THE WISCONSIN INTEGRATED CROPPING SYSTEMS TRIAL - FIFTH REPORT

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PROLOGUE

This is the fifth 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 five production years (1990-1994). In this report we discuss the results of the sixth year of field trials (1995). This is the third time we have had all the phases of the six rotations running concurrently, permitting us to again compare all the systems. We have also included research results of satellite trials conducted both on-farm and adjacent to the WICST core trials.

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

Summer, 1996

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

INTRODUCTION

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

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

The selection of cropping systems provoked a great deal of discussion within the group. Ultimately a factorial array of rotations was selected. It was observed that within southern Wisconsin there were two principal types of farm enterprises; cash-grain and forage-based systems, each with its own production requirements. At the level of production strategy, the hypothesis developed was that as systems became more complex, they would require less and less external inputs to remain productive. As a result, production strategies with a high, medium and low level of complexity were designed. Put in an inverse fashion, systems that required a high, medium and low level of purchased inputs were put into practice. The six rotations are schematically represented in Figure 2. Some of the anticipated differences between the rotations are outlined in Table 1.

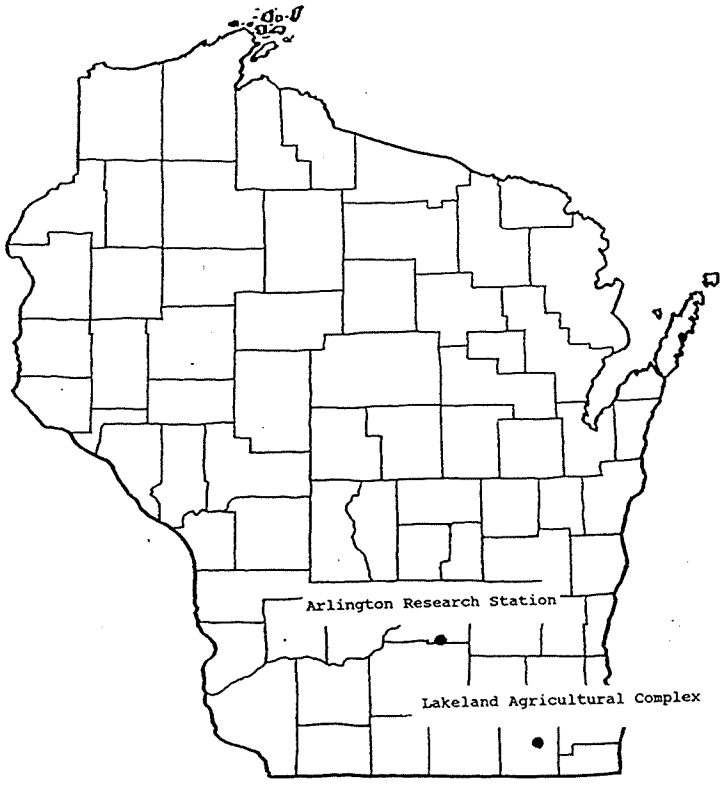
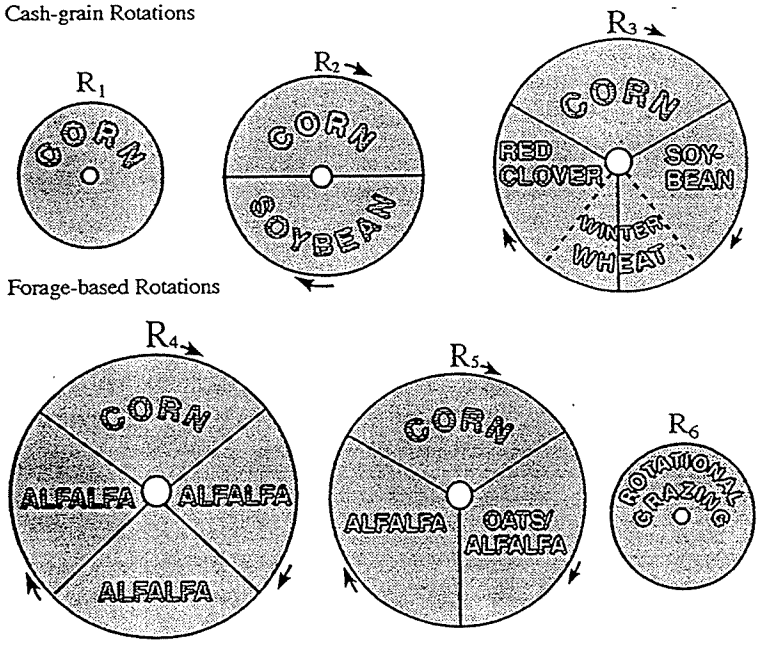


Figure 1. Outline of Major Land Resource Area 95B and Two Sites of the Wisconsin Integrated Cropping Systems Trial



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

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

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

Rotation	Predicted yield/acre	Mean above ground productivity[1]	Mean energy input[2]	Energy output/input[3]	Variable costs[4]	Chemical inputs			Erosion[5]
						Fert N on corn	Herbicide	Insecticide	
	lb/a/yr	Mcal/a/yr	ratio	$/a/yr	lb/a	Al/a	Al/a	t/a/yr	
R_1									
Cont. 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 .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.

THE MAIN SYSTEMS TRIAL - 1995

1. ARLINGTON AGRICULTURAL RESEARCH STATION - 1995 AGRONOMIC REPORT

Dwight Mueller*

The summer of 1995 was very warm with 18 days over 90. During a five day period in mid-July when corn was pollinating, temperatures were at or close to 100 degrees. For the period April- August 1995, Arlington had 19.30 inches of precipitation. This is 2.35 inches more than the long term average 16.95 inches. Rainfall for the months of April, May and August were above average while June and July were below average. (see Table 1a and Figure 1a).

A. Corn Phase

Treatment practices were maintained much the same as 1994. Corn in CS1, CS2, and CS4 were planted on May 1 at 32,000 seeds/a and CS3 and CS5 were planted on May 12 at 34,000 seeds/a. Deep nitrate soil tests indicated a 60 lb N/a credit could be taken in the CS1 rotation consequently, 100 lb N/a as anhydrous ammonia was applied. Legume and manure credits were taken in the other systems and only the CS2 system received additional N (120 N/a). Weed control was very good in all treatments. Systems CS3 and CS5 required three passes with the rotary hoe and two cultivation's. In addition replicate 1 of CS5 received a broadcast application of accent for quackgrass control and spot treatments of Stinger for thistle control. The goal of this system is not to use chemicals but the committee decided these chemicals were needed as a rescue treatment. The quackgrass infestation may have resulted from a border rather than treatment affect. Monitoring and routine spraying the edges of these plots maybe needed in order to minimize this affect. Corn yields averaged 158 bu/acre across all rotations which is normal for the Arlington Prairie. The high temperatures in July and the late outbreak of European Corn Borer probably lowered yields.

B. Soybean Phases:

Kaltenberg 241 (Maturity Class 2.4) soybeans were planted May 6 at 235,000 seeds/a in 7" rows for the R2 rotations. Asgro 1990 (Maturity Class 1.9) soybeans were planted on May 12 at 180,000 in 30" rows. The CS2 soybeans were no-tilled in very high residue cover (in excess of 75% cover) and the surface was uneven from the previous year cultivation of the corn. As a result, there were areas where planting depth was too shallow or the seed did not make good seed soil contact because of the thick residue mat. Stands averaged approximately 135,000 plants/a which while less than optimum were still acceptable. In contrast, there were excellent plant stands in the wide row beans. There was good seed soil contact and the soybeans were planted later when the temperatures were warmer. Weed control was excellent in the CS2 rotation. An application of 12 oz/a of roundup was added to this rotation at the suggestion of the farmers on the advisory committee and this may have helped control very small seedling weeds. Weed control was good for CS3; however, some grasses and broadleaf weeds broke the soybean canopy. As the yield data indicates, weed pressure did not appear to affect yield.

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C. Wheat/Red Clover Phase:

Wheat was planted in mid-October following soybean harvest and light tillage at a seeding rate of 180 lb/a. The Red Clover was frost seeded on February 24 at 20 lb/a. The wheat stand was very good and yields (Table 2) were the best we have had in the trial thus far. The red clover stand was marginal, but a decision was made not to till the clover under. The red clover had germinated and emerged folowing the spring frost-seeding but apparently plants were lost due to very cold temperatures shortly after the seedlings emerged. Herbage harvest in the fall of 1995 however, indicated that the red clover tops included 71 lb N/a.

D. Forage Phases:

The new seedings in CS4 an CS5 systems were planted on April 24 at a rate of 15 lb/a. The oats were seeded in CS5 at 64 lb/a. The established CS4 systems were harvested three times before September 1 and the CS5 systems were harvested three times before September 1 with a fourth cutting on September 14. A decision was made to take three cuttings instead of four because of the stress that four cuttings has on the established stands of alfalfa. This was evidenced by the poor stand and yield (Table 2) in the CS4 Alfalfa II treatment. It was questionable whether this phase of the rotation should have stayed in alfalfa. The previous year these plots had four cuttings before September 1, and, although plants were still there, they were weakened and performed poorly. We have also observed this on Research Station production fields and have gone to a three cut system.

Yields of newly seeded CS4 and CS5 systems were equivalent. There was a continued trend of higher yields in the CS5 alfalfa I compared to the CS4 alfalfa I. CS5 alfalfa II yields continue to average below what would be expected for this system.

* Appendix I is an agronomic diary of the 1995 field operations and input/output data for the Arlington Agricultural Research Station site.

2. LAKELAND AGRICULTURAL COMPLEX - 1995 AGRONOMIC REPORT

John Hall[1], Alan Wood[2] and Lee Cunningham[2]

The weather was again the factor that had the most impact on crop production. Cool wet April weather kept us out of the field until May when drier conditions allowed mid-May alfalfa seeding followed soon by corn and soybean planting later in the month. Temperatures were normal in May through mid June and very warm from the second half of June through July with nine days of 90 ° or above and many days in the upper 80's. Rainfall for this same three-month period was nearly 4.5 inches below normal. Crops were beginning to show signs of stress by the end of July and there was concern that the dry weather during pollination would reduce corn yields. Rain showers beginning late July and continuing through August more than made up for the earlier lack of rain and actually made forage harvest difficult. (see Table 1b and Figure 1b)

The hot summer weather helped the late planted corn grow quickly but the dry conditions during the end of this warm period likely reduced yield. Mid-season conditions for corn growth however, were excellent and corn looked good in all the systems. Systems 4 did not have a fall application of Roundup in 1994 as there was little quackgrass and the chisel plowing with sweeps did a good job of killing the alfalfa. This was not a good decision as there were some areas of quackgrass in the some of the System 4 and 5 corn plots which added stress during the dry period of the summer. Although a cultivation with the no-till cultivator covered up much of the quack, it had already had had a negative effect by moisture competition. As in previous years there was again a fair amount of giant foxtail in the system 3 corn which may have reduced yield. Corn stalk borer was present in all systems and reduced both real yield and harvestable yield as some corn ears fell from stalks before harvest. Corn yield variation between systems was small with yield highest in System 4 and lowest in System 3 (Table 2).

Mechanical weed control was very good in the wide-row soybeans and yield reduction from weeds was slight. Windy weather made timely herbicide application difficult in the narrow-row no-till soybeans but they responded well to the late weed control followed by rain showers and yielded well.

Wheat again over-wintered well and yielded surprisingly well in spite of the hot and dry weather during grain formation. Wet weather that began late July made both wheat and straw harvest difficult. Germination was good for the frost seeded red clover and it grew well following wheat harvest and the wet August weather.

Established forages produced well with lower yields in the second year System 4 alfalfa. The result of our missing the application window for herbicide application to the direct seeded alfalfa was a weedy first cutting. In the oats/alfalfa the oats matured quickly during the warm weather and were heading out by oatlage harvest, therefore although yields were good, quality was low. The second harvests of the new seedings of alfalfa were ruined by rain in both Systems 4 and 5. The established forage treatments were each harvested three times. Rotational grazing animals were on pasture from May 1 through October 2 and the eight animals (two animals/plot) gained an average of 1.9 lb/day.

* Appendix II is an agronomic diary of the 1995 field operations and input/output data for the Lakeland Agricultural Complex site.

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

a. Arlington Research Station[1]

Month	1995	1994	1993	30-yr avg 1959-1988
April	3.37(+0.38)	2.28(-0.71)	7.06(+4.07)	2.99
May	5.95(+2.76)	1.99(-1.20)	4.52(+1.33)	3.19
June	2.15(-1.65)	7.93(+4.13)	6.10(+2.30)	3.80
July	2.81(-0.65)	6.08(+2.62)	9.40(+5.94)	3.46
August	5.02(+1.13)	4.03(+0.14)	3.20(-0.69)	3.89
September	1.78(-2.45)	4.65(+0.42)	4.20(-0.03)	4.23
Growing Season Total	21.08	26.96	34.48	21.56
Yearly Total	31.84	33.99	34.43	31.14

b. Lakeland Agricultural Complex

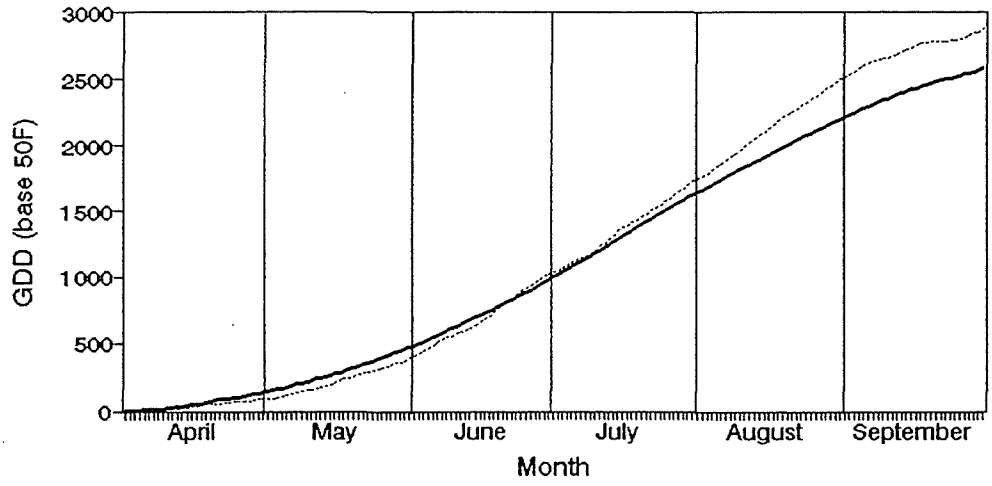
Month	1995[2]	1994[2]	1993[2]	30-yr avg 1959-1988[3]
April	4.75(+0.95)	2.37(-1.43)	5.55(+1.75)	3.80
May	2.44(-0.82)	0.66(-2.60)	1.90(-1.36)	3.26
June	1.57(-2.36)	3.71(-0.22)	8.50(+4.57)	3.93
July	3.13(-1.22)	1.97(-2.38)	4.35(+0.00)	4.35
August	8.34(+4.33)	4.48(+0.47)	2.80(-1.21)	4.01
September	2.08(-1.98)	1.90(-2.16)	3.59(-0.47)	4.06
Growing Season Total	22.31	15.09	26.69	23.41
Yearly Total[3]	35.27	21.19	36.69	37.53

[1]Data from Arlington National Weather Service Cooperative station.

[2]Data from Lakeland Ag. Complex Automated Weather Station.

[3]Data from Lake Geneva National Weather Service Cooperative station (7 miles southeast of the Lakeland Ag. Complex).

a. Arlington Agricultural Research Station



b. Lakeland Agricultural Complex

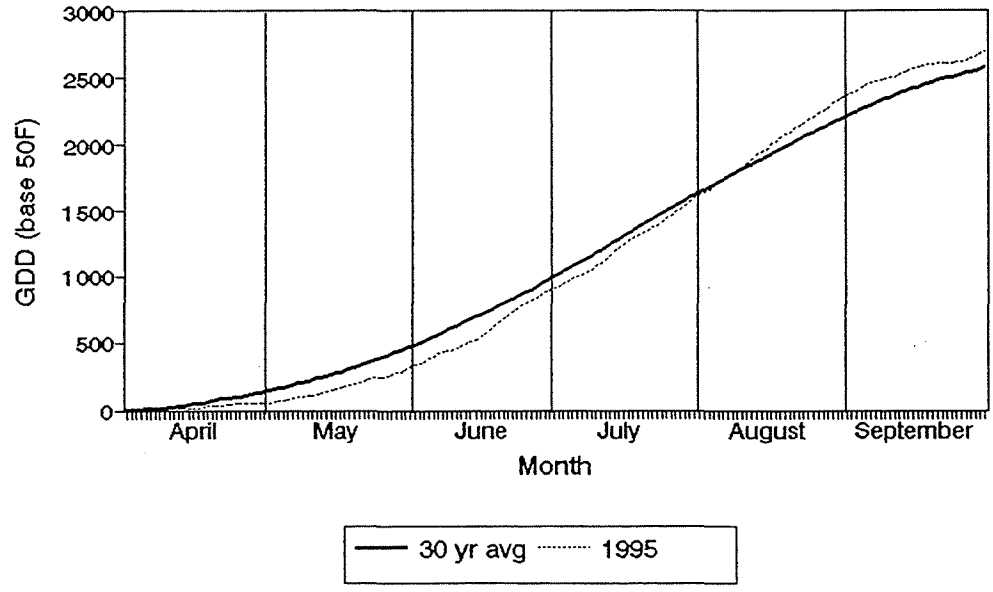


Figure 1. Cumulative corn growing degree days for the two WICST sites

* GGD = (Daily Maximun (86°) + Daily Minimum (50°))/2 - 50°; where 86° is used if the Maximum exceeds 86° and 50° is used if the Minimum falls below 50°.

Table 2. Yield Results for the Wisconsin Integrated Cropping Systems Trial (1991 - 1995)

a. Arlington Agricultural Research Station

Corn	1991	1992	1993	1994	1995
			bu/acre		
R_1 - Continuous corn	160.0	144.0	123.7	178.1	143.1
R_2 - Corn after soybean	185.7	150.1	129.8	190.2	167.7
R_3 - Corn after red clover	-	99.2	87.1	188.4	155.6
R_4 - Corn after alfalfa	-	-	165.1	196.5	167.5
R_5 - Corn after alfalfa	-	112.0	119.1	198.8	157.1
LSD ($P<0.05$)	4.0	12.6	7.4	9.9	9.1

Soybean	1991	1992	1993	1994	1995
			bu/acre		
R_2 - Drilled soybean	58.5	30.1	52.8	42.7[1]	58.1
R_3 - Row soybean	49.2	38.0	53.3	44.4	63.3
LSD ($P<0.05$)	6.1	NS	NS	NS	2.2

Wheat	1991	1992	1993	1994	1995
			bu/acre		
R_3 - Wheat	63.6	45.2	28.6	60.9	67.8

Seeded Alfalfa	1991	1992	1993	1994	1995
			ton dry matter/acre		
R_4 - Direct seeded	4.94	3.59	3.27	3.21	3.19
R_5 - Oats/alfalfa	3.12[3]	2.63[2]	2.38[3]	3.37[2]	3.21[2]
LSD ($P<0.05$)	0.36	0.49	0.51	NS	NS

Established Forage	1991	1992	1993	1994	1995
			ton dry matter/acre		
R_4 - Hay I	5.86	3.46	3.70	4.56	4.02
R_5 - Hay I	5.86	5.17	4.65	5.30	4.89
R_4 - Hay II	-	3.99	3.25	3.68	2.24
R_6 - Pasture	4.70	2.81	[6]	[6]	[6]
LSD ($P<0.05$)	0.44	1.20	1.15	0.36	0.45

[1] Soybeans replanted June 15 due to severe herbicide damage to soybeans and poor weed control.
[2] Oats harvested as oatlage followed by one alfalfa harvest.
[3] Oats harvested as grain (grain and straw converted to tons of dry matter per acre).
[4] Intensive rotational grazing of heifers

Table 2. Yield Results (continued)

b. Lakeland Agricultural Complex

Corn	1991	1992	1993	1994	1995
			bu/acre		
R_1 - Continuous corn	121.2	119.0	99.7	177.0	150.1
R_2 - Corn after soybean	144.7	126.2	101.2	184.4	149.7
R_3 - Corn after red clover	-	73.0	77.7	187.0	130.9
R_4 - Corn after alfalfa	-	-	113.3	211.3	154.4
R_5 - Corn after alfalfa	-	101.7	80.6	198.3	143.7
LSD ($P<0.05$)	13.1	16.9	22.2	7.7	14.6

Soybean	1991	1992	1993	1994	1995
			bu/acre		
R_2 - Drilled soybean	52.9	46.9	49.0	63.1	54.9
R_3 - Row soybean	54.5	51.9	32.3	47.4	59.1
LSD ($P<0.05$)	NS	NS	12.7	2.3	2.9

Wheat	1991	1992	1993	1994	1995
			bu/acre		
R_3 - Wheat	32.1	25.7	22.3	50.9	70.0

Seeded Alfalfa	1991	1992	1993	1994	1995
			ton dry matter/acre		
R_4 - Direct seeded	0.46	1.11	2.01[1]	2.37[2]	1.24[2]
R_5 - Oats/alfalfa	2.47[4]	3.03[3]	1.67[4,5]	3.49[4]	1.51[2,4]
LSD ($P<0.05$)	0.63	1.02	NS	0.54	NS

Established Forage	1991	1992	1993	1994	1995
			ton dry matter/acre		
R_4 - Hay I	3.88	3.65	2.87	4.12[2]	4.47
R_5 - Hay I	3.49	3.54	3.37	3.82[2]	4.62
R_4 - Hay II	-	3.57	2.61	4.05[2]	3.34
R_6 - Pasture	3.39	[6]	[6]	[6]	[6]
LSD ($P<0.05$)	NS	NS	NS	NS	0.72

[1] Only one harvest; yield from 1 of 4 reps (3 reps ruined by rain and chopped onto field).
[2] August cutting ruined by rain and chopped onto field.
[3] Oats harvested as grain (grain and straw converted to ton of dry matter per acre).
[4] Oats harvested as oatlage followed by one alfalfa harvest.
[5] Alfalfa yield was avg. from 3 of the 4 reps (1 rep ruined by rain and chopped onto field).
[6] Intensive rotational grazing of heifers

3. 1995 Weed Seed Bank And Biomass Results

Jerry Doll[1]*, Tom Mulder and Josh Posner[2]

We continued sampling weed seeds as in previous years by counting weed seedlings germinating in soil that had been collected from selected plots early in the spring. We took four subsamples per plot, each consisting of eight .75" diameter cores taken to a 6" depth. The soil was mixed with sand, placed in plastic trays in the greenhouse and seedlings were counted and identified through three germination cycles. All plots that had been in corn in 1994 were sampled as well as those following alfalfa in systems 4c and 5a (tmts. 8 and 13, respectively). Weed seed banks are grouped into population categories as follows:

low = less than 400 seeds/ft^2
moderate = 401 to 800 seeds/ft^2
high = 801 to 1200 seeds/ft^2
severe = more than 1200 seeds/ft^2.

The weed biomass present in the corn and soybean plots is measured by cutting all weeds taller than 4 inches in nine 5 by 5-ft areas when corn is approximately 36 inches tall. Weeds are dried and weighed and pounds of weeds per acre are calculated.

Seed bank results.

Weed populations vary bewtween sites and years, but the overall trend is that seed banks in CS1 (continuous corn) are holding steady at ARS and are increasing at LAC. Although not measured in 1995, seed populations are still considered low at both sites. Broadleaf species continue to predominate at ARS while grasses are increasing at LAC (Tables 1 and 2).

The populations in the corn-soybean system (CS2) have been low to moderate. The higher than expected numbers (ARS 2a (94) and LAC 2b (95) correspond to relatively high weed biomass the previous year. The system has been completely no-till since 1994 and to date there is no clear pattern in the shift of relative importance of broadleaf and grassy weeds.

Our weed management strategy in the soybean-wheat/red clover/corn system (CS3) has been to rotate a vigorously growing cool season cropping phase (wheat/red clover) with timely mechanical weedings during the two warm season cropping phases (corn and soybeans). Weed seed population during our third time initiating this cropping system (CS3c) have dropped (figure 1). This was not the case with the plots initiated in 1990 (CS3a) or 1991 (CS3b). It appears that this is due to (1)better management of the weeds during the row crop phases as rotary hoeing and cultivation skills and timings have improved, (2) better stands of corn and soybeans, and (3) the competitive effect of wheat and red clover with weeds during the "sod" phase of this system. No clear trend is evident in the relative importance of grassy and broadleaf species..

Weed seed populations following corn treated with herbicide in the high input "green gold" alfalfa-corn system (CS4a) are relatively low at both sites. Soil samples are taken in the spring after manure has been applied in the fall and this may add weed seeds in this system. Nearly all weeds in this system are broadleaves at both sites except for system 4d at LAC which is about half grass and half broadleaves, but the tendency has been for a shift to a higher percentage of broadleaf weeds.

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Table 1. Weed seedbank changes in WICST at the Arlington Ag. Research Station from 1990 - 1995.

Trt	Cropping sys.	CS no.	Variable	90	91	92	93	94	95
				C	C	C	C	C	C
1	Contin. corn	1	seeds/ft^2	448	166	206	266	171	--
			% bdlf	86	84	87	86	81	--
			% grass	14	16	13	14	19	--
				C	Sb	C	Sb	C	Sb
2	Cn-Sb	2b	seeds/ft^2	--	144	--	215	--	280
			% bdlf	--	70	--	86	--	93
			% grass	--	30	--	14	--	7
				Sb	C	Sb	C	Sb	C
3	Sb-Cn	2a	seeds/ft^2	429	480	571	--	807	--
			% bdlf	75	73	78	--	88	--
			% grass	25	27	22	--	12	--
				F	F	Sb	Wh	CSb	
4	F-F-Sb-Wh/RdCl-C	3c	seeds/ft^2	--	--	1066	--	725	471
			% bdlf	--	--	88	--	64	51
			% grass	--	--	12	--	56	49
				Sb	Wh	C	Sb	Wh	C
5	Sb-Wh/RdCl-C	3a	seeds/ft^2	206	459	894	850	--	--
			% bdlf	68	80	85	83	--	--
			% grass	32	20	15	17	--	--
				F	Sb	Wh	C	Sb	Wh
6	F-Sb-Wh/RdCl-C	3b	seeds/ft^2	--	703	--	1079	1035	--
			% bdlf	--	88	--	67	43	--
			% grass	--	12	--	33	57	--
				A	A	A	C	A	A
7	A-A-A-C	4a	seeds/ft^2	472	264	--	--	239	--
			% bdlf	82	81	--	--	93	--
			% grass	18	19	--	--	7	--
				F	A	A	A	C	A
8	F-A-A-A-C	4b	seeds/ft^2	--	288	--	--	1141	341
			% bdlf	--	59	--	--	99	96
			% grass	--	41	--	--	1	4
				F	F	A	A	A	C
9	F-F-A-A-A-C	4c	seeds/ft^2	--	--	584	--	--	272
			% bdlf	--	--	90	--	--	94
			% grass	--	--	10	--	--	6
				F	F	F	A	A	A
10	F-F-F-A-A-A-C	4d	seeds/ft^2	--	--	720	269	--	--
			% bdlf	--	--	93	88	--	--
			% grass	--	--	7	12	--	--
				O	A	C	O	A	C
11	O/A-A-C	5a	seeds/ft^2	444	755	692	339	--	385
			% bdlf	82	64	91	95	--	77
			% grass	18	36	9	5	--	23
				F	O	A	C	O	A
12	F-O/A-A-C	5b	seeds/ft^2	--	546	--	506	717	--
			% bdlf	--	82	--	88	86	--
			% grass	--	18	--	12	14	--
				F	F	O	A	C	O
13	F-F-O/A-A-C	5c	seeds/ft^2	--	--	1198	--	321	275
			% bdlf	--	--	86	--	90	83
			% grass	--	--	14	--	10	17
				P	P	P	P	P	P
14	Pasture	6	seeds/ft^2	386	405	--	--	--	377
			% bdlf	82	75	--	--	--	89
			% grass	18	25	--	--	--	11

Table 2. Weed seedbank changes in WICST at the Lakeland Agric. Complex from 1990 through 1995.

Trt	Cropping sys.	CS no.	Variable	90	91	92	93	94	95
				C	C	C	C	C	C
1	Contin. corn	1	seeds/ft^2	190	68	152	310	361	--
			% bdlf	87	72	80	74	56	--
			% grass	13	28	20	26	44	--
				C	Sb	C	Sb	C	Sb
2	C-Sb	2b	seeds/ft^2	--	22	--	206	--	512
			% bdlf	--	50	--	50	--	49
			% grass	--	50	--	50	--	51
				Sb	C	Sb	C	Sb	C
3	Sb-Cn	2a	seeds/ft^2	193	174	106	--	131	--
			% bdlf	28	22	51	--	77	--
			% grass	72	78	49	--	33	--
				F	F	Sb	Wh	C	Sb
4	F-F-Sb-Wh/RdCl-C	3c	seeds/ft^2	--	--	570	--	275	418
			% bdlf	--	--	33	--	70	66
			% grass	--	--	67	--	23	34
				Sb	Wh	C	Sb	Wh	C
5	Sb-Wh/RdCl-C	3a	seeds/ft^2	196	328	1117	1288	--	--
			% bdlf	42	7	42	44	--	--
			% grass	58	93	58	56	--	--
				F	Sb	Wh	C	Sb	Wh
6	F-Sb-Wh/RdCl-C	3b	seeds/ft^2	--	81	--	272	1570	--
			% bdlf	--	42	--	63	21	--
			% grass	--	53	--	37	79	--
				A	A	A	C	A	A
7	A-A-A-C	4a	seeds/ft^2	236	956	--	--	315	--
			% bdlf	47	14	--	--	84	--
			% grass	53	86	--	--	16	--
				F	A	A	A	C	A
8	F-A-A-A-C	4b	seeds/ft^2	--	68	--	--	228	151
			% bdlf	--	68	--	--	96	95
			% grass	--	32	--	--	4	5
				F	F	A	A	A	C
9	F-F-A-A-A-C	4c	seeds/ft^2	--	--	117	--	--	204
			% bdlf	--	--	65	--	--	95
			% grass	--	--	35	--	--	5
				F	F	F	A	A	A
10	F-F-F-A-A-A-C	4d	seeds/ft^2	--	--	125	380	--	--
			% bdlf	--	--	63	46	--	--
			% grass	--	--	37	54	--	--
				O	A	C	O	A	C
11	O/A-A-C	5a	seeds/ft^2	307	646	454	587	--	194
			% bdlf	28	11	31	46	--	84
			% grass	72	89	69	54	--	16
				F	O	A	C	O	A
12	F-O/A-A-Cn	5b	seeds/ft^2	--	92	--	112	625	--
			% bdlf	--	47	--	88	19	--
			% grass	--	53	--	12	81	--
				F	F	O	A	C	O
13	F-F-O/A-A-C	5c	seeds/ft^2	--	--	462	--	206	242
			% bdlf	--	--	25	--	64	56
			% grass	--	--	75	--	36	44
				P	P	P	P	P	P
14	Pasture	6	seeds/ft^2	136	951	--	--	--	168
			% bdlf	50	7	--	--	--	79
			% grass	50	93	--	--	--	21

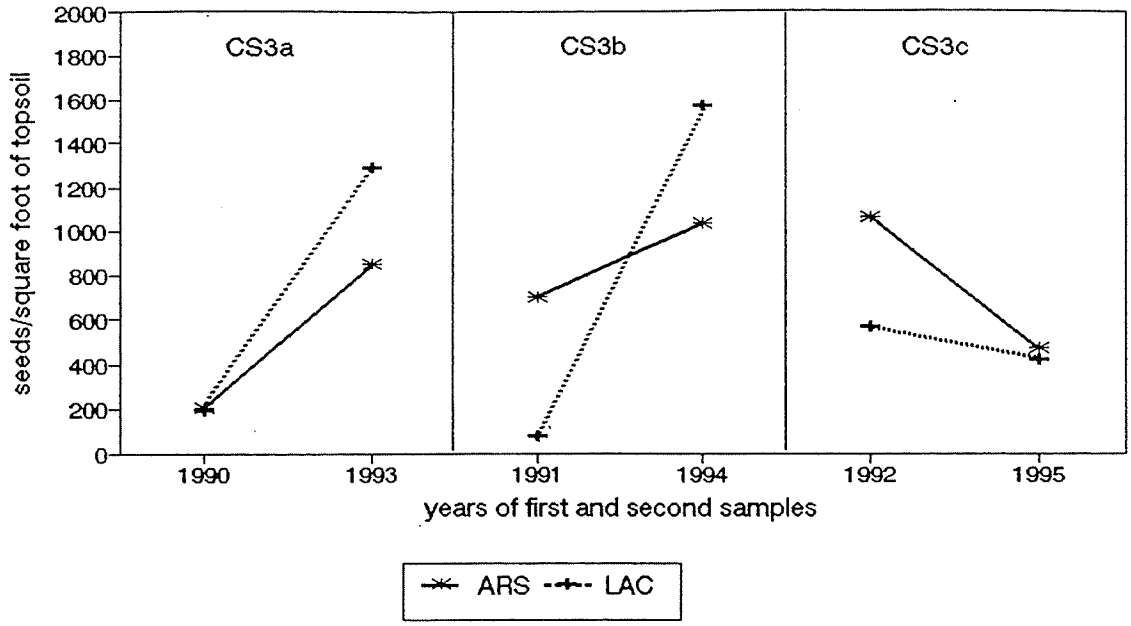

Figure 1. WICST CS3 weed seed changes during a complete rotation cycle

* seeds counted in the spring following the corn phase of the rotation

Weed seed populations in the rapid turn around oats-alfalfa-corn system (CS5) followed a similar pattern to CS3. Weed control has improved with the third time we initiated this system (CS5c compared to CS5a and 5b). Improved rotary hoeing cultivating skills and harvesting the oats as oatlage have helped suppress weed populations at both sites. Broadleaves have always predominated in CS5 at ARS, but the species composition varies greatly between systems at LAC. The continuous pasture system (CS6) has low weed seed densities at both sites and the populations are essentially the same as when the trial started in 1990.

In summary, the weed seed bank populations in the high and moderate input cash grain systems are relatively low to moderate and broadleaves generally comprise more than 85% of the population. Populations in the mechanically weeds cash grain systems are generally steady or decreasing, but were at high (ARS) to severe (LAC) levels in CS3b in 1994. In 1995 the seed populations were moderate at both sites in CS3. Broadleaves predominate in all CS3 phases except 3b in 1994. In the high input livestock based systems, seed bank populations vary by phase of the system and site, but populations are generally low. Broadleaf species are heavy to very heavy at both sites. In the medium input livestock systems (CS5), seed bank populations are low to moderate and density changes are generally consistent across locations, but often vary within the phase of the system.

Biomass results

Weed biomass was low in system CS1 at both sites; in the soybeans of systems CS2b at ARS and the corn of system CS2a at LAC; and the corn of both sites in system CS4 (Table 3). Weed biomass was low in the soybeans in the low input system (CS3) at both sites and for corn at ARS, but biomass was moderate for corn in this system at LAC. Weed biomass in CS5 was light to moderate. Broadleaves generally predominate in the biomass data, but there is much variation between systems and sites.

Table 3. Weed biomass dry weight in the WICST trials in early July at the Arlington Agricultural Research Station and the Lakeland Agricultural Complex for 1992 - 1995.

Trt	Cropping system 90-91-92-93-94-95	CS no.		ARS				LAC			
				92	93	94	95	92	93	94	95
1	C-C-C-C-C-C	1	lb/acre	9	2	10	4	48	< 1	2	1
			% bdlf	100	72	90	96	77	0	25	92
			% grass	0	28	10	4	23	100	75	8
2	C-S-C-S-C-S	2b	lb/acre	27	12	2	2	16	19	59	-
			% bdlf	82	77	85	26	63	90	40	-
			% grass	18	33	15	74	37	10	60	-
3	S-C-S-C-S-C	2a	lb/acre	179	4	2	85	160	3	9	28
			% bdlf	61	48	0	22	100	96	95	27
			% grass	39	52	100	78	0	4	5	73
4	C-C-SW-WR-C-SW	3c	lb/acre	137	-	255	12	21	-	117	5
			% bdlf	81	-	75	11	10	-	83	26
			% grass	19	-	25	89	90	-	17	74
5	SW-WR-C-SW-WR-C	3a	lb/acre	46	44	-	16	21	44	-	73
			% bdlf	87	88	-	70	37	31	-	11
			% grass	13	12	-	30	63	69	-	89
6	C-CW-WR-C-SW-WR	3b	lb/acre	-	161	242	-	-	160	69	-
			% bdlf	-	19	47	-	-	28	11	-
			% grass	-	81	53	-	-	72	89	-
7	A-A-A-C-A-A	4a	lb/acre	-	13	-	-	-	18	-	-
			% bdlf	-	21	-	-	-	76	-	-
			% grass	-	79	-	-	-	24	-	-
8	C-A-A-A-C-A	4b	lb/acre	-	-	6	-	-	-	12	-
			% bdlf	-	-	85	-	-	-	85	-
			% grass	-	-	15	-	-	-	15	-
9	C-C-A-A-A-C	4c	lb/acre	-	-	-	4	-	-	-	35
			% bdlf	-	-	-	4	-	-	-	70
			% grass	-	-	-	96	-	-	-	30
10	C-C-C-A-A-A	4d	lb/acre	-	-	-	-	-	-	-	-
			%bdlf	-	-	-	-	-	-	-	-
			% grass	-	-	-	-	-	-	-	-
11	O/A-A-C-O/A-A-C	5a	lb/acre	60	-	-	29	186	-	-	65
			% bdlf	95	-	-	70	58	-	-	61
			% grass	5	-	-	30	42	-	-	39
12	C-O/A-A-C-O/A-A	5b	lb/acre	-	46	-	-	-	36	-	-
			% bdlf	-	50	-	-	-	57	-	-
			% grass	-	50	-	-	-	43	-	-
13	C-C-O/A-A-C-O/A	5c	lb/acre	-	-	131	-	-	-	201	-
			% bdlf	-	-	90	-	-	-	67	-
			% grass	-	-	10	-	-	-	33	-

Superimposed results.

We again tried to determine the impact on yields and profitability of uncontrolled weeds in the mechanically weeded corn and soybeans of the low input cash grain system (CS3) at LAC. Weed populations at ARS did not justify making such applications (as seen by the low biomass weights for Systems 3b and 3c in Table 3). The appropriate superimposed treatments were applied to two subplots four rows wide and 40 ft long in each of the four large plots for each crop on July 5. Treatments were applied after all the mechanical weeding was complete. Corn received a mixture of Clarity (dicamba) at .5 pt/a and Accent (nicosulfuron) at .67 oz/a. The soybeans were treated with Poast Plus (sethoxydim) at 24 fl oz/a plus 1 qt/a of a crop oil concentrate as only grasses were present. Weed pressure and control ratings were taken at the time of application and again at harvest. Table 4 shows that in each crop uncontrolled weeds reduced yield.

Table 4. Effect of removing annual weeds with postemergence herbicides in corn and soybeans of the low input, cash grain system (CS3) at LAC in 1995 (superimposed trial).

Site/ year	Corn			Soybean		
	yield bu/acre	Diff. with herb., bu	Change net ret. $/acre	Yield bu/acre	Diff. with herb., bu	Change net ret. $/acre
LAC/94	179	+23	14.90	40.8	+16.8	68.65
ARS/94	186	+15	.50	45.2	+6.9	21.10
LAC/95	142	+10	1.55	53.2	4.7	14.78

[1] Value of increased yield calculated by multiplying value in dollars per bushel by the increase in bushels; values used were those at the time of harvest.

[2] Costs are based on $5.00 (labor and machinery costs) for the application and the following values for herbicides and additives:
- corn at ARS and LAC treated with .67 oz/a Accent ($17.75), 0.5 pt/a Clarity ($5.25) and 0.25% NIS ($0.75) = $23.75/acre.
- soybeans at ARS 7 oz/a Assure ($7.75) and 1 qt/a crop oil concentrate ($1.00) = $8.75/acre.
- soybeans at LAC 7 oz/a Assure ($7.75), 0.25 oz/a Pinnacle ($7.40), 0.25% NIS ($0.75) and 1 gal/acre 28%N ($1.00) = $1.00) = $16.90/acre.

[3] Superimposed trial not done at Arlington in 1995 due to lack of weeds in mechanically weeded system.

A second trial was superimposed on the corn phase of CS5 (oats/alfalfa-alfalfa-corn) to determine the impact of quackgrass on corn yield. There were quackgrass areas in all four reps of the plots with this treatment but on only one rep was it serious enough that we decided to apply Accent (nicosulfuron) at .67 oz/a to the whole plot. On the other three reps a postemergence application of Accent at .67 oz/a was applied June 14 to the six border rows (not considered when determining whole plot yield) to control quackgrass encroachment from the alleys.

Since there were also some areas of quackgrass in the center of +these plots, we wanted to determine if the decision to not use a rescue herbicide was correct. The plots were rotary hoed three times and cultivated twice with a danish tine cultivator. The plots were scouted following the first cultivation on June 12 (10" corn height) to determine areas of high quackgrass pressure and no quackgrass. Six subplots (two with quackgrass, two without quackgrass, and two in the border rows where herbicide had been applied) were chosen in each plot. Subplot size was 5 ft (two rows) wide x 30 ft long. Corn was hand harvested in the fall to determine yield. Table 5. Shows that yield and economic return were reduced by the quackgrass but since the quackgrass subplots represented small areas of highest quackgrass competition, when averaged over the entire plots, not applying herbicide appears to have been the right decision.

Table 5. Effect of quackgrass on corn yield in the low input dairy system (CS5) at ARS in 1995 (superimposed trial).

CS5 Corn following alfalfa		
Treatment	yield (bu/acre)	corn value less herb. costs ($/acre)
quackgrass - no herbicide	167	426
no quackgrass - no herbicide	186	474
quackgrass - herbicide	187	454

[1] Corn valued at $2.55/bushel

[2] Herbicide costs of $22.94/acre based on $5.00/acre labor and machinery costs for application and $17.94/acre for Accent.

4. Monitoring Soil Test Phosphorus and Potassium Changes in the WICST Trial

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ABSTRACT

Farmers are concerned about the effects of low-input cropping systems on soil fertility, even on the historically rich and heavily manured and fertilized prairie soils of Wisconsin. Soil test phosphorus (STP) and potassium (STK) changes in the top 6 in. of the soil profile are being monitored in the WICST trial since 1990. The initial STP and STK values were in the high to excessively high range at both sites (STP 59-89 ppm and STK 182-238 ppm). No inorganic P or K fertilizers were applied in the low-input systems. Dairy manure was applied at a rate of 10 T/acre/yr before the corn and seeding phases in the forage-based systems. The STP levels dropped by a rate of 7 ppm/yr in the low-input cash grain (soybean-wheat/red clover-corn) and forage (rotationally grazed) systems at the Arlington site and at a rate of 4 ppm/yr at the less productive Lakeland site. The STK values decreased at a faster rate than the STP values, especially in the forage-based low-input systems. These data suggest that although these systems are "mining" the soil, they may remain economically viable for at least another 10 years.

INTRODUCTION

During the past two decades, farmers have applied phosphorus and potassium fertilizers in excess of crop removal, expecting greater yields and profits. As a consequence of these P and K fertilization practices, the soil test summaries of results from the Univ. of Wisconsin Soil Testing Laboratory (Table 1) show that the state average STP has increased by 41% from 1968-73 to 1986-90. Similarly, the average STK value has increased by 51% during the same period. Although the high-input systems have resulted in a build-up of soil fertility on many conventional farms, many farmers and scientists feel that the low- or zero-input systems will simply mine the soil and ultimately reach an equilibrium at an uneconomically low yield level. Therefore, it was decided to monitor the changes in the soil test phosphorus and potassium levels in the WICST.

Table 1. Changes in the State Average Soil Test Phosphorus and Potassium Values with Time for Wisconsin†.

	Summary Period				
Soil test (mg kg^{-1})	1968-73	1974-77	1978-81	1982-85	1986-90
P	34	37	40	44	48
K	88	98	106	124	133
No. of samples (x 10^{-3})	513	477	670	513	414

† Source: Schulte (1986);Combs and Bullington (1992)

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[2]Project Coordinator, interim Project Coordinator and Project Statistician, and Project Manager, respectively.

MATERIALS AND METHODS

Inputs: No inorganic P or K fertilizers were applied in the low-input systems (CS3, CS5, and CS6) while the corn in CS1, CS2, and CS4 received inorganic P and K in the form of starter fertilizer (100 lb/acre of 6-24-24). Dairy manure was applied at a rate of 10 T/acre/yr (approximate nutrient analysis of 12-8-16 lb/T) prior to the corn and seeding phases in the machine-harvested, forage-based (CS4 and CS5) systems. In CS6 we estimated that the animals would deposit 10 T/acre during the 150-day grazing season.

Soil sampling for available P and exchangeable K took place in the fall on each plot. Sampling consisted of three composite samples per plot. Each composite sample contained six cores. The six cores were taken in two groups of three, such that the three cores in a group are taken in the row, 7 in. from the row, and 15 in. from the row. We expect this sampling scheme to result in variances of the mean that are less than 15% above the minimum possible level. We also expect that if the ln transformation is used, the homogeneity of the variances will be improved and the CVs will be below 10%.

Soil available P and exchangeable K were analyzed after extraction with 0.03 N NH_4F in 0.025 N KCl (Bray-1 extract) according to the methods of Schulte et al. (1987).

RESULTS

In this paper, the change in the STP and STK in all the six cropping systems is discussed for those plots that were initiated in 1990 (Fig 1-2). A simple linear regression analysis was conducted over the 6-yr period (1989-1995) to determine the rate of change (per year) in the STP and STK values (Table 2).

Cash Grain Systems:

The use of starter fertilizer during the corn phase in CS1 and CS2 almost cover the P and K needs of the system at the less productive LAC site while at the more productive ARS site, there is a 4-6 ppm/yr drawdown in P levels in CS1 and CS2.

In CS3 there has been a rapid drawdown of P and K at both sites. The drawdown in soil test P and K is reflected by the negative balance for both P and K nutrients in this system at both sites (Tables 3 and 4).

Forage Dairy Systems:

Dairy manure additions based on the current stocking rate of a cow +replacements/4 acres results in a "mathematical" accumulation of P and K at both sites in years when dairy manure was applied and in large negative balances in years when no dairy manure was applied, especially for K (Tables 3 and 4). Actual STP and STK levels however, are dropping probably due to the fact the added P and K in manure is not all being identified in the procedure for estimating available P and exchangeable K.

The organic rotational grazing system is experiencing a P drawdown similar to the low-input cash grain system while the STK values are dropping at a much faster rate in CS6 compared to CS3 at the ARS site.

The gross margins (market value of the crop minus variable costs such as seed, fertilizer, pesticides, leased equipment, fuel, repairs, interest, etc) have been competitive for the CS3 system. By 1994, it was the most profitable system at Arlington and equal to corn-soybean (CS2) system at Lakeland. Weight gains for the heifers in the organic grazing system (S6) have been about 1.8 lb/day and the average relative feed value (RFV) on the paddocks has been a respectable 140 over the past 3 years.

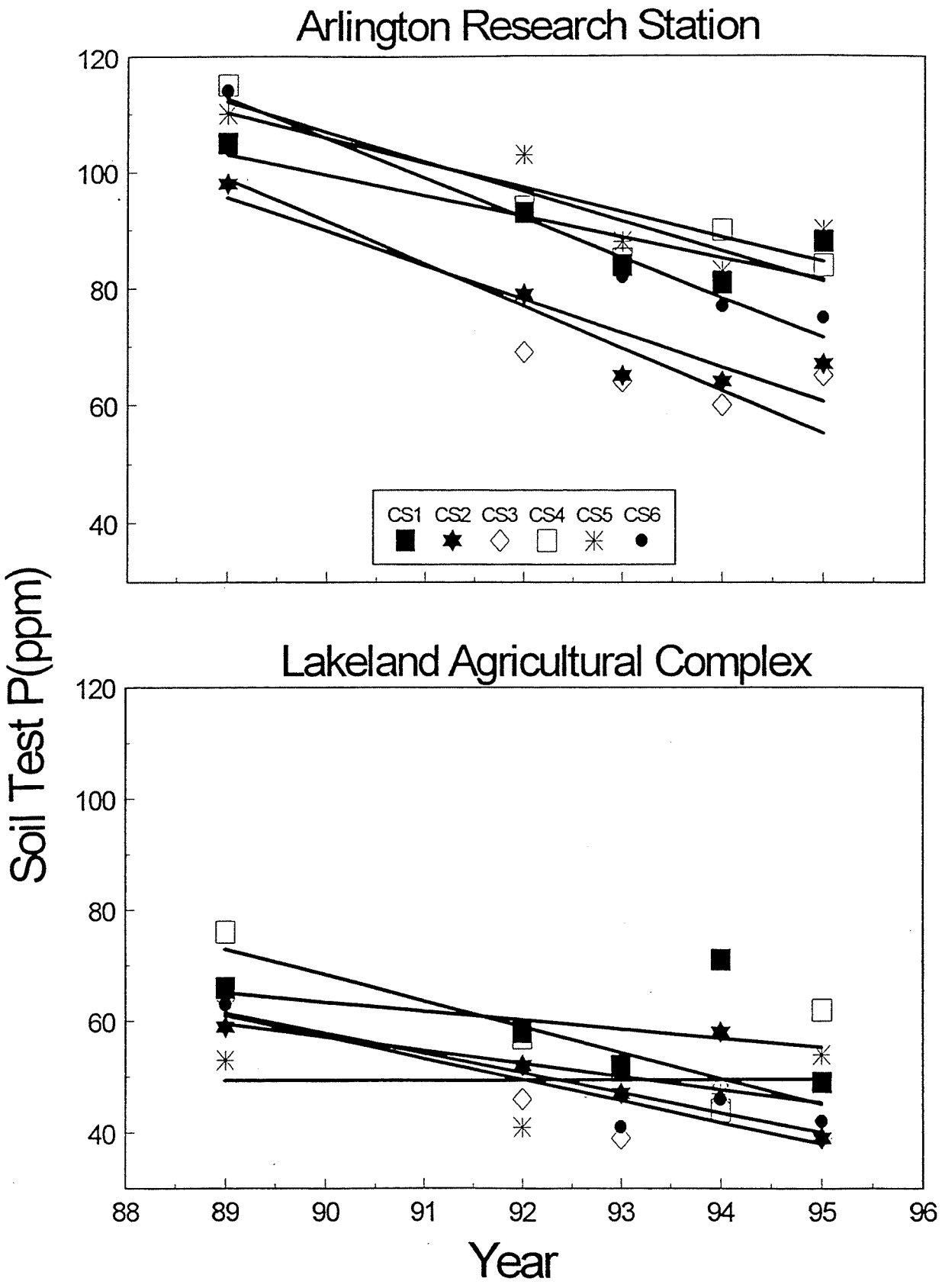

Figure 1. Change in soil test P over years in the WICST Trial

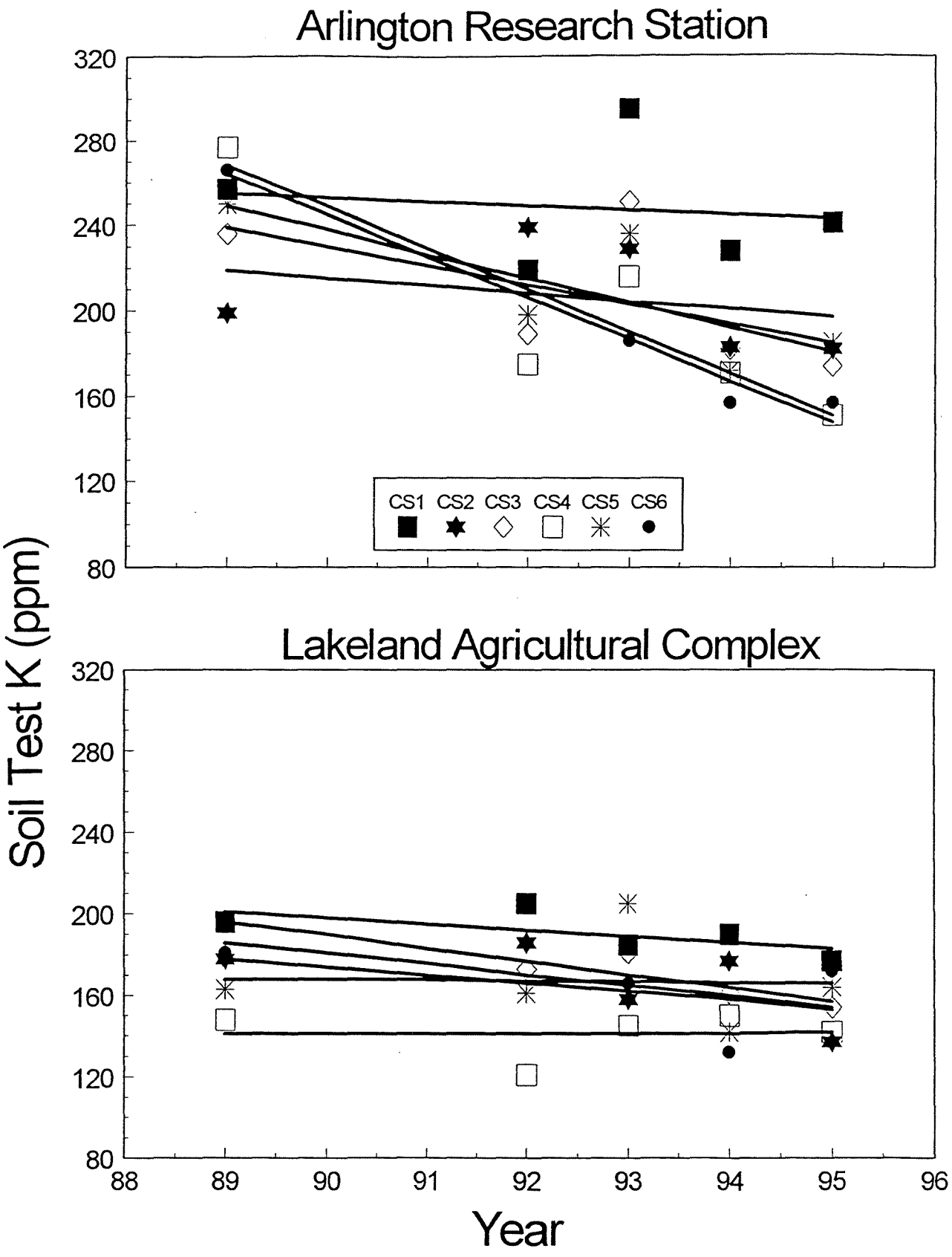

Figure 2. Change in soil test K over years in the WICST Trial

Table 2. Rate of Change in the Soil Test P and K in Different Cropping Systems Based on the Regression Analysis in the WICST Trial during 1989-95.

	Soil Test Phosphorus (ppm)				Soil Test Potassium (ppm)			
Cropping System	ARS	Pr > F	LAC	Pr > F	ARS	Pr > F	LAC	Pr > F
CS1. Cont. corn	-3.5	0.054	-1.6	0.498	-1.9	0.811	-3.0	0.234
CS2. Sb-C	-5.8	0.020	-2.4	0.229	-3.5	0.611	-5.3	0.266
CS3. Sb-W/rc-C	-7.2	0.033	-3.8	0.058	-8.9	0.289	-6.5	0.024
CS4. A-A-A-C	-5.1	0.019	-4.6	0.043	-19.5	0.039	0.2	0.960
CS5. O/A-A-C	-4.3	0.054	0.04	0.980	-11.3	0.121	-0.4	0.946
CS6. Pasture†	-6.8	0.013	-3.6	0.083	-19.3	0.012	-4.1	0.495

† Mixture of brome, timothy, and red clover.
ARS = Arlington Research Station; LAC = Lakeland Agricultural Complex.
Sb = soybean; C = corn; W/rc = wheat/red clover; A = alfalfa; O/A = oats/alfalfa companion seeded.

CONCLUSIONS

Even though the low-input systems are "mining" the soil, based on the draw-down rates in the initial 6 yr of the trial, we calculated that it would take at least another 10 yr for both the STP and STK levels to reach the critical level at both sites. Also, the gross margins of the low-input cash-grain system, CS3 were comparable to the conventional (CS2) corn-soybean system. In the low-input CS6 system, although the STP and STK values are decreasing at a faster rate, the weight gain of the dairy heifers was very close to our target of 1.8 lb/animal/day at both sites. The results from this study suggest that reduced P and K fertilization does not appear to have adversely affected yields during the first 6 yr of the trial.

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* Appendix III is a record of the P and K soil levels by system for each site and year.

Table 3. Phosphorus and Potassium Nutrient Balance at Arlington Agricultural Research Station (1989-1995)†.

	Crop						Phosphorus						Potassium					
Year	90	91	92	93	94	95	90	91	92	93	94	95	90	91	92	93	94	95
Cropping System							---------- lb/acre ----------						---------- lb/acre ----------					
CS1	C	C	C	C	C	C	-15	-14	-11	-4	-16	-8	-8	-7	-7	-4	-13	-33
CS2	Sb	C	Sb	C	Sb	C	-21	-18	-11	-6	-16	-12	-62	-11	-33	-7	-48	-44
CS2	*f*	Sb	C	Sb	C	Sb	-	-23	-11	-20	-16	-19	-	-66	-8	-63	-14	-64
CS3	Sb	W/c	C	Sb	W/c	C	-19	-15	-15	-19	-16	-23	-56	-40	-18	-60	-27	-62
CS3	*f*	Sb	W/c	C	Sb	W/c	-	-18	-9	-11	-15	-13	-	-57	-19	-19	-46	-49
CS3	*f*	*f*	Sb	W/c	C	Sb	-	-	-14	-16	-28	-20	-	-	-42	-82	-36	-67
CS4	A	A	A	C	A	A	+42	-33	-26	+42	+15	-24	-85	-242	-215	+214	-72	-193
CS4	*f*	A	A	A	C	A	-	+35	-23	-23	+17	+32	-	-128	-213	-206	+168	-4
CS4	*f*	*f*	A	A	A	C	-	-	+41	-29	-25	+39	-	-	-13	-246	-222	+128
CS4	*f*	*f*	*f*	A	A	A	-	-	-	+31	-27	-17	-	-	-	+35	-281	-132
CS5	O/a	A	C	O/a	A	C	+25	-33	+32	+31	-31	+17	-113	-261	+178	+80	-335	+68
CS5	*f*	O/a	A	C	O/a	A	-	+29	-30	+24	+7	-32	-	-55	-266	+146	-162	-217
CS5	*f*	*f*	O/a	A	C	O/a	-		+30	-32	-2	+16	-	-	-34	-263	+101	-85
CS6	P	P	P	P	P	P	+8	+3	+15	+20	-18	-9	-220	-190	-58	+91	-136	-67

† Nutrient additions by fertilizer or manure and removal by crop harvest.
‡ Nutrient additions from manure, fertilizer, fed hay, and fed grain and removal from live weight gain of animals and harvested hay.
f = filler corn (grown before initiation of each rotation).

Table 4. Phosphorus and Potassium Nutrient Balance at Lakeland Agricultural Complex (1989-1995)†.

	Crop						Phosphorus						Potassium					
Year	90	91	92	93	94	95	90	91	92	93	94	95	90	91	92	93	94	95
Cropping System							---------- lb/acre ----------						---------- lb/acre ----------					
CS1	C	C	C	C	C	C	-18	-16	-12	-5	-14	-11	-18	-13	-12	-6	-30	-9
CS2	Sb	C	Sb	C	Sb	C	-18	-11	-16	-5	-22	-8	-57	0	-51	-6	-63	-6
CS2	*f*	Sb	C	Sb	C	Sb	-	-20	-13	-17	-18	-17	-	-63	-13	-58	-30	-59
CS3	Sb	W/c	C	Sb	W/c	C	-18	-5	-11	-10	-19	-16	-58	-19	-13	-35	-84	-23
CS3	*f*	Sb	W/c	C	Sb	W/c	-	-18	-5	-10	-15	-15	-	-56	-6	-18	-47	-45
CS3	*f*	*f*	Sb	W/c	C	Sb	-	-	-19	-14	-23	-19	-	-	-59	-91	-46	-65
CS4	A	A	A	C	A	A	+73	-21	-25	+78	+63	-33	+266	-211	-206	+299	+185	-234
CS4	*f*	A	A	A	C	A	-	+85	-25	-19	+54	+106	-	+251	-220	-190	+285	+362
CS4	*f*	*f*	A	A	A	C	-	-	+45	-20	-28	+105	-	-	+414	-176	-296	+420
CS4	*f*	*f*	*f*	A	A	A	-	-	-	+82	-26	-23	-	-	-	+274	-218	-175
CS5	O/a	A	C	O/a	A	C	+49	-19	+24	+56	-26	+66	+146	-171	+341	+133	-218	+293
CS5	*f*	O/a	A	C	O/a	A	-	+53	-23	+59	+39	-30	-	+102	-207	+227	+106	-243
CS5	*f*	*f*	O/a	A	C	O/a	-		+31	-25	+34	+76	-	-	+232	-230	+200	+227
CS6	P	P	P	P	P	P	+37	+24	+16	-5	-7	-7	+133	-63	+204	-1	-17	-22

† Nutrient additions by fertilizer or manure and removal by crop harvest.
‡ Nutrient additions from manure, fertilizer, fed hay, and fed grain and removal from live weight gain of animals and harvested hay.
f = filler corn (grown before initiation of each rotation).

5. Monitoring Fall Nitrates in the Wisconsin Integrated Cropping Systems Trial

T.K. Iragavarapu[1], J.L. Posner[2], J.O. Baldock[2], and T.A. Mulder[2]

ABSTRACT

Minimizing the amount of inorganic N in the rooting zone following crop harvest reduces the potential for nitrate-N (NO_3-N) losses via leaching to groundwater. Soil NO_3-N levels in the top 3 ft. of the soil profile are being measured since 1990 in all six cropping systems of the WICST. Among the cash grain systems, fall nitrates were highest for continuous corn and lowest in the three-phase system (CS3 - soybean-wheat frost seeded with red clover-corn) without any inorganic fertilizer-N additions. Among the forage-based systems, fall nitrates were lowest in the low-input continuous pasture (CS6) while nitrate levels were similar between CS4 and CS5. Among the different phases, nitrate levels were highest for corn grown after plowing down alfalfa and dairy manure. These data suggest that very careful N management during the corn phase is the key to reducing fall soil nitrate levels, and that in forage systems, there can be a large NO_3-N surplus in the soil following the corn phase.

INTRODUCTION

The amount of inorganic N remaining in the soil profile following crop harvest is an important factor that reflects the nitrate leaching potential of a particular field situation. The two major reasons that NO_3-N accumulates after crop harvest are: a) N uptake was less than expected (due to poor soil structure, drought, pest damage, etc.), and b) over fertilization (due to overestimation of crop yield, failure to credit the N in manure or previous legume crops, greater mineralization than anticipated, etc). Since one of our objectives was to measure the environmental impact of alternative cropping systems, it was decided to monitor the soil NO_3-N levels under the six cropping systems of the WICST.

MATERIALS AND METHODS

Continuous corn (CS1) was fertilized according to the spring preplant nitrate-N test while the corn in CS2 received 40 lb N/acre soybean credit. Corn in the CS3 system did not receive any inorganic N while the corn in CS4 and CS5 received 20 and 15 T/acre of dairy manure, respectively (Table 1). Dairy manure was applied to the seeding phase and the corn phases in CS4 and CS5 to equal an annual application rate of 10 T/acre (50-cow herd with replacements on 200 tillable acres produces on an average 8.1 tons of manure/acre/yr- we rounded it to 10 t/A/yr). Manure was applied at an annual rate of 10 T/acre for CS6 through 1992. Starting in 1993, rotational grazing was started at both locations in CS6.

1993, the number of cores were increased to six in groups of three, such that the three cores in a group are taken in the row, 7.5 in. and 15 in. from the row (or equivalent in non-row crops).

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[2] Project Coordinator, interim Project Coordinator and Statistician, and Project Manger, respectively.

Table 1. Available N in the dairy manure applied in the fall at Arlington Research Station and Lakeland Agricultural Complex in 1990-94†.

Location	Arlington Res. Station					Lakeland Agri. Complex				
Year	1990	1991	1992	1993	1994	1990	1991	1992	1993	1994
Cropping System	lb/acre									
CS4	106	86	79	71	84	102	104	124	108	110
CS5	79	64	59	53	63	76	78	93	81	82
CS6	53	43	39	36	42	51	52	62	54	53

† First year "available N" was calculated as 40% of the total N content in the manure. Dairy stacked manure was applied to the seeding phase and the corn phase at a rate of 20 T/acre and 15 T/acre in CS4 and CS5 systems, respectively, and at an annual rate of 10 T/acre in CS6.
CS4 = Alfalfa-alfalfa-alfalfa-corn; CS5 = Oats/alfalfa-alfalfa-corn; CS6 = Continuous pasture.

In 1990, 1991, and 1992 soil samples were collected in 1 ft. increments to a depth of 3 ft. with a 1.5 in. diameter probe. Five cores were taken per plot and composited by depth. In On eight of the 14 treatments (phases), soil samples were taken to a 2 ft. depth and nitrates in the 2-3 ft. depth were predicted by the nitrate levels in the 1-2 ft. depth. Nitrate data from 1990-92 were used to develop regression equations to predict nitrates in the 2-3 ft. depth.

RESULTS

Nitrate levels among the cropping systems were compared on a whole-farm basis and also among the different phases of the six systems. A whole-farm comparison was done in 1993, 1994, and 1995 when all the phases in each of the six cropping systems were present (Fig 1). This comparison was made by taking the proportionate amounts of fall NO_3-N from each of the phases in a system in a particular year. For example, in a CS2 system we assumed that one-half of the farm was in soybeans and the other half in corn. As a result, farm-wide fall nitrate levels is the average of the levels under each crop.

Nitrate levels were highest in the continuous corn system (CS1) and lowest in CS6 at ARS in 1994 and 1995. At LAC however, nitrate levels in the forage systems (CS4, CS5, and CS6) did not differ from those in the continuous corn system possibly due to lower forage yields in these systems.

Among the different phases, corn is the major contributor to the NO_3-N levels in all the systems as seen in Table 2. The surplus N balance for corn in CS4 and CS5 (Table 3) is reflected in higher amounts of fall nitrates following corn in these two systems. Fall nitrates were consistently lower following wheat/red clover phase of the CS3.

CONCLUSIONS

The data from this trial indicate that plowed down alfalfa and manure applications could result in a build-up of fall nitrates following corn harvest, especially if recovery of N by the corn is poor due to unfavorable growing conditions. With the exception of CS1, within a given year the differences among the other five systems were small. Fall nitrate levels differed significantly among the different phases in the six cropping systems at both locations.

* Appendix IV is a record of groundwater nitrate levels in the wells under the LAC cropping systems.

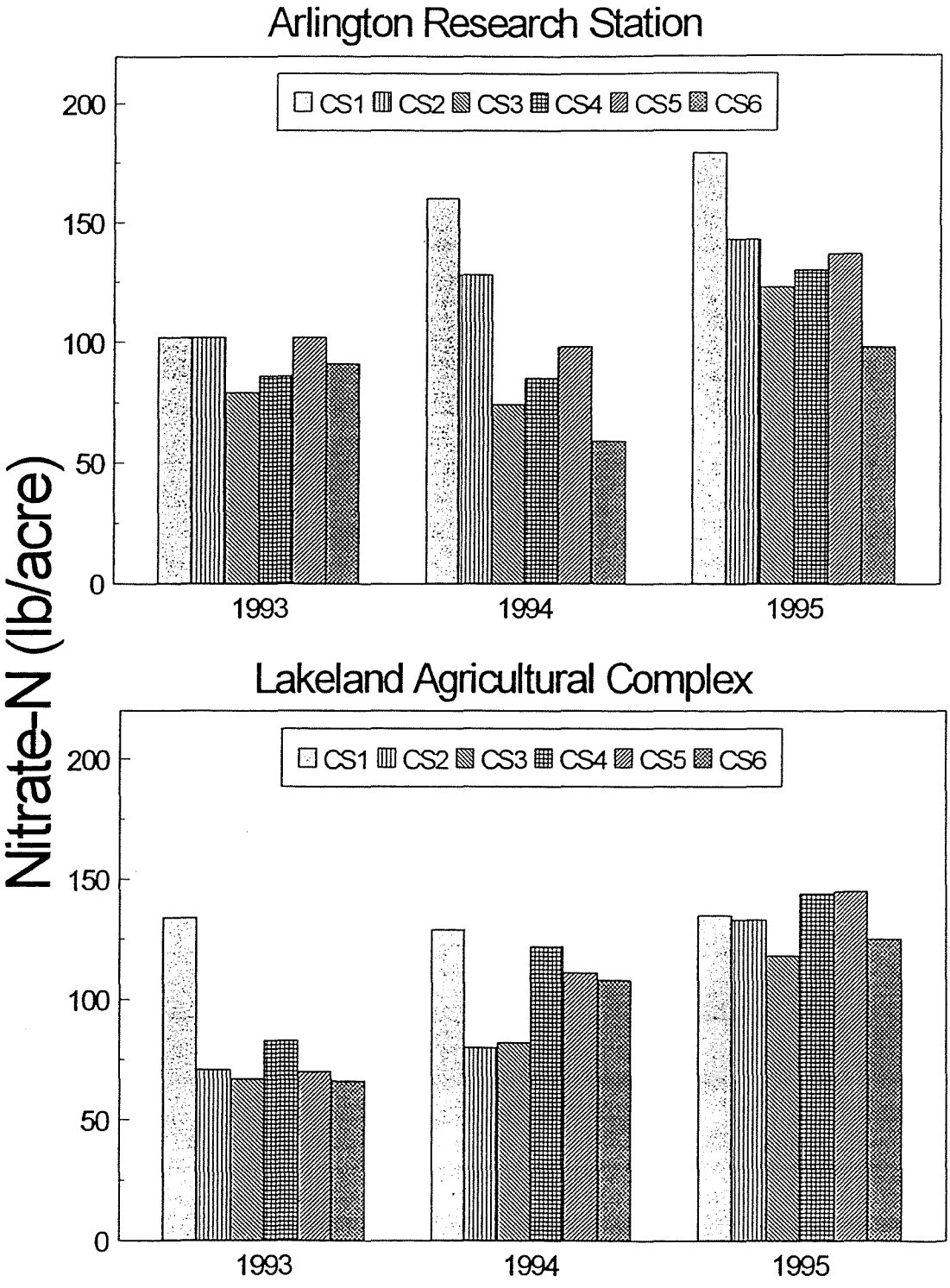

Figure 1. Nitrate-N in the 0-3 ft. Profile after crop harvest in the WICST trial in 1993-95.

Table 2. Fall Nitrates in the top 3 ft of the soil at the Arlington Research Station and Lakeland Agricultural Complex sites in 1990-1995.

	Arlington Research Station						Lakeland Agricultural Complex					
Year	1990	1991	1992	1993	1994	1995	1990	1991	1992	1993	1994	1995
Cropping system	lb/A											
Corn:												
CS1. Continuous Corn	87	48	97	102	160	179	198	132	86	134	129	135
CS2. Corn after Soybeans	-†	41	105	105	172	141	-	125	78	57	81	146
CS3. Corn after Red Clover	-	-	67	83	102	144	-	-	62	59	119	130
CS4. Corn after Alfalfa	-	-	-	142	170	184	-	-	-	122	215	209
CS5. Corn after Alfalfa	-	-	101	118	156	202	-	-	81	80	183	160
Soybean:												
CS2. Narrow-row Soybeans	78	42	74	100	85	145	55	76	86	86	79	120
CS3. Wide-row Soybeans	75	25	66	89	72	140	49	34	63	86	67	125
Wheat:												
CS3. Wheat/Red Clover	-	26	48	65	48	85	-	49	45	56	61	100
Alfalfa:												
CS4. DS Alfalfa	46	32	61	80	77	117	34	67	41	78	97	118
CS4. Alfalfa Hay I	-	27	49	55	47	117	-	71	54	71	84	122
CS4. Alfalfa Hay II	-	-	60	69	46	104	-	-	63	60	91	128
CS5. Alfalfa with Oats	-	-	-	103	68	101	-	-	-	53	73	131
CS5. Alfalfa	-	-	-	84	69	107	-	-	-	78	77	143
Pasture:												
CS6.	-	-	-	91	59	98	-	-	-	66	108	125

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

Table 3. Nitrogen Balance among Different Crops in the Cropping Systems Trial at Arlington Research Station and Lakeland Agri. Complex during 1991-95.

	Arlington Research Station					Lakeland Agricultural Complex				
Year	1991	1992	1993	1994	1995	1991	1992	1993	1994	1995
Cropping system	lb/A									
Corn:										
CS1. Continuous Corn	-1	39	98	8	4	8	57	95	-43	11
CS2. Corn after Soybeans	-45	19	54	2	13	6	35	73	-9	34
CS3. Corn after Red Clover	--	-70	-50	-125	-110	--	-37	-41	-133	-73
CS4. Corn after Alfalfa	--	--	110	58	105	--	--	203	134	171
CS5. Corn after Alfalfa	--	81	77	-2	43	--	119	172	63	105
Soybean:										
CS2. Narrow-row Soybeans	-188	-50	-174	-142	-206	-184	-77	-164	-219	-192
CS3. Wide-row Soybeans	-157	-60	-173	-143	-211	-162	-83	-105	-158	-200
Wheat:										
CS3. Wheat/Red Clover	-78	-47	-91	-79	-72	-25	-24	-105	-98	-63
Alfalfa:										
CS4. DS Alfalfa	-31	-51	-14	-38	22	232	184	237	112	186
CS4. Alfalfa Hay I	-325	-190	-248	-299	-246	-202	-249	-165	-289	-279
CS4. Alfalfa Hay II	--	-234	-197	-222	-136	--	-234	-156	-285	-208
CS5. Alfalfa with Oats	46	6	96	-51	0	104	130	127	76	116
CS5. Alfalfa	-328	-310	-283	-324	-310	-182	-238	-194	-268	-282
Pasture:										
CS6.	-137	-45	110	-71	-68	-38	101	0	-15	-18

6. Rotational Grazing of Dairy Heifers: A Low-Input Dairy Rotation in the Wisconsin Integrated Cropping Systems Trial

Sean Weber-Small[1] and Dan Undersander[1*]

In 1990, pastures were established at the Lakeland Agricultural Complex (LAC) and the Arlington Agricultural Research Station (ARS). The pasture seeding mixture for LAC was comprised of smooth bromegrass, timothy and red clover at rates of 3, 3.5, and 6 lb acre^{-1}, respectively. The pasture seeding mixture for ARS was comprised of timothy and red clover, both at the rate of 11 lb acre^{-1}. Fencing and water lines for pastures at both locations were built during the spring of 1992 (Fig. 1). A grazing trial was established at LAC in 1992. Severe winterkill at ARS necessitated reseeding of the pasture grasses in 1992, thus grazing of paddocks was not possible until 1993. Red Clover was broadcast seeded over pastures at both sites (20 lb acre^{-1} at LAC, 12 lb acre^{-1} at ARS) in early April 1993 for legume renovation. Red Clover was not seeded in the pastures at either site in 1994. Red Clover was broadcast seeded (18 lb acre^{-1}) in late March at LAC and no-till drilled (15 lb acre^{-1}) in mid March at ARS.

Our stocking rate has been 2, four hundred pound heifers per o.72 a paddock. Climatic conditions for 1995 growing season are outlined in chapter one. Of particular importance to the rotational grazing study was the above normal temperatures and below normal precipitation. These conditions slowed the pasture regrowth rate subsequent to the first grazing event. Slow regrowth persisted through much of the summer until significant precipitation occurred in mid-august.

Forage yields were determined by random sampling of each paddock. The acreage of pasture allocated to the animals for each rotational movement was determined by the management specialists at the individual sites.

During the 1992 season, the grazing trial conducted at LAC produced daily weight gains of 2.27 lb animal^{-1} day^{-1} (Fig. 2). In 1993, grazing trials were conducted at both sites with LAC producing gains of 1.64 lb animal^{-1} day^{-1} and ARS producing gains of 1.76 lb animal^{-1} day^{-1} (Fig. 2). In 1994 daily weight gains for LAC and ARS were 1.97 and 1.60 lb animal^{-1} day^{-1} (Fig. 2), respectively. Variability in weight gains continued in the 1995 season with LAC and ARS producing 1.91 and 0.78 lb animal^{-1} day^{-1} (Fig. 2), respectively.

While management and climate among the sites influenced these results, the largest impact in 1995 may have been due to the length of grazing season. The grazing season length in 1995 at LAC was 154 days, while the grazing season length at ARS was 60 days (Fig. 3). (The ARS grazing season was ended July 10 when the animals were removed for weighing and fed in confinement while waiting for the pastures to recover. With labor in short supply the animals were not returned to the pastures.) Animal weight gains seem to be directly affected by the length of grazing season. Also effected were the average animal per acre weight gains. At LAC animal weight gains were 354 lb acre^{-1}, while at ARS they were 67 lb acre^{-1} (Fig. 4.). The below average animal gains at ARS are due to two factors: 1) the shortened grazing season and 2) ruminant physiological growth characteristics which cause the majority of seasonal weight gains to occur at the end of the season.

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Forage yield and quality comparisons are limited due to the truncated grazing season at ARS. All comparisons between LAC and ARS and concerned only with the weeks that both sites were managed in similar fashion. Comparisons among the two sites in the areas of; forage yield (Fig. 5), crude protein (Fig. 6), acid detergent fiber (Fig. 7), neutral detergent fiber (Fig. 8), and relative feed value (Fig. 9), all seemed comparable. At ARS, the average ADF value was 37% while at LAC the average ADF value was 33%, where values ranging from 30-35% are required for forage to be considered of good quality. At ARS, the average NDF value was 55% while at LAC the average NDF value was 51%, where values less than 46% are considered to be of good quality. Both ADF and NDF are used to calculate the relative feed value (RFV) where a value of 150 is representative of prime hay. At ARS, the average RFV was 103 while at LAC the average RFV was 117.

Both sites mechanically removed forage throughout the summer. LAC removed 0.44 ton acre^{-1} as hay while ARS removed 1.37 ton acre^{-1} as green chop. Both sites also supplemented the animals during the season. Supplemental feed at LAC was: 288 lb of grain and 1.1 ton of hay during periods of pasture regrowth. Supplemental feed at ARS was: 608 lb of grain.

Once again, differing management strategies seemed to cause the major differences seen in the rotational grazing study in 1995. Because forage quality and yield for both sites appeared to be relatively similar, the vast differences observed in animal performance must then be attributed to experimental management.

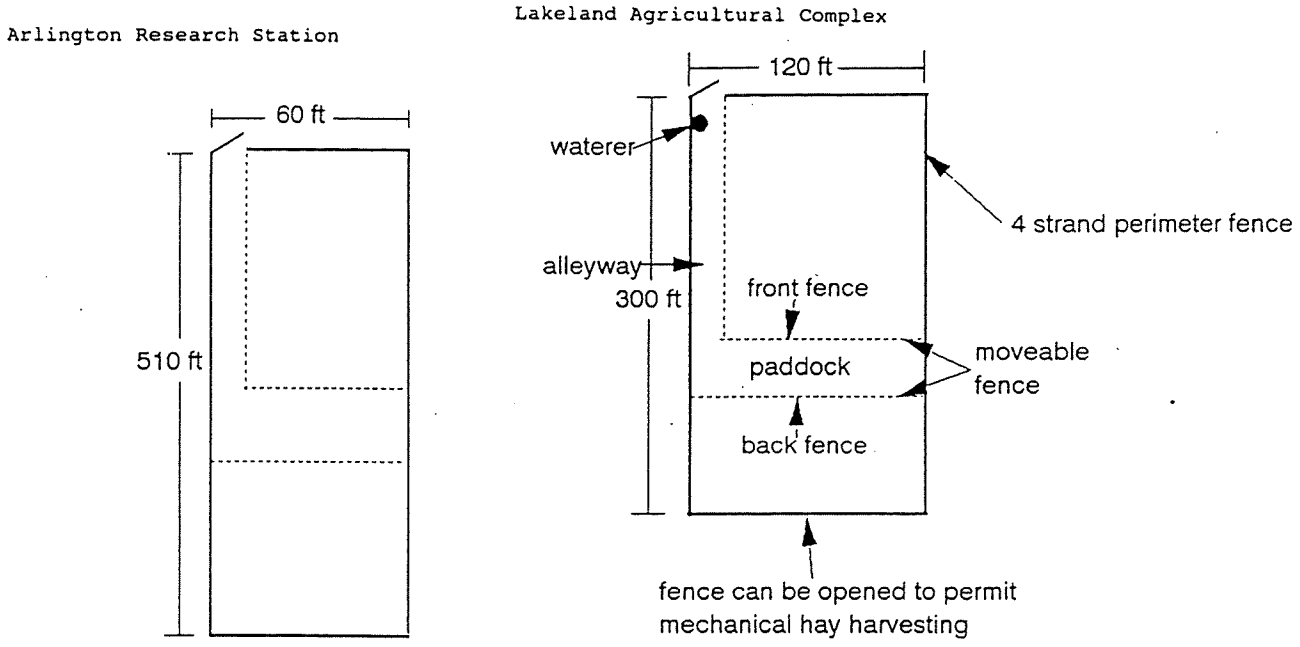

Figure 1. WICST rotational grazing pasture layout

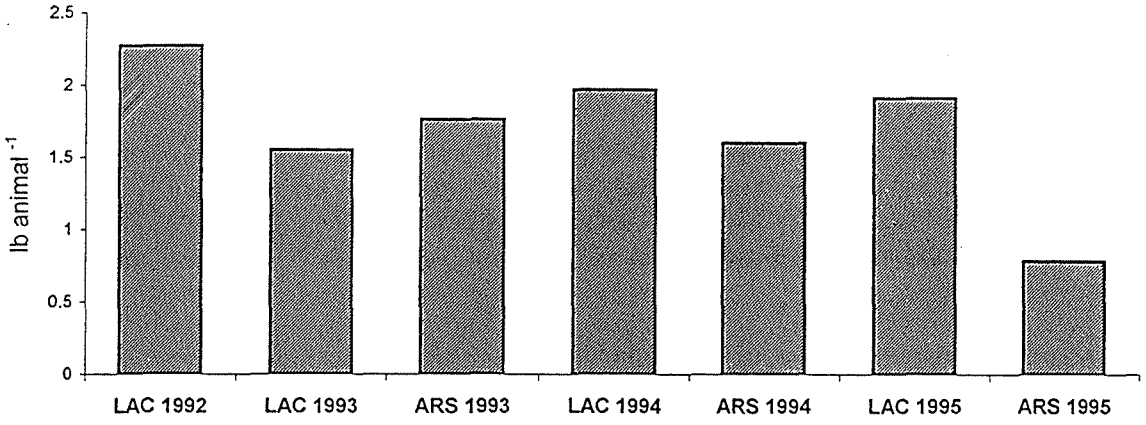

Figure 2. Weight gains per day, per animal from Lakeland Agricultural Complex (LAC) and Arlington Agricultural Research Station (ARS).

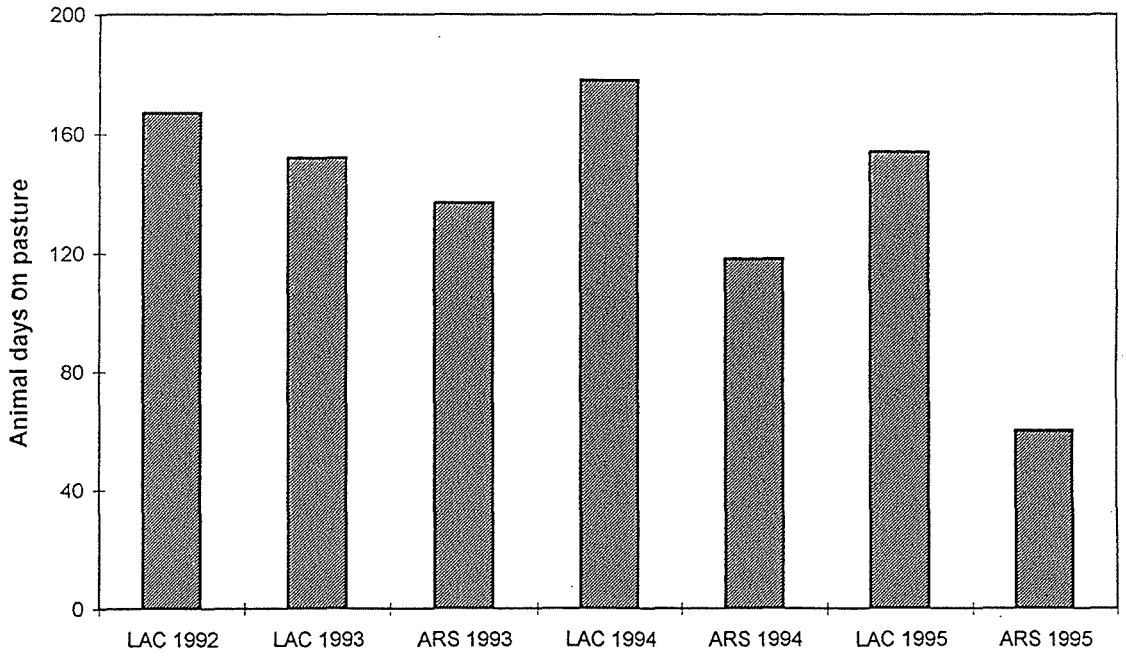

Figure 3. Animal days on pasture for Lakeland Agricultural Complex (LAC) and Arlington Agricultural Research Station (ARS).

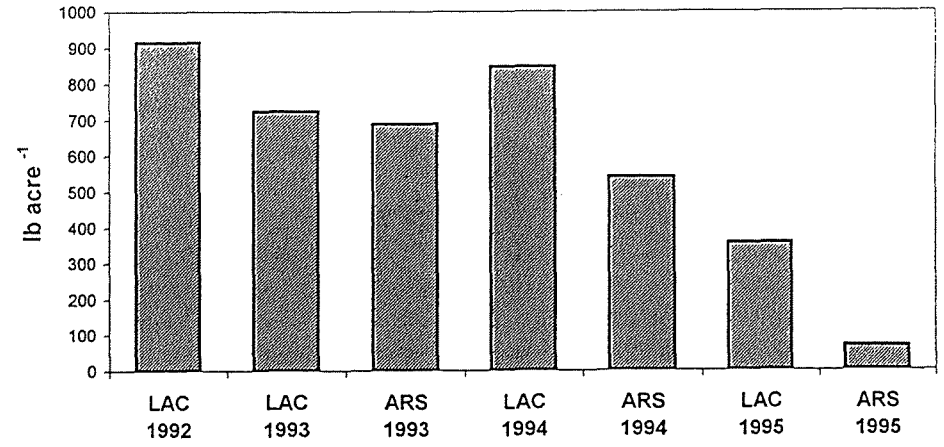

Figure 4. Per acre weight gains from Lakeland Agricultural Complex (LAC) and Arlington Agricultural Research Station (ARS).

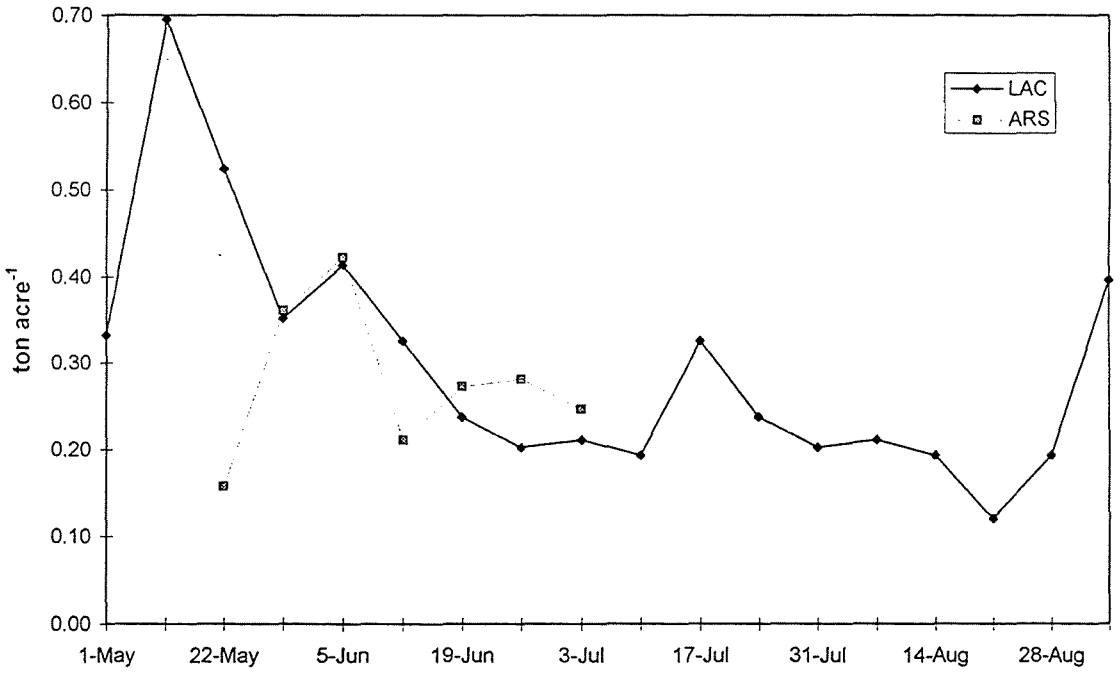

Figure 5. 1995 Average dry matter forage availability from Lakeland Agricultural Complex (LAC)and Arlington Agricultural Research Station (ARS).

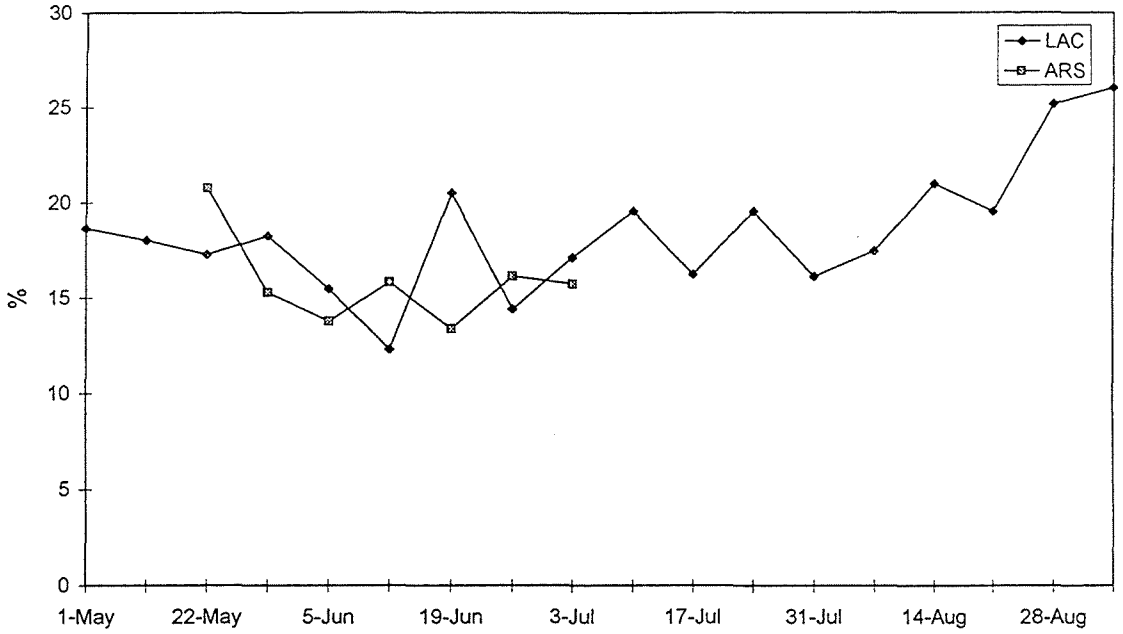

Figure 6. 1995 Crude protein analysis from Lakeland Agricultural Complex (LAC) and Arlington Agricultural Research Station (ARS).

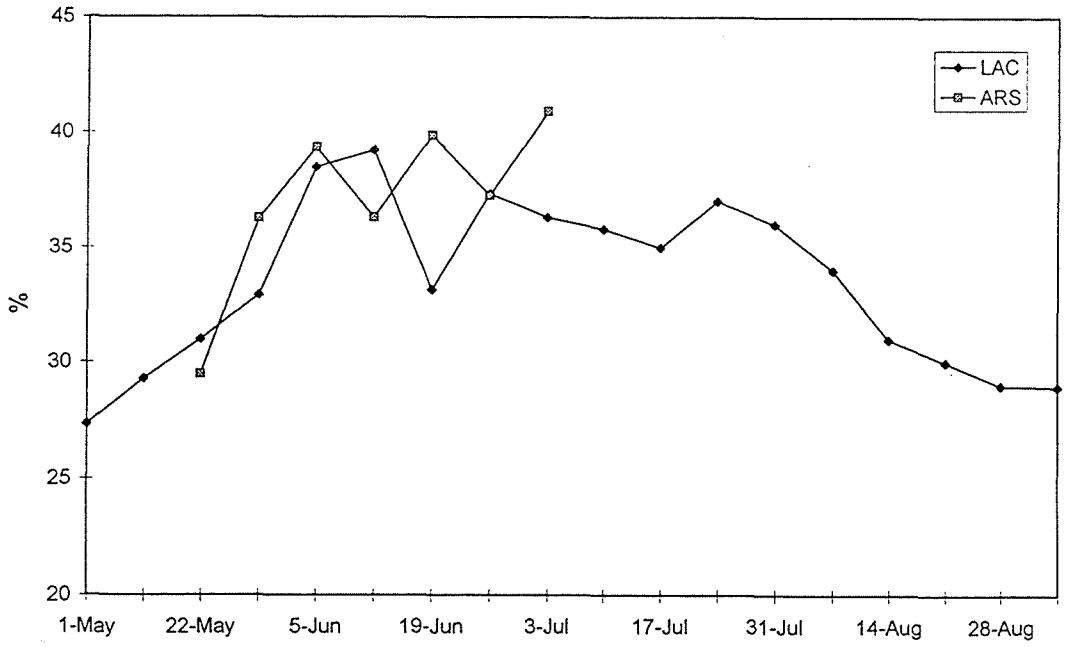

Figure 7. 1995 Acid detergent fiber (ADF) from Lakeland Agricultural Complex (LAC) and Arlington Agricultural Research Station (ARS).

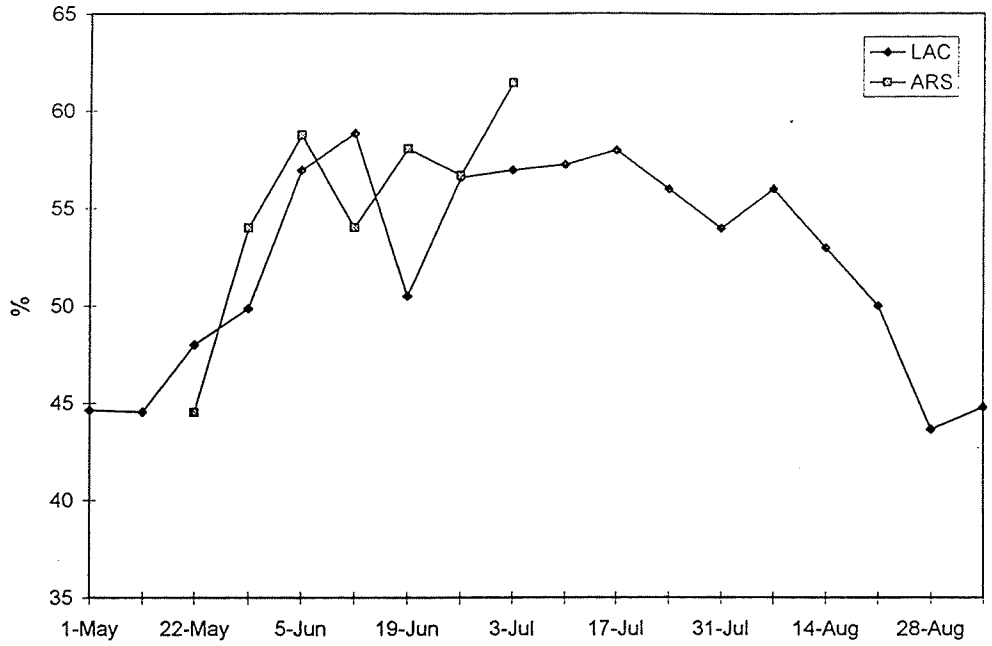

Figure 8. 1995 Neutral detergent fiber (NDF) from Lakeland Agricultural Complex (LAC) and Arlington Agricultural Research Station (ARS).

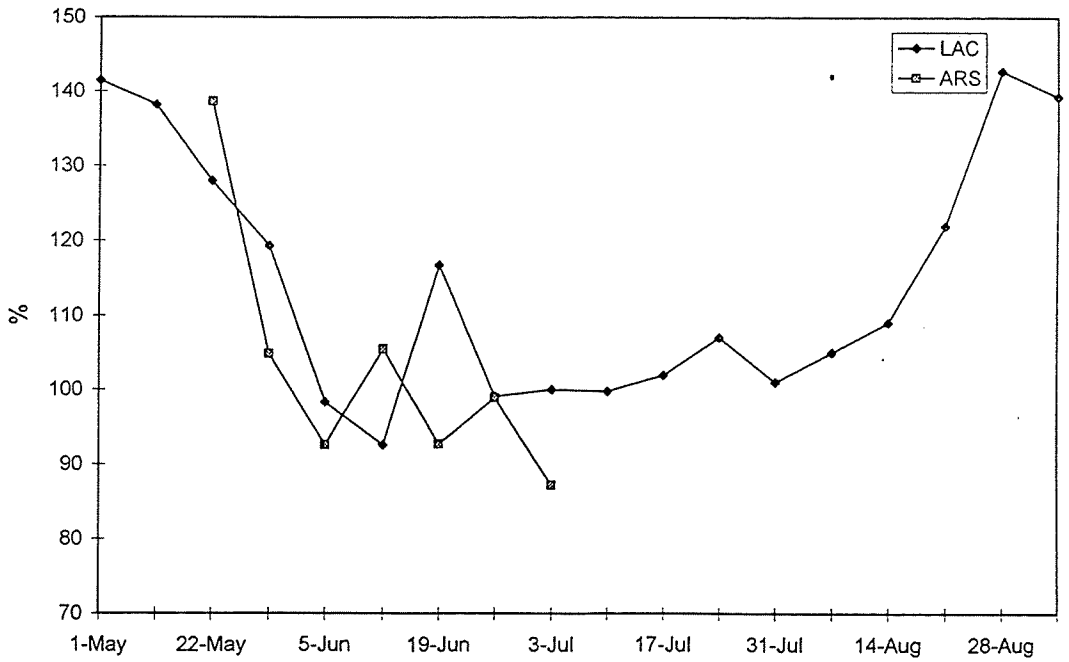

Figure 9. 1995 Relative fed value (RFV) from Lakeland Agricultural Complex (LAC) and Arlington Agricultural Research Station (ARS).

9. Wisconsin Cropping Systems Trial Economic Analysis - 1995

Richard Klemme[1]

The 1995 economic analysis for the WICST experiment continue to show a level of profitability for the lower input systems comparable with those of the higher input systems (see attached graphs). In particular, cropping system 3 (corn\soybean\wheat\red clover) continues to have gross margins very comparable with the corn-soybean cropping system and greater than those of the continuous corn system. On the forage crop side, the shorter term lower input corn, oats\alfalfa establishment, alfalfa rotation (CS#5) continue to have comparable profitability to the more intensive rotation consisting of corn, direct seed alfalfa and 2 years of alfalfa stand (CS#4). Finally, the grazing cropping systems (CS#6) had lower gross margins in 1995 and was very disappointing at the Arlington, but changes have been made there and additional analysis on these grass-based systems indicate potential profitability for dairy heifers being custom grazed.

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

As seen in the first two graphs, the gross margins for the cropping systems (CS) #3 in 1995 exceeded those of CS#2 which, in turn, exceeded those of CS#1 at both sites. 1995 was a good growing season which would tend to favor lower input compared to the higher input systems. It is only in the tougher years (1992 and 1993, for example) that cropping system #3, in particular, would be challenged to generate adequate gross margins. CS#3 also performed well in 1994 which was another good growing season. Whether the rotation effect is starting to show up in the more diversified system (CS#3) remains to be seen.

The bottom two graphs reveal some interesting results particularly when we look at the shorter term forage rotations (CS#5) as compared to the longer and more intensive forage rotation (CS#4). You can see over the period from 1993-95 that the these rotations generate similar amounts of gross margins per acre. The gross margins on these two rotations are calculated by taking the harvested prices for corn and oats and using a computer model to estimate the value of the alfalfa. We are assuming that this alfalfa will be fed to a Holstein cow producing around 70 pounds of milk per day. We then use the assumed production level along with those other feed prices we can generate a value of the

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alfalfa feed. We commonly see prices of $100-$110 per ton of dry matter for high quality alfalfa (RFV = 120-150). This is shown in the results as we consistently are generating from $250-$350 per acre of gross margins on those two cropping systems at both sites.

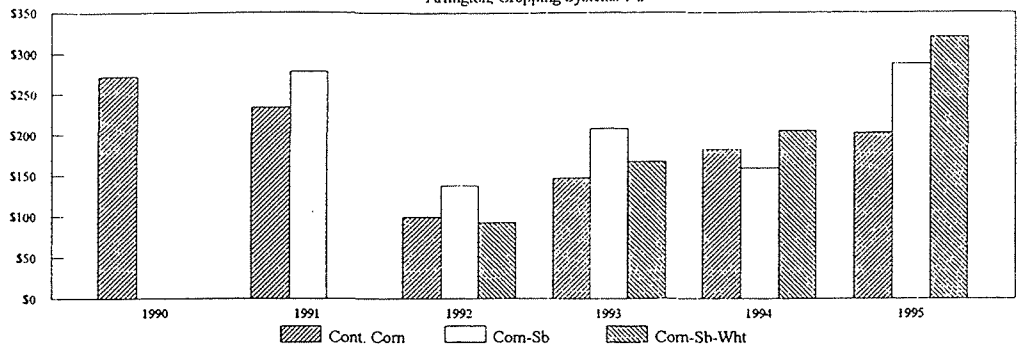
CS#6 presents us with a bit more challenge in terms of generating a return per acre. What we have done here is to estimate the value of the weight gain of the holstein heifers being grazed on those plots. Knowing the beginning and ending weights and assigning a per pound price at each weight to those animals gives us a gain in dollars from which we deduct the variable costs (feed costs and some labor cost). The performance of CS#6 is quite variable. This is due to a number of factors, including the sharp decline during season of prices in the beef market and some learning curve adjustments as the crews at the two sites have learned more about effectively grazing these animals. However, we can see that we have been able to generate gross margins in the $150-$250 range at both sites even assuming a declining price per pound of the animal through the grazing season. In fact, if we can make the assumption that the per pound of value of the Holstein heifer stays the same through the grazing period, we could easily generate $300-$350 of gross margins per acre. This is a very attractive number given the relatively low fixed cost of this system. In particular, CRP land coming out of the program might be an excellent place to think about grazing heifers on a contract basis from large confinement dairy farms as their land base continues to shrink relative to the number of animals they have on the farm.

In summary, the results indicate that the profitability of the lower input systems is comparable to those of the higher input systems. There is a significant amount of analysis left particularly related to the cost of capital, land, labor, and management. In particular the capital cost per acre, primarily for machinery, may vary across these systems and will effect the overall profitability. While there may be more machines in a more diversified cropping systems the fact that you have extended periods of time for harvest and planting of more crops may mean a downsizing of equipment.

Environmental costs also remain an issue to address. These may be more significant at the Lakeland site, but one would expect that they could influence the profitability of the single crop systems, in particular. Market seasonality has also not been considered in the analysis thus far; this would be particularly interesting to look at in light of more highly variable market prices recently experienced. Variability itself is an issue to look at as we begin to examine the possibilities of having more variation in weather and climate. More diversified systems may in fact offer some insurance against higher variability. On the other hand, the lower input systems with fewer pesticide control tools available may result in more variable yields from year to year.

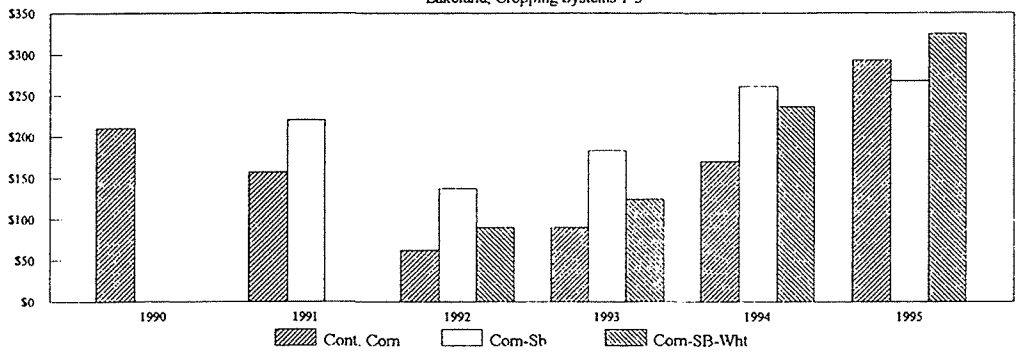
WICST Gross Margins ($/a), 1990-95

Arlington, Cropping Systems 1-3



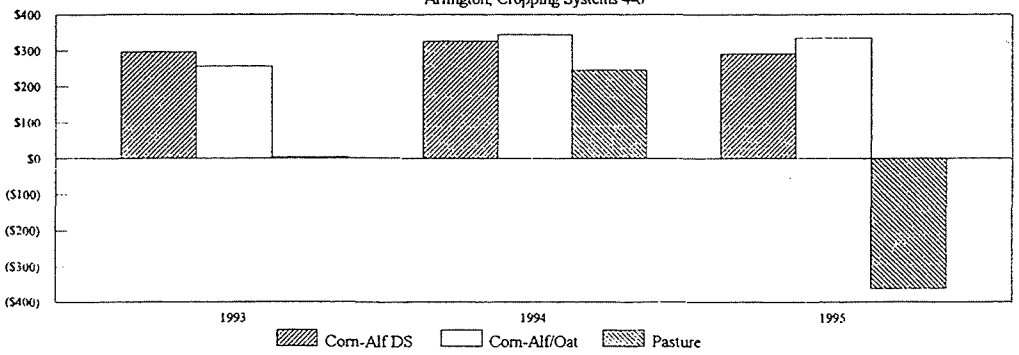
WICST Gross Margins ($/a), 1990-95

Lakeland, Cropping Systems 1-3



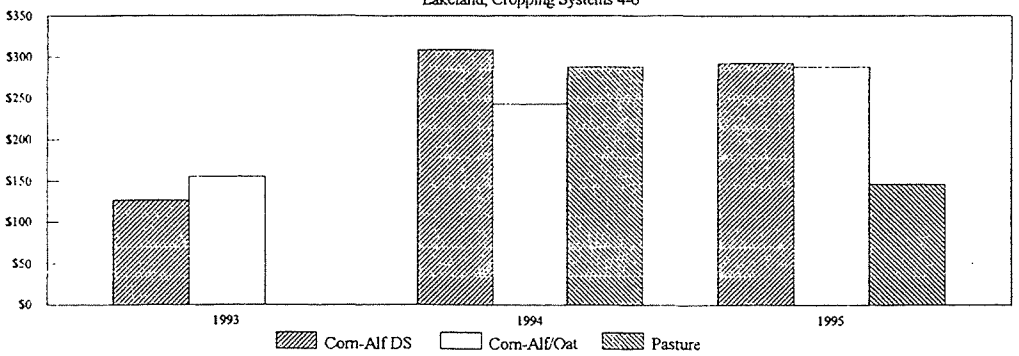
WICST Gross Margins ($/a), 1993-95

Arlington, Cropping Systems 4-6



WICST Gross Margins ($/a), 1993-95

Lakeland, Cropping Systems 4-6



8. Labor Implications of Cropping System Changes

Tom Mulder*

Cropping system design impacts many more factors besides yield and profitability. In the three WICST cash- grain cropping systems we have been comparing yields, inputs, fertility, economic returns, environmental impacts, and energy requirements. We had not looked closely at time requirements.

There have been concerns voiced by farmers that reducing purchased inputs requires a greater input of time. This would certainly be true if all the components of a particular system were kept constant except changing the weed control strategy from herbicides to mechanical controls. But, when comparing systems not just one but many of the components change. Therefore, we felt it was important to get a realistic measurement of the field time required for each of the WICST cash-grain systems.

The process of doing a time comparison was part a whole farm economic comparison for the WICST cropping systems. We decided to do this comparison using the Agriculture Budget Calculation Software (ABCS) Program. This program, designed by University of Wisconsin economists, develops crop budgets using detailed information of field operations and purchased inputs for expenses and crop yields and selling prices for income.

We set the farm size to 1000 acres which is representative of cash-grain farm sizes in Columbia and Walworth counties. To obtain realistic machinery inputs we sent a form to the farmers on the WICST committee where they selected the tractor sizes and the width of tillage and planting equipment they would want if they were farming 1000 acres using each of the three WICST cash-grain systems. We also looked at actual farm machinery sets used by farmers and county extension agents who had worked with UW Ag economist Gary Frank on the Top Farmer Program using ABCS. Using these data sets we chose a farm machinery set for each of the three systems. Before entering the data into ABCS we met with the three farmers from the Columbia County WICST committee and they made some final editing changes in equipment size and purchase prices.

Although field operations used in the WICST cropping systems from 1992 - 1995 were slightly different each year, they were similar enough to set up a representative yearly field equipment and operations list for each of the cropping systems (Table 1). The ABCS program calculates the field time required to do each operation using equipment at the specified width, and then adds 10% transportation time and 11% maintenance and setup time to determine total labor. Average yields were also a part of the labor equation since volume of grain harvested has an impact on field time. Over the road grain hauling was considered a custom operation and not included in field labor.

To determine distribution of field time requirements during the cropping season, operations were grouped together if they would normally be done during the same time period. Hours per day were limited to 12 to allow for rainy periods when soil would be too wet for field work. In Figure 1 the field labor time and distribution is shown for all the field operations used in each of the three cropping systems. Results show total field time least for the no-till system with the continuous corn system time requirement slightly less than for the more diversified corn/soybean/wheat-red clover system. The more diverse 3-phase system however, has a more even distribution of field work during the entire growing season than the continuous corn system. It is clear that labor implications should be considered by a farmer when setting up a cropping system.

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Table 1. Field Equipment and Operations for the Three WICST Cash-Grain Cropping Systems.

Machinery Description : 1000 acre cash grain farm - Cropping System 1 - Continuous Corn

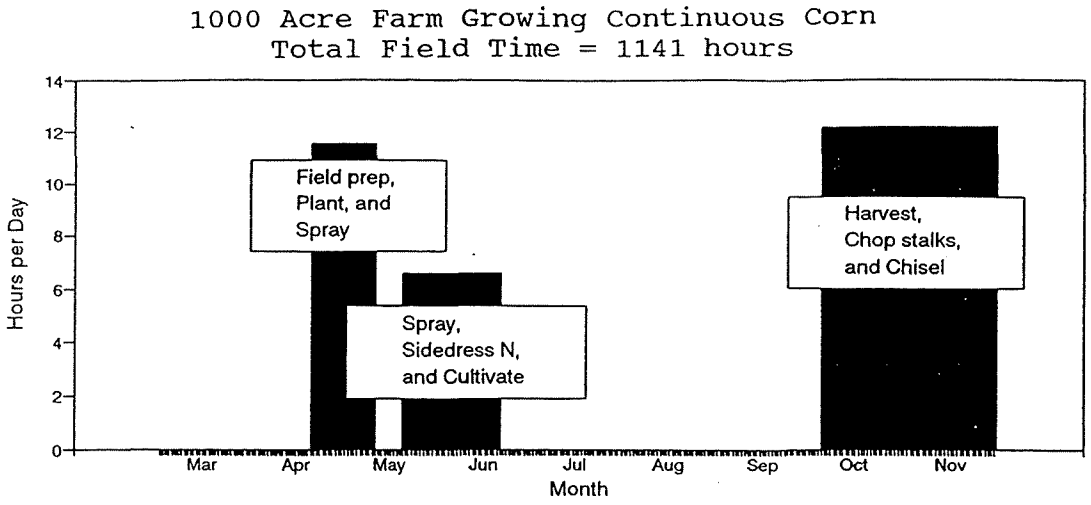
Power Unit	Main Implement
Tractor 225 HP 4wd	Soil finisher 25ft 1X
Tractor 120 HP	Planter 12-30
Tractor 75 HP	Sprayer 60 ft boom - preemerge grass herbicide
Tractor 75 HP	Sprayer 60 ft boom - postemerge broadleaf herbicide
Tractor 225 HP 4wd	Fert NH3 (rent 30' toolbar)
Tractor 120 HP	Cultivator, Danish tine 12-30 1X
Combine, large 175 HP	Corn grain head 6-30
Tractor 120 HP	Grain cart 350 bu
Tractor 120 HP	Stalk chopper 15 ft
Tractor 225 HP 4wd	Disk, chisel 12 ft

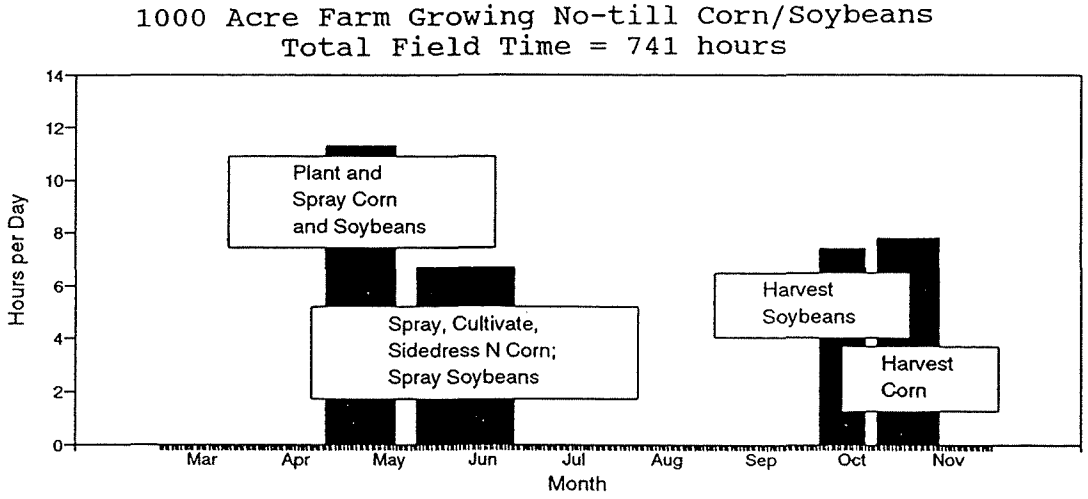
Machinery Description : 1000 acre cash grain farm - Cropping System 2 - No-till Corn/Soybeans

Power Unit	Main Implement
Tractor 75 HP	Planter 06-30 min-till (corn)
Tractor 140 HP	Drill, min-till 15 ft (soybeans)
Tractor 75 HP	Sprayer 60 ft boom (burndown and preemerge grass herbicides for corn)
Tractor 75 HP	Sprayer 60 ft boom (burndown herbicide for soybeans)
Tractor 75 HP	Sprayer 60 ft boom (postemerge grass herbicide for corn)
Tractor 75 HP	Sprayer 60 ft boom (postemerge grass and bdlf herbicides for soybeans)
Tractor 140 HP	Fert NH3 for corn (rent 15' toolbar)
Tractor 140 HP	Cultivator, min-till 6-30 1X
Combine, large 175 HP	Soybean head 20 ft
Tractor 120 HP	Grain cart 350 bu
Combine, large 175 HP	Corn grain head 6-30

Machinery Description : 1000 acre cash grain farm - Cropping System 3 - Corn/Soybeans/Winter Wheat-Red Clover

Power Unit	Main Implement
Tractor 75 HP	Drill, double disk 13 ft (frost seeding)
Tractor 225 HP 4wd	Soil finisher 25Ft (2X corn and soybeans, 1X wheat)
Tractor 75 HP	Planter 06-30 - corn
Tractor 75 HP	Planter 06-30 - soybeans
Tractor 75 HP	Rotary hoe 30 ft (3X corn & soybeans)
Tractor 75 HP	Cultivator 06-30 (2X corn & soybeans)
Tractor 75 HP	Sprayer 60 ft boom (thistles in corn)
Combine, medium 145 HP	Grain head 15 ft
Combine, medium 145 HP	Soybean head 15 ft
Tractor 75 HP	Drill, double disk 13 ft (drill wheat)
Tractor 120 HP	Grain cart 350 bu
Combine, medium 145 HP	Corn grain head 6-30
Tractor 120 HP	Stalk chopper 15 ft
Tractor 225 HP 4wd	Disk, chisel 12 ft





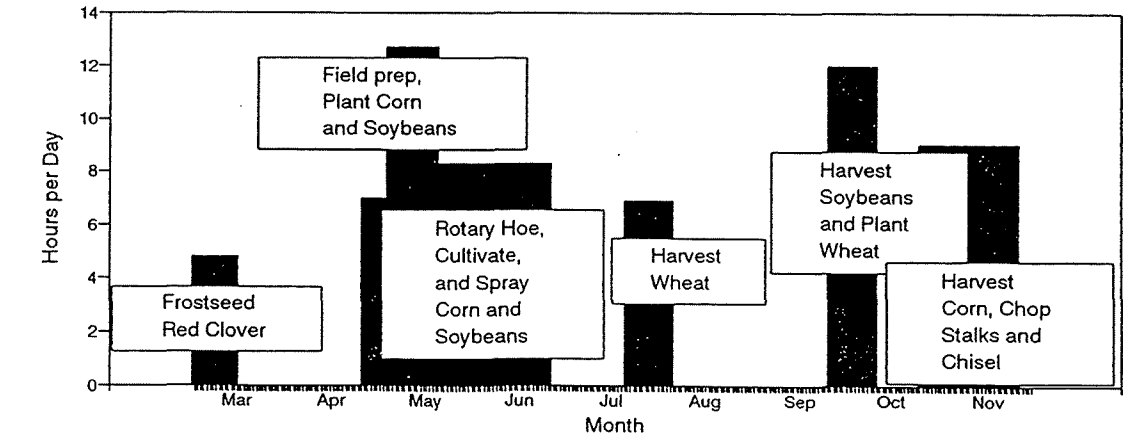


Figure 1. Labor flow analysis for three cash-grain farm types (March - November)

WICST SATELLITE TRIALS - 1995

9. Crop Response to Commercial Fertilizer Additions in a Low Input Cash Grain System

John Hall[1], Dwight Mueller[2], Alan Wood[3], Paul Bergum[2], Tom Mulder[4*]

Introduction

Corn yields in the WICST corn-soybean-wheat/red clover (R3) rotation have been lower than in the other systems in 1992 and 1993. These lower yields were thought to be caused by either weeds or lower fertility. Satellite trials were initiated at both sites in 1994 to determine the cause of the low yields and to find out whether adding some purchased inputs would be cost effective.

Materials and Methods

Arlington:

The effects of adding starter fertilizer and sidedress nitrogen were tested at Arlington in the edge rows of R3 corn plots. Weed and weed free comparisons were also tested in the edge rows at both sites (page 13). We were able to use these rows since we had decided to negate the edge effect on the outer two rows of each plot by leaving one harvest pass (6 rows) along the edge of each plot planted to corn when measuring yield. This allowed us to do some testing on the inner four rows of this 6-row strip.

At Arlington the experiment was a randomized complete block design. Plot size was 40 ft x 15 ft (6 30-in. rows) for a total area of 160 x 15 ft along the west edge of each R3 corn plot. The four randomized treatments were 1) no additional fertilizer, 2) starter only (100 lb/a 6-24-24), 3) only sidedress N (135 lb/a 33-0-0), and 4) starter and sidedress. Corn was planted on May 12, and sidedress N applied on June 2, 1995. Starter was applied with the corn planter by engaging and disengaging the fertilizer drive unit while sidedress N was hand spread on the soil surface two inches from the corn row. Soil preparation and row-cultivation were identical to that of the main plots. Corn was hand harvested, mechanically shelled, weighed, and moisture determined. The harvest area was 30 ft. of two rows (4th and 5th rows from edge of plot).

Lakeland:

At Lakeland, fertilizer additions were tested on a satellite plot in conjunction with a trial comparing clover kill by fall chisel plowing, spring chisel plowing and a spring herbicide application followed by no-till corn planting. The experimental design at Lakeland was a randomized complete block, split plot design. Main plots were 1) fall clover kill by chisel plowing with sweeps at 3 in-depth, 2) spring clover kill by chisel plowing, 3) spring herbicide kill of clover followed by no-till corn. Sub plots were identical to those at Arlington except starter application rate was 16 gal/a (192 lb/a) 4-10-10. Main plot size was 20 x 220 ft and subplots 10 x 110 ft. The fall killed clover was chisel plowed Nov 16, 1994 and received two additional passes with a mulchmaster on May 18 and 19, 1995 and the spring killed treatment was tilled the same spring dates with the sweeps of the mulchmaster uprooting the clover in place of a chisel plow. Roundup was applied to the

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no-till treatment areas Nov 16, 1994. Starter fertilizer was applied by planter and sidedress N by hand as at Arlington. Corn was planted at 31,200 seeds/a on May 20, and sidedress N applied on June 14. Lasso was applied May 22 (2.5 qt/a) for foxtail control and Buctril on June 20 (1 pt/a) for broadleaf weed control. All treatments were cultivated once on July 3 with a disk and sweep no-till cultivator. Harvest was by small plot harvester, harvesting the center two rows of the four-row plots (110 x 5 ft harvest area). Corn was weighed and moisture determined after harvest on October 26.

Results:

Arlington:

Yield means in bushels per acre for the four treatments were 166.5 with no added fertilizer, 164.3 when adding only starter fertilizer, 164.7 when adding only sidedress fertilizer, and 162.9 when adding both starter and sidedress fertilizer. Since yields were not significantly different, there was no measurable yield response and adding fertilizer in this system would have decreased economic returns.

Lakeland:

No-till corn yield was significantly lower (Table 1) than yield in both the fall and spring chisel plowed clover treatments. When combining tillage main treatments, sidedress N significantly increased corn yield while the addition of starter alone did not cause a significant yield increase at the .05 LSD level. When fertilizer treatments were compared under each tillage treatment alone yield differences were not significant but in all three clover kill main treatments there was a trend of increased yield when adding fertilizer. Neither method of clover kill nor fertilizer additions had a significant effect on harvest moisture or field corn plant populations.

Conclusions:

The 1995 growing season was not as warm as 1994 and clover decomposition may have been slower than last year. This may be the reason for the yield response to added nitrogen at the Lakeland Complex. At Arlington the corn followed a crop of hairy vetch since germination of the frost seeded red clover was very poor. The lack of response to additional nitrogen at Arlington suggests that the hairy vetch may decompose quicker than the red clover or the decomposition may have been slower at Lakeland where the soils may have been cooler and wetter earlier in the growing season. The fertilizer addition trials will be continued at both sites in 1996 similar to as they have been at Arlington the past two years. The comparison of the methods of clover kill will not be continued in 1996.

Table 1. Corn following a red clover cover crop - Lakeland - 1995

Clover kill tillage	plant stand	harvest moisture	grain yield
	plants/a	- % -	bu/a
fall	28,833	17.4	134.6
spring	29,542	17.4	129.6
herbicide/no-till	29,000	17.6	109.8
lsd (0.05)	ns	ns	20.0

Fertilizer additions	plant stand	harvest moisture	grain yield
	plants/a	- % -	bu/a
None	29,333	17.6	112.6
Starter only	29,500	17.4	122.2
Sidedress N only	28,722	17.5	134.6
Starter and sidedress	28,944	17.5	129.0
lsd (0.05)	ns	ns	13.2

* Tillage fertilizer interaction was not significant

Clover kill tillage	**Fertilizer additions**	**Yield**
		bu/a
Fall kill		
	None	128.0
	Starter only	137.1
	Sidedress N only	137.7
	Starter and sidedress	135.5
LSD (0.05)		ns
Spring kill	None	116.8
	Starter only	127.5
	Sidedress N only	138.7
	Starter and sidedress	135.5
LSD (0.05)		ns
Herbicide/no-till	None	93.7
Starter only	102.0	
Sidedress N only	127.5	
Starter and sidedress	115.5	
LSD (0.05)		ns

10. On-Farm Evaluation of Legumes Seeded After Winter Wheat

Jim Stute[1*] and Tom Mulder[2]

INTRODUCTION

Growers whose crop rotation includes winter wheat can reduce corn nitrogen costs by planting a legume green manure with or after wheat. In addition to converting unused solar energy into nitrogen after wheat harvest, properly managed legumes can provide soil conservation benefits.

Legumes can be frost seeded in spring or seeded after harvest with equally satisfactory results. Frost seeding red clover in March offers the advantages of lower establishment costs and the greatest degree of soil protection, but may reduce yield of clean straw and hence income. Seeding hairy vetch after wheat harvest maximizes straw yield but has higher establishment costs do in part to high seed cost. The objective of this study is to compare two promising legumes: berseem clover and annual medic to hairy vetch for productivity under real farm conditions.

METHODS

Legumes were seeded into wheat stubble following tillage at three sites in 1995. Two of the sites were near Bristol in Kenosha County, and the third near Arlington in Columbia County. Inoculated legume seed was seeded with a grain drill at the following rates (lb/acre): Hairy vetch, 25-30; beseem clover, 12- 15; and annual medic, 12-15 by the cooperating farmer. Legume herbage yield was estimated in late fall by random sampling of above ground growth. Material was analyzed for DM and N content.

The experimental design is a randomized complete block, using sites as replicates. Individual plots were a minimum of 1 acre in size. Data were subject to analysis of variance procedures to detect significant main effects and interactions. Means were separated using a protected LSD at the 0.05 level of probability.

RESULTS

Legumes did not differ significantly in DM yield (Table 1) in 1995. Hairy vetch had the greatest DM yield at each site, ranging from 9 to 48% greater than the next best yielding legume. Vetch N content was significantly greater than the other two legumes which results from a combination of DM yield and significantly greater tissue N content.

This study continues in 1996 with the assistance of the WDATCP Sustainable Agriculture Program.

Table 1. Legume herbage DM yield and N content.

Legume	DM (t/a)	N (%)	N (lb/a)
Hairy Vetch	1.88	3.39	127
Beseem Clover	1.20	2.49	72
Annual Medic	1.36	2.67	60
LSD	NS	0.13	3

*NS, not significant

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11. Effect of Added Fertilizer Nitrogen on Corn Yield Following Green Manure

Jim Stute[1]

INTRODUCTION

Can the application of supplemental nitrogen be used to optimize yield of corn following a green manure? Even though legume N may be released in a timely fashion, there may not be sufficient quantities of N available to meet the need of corn. Such would be the case if the total amount of legume N was limited by factors such as late planting, poor stands, less than favorable growing conditions for the legume, or if legume herbage was harvested for forage. The objective of this study is to determine the optimum rate of additional N fertilizer for corn following a legume green manure.

METHODS

The response of corn yield to additional N was studied in 1994 and 1995 at the Lakeland Agricultural Complex and a Pella silt loam, and in 1995 near East Troy on a Fox silt loam. Corn (Pioneer 3751) was grown following oat/red clover with six rates of additional N (as ammonium nitrate): 0, 40, 80, 120, 160, and 200 lb/acre broadcast before planting. Total red clover N content was measured the previous year, before fall chisel plowing. Corn grain yield and moisture was measured in the center two rows of each plot and yield adjusted to 15% moisture.

Data were subject to regression analysis evaluating linear, linear-plateau, quadratic, and quadratic-plateau response models. The "best-fit" response model for each site year has used to describe yield response. The agronomically optimum N rate was defined by a zero-slope on the response curve.

RESULTS

Corn grain yield has responded positively to added N in every trial. The effect of supplemental N on yield can be seen in Table 1. Yield response at the Lakeland Agricultural Complex was best characterized by a quadratic plateau model in each year, with an optimum N rate of 125 in 1994 and 33 in 1995. The greater optimum N rate occurred in a high yield year, while the lower occurred in a year when late planting and low precipitation during the growing season reduced yield potential. Addition of the optimum amount of N increased yield approximately 25-30 bu/acre in either year, relative to no added N.

A linear model best described the yield response at East Troy in 1995, which is why no value for optimum is assigned. Addition of the maximum N rate increased yield 28 bu/acre relative to clover alone. Two-thirds of this yield increase was achieved with 80 lb/acre of fertilizer N.

The variability of yield response does not appear to be related to the N content of the previous legume, rather to the nature of the growing season. This is clearly evident at the Lakeland Agricultural Complex where the greatest optimum N rate followed the greatest green manure N content, in a high yield potential year, 1994.

Continuation of these response studies will help clarify the relationship between legume N content and optimum rate of fertilizer N in both high and low yield potential years. Ultimately it will help us to refine management guidelines for use of green manures on-farm.

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Table 1. Effect of added N on yield of corn following red clover.

Year/Location	1992 LAC	1993LAC	1994LAC	1995LAC	1995ET
Clover N Content (lb/a)	101	95	117	78	130
Corn Yield			(bu/a)		
N rate (lb/a)					
0	119	50	157	125	94
40	117	58	171	153	102
80	133	83	192	131	111
120	156	104	186	139	113
160	153	107	189	146	112
200	148	80	200	142	122
optimum N rate	124	120	125	33	na

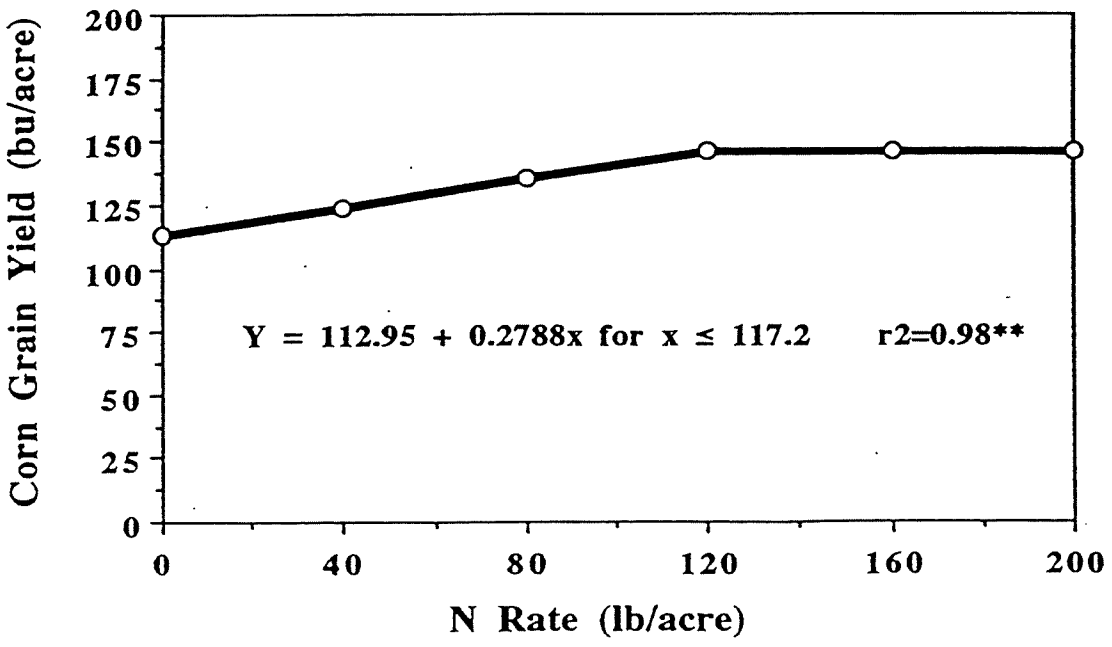

Figure 1. Yield response of corn following red clover to supplemental N fertilizer on a Pela silt loam soil, 1992 to 1995.

12. Two Trials using Annual Medic as Cover Crops

John Hall[1]*

Trial 1. Comparison of Annual Medics with other Legumes for Use as Green Manure Cover Crops in Crop Rotations that Include Winter Wheat

Replicated trials were established on the Lakeland Farm near Elkhorn, WI in 1994 and repeated in 1995, to evaluate the potential of legume cover crops that were spring interseeded (frost-seeded) into winter wheat and sequentially seeded following wheat harvest. The objective was to compare the potential of three annual medics species (Sava snail, Santiago burr, and Caliph barrel) with three alternative legumes (red clover, sweet clover and hairy vetch) which are currently being used as the primary cover crops in corn/soybean/wheat + cover crop rotations in South Eastern Wisconsin. These legumes were compared for total biomass production and nitrogen accumulation potential for each of the two methods and timings of cover crop establishment, with the exception of hairy vetch which was only established following wheat harvest (sequentially seeded).

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

Results and Findings

Legume dry matter production and nitrogen accumulation are reported in Table 1. The results show that the annual medics and sweet clover were less productive than red clover when spring interseeded, but slightly more productive when planted after wheat harvest. Hairy vetch was the most productive species in both dry matter yield and nitrogen accumulation when sequentially seeded. This indicates that red clover or hairy vetch are probably still the best cover crop choices depending on planting time and method. However, the annual medics may be useful in systems that want to avoid using tillage or chemicals to kill cover crops prior to corn planting.

Dissemination

Two field days were held in each of the two years of the trial. These field days were organized to show and discuss progress of the Wisconsin Integrated Cropping Systems Trial (WICST). The medic trials were one of the stops including in site tours and discussions. Each field day averages an attendance of about 100, with a mixed audience of farmers, researchers and extension.

In addition, many visits were arranged each year for smaller groups which included observations and discussions of the medic trials. A full scientific report of the medic trials will be included in the 1996 WICST annual report, and the practical applications of the research will be included in upcoming WICST publications, as a part of the discussion of overall advantages of including small grains + legume cover crops in row crop based rotations.

Practical Applications and Farmer Adoption

Annual medics may be best suited for seeding after small gain harvest in reduced or no-till systems. Although hairy vetch performed better in our trials, many producers would prefer a cover crop that winter kills for use in reduced tillage systems. We plan to continue to evaluate the annual medics for the purpose.

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Many farmers in south Eastern Wisconsin are experimenting with adding a small grain and legume cover crop to their rotations. However, few if any are planning to use annual medics. This could change if seed costs were reduced and seed was readily available. Many growers are aware of annual medics as a direct result of our research and demonstrations and may find reasons to use them in the future.

Table 1. Mean Dry Matter Yield and Nitrogen Accumulation of Cover Crops Spring Interseeded into Winter Wheat and Summer Planted Following Wheat Harvest at Lakeland Farm, Elkhorn, WI, 1994 and 1995

	Spring Interseeded		Sequentially Seeded	
Cover Crops	DM Yield	N accum.	DM Yield	N accum.
	lbs/a			
Medics				
Sava snail	1720	51	1509	46
Santiago burr	1115	32	1196	27
Caliph barrel	1360	40	1280	33
Mean	1398	41	1328	35
Sweet Clover	3199	72	1460	42
Red Clover	4486	88	1080	30
Hairy Vetch	----	--	3204	134
Control *	----	--	1071	26
LSD (0.05)	987	26	1003	29

* Control was no cover crop following wheat harvest; plot herbage was from annual weeds and volunteer wheat.

Trial 2. Intercropping of Annual Medics and Corn

Replicated trials were established on Lakeland Farm near Elkhorn, WI in 1994 and repeated in 1995 to evaluate the potential for a corn-medic intercropping system. The objectives were to evaluate the effects of three annual medic species and three methods of intercrop establishment on corn grain yield, weed suppression and medic biomass production.

Three annual medic species (Sava snail, Santiago burr and Caliph barrel) were intercropped with field corn in replicated split plots using three different methods and timings of establishment as follows:

(1.) by companion seeding in which corn was planted in 30" rows and medic was drilled uniformly over plots on the same date;

(2.) by broadcasting medics into corn following two rotary hoe operations for weed control, (medics were seeded 14 and 11 days after corn planting in 1994 and 1995 respectively); and

(3.) by broadcasting medics into corn following two rotary hoe operations and one cultivation for weed control, (medics were seeded 28 and 23 days after corn planting in 1994 and 1995 respectively).

Control plots were included within each method of establishment treatment in which mechanical operations foe weed control in corn were as described in 1-3 but medics were not interseeded in those plots.

Results and Findings

Two of the three methods of establishment of annual medics into corn resulted in reduced corn grain yields (Table 2.). Corn grain yield was lowest in the early companion seeded treatments, and reduced less by interseeding after rotary hoeing. Corn yields were not reduced by interseeding medics after rotary hoeing and one cultivation for weed control in corn. Also, there was no difference between the three medic species in their affects on corn yield.

Biomass production of the annual medics and annual weeds were calculated from samples taken 60 days after medic establishment and are reported in Table 3. There was relatively little difference in effectiveness of establishing the medics among the three methods, however weed control was much more effective with methods that included mechanical operations prior to the interseeding of medics, i.e. rotary hoeing and cultivation. Although the medics had some affect on direct weed suppression when compared to weed biomass in control plots, they were not effective enough to allow the elimination of mechanical cultivation. Corn yield reductions were probably due both to weed and medic competition when companion planted, and due primarily to weed competition when interseeded after rotary hoeing.

There was little difference among the three medic species in biomass production or weed suppression, although "sava snail" appeared to be the most prolific in producing seed that would re-establish in corn and therefore last throughout the season.

Observations indicate that the total biomass production of the medics peaked at about 60 days after seeding, although this does not account for the re-seeding from shattered-out seed. However, the weed biomass production increased greatly after the 60 day samples were taken. The total 60 DAP medic biomass was not great when compared to other alternatives which we have tested in other corn-interseeding trials. The average nitrogen accumulation for the medics would be only about 25 lbs/a in these trials. Thus, due to the high seed cost of these medics and the relative poor effect on weed suppression, there is little or no interest in utilizing annual medics for corn intercropping.

Dissemination

Dissemination and outreach was generally the same as described for Trial 1, with field days and visits occurring regularly as part of the WICST events. Although a lot of farmers observed the trial, the general impression was that the weed control was not adequate and corn yield would suffer. There seemed to be relatively little interest in the potential nitrogen contribution to the system or to in having medics for providing fall ground cover in corn stubble.

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Table 2. Effect of Companion Seeding and Interseeding of Annual Medics on Corn Grain Yields at Lakeland Farm, Elkhorn, WI 1994 and 1995.

Cover Crops	Corn Grain Yields			
	Companion Seeded *	Interseeded Rotary Hoe	Interseeded Cultivation	LSD (0.05)
	bu/a			
Medics				
Sava snail		102	123	132
Santiago burr	106	126	139	
Caliph barrel	94	119	136	
Mean	101	123	136	11.4
Control **	91	118	136	10.8
LSD (0.05)	14.8(NS)	10.2(NS)	9.8(NS)	

* (1.) Companion seeded medics were drilled into corn at the same time as corn plantings. No mechanical or chemical weed control used.
(2.) Interseeded rotary hoe treatment was broadcasting of medics into corn following the rotary hoeing; no cultivations and no herbicides were used for weed control.
(3.) Interseeded cultivation treatment was broadcasting of medics into corn following two rotary hoeings and one cultivation.
** Control was no cover crop seeding in corn and mechanical weed control as described for above treatments.

Table 3. Annual Medic Herbage and Weed Biomass 60 Days After Companion and Interseeding of Medics into Corn at Lakeland Farm, Elkhorn, WI 1994 and 1995.

Cover Crops	Dry Matter Yield					
	Companion Seeded *		Interseeded Rotary Hoe		Interseeded Cultivation	
	Medic	Weeds	Medic	Weeds	Medic	Weeds
	lb/a					
Medics						
Sava snail	1060	1241	1240	814	969	618
Santiago burr	892	994	939	698	852	415
Caliph barrel	940	1103	768	876	702	786
Mean	964	1113	982	796	841	606
Control **	----	789	----	1312	----	819

* (1.) Companion seeded medics were drilled into corn at the same time as corn plantings. No mechanical or chemical weed control used.
(2.) Interseeded rotary hoe treatment was broadcasting of medics into corn following two rotary hoeing; no cultivations and no herbicides were used for weed control.
(3.) Interseeded cultivation treatment was broadcasting of medics into corn following two rotary hoeings and one cultivation.
** Control was no cover crop seeding in corn and mechanical weed control as described for above treatments.

13. Weed Control with the Rotary Hoe

Tom Mulder[1]

In WICST cropping systems 3 (corn-soybeans-wheat/red clover) and 5 (corn-oats/alfalfa-alfalfa) weeds in the row crops are controlled without using herbicides. The alternative to herbicides is a combination of cultural and mechanical methods of weed control. The two post-plant mechanical methods used for weed control are rotary hoeing and row-cultivation. The rotary hoe is the tool used to control weeds before the plants are large enough for row-cultivation.

Past research and farmer comments recommend the rotary hoeing when weeds are ready to emerge with roots in the "white thread stage". Research by Mulder and Doll has shown this can often be determined by corn growth stages (first hoeing when tip of corn leaf is 1"below soil surface and second when and corn height is 2"). Satellite research has been done the past few years to determine methods and timing to maximize effectiveness of the rotary hoe. Research in 1992 and 1993 (Second and Third WICST Annual Reports) concluded that rotary hoe design (one or two wheels per tensioned shank), varying the hoe weight, and varying the speed of rotary hoeing, all had no significant effect on weed control, corn plant damage, or corn population. This research did show however, that a double pass rather than a single pass during each hoeing increased weed control but reduced corn population and slowed growth of the young corn plants.

Further research was begun in 1995 and is continuing in 1996 in an attempt to determine if there is a way to use the timing of the rotary hoeing along with the double pass to increase weed control yet minimize its negative effect on the corn crop. Four treatments using a rotary hoe and a non-rotary hoed check were compared. Two of the treatments used a early (1st)and a later (2nd) hoeing while the other two treatments used only the later hoeing. Treatments were 1) 1st 1x & 2nd 1x; 2) 1st 2x & 2nd 2x; 3) 2nd 1x; 4)2nd 2x; 5) no rotary hoeing. The later rotary hoeing only was considered since: 1) damage to the corn plant may decrease as the corn root system develops; and 2) the initial rotary hoeing when soil is ridged from the planter seems to be the most effective; and 3) this may be an alternative procedure if wet weather prevents the first hoeing at its recommended time.

1995 Results

Corn was planted May 6, 1995 and rotary hoeings were May 15 and May 21. Weed pressure was determined by using the line intersect technique that is commonly used for measuring soil residue cover. Results in figure 1 show that weed control was increased by the double pass and that a double pass on the second hoeing date only (trt 4) controlled weeds as well as or better than the commonly used single pass at the first and second dates (trt 1). The population reduction and corn damage by rotary hoeing was slight compared to the non-hoed check (Figure 2) but there may also have been some damage to the corn in the check plot by difficulty of emerging due to soil crusting from a heavy rainfall. Again, corn population reduction and corn damage in treatment 4 was similar to treatment 1. A double pass later than recommended (after weeds have emerged) may be an effective substitute when wet soil or other reasons prevent an early hoeing when weeds are in the ideal "white thread stage". As in previous research there is a trend toward increased corn damage with increased weed control.

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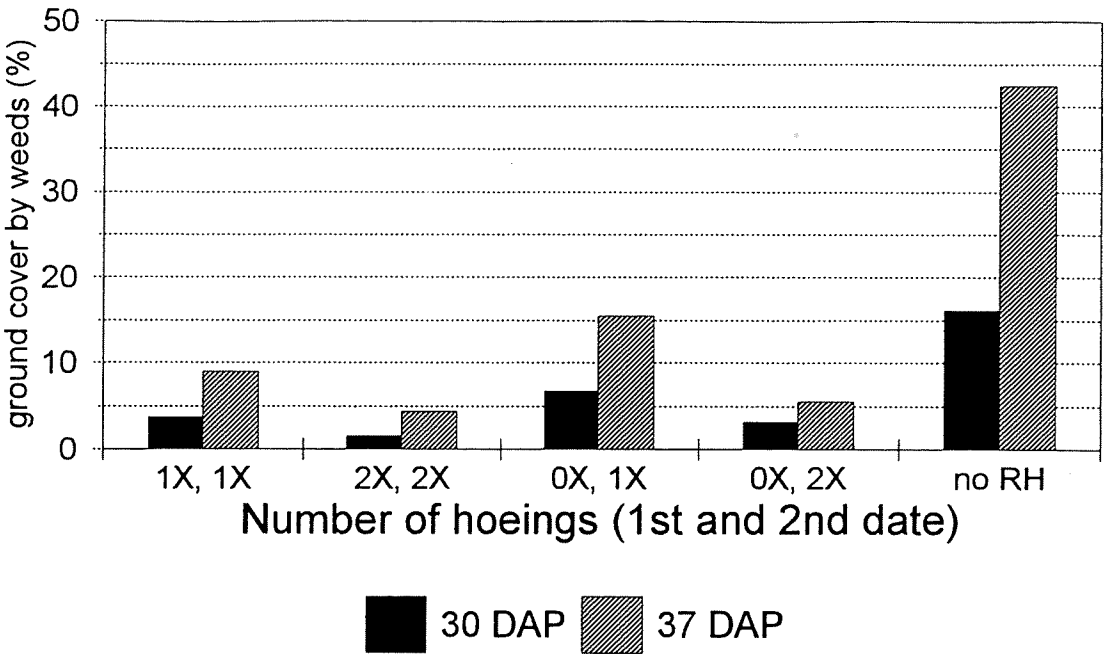

Figure 1. Effect of Rotary Hoeing Treatments on Weeds

* measured using line transect technique

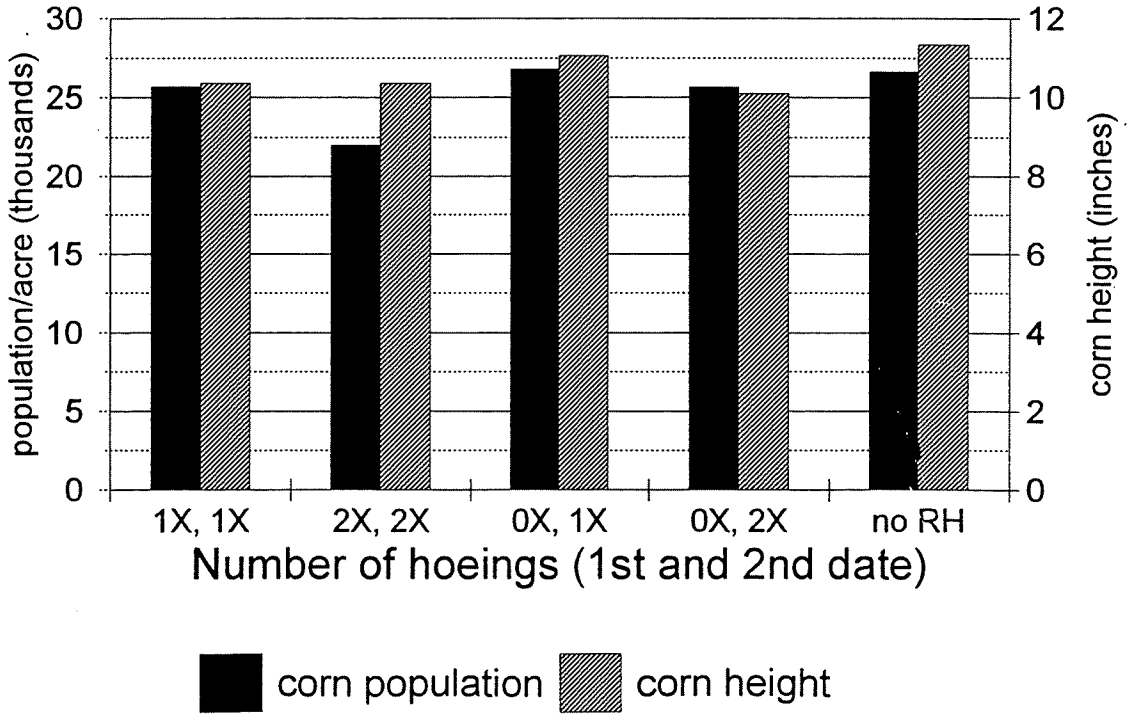

Figure 2. Effect of Rotary Hoeing Treatments on Corn Population and Corn Height

* corn population at 37 days and corn height at 30 days after planting

WICST SOIL BIODIVERSITY STUDY

14. Relevance of Biodiversity to the Sustainability of Agricultural Systems

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

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

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

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

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

15. Pitfall Trap Analysis of Soil Macroarthropods Associated with the Wisconsin Integrated Cropping Systems Trial, 1994

E.J. Rebek[1*], D.K. Young[1], and D.B. Hogg[1]

Background

The Wisconsin Integrated Cropping Systems Trial continues to provide an excellent laboratory for examining the ecological ramifications, both short and long term, of different approaches to farming and philosophies of land stewardship. Ecological changes will take place in and on the soil surface, and will reflect soil health measured in chemical, physical, and biological terms. Soil health is often quantified by determining the abundance and diversity (i.e. number of species) of organisms inhabiting the soil. In general, a more biologically diverse and active soil is more healthy; biodiversity contributes to the overall "stability" of the system as evidenced in the trophic or feeding structure of those soil organisms. An important biological component in the analysis of agroecosystems is the insect fauna and other arthropods in the soil.

Our operational hypothesis in the study of arthropod diversity continues to be that *the level and frequency of soil disturbance (both physical and chemical) in the various cropping systems influence the numbers and kinds of arthropods inhabiting the plots.* Differences in arthropod populations could contribute to, as well as result from, changes in soil characteristics.

In the two previous years of pitfall sampling in the WICST study (1992 & 93), our objective has been to infer differences in arthropod diversity among cropping systems by sampling only the corn phase of selected systems (Young et al. 1994, 1995). Our goal for the 1994 sampling shifted to a slightly different question, namely to determine if differences in arthropod diversity occur among the various crops utilized within a cropping system, i.e. how important the "crop effect" might be. We chose to examine the low input grain system (wheat/red clover- wide row soybean- corn) for this purpose. In addition, we sampled from the relatively undisturbed "pasture" system (low input forage) for the first time in 1994.

Methods

The 1994 pitfall trap sampling for soil macroarthropods was conducted at both the Arlington Research Station (ARS) in Columbia County and the Lakeland Agricultural Complex (LAC) in Walworth County. Pitfall traps were used between early July and late August to trap soil surface-dwelling arthropods. This technique passively captures arthropods as they move across the soil surface. Although this technique is not an exhaustive species inventory strategy, we feel it serves as one standardized method for both treatment and site comparisons.

All phases of the Rotation 3 cropping system and the Rotation 6 pasture system were sampled. The phases of the Rotation 3 system included winter wheat/red clover (treatment 5), corn following wheat/red clover (treatment 4), and wide row soybeans following corn (treatment 6). The Rotation 6 system (treatment 14) was rotationally grazed by dairy cattle.

Two pitfall traps were placed in each plot for 2 replications at each site except for the Rotation 6 system, where 4 traps were placed in each plot. Our reason for placing 4 traps in the pasture system was to sample pre-grazed and post-grazed sections of pasture. Thus, 2 traps were placed in long grass (pre-grazed) and 2 were placed in shorter grass

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(post-grazed). However, conflicts with the rotation schedule of the cows and a lack of discernible differences prompted us to discontinue this practice. The arthropod counts for pasture plots were corrected by dividing the total number of specimens by four in order to make the numbers equivalent to the other three treatments. Traps were placed 10 rows (about 30 ft. for pasture) in from each side of the plots and about 40 feet in from the front of the plots. Samples were collected every two weeks at each site for a total of 14 collection dates, seven for both ARS and LAC (see graphs). All traps from each plot were bulked resulting in a total of 8 samples for each collection date (4 treatments/rep x 2 reps/site). Treatment 6 was eliminated from week 3, and treatment 5 was eliminated from weeks 7 and 8 due to conflicts with the cultivation schedule; traps were often buried following tillage during these weeks (see graphs).

Samples were separated, cleaned, and sorted to the first level of taxonomic comparison. Specimens went through an alcohol wash to remove organic and soil debris and were separated into major taxonomic groups. Groups of particular interest and high species diversity, such as the beetles (Coleoptera), will be further processed taxonomically as sorting continues. This will enable us to make more specific taxonomic comparisons and to better identify "functional groups" from an ecological standpoint.

Results

Preliminary sorting has been completed for the 1994 samples. This analysis will be used for comparing results to 1992 and 1993, even though the focus was different for 1994. Seven of the groups under study were the same as they have been in the past: millipedes (Diplopoda), centipedes (Chilopoda), spiders (Araneae), harvestmen (Opiliones), beetles (Coleoptera), crickets and grasshoppers (Orthoptera), and springtails (Collembola). The eighth group was Hymenoptera, which consists of wasps, bees and ants (Family Formicidae). In the past, we looked solely at the ants. We recently decided upon a shift in focus toward all members of the order Hymenoptera.

Millipedes (Diplopoda), acting as scavengers in the cropping systems, were again virtually absent from the LAC site (Fig. 1), which is consistent with 1992 and 1993 data. The higher water table at LAC compared to ARS may have a negative impact on millipede populations. The peaks and valleys seen with the millipede numbers for each treatment are interesting, especially when comparing treatments 4 and 6. In Rotation 3 corn, the abundance of millipedes remained steady until week 10 and then gradually increased later in the season. The same is true for Rotation 3 soybean, except that millipedes were not found in these plots until week 8. In contrast, Rotation 3 wheat/red clover supported a constant but relatively small number of millipedes. Thus, millipede populations seem to have been affected by crop type within Rotation 3. The lowest numbers of millipedes at ARS were recorded in the pasture samples.

Centipedes (Chilopoda) were much more abundant at LAC than at ARS in 1994 (Fig. 2). At LAC, centipede populations showed similar patterns for all crops in Rotation 3, an early season peak followed by population decline through the remainder of the season. As was the case with millipedes, centipede numbers were lowest in the pasture plots.

Two interesting trends can be seen when comparing harvestman (Opiliones) populations for all treatments in Rotation 3 (Fig. 3). First, the numbers of harvestmen showed significant peaks late in the season for wheat/red clover at both ARS and LAC. Second, harvestman population trends were similar for corn and soybean at both sites. The lowest numbers of harvestmen were recorded for the pasture plots.

Spiders (Araneae), serving as generalist predators in the cropping systems, were most abundant in wheat/red clover at ARS (Fig. 4), where their numbers increased through the season and peaked the final week of sampling. Spider populations either declined

significantly from early season peaks (corn at ARS, pasture at LAC) or remained relatively constant in the remainder of the plots.

Springtail (Collembola) populations remained steady throughout the 1994 season for all treatments, except for notable peaks in week 2 in wheat/red clover at ARS and week 7 in soybean at LAC (Fig. 5). Springtail counts were lowest for the pasture plots at both sites. Cricket and grasshopper (Orthoptera) populations were highest in the wheat/red clover plots at LAC (Fig. 6), relatively low in the other Rotation 3 plots, and very low to scarce in the pasture plots.

Beetles (Coleoptera), comprised mostly of predaceous ground beetles (Family Carabidae), were abundant in all treatments (Fig. 7). This group of soil arthropods constitutes the majority of macroarthropods present in our traps every year. Beetles and springtails are two groups we will give particular attention as we further classify these arthropods. One trend that can be seen even at this level of processing is that beetle numbers parallel the numbers of springtails for most weeks in all treatments except pasture. This trend seems reasonable since springtails are the most available and often preferred food choice of many ground beetle species.

Ants, wasps and bees (Hymenoptera) were most abundant in the corn phase of Rotation 3, especially at LAC (Fig. 8). Numbers were relatively constant in the rest of the Rotation 3 plots and were lowest in the pasture plots.

In conclusion, preliminary analysis of the 1994 pitfall data suggests that the different crop types within a cropping system can have important effects on arthropod diversity and seasonal patterns of abundance. The data also indicate that, with the exceptions of beetles and spiders, the pasture plots harbor relatively few arthropods. As a low input system (i.e. no fertilizer or pesticides) with a diversity of grasses and forbs, we would expect pasture systems to support a greater number and diversity of arthropod species. Perhaps the low soil bulk density inherent in these plots due to soil compaction from the grazing cows negatively affects the populations of soil arthropods. High soil compaction would restrict movement of arthropods through the soil, especially larger insects.

Alternatively, the apparent lack of arthropod diversity in the pasture plots, plus lack of consistent patterns in all treatments over time (Young et al. 1993, 1994), may be due to the fact that the WICST study has been in operation for a relatively short time (since 1990), and an insufficient amount of time to allow the arthropod species normally or perhaps historically associated with the various cropping systems represented to find and recolonize the appropriate plots. This possibility has prompted us to initiate a comparison of these agricultural systems with natural sites (i.e. non-farmed systems). One natural site is situated in Columbia County in the Mud Lake Recreational Area and the other is located on privately owned land near Springfield in Walworth County. Criteria for choosing natural sites was the land had to have been out of crop production for at least twenty years (allowing for recolonization of natural arthropod inhabitants) and had to be sufficient large for us to conduct sampling similarly to how it is conducted in the WICST plots. Sampling at these sites has been implemented for the 1996 season.

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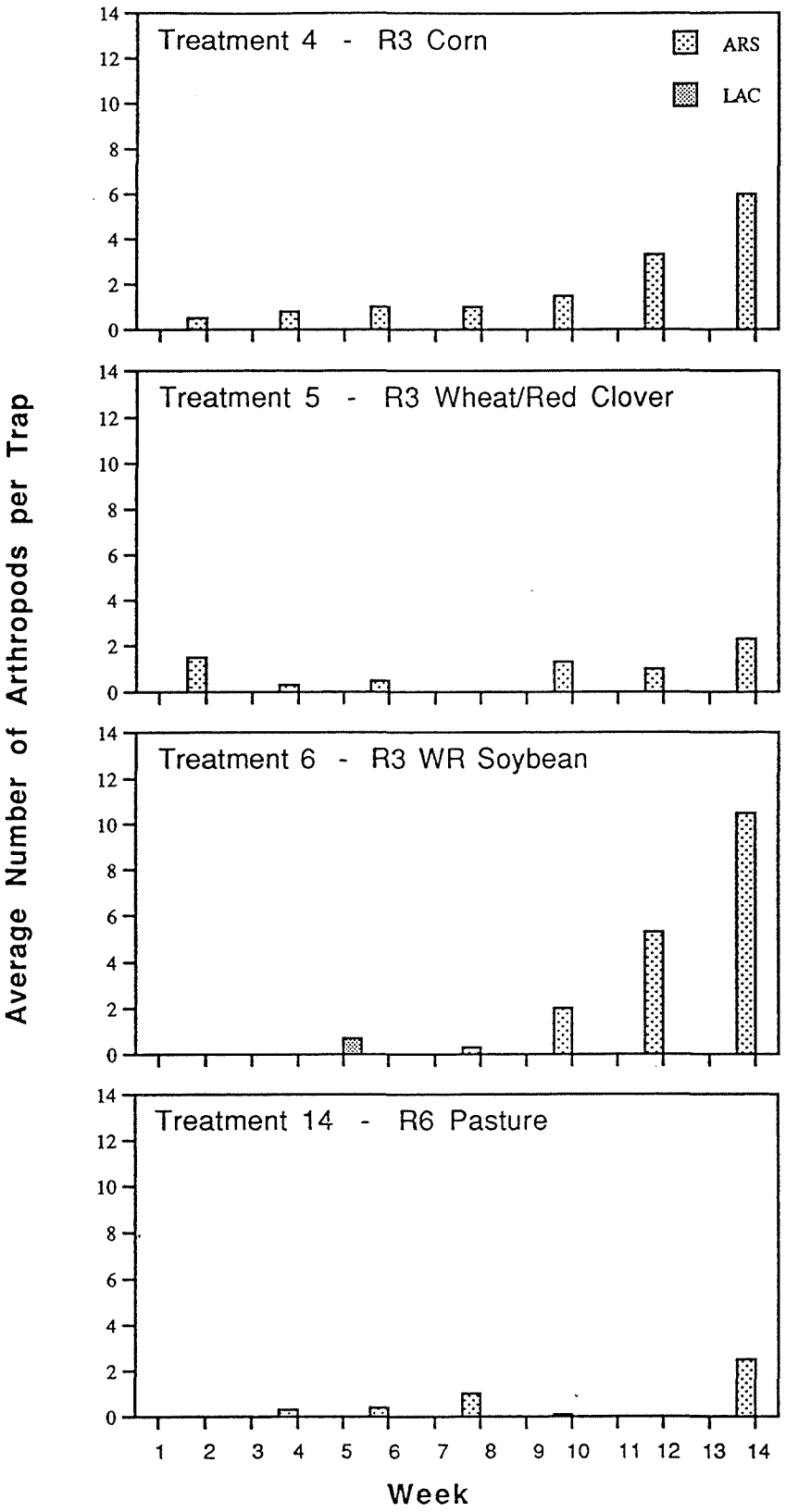
Young, D.K., D.B. Hogg, and E.J. Rebek. 1995. Pitfall trap analysis of soil macroarthropods associated with the Wisconsin Integrated Cropping Systems Trial, 1993. Fourth Report of the Wisconsin Integrated Cropping Systems Trial, University of Wisconsin-Madison, pp. 26-36.



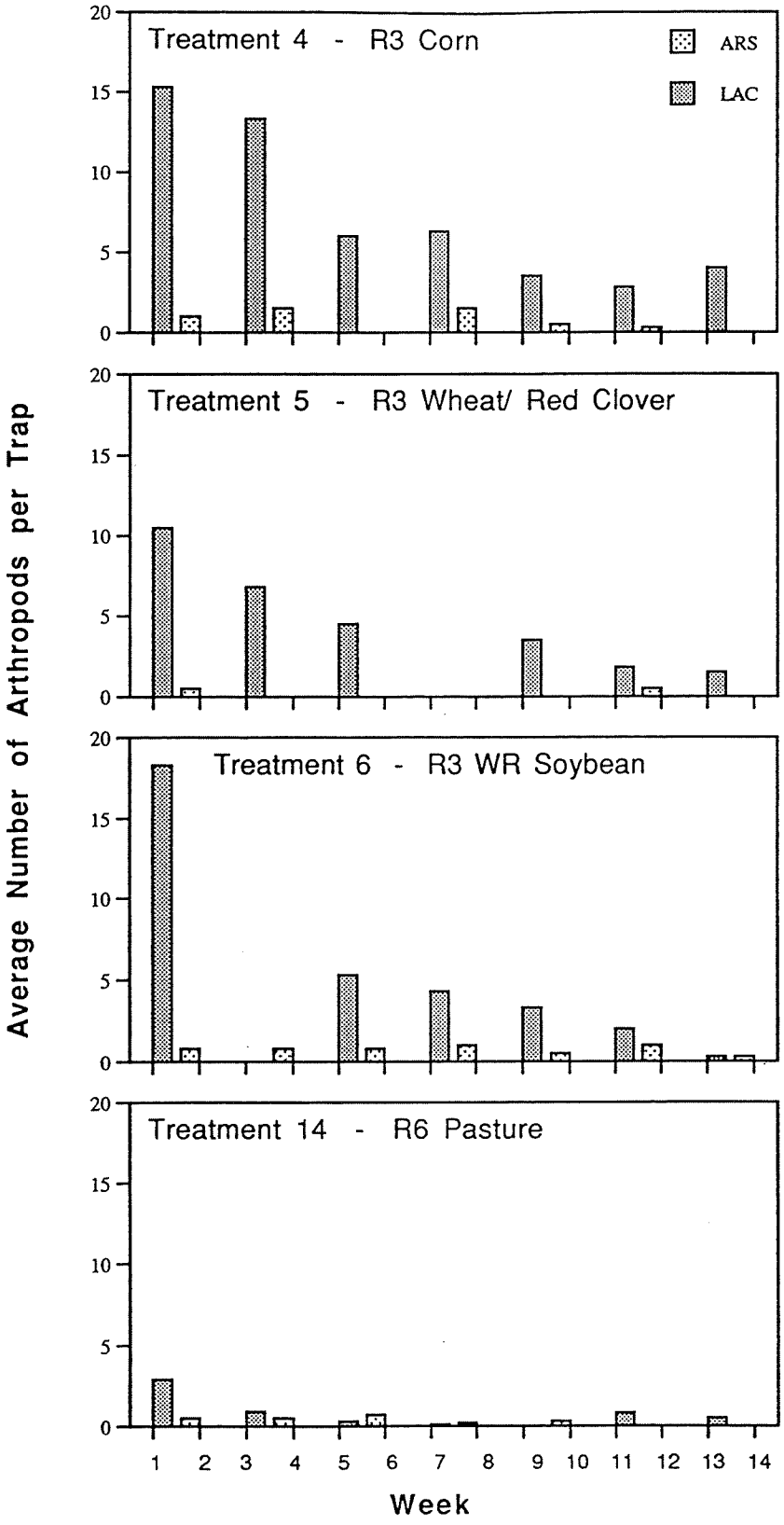
Weeks:

1 July 6-13
2 July 8-18
3 July 13-20
4 July 18-22
5 July 20-28
6 July 22-29
7 July 28 - August 4
8 July 29 - August 6
9 August 4-10
10 August 6-12
11 August 10-18
12 August 12-19
13 August 18-24
14 August 19-26

Notes:

T6 eliminated from Week 3
T5 eliminated from Week 7
T5 eliminated from Week 8

Figure 1. Diplopoda captured in WICST pitfall traps in 1994.



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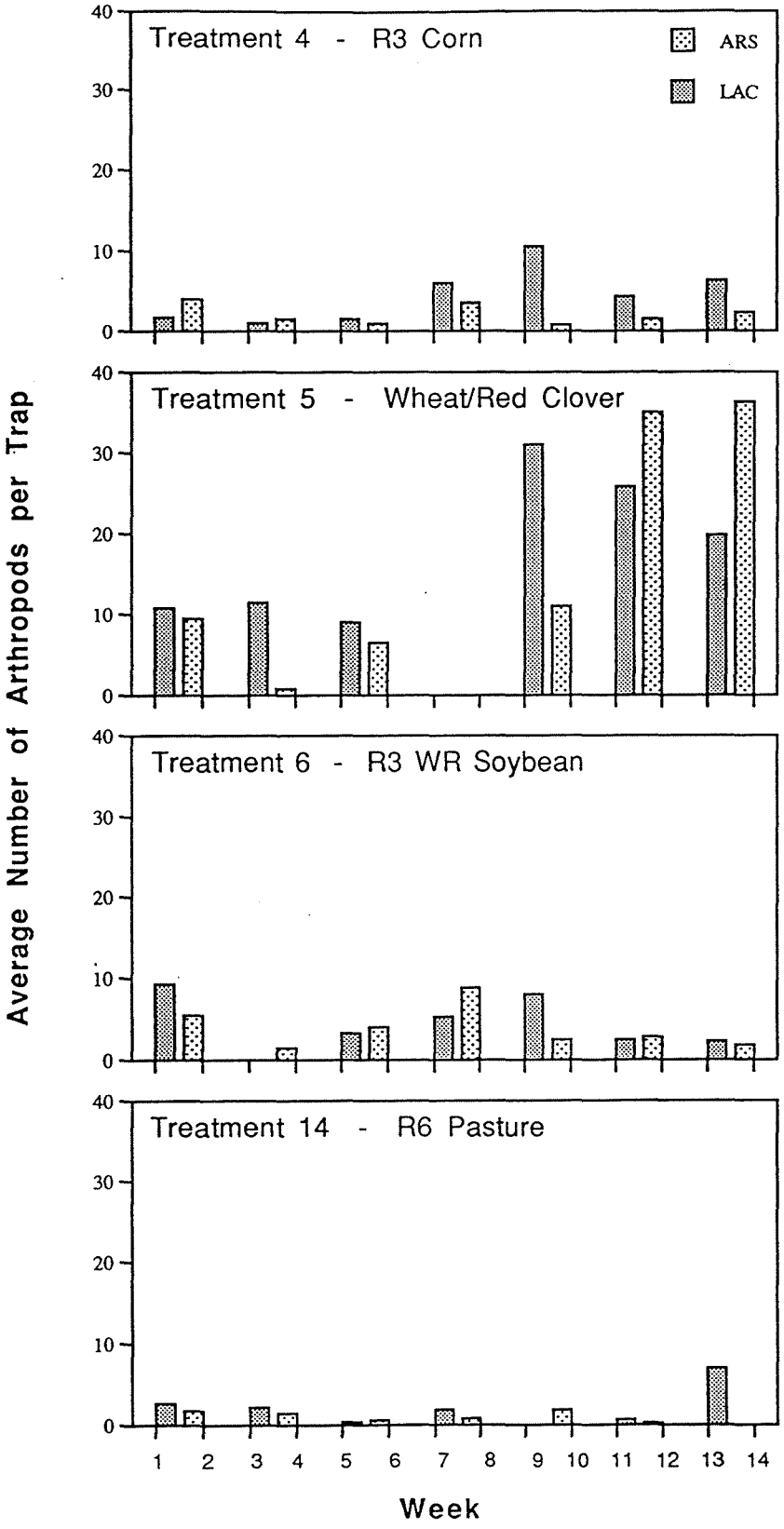
11 August 10-18
12 August 12-19
13 August 18-24
14 August 19-26

Notes:

T6 eliminated from Week 3
T5 eliminated from Week 7
T5 eliminated from Week 8

Figure 2. Chilopoda captured in WICST pitfall traps in 1994.



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11 August 10-18
12 August 12-19
13 August 18-24
14 August 19-26

Notes:

T6 eliminated from Week 3
T5 eliminated from Week 7
T5 eliminated from Week 8

Figure 3. Opiliones captured in WICST pitfall traps in 1994.

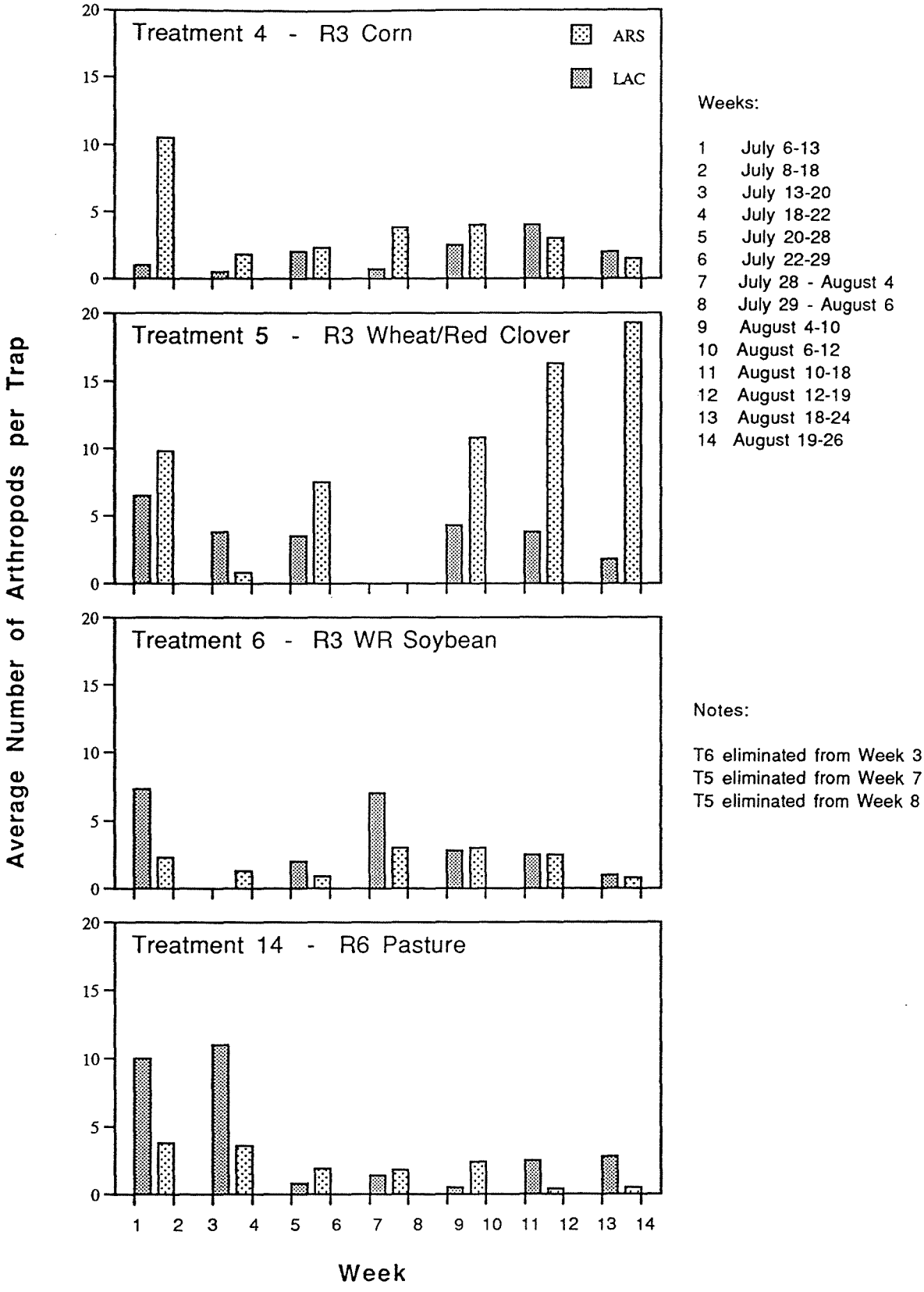
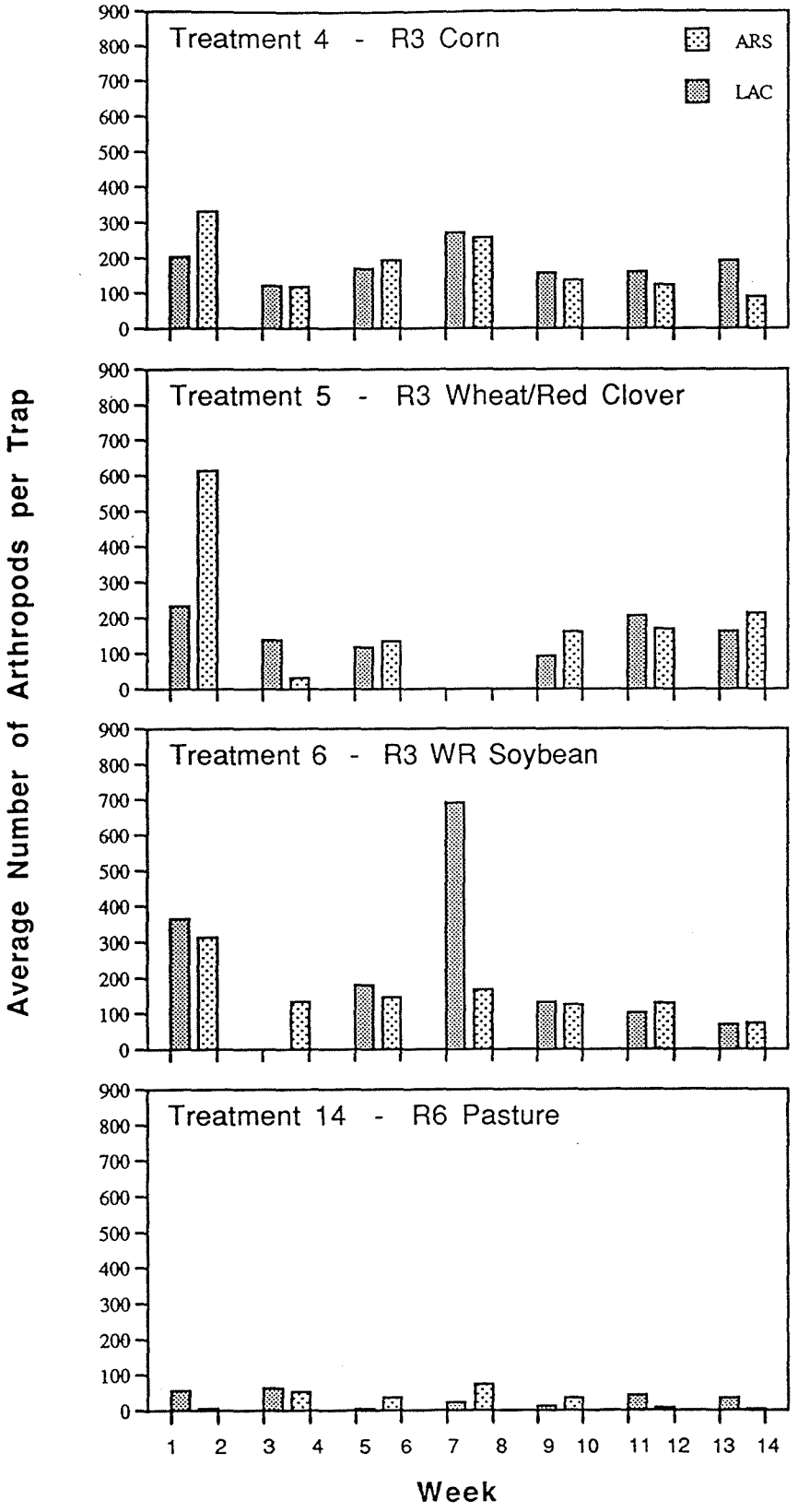


Figure 4. Araneae captured in WICST pitfall traps in 1994.



Weeks:

1 July 6-13
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4 July 18-22
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8 July 29 - August 6
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10 August 6-12
11 August 10-18
12 August 12-19
13 August 18-24
14 August 19-26

Notes:

T6 eliminated from Week 3
T5 eliminated from Week 7
T5 eliminated from Week 8

Figure 5. Collembola captured in WICST pitfall traps in 1994.

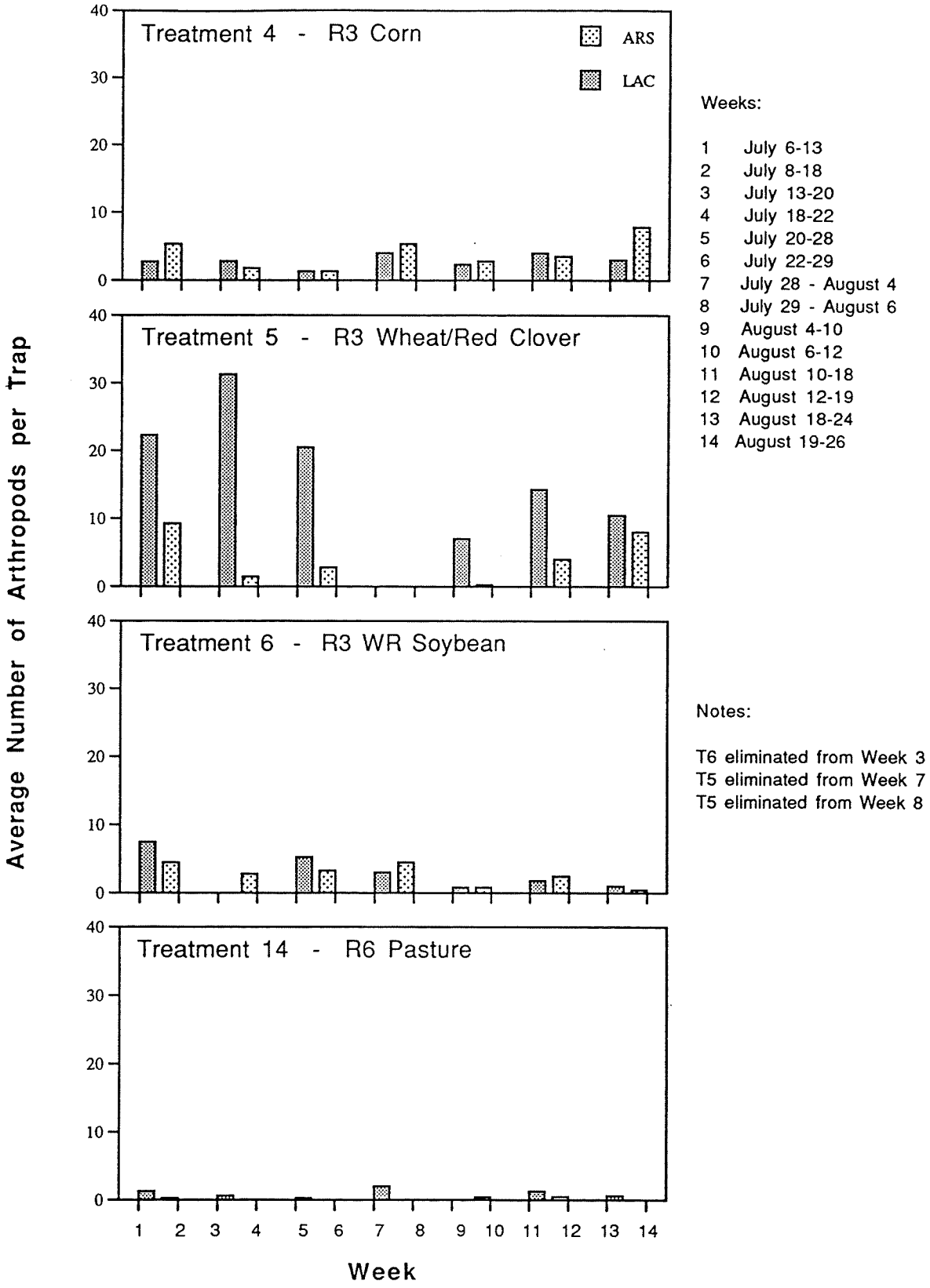
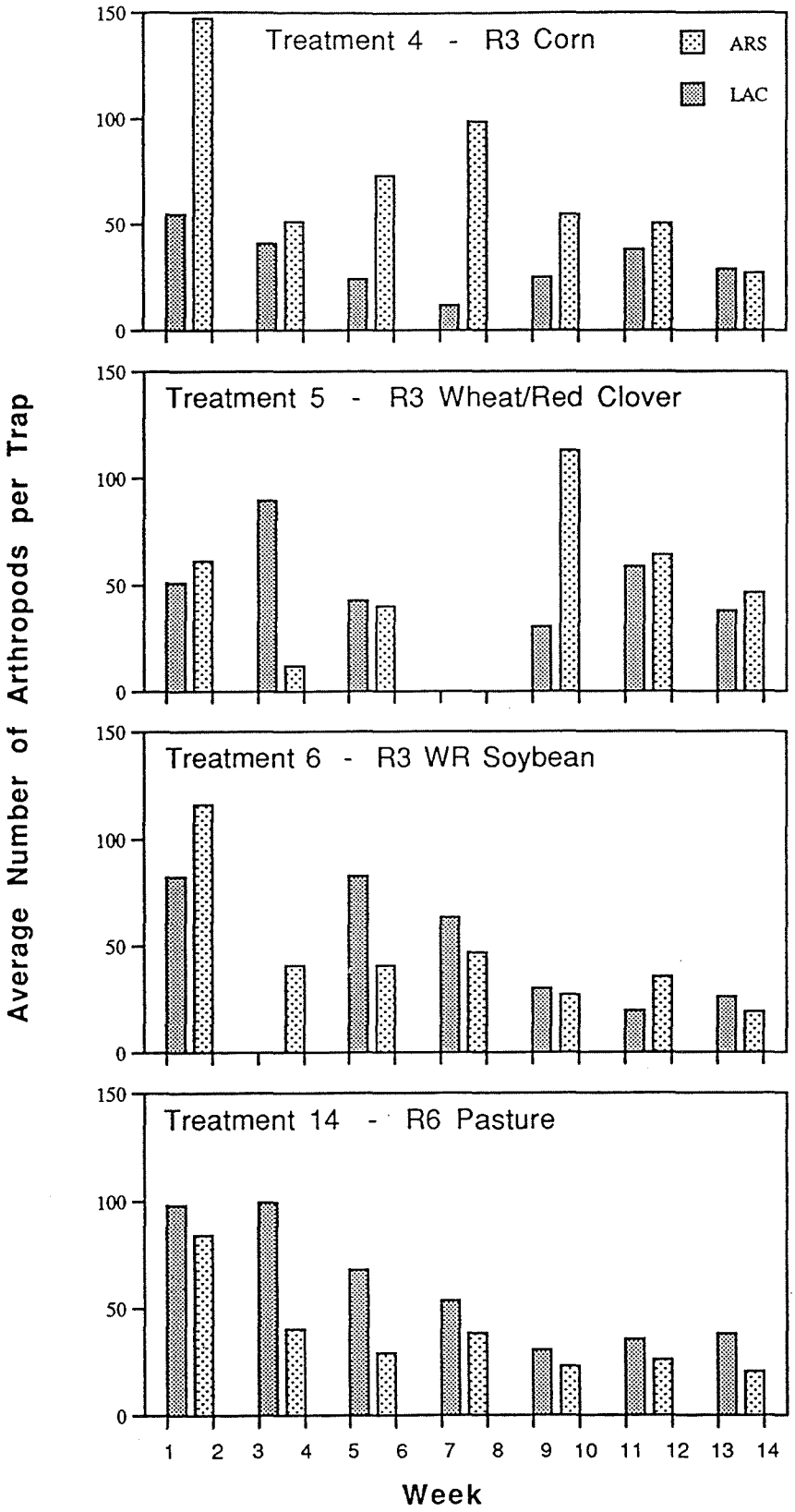


Figure 6. Orthoptera captured in WICST pitfall traps in 1994.



Weeks:

1 July 6-13
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9 August 4-10
10 August 6-12
11 August 10-18
12 August 12-19
13 August 18-24
14 August 19-26

Notes:

T6 eliminated from Week 3
T5 eliminated from Week 7
T5 eliminated from Week 8

Figure 7. Coleoptera captured in WICST pitfall traps in 1994.

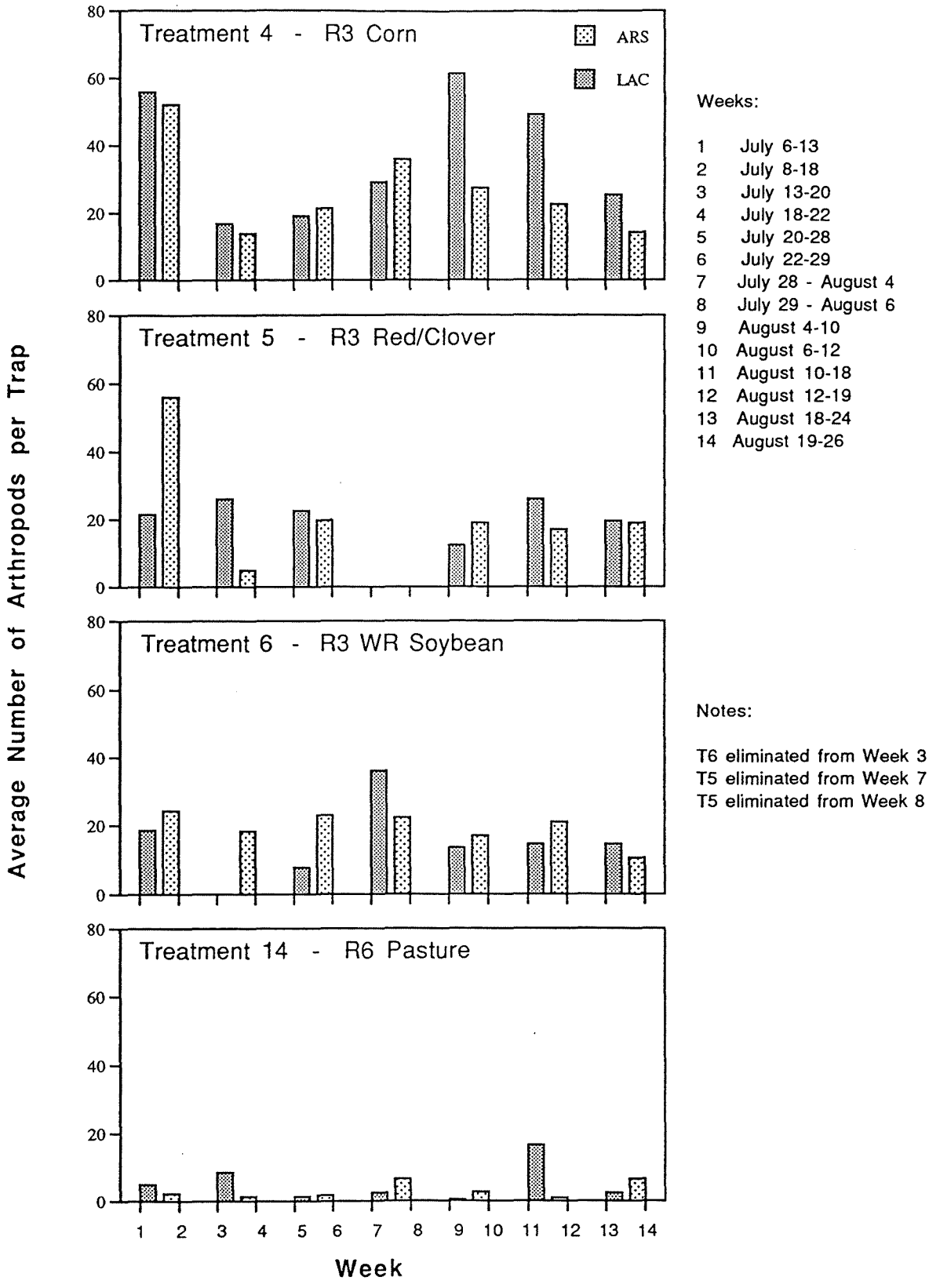

Figure 8. Hymenoptera captured in WICST pitfall traps in 1994.

16. Soil Invertebrates Associated with Soil Core Sampling and Residue Decomposition, 1995

E.J. Rebek[1*], D.B. Hogg[1], and D.K. Young[1]

Background

Soil core sampling was initiated in 1995 to complement both the litter bag and pitfall trap sampling studies that have been ongoing in the WICST plots. The objective of the soil core study is to determine the influence of crop rotation, fertilizer inputs and pesticide/herbicide inputs on soil arthropod populations. However, in contrast with both pitfall and litter bag sampling, the soil core method provides a direct, absolute sampling method for animals residing in both the surface and subsurface soil layers.

Litter bag sampling was conducted for a third year in 1995. The objectives of the litter bag study are to determine the influence of crop rotation on residue decomposition, and to document the role of soil arthropods in the decomposition process. Results from the litter bag studies in 1993 and 1994 indicated no statistically significant differences in total numbers of animals extracted among cropping systems and/or phases (e.g. crop rotations).

Methods

The Arlington Research Station (ARS) located in Columbia County and the Lakeland Agricultural Complex (LAC) located in Walworth County again served as the sites for our sampling studies.

Soil Cores

Soil core samples were taken using a 2.5-inch diameter soil probe. Each sample consisted of three 6-in. cores, corresponding to 1104.5 cubic centimeters of soil. These samples were taken at two randomly chosen areas in each plot (within rows 6 and 19). In addition, between-row and in-row samples were collected for all corn plots. Thus, four samples were taken in all corn phases and two samples were taken for soybean, oats/alfalfa and pasture plots. Soybean (treatment 6) and oats/alfalfa (treatment 12) plots were sampled once per month, as noted above.

Invertebrates were extracted from the soil core samples by two methods. Larger annelids and arthropods were removed from the soil by hand sorting. Smaller arthropods were separated by placing 200 cm^3 of the soil sample in a 30% sodium chloride solution. This process is referred to as "flotation" because all organic material floats to the top of the solution while the soil sinks to the bottom. Thus, separation relies on the specific density of the arthropods collected with the soil probe. However, in addition to the soil arthropods recovered from flotation, large amounts of plant material and detritus float as well. As a result, both animal and plant material were sieved and collected. Animals were subsequently separated from plant material with the aid of a microscope. All animals recovered were then sorted, counted and classified.

Litter Bags

We used litter bags with relatively coarse mesh (pore size = 4 mm), filled with corn stover (see Hogg et al. 1994), which allowed meso- and macro-invertebrates to enter. In a complementary study, small pore bags (0.0053 mm) were used to exclude annelids and arthropods, allowing only microorganisms to enter, thus providing a direct comparison to

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determine the importance of soil invertebrates on the decomposition process (Edwards & Heath 1963, Curry 1969, Vossbrinck et al. 1979, House & Stinner 1987).

Soil invertebrates were extracted from the large pore litter bags using Berlese funnels. This apparatus consists of a lamp mounted over a metal funnel. The litter bags were placed on hardware cloth about six inches from the lamp. A jar of 80% ethyl alcohol was placed directly beneath the funnel to capture and preserve animals as they escaped from the heated and dried conditions of the bags. Litter bags and jars were collected after two days of extraction. Soil invertebrates, mostly arthropods, were later sorted, counted and classified.

The litter bags were buried on May 16 at ARS and May 23 at LAC in the following plots: continuous corn (treatment 1), rotation 3 corn (treatment 4), rotation 5 corn (treatment 13), rotation 3 wide-row soybean (treatment 6), rotation 5 oats/alfalfa (treatment 12), and pasture (treatment 14). The bags were retrieved on June 27, July 11, July 25, August 8, and August 22 at ARS, and June 20, July 5, July 18, August 1, August 16, and August 29 at LAC for all plots except the oats/alfalfa and WR soybean plots. Bags in treatments 6 and 12 were only retrieved June 27, July 25, and August 22 at ARS, and July 5, August 1, and August 29 at LAC.

Results

Data for the 1995 soil core samples are presented in Figs 1-4. We focused on Coleoptera (beetles), Diptera (flies), Diplopoda (millipedes), and Annelida (earthworms) because these 4 groups were collected in the greatest numbers. Two surprising observations were evident for these groups. First, there was no apparent difference between in-row and between-row corn plot samples. We expected to find greater numbers in the in-row samples because of possible arthropod/crop associations. Second, we collected an unexpectedly rich diversity of soil fauna using the soil core sampling technique. For instance, flies and beetles were present in both larval and adult forms, and each group was represented by about five families. However, the numbers of soil invertebrates recovered were not sufficient to establish a reliable pattern. Thus, we must be careful when trying to interpret the treatment effects on soil invertebrate populations using these data. Considering these sampling problems, we plan to combine data for the entire sampling season and perform analyses of variance to explore statistical relationships.

Differences between sites were evident for some groups in the numbers of soil arthropods recovered from the soil cores. Diptera were more abundant at ARS than LAC in rotation 3 corn and rotation 5 corn. We also found more Diplopoda at ARS than LAC over all cropping systems. This may be due to the higher water table at LAC deterring the presence of millipedes in the relatively anaerobic conditions of deeper soil layers. Millipedes may be more sensitive than other arthropods to the water content of the soil.

In summarizing the 1995 litter bag results we focused on the 4 most abundant arthropod groups: Collembola (springtails), Coleoptera, Diptera, and Acari (mites) (Figs. 5-8). In 1994 we focused on Diplopoda (millipedes) and Annelida (earthworms) in addition to Coleoptera and Diptera. Many more springtails (gross numbers and probably species as well) were collected from litter bags in 1995 than in either 1993 or 1994, i.e. hundreds of individuals per litter bag early in the season for all treatments during 1995, compared with less than 3 per bag in 1993-94. Mite numbers were also much higher in 1995 than in 1993 or 1994. At this point we can offer no explanation for these curious patterns.

With a few exceptions, for the litter bag data all arthropod groups showed a general pattern of higher numbers early in the season (June 20-27) and lower numbers later in the season. This pattern held true over all treatments, and it was also evident in the 1994 data. However, as was the case in 1994, no consistent patterns in numbers of animals appears evident among treatments, although we have not yet done a thorough statistical analysis of the 1995 litter bag data.

Differences between sites for the litter bag study were apparent for some groups. For instance, Diptera were present in greater numbers at LAC than ARS for rotation 3 wide-row soybeans, rotation 5 corn and pasture. Mites were more abundant at LAC than at ARS for all cropping systems included in the study. These site differences in arthropod numbers were especially profound early in the season. Coleoptera were much more abundant at LAC on June 20 than they were at ARS on June 27 for all cropping systems. Diptera were more abundant at LAC than at ARS in rotation 3 corn and continuous corn early in the season. Collembola also displayed early differences in numbers between sites, e.g. being more abundant at ARS than at LAC in continuous corn, rotation 5 corn and oats/alfalfa.

One major difference between soil core and litter bag sampling methods is the sheer numbers of soil arthropods collected. Soil core sampling offers a direct measure of the number of animals present in the soil at a particular point in time, and thus the numbers recovered are low compared to the litter bag method. Also, perhaps soil invertebrates are able to move quickly enough to escape the probe. This may be the case with Collembola, which we expect to recover in soil core samples but rarely accomplish. Litter bag sampling collects greater numbers and kinds of soil arthropods than does soil core sampling, but it is indirect in that it relies on trophic (feeding) relationships among soil invertebrates. For example, a likely scenario is that the corn stubble present in litter bags is first colonized by soil microbes which work to decompose the simple molecular contents of the corn. Invertebrates such as Collembola are then attracted to the corn stubble where they feed on microbes and decomposing plant matter. This attracts larger invertebrates such as beetles which prey upon the springtails. Thus, the arthropods that are recovered are present in the litter bag as a result of their feeding habits, and so not all soil invertebrate groups are going to be equally represented. This stresses the need to continue using both sampling techniques to get a well-rounded view of situations affecting soil arthropods.

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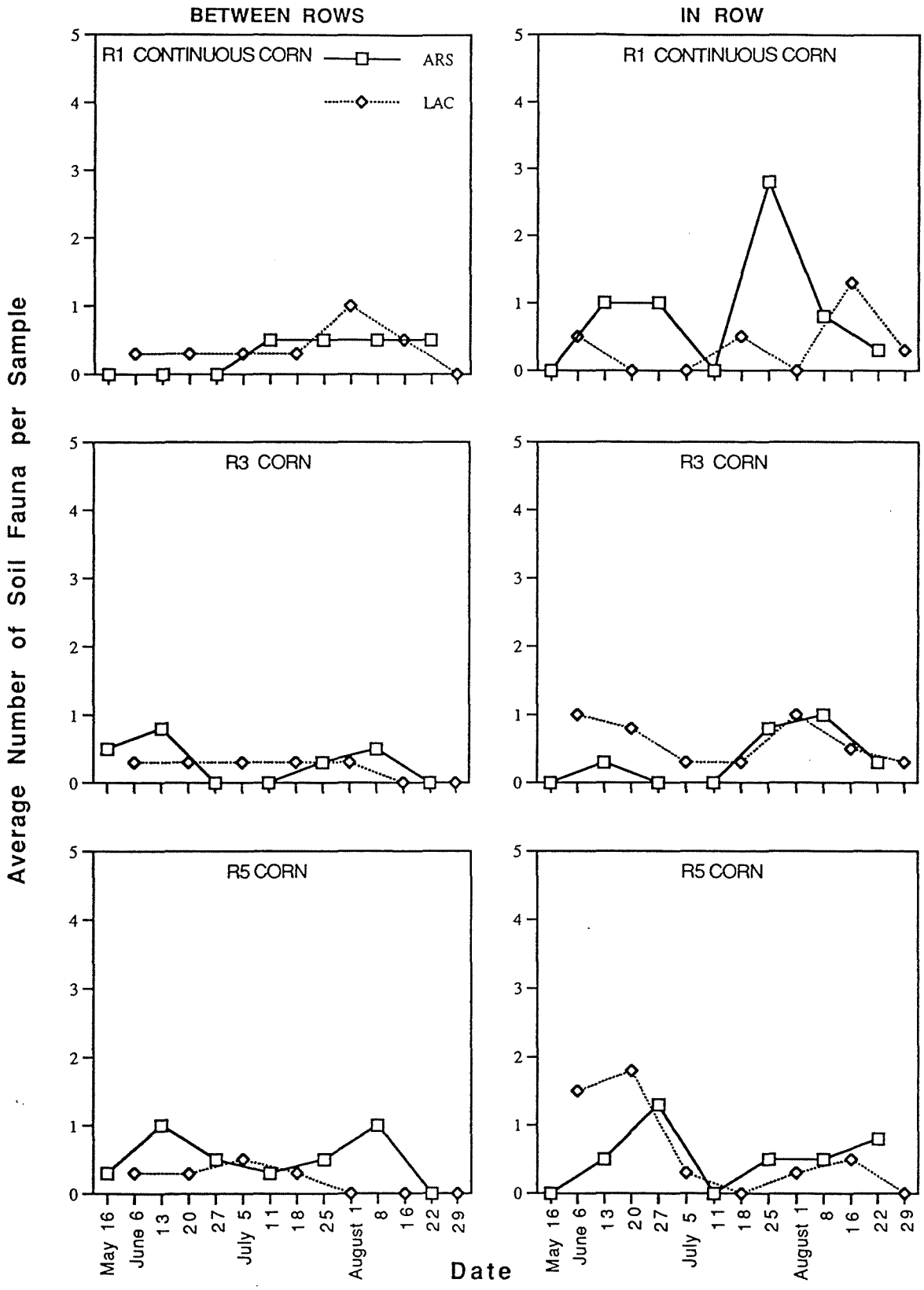
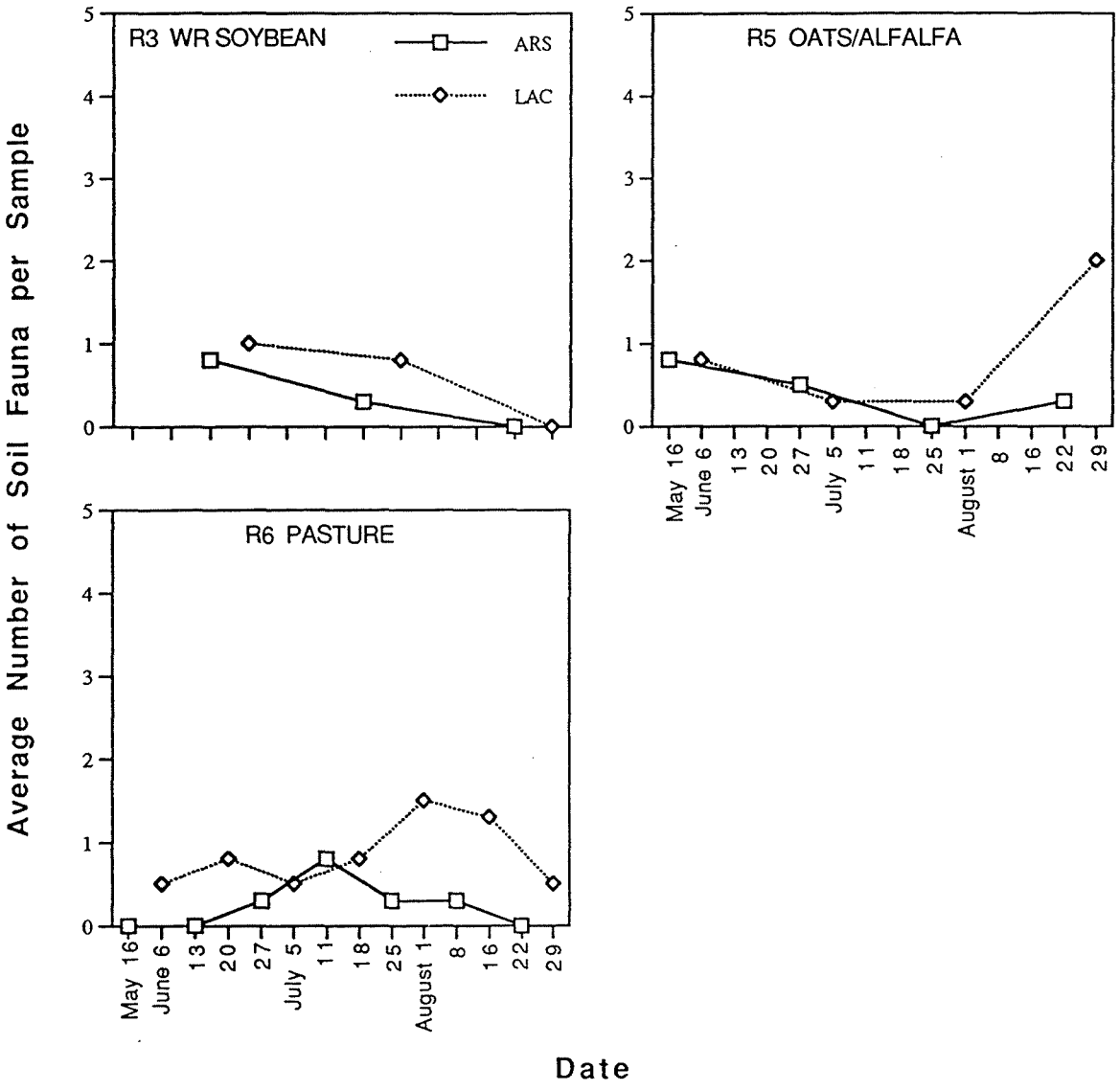


Figure 1. Coleoptera associated with 1995 WICST soil core samples.

Figure 1 (cont.)



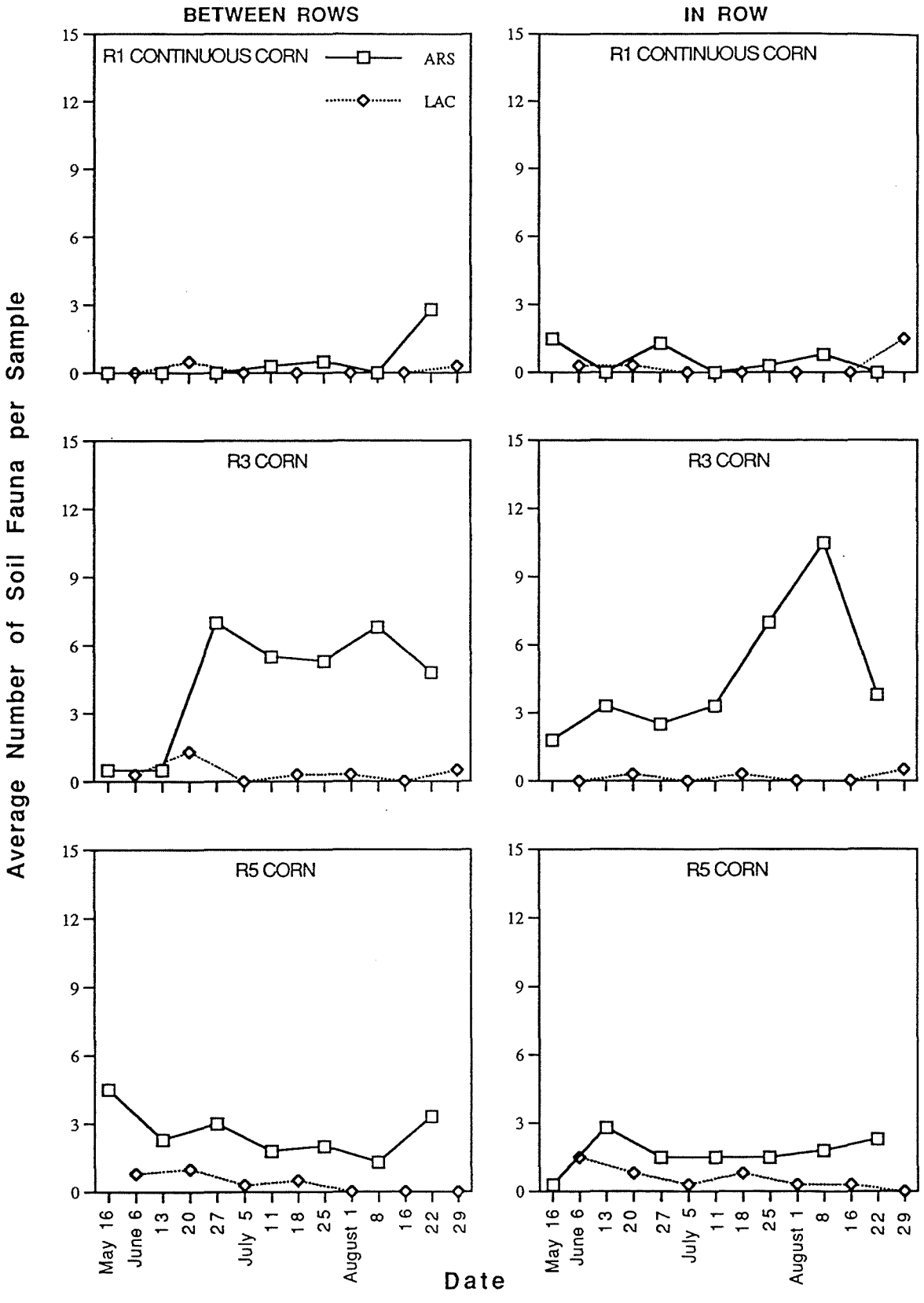
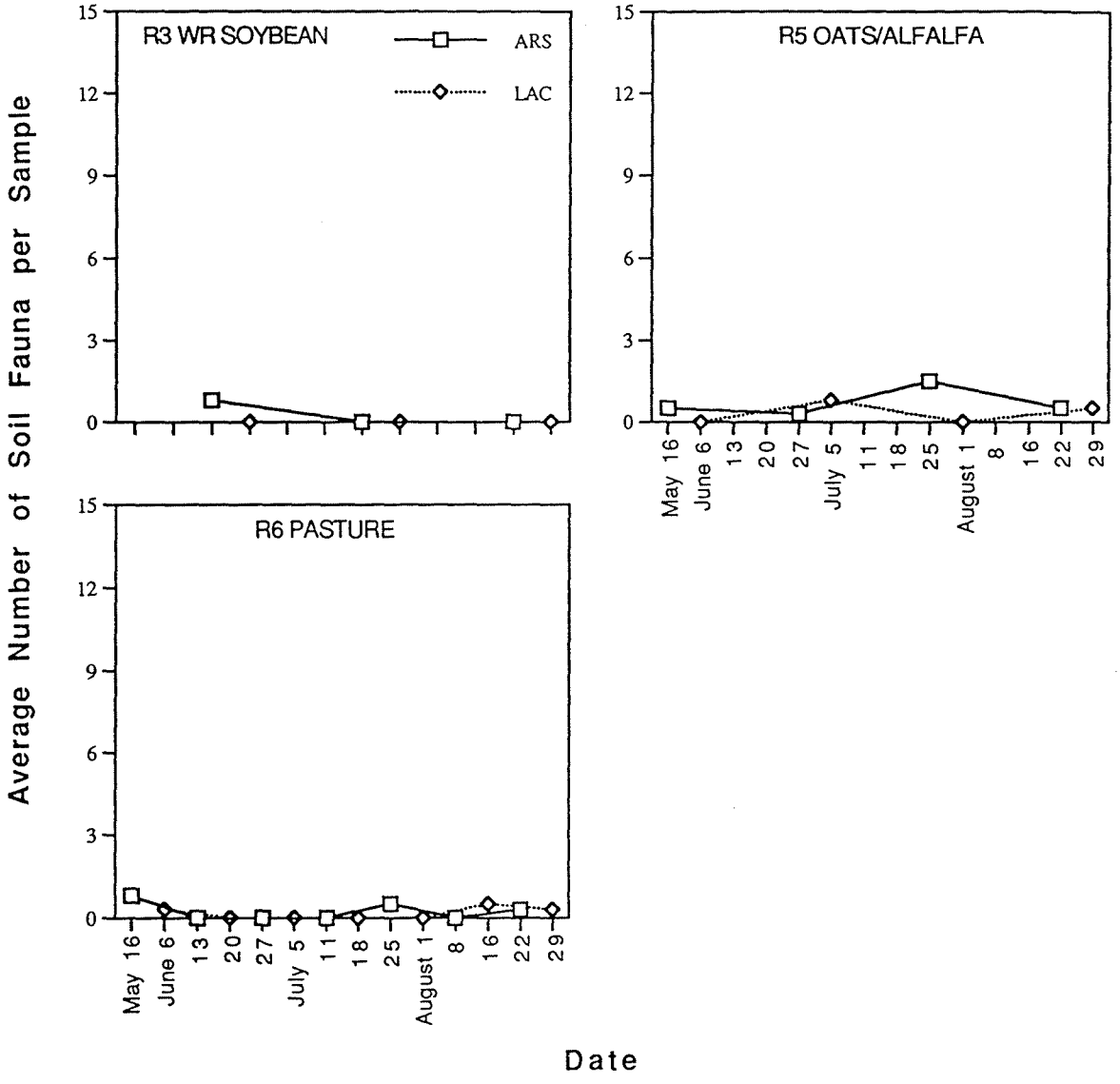


Figure 2. Diptera associated with 1995 WICST soil core samples.

Figure 2 (cont.)



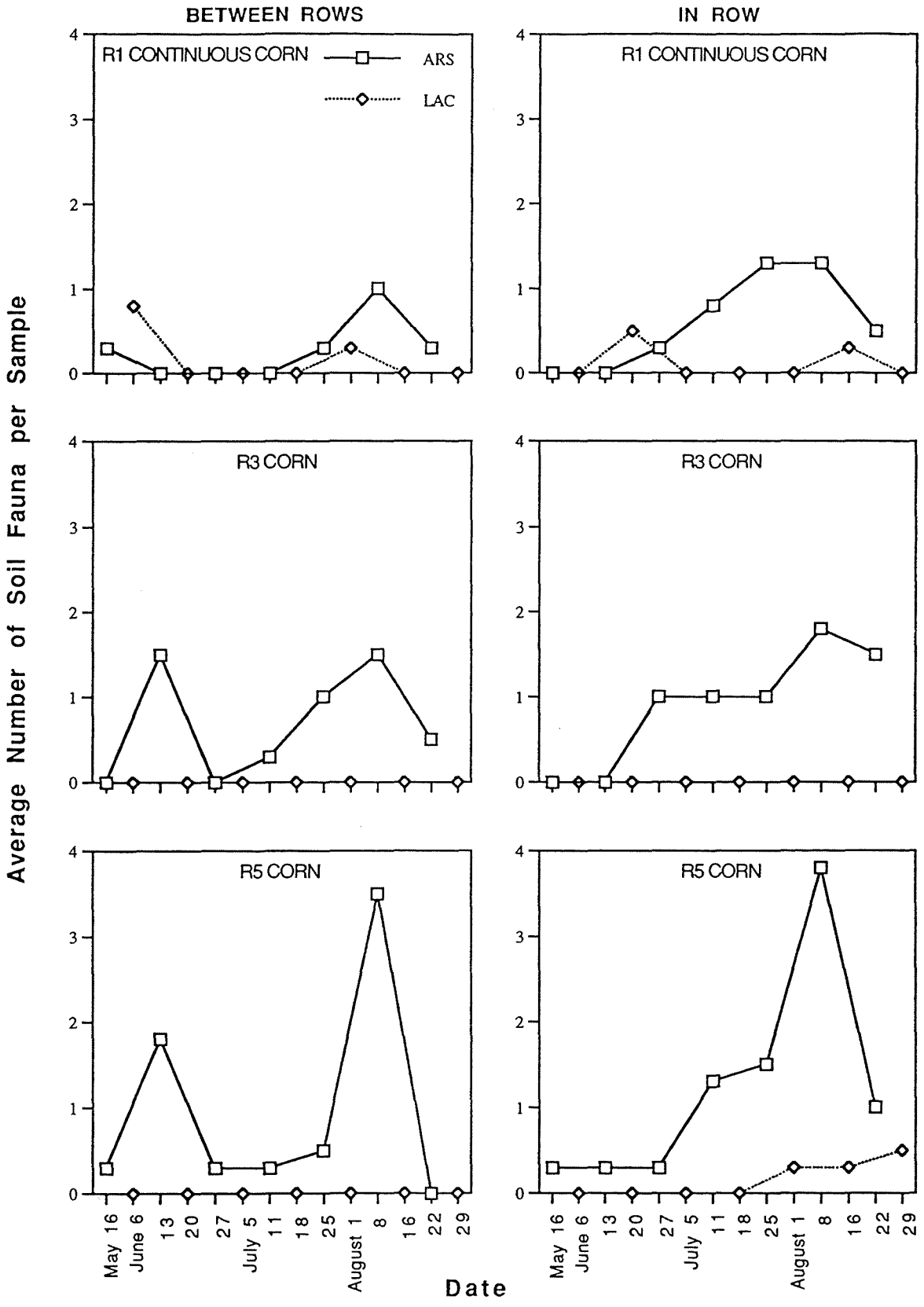
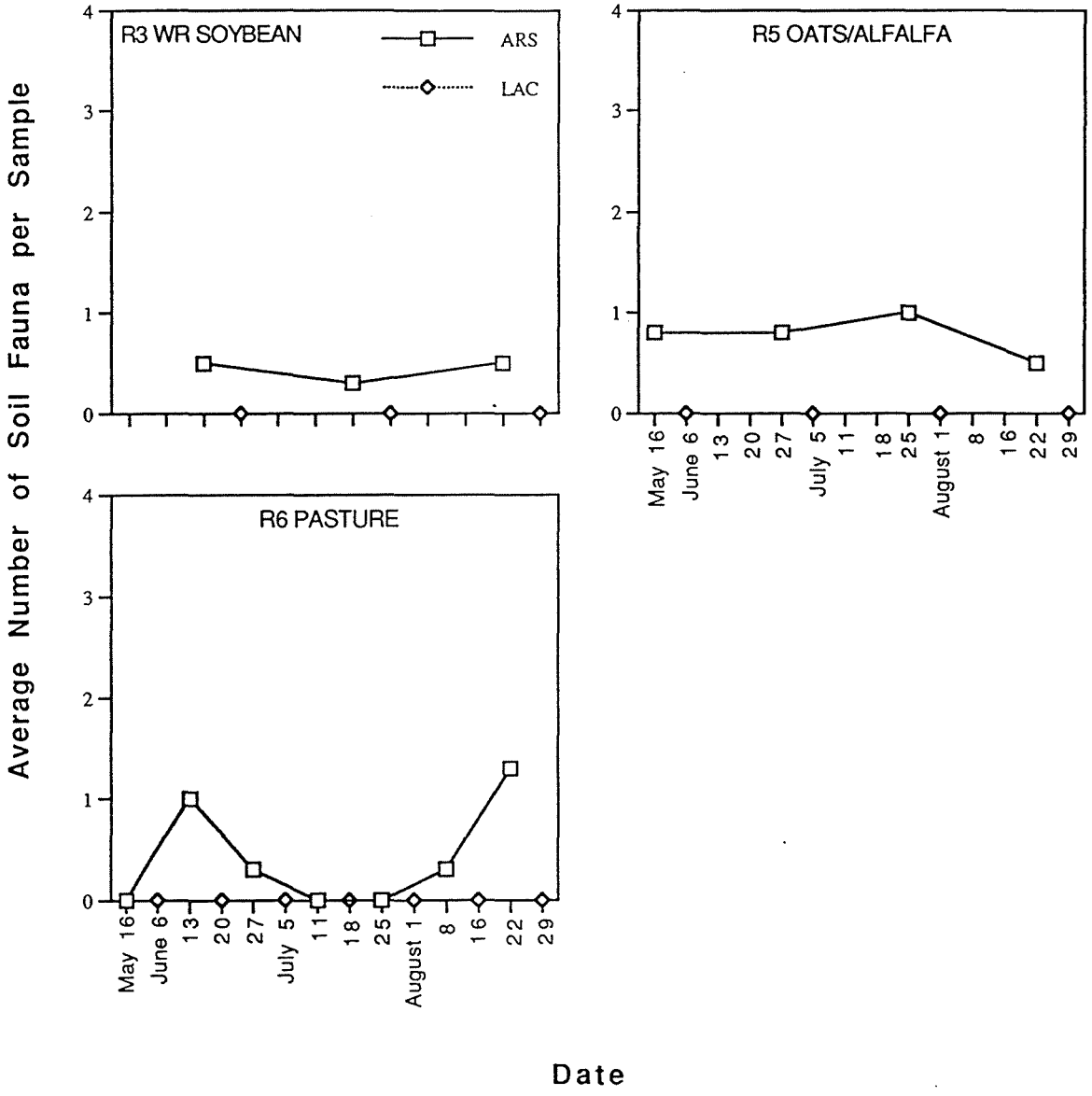


Figure 3. Diplopoda associated with 1995 WICST soil core samples.

Figure 3 (cont.)



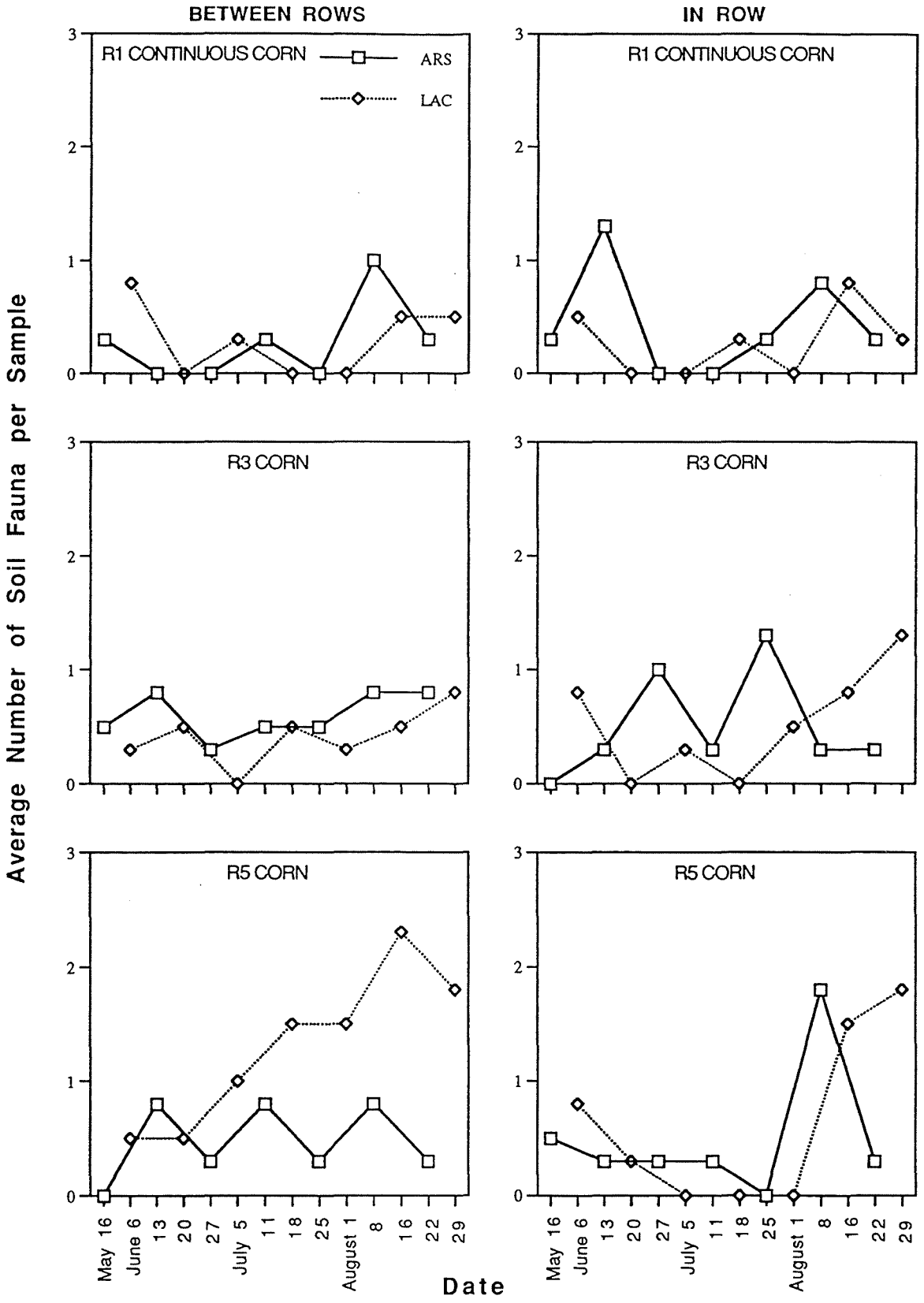
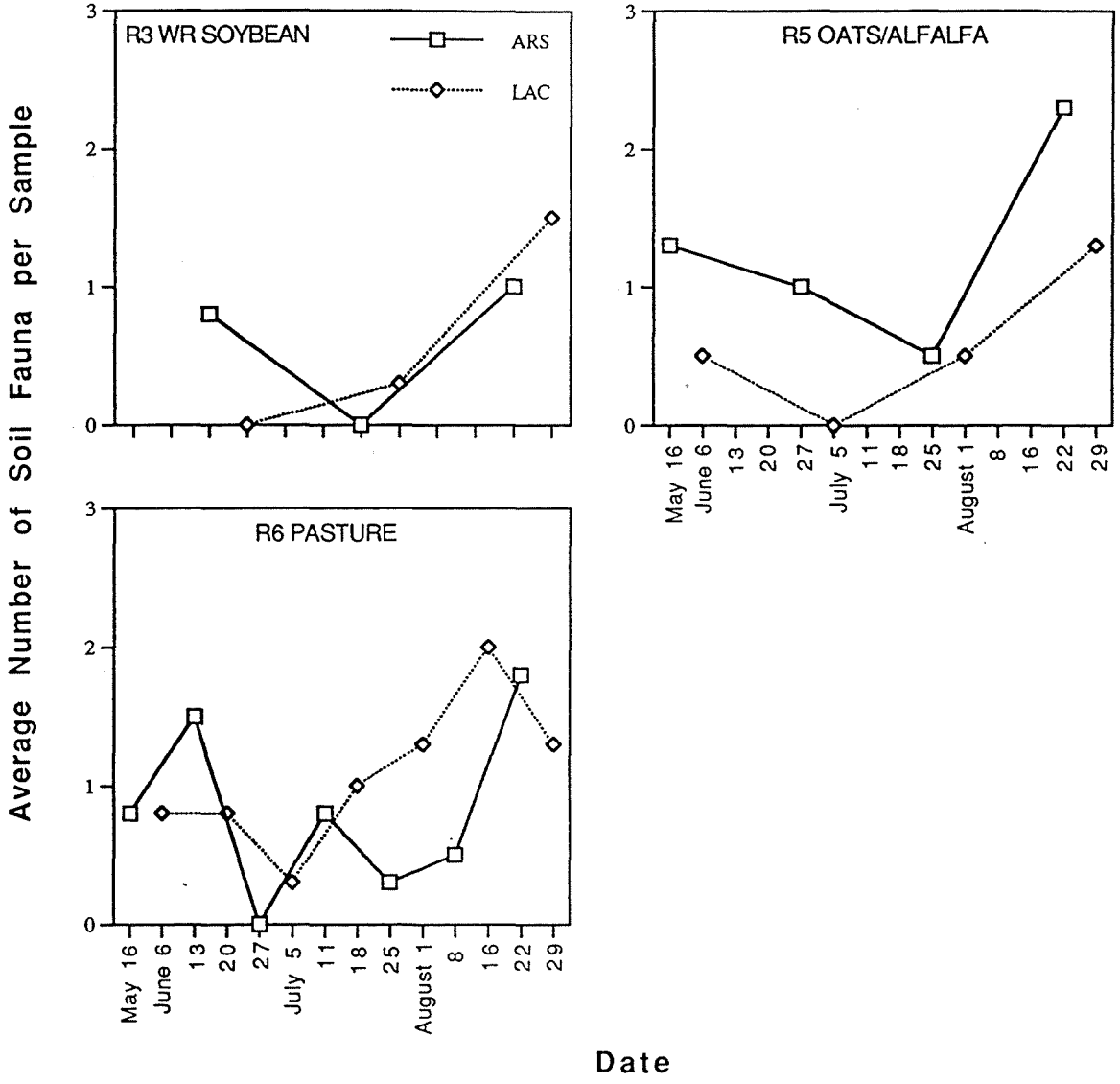


Figure 4. Annelida associated with 1995 WICST soil core samples.

Figure 4 (cont.)



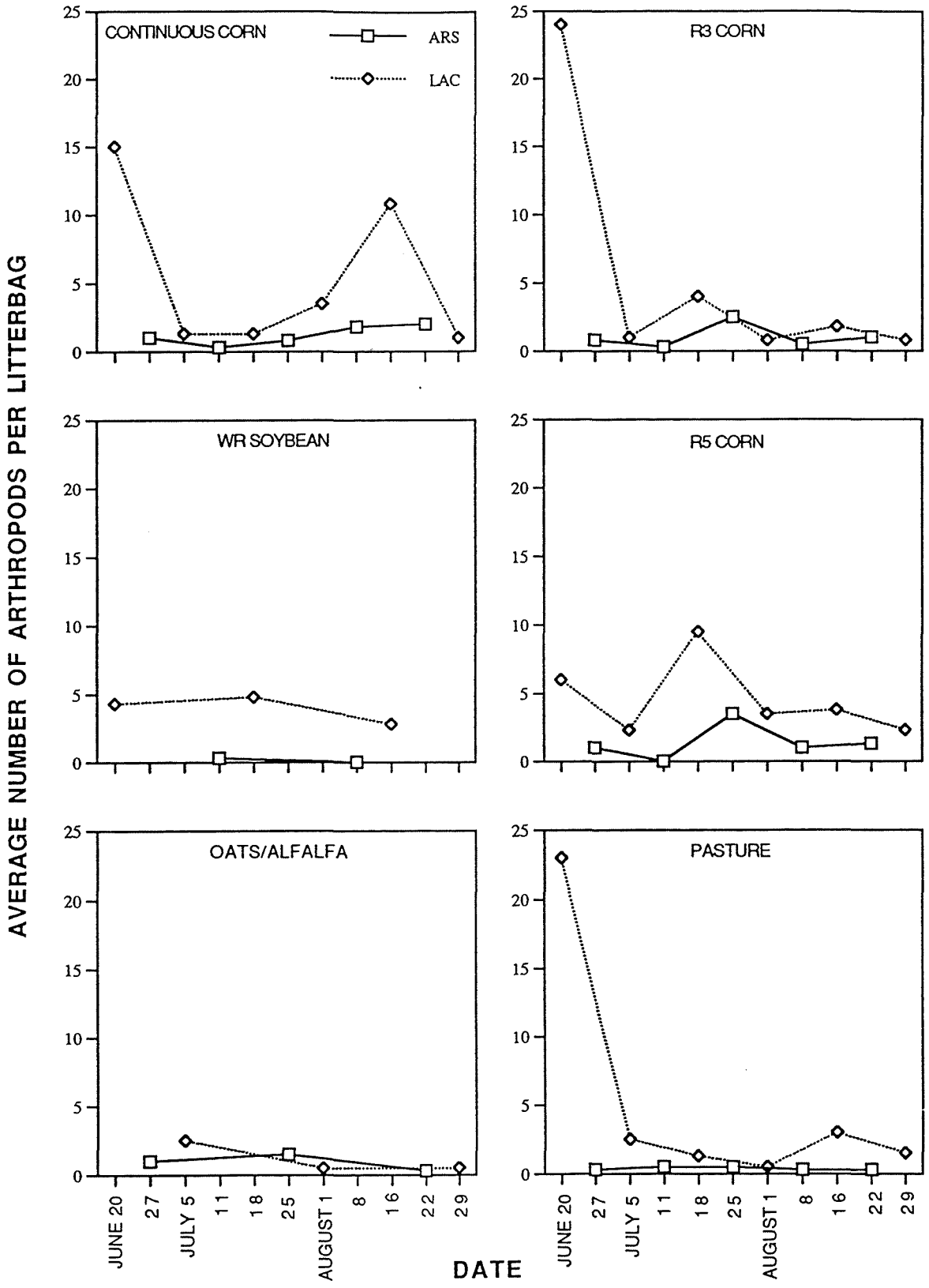


Figure 5. Coleoptera associated with 1995 WICST litter bags.

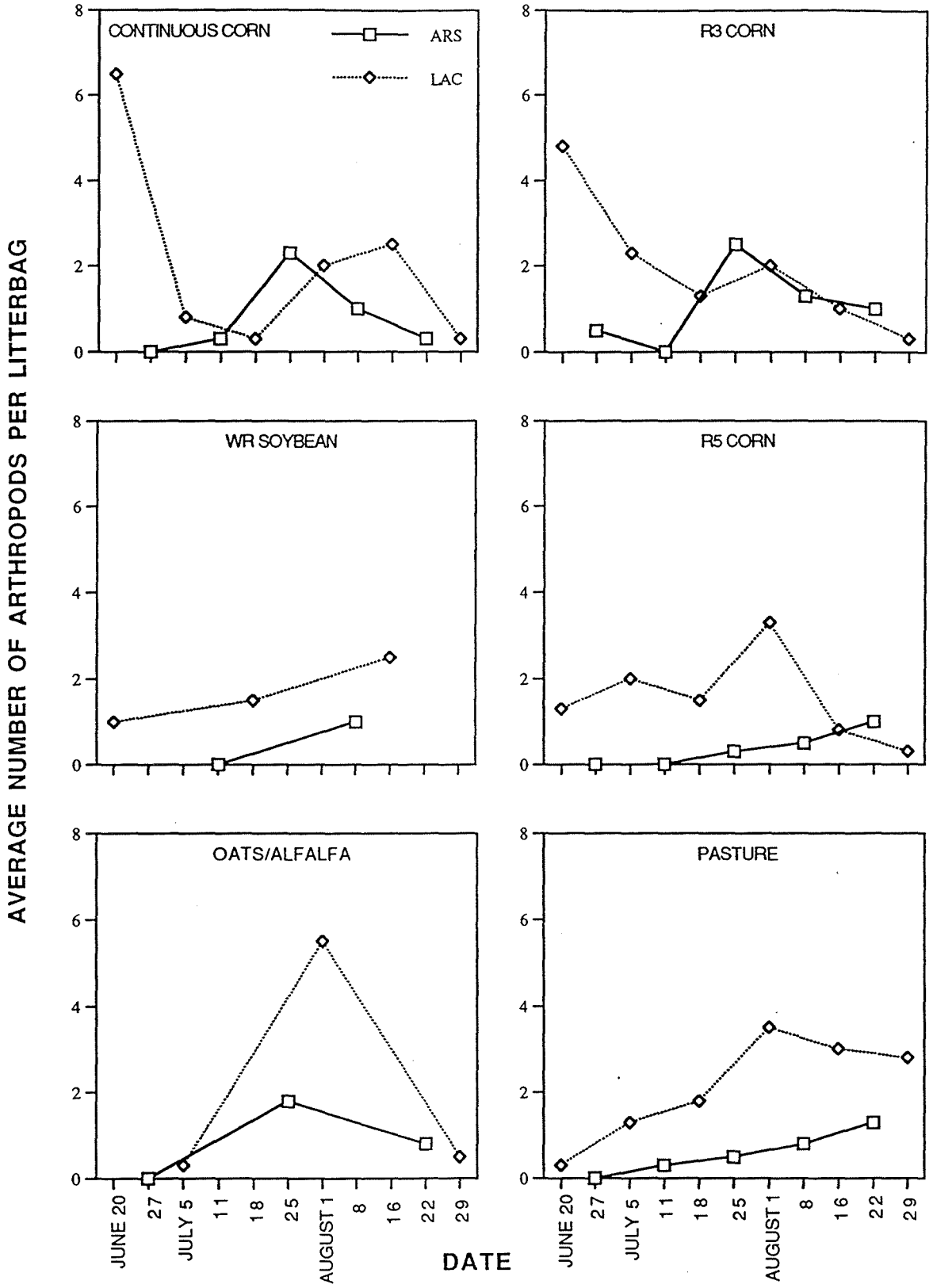


Figure 6. Diptera associated with 1995 WICST litter bags.

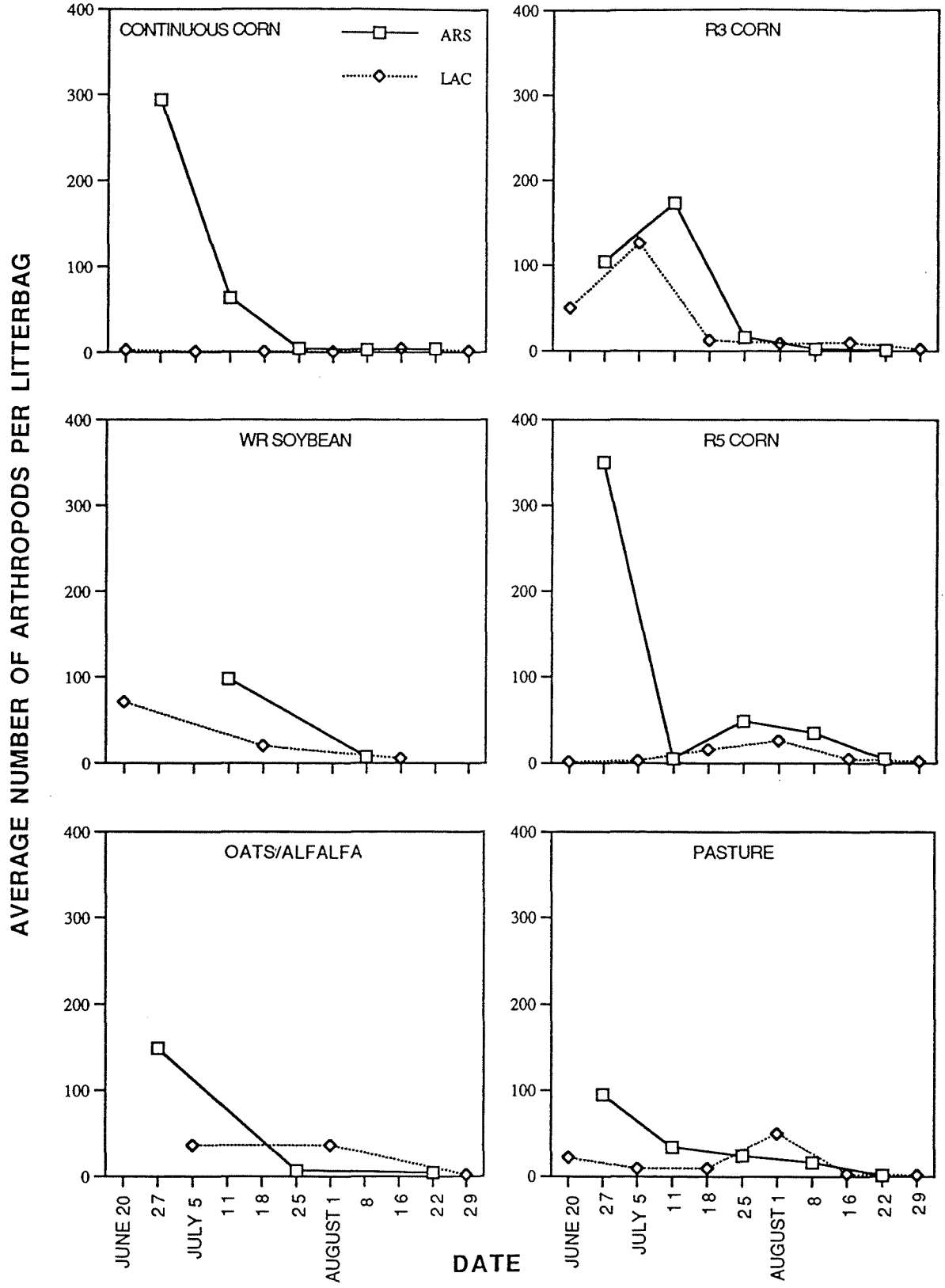


Figure 7. Collembola associated with 1995 WICST litter bags.

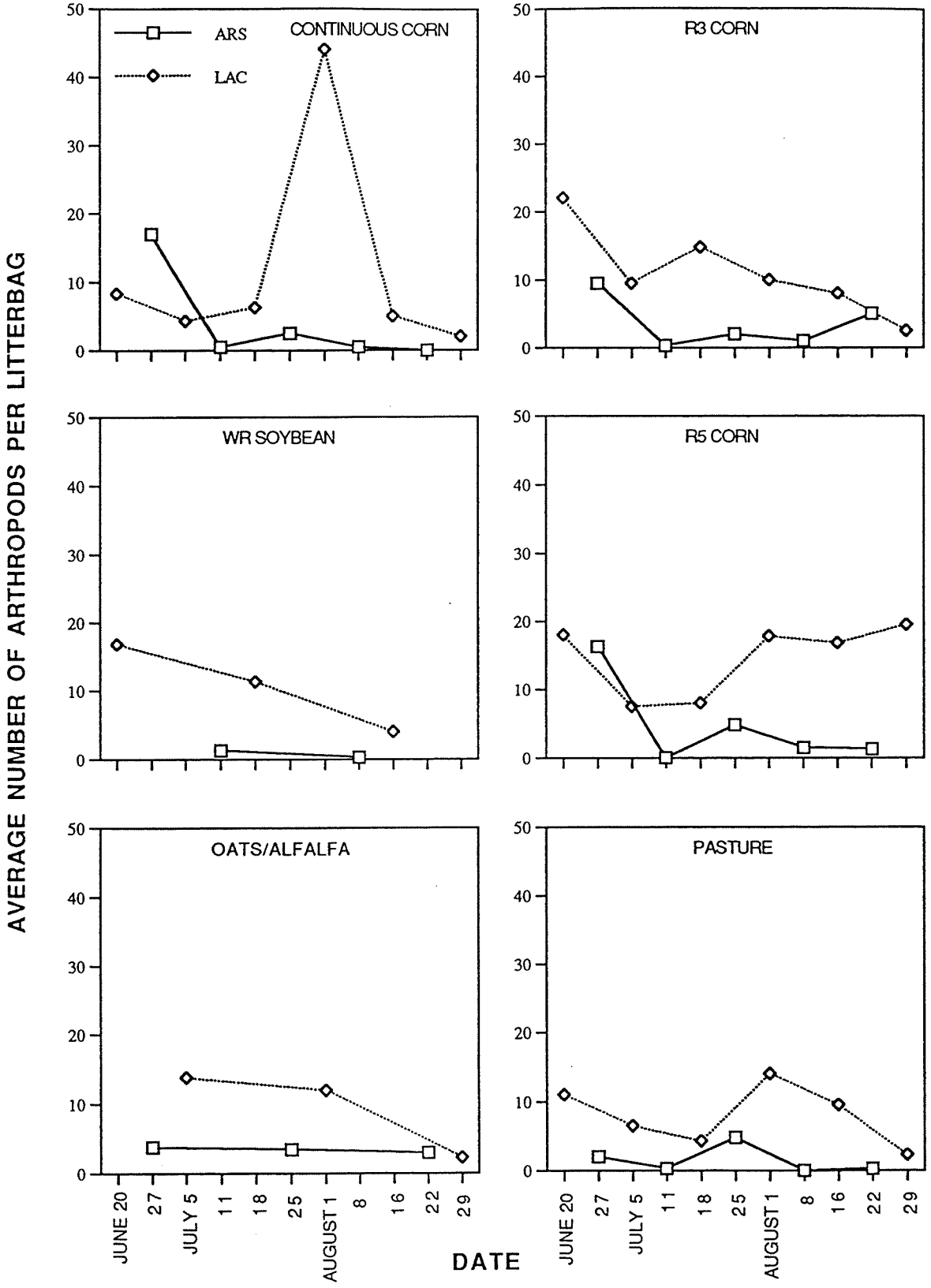


Figure 8. Acari associated with 1995 WICST litter bags.

17. Root Health and Soil Structure under Different Management Systems

Walter Goldstein[1]

The WICST trials on the Lakeland Farm and Arlington Research Station examine how different farming systems affect crop yields, economics, energy use, and potential groundwater pollution. Previous results with these trials (Voland and Rouse, 1992) indicated that there may be differences in root health of corn associated with these different systems in favor of the low-input rotations. General relationships between farming systems and root health were also discussed in a previous WICST report (Goldstein, 1992). If monocultured corn does have greater disease problems it is as yet unclear why (is it due to more disease inoculum, phytotoxic effects of residues, poorer soil structure and aeration, or other factors?)

As part of the NRI team on biodiversity, we examined the effects of three of the WICST farming systems on the health of corn roots with particular emphasis on describing the developmental course of the disease. The farming systems (and their phases) that we sampled are monoculture corn with agrochemical inputs (CS1), where corn follows red clover that was underseeded in winter wheat (CS3) without fertilization, and where corn follows alfalfa with manure fertilization (CS5). To determine if there is a linkage between soil structure and root health we also examined soil structure for soils from these systems as well as from the pasture system (CS6).

Materials and Methods

Root Measurements

Root samples were taken with a square-tipped trowel (6x6x6 inch sample) from around the root crown. We sampled that area because it allowed us to measure the most roots, to be able to identify root systems of different orders and thereby to follow the ontogeny of root disease. Five samples were taken per plot, with three replicate plots per treatment; samples were taken five times through the year at approximately monthly intervals.

Our goal was to monitor the development of different rooting systems and how disease developed on them in order to gain insight into the disease process. To do this the roots were cleaned by washing over a 1 mm sieve and dissected into seminal and adventitious roots. The adventitious roots were divided according to their node of development. As the plants grew through the season, they progressively produced new adventitious roots on higher order nodes until they achieved production of roots on a maximum of eight nodes by harvest. Two root length density measurements were made according to the modified line-intersect method of Tennant (1975) on each set of roots: first the total number of root line intersections was counted to estimate total root length; second, the number of line intersections with necrotic roots was counted to estimate the length associated with necrotic roots. Roots were judged as being necrotic or not necrotic on the basis of their appearance, i.e., if they appeared to be decayed or if lesions were apparent. Determinations were made by a team of three people who interacted to strive for concensus in making judgements. Estimates of healthy roots and the percent necrosis were derived by simple subtraction or division from the values of total length and necrotic root length.

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Soil Structure

Undisturbed soil cores were taken from three replications of each treatment. Samples were taken to a depth of six inches using a cylindrical sampler with a plastic sleeve having a 2.25 inch internal diameter. In each plot two soil samples were taken from beside the corn plants and two from between the rows. These samples were air dried and then shaken for five minutes over a nest of sieves with mesh sizes of 8, 4, 2, 1, 0.5, 0.25, and 0.125 mm. The sieved soil was weighed from each sieve and results were used to calculate the percentage of the total weight found in three size categories: > 8 mm; 0.25-8 mm, and <0.25.

The size category 0.25-8 mm was chosen to represent the macro-aggregates that are generally associated with pores sizes needed for root growth (MacRae and Mehuys, 1985), while < 0.25 mm represented the amount of microaggregates associated with micropores. The total weight of the soil was also used to calculate the soil's bulk density. Replicated samples of the air dried soil from the 1-2 mm size fraction were used to determine aggregate stability using a wet-sieving procedure which was corrected for sand and gravel (Kemper and Rosenau, 1986).

Results

Root Measurements

Some of the results with root growth are graphically displayed in the following three diagrams. Corn plants continued to progressively develop roots up to the latest harvest dates, though the peak of root production appeared to occur in the beginning of August when the corn was flowering.

Examination of the relationship between growth on different nodes and necrosis suggests that disease progressed from the seminal roots and lower order adventitious roots to the higher order seminals. Where corn followed corn, the relative amount of necrosis appeared to be greater on lower order roots and to progress faster than on the other systems. However, at the Arlington site the monoculture corn clearly produced more roots.

Inspection of the diagrams showing the seasonal dynamics of both healthy and necrotic roots suggests that disease was a greater problem for the monoculture corn, especially before the corn had flowered in late July and early August. This is also borne out by the statistical analysis which shows less frequent significant treatment effects after the corn had flowered (Table 1).

Soil Structure

Evaluation of the results with soils showed that changes in the physical conditions of the soil paralleled the dynamics of corn root growth. The peak production of roots in August corresponded with peak values for aggregates in the 0.25-8 mm and < 0.25 mm category and for aggregate stability. Bulk density increased after the corn had flowered for the soils taken from within the row but increased from planting to flowering for the soil samples that were taken from between the rows.

At the Arlington site the rotational grazing plots had consistently higher bulk density than the other plots. This was not the case at the Lakeland farm site where there was no significant difference between any of the treatments. On both sites the monocultured corn had the highest percentages of soil in the < 0.25 mm category, while the pasture had the lowest quantity of soil in this category (see Table 2). The same pattern was apparent at the Arlington site for soils in the 0.25-8 mm category (Table 3). However, at Lakeland there seemed to be no difference between any of the arable systems while the pasture had the highest amounts of soil in the 0.25-8 mm category.

Aggregate stability values were generally the lowest for the monoculture corn and the highest for the pasture (Table 4), but at Arlington the values climbed to equal those obtained by the pasture in the middle of the summer. Statistically significant differences were mostly between the continuous corn and pasture systems.

Table 1. The significance level for F-test values testing treatment effects for healthy, necrotic, and % necrotic roots, and the LSD values at the P < 5% level, measured at the Arlington and Lakeland sites in 1995.

		F-Test Value Treatments			LSD 5%		
Site	Date	Total Healthy	Total Necrotic	Percent Necrotic	Total Healthy	Total Necrotic	Percent Necrotic
					cm		%
Arlington							
	6-13	*	*	*	60	22	4
	7-11	NS	NS	+	NS	NS	14
	8-8	*	NS	NS	634	NS	NS
	9-5	NS	x	NS	NS	NS	NS
	10-3	NS	**	NS	NS	686	NS
Lakeland							
	6-6	NS	**	***	NS	8	4
	7-5	NS	*	*	NS	333	13
	8-1	*	x	NS	1,122	NS	NS
	8-29	NS	NS	NS	NS	NS	NS
	9-26	NS	NS	NS	NS	NS	NS

The meaning of ***, **, *, +, and x is that P is < 0.001, 0.01, 0.05, 0.1, 0.20, respectively. NS means no significant difference.

Table 2. The effects of treatments on the percentage of soil in the < 0.25 mm category at the Arlington and Lakeland sites in 1995.

System or	Arlington Sampling Date						Lakeland Sampling Date				
Test	5-16	6-13	7-11	8-8	9-5	10-3	6-6	7-5	8-8	8-29	9-26
						%					
CS1	4.9	5.2	8.2	7.9	5.7	6.0	2.6	5.5	5.1	3.1	3.9
CS3	4.6	4.1	8.1	6.9	5.2	5.2	1.9	4.4	3.5	2.5	3.0
CS5	4.6	4.9	6.8	6.8	4.5	5.3	1.3	3.8	4.0	2.3	2.8
CS6	3.1	3.1	4.3	5.3	4.0	4.0	2.1	2.8	3.2	2.1	2.4
F-Test	*	*	*	*	*	*	+	+	+	**	+
LSD	1.0	2.5	3.3	2.2	1.5	1.9	0.7	3.2	2.4	0.7	1.7

The meaning of **, *, and + is that the P values for the F test comparing treatment differences are < 0.01, 0.05, and 0.1, respectively. NS means no significant difference.

Table 3. The effects of treatments on the percentage of soil in the 0.25-8 mm categories at the Arlington and Lakeland sites in 1995.

System or Test	Arlington Sampling Date						Lakeland Sampling Date				
	5-16	6-13	7-11	8-8	9-5	10-3	6-6	7-5	8-8	8-29	9-26
	----------	----------	----------	----------	----------	----------%	----------	----------	----------	----------	----------
CS1	34	28	42	40	38	35	17	31	46	27	29
CS3	40	30	41	44	38	39	16	31	32	21	28
CS5	43	38	40	42	35	38	13	31	36	28	30
CS6	38	40	45	56	57	51	39	39	50	38	44
F-Test	NS	*	NS	*	***	*	x	NS	+	*	+
LSD	NS	6	NS	15	11	16	NS	NS	25	14	22

The meaning of ***, **, *, +, and x is that the P values for the F test comparing treatment differences are < 0.001, 0.01, 0.05, 0.1, 0.20, respectively. NS means no significant difference.

Table 4. The effects of treatments on the percentage of water stable aggregates at the Arlington and Lakeland sites in 1995.

System or Test	Arlington Sampling Date						Lakeland Sampling Date				
	5-16	6-13	7-11	8-8	9-5	10-3	6-6	7-5	8-8	8-29	9-26
	----------	----------	----------	----------	----------	----------%	----------	----------	----------	----------	----------
CS1	33	37	57	51	50	44	38	44	46	43	43
CS3	37	45	53	50	49	46	36	49	55	41	46
CS5	37	41	53	44	45	41	41	49	56	44	50
CS6	45	54	57	51	61	60	51	64	68	52	53
F-Test	x	*	NS	NS	*	+	+	**	*	**	NS
LSD NS	9	NS	NS	17	28	10	10	17	6	NS	

The meaning of **, *, +, and x is that the P values for the F test comparing treatment differences are < 0.01, 0.05, 0.1, 0.20, respectively. NS means no significant difference.

Discussion

The results suggest that the lower input systems may produce roots more slowly than the monoculture corn but that their roots remain healthy longer. The continuous corn apparently put a lot of resources into growing roots, especially at the Arlington site. It was probably stimulated to do so by the higher level of soluble nitrogen applied in the form of ammonia to this system. Because of increased root disease in this system, such root growth may be necessary to achieve adequate yields. On the other hand, the lower input systems produced higher yields at Arlington than the monoculture corn, despite the large numbers of roots produced in this system.

The results suggest again that the use of clover or alfalfa may reduce problems with root disease.

Following the dynamics of both root growth and soil structure suggested a parallel relationship between root growth, crumbling of the soil into fractions < 8 mm in size, and the formation of stable crumbs. Though the differences were not always significant, the use of forages in systems tended to increase aggregate stability. On the other hand, the high root production in monoculture corn at Arlington paralleled increases in aggregate stability to levels similar to pasture by August.

Aggregate stability is sensitive to amounts of available organic material, and it is increased by forage legumes, green manuring or any addition of readily available organic matter (Harris et al., 1966). It is sensitive to rhizosphere dynamics (Burns and Davies, 1986). Large quantities of root exudates and decaying roots, such as those produced at the Arlington site by the monoculture corn, would have been expected to temporarily increase aggregate stability.

In contrast to this, the fact that the monoculture corn consistently produced higher quantities of powdery soil in the micro-aggregate category (< 0.25 mm), suggests that cropping corn may gradually reduce the amounts of substances that bind micro-aggregates into macro-aggregates. Reid and Goss (1981) found that corn root exudates actively destabilized aggregates. In our results, the dynamics of corn root production paralleled an increase in the percent of micro-aggregates. This suggests, paradoxically, that corn roots might be somehow affecting a degradation of aggregates or at least decreasing their stability to dry sieving while at the same time they temporarily increase the stability of those aggregates in water. In contrast to the results obtained with corn, the amount of microaggregates under pasture was low and hardly changed through the season while the wet aggregate stability under pasture increased during the growing season.

Studies with farms in the Great Plains showed that the percent of soil in the 0.25-8 mm category generally increased while the soil in the < 0.25 mm category decreased when green manures or forages were used in the farming system (unpublished data, W.A. Goldstein). In the WICST study, the percentage of aggregates found in the size range between 0.25-8 mm did not always reflect the use of forage legumes in the arable rotations. Furthermore, it did not consistently relate to differences in root health between systems. This aggregate group is thought to be associated with the pores that are important for aeration and rooting. Nevertheless, our results do not yet rule out a possible link between disease and macro or mesoporosity.

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18. Diversity of Nematodes in the Wisconsin Integrated Cropping System Trial in 1995

Ann MacGuidwin[1]

Our objective is to determine population densities of soil-dwelling nematodes. Nematodes are the most abundant multicellular animal in the soil. The majority of nematodes feed on bacteria, fungi, and small soil animals, but there are also groups that parasitize plants. Plant-parasitic nematodes are harmful to crop growth and productivity. Microbivorous nematodes are beneficial because they simulate decomposition and nutrient cycling processes.

We share the soil samples collected from the WICST trial with entomologists working on the soil biology project. After dividing each soil sample in half, we remove the nematodes by wet-sieving. Root fragments contained within a standardized soil volume are incubated and the nematodes that leave roots in a 48-hour period are collected. The total number off nematodes present in each soil sample are counted, as are the rotifers, oligochaetes, and other microscopic soil animals captured by the nematode assay. The nematodes are preserved in a fixative and identified. Nematode identification is based on body size and morphology. Nematodes are second only to insects in the number of species in the animal kingdom. However, only about 3 percent of all nematode species have been studied and identified. The WISCT trial provides an opportunity to discover new nematode taxa.

The number of nematodes recovered per 100 cm^3 soil averages from 1500-3500 specimens. We know that our techniques are capable of recovering only about 33 % of the nematodes present, so actual figures range to about 10,000 nematodes per 100 cm^3 soil. Population densities were lowest in the spring. More nematodes were recovered in- than between- rows of corn. Bacteria-feeding nematodes are the most prevalent in the WICST trial, but all nematode groups are represented in every plot including the plant-parasitic genus *Pratylenchus* spp. In our analyses completed to date for 1995, we have found no consistent differences among the cropping systems treatments.

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19. Soil Microbial Biodiversity in Agroecosystems

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Objective: Evaluate the use of nucleic acid (ribosomal RNA) probes to assess impacts of cropping systems on biodiversity in soil microbial populations.

Background: Microbial populations are potentially one of the greatest sources of biodiversity in soil. Torsvik et al. (1990) estimated that one gram of a Norwegian forest soil contained at least 4 million different bacteria. Yet, many investigators report that only 1 to 10% of these organisms are culturable on laboratory media. This "great plate count anomaly" has prompted speculation that the majority of soil microorganisms have yet to be described, and spurred development of approaches that don't rely on culturing for analyzing microbial populations.

Probes targeting regions of ribosomal RNA (rRNA) characteristic of specific microbial groups are a promising alternative to culturing for describing microbial populations. Differential conservation of nucleotides composing rRNA allows probes of various specificities to be designed. Probes targeting conserved regions can detect all organisms while those specific to variable positions are capable of differentiating closely related species. For analysis of natural microbial populations, nucleic acids may be extracted from a sample and the relative abundance of specific microbial groups determined by quantifying the amount of probe bound (i.e., hybridized). These hybridization assays can thus be used to quantitatively assess target sequence (organism) abundance, but have not yet been applied for quantitative, comparative analysis of biodiversity in soil microbial populations.

Approach: Microbial populations are being analyzed by using rRNA probes in hybridization assays to evaluate changes in population density and composition as a function of cropping system and time. Our initial efforts have focused on 1.) developing high sample capacity nucleic acid extraction techniques that minimize humic substance contamination, 2.) assessing the reproducibility of extraction techniques, and 3.) evaluating the specificity and reproducibility of selected probes in hybridization tests. Establishing method performance characteristics with respect to the latter two issues is essential before attempting extensive quantitative comparisons.

Results: Nucleic acid extraction techniques. In preliminary experiments we evaluated a variety of physical/chemical/enzymatic approaches for recovering DNA and/or RNA from soil. These efforts lead to development of a procedure modified from Tsai and Olsen (1991) using lysozyme (dissolves bacterial cell walls) and freeze/thaw cycling to effect cell lysis, combined with a novel buffer that minimizes humic substance contamination; elimination of the latter is necessary as these interfere with nucleic acid quantification and probe hybridization. Since this project could entail preparation of hundreds of extracts, the capacity to process multiple samples was an important characteristic leading us to select the lysozyme-freeze/thaw method.

Two important qualitative aspects of the extraction technique are the degree to which it recovers nucleic acids from the variety of microbes present in soil (e.g., fungi vs. bacteria, Gram negative- vs. Gram positive-bacteria, spores vs. vegetative cells, etc.) and whether it recovers DNA, RNA or both. Our technique is effective for recovering DNA from Gram-negative bacteria and vegetative cells of at least some Gram-positives (e.g.,*Arthrobacter*, *Streptomyces*). Fungal hyphae and spores, however, are not effectively extracted; further methodological work will be necessary to analyze biodiversity in this group of organisms. Thus, the predominant targets for our probes will be bacterial genes encoding RNA (i.e., rDNA) and probably not RNA itself.

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Theoretically, targeting RNA rather than rDNA could provide better sensitivity in hybridization experiments because growing, metabolically active bacteria may contain thousands of rRNA molecules (targets) per cell but only one to four copies (targets) of the rDNA genes. However, bacterial populations in soil are far less metabolically active than those examined in laboratory cultures and have a correspondingly low RNA content. Furthermore, RNA is more labile to enzymatic decomposition than is DNA, thus reducing recoveries from soil. Considering the latter two issues, whether or not any of the theoretical advantage of targeting RNA would be realized is questionable.

Quantitative analysis of soil extracts: Using the standard extraction method, the first issues we examined were 1.) the reproducibility of DNA yields in extracts made on a given soil, and 2.) how DNA yields in these extracts vary as a function of quantification method.

Soil from Arlington (sampled 8/8/95) and from Lakeland (sampled 8/16/95) were used for DNA extractions. All were within row samples from CS1 (corn), CS3(corn), CS3 (soybean), CS5(corn), and CS6(pasture). A 50 g subsample was taken from each sample bag, homogenized, and passed through a 2.0 mm mesh sieve. Three subsamples from each homogenized sample were processed for DNA extraction. Three procedures were used for DNA quantification: 1.) UV-spectrophotometry (absorbance at 260 nm), 2.) colorimeter by diphenylamine procedure, and 3.) densitometry of images scanned from photos of nucleic acid extracts electrophoresed in agarose gels.

Depending on the nucleic acid quantification method used, DNA yields measured in the extracts varied widely; colorimetry generally gave the highest values and densitometry the lowest (Tables 1A,B - 3A,B). Densitometry also had the poorest reproducibility of the measurement techniques. Sample measurements showed little correlation between techniques. These results indicate that each method is affected by different set of biases/interferences. However, we have selected UV absorption as our standard method for DNA quantification because of convenience and because the technique is widely used by other investigators.

There were no differences between treatments in DNA yields as determined by any of three methods (Tables 4A,B - 6A,B). There were, however, large differences between field replicates in all treatments at each location. For example, considering the UV measurement data only, at Arlington, plot 1 values were consistently greater than plot 2; while at Lakeland the trend was reversed (Table 4A,B). In order to determine if these trends were reproducible, a second set of extractions were done on the Lakeland CS1 and CS6 samples. UV analysis of the second set of extracts showed DNA yields in the plot 2 subsamples were ca. 25-28 mg/g soil (Table 7A) while UV analysis of the first extracts gave readings of ca. 104-123 mg DNA/g soil (Table 4A). The pooled data for the second set of extractions showed no significant treatment differences (Table 7B); the treatment averages were, however, significantly less than those determined for the first extracts.

The forgoing data summary indicates that the variability encountered in the processing and analysis of laboratory replicates can be significant. Further efforts will be directed at determining which if any sample processing steps can be modified to reduce this variability.

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Table 1A. UV-spectrophotometry-determined DNA yields (μg/g dry soil): Arlington soil.

Treatment-plot	Rep 1	Rep 2	Rep 3	Mean ± SE*
CS1-109 corn	101.56	108.66	99.73	103.32 ± 2.72
CS1-204 corn	36.68	38.01	65.59	46.76 ± 9.42
CS3-106 corn	78.97	110.50	141.72	110.40 ± 18.11
CS3-202 corn	51.77	53.27	47.81	50.95 ± 1.63
CS3-104 soy	89.49	136.01	77.46	100.99 ± 17.85
CS3-201 soy	44.75	54.58	65.07	54.80 ± 5.87
CS5-110 corn	112.38	68.01	103.63	94.67 ± 13.57
CS5-208 corn	73.23	68.25	54.44	65.31 ± 5.62
CS6-112 past	117.33	88.89	73.41	93.21 ± 12.86
CS6-207 past	65.67	51.17	46.09	54.31 ± 5.87

*Mean ± standard error of three subsamples / plot sample.

Table 1B. UV-spectrophotometry-determined DNA yields (μg/g dry soil): Lakeland soil.

Treatment-plot	Rep 1	Rep 2	Rep 3	Mean ± SE*
CS1-101 corn	43.73	50.22	40.65	44.87 ± 2.82
CS1-210 corn	106.03	103.14	102.44	103.87 ± 1.10
CS3-107 corn	72.18	78.60	80.31	77.03 ± 2.47
CS3-205 corn	92.21	99.86	92.88	94.98 ± 2.44
CS3-109 soy	58.57	75.78	62.29	65.55 ± 5.23
CS3-204 soy	112.03	89.87	119.66	107.19 ± 8.93
CS5-106 corn	75.07	63.35	67.44	68.62 ± 3.43
CS5-211 corn	115.08	111.29	108.99	111.79 ± 1.77
CS6-104 past	69.24	65.02	70.48	68.25 ± 1.65
CS6-213 past	123.86	116.70	127.53	122.70 ± 3.18

*Mean ± standard error of three subsamples / plot sample.

Table 2A. Colorimetry-determined DNA yields (μg/g dry soil): Arlington soil.

Treatment-plot	Rep 1	Rep 2	Rep 3	Mean ± SE*
CS1-109 corn	43.25	89.31	97.69	76.75 ± 16.92
CS1-204 corn	38.48	25.61	188.62	84.24 ± 52.32
CS3-106 corn	152.70	169.52	169.52	163.91 ± 5.61
CS3-202 corn	147.71	270.19	46.33	154.74 ± 64.72
CS3-104 soy	151.40	168.54	151.40	157.11 ± 5.71
CS3-201 soy	38.13	161.41	199.67	133.07 ± 48.74
CS5-110 corn	279.96	82.83	279.96	214.25 ± 65.71
CS5-208 corn	225.36	187.78	162.72	191.95 ± 18.20
CS6-112 past	94.79	200.43	188.24	161.15 ± 33.37
CS6-207 past	183.35	91.61	163.41	146.12 ± 27.86

*Mean ± standard error of three subsamples / plot sample.

Table 2B Colorimetry-determined DNA yields (μg/g dry soil): Lakeland soil.

Treatment-plot	Rep. 1	Rep. 2	Rep. 3	Mean ± SE*
CS1-101 corn	91.25	40.99	40.99	57.74 ± 16.75
CS1-210 corn	17.96	17.96	31.54	22.48 ± 4.53
CS3-107 corn	246.73	143.50	233.27	207.83 ± 32.40
CS3-205 corn	27.39	22.80	27.39	25.86 ± 1.53
CS3-109 soy	35.77	152.47	219.80	136.01 ± 53.76
CS3-204 soy	23.12	27.78	23.12	24.67 ± 1.55
CS5-106 corn	165.02	165.02	279.36	203.13 ± 38.11
CS5-211 corn	22.01	30.86	17.58	23.48 ± 3.90
CS6-104 past	290.95	83.66	39.56	138.06 ± 77.50
CS6-213 past	44.93	31.41	17.89	31.41 ± 7.81

*Mean ± standard error of three subsamples / plot sample.

Table 3A. Densitometry-determined DNA yields (μg/g dry soil): Arlington soil.

Treatment-plot	Rep. 1	Rep. 2	Rep. 3	Mean ± SE*
CS1-109 corn	38.70	5.42	8.31	17.48 ± 10.64
CS1-204 corn	15.99	17.65	25.22	19.62 ± 2.84
CS3-106 corn	15.29	11.17	22.13	16.20 ± 3.20
CS3-202 corn	33.41	8.02	40.23	27.22 ± 9.80
CS3-104 soy	10.25	31.78	26.12	22.72 ± 6.44
CS3-201 soy	21.26	7.88	11.16	13.43 ± 4.03
CS5-110 corn	18.26	19.05	4.72	14.01 ± 4.65
CS5-208 corn	0.39	13.29	4.95	6.21 ± 3.78
CS6-112 past	5.79	3.19	5.15	4.71 ± 0.78
CS6-207 past	12.35	43.03	16.68	24.02 ± 9.59

*Mean ± standard error of three subsamples / plot sample.
**DNA bands visible in original photo, but image intensity following digitization insufficient for quantification.

Table 3B. Densitometry-determined DNA yields (μg/g dry soil): Lakeland soil.

Treatment	Rep. 1	Rep. 2	Rep. 3	Mean ± SE*
CS1-101 corn	5.88	0**	0	1.96 ± 1.96
CS1-210 corn	0	0	5.30	1.77 ± 1.77
CS3-107 corn	17.67	2.11	17.07	12.28 ± 5.09
CS3-205 corn	5.08	0.22	17.06	7.45 ± 5.00
CS3-109 soy	1.59	5.53	0	2.37 ± 1.64
CS3-204 soy	0.81	67.80	24.18	30.93 ± 19.63
CS5-106 corn	6.80	6.14	10.81	7.92 ± 1.46
CS5-211 corn	19.09	21.34	0	13.48 ± 6.77
CS6-104 past	16.26	0	4.46	6.91 ± 4.85
CS6-213 past	15.80	0	2.82	6.21 ± 4.86

*Mean ± standard error of three subsamples / plot sample.
**DNA bands visible in original photo, but image intensity following digitization insufficient for quantification.

Table 4A - DNA amounts (μg/g dry soil), determined by UV-spectrophotometry, extracted from soil under different cropping systems. Arlington.

Treatment	Plot 1*	Plot 2 *	Mean ± SE **
CS1 corn	103.32 ± 2.72	46.76 ± 9.42	75.04 ± 28.28
CS3 corn	110.40 ± 18.11	50.95 ± 1.63	80.68 ± 29.72
CS3 soybean	100.99 ± 17.85	54.80 ± 5.87	77.90 ± 23.10
CS5 corn	94.67 ± 13.57	65.31 ± 5.62	79.99 ± 14.68
CS6 pasture	93.21 ± 12.86	54.31 ± 5.87	73.76 ± 19.45

*Mean ± standard error of three subsamples / plot sample.
** Mean ± standard error of two samples from field plots.

Table 4B - DNA amounts (μg/g dry soil), determined by UV-spectrophotometry, extracted from soil under different cropping systems. Lakeland.

Treatment	Plot 1*	Plot 2*	Mean ± SE**
CS1 corn	44.87 ± 2.82	103.87 ± 1.10	74.37 ± 29.50
CS3 corn	77.03 ± 2.47	94.98 ± 2.44	86.00 ± 8.98
CS3 soybean	65.55 ± 5.23	107.19 ± 8.93	86.37 ± 20.82
CS5 corn	68.62 ± 3.43	111.79 ± 1.77	90.20 ± 21.58
CS6 pasture	68.25 ± 1.65	122.70 ± 3.18	95.48 ± 27.22

*Mean ± standard error of three subsamples / plot sample.
**Mean ± standard error of two samples from field plots.

Table 5A - DNA amounts (μg/g dry soil), determined by colorimetry, extracted from soil under different cropping systems. Arlington.

Treatment	Plot 1*	Plot 2*	Mean ± SE**
CS1 corn	76.75 ± 16.92	84.24 ± 52.32	80.50 ± 3.74
CS3 corn	163.91 ± 5.61	154.74 ± 64.72	159.32 ± 4.58
CS3 soybean	157.11 ± 5.71	133.07 ± 48.74	145.09 ± 12.02
CS5 corn	214.25 ± 65.71	191.95 ± 18.20	203.10 ± 11.15
CS6 pasture	161.15 ± 33.37	146.12 ± 27.86	153.64 ± 7.52

*Mean ± standard error of three subsamples / plot sample.
**Mean ± standard error of two samples from field plots.

Table 5B - DNA amounts (μg/g dry soil), determined by colorimetry, extracted from soil under different cropping systems. Lakeland.

Treatment	Plot 1*	Plot 2*	Mean ± SE**
CS1 corn	57.74 ± 16.75	22.48 ± 4.53	40.11 ± 17.63
CS3 corn	207.83 ± 32.40	25.86 ± 1.53	116.84 ± 90.98
CS3 soybean	136.01 ± 53.76	24.67 ± 1.55	80.34 ± 55.67
CS5 corn	203.13 ± 38.11	23.48 ± 3.90	113.30 ± 89.82
CS6 pasture	138.06 ± 77.50	31.41 ± 7.81	84.74 ± 53.32

*Mean ± standard error of three subsamples / plot sample.
**Mean ± standard error of two samples from field plots.

Table 6A - DNA amounts (μg/g dry soil), determined by densitometry, extracted from soil under different cropping systems. Arlington.

Treatment	Plot 1*	Plot 2*	Mean ± SE**
CS1 corn	17.48 ± 10.64	19.62 ± 2.84	18.55 ± 1.07
CS3 corn	16.20 ± 3.20	27.22 ± 9.80	21.76 ± 5.51
CS3 soybean	22.72 ± 6.44	13.43 ± 4.03	18.08 ± 4.64
CS5 corn	14.01 ± 4.65	6.21 ± 3.78	10.11 ± 3.90
CS6 pasture	4.71 ± 0.78	24.02 ± 9.59	14.36 ± 9.66

*Mean ± standard error of three subsamples / plot sample.
**Mean ± standard error of two samples from field plots.

Table 6B - DNA amounts (μg/g dry soil), determined by densitometry, extracted from soil under different cropping systems. Lakeland.

Treatment	Plot 1*	Plot 2*	Mean ± SE**
CS1 corn	1.96 ± 1.96	1.77 ± 1.77	1.86 ± 0.09
CS3 corn	12.28 ± 5.09	7.45 ± 5.00	9.86 ± 2.42
CS3 soybean	2.37 ± 1.64	30.93 ± 19.63	16.65 ± 14.28
CS5 corn	7.92 ± 1.46	13.48 ± 6.77	10.70 ± 2.78
CS6 pasture	6.91 ± 4.85	6.21 ± 4.86	6.56 ± 0.35

*Mean ± standard error of three subsamples / plot sample.
**Mean ± standard error of two samples from field plots.

Table 7A - DNA amounts measured by UV-spectrometry (μg/g dry soil) extracted from soil for confirmation. Lakeland.

Treatment	Rep. 1	Rep. 2	Rep. 3	Mean ± SE
CS1 corn	24.73	66.53	35.19	42.15 ± 12.56
CS1 corn	22.21	30.86	21.52	24.86 ± 3.00
CS6 pasture	48.90	20.69	66.20	45.26 ± 13.26
CS6 pasture	35.22	27.18	21.14	27.85 ± 4.08

Table 7B - DNA amounts measured by UV-spectrometry (μg/g dry soil) extracted from soil for confirmation. Lakeland

Treatment	Plot 1	Plot 2	Mean ± SE
CS1 corn	42.15 ± 12.56	24.86 ± 3.00	33.51 ± 8.64
CS6 pasture	45.26 ± 13.26	27.85 ± 4.08	36.56 ± 8.71

We also hope to identify and refine critical soil health indicators from the Wisconsin Soil Health Scorecard that seem to be important to farmers and also have corresponding quantitative analyses. Moreover, we will be surveying the sites on a more frequent schedule to improve the timing at which soil health indicators are scored. For the 1996 field season, qualitative soil health data will be collected simultaneously with scheduled sampling by other WICST researchers to facilitate the comparison of soil health and quantitative soil quality data. In addition to scoring with the farmer-based scorecard, we are also assessing soil morphological features commonly used in field descriptions used in soil surveys[1]. Some of the morphological descriptions being assessed include: friability, soil structure, crust expression, macropores, and erosional features. Approaches to integrate additional data gathered by Michael Fields Agricultural Institute on root health and other WICST researchers are also being conducted. With this additional information we hope to better calibrate and improve the qualitative descriptions used in the scorecard and begin to relate them to quantitative data as well as morphological descriptions.

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[1]The morphological assessment procedure is similar with the Soil Quality Initiative, a NRI pilot project being conducted by the Natural Resources Conservation Service. In addition to chemical, biological and physical analyses, a number of qualitative, morphological parameters are being collected to monitor nearly 200 sites in the Northern Mississippi Valley Loess Hills including several in southwestern Wisconsin.

Table 1. Soil Health Scores for 1995 Biodiversity Project for the WICST at Arlington and Lakeland.

			Arlington						Lakeland					
			S1	S3		S5		S6	S1	S3		S5		S6
			Phase[c]	Phase		Phase		Phase	Phase	Phase		Phase		Phase
Property[a]	Status[b]	Scorecard Description	C	C	B	C	O/A	P	C	C	B	C	O/A	P
Organic matter[1,21]	H	Organic matter 4–6%	3.0	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0
	I	Organic matter 2–4% or 6–8%												
	U	Organic matter <2% or >8%												
pH[8,22]	H	pH 6.7–7.0	3.0	4.0	3.0	4.0	4.0	3.0				4.0		3.0
	I	pH 6.4–6.7 or 7.0–7.2							2.0				2.0	
	U	pH <6.4 or >7.2								1.0	1.0			
Soil test–N,P,K[9,23]	H	All nutrient levels at recommended levels	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	I	Soil tests below recommended levels												
	U	Two or more nutrients very low												
Decomposition[16,10]	H	Rapid rotting of residues and manures	3.0	3.5	3.0	4.0		4.0	3.3	3.5	3.5	3.8	4.0	4.0
	I	Slow rotting of residues and manures					2.5							
	U	Residues and manures do not break down												
Soil fertility[20,11]	H	Fertility balanced, nutrients available	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	I	Fertility not balanced, needs help												
	U	Poor fertlity, nutrients do not move,												
Micronutrients[30,24]	H	Micronutrients high and balanced	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0
	I	Micronutrients at a minimal level												
	U	Severe shortage of micronutrients												
Biolog. activity[36,19]	H	Activity high, wormlike threads, moss, algae	3.5	3.0	3.0	3.5	3.5	4.0	2.8	3.8	3.3	3.3	4.0	4.0
	I	Moderate activity,												
	U	Little biological activity												
Drainage[6,8]	H	Soil drains, water moves through well	3.5	3.5	3.3	4.0	4.0	3.5						
	I	Soil drains slowly, slow to dry out							2.5	2.5	2.5	2.5	2.5	2.3
	U	Poor drainage, waterlogged, over saturated												
Infiltration[12,7]	H	Water soaks right in, soil is spongy, no ponding	3.5	3.5	3.0	4.0	4.0	3.5	4.0	4.0	4.0	4.0	4.0	3.0
	I	Water soaks in slow, some runoff/puddling												
	U	Water doesn't soak in, sits on top or runs off												
Water retention[14,9]	H	Soil holds moisture well, gives/takes water	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5	3.5
	I	Soil is drought prone in dry weather												
	U	Soil drys out too fast, droughty												
Soil texture[31,17]	H	Texture is loamy	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	3.0	3.0	3.0	4.0
	I	Texture is too heavy or too tight												
	U	Texture is very sandy, clayey or rocky												
Earthworms[3,1]	H	Worm holes and castings numerous	3.0	4.0	4.0	4.0	4.0	4.0		3.5	4.0	4.0	4.0	4.0
	I	Few worms or castings							2.3					
	U	Little sign of worm activity												
Tillage ease[5,3]	H	Plow field in higher gear, soil flows, mellow	4.0	4.0	4.0	4.0	4.0	–	3.0	3.0	3.0	3.0	3.0	–
	I	Soil grabs plow, difficult to work, extra passes												
	U	Plow scours hard, soil never works down												

Table 1. (continued)

			Arlington						Lakeland					
			S1	S3		S5		S6	S1	S3		S5		S6
			Phase	Phase		Phase		Phase	Phase	Phase		Phase		Phase
Property[a]	Status[b]	Scorecard Description	C	C	B	C	O/A	P	C	C	B	C	O/A	P
Soil structure[7,4]	H	Soil is crumbly, granular	3.5	3.5	3.0	4.0	4.0	4.0	3.5	3.8	3.5	3.0	3.5	4.0
	I	Soil is lumpy or will not hold together												
	U	Soil is cloddy with big chunks, or dusty												
Compaction[11,6]	H	Soil stays loose, doesn't pack, no hardpan	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0
	I	Soil packs down, thin hardpan or plow layer												
	U	Soil is tight, compacted, thick hardpan												
Hardness[28,15]	H	Soil is soft, crumbles easily under light pressure	4.0	3.5	4.0	4.0	4.0	3.5	3.8	3.5	3.8	3.0	3.3	3.0
	I	Soil firm, breaks up under moderate pressure												
	U	Soil hard, dense or solid, does not break up												
Aeration[35,18]	H	Soil is open, porous, breaths				4.0	4.0	4.0		4.0	3.8	3.3	3.5	4.0
	I	Soil is dense, has a few pores	2.0	2.0	2.5				2.3					
	U	Soil is tight, closed, almost no pores												
Erosion[4,2]	H	Little erosion evident	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	I	Moderate erosion, signs of sheet, rill erosion												
	U	Severe erosion, considerable topsoil loss												
Surface cover[23,14]	H	Surface is trashy or cover crop used		4.0	3.0	4.0	3.0	4.0	4.0	4.0		4.0	4.0	4.0
	I	Surface has little residue, mostly buried	2.0								2.5			
	U	Surface is clean, bare, residue removed												
Surface crust[24,13]	H	Soil surface doesn't crust, porous	4.0	4.0	3.0	4.0	4.0	4.0	3.5	4.0	3.3	3.0	4.0	4.0
	I	Surface is smooth with few holes, thin crust												
	U	Soil surface is hard, compacted												
Color (moist) [13,5]	H	Soil color is black, dark brown, or dark gray	4.0	4.0	3.0	4.0	4.0	4.0	3.5	4.0	3.5	3.3	4.0	4.0
	I	Soil color is brown, gray, or reddish												
	U	Soil color is tan or light gray												
Feel[21,12]	H	Soil is loose, fluffy	4.0	3.5	4.0	4.0	4.0	3.5	4.0	3.5	3.5	3.8	3.0	4.0
	I	Soil is smooth or grainy												
	U	Soil is mucky, greasy, or stickey												
Soil smell[25,16]	H	Soil has an earthy, sweet, fresh smell			3.0	3.0			2.8		3.0			3.0
	I	Soil has no odor or a mineral smell	2.0	2.0			2.0	2.5		2.0		2.5	2.5	
	U	Soil has sour, putrid or chemical smell												
Topsoil depth[38,20]	H	Topsoil is deep	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	I	Topsoil is shallow												
	U	Subsoil is exposed or near surface												
Total Soil Average	H		3.5	3.6	3.5	3.9	3.8	3.6	3.3	3.4	3.4	3.5	3.5	3.5

Table 1. (continued)

Property[a]	Status[b]	Scorecard Description	Arlington S1 Phase C	Arlington S3 Phase C	Arlington S3 Phase B	Arlington S5 Phase C	Arlington S5 Phase O/A	Arlington S6 Phase P	Lakeland S1 Phase C	Lakeland S3 Phase C	Lakeland S3 Phase B	Lakeland S5 Phase C	Lakeland S5 Phase O/A	Lakeland S6 Phase P
Crop appearance[2,25]	H	Overall crop is dark green, large, tall	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	I	Overall crop is light green, small												
	U	Overall crop is poor, stunted, discolored												
Yield[10,35]	H	Corn greater than 130 bushels/acre	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	I	Corn 85 to 130 bushels/acre												
	U	Corn less than 85 bushels/acre												
Nutrient deficient[15,26]	H	Crop has what it needs, shows little deficiency	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	I	Crop falls off or discolors as season progresses												
	U	Crop shows severe signs												
Roots[17,29]	H	Roots are deep, fully developed with root hairs	4.0	3.5	4.0	4.0	4.0	4.0	–	–	–	–	–	–
	I	Roots shallow, hard angles, few fine roots												
	U	Roots unhealthy, poorly developed												
Mature crop[18,34]	H	Rapid even growth, matures on time	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0
	I	Uneven growth, late to mature												
	U	Crop slow to get started, never seems to mature												
Growth rate[19,28]	H	Rapid even growth, matures on time	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	I	Uneven growth, late to mature												
	U	Crop slow to get started, never seems to mature												
Resists drought[27,32]	H	Plants withstand dry weather, recover fast	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	I	Plants suffer in dry weather, slow to recover												
	U	Plants dry out quickly, never recover												
Pests/disease[29,33]	H	Plants tolerate pests and disease well	3.0	3.5	3.5	3.5	4.0	4.0	3.5	3.5	3.5	3.5	3.5	3.5
	I	Plants stressed by diseases and insects												
	U	Plants damaged severely by diseases & insects												
Plant leaves[33,31]	H	Leaves are full, lush, dark green	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	I	Leaves are small, narrow, light green												
	U	Leaves are yellow, discolored, few in number												
Seed germination[34,27]	H	Seeds come up right away, good emergence	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	I	Germination is uneven												
	U	Germination is poor												
Crop Average	H		3.9	3.9	3.9	3.9	4.0	3.9	3.7	3.7	3.7	3.7	3.7	3.7
Scorecard Average	H		3.6	3.7	3.6	3.9	3.8	3.7	3.5	3.5	3.5	3.5	3.6	3.5

[a] The first superscript number corresponds to farmer–based ranking, the second corresponds to the question number of the Wisconsin Soil Health Scorecard, that emphasizes crop production (Romig et al., 1995, 1996).

[b] H = Healthy (2.8–4.0); I = Impaired (1.4–2.7); U = Unhealthy (0–1.3).

[c] Scores are the average for two plots where C=corn, B=soybean, O/A=oats/alfalfa, P=pasture.

Figure 1: Selected soil health scores for WICST, fall 1995

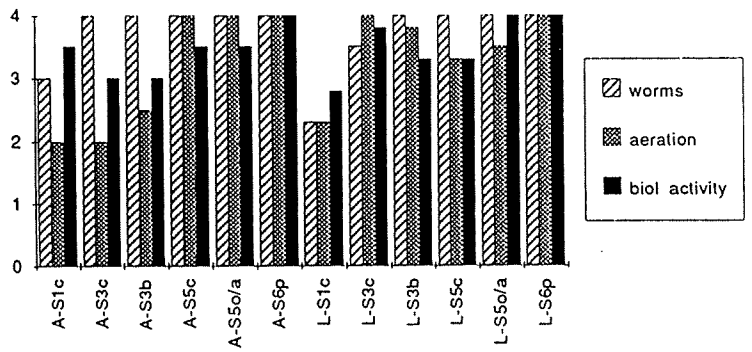

Figure 2: Selected soil health scores for WICST, fall 1994

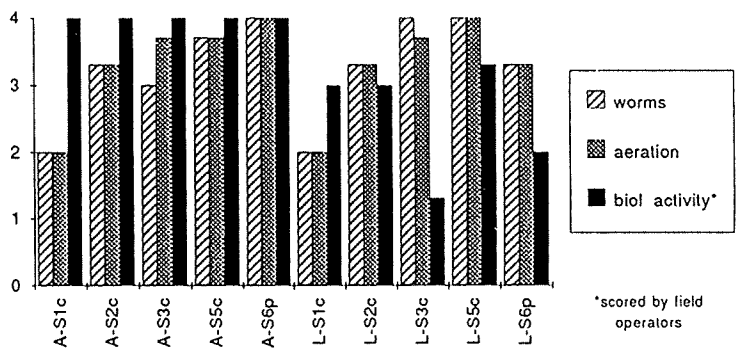

Figure 3: Earthworm scores for corn phases and pasture at Arlington, 1993-95

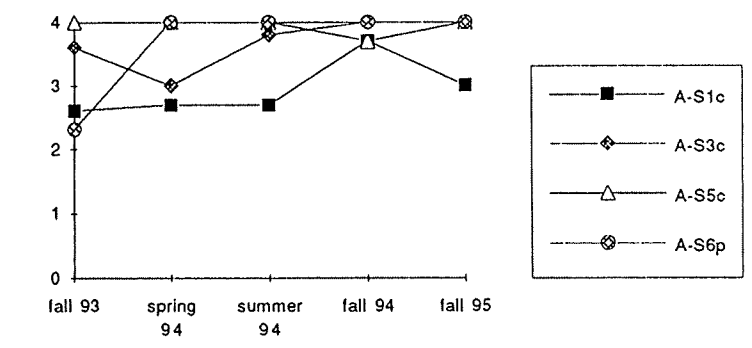

Figure 4: Earthworm scores for corn phases and pasture at Lakeland, 1993-95

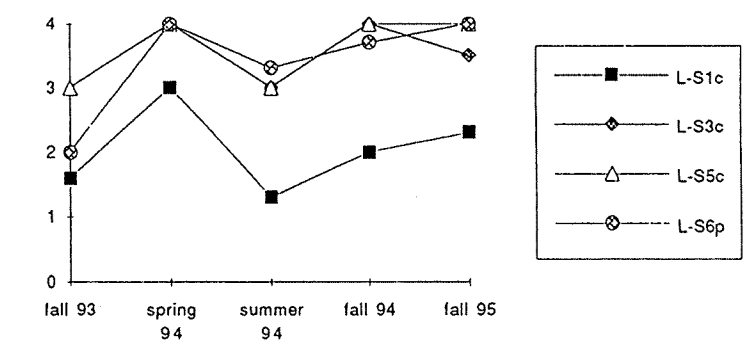

Table 2: Analytical Soil Quality Indicator Properties for 1995 WICST Systems

Soil Quality Properties		Analytical Data[1] for Systems																		
Name	Units	S1: continuous corn			S3: wide row beans						S5: oats & alfalfa						S6: contin. pasture		
		corn			corn phase			bean phase			corn phase			oats & alfalfa			pasture		
		Spr	Su	Fall	Spr	Su	Fall	Spr	Su	Fall	Spr	Su	Fall	Spr	Su	Fall	Spr	Su	Fall
ARLINGTON																			
Nitrate	mg kg^{-1}	–	–	8	–	–	6[a]	–	–	4[a]	–	–	11[a]	–	–	7	–	–	6[a]
Extractable P	mg kg^{-1}	–	–	98	–	–	64[a]	–	–	58[a]	–	–	97	–	–	94	–	–	81
Exchangeable K	mg kg^{-1}	–	–	244	–	–	146[a]	–	–	165[a]	–	–	191[a]	–	–	226	–	–	180[a]
pH	$-\log[H^+]$	–	–	6.7	–	–	6.9[a]	–	–	7.0[a]	–	–	6.9	–	–	6.9	–	–	6.7
Organic matter	%	–	–	4.6	–	–	4.1	–	–	4.0[a]	–	–	4.8	–	–	4.6	–	–	5.0
Labile carbon	ugC g^{-1}	173	126	145	151	128	119	–	165	162	153	199	104[a]	155	–	118	202	161	178
Microbial biomass	mgC $100g^{-1}$	168	204	285	230	302	327	–	112	254	289	201	410[a]	226	–	487[a]	270	248	518[a]
Bulk density	g cm^{-3}	–	–	1.04	–	–	1.16	–	–	1.24[a]	–	–	1.06	–	–	1.24[a]	–	–	1.24[a]
Total porosity	%	–	–	61	–	–	56	–	–	53[a]	–	–	60	–	–	53[a]	–	–	53[a]
LAKELAND																			
Nitrate	mg kg^{-1}	–	–	5	–	–	5	–	–	5	–	–	12[a]	–	–	6	–	–	5
Extractable P	mg kg^{-1}	–	–	62	–	–	57	–	–	50	–	–	76	–	–	97	–	–	53
Exchangeable K	mg kg^{-1}	–	–	163	–	–	160	–	–	146	–	–	190	–	–	250[a]	–	–	183
pH	$-\log[H^+]$	–	–	6.6	–	–	6.3	–	–	6.4	–	–	7.0	–	–	7.2	–	–	7.0
Organic matter	%	–	–	4.5	–	–	5.1	–	–	4.8	–	–	4.8	–	–	5.2	–	–	5.9[a]
Labile carbon	ugC g^{-1}	112	227	97	106	165[a]	92	–	183	89	120	186	79	187[a]	–	166[a]	149	174[a]	153[a]
Microbial biomass	mgC $100g^{-1}$	339	334	348	475	490	491	–	345	486	369	413	533[a]	356	–	517	426	476	728[a]
Bulk density	g cm^{-3}	–	–	1.11	–	–	1.08	–	–	1.26[a]	–	–	1.06	–	–	1.21[a]	–	–	1.25[a]
Total porosity	%	–	–	58	–	–	59	–	–	52[a]	–	–	61	–	–	55[a]	–	–	53[a]

[1] Analytical data are average of 4 replicate values from 2 plots.
Statistical analysis: a = values significantly different from R1 at a level of $P<0.1$

21. Molecular Microbial Diversity of an Agricultural Soil in Wisconsin

James Borneman,[1] Paul W. Skroch,[2] Katherine M. O'sullivan,[1] James A. Palus,[1] Norma G. Rumjanek,[1] Jennifer L. Jansen,[1] James Nienhuis,[2] and Eric W. Triplett[1*]

A culture-independent survey of the soil microbial diversity in a clover/grass pasture in southern Wisconsin (USA) was conducted by sequence analysis of a universal small-subunit rDNA clone library. A rapid and efficient method for extraction of DNA from soils was developed which resulted in highly purified DNA with minimal shearing. Universal small-subunit rRNA primers were used to amplify DNA extracted from the pasture soil. The PCR products were cloned into pGEM-T and either hypervariable or conserved regions were sequenced. The relationships of 124 sequences to cultured organisms of known phylogeny were determined. Of the 124 clones sequenced, 98.4% were from the *Bacteria*. Two of the rDNA sequences were derived from eukaryotic organelles. Two of the 124 sequences were of nuclear origin, one being fungal and the other a plant sequence. No *Archaea* sequences were found. Within the domain *Bacteria*, three major taxa were highly represented: the Proteobacteria (16.1%), the Cytophaga/Flexibacter/Bacteroides group (21.8%), and the Low and G+C Gram$^+$ group (21.8%) (Table 1.). Some groups such as the Thermotogales, the Green Nonsulfur group, the Fusobacteria, and the Spriochaetes were absent. A large number of the sequences (39.4%) were distributed among several clades that are not among the major taxa described by Olsen et al. (1994). From the alignments of the sequence data, distance matrices were calculated to display the enormous microbial diversity found in this soil in two ways, as phylogenetic trees and as multidimensional scaling plots.

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Table 1. Distribution of organisms identified in the rDNA library made from Wisconsin soil DNA within the major taxa[a]

Major taxon and Group	No.(%) of organisms identified: Hyper-variable region	Less variable region	Total
Bacteria	74(97.4)	48(100)	122(98.4)
Thermotogales	0	0	0
Green nonsulfur	0	0	0
Cyanobacteria-chloroplasts	0	1(2.1)[b]	1(0.8)
Low G+C Gram$^+$		19(25.0)	8(16.7) 27(21.8)
Fusobacteria	0	0	0
High G+C Gram$^+$		1(1.3)	0 1(0.8)
Cytophaga-Flexibacter-Bacteroides	20(26.3)	7(14.6)	27(21.8)
Fibrobacteria	3(3.9)	0	3(2.4)
Spriochaetes	0	0	0
Planctomyces-Chlamydia		4(5.3)	0 4(3.2)
Proteobacteria	8(10.5)	12(25.0)	20(16.1)
α	1(1.3)	1(2.1)[c]	2(1.6)
β	6(7.9)	4(8.3)	10(8.1)
γ	1(1.3)	3(6.3)	4(3.2)
δ	0	4(8.3)	4(3.2)
Unknown	19(25.0)	20(41.6)	39(31.4)
Archaea	0	0	0
Eucarya	2(2.6)	0	2(1.6)
Fungi	1(1.3)	0	1(0.8)
Plants		1(1.3)	0 1(0.8)

[a]Distributions are listed for each of the two regions sequenced and for the total of the two regions sequenced.
[b]This sequence is a chloroplast rDNA sequence from a plant.
[c]This sequence is a mitochondral rDNA sequence from an insect.

22. Residue Decomposition: A Review of the First Three Years of Results

Tom Mulder[1] and Josh Posner [1*]

The litter bag study was initiated in 1993 on the Wisconsin Integrated Cropping Systems Trial (WICST). The objectives of this study are to characterize the influence of crop rotation on residue decomposition. In collaboration with the team Entomologists, the role of macro- and meso-invertebrates in the decomposition process were also monitored (see pages 52-77). This latter objective was accomplished using litter bags with different pore sizes to isolate the influence of microorganisms and soil fauna in the decomposition process.

Our primary hypothesis is that the speed of organic matter turn-over (eg. corn stover decomposition) would be most rapid in the rotations with added manure, frequent legumes phases and pesticide free. As a result, we expected our organic forage system (CS5) to have the most rapid rates of corn stover disappearance, our organic cash grain system (CS3) to be intermediary, and our high input continuous corn system (CS1) to have the slowest rates of litter disappearance. System 5 includes two years of alfalfa plus manure, System 3 has two legume years in the 3-phase rotation, and System 1 is corn every year with root worm insecticide, herbicide and applications of anhydrous ammonia.

Methods

Small pore bags (0.0053 mm) were used to exclude annelids and arthropods, allowing only microoganisms to enter, and large pore bags (4 mm) allowed animals to enter. These bags were filled with 13-15 gms of air-dried corn stover and buried in pairs, following preplant tillage and planting of corn. The bags were buried in the top 6 inches of the soil profile at a 45 degree angle to the surface. Bags were harvested every two weeks in 1995 (once a month in 1993 and 1994), opened, air dried and once large soil particles and earthworm casts removed (large pore bags only), weighed. They were then ashed, to get an accurate measure of organic matter disappearance from each bag.

Results

As can be seen in Table 1, by mid-October, one-half to two-thirds of the corn stover disappeared in the large-pore bags. At the Arlington site, in two of our study years (1994 and 1995), our hypothesis was borne out and corn disappearance was significantly higher in System 5 than the other two systems. In the other site-years, there was no clear effect of cropping system and corn residue disappearance. For the past two years we have been also measuring the weight of earthworm casts in the large pore bags. It appears in general that there is more earthworm activity in the CS5 plots than in CS3 and CS1 (Table 2)

With the exclusion of earthworms and insects in the small pore bags, there is less disappearance of the stover by the end of the season. The summary of two years of data from the small pore bags is presented in Table 3. We find that only one-third to one-half of the stover disappears from the bag by mid-October. The 1993 data from Lakeland is somewhat surprising as the greatest rates of disappearance were observed in continuous corn. When we do a paired t-test, we find that at both sites in 1993 and at ARS in 1995, there is greater residue loss in the large pore bags than the small pore bags for each cropping system.

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Special thanks to summer helpers Jill Stengle, Joe Hoffman and Sara Zydowicz.

It appears that corn stover disappearance is not a particularly useful measure to distinguish between cropping systems. Our hypothesis is that under rotations that promote increased biological life (arthropods, earthworms, soil bacteria) we would find more rapid stover disappearance. To date (our 6th season), while we have been able to see a difference between the forage rotation and the cash grain rotations, we have not been able to see consistent differences between the two cash grain rotations. We will however, continue this monitoring for one more season.

Table 1. Corn residue reduction in large pore bags at final sampling date.[1]

	ARS			LAC		
	1993	1994	1995	1993	1994	1995
	---------- % reduction ----------			---------- % reduction ----------		
CS1	65	62	59	71	67	45
CS3	66	66	60	62	58	43
CS5	71	81	81	54	68	52
LSD (0.1)	ns	17.3	19.5	ns	ns	ns

[1]based on ash-free estimation, final sampling date ranged from late September to mid-October depending on the year.

Table 2. Weight of earthworm soil castes in large pore bags.[1]

	ARS		LAC	
	1994	1995	1994	1995[2]
	----- grams/bag -----		----- grams/bag -----	
CS1	33.7	12.4	7.7	2.2
CS3	42.6	12.4	73.4	6.6
CS5	69.2	33.4	59.2	23.5
LSD (0.1)	26.1	11.7	32.8	13.7

[1]weights may also include soil particles which were carried into the bags by other soil macro-organisms.
[2]data from second to last harvest date.

Table 3. Corn residue reduction in small pore bags at final sampling date.[1]

	ARS			LAC		
	1993	1994	1995	1993	1994	1995
	---------- % reduction ----------			---------- % reduction ----------		
CS1	41	-	48	43	-	57
CS3	35	50	48	16	39	45
CS5	39	43	46	27	38	44
LSD (0.1)	ns		ns	12		3

[1]these samples were not ashed, final sampling date ranged from late September to mid-October.

23. NRI Soil Biodiversity Project Sampling and Data Collection Protocol

Jon Baldock[1]

A- List of treatments to sample

1- Four cropping systems will be sampled; namely, Continuous corn (CS1), Corn-soybean-wheat(red clover) (CS3), Corn-oats-alfalfa-alfalfa (CS5), and Rotational grazing (CS6).

2- The corn phase of each of the first three cropping systems and the pasture will be sampled at each sampling date for most types of samples.

3- The soybean phase in R3 and the oats/alfalfa phase in R5 will be sampled at alternate dates to gain experience with other types of crops.

B- Types of samples to be taken

1- Litter bags: large pore and small pore
2- Pitfall traps for arthropods
3- Two 2.25 inch diameter soil cores for arthropods - macrocores
4- One 2.25 inch diameter soil cores for nematodes - mesocores
5- Small soil cores for bacteria - microcore
6- Small soil cores for soil health/physical data - health core
7- Root samples - corn only
8- Mycorrhizae samples
9- Soil aggregate stability and pore size

C- Sampling units and random selection

1- Each plot will be divided into 2.5 by 10.0-foot quadrats. The size of these quadrats is designed to be one row wide and long enough to allow working around one quadrat without disturbing an adjacent quadrat. This system will also facilitate locating spots over a season and over years.

a- Quadrats will be identified a single number which gives the column number as an integer value and the distance from one end of the plot to the center of the quadrat as the decimal portion of the number. For example, 6.205 would identify the quadrat that is in the sixth column of quadrats with a center 205 feet from the end of the plot.

b- A system of determining column numbers (crop row numbers) and which end of the plot to measure from will be established for both sites.

2- The quadrats will be put in a random order for sampling with the following technique or an equivalent method.

a- List the quadrats in one column of a spreadsheet.
b- Put a random number in each cell of the adjacent column using the random number function in the spreadsheet.
c- Hit the recalculate key to be sure you have a fresh set of random numbers.
d- Sort both columns according to the random numbers.
e- Copy the random order of quadrats into a column for one of the plots to be sampled.
f- Repeat steps c through e for each plot.

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3- The random sampling points for the row crops will be marked in the field while the crops are small enough to flag easily. The solid seeded crops will most likely have to be measured for each sampling.

4- Samples will not be taken from wheel tracks. This limitation and the desire to limit damage to the central harvest areas of each plot will restrict sampling to a small subset of the possible quadrats, at least during the initial year of the project. When the methods are well established a larger set of quadrats may be used.

5- If weeds are present, the samples should be taken, but the weed species and size should be noted.

D- Sampling schedule

1- Arlington and Lakeland will be sampled on alternate weeks. Tuesdays will be the targeted sampling date, so that rainouts etc. can be rescheduled later in the same week.

2- In general the samples will be taken every other week. However, that interval maybe extended at the beginning and end of the season. Also, that schedule does not fit several types of observations, so the detailed sampling schedules is given in Appendices A (Arlington) and B (Lakeland) (not included).

E- Field sampling procedures

1- Soil samples.

a- Corn

1) Two samples will be taken in the row and two will be taken half way between the rows. This will provide information on the effect of the current crop and for combining row crop data with data from solid seeded crops.

2) The in-row samples will be taken around a plant near the center of the quadrat. The plant will be divided in approximately half with the plant stem near the center (see diagrams below). The "smaller half" will be used for the organism soil samples and the "larger half" for plant health evaluations. Taking those samples close together should provide the greatest opportunity to detect correlations between the two types of observations. The two halves do not split the plant exactly in the middle because the root health evaluations require the stem and the crown to identify root nodes (whorls).

3) The species sampling requires large cores for macro fauna (macrocores) and smaller cores (mesocores and microcores) for the mesofauna and microfauna. The macrocores will consist of two 2.25 inch diameter cores taken to a depth of 4 inches. The mesocores will consist of one 2.25 inch diameter core taken to a depth of four inches. The microcore will consist of one 0.75 inch diameter core taken to a depth of 8 inches and split into two 4-inch depths. The cores will be taken as close together as possible to ensure that the same community of organisms is being sampled. Initially, the microcores should be taken after the macrocores and mesocores. If the soil is too loose to resample after the macrocores have been removed, then the sampling plan will have to be revised.

4) The cores will be taken in an arc that is centered about three inches from the center of the plant. If the center macocore is taken first directly in line with the row, then the other cores can easily be taken in relationship to it.

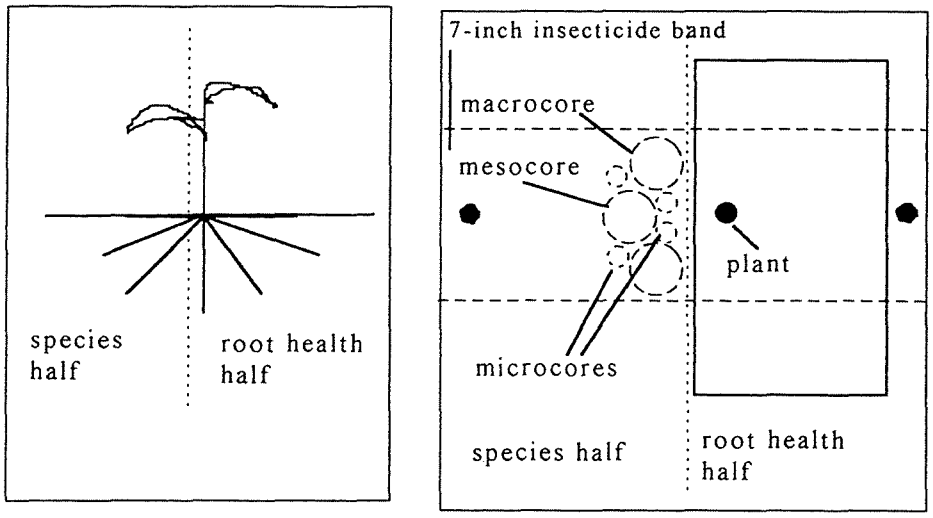

Diagram of split halves for soil sampling in-row.

2- Soybeans

a- When the soybeans are planted in rows spaced 15 or more inches apart the same method as used in corn will be employed.

b- When the soybean rows are less than 15 inches apart the same plan as designed for drilled and broadcast seeded crops will be used.

3- Drilled and broadcast seeded crops

a- Forage legumes, pasture, and drilled soybeans.

b- The procedure will be similar to the method used for the in-row samples in corn. The proximity of the cores will be the same as in the corn, so the area sampled is the same. Since there are no rows. no between row samples will be taken. Also, the quadrat location will be strictly metrical because there are rows to use as approximations to the columns of quadrats.

F- Sample handling

1- Labeling parameters

a- Date

1) Use calendar date (17 May 1995) or Julian date (95.137)

2) Do not use consecutive sampling date number (1, 2,...)

b- Site (Arlington, Lakeland)

c- Plot (3 digit number)

d- In-row/between row position

e- Depth (give increment and units; e.g. 0-4 inches)

f- Type (macrocore, mesocore, root, etc.)

g- Field subsample if any

h- Lab subsample or subsubsample, if any

G- Sample distribution/routing among investigators (if samples are shared).

24. WICST Educational Outreach 1995- Columbia County

Dwight Mueller*

The highlights of outreach activities for the Columbia County WICST project were the expansion of farmer involvement in several outreach activities and the WICST sponsorship of an 8th grade Science Field Day. As in past years, many visitors toured the plots in 1995, (Table 1).

Columbia County's WICST farmer committee expanded to include six or seven new faces. These farmers brought some fresh ideas and renewed energy to the group. The farmers decided that they wanted to sponsor a no-till/zone till field day. The field day, which took place on August 10th, was held on the Ken and Dick Schroeder farm. The Schroeder's along with Fred Kaltenberg of Kaltenberg Seed Farm gave brief presentations and lead the discussion.

Ken and Dick farm approximately 5,000 acres of corn, soybeans and wheat. They are in the process of converting most of their acreage to no-till with the additional steps of zone tilling and in-row residue removal. Ken and Dick described how they have used both spring and fall zone tillage, and residue row cleaners. They discussed how they are committed to these systems but have not determined what is the best combination. Their zone till and planting equipment were on display and people gathered informally around it to discuss the systems the Schroeder's were using in more detail.

Fred Kaltenberg from Kaltenberg Seed Farm, is also using zone till in their operation. He briefly described how they use it, and displayed the equipment they use for zone-tilling and removing residue from the corn row. He discussed why it is difficult to evaluate different treatments in a seed corn operation. Fred feels it is very site specific in terms of the benefits of zone tillage. Approximately 70 people attended the field with a high proportion being farmers. Many commented that this was a very worthwhile field day and expressed interest in a winter follow-up meeting.

The Committee held another planning meeting in the fall and put together an agenda for a follow-up no-till/zone-till meeting which was held on March 21. Dick Schroeder presented results from his on-farm trials and slides of his equipment. Several University of Wisconsin researchers presented their findings in the no-till and zone-till area with corn and soybeans. An excellent two hour discussion took place with farmers and others asking very good questions of the panelist. Approximately 125 people from all over southern and central Wisconsin attended the field day.

The Farmer Committee met once again after the meeting and discussed the possibilities of future on-farm trials, meetings, and field days. Later in the meeting, the idea was proposed of forming a farmer club. Many liked the idea and it was decided to send out a survey to determine farmer interest in the club. The response was favorable and the group is in the initial stages of planning a field day(s) for the summer.

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On September 26 and 27th, WICST helped sponsor a Science field day for 250 DeForest 8th graders. This was an interactive hands-on field day and it turned out to be very successful. Students moved among five different stops which included presentations and activities on soil profile descriptions, groundwater and soil water movement, rainfall simulation and soil erosion, soil biodiversity and crop production and nitrogen. Each student had to collect data which was later used for quizzes and exams in the classroom.

Once again WICST help sponsor Prairies Jubilee Field Day with the Madison Audubon Society which attracted an audience of over 400 people. The Field Day included a stop at the WICST plots where presentations on crop production and nitrogen, crops for wildlife, and the use of native plants for forage were given. Table indicates that many people visited the plots in 1995. Information on WICST was also presented to students attending the University of Wisconsin Short Course Program.

Educational Activity Listing for Columbia County

EVENT	NO. ATTENDING
Prairie Jubilee200	
Elementary School Students	300
Middle Sch. Students (Science Field Day)	250
UW Soil Science Summer School Class	50
No-till/Zone-till Field Day	70
Russian, Nepal, Lithuanian Delegations	150
Wis. Assoc. of County Extension. Committees.	100
Beaver Dam High School Students	50
Summer Institute of African Agricultural Research	50
Total	1220

25. WICST Educational Outreach Program 1995 — Walworth County

Lee Cunningham*

Once again the WICST project and the people involved in it have lived up to their past reputation of being in the forefront of the ongoing process of developing the sustainable future of agriculture in Wisconsin and the surrounding geographical region.

The first three to five years of the WICST systems research were and still are considered TRANSITION years. For this reason, some people have been less than pleased with the lack of results they have been looking for. These critics are starting to realize that the effect of a whole farming system on profit, production, environmental safety, weed management, and soil and water impact takes more time to do an honest evaluation than our traditional methods of research. The traditional methods of research form a very specific question to be researched in a very short time period. This places a limitation on the kinds of research that can be accomplished. The project's systems research information is becoming more available and comparable as we complete the sixth year. The complex systems being evaluated allow all the variables a farmer faces to affect, interact and complicate the process. Yes, this is real world research. We have emerged from the test tube and the laboratory and come face to face with real, whole farm systems research, demonstrations, and opportunities to learn, debate and question where we have been and where we are going.

In 1994 we reported on three areas where the WICST project had begun to have impact outside the confines of our systems research emphasis. Those three areas included fostering change in institutions, influencing public Ag policy, and identification of ways the WICST project could help create a vehicle for information exchange.

In 1995 the members of the WICST team were presented with new challenges and opportunities to continue their efforts in the ongoing process we refer to as the search for sustainability. We began to recognize just how diversified everyone's efforts become as each individual gets more involved in events and personal program directions outside the confines of the WICST project. As the members of the WICST team have expanded their personal directions, they have utilized many of their WICST project experiences and continue to influence the search for sustainability. For example, the efforts of some WICST team members on the University of Wisconsin Extension Sustainable Ag Task Force have developed into a broader vision and scope of work to be done. A State Sustainable Ag Coordinator position became a reality. The Center for Integrated Ag Systems (CIAS) has always been a supporter of the WICST efforts and has also become a stronger influence on program directions within the University system.

As the scope of potential WICST influence broadens, so do the demands on individuals' time commitment. The realization that more people are needed to handle these demands has created new positions within the project and has also created the need for additional funds to support these expanded efforts. Because this work has become so personally important to a number of people involved, it is apparent that we will find the ways and means to continue.

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This outreach report begins with a brief summary of the winter WICST meeting held in February of 1995. In this annual event we chose to focus our outreach attention on the discussion of the following question, "Is the current Wisconsin/Midwestern food production system sustainable?" To broaden our audience and to stimulate interest and debate, the following agriculture leaders were asked to address the question from different perspectives or viewpoints. Ironically those viewpoints included the three criteria we have chosen to use to evaluate the systems within the WICST project. Dan Poulson, (Wisconsin Farm Bureau President) was asked to answer the question from a production point of view. Mr. Dwaine Sievers (President of M & I Bank, Cambridge, WI) was asked to answer the question from a farm profitability point of view. Dr. Fred Madison (UW Soil Scientist) approached the question from an environmentally safe perspective. Upon completion of the three perspectives, Fred Kirschenmann (a regional farmer and member of the National Sustainable Ag Council) was asked to respond from a farmer's point of view. After discussion of these presentations, the focus of our meeting was turned to answering the question of how can we improve the sustainability of our food production system. Dr. Robert Steele, Associate Dean, College of Ag and Life Science, gave a University of Wisconsin research response to this question. Dr. Richard Vatthauer, State Extension Program Director and Assistant Dean of Extension, gave a University of Wisconsin Extension response which consisted of a list of things we in Extension need to do. The farmer response to this question was summarized by Fred Kirschenmann. He listed ten things farmers can do to improve the sustainability of our food production system. A complete summary of this WICST outreach event can be obtained by contacting Lee Cunningham.

After this winter kick off, the spring events began to unfold. A team was formed out of the University of Wisconsin, Sustainable Ag Task Force to participate in Chapter 3 Extension training. This team participated in a Train the Trainer workshop in Indiana.

The WICST project was presented to the Wisconsin Association of Extension Committees at their winter conference. It was highlighted as an innovative way for Wisconsin Agricultural Extension to meet the challenge of sustainability.

Organic vegetable growers workshop utilized WICST information in preparing for spring planting projects.

An annual event sponsored by the Burlington Kiwanis called, "Farm City Night", featured the WICST project as a sustainable ag resource for both urban and rural neighbors.

The annual Sustainable Agriculture Mouse, "SAM," was very busy in April and May preparing 4th grade teachers and their students to study sustainable agriculture in their classrooms as well as participate in field days at the WICST site. These hands-on units have proven to be a very effective way to introduce and promote sustainable agriculture in the classroom. The students, teachers, and family members take part in hands-on field days at the one-hundred acre WICST site by doing activities in the field. They count earth-worms, identify plants, and — in the process — become aware of where their food comes from. A copy of the student and teacher training materials/unit can be obtained by calling Lee Cunningham.

In June a farmer field day was held to focus on weed management within each of the 6 systems being evaluated within the WICST project. Farmers had a chance to see different weed management strategies used side by side. Some involving chemical controls and some relying on mechanical weed control assisted by crop rotation.

The annual Farm Bureau Dairy Breakfast on the farm was held at the Lakeland Ag Complex in June. Tours of the WICST project were conducted for both farm and urban participants. Over 770 people were given an overview of the project. Many questions were answered regarding the sustainable future of our food production system. Throughout the rest of the year, people continue to come back to the project after they have been introduced to it at events like this.

A 5-day, midwestern tour of sustainable agriculture farms was accomplished at the end of June. Alan Wood, Lakeland Ag Complex Manager and WICST Superintendent, expanded his outreach efforts to include farmers from Lithuania. These farmers along with representatives from University of Wisconsin Extension, local farmers and Michael Fields Ag Institute toured Wisconsin, Iowa, Nebraska, North and South Dakota and Minnesota by motorhome. The time spent in discussion between stops was very valuable to all the participants. These types of events can be expensive in relation to both time and money but the rewards will be very gratifying and long lasting.

WICST weekly walks were conducted throughout the summer. These informal walks through the 100-acre project provide a time for the WICST team to discuss the progression within each system represented, as well as talk to individuals who have been interested enough to take time to walk along with the team and discuss their questions about the sustainability of our food production system.

The summer meeting of the Walworth and Columbia County WICST Committees was held in August. The agenda of this event was built around visits to farms in the Walworth area where interesting things are taking shape in the form of change due in part by the influence of the WICST project.

In August an interesting chain of events began to take place that were not planned, but proved to be very fruitful. A number of Walworth County Board members began to question the county's need to continue the Lakeland Ag Complex as an active county department. The basic question being raised was whether or not a county should have any department or activity that was not mandated by some entity. What goods and services should the county government provide to its constituents? A concerned citizens group formed rapidly to stand up for the educational mission of the Lakeland Ag Complex. This group of local citizens included farmers as well as non-farmers. They chose to take this discussion of the future of agriculture's importance to Walworth County to the people. The Farm Bureau soon began to get involved and mobilized their members and Board of Directors to bolster support for the Lakeland Ag Complex and the WICST project. The State Farm Bureau President, Dan Paulson, actively supported the efforts as well. Soon numerous news articles and radio spots were appearing in and around the county supporting the educational mission of the Lakeland Ag Complex and WICST. In all, over 35 newspaper articles in support of the complex were written in local and state publications. The Farm Bureau and members of the citizen's committee, who became known as the "Friends of Lakeland Ag Complex" (or FLAC) Committee jointly took a petition to the residents of the community. Over 700 residents of Walworth County chose to support our efforts by signing the petition. A positive resolution was presented to the Walworth County Board in September by the Agriculture, Conservation, Extension committee. After presentations from board members, farmers, the Farm Bureau and the FLAC committee, the County Board voted to continue support of the Lakeland Ag Complex and the WICST project educational and research mission. The real importance of these events is that they provided a forum for the WICST

outreach efforts to be heard and discussed by a larger number of people. It heightened the awareness of just how important a sustainable agriculture future is to all people, not just farmers. The FLAC committee continues to be active after the County Board vote. These citizens began to realize that they want to be a part of the decision making process within the county in regard to the future of agriculture. This group of citizens have taken a giant step in the process of controlling their own future in agriculture. The search for the sustainability of agriculture has become the glue that holds them together and given them a reason to become involved at the local level. We will here more from these active citizens in the future.

The Land Conservation Committees from across the state of Wisconsin toured the WICST sight during their fall conference. This group consisted of both elected officials from other counties and LCC personnel working in land conservation. The WICST project can and is serving as a valuable resource in watershed projects conducted by the local LCC and the Department of Natural Resources. A local watershed project has been started in Walworth County. The Sugar/Honey Creek watershed project used the WICST as a local source of information for farmers and land owners to draw on as they developed their individual farm plans.

The Urban Rural Conference was held at the Michael Fields Ag Institute. Participants toured the WICST project and entered into numerous discussions about the sustainable future of agriculture. These events continue to grow in numbers of people concerned about our food production system's sustainable future.

Our outreach efforts were strengthened greatly by the addition of Kat Griffith to our WICST team. Her expertise and enthusiasm have enhanced our efforts through the use of news media as well as newsletters, public events and farmer fact sheets that highlight changes farmers are making due in part to the influence of the WICST project.

Presentations were made to USDA officials in Washington by Lee Cunningham and John Hall. Both individuals spoke to a group of Under Secretaries and staff members at the USDA in regard to the sustainability of our food production system or the lack of it as well as ways and means we all can help promote sustainability of our food production system.

A Wisconsin/Illinois tillage conference was held in Harvard, Illinois. The WICST project was featured as a valuable resource to producers in both states.

Internships were set up at the Lakeland Ag Complex through the local Vocational College that will provide learning opportunities for students looking for careers in agriculture.

Many other events have been conducted in the past year that have included information from the WICST project. Researchers have used information gathered here in their presentations to farmers as well as colleges around the United States. The seeds that have been planted here in the fertile soil of southern Wisconsin will continue to sprout and grow in many different ways.

If everyone who reads this outreach report would ask themselves, "What can I do to support the sustainable future of our food production system?" and then use the following questions as a guide, we all can make a difference in the future. When you need to make a decision that could make a difference in the sustainability of our food production system ask yourself, "Will my decision be profitable for farmers? Will my decision help agriculture to be productive? Will my decision be environmentally sound? Will the decision be supported by the community outside of agriculture?" If you can answer "yes" to all four questions, you too are helping to create a sustainable food production system.

OUTREACH SUMMARY

Event	No. Attending
WICST Winter Conference	126
Indiana Train the Trainer workshop	5 WICST team members Over 35 other team members from 5 states
Wisconsin Association of County Extension Committees	78
Organic Grower Meetings	54
Burlington Farm City Night	159
Teachers and Students participating in SAM Unit	149
WICST WEED Field Day	87
Farm Bureau Dairy Breakfast WICST Tours	769
Midwest Tour of Sustainable Farms	27
Weekly WICST walks	41
WICST County Committee Summer Farm Tours	32
Walworth County Residents who supported the Educational Mission of the WICST/LAC by choosing to sign the Farm Bureau supported petition	702
Sugar/Honey Creek Watershed Project	358
Land Conservation Conference	69
Friends of Lakeland Ag Complex Committee (FLAC)	36 and growing
Citizens reached through news media	Over 50,000
USDA Officials	86
Wisconsin/Illinois Tillage Conference	77

Appendix I. Arlington Agricultural Research Station WICST Input/Output Data - 1995

Corn Treatments

Crop-95	Cont. Corn	Corn	Corn	Corn	Corn
Prev Crop	Corn	Soybean	Wheat/RC	Alfalfa II	Alfalfa I
Cropping sys.	CS1	CS2	CS3	CS4	CS5
Treatment	1	3	5	9	11
Primary Tillage	Chisel Plow 11/7/94	No-till	Chisel Plow Sweeps 11/7/94	Chisel Plow 11/7/94	Chisel Plow Sweeps 11/7/94
Secondary Tillage	Digger 5/1/95	None	Digger 5/1/95 5/12/95	Digger 5/1/95	Digger 5/1/95 5/12/95
Planted	5/1/95	5/1/95	5/12/95	5/1/95	5/12/95
Variety	Pioneer 3563	Pioneer 3563	Pioneer 3751	Pioneer 3563	Pioneer 3751
Rate	31,500	31,500	34,000	31,500	34,000
Population	29,250	30,200	28,100	27,850	28,300
Fertilizer					
Starter	100 lb 6-24-24	100 lb 6-24-24	None	100 lb 6-24-24	None
Nitrogen	100 lb N/a* as 82-0-0 6/12/95	120 lb N/a as 82-0-0 6/16/95	None	None	None
Manure	None	None	None	20 Ton/a 11/3/94	15 Ton/a 11/3/94
Pesticides	pre 5/12/95 Dual 2 pt/a postemerge Buctril 1 pt/a 6/6/95 Counter 15G 9 lb/a with planter	pre 5/12/95 Dual 1.3 pt/a postemerge Buctril 1 pt/a 6/6/95	None **	Buctril 1 pt/a 6/6/95 postemerge ***	None ****
Rotary Hoe	5/19/95	5/19/95	#1 5/19/95 #2 5/25/95 #3 6/2/95	5/19/95	#1 5/19/95 #2 5/25/95 #3 6/2/95
Cultivation (S-tine)	6/12/95	6/12/95	6/12/95 6/22/95	6/12/95	6/12/95 6/22/95
Harvest	10/13/95	10/13/95	10/13/95	10/13/95	10/13/95
Yield	143 bu/a	168 bu/a	156 bu/a	167 bu/a	157 bu/a
Fall Practices	Chisel Plow 11/8/95	None	Chisel Plow 11/8/95	20 T/a manure 11/7/95 Chisel Plow 11/8/95	15 T/a manure 11/7/95 Chisel Plow 11/8/95
Crop-96	Corn	NR Soybeans	WR Soybeans	D.S. Alfalfa	Oats/Alfalfa

* Reps 1,3,4 - 110 lb/a, rep 2 - 70 lb/a.
** Reps 3 and 4 - spot treatment of Stinger for thistle control (.37 pt/a).
*** Rep 2 - .67 oz/a Accent to control foxtail.
**** Rep 1 - .67 oz/a Accent to control quackgrass, spot treatment of Stinger for thistle control (37 pt/a).

Appendix I. Arlington Agricultural Research Station WICST Input/Output Data (continued)

Soybean and Wheat Treatments

Crop-95	NR Soybean	WR Soybean/ Wheat	Wheat/ Red Clover
Prev. Crop	Corn	Corn	Soybean/Wheat
Cropping sys.	CS2	CS3	CS3
Treatment	2	4	6
Primary Tillage	No-till	Chisel Plow 11/7/94	None
Secondary Tillage	None	Digger 5/3, 5/12/95	None
Planting	5/6/95	5/12/95	10/14/94 Wheat
Date			2/24/95 Rd Clov
Rate/Variety	235,000 s/a Kalt. 241	200,000 s/a As 1900	180 lb/a Merrimac Wh 20 lb/a Arlington RC
Population	153,406	199,542	
Fertilizer	None	None	None
Pesticides	preemerge 5/10/95 12 oz/a Roundup post emerge 6/17/95 4 oz/a Pursuit + NIS .125 oz/a Pinnacle + NIS 2 qt/A 28%	None	None
Rotary Hoe	None	#1 5/19/95 #2 5/25/95 #3 6/2/95	None
Cultivation (S-tine)	None	6/12/95 6/22/95	None
Harvest	10/13/95	9/29/95	7/25/95
Yield	58 bu/a	63 bu/a	67.7 bu/a wheat 1.21 T/a straw
Fall Practices	None	Field Cult. 2X 9/29/95 Double disk drill 9/29/95 Glacier W. Wheat 150 lb/a	Chisel plow (sweeps) 11/8/95
Crop-96	Corn	Wheat/Red Clover	Corn

Appendix I. Arlington Agricultural Research Station WICST Input/Output Data (continued)

Forage Treatments

Crop-95	D. Seeded	Estab. Alfalfa	Estab. Alfalfa II	Oats/ Alfalfa II	Estab. Alfalfa	Pasture Alfalfa I
Prev. Crop	Corn	D.S. Alf.	Alfalfa I	Corn	Oats/Alf.	Pasture
Crop. sys.	CS4	CS4	CS4	CS5	CS5	CS6
Treatment	8	7	10	13	12	14
Primary Tillage	Chisel Plow 11/8/94			Chisel Plow 11/8/94		
Secondary Tillage	Soil Finisher 2X 4/17/95			Soil Finisher 4/17/95		
Planting Date	4/24/95	4/18/94	5/1/93	4/20/95	4/18/94	4/30/92 O,B,T 7/31/92 O 4/9/93 RC* 3/17/95 RC**
Variety	ICI	Magnum III	Magnum III	Bay-oats ICI-alf.	Magnum III	Timothy-Toro Brome-Badger Arl Rd Clov
Planting Rate	15 lb/a			64 lb/a oats 15 lb/a alfalfa		15 lb/a RC
Fertilizer Manure	20 ton/a	None 11/3/94	None	15 ton/a	None 11/3/94	grazing
Pesticides	Eptam 2 qt/a	Dimate 4E ppi 4/24/95 Dimate 4E .75 pt/a 7/25/95	Dimate 4E .75 pt/a 7/25/95	None .75 pt/a 7/25/95	None	None
Harvest	7/6/95 haylage 8/21/95 haylage	5/31/95 haylage 7/6/95 haylage 8/10/95 haylage 9/5/95 haylage	5/31/95 haylage 7/6/95 haylage 8/8/95 haylage 9/5/95 haylage	6/23/95 oatlage 8/23/95 haylage	5/31/95 haylage 7/6/95 haylage 8/10/95 haylage 9/14/95 haylage	began grazing May 11, 1995
Yield	3.19 TDM/a	4.02 TDM/a	2.24 TDM/a	3.21 TDM/a	4.89 TDM/a	1.37 TDM/a + 134 lb gain/a
Fall Practices	None	None	Roundup 2 qt/a Surfactant 6 oz/a 10/12/95 20 T/a manure 11/7/95 Chisel Plow Spring 1996	None	Roundup*** 15 T/a manure 11/7/95 Chisel Plow (sweeps) Spring 1996	None
Crop-96	Alfalfa I	Alfalfa II	Corn	Alfalfa I	Corn	Pasture

* Seeding with hand operated cyclone seeder
** No-till drill
*** Roundup applied to reps 1 and 2 to control quackgrass (same rates as to R4, trt 10)

Appendix II. Lakeland Agricultural Complex WICST Input/Output Data - 1995

Corn Treatments

Crop-95	Cont. Corn	Corn	Corn	Corn	Corn
Prev Crop	Corn	Soybean	Wheat/RC	Alfalfa II	Alfalfa I
Cropping sys.	CS1	CS2	CS3	CS4	CS5
Treatment	1	3	5	9	11
Primary Tillage	Chisel Plow 11/17/94	No-till	Mulchmaster Sweeps 11/17/94	Chisel Plow Sweeps 11/17/94	Mulchmaster Sweeps 11/17/94
Secondary Tillage	Mulchmaster 5/19/95	None	Mulchmaster 5/18, 5/19/95	Mulchmaster 5/18/95	Mulchmaster 5/18, /19, /20/95
Planted	5/19/95	5/20/95	5/20/95	5/19/95	5/20/95
Variety	Pioneer 3751	Pioneer 3751	Pioneer 3751	Pioneer 3751	Pioneer 3751
Rate	31,200	31,200	33,800	31,200	33,800
Fertilizer					
Starter	190 lb/a* 4-10-10	222 lb/a 4-10-10	None	235 lb/a 4-10-10	None
Nitrogen	110 lb N/a* 5/19/95 as 28%	130 lb N/a 5/20/95 as 28%	None		None
Manure	None	None	None	20 Ton/a 11/11/94	15 Ton/a 11/11/94
Pesticides	pre 5/22/95 Extrazine IIDF 2.5 lb/a Lasso 2.5 qt/a postemergence Buctril 1.5 pt/a 6/20/95 ** Counter 15G 10 lb/a	pre 5/22/95 Roundup 1 pt/a NIS .5 pt/a Lasso 2.5 pt/a postemergence Buctril 1.5 pt/a 6/20/95	None **	pre 5/15/95 Lasso 2.5 qt/a postemerge Buctril 1.5 pt/a 6/20/95	None **
Rotary Hoe	None	None	#1 5/31/95 #2 6/5/95	None	#1 5/31/95 #2 6/5/95
Cult. No-till	7/3/95	7/3/95	7/3/95	7/3/95	7/3/95
Harvest	10/24/95	10/24/95	10/24/95	10/24/95	10/24/95
Yield	150 bu/a	150 bu/a	131 bu/a	154 bu/a	144 bu/a
Fall Practices	Chisel Plow Spring 1996	None	Chisel Plow Spring 1996	20 T/a manure Spring 1996 Chisel Plow Spring 1996	15 T/a manure Spring 1996 Chisel Plow Spring 1996
Crop-96	Corn	NR Soybeans	WR Soybeans	D.S. Alfalfa	Oats/Alfalfa

* 32/68% mix of starter and 28% applied according to preplant soil nitrate tests, range of 80 to 134 lb N/a.
** Spot treatment of Stinger for thistle control (.37 pt/a) on CS1 reps 1 and 3, CS3 reps 1,3 and 4, CS5 reps 1,2 and 3.

Appendix II. Lakeland Agricultural Complex WICST Input/Output Data (continued)

Soybean and Wheat Treatments

Crop-95	Narrow Row Soybean	Wide Row Soybean	Wheat/ Red Clover
Prev. Crop	Corn	Corn	Soybean
Cropping sys.	CS2	CS3	CS3
Treatment	2	4	6
Primary Tillage	No-till	Chisel Plow 11/17/94	None
Secondary Tillage	None	Mulchmaster 5/21/95	None
Planting Date	5/22/95	5/22/95	10/17/94 Wheat 3/24/95 Red Clover
Rate/Variety	235,000 s/a Kalt. 241	151,000 s/a Asgrow 1900	175 lb/a Glacier Wh
Rate/Variety			18 lb/a Medium RC
Fertilizer	None	None	None
Pesticides	pre 5/22/95 Roundup 1 pt/a NIS .5 pt/a postemergence 7/13/95 Pinnacle .25 oz/a Assure II 10 oz/a COC .8 qt/a Amm. Sulf. 2 lb/a	None	None
Rotary Hoe	None	#1 5/31/95 #2 6/5/95 #3 6/10/95	None
Cultivation	None	No-till 6/25/95 No-till 7/3/95	None
Harvest	10/11/95	10/11/95	7/29/95
Yield	55 bu/a	59 bu/a	70 bu/a wheat 1.23 TDM/a straw
Fall Practices	None	Mulchmaster 1X No-till drill 10/13/95 Glacier W. Wheat 150 lb/a	Chisel Plow (sweeps) Spring 1996
Crop-96	Corn	Wheat/Red Clover	Corn

Appendix II. Lakeland Agricultural Complex WICST Input/Output Data (continued)

Forage Treatments

Crop-95 Prev. Crop Crop. Sys. Treatment	D. Seeded Alfalfa Corn CS4 8 14	Estab. Alfalfa I D.S. Alf. CS4 7	Estab. Alfalfa II Alfalfa I CS4 10	Oats/ Alfalfa Corn CS5 13	Estab. Alfalfa I Oats/Alf. CS5 12	Pasture Pasture CS6
Primary Tillage	Chisel Plow 11/17/94			Chisel Plow 11/17/94		
Secondary Tillage	Mulchmaster 5/3/95 2X			Mulchmaster 5/3/95 2X		
Planting Date	5/7/95	4/11/94	5/20/93	5/13/95	4/11/94	3/24/95* 4/7/93*
Variety	Magnum III	Magnum III	Magnum III	Bay-oats Magnum III-alf.	Magnum III	Arlington RC
Planting Rate	15.6 lb/a			64 lb/a oats 15.6 lb/a alf		18 lb/a Arl RC
Fertilizer Manure	20 ton/a 11/11/94	None	None	15 ton/a 11/11/94	None	grazing
Pesticides	None	None	None	None	None	None
Harvest	7/11/95 haylage **	6/7/95 haylage 7/11/95 haylage 8/26/95 haylage	6/7/95 haylage 7/11/95 haylage 8/26/95 haylage	8/15/95 oatlage **	6/4/95 haylage 7/11/95 haylage 8/26/95 haylage	began grazing May 1, 1995
Yield	1.24 TDM/a	4.47 TDM/a	3.34 TDM/a	1.51 TDM/a	4.62 TDM/a	.44 TDM/a + 711 lb gain/a
Fall Practices	None	None	Roundup 1.5 qt/a 2,4-D Hi dep .5 pt/a NIS .5 pt/a 20 T/a manure Spring 1996 Chisel Plow Spring 1996	None	Roundup 1.5 qt/a 2,4-D Hi dep .5 pt/a NIS .5 pt/a *** 15 T/a manure Spring 1996 Chisel Plow Spring 1996	None
Crop-96	Alfalfa I	Alfalfa II	Corn	Alfalfa I	Corn	Pasture

* Seeded with cyclone seeder on ATV.
** Damaged by rain, chopped back into field.
*** herbicide applied to CS5 to control quackgrass.

APPENDIX III. WICST Phosphorus and Potassium Soil Test Results (0-6") 1989-1995 Arlington Agricultural Research Station.[1]

	Crop							Phosphorus							Potassium						
Year	89	90	91	92	93	94	95	89	90	91	92	93	94	95	89	90	91	92	93	94	95
System								ppm							ppm						
CS1	*f*	C	C	C	C	C	C	105	-	-	93	84	91	88	257	-	-	219	295	228	241
CS2	*f*	Sb	C	Sb	C	Sb	C	98	-	-	79	65	68	67	199	-	-	239	229	183	182
CS2	*f*	*f*	Sb	C	Sb	C	SB	-	88	-	89	78	89	72	-	283	-	198	264	214	208
CS3	*f*	Sb	W/c	C	Sb	W/c	C	105	-	-	69	64	68	65	236	-	-	189	251	182	175
CS3	*f*	*f*	Sb	W/c	C	Sb	W/c	-	69	-	-	57	63	52	-	200	-	-	226	171	164
CS3	*f*	*f*	*f*	Sb	W/c	C	Sb	-	-	57	-	53	57	49	-	-	195	-	201	142	149
CS4	*f*	A	A	A	C	A	A	115	-	-	94	85	99	84	277	-	-	175	216	171	151
CS4	*f*	*f*	A	A	A	C	A	-	93	-	105	81	92	93	-	256	-	203	170	154	184
CS4	*f*	*f*	*f*	A	A	A	C	-	-	66	-	62	65	74	-	-	214	-	170	128	160
CS4	*f*	*f*	*f*	*f*	A	A	A	-	-	-	77	71	72	67	-	-	-	189	224	155	153
CS5	*f*	O/a	A	C	O/a	A	C	110	-	-	103	88	93	91	250	-	-	198	236	172	185
CS5	*f*	*f*	O/a	A	C	O/a	A	-	70	-	72	67	72	64	-	211	-	181	210	144	127
CS5	*f*	*f*	*f*	O/a	A	C	O/a	-	-	84	-	73	83	78	-	-	293	-	211	173	180
CS6	*f*	P	P	P	P	P	P	114	-	-	-	82	84	75	266	-	-	-	186	157	176

[1] Samples collected after crop harvest.

* original overall fertility average (top 6 inches of soil profile): P-89 ppm, K-238 ppm.

f = filler corn (grown before initiation of each rotation)

APPENDIX IV. WICST Phosphorus and Potassium Soil Test Results (0-6") 1989-1995 Lakeland Agricultural Complex.[1]

	Crop							Phosphorus							Potassium						
Year	89	90	91	92	93	94	95	89	90	91	92	93	94	95	89	90	91	92	93	94	95
System								ppm							ppm						
CS1	*f*	C	C	C	C	C	C	66	-	-	58	52	95	49	196	-	-	205	185	219	177
CS2	*f*	Sb	C	Sb	C	Sb	C	59	-	-	52	47	64	39	178	-	-	186	158	177	137
CS2	*f*	*f*	Sb	C	Sb	C	Sb	-	65	-	53	43	71	47	-	193	-	204	196	188	183
CS3	*f*	Sb	W/c	C	Sb	W/c	C	64	-	-	46	39	56	39	195	-	-	173	181	161	154
CS3	*f*	*f*	Sb	W/c	C	Sb	W/c	-	54	-	-	36	49	30	-	153	-	-	173	147	136
CS3	*f*	*f*	*f*	Sb	W/c	C	Sb	-	-	49	-	39	46	37	-	-	183	-	179	152	156
CS4	*f*	A	A	A	C	A	A	76	-	-	57	51	50	62	148	-	-	121	145	150	159
CS4	*f*	*f*	A	A	A	C	A	-	59	-	52	52	43	77	-	179	-	171	165	150	256
CS4	*f*	*f*	*f*	A	A	A	C	-	-	37	-	36	69	54	-	-	149	-	181	180	192
CS4	*f*	*f*	*f*	*f*	A	A	A	-	-	-	59	62	52	62	-	-	-	181	203	150	152
CS5	*f*	O/a	A	C	O/a	A	C	53	-	-	41	52	47	55	163	-	-	161	205	142	164
CS5	*f*	*f*	O/a	A	C	O/a	A	-	68	-	55	48	45	53	-	213	-	159	181	130	151
CS5	*f*	*f*	*f*	O/a	A	C	O/a	-	-	54	-	46	50	64	-	-	171	-	200	139	195
CS6	*f*	P	P	P	P	P	P	63	-	-	-	41	46	42	181	-	-	-	166	132	177

[1] Samples collected after crop harvest.

* original overall fertility average (top 6 inches of soil profile): P-59 ppm, K-182 ppm.

f = filler corn (grown before initiation of each rotation)

APPENDIX V. Nitrate + Nitrite-N Concentration in the Groundwater at the Lakeland Agricultural Complex: 1991-1995.

Field ID#	Treatment #	water collection dates				
		12/10/91	12/9/92	11/23/93	11/23/94	4/23/96
		ppm				
101	1	41.5	39.7	29.2	21.3	39.0
210	1	48.5	44.2	42.0	27.1	21.2
303	1	21.3	36.4	28.5	18.0	23.5
Mean		**37.1**	**40.3**	**33.2**	**22.1**	**27.9**
Crop	cont. Corn	C	C	C	C	C
108	2	60.5	47.8	45.6	49.8	15.5
203	2	14.0	20.0	18.7	19.1	13.2
304	2	20.1	20.1	16.4	14.8	14.0
Mean		**31.5**	**29.3**	**26.9**	**27.9**	**14.2**
Crop	C-Sb Sb	Sb	C	Sb	C	Sb
111	6	43.8	18.4	14.5	--	8.3
208	6	28.6	38.4	21.3	16.3	15.3
306	6	42.3	23.8	23.1	19.1	10.6
Mean		**38.2**	**26.9**	**19.6**	**17.7**	**11.4**
Crop	Sb-W/rc-C	Sb	W/rc	C	Sb	W/rc
102	8	15.1	4.8	2.9	10.3	6.9
209	8	6.8	14.4	20.1	25.3	10.9
305	8	10.3	5.7	9.0	14.3	9.1
Mean		**10.7**	**8.3**	**10.7**	**16.6**	**9.0**
Crop	C-A-A-A	A	A	A	C	A
105	12	15.4	10.8	10.4	14.8	6.9
207	12	49.7	38.7	26.1	28.1	12.3
309	12	7.3	8.3	13.3	14.7	9.1
Mean		**24.1**	**19.3**	**16.6**	**19.2**	**9.4**
Crop	O/A-A-C	O/A	A	C	O/A	A
104	14	21.3	21.4	18.4	21.1	10.7
213	14	2.2	2.8	3.3	2.2	2.9
314	14	63.2	30.0	16.1	--	13.7
Mean		**28.9**	**18.1**	**12.6**	**11.7**	**9.1**
Crop	Rot. grazing	*	RG	RG	RG	RG
1s[1]	-	31.1	2.1	2.32	2.8	0.9
1d[2]	-	6.9	10.6	ND	4.2	6.8

* Red Clover/Grass removed as hay 1991, grazed 1992 - 1995

[1] Check well #1 - 13 feet deep
[2] Check well #2 - 28 feet deep
ND = no detection

APPENDIX VI. Energy Use and Output/Input Ratios for the Six WICST Cropping Systems 1990-1995.[1/]

Cropping System	Crop	Crops or completed rotations	Mean 1990 - 1994 Energy input/yr ARS	Energy input/yr LAC	Output/input avg. ARS	Output/input avg. LAC
		-- # --	----- Mcal/A -----		----- ratio -----	
1	Corn	6	2572	1968	5.6	6.7
2	Soybean	6	561	500	12.0	14.3
	Corn	5	2021	1916	6.5	7.0
	System average[2/]	5	1260	1209	7.4	8.5
3	Soybean/Wheat	6	500	518	12.3	11.7
	Wheat/Red Clover	5	873	876	10.2	8.9
	Corn	4	1836	1126	6.9	9.8
	System average	4	1108	860	8.3	9.9
4	Direct Seeded Alfalfa	6	1612	1394	8.9	2.6
	Alafalfa I	5	759	681	21.9	21.5
	Alfalfa II	4	948	750	13.3	17.4
	Corn	3	1723	1162	9.7	13.1
	System average	3	1235	993	11.5	12.1
5	Oats/Alflafa	6	1047	967	11.1	8.1
	Alfalfa I	5	603	591	25.5	19.9
	Corn	4	2326	1259	6.0	9.9
	System average	4	1364	991	11.2	11.5
6	Rotational Grazing[3/]	6	610	314	22.1	35.5

[1/] See Appendix II in the 1992 Annual Report (pp 118-121) for information on calculation of the energy values.
[2/]Averages calculated using data from years when all the crops of a particular system were grown.
[3/] Forage harvested mechanically until animals began grazing in 1992 at LAC and 1993 at ARS; with grazing animals, energy output calculated using forage production, either harvested mechanically or an estimation of forage consumed by grazing animals .

APPENDIX VII. WICST Corn and Soybean Populations - 1991-1995.

A. Arlington Agricultural Research Station

Year	1991	1992	1993	1994	1995
			plants/acre		
Corn CS1[1/]	27,150	27,750	30,850	26,950	29,250
Corn CS2	26,555	28,650	30,800	27,300	30,200
Corn CS3		24,700	20,800	28,050	28,100
Corn CS4			32,300	26,000	27,850
Corn CS5			27,500	28,000	28,300
Soybean CS2[2/]	132,741	118,547	179,823	187,488	153,406
Soybean CS3[3/]	98,746	70,350	135,250	151,091	199,542

[1/] Corn - all planted at 32,100 seeds/a in 1991 and 1992, and 32,500 seeds/a in 1993; CS1,CS2 and CS4 at 31,500 and CS3 and CS5 at 34,000 seeds/a in 1994 and 1995.
[2/] Narrow row soybean - planted at 235,000 seeds/a.
[3/] Wide row soybean - planted at 156,000 seeds/a in 1991 - 1993 and 175,000 seeds/a in 1994 - 1995.

B. Lakeland Agricultural Complex

Year	1991	1992	1993	1994	1995
			plants/acre		
Corn CS1[4/]	30,700	29,050	30,150	28,200	28,200
Corn CS2	29,500	24,550	29,900	27,900	28,900
Corn CS3		24,250	21,100	30,350	28,200
Corn CS4			31,250	30,050	29,250
Corn CS5			21,400	30,850	28,850
Soybean CS2[4/]	116,553	97,000	139,228	143,278	176,879
Soybean CS3[6/]	117,633	122,952	86,950	113,050	118,500

[4/] Corn - all planted at 32,000 seeds/a in 1991 - 1993; CS1, CS2 and CS4 at 32,000 and CS3 and CS5 at 35,000 seeds/a in 1994; CS1, CS2 and CS4 at 31,200 and CS3 and CS5 at 35,000 seeds/a in 1994.
[5/] Narrow row soybean - planted at 220,000, 196,000, 222,000 230,000 and 225,000 seeds/a in 1991, 1992, 1993, 1994 and 1995, respectively.
[6/] Wide row soybean - planted at 140,000, 155,000, 156,000, 175,000, and 151,000 seeds/a in 1991, 1992, 1993, 1994 and 1995, respectively.

APPENDIX VIII. WICST Fall Legume Nitrogen for following Corn Crop - 1991-1995.

A. Arlington Agricultural Research Station

Year	Cropping Sys.	Crop	Foliage		Roots		Total
			DM	N	DM	N	N
			lb/a	%	lb/a	%	lb/a
1991	3	Red Clover	1852	3.24	2604	2.63	128
1992	3	Red Clover	2102	2.89	1816	2.72	110
1992	4	Alfalfa	2697	2.03	1767	2.27	95
1992	5	Alfalfa	2090	3.42	3352	2.29	148
1993	3	Red Clover	2811	2.81	1314	3.18	119
1993	4	Alfalfa[1/]	1867	2.91	1233	3.36	94
1993	5	Alfalfa[1/]	1614	4.05	1443	2.18	97
1994[2/]	3	Hairy Vetch	4325	3.29	134	3.24	146
1994	4	Alfalfa[1/]	2242	1.75	1233	1.67	60
1994	5	Alfalfa	500	3.41	2327	2.04	64
1995	3	Red Clover	2640	2.89	947	3.09	100
1995	4	Alfalfa[4/]	163	3.18	1235	2.51	36
1995	5	Alfalfa[4/]	308	3.59	2345	2.32	66

B. Lakeland Agricultural Complex

Year	Rotation	Crop	Foliage		Roots		Total
			DM	N	DM	N	N
			lb/a	%	lb/a	%	lb/a
1991	3	Red Clover	669	3.12	916	2.63[3/]	45
1992	3	Red Clover	3316	2.52	2984	2.58	161
1992	4	Alfalfa	977	4.25	2731	1.87	93
1992	5	Alfalfa	1018	4.24	2627	1.91	93
1993	3	Red Clover	2687	3.24	1224	2.90	123
1993	4	Alfalfa[1/]	2043	3.46	1251	2.74	104
1993	5	Alfalfa[1/]	2127	3.18	1222	2.72	101
1994	3	Red Clover	1240	3.03	1182	2.52	67
1994	4	Alfalfa[1/]	895	2.32	2251	2.08	68
1994	5	Alfalfa	713	3.13	1495	2.24	56
1995	3	Red Clover	2646	2.77	939	3.21	97
1995	4	Alfalfa[4/]	423	3.64	1884	2.49	62
1995	5	Alfalfa[4/]	896	3.36	1528	2.71	71

[1/] Spring seeded with red clover in 1993 because of severe winterkill to alfalfa.
[2/] 1994 - CS3 - Hairy vetch planted after wheat harvest because of thin stand of red clover, CS4 - 8/30 harvest, 10/10 Roundup application, CS5 - 9/30 harvest.
[3/] Root N was not analyzed, used same % root N as at Arlington.
[4/]CS4 - 9/5 harvest, 10/12 Roundup, CS5 - 9/14 harvest at ARS, 8/26 harvest and 10/10 Roundup for both CS4 and CS5 at LAC.

APPENDIX IX. LIST OF PUBLICATIONS

1990

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1991

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APPENDIX IX. (Cont.)

1992

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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.

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1993

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