 trt 8 113,210,311,414	105	81	92	93	94	81	91	93	81	81	101	97	95	203	170	154	184	189	153	166	179	128	96	142	156	112
CS4 trt 9 105,203,308,406	--	62	65	74	91	72	66	79	78	80	83	80	90	---	170	128	160	228	143	115	134	133	107	91	153	135
CS4 trt 10 107,205,309,404	77	71	72	67	77	76	63	66	74	86	84	73	91	189	224	155	153	196	205	141	133	137	163	111	124	153
CS5 trt 11 110,208,304,413	103	88	93	91	96	82	90	81	75	95	103	83	93	198	236	172	185	201	153	154	135	95	108	122	98	115
CS5 trt 12 103,213,314,410	72	67	72	64	72	66	59	68	60	65	80	70	70	181	210	144	127	143	128	98	110	87	75	103	121	89
CS5 trt 13 114,211,312,403	--	73	83	78	76	71	66	68	71	77	80	74	86	---	211	173	180	174	153	153	130	120	110	101	117	117
CS6 trt 14 112,207,302,405	--	82	84	75	74	73	64	68	64	73	54	69	78	---	186	157	176	208	210	180	202	148	153	163	175	174

Appendix III-A. WICST Phosphorus Soil DepthTest Results (0-6", 6–12", 12-24", 24-36") Arlington Research Station[1]

		0-6"			6-12"			12-24"			24-36"		
System	Trt.	Initial Year	7th year	12th year	Initial Year	7th year	12th year	Initial year	7th year	12th year	Initial Year	7th year	12th year
		ppm											
CS1 c-c-c	1	105	91	85	65	43	43	59	29	28	85	49[3]	51
CS2 c-sb-c	2	88	48	77	47	35	58	50	10	70	73	ns	98
CS2	3	98	66	57	43	30	38	24	28	23	51	42[3]	53
CS3 c-sb-w/rc	4	57	45	36	38	21	27	16	23	24	39	42	31
CS3	5	105	66	55	59	34	43	20	20	28	43	ns	50
CS3	6	69	48	59	24	35	32	22	7	31	47	ns	52
CS4 c-a-a-a	7	115	90	95	46	47	52	35	31	29	57	ns	48
CS4	8	93	45	108	39	34	45	32	8	31	52	ns	54
CS4	9	66	66	80	44	38	45	21	25	25	45	52	45
CS4	10	77	66	91	34	40	62	51	52	77	86	75	103
CS5 c-o/a-a	11	53	96	95	20	44	48	8	28	41	5	ns	68
CS5	12	70	77	80	27	36	29	22	16	30	47	ns	54
CS5	13	84	66	74	42	34	30	21	29	23	36	41	41
CS6 pasture	14	114	74	73	56	52	53	74	43	81	96	75[3]	92

[1] Sampling done in the 7th year after the initiation of each treatment.

[2] Samples taken in the year prior to the treatment start year – 1989: treatments 1, 3, 5, 7, 11, 14; 1990 trts 2, 6, 8, 12; 1991: trts 4, 9, 13; and 1992: trt 10

[3] 3rd foot sampled in 2000, not 7th year after start of rotation

ns = no samples taken for 24–36".

Appendix III-B. WICST Potassium Soil DepthTest Results (0-6", 6–12", 12-24", 24-36") Arlington Research Station[1]

		0-6"			6-12"			12-24"			24-36"		
System	Trt.	Initial Year	7th year	12th year	Initial Year	7th year	12th year	Initial year	7th year	12th year	Initial Year	7th year	12th year
		ppm											
CS1 c-c-c	1	257	257	194	143	100	83	125	74	88	135	88[3]	121
CS2 c-sb-c	2	283	144	179	126	130	96	125	124	104	123	ns	110
CS2	3	199	214	126	121	91	90	134	83	99	155	98[3]	118
CS3 c-sb-w	4	195	135	102	124	91	71	86	121	89	98	123	94
CS3	5	236	209	136	133	95	80	126	80	93	156	ns	119
CS3	6	200	129	133	78	95	78	88	108	86	100	ns	104
CS4 c-a-a-a	7	277	180	127	123	81	68	126	80	82	131	ns	96
CS4	8	256	124	149	126	121	67	86	106	82	119	ns	106
CS4	9	214	115	152	103	79	66	85	95	69	101	133	95
CS4	10	189	133	153	96	91	89	109	101	102	111	124	118
CS5 c-o/a-a	11	163	201	108	113	86	64	120	80	80	115	ns	102
CS5	12	211	176	103	83	98	64	85	113	91	113	ns	105
CS5	13	293	153	117	123	89	67	98	99	79	95	114	92
CS6 pasture	14	266	208	153	143	101	85	154	86	89	135	88[3]	116

[1] Sampling done in the 7th year after the initiation of each treatment.

[2] Samples taken in the year prior to the treatment start year – 1989: treatments 1, 3, 5, 7, 11, 14; 1990 trts 2, 6, 8, 12; 1991: trts 4, 9, 13; and 1992: trt 10

[3] 3rd foot sampled in 2000, not 7th year after start of rotation

ns = no samples taken for 24–36".

Appendix IV-A. Corn seeding rate and plant population at Arlington Research Station over the course of the trial.

	Conventional		Low input	
YEAR	SEEDED RATE	PLANTS PER ACRE	SEEDED RATE	PLANTS PER ACRE
1992	32,100	28,200	32,100	24,700
1993	32,500	31,317	32,500	24,150
1994	31,500	26,750	34,000	28,425
1995	31,500	28,200	34,000	28,200
1996	31,500	30,133	34,000	26,950
1997	31,217	30,700	34,000	32,450
1998	32,000	28,139	34,500	27,083
1999	32,000	29,242	34,500	27,075
2000	32,000	29,538	34,500	24,075
2001	32,000	31,483	34,500	28,875
2002	32,000	28,033	34,500	27,675
2003	32,000	28,900	34,500	29,725
2004	32,000	30,717	34,500	22,100
mean	*31,871*	*29,335*	*34,008*	*27,037*

* conventional = CS1, CS2, CS4; low input = CS3 and CS5

Appendix IV-B. Corn seeding rate and plant population at Lakeland Ag Complex over the course of the trial.

	Conventional		Low input	
YEAR	SEEDED RATE	PLANTS PER ACRE	SEEDED RATE	PLANTS PER ACRE
1992	32,000	26,800	32,000	24,250
1993	32,000	30,433	32,000	22,950
1994	32,000	28,717	35,000	30,600
1995	31,200	28,783	31,200	26,800
1996	31,500	26,783	34,000	26,350
1997	32,000	28,028	34,000	25,000
1998	32,000	x	34,000	x
1999	32,833	27,772	34,500	28,000
2000	31,000	22,528	33,900	18,917
mean	*31,837*	*27,481*	*33,400*	*25,358*

* conventional = CS1, CS2, CS4; low input = CS3 and CS5

x = missing data

Appendix V-A. Soybean seeding rate and plant population at Arlington Research Station over the course of the trial.

	Conventional		Low input	
YEAR	SEEDED RATE	PLANTS PER ACRE	SEEDED RATE	PLANTS PER ACRE
1992	235,000	118,548	156,000	70,350
1993	235,000	179,822	156,000	135,250
1994	235,000	187,489	175,000	152,125
1995	235,000	156,016	200,000	199,542
1996	235,000	151,497	175,000	105,583
1997	250,000	231,709	190,000	141,200
1998	250,000	249,709	190,000	x
1999	250,000	178,826	190,000	64,300
2000	250,000	238,244	190,000	77,827
2001	250,000	177,570	190,000	152,136
2002	250,000	173,408	190,000	66,000
2003	250,000	139,189	190,000	124,300
2004	250,000	209,939	190,000	87,450
mean	*244,231*	*183,997*	*183,231*	*114,672*

* conventional = CS1, CS2, CS4; low input = CS3 and CS5
x = missing data

Appendix V-B. Soybean seeding rate and plant population at Lakeland Ag Complex over the course of the trial.

	Conventional		Low input	
YEAR	SEEDED RATE	PLANTS PER ACRE	SEEDED RATE	PLANTS PER ACRE
1992	196,000	122,953	156,000	97,000
1993	199,500	139,228	175,000	86,950
1994	230,000	143,278	151,000	113,050
1995	235,000	176,880	175,000	118,500
1996	235,000	236,209	225,000	80,458
1997	250,000	298,501	225,000	x
1998	230,000	145,353	225,000	x
1999	230,000	63,250	225,000	119,548
2000	250,000	119,230	250,000	135,762
mean	*228,389*	*160,542*	*200,778*	*107,324*

* conventional = CS1, CS2, CS4; low input = CS3 and CS5
x = missing data

Appendix VI. WICST Fall Legume Nitrogen from Plowdown Crop Preceding Corn Phase at Arlington (1991-2004).

Year	Crop System	Crop[1/]	Foliage		Roots		Total
			lb DM/a	%N	lb DM/a	%N	lb N/a
1991	3	Red Clover	1853	3.24	2604	2.63	129
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	3.43	3352	2.29	148
1993	3	Red Clover	2811	2.81	1314	3.18	121
1993[2/]	4	Alfalfa	1866	2.91	1233	3.36	96
1993[2/]	5	Alfalfa	1613	4.05	1443	2.18	97
1994[3/]	3	Hairy Vetch	4325	3.29	134	3.24	147
1994[2,4/]	4	Alfalfa	2242	3.50	1233	2.50	109
1994	5	Alfalfa	500	3.41	2327	2.04	65
1995	3	Red Clover	2460	2.90	948	3.09	101
1995	4	Alfalfa	163	3.18	1235	2.51	36
1995	5	Alfalfa	308	3.59	2345	2.32	65
1996	3	Red Clover	3213	3.01	(1453)	(2.72)	136
1997	3	Hairy Vetch	1343	4.66	767	(2.72)	83
1998	3	Red Clover	3229	2.36	1229	(2.72)	110
1998	4	Alfalfa	1283	3.83	2582	(2.45)	119
1998	5	Alfalfa	1635	3.50	2328	(2.25)	121
1999	3	Red Clover	5354	4.00	2253	2.27	265
1999	4	Alfalfa	889	3.05	3026	2.16	92
1999	5	Alfalfa	1104	3.44	3069	2.34	110
2000	3	Red Clover	5974	2.53	1414	2.53	187
2000	4	Alfalfa	1180	4.47	2774	1.91	106
2000	5	Alfalfa	1260	3.98	2780	1.89	103
2001	3	Red Clover	6521	2.18	1370	2.90	182
2001	4	Alfalfa	326	2.58	3730	2.47	101
2001	5	Alfalfa	681	2.54	3216	2.46	96
2002	3	Red Clover	3723	2.11	1640	2.70	118
2002	4	Alfalfa	462	3.07	624	2.33	63
2002	5	Alfalfa	0	0	(2607)	(2.25)	59
2003	3	Red Clover	816	3.43	(1453)	(2.72)	68
2003	4	Alfalfa	1545	3.00	(2007)	(2.45)	96
2003	5	Alfalfa	1060	2.94	(2607)	(2.25)	90
2004	3	Red Clover	5893	2.04	(1453)	(2.72)	160
2004	4	Alfalfa	1349	3.08	(2007)	(2.45)	91
2004	5	Alfalfa	1055	2.86	(2607)	2.25)	89

[1/] Red clover estimates do not include wheat stubble contribution to N
[2/] Spring seeded with red clover because of severe winterkill to alfalfa in 1993.
[3/] Hairy vetch planted after wheat harvest because of thin stand of red clover.
[4/] Values in parentheses are estimates using used trial averages since no root samples were taken.

Appendix VII. WICST Nitrogen Additions as Purchased Fertilizers and Cattle Manure[1] (1991-2004).

Yr	92	93	94	95	96	97	98	99	00	01	02	03	04	92	93	94	95	96	97	98	99	00	01	02	03	04
CS1	C	C	C	C	C	C	C	C	C	C	C	C	C	141	166	124	106	99	126	151	86	249	105	135	105	165
CS2	Sb	C	Sb	C	Sb	C	Sb	C	Sb	C	Sb	C	Sb	0	126	0	126	0	126	0	80	0	125	0	85	0
CS2	C	Sb	C	Sb	C	Sb	C	Sb	C	Sb	C	Sb	C	126	0	126	0	126	0	126	0	209	0	85	0	165
CS3	C	Sb	w/rc	C	Sb	w/rc	C	Sb	w/rc	C	Sb	w/rc	C	0	0	0	0	0	0	0	0	0	0	0	0	0
CS3	w/rc	C	Sb	w/rc	C	Sb	w/rc	C	Sb	w/rc	C	Sb	w/rc	0	0	0	0	0	0	0	0	0	0	0	0	0
CS3	Sb	w/rc	C	Sb	w/rc	C	Sb	w/rc	C	Sb	w/rc	C	Sb	0	0	0	0	0	0	0	0	0	0	0	0	0
CS4	A	C	A	A	A	C	A	A	A	C	A	A	A	0	203	179	0	0	191	205	0	0	269	192	0	0
CS4	A	A	C	A	A	A	C	A	A	A	C	A	A	0	0	185	211	0	0	211	222	0	0	197	158	0
CS4	A	A	A	C	A	A	A	C	A	A	A	C	A	215	0	0	217	196	0	0	228	232	0	0	163	172
CS4	f	A	A	A	C	A	A	A	C	A	A	A	C	---	197	0	0	202	185	0	0	241	264	0	0	177
CS5	C	O/a	A	C	O/a	A	C	O/a	A	C	O/a	A	C	161	148	0	158	147	0	154	166	0	198	144	0	129
CS5	A	C	O/a	A	C	O/a	A	C	O/a	A	C	O/a	A	0	148	134	0	147	139	0	166	173	0	144	119	0
CS5	O/a	A	C	O/a	A	C	O/a	A	C	O/a	A	C	O/a	161	0	134	158	0	139	154	0	173	198	0	119	129
CS6[2]	P	P	P	P	P	P	P	P	P	P	P	P	P	107	82	68	44	97	110	132	94	104	143	189	227	272

* *f* Filler corn; C Corn; Sb Soybean; W/Rc Winter wheat followed by frost-seeded red clover; A Alfalfa; O/a Alfalfa w/oats nurse crop; P Pasture.

[1] Manured prior to corn planting and legume establishment in the harvested forage systems (20 t/a in CS4, 15 t/a in CS5). Nitrogen from green manure (alfalfa sod, red clover) plowdown is not included (see Appendix VI for plowdown credits).

2 Calculation of N input on pasture based on estimated forage intake (i.e. 15 lb DMI/d, N% of plants (2.9%), 75% N excretion rate for stocking density and # of grazing days in season. Nitrogen from 10 t/a manure application (1990 – 1992).

Appendix VIII. Fall nitrates in the top 3-ft of soil at Arlington Research Station in 1991-2004.

Crop	Sys	Phase	91	92	93	94	95	96	97	98	99	00	01	02	03	04
Corn	CS1	**Cont. Corn**	48	97	102	154	179	164	115	148	87	130	79	110	110	82
	CS2	**After Soybeans**	41	105	105	166	141	170	128	100	77	107	68	55	59	77
	CS3	**After Red Clover**	--[1]	67	83	100	145	45	129	112	83	61	81	44	96	70
	CS4	**After 3 yrs. Alf**	--	--	142	164	184	94	229	121	153	189	171	140	187	142
	CS5	**After 2 yrs. Alf**	--	101	118	150	202	82	180	145	173	121	154	121	142	151
Soybean	CS2	**Narrow-row**	42	74	100	71	145	73	143	100	94	81	101	71	108	61
	CS3	**Wide-row**	25	66	89	83	140	76	127	98	71	68	53	64	100	55
Wheat	CS3	**Wheat / Red Clover**	26	48	65	48	85	38	90	76	51	57	53	37	46	45
Alfalfa	CS4	**Dir-seed Alfalfa**	32	61	80	77	117	59	114	100	75	69	101	96	101	75
	CS4	**Alfalfa Hay I**	27	49	55	46	117	62	112	111	74	65	85	66	93	69
	CS4	**Alfalfa Hay II**	--	60	69	46	105	61	141	92	69	98	83	87	58	87
	CS5	**Alfalfa with Oats**	--	--	103	67	101	65	97	81	62	65	72	77	98	69
	CS5	**Alfalfa Hay**	--	--	84	67	107	51	116	72	63	70	71	57	79	56
Pasture	CS6	**Rotational Grazing**	--	--	91	58	98	90	100	88	62	60	50	50	76	88
Check			26	28	-	72	108	31	209	158	50	38	26	19	33	31

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

[2] prairie plots established in 1999 which were then used as the check. Previous years, the check was the North fenceline, adjacent to a neighboring field which received hog manure.

Starting in 1998, soil was sampled to a 3-ft depth for every plot using Giddings probe from Soils Dept.

3rd foot nitrate levels from 1993 to 1997 estimated using various regression equations (see previous WICST Technical Reports): Source: Ehrhardt, P.D. and L.G. Bundy. 1995. Predicting Nitrate-N in the two- to three-foot soil depth from nitrate measurements on shallower samples. J. Prod. Agric. Vol. 8, no. 3.

Appendix IX. Weighted Relative feed values on WICST forage systems 1992-2004.

A. Arlington Agricultural Research Station

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	**trial avg**
CS4														
Direct seed alfalfa	184	152	160	126	150	123	140	153	141	164	165	179	157	**153**
Haylage I	128	138	156	147	126	152	154	128	154	155	161	148	152	**146**
Haylage II	134	141	143	151	155	144	164	141	162	148	183	160	148	**152**
CS5														
O/a-Oatlage	124	missing[1]	103	116	103	116	96	95	95	115	90	112	90	**105**
O/a haylage	143	missing[1]	149	103	116	141	111	104	125	155	183	-	125	**132**
Haylage I	142	139	141	132	147	143	148	141	149	147	177	124	110	**142**
CS6														
Pasture	128	134	125	101	143	134	137	127	101	112	131		128	**125**

B. Lakeland Agricultural Complex

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	**trial avg**
CS4														
Direct seeded alfalfa	148	missing[2]	172	159	missing[2]	159	137	na[3]	132	98	114	-	-	**140**
Haylage I	164	136	162	140	137	144	152	142	na[3]	149	165	-	-	**149**
Haylage II	164	153	170	155	131	152	138	139	142	na[3]	na[3]	-	-	**149**
CS5														
O/a-Oatl	missing[1]	95	90[4]	108	missing[1]	130	137	102	102	121	110	-	-	**111**
O/a haylage	missing[1]	130	171	missing[5]	94	114	101	123	104	104	102	-	-	**116**
Haylage I	159	133	167	135	145	125	136	142	136	137	145	-	-	**142**
CS6														
Pasture	118	116	140	118	missing[6]	missing[6]	na7	102	110	103	102	-	-	**114**

[1] missing data because oats harvested as grain not oatlage or haylage.
[2] missing value because 3 of 4 plots chopped back on to field - only have data for one plot.
[3] Treatment no longer exists due to system changes at LAC starting in 1999.
[4] Assume 90 RFV for economic analysis--forage harvested in mid-August, oats were mature, forage rained on.
[5] no second cut taken
[6] no data collected due to reestablishment
[7] not available (grazing did occur this year)

formula for weighted RFV = [(Y1*RFV1) + (Y2*RFV2) + (Y3*RFV3) + (Y4*RFV4)]/(Y1+Y2+Y3+Y4)
* pasture is not weighted average

Appendix X. Total nutrient composition of manure applied to CS4 and CS5 on WICST plots at Arlington and Lakeland 1990-2004.[1]

	Arlington Agriculture Research Station[5]				Lakeland Agricultural Complex			
Year	DM%	Total N	P205	K20	DM%	Total N	P205	K20
		lbs/ton				lbs/ton		
1990 [2]	19.4	11.9	7.1	10.1	29.0	12.5	10.3	17.1
1991	17.0	13.2	7.4	12.9	27.2	12.7	10.9	16.7
1992 [2]	17.0	10.7	7.5	16.0	24.7	15.5	7.2	35.0
1993 [3]	-	-	-	-	27.3	13.5	10.4	19.8
1994	12.1	8.9	4.5	11.3	26.4	13.8	9.2	20.3
1995	15.6	10.6	5.8	10.4	35.2	13.0	13.0	25.6
1996 [4]	15.3	9.8	7.2	9.8	21.5	12.8	5.1	16.7
1997	11.7	9.2	3.6	8.8	34.3	11.3	9.3	14.8
1998	14.3	10.3	3.7	9.9	36.8	34.9	7.9	17.6
1999	16.8	11.1	3.8	7.1	44.9	14.9	6.7	14.0
2000	13.2	11.6	3.1	6.8	47.4	14.8	13.2	17.4
2001	11.8	13.2	4.8	11.4	24.1	15.2	12.0	17.3
2002	14.6	9.6	3.2	6.0	not sampled this year			
2003	16.1	7.9	3.6	7.1	Project ended at LAC in 2002			
2004	13.8	8.6	4.2	7.2				

1 Manure applied previous fall before tillage unless otherwise noted

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

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

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

5 Manure at Arlington has been taken from the West Pit at Blaine Dairy, ARS

Appendix XI. List of Publications involving WICST project over the duration of the trial (posters, abstracts and theses).

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, Aglime and Pest Management Conference. Jan 16-18, 1990. Vol. 29:244-252.

1991

Abstracts:

IRAGAVARAPU, T.K., J.L. POSNER, and G.D. BUBENZER. 1991. Using bromide to study water movement through a prairie derived silt-loam soil in Wisconsin. American Society of Agronomy Meetings, Oct 27 – Nov 01, Denver, CO. Agronomy Abstracts p. 333.

MULDER, T. and J. DOLL. 1991. Best management practices for corn weed control. American Society of Agronomy Meetings, Oct 27 – Nov 01, Denver, CO. Agronomy Abstracts p. 155.

Extension Bulletins:

STUTE, J.K. and J.L. POSNER. 1991. Cover crops as an internal source of nitrogen in cash grain production. Sustainable Agriculture Project Papers. Wisconsin Department of Agriculture, Trade, and Consumer Protection. ARM-PUB 53-42.

PORTER, P.A. 1991. Soil biological health: What do farmers think? NPM Field Notes 2:3. Center for Integrated Agricultural Systems, Univ. of Wisconsin, Madison, WI.

Proceedings:

DOLL, J. and T. MULDER. 1991. Reduced herbicide rates – The Wisconsin experience. Proc. Crop Protection and Production Conference. Iowa State University. Dec 03-04. Pp. 35-38.

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

Appendix XIII. List of Publications (cont'd)

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

Thesis:

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

1992

Abstracts:

BALDOCK, J.O. and J.L. POSNER. 1992. Crop rotations option program: computer aid to evaluating alternative cropping systems. American Society of Agronomy meetings. Minneapolis, MN. Nov. 1-6. Agronomy Abstracts p. 78.

GARLYND, M.J., A.V. KURAKOV, P.A. PORTER, and R.F. HARRIS. 1992. Descriptive and analytical characterization of soil quality/health. American Society of Agronomy meetings. Minneapolis, MN. Nov. 1-6. Agronomy Abstracts p. 257.

HARRIS, R.F. and D.F. BEZDICEK. 1992. Descriptive aspects of soil quality. Invited presentation in the symposium on "Defining soil quality for a sustainable environment. American Society of Agronomy meetings. Minneapolis, MN. Nov. 1-6. Agronomy Abstracts. p. 258.

HARRIS, R.F., M.J. GARLYND, P.A. PORTER, and A.V. KURAKOV. 1992. Farmer/Institution partnership in developing a soil quality/health report card. Participatory On-Farm Research and Education for Agricultural Sustainability. University of Illinois, Urbana-Champaign, IL. p. 223.

IRAGAVARAPU, T.K., J.L. POSNER, and G.D. BUBENZER. 1992. Using bromide to study water percolation and solute transit times under different crops. American Society of Agronomy meetings. Minneapolis, MN. Nov. 1-6. Agronomy Abstracts p. 327.

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.

Extension Bulletins:

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

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.

Proceedings:

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

Appendix XIII. List of Publications (cont'd)

DOLL, J. and T. MULDER. 1992. Update on effectiveness of mechanical weed control. Proceedings of the 1992 Fertilizer, Aglime 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, Aglime 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. Michigan State University, East Lansing. Sept. 13-18.

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.

Teaching module:

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

1993

Abstracts:

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

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

IRAGAVARAPU, T.K., J.L. POSNER and L. BUNDY. 1993. Soil nitrate levels under three cash grain rotations in southern Wisconsin. In abstracts of Agricultural Research to Protect Water Quality. Soil and Water Conservation Society meeting held at the Radisson Hotel, Minneapolis, MN. Feb. 21-24. p. 36.

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

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

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.

Appendix XIII. List of Publications (cont'd)

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, Aglime, and Pest Management Conference. 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.

GARLYND, M.J. D.E. ROMIG, and R.F. HARRIS. 1994. Characterization of soil health and soil quality of selected sites in Wisconsin. American Society of Agronomy Meeting, Seattle, WA., Nov. 13-18. Agronomy Abstracts. p.288.

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, American Society of Agronomy, Des Moines, IA, Aug. 1-3. Agronomy Abstracts, Appendix 5. p.1.

KLEMME, R.M., R. GUMZ, T.A. MULDER, J.L. 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.A. and J. HALL. 1994. The Wisconsin integrated cropping systems trial – a learning center for studying alternative production strategies. North Central Branch Meeting, American Society of Agronomy, Des Moines, IA, Aug. 1-3. Agronomy Abstracts, Appendix 5. p.1.

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. p.288.

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*: . J.W. Doran *et al.* (Eds.) Defining Soil Quality for a Sustainable Environment. Soil Sci. Soc. Amer. Special Pub. 35:159-168.

HARRIS, R.F. and D.F. BEZDICEK. 1994. Descriptive Aspects of soil quality. *In*: . J.W. Doran *et al.* (Eds.) Defining Soil Quality for a Sustainable Environment. 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. Addressing the challenges of sustainable agriculture research and extension at land-grant universities: Radially organized teams at Wisconsin. Am. J. Altern. Agric. 9:76-83.

Theses:

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.

1995

Abstracts:

GARLYND, M.J., D.E. ROMIG, and R.F. HARRIS. 1995. Effect of cropping systems shift from continuous corn on descriptive and analytical indicators of soil quality. American Society of Agronomy Meeting, St. Louis, MO. Oct. 29 – Nov. 3, 1995. Agronomy Abstracts. p.58.

POSNER, J.L., M.D. CASLER, and J.O. BALDOCK. 1995. The Wisconsin Integrated Cropping Systems Trial: Combining agroecology with production agronomy. Invited presentation. American Society of Agronomy Meeting, St. Louis, MO. Oct. 29 – Nov. 3, 1995. Agronomy Abstracts. p.50.

POSNER, J.L., T.K. IRAGAVARAPU, J.O. BALDOCK, and T.A. MULDER. 1995. Monitoring phosphorus and potassium soil test on the Wisconsin Integrated Cropping Systems Trial. American Society of Agronomy Meeting, St. Louis, MO. Oct. 29 – Nov. 3, 1995. Agronomy Abstracts. p.51.

POSNER, J.L., T.K. IRAGAVARAPU, J.O. BALDOCK, and T.A. MULDER. 1995. Monitoring fall nitrate levels on the Wisconsin Integrated Cropping Systems Trial. American Society of Agronomy Meeting, St. Louis, MO. Oct. 29 – Nov. 3, 1995. Agronomy Abstracts. p.51.

YOUNG, D.K. J.O. BALDOCK, W. GOLDSTEIN, J. HALL, R.F. HARRIS, W. HICKEY, D. HOGG, A. MACGUIDWIN, J.L. POSNER, and D. ROUSE. 1995. Relevance of soil biodiversity to the sustainability of agricultural systems. Annual Soil Ecology Society Meetings, Colorado Springs, CO.

Publications:

POSNER, J.L., M.D. CASLER, and J.O. BALDOCK. 1995. The Wisconsin integrated cropping systems trial: Combining agroecology with production agronomy. Am. J. of Alt. Agric. 10:3:98-107.

ROMIG, D.E., M.J. GARLYND, R.F. HARRIS, AND K. McSWEENEY. 1995. How farmers assess soil health and quality. J. Soil Water Conserv. 50:229-236.

STUTE, J.K. and J.L. POSNER. 1995. Synchrony between legume nitrogen release and corn demand in the Upper Midwest. Agron. J. 87:1063-1069.

STUTE, J.K. and J.L. POSNER. 1995. Legume cover crops as a nitrogen source for corn in an oat-corn rotation. J. of Production Agriculture. 8:3:385-390.

Extension Bulletins:

HICKEY, W., A. MacGUIDWIN, D. HOGG, and D. YOUNG. 06/27/95. "It's not just dirt." Wisconsin Teacher Enhancement Program.

1996

Abstracts:

BALDOCK, J.O., J.L. POSNER, and D.R. FISHER. 1996. CROP: A whole farm planning tool. American Society of Agronomy, Indianapolis, IN. Nov. 3-8, 1996. Agronomy Abstracts. p.65.

FISHER, D.R., J.L. POSNER, and J.O. BALDOCK. 1996. Whole-farm nutrient budgeting on 30 crop/livestock operations in the Upper Midwest. American Society of Agronomy, Indianapolis, IN. Nov. 3-8, 1996. Agronomy Abstracts. p.59.

POSNER, J.L. and J.O. BALDOCK. 1996. Wisconsin Integrated Cropping Systems Trial: Environmental and agronomic assessment of six cropping systems. American Society of Agronomy, Indianapolis, IN. Nov. 3-8, 1996. Agronomy Abstracts. p.59.

REBEK, E.J., HOGG, D.B., and D.K. YOUNG. 1996. Cropping system effects on soil arthropod biodiversity in southern Wisconsin. Entomology Soc. of America.

Publications:

BORNEMAN, J., P.E. SKROCH, K.M. O'SULLIVAN, J.A. PALUS, N.G. RUMJANEK, J.L. JANSEN, J. NIENHUIS, and E.W. TRIPLETT. 1996. Molecular microbial diversity of an agricultural soil in Wisconsin. Applied and Environmental Microbiology. 62:6:1935-1943.

HARRIS, R.F., D.L. KARLEN, and D.J. MULLA . 1996. A conceptual framework for assessment and management of soil quality and health. *In* J.W. Doran and A.J. Jones (Eds.) Methods for assessing soil quality. SSSA Special Publ. #49. Am. Soc. of Agronomy. 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 Science Soc. Amer. J. (In press)

ROMIG, D.E., M.J. GARLYND, and R.F. HARRIS. 1996. Farmer based assessment of soil quality. *In* J.W. Doran and A.J. Jones (Eds.) Methods for assessing soil quality. SSSA Special Publ. #49. Am. Soc. of Agronomy. Madison, WI.

Extension Bulletins:

HARRIS, R.F. 01/19/96. Soil quality: From pictorial images to assessment and management plans. Invited paper to the Ohio Soil and Water Conservation meeting. Columbus, OH.

ROUSE, D., J. DOLL, R. KLEMME, J.K. STUTE, and J.L. POSNER. 07/11/96. Annual Agronomy Field Day. Arlington, WI.

REBECK, E., A. YUROFF, and V. GOLWITZER. 08/28/96. Presentation to DeForest Middle Schools.

BALDOCK, J.O., and D.R. FISHER. 09/17/96. CROP SPREADSHEET. New Approaches to Rural Nonpoint Source Pollution: What makes them work. Sept. 16-18, 1996. La Crosse, WI.

1997

Abstracts:

BALDOCK, J.O., J.L. POSNER, and D.B. HOGG. 1997. Soil biodiversity in Wisconsin agroecosystems. Soil Ecology Society. May 27-30, 1997. Manhattan, KS.

MACGUIDWIN, A.E. 1997. The response of soil nematode communities to agricultural inputs. Soil Ecology Society. May 27-30, 1997. Manhattan, KS.

REBEK, E.J., HOGG, D.B., and D.K. YOUNG. 1997. Cropping systems effects on soil arthropod biodiversity in southern Wisconsin. Soil Ecology Society. May 27-30, 1997. Manhattan, KS.

Publications:

KARLEN, D.L., MAUSBACH, M.J., DORAN, J.W., CLINE, R.G., HARRIS, R.F., SCHUMAN, G.E. 1997. Soil quality: a concept, definition, and framework for evaluation. Soil Sci. Soc. Am. J. Madison, Wis. Soil Science Society of America. Jan/Feb 1997. v. 61 (1) p.4-10.

Bulletins:

GRIFFITH, K. Profitable Farming Update #1 1997. 'A profitable alternative to continuous corn'.

GRIFFITH, K. Profitable Farming Update #2 1997. 'Manage weeds for profit, not appearance'.

GRIFFITH, K. Profitable Farming Update #3 1997. 'Effective rotary hoeing'.

GRIFFITH, K. Profitable Farming Update #4 1997. 'Grow profitable corn-without purchased N or herbicides'.

GRIFFITH, K. Profitable Farming Update #5 1997. 'Cheap nitrogen and erosion control too'.

GRIFFITH, K. Profitable Farming Update #6 1997. 'Saving labor and making money with rotational grazing'.

GRIFFITH, K. Profitable Farming Update #7 1998. 'Why and how to add vetch to your cash grain rotation'.

GRIFFITH, K. Profitable Farming Update #8 1998. 'Wheat: new reasons for a traditional crop'.

1998

Theses:

FISHER, D.R. 1998. Whole farm nutrient budgeting: Estimating nutrient balance and identifying strategies for improvement. M.S. Thesis, Agronomy Dept., University of Wisconsin-Madison

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

Bulletins:

STUTE, J.K. 1998. Including a small grain in the corn-soybean rotation: production economics of small grains. Michael Fields Agricultural Institute Bulletin #5. 4 pages.

STUTE, J.K. 1998. Using hairy vetch residue for nitrogen and weed suppression. Michael Fields Agricultural Institute Bulletin #6. 2 pages.

Publications:

IRAGAVARAPU, T.K., J.L. POSNER, and G.D. BUBENZER. 1998. The effect of various crops on bromide leaching to shallow groundwater under natural rainfall conditions. J. Soil and Water Conserv. 53(2):146-151.

MALLORY, E.B., J.L. POSNER, and J.O. BALDOCK. 1998. Performance, economics, and adoption of cover crops in WI cash grain rotations. On-farm trials. Am. J. Alt. Ag. 13(1):2-11.

POSNER, J.L., G.G. FRANK, K.V. NORDLUND, and R.T. SCHULER. 1998. Constant goal, changing tactics: A Wisconsin dairy farm start-up. Am. J. Alt. Ag. 13(2):50-60.

1999

Thesis:

GOLLWITZER, V. 1999. Molecular analysis of ammonia-oxidizing bacteria in Wisconsin agricultural soils. M.S. Thesis, Soil Science Dept., University of Wisconsin-Madison.

Bulletins:

DOETCH, R.G., D. KANE, J.K. STUTE, J.L. POSNER, AND T. ENDS. 1999. Farmers Guide & Resource to Quality Small Grains Production. Michael Fields Agricultural Institute.

DOETCH, R.G., AND T. ENDS. 1997-99. Small Grains Update: Striving for the production, handling, and processing of small grains. Fortnightly newsletter. Michael Fields Agricultural Institute, East Troy, WI.

KLEMME, R. 1999. Cropping Systems trial provides unique analysis. CIAS Research Brief #43. UW-CALS.

KLEMME, R., AND D. SCHUSTER. 1999. Diversity pays off on cash grain farms. CIAS Research Brief #44. UW-CALS.

Publications:

REBEK, E.J., D.K. YOUNG, AND D.B. HOGG. 1999. A list of Wisconsin springtails with new records and annotations (Hexapoda: Parainsecta: Collembola). Great Lakes Ent. 32(1): 51-62.

2000

Publications:

GOLDSTEIN, W. 2000. The effect of farming systems on the relationship of corn root growth to grain yields. Amer. J. of Alternative Agriculture. 15(3):101-109.

Posters:

AVILA-SEGURA, M. ET AL. 2000. Coupling of H and C cycles in several common agroecosystems of Midwestern United States. ASA, CSSA, SSSA Annual Meeting. Minneapolis, MN. November 5-9, 2000.

SIMONSEN, J., ET AL. 2000. Earthworm populations and functional group dynamics in conventional and alternative cropping systems. ASA, CSSA, SSSA Annual Meeting. Minneapolis, MN. November 5-9, 2000.

Bulletins:

SCHUSTER, D., AND R. KLEMME. 2000. Low-input forage rotation: similar returns, reduced costs. CIAS Research Brief # 53. UW-CALS.

2001

Publication:

GRIFFITH, K AND J. POSNER. 2001. Comparing upper Midwestern Farming Systems: Results from the first 10 years of the Wisconsin Integrated Cropping Systems Trial (WICST). Agronomy Dept. UW-Madison.

Newspaper Articles (4 part series):

AGRI-VIEW. Jane Fyksen (ed). November 1, 2001. p. D-8. "No cropping system clear winner"

AGRI-VIEW. Jane Fyksen (ed). November 8, 2001. p.D-5. "Crop diversity promotes better yields" and "Weed seed bank, weed pressure not as 'simple' as many think".

AGRI-VIEW. Jane Fyksen (ed). November 15, 2001. p.D-1, D-10. "Soil impact observed in long-term study".

AGRI-VIEW. Jane Fyksen (ed). November 22, 2001. p. D-5, D-10, D11. "Continuous corn greatest nitrate threat" and "Research turns up rotary hoe hints" and "Continuous corn least profitable of systems examined" and Cover crops play key role in study".

Abstracts:

BALDOCK, J., J. POSNER, D. SCHUSTER, R. KLEMME, J. HEDTCKE. Economic analysis of five cropping systems in the Wisconsin Integrated Cropping Systems Trials. ASA, CSSA, SSSA Annual Meetings Abstracts. Charlotte, NC. October 21-25, 2001. Abstracts CD-ROM. ASA, Madison, WI

BALDOCK, J. J. POSNER, D. FISHER. Simultaneous management of N and P in land application of manure. ASA, CSSA, SSSA Annual Meetings Abstracts. Charlotte, NC. October 21-25, 2001. Abstracts CD-ROM. ASA, Madison, WI

GISH, T.J., K. KUNG, E.J. KLADIVKO, J. POSNER, G. BUBENZER, C. HELLING, T. STEENHUIS. Comparison of preferential chemical transport at high and low irrigation rates. ASA, CSSA, SSSA Annual Meetings Abstracts. Charlotte, NC. October 21-25, 2001. Abstracts CD-ROM. ASA, Madison, WI

GOLDSTEIN, W., W. BARBER, L. CARPENTER-BOGGGS, D. DALSORN, C. KOOPMANS. Comparisons of conventional, organic and biodynamic methods. ASA, CSSA, SSSA Annual Meetings Abstracts. Charlotte, NC. October 21-25, 2001. Abstracts CD-ROM. ASA, Madison, WI

GOLDSTEIN, W., C. CAMBARDELLA, M. WANDER, J. MULCAHY. Organic matter and nutrient budgeting for sustainable farming. ASA, CSSA, SSSA Annual Meetings Abstracts. Charlotte, NC. October 21-25, 2001. Abstracts CD-ROM. ASA, Madison, WI

HEDTCKE, J., J. POSNER, J. BALDOCK. Wisconsin Integrated Cropping Systems Trial: A comparison of low input systems. ASA, CSSA, SSSA Annual Meetings Abstracts. Charlotte, NC. October 21-25, 2001. Abstracts CD-ROM. ASA, Madison, WI

HEDTCKE, J, AND D. SCHUSTER. 2001. 'Environmental and economic aspects of high-input vs. low-input forage rotations'. Agronomy Field Days, June 27, 2001. Arlington Ag. Research Station, Arlington, WI. WICST plots.

SIMONSEN, J. M. ROSEMEYER, J. POSNER. Wisconsin Integrated Cropping Systems Trial: Investigating the impacts of cropping system on soil health. ASA, CSSA, SSSA Annual Meetings Abstracts. Charlotte, NC. October 21-25, 2001

2002

Thesis:

BROCK, C. 2002. Mycorrhizal colonization comparison with high-input/continuous corn. MS Thesis, Land Resources, Institute for Environmental Studies, University of Wisconsin-Madison.

SIMONSEN, J. 2002. Earthworm populations in six Midwestern cropping systems. MS Thesis, Agronomy Dept., University of Wisconsin-Madison.

Abstracts:

M. AVILA-SEGURA, P. BARAK, J. L. POSNER, AND D.A. LAIRD. 2002 "Accelerated Aging of Agricultural Soils and the Coupling of the Nitrogen and Proton Cycles." Symposium--Dynamic Soil Properties, Pedology, and Soil Function, ASA/CSSA/SSSA 2002 Annual Meetings (Nov 10-16, Indianapolis) Abstracts CD-ROM. ASA, Madison, WI.

HANKE, M., S. KUNG, J. STUTE, J. POSNER, AND G. BUBENZER. 2002. 'Leaching of Agricultural Chemicals to Tile Drains on the Walworth County Farm'. Agronomy Field Days, September 5, 2002. Arlington Ag. Research Station, Arlington, WI. WICST plots.

HEDTCKE, J., J. POSNER AND J. BALDOCK. 2002. 'Expanding the Corn-Soybean Rotation with Wheat and Red Clover: An Economic Analysis'. Agronomy Field Days, September 5, 2002. Arlington Ag. Research Station, Arlington, WI. WICST plots.

POSNER, J., AND J. BALDOCK. 2002. 'Yield and Yield Variability: 10 Years of Comparing Alternative Cropping Systems'. Agronomy Field Days, September 5, 2002. Arlington Ag. Research Station, Arlington, WI. WICST plots.

SIMONSEN, K. 2002. 'Establishing Prairie in an Agricultural Landscape'. Agronomy Field Days, September 5, 2002. Arlington Ag. Research Station, Arlington, WI. WICST plots.

Posters:

HANKE, M., S. KUNG, J. STUTE, J. POSNER, AND G. BUBENZER. 2002. 'Leaching of Agricultural Chemicals to Tile Drains on the Walworth County Farm'. UW-Madison, Agronomy Dept.

HEDTCKE, J., J. POSNER AND J. BALDOCK. 2002. 'Expanding The Corn-Soybean Rotation with Wheat and Red Clover'. UW-Madison, Agronomy Dept.

HEDTCKE, J., and J. POSNER. 2002. 'Using Cattle To Restore Oak Savanna Structure: Preliminary Data'. UW-Madison, Agronomy Dept.

HEDTCKE, J. POSNER, J. BALDOCK, and D. MUELLER. Using pre-plant nitrate test to reduce n inputs on corn: 11-year history on the WICST plots. UW-Madison, Agronomy Dept.

POSNER, J., J.L HEDTCKE, J.K. STUTE, AND J. OOSTERWYKE. 2002. 'Ten-Year Summary of Energy and Labor Use on WICST'. UW-Madison, Agronomy Dept.

SIMONSEN, J., M. ROSEMEYER, AND J. POSNER. 2002. 'Earthworm Populations On The WICST Plots: 1999-2001'. UW-Madison, Agronomy Dept.

2003

Theses:

KATHOL, EMILY. August 2003. Effectiveness of rotational grazing and burning on composition and structure of oak savanna. [MSc Thesis]. Madison, WI: University of Wisconsin. 152 pp

Abstracts:

BALDOCK, J, J. POSNER, AND J. HEDTCKE. 2003. Crop Yields and Variability of Five Cropping Systems in the Upper Midwest. [abstract] 95th Annual Meeting of American Society of Agronomy (Nov 2-6, Denver, CO) CD-ROM abstract A08-780807.

HEDTCKE, J. AND J. POSNER. 2003. Using cattle to restore oak savanna/woodland in southern Wisconsin. [abstract]. Natural Areas Conference. (September 24-27, Madison, WI.) website http://64.92.126.53/03conference/NAA_ABSTRACTS.pdf

Posters:

HEDTCKE, J., J. POSNER, AND K. ALBRECHT. Using managed grazing to restore oak savanna structure: Impact on cattle. Prairies Jubilee, Arlington, WI. September 28th, 2003

SIMONSEN, K., J. HEDTCKE, E. HOWELL, J. POSNER. Restoring native prairie to the 'Empire Prairie' of south central Wisconsin. Prairies Jubilee, Arlington, WI. September 28th, 2003

Website:

http://www.cias.wisc.edu/wicst/

2004

Theses:

AVILA-SEGURA, M. June, 2004. Soil Acidification processes in agroecosystems. [PhD thesis]. Madison: University of Wisconsin. 150 pp

MARIOLA, M. August 2004. Who is a farmer? The identity crisis in modern agriculture. [MSc thesis]. Madison, WI: University of Wisconsin 139 pp

MEYER, J. August 2004. The vertical distribution of phoshorus at the Wisconsin Integrated Cropping Systems Trial. [MSc thesis]. Madison, WI: University of Wisconsin. 134 pp

SIMONSEN, C. June 2004. Investigations of composition, germination, structure and physiognomy in three southern Wisconsin tallgrass prairies. [MSc Thesis]. Madison, WI: University of Wisconsin. 183 pp

WAGNER, T. January 2005. Manure Management: Using a land evaluation site assessment approach. [MSc Thesis]. Madison, WI: University of Wisconsin. 120 pp.

Abstracts:

AVILA, M., P. BARAK, J. POSNER, D. LAIRD. 2004. Comparative rates of acidification of Midwestern agricultural systems. [abstract] 96th Annual Meeting of American Society of Agronomy (Oct 31-Nov 4, Seattle, WA) CD-ROM abstract S-11 6317.

BALDOCK, J., J. POSNER, J. HEDTCKE. 2004. Soil test P and K trends in alternative cropping systems: Data from WICST. [abstract] 96th Annual Meeting of American Society of Agronomy (Oct 31-Nov 4, Seattle, WA) CD-ROM abstract S-04 5935.

BALDOCK, J., J. POSNER, J. HEDTCKE. 2004. Does diversification reduce yield variability?: Data from WICST. [abstract] 96th Annual Meeting of American Society of Agronomy (Oct 31-Nov 4, Seattle, WA) CD-ROM abstract C-03, A-08, C-01 5902.

HEDTCKE, J., J. POSNER, AND K. ALBRECHT. 2004. Using managed grazing to restore oak savanna structure: Impact on cattle. [abstract]. North American Prairie Conference. (August 8-12, Madison, WI. Conference proceedings pg 66.

HEDTCKE, J., J. POSNER, J. BALDOCK. 2004. Eleven season of pasture productivity and heifer performance under rotational grazing: Data from WICST. [abstract] 96th Annual Meeting of American Society of Agronomy (Oct 31-Nov 4, Seattle, WA) CD-ROM abstract C-06 6087.

HEDTCKE, J., J. POSNER, J. BALDOCK. 2004. Benefits of diversifying the corn/soybean rotation: Data from WICST. [abstract] 96th Annual Meeting of American Society of Agronomy (Oct 31-Nov 4, Seattle, WA) CD-ROM abstract C-03, A-08, C-01 6058.

POSNER, J., J. HEDTCKE, J. BALDOCK. 2004. Does diversification reduce fall nitrates?: Data from WICST. [abstract] 96th Annual Meeting of American Society of Agronomy (Oct 31-Nov 4, Seattle, WA) CD-ROM abstract C-03, A-08, C-01 6066.

SIMONSEN, K., J. HEDTCKE, E. HOWELL, J. POSNER. 2004. Restoring native prairie to the 'Empire Prairie' of south central Wisconsin. (abstract) North American Prairie Conference. (August 8-12, Madison, WI.) Conference proceedings pg 70.

WAGNER, T., J. POSNER. 2004. Linking farms: Land evaluation and suitability assessment for manure spreading. [abstract] 96th Annual Meeting of American Society of Agronomy (Oct 31-Nov 4, Seattle, WA) CD-ROM abstract S-06 6161.

Posters:

HEDTCKE, J., J. POSNER, AND K. ALBRECHT. Using managed grazing to restore oak savanna structure: Impact on cattle. Prairies Jubilee, Arlington, WI. September 26th, 2004

SIMONSEN, K., J. HEDTCKE, E. HOWELL, J. POSNER. Restoring native prairie to the 'Empire Prairie' of south central Wisconsin. Prairies Jubilee, Arlington, WI. September 26th, 2004

Journal Articles:

SAAM, H., J.M. POWELL, D.B. JACKSON-SMITH, W. BLAND, J. POSNER. 2005. Use of animal density to estimate manure nutrient recycling ability of Wisconsin dairy farms. Agricultural Systems. 84:343-357.